OPERATIONAL RESILIENCE IN WESTERN US FREQUENT-FIRE FORESTS:
WHAT IS FOREST RESILIENCE & HOW DO WE RESTORE IT?

UC CE

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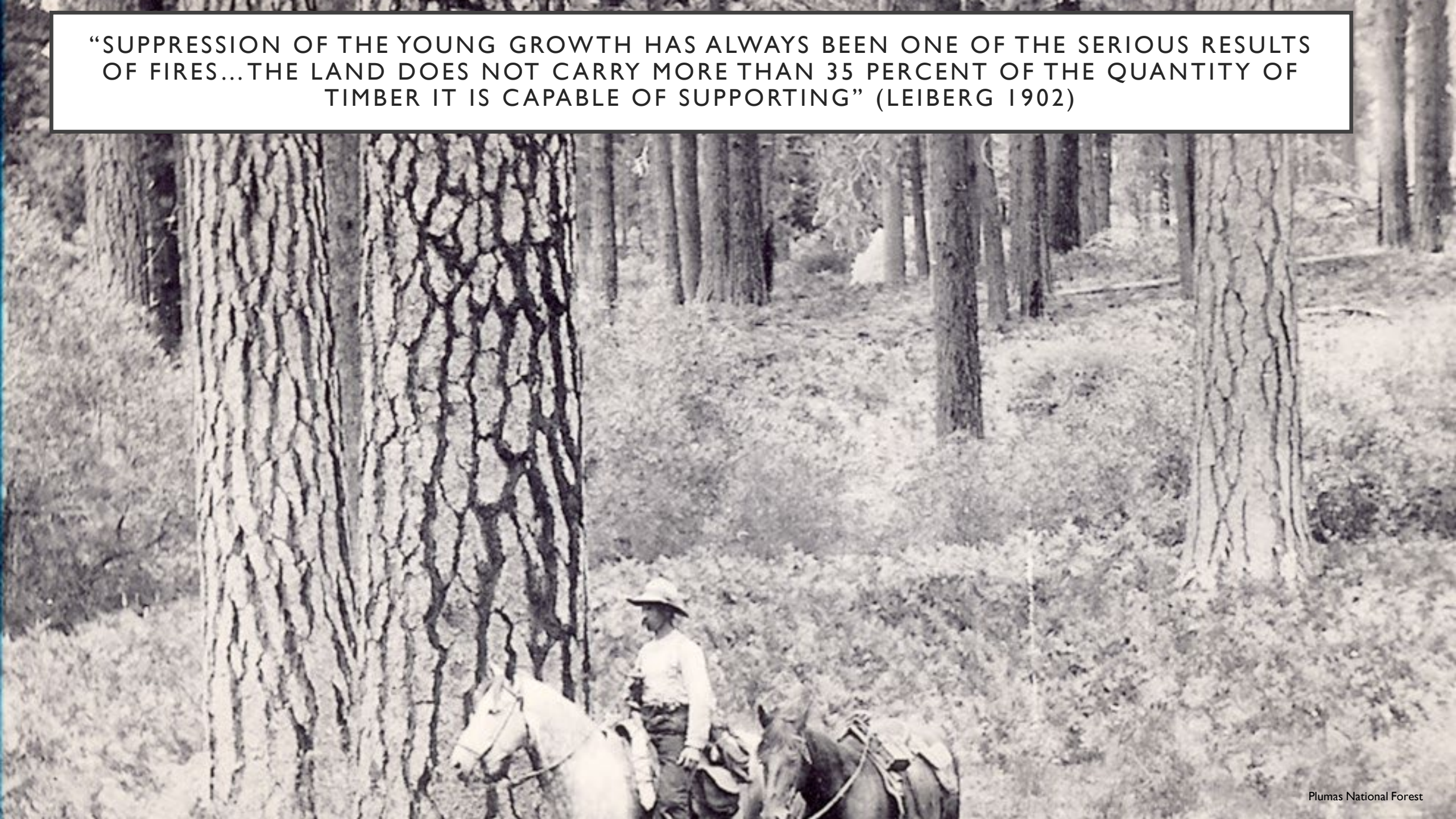
North, M.P., Tompkins, R.E., Bernal, A.A., Collins, B.M., Stephens, S.L. and York, R.A., 2022. Operational resilience in western US frequent-fire forests. *Forest Ecology and Management*, *507*, p.120004.

Plumas National Forest

"SUPPRESSION OF THE YOUNG GROWTH HAS ALWAYS BEEN ONE OF THE SERIOUS RESULTS OF FIRES…THE LAND DOES NOT CARRY MORE THAN 35 PERCENT OF THE QUANTITY OF TIMBER IT IS CAPABLE OF SUPPORTING" (LEIBERG 1902)



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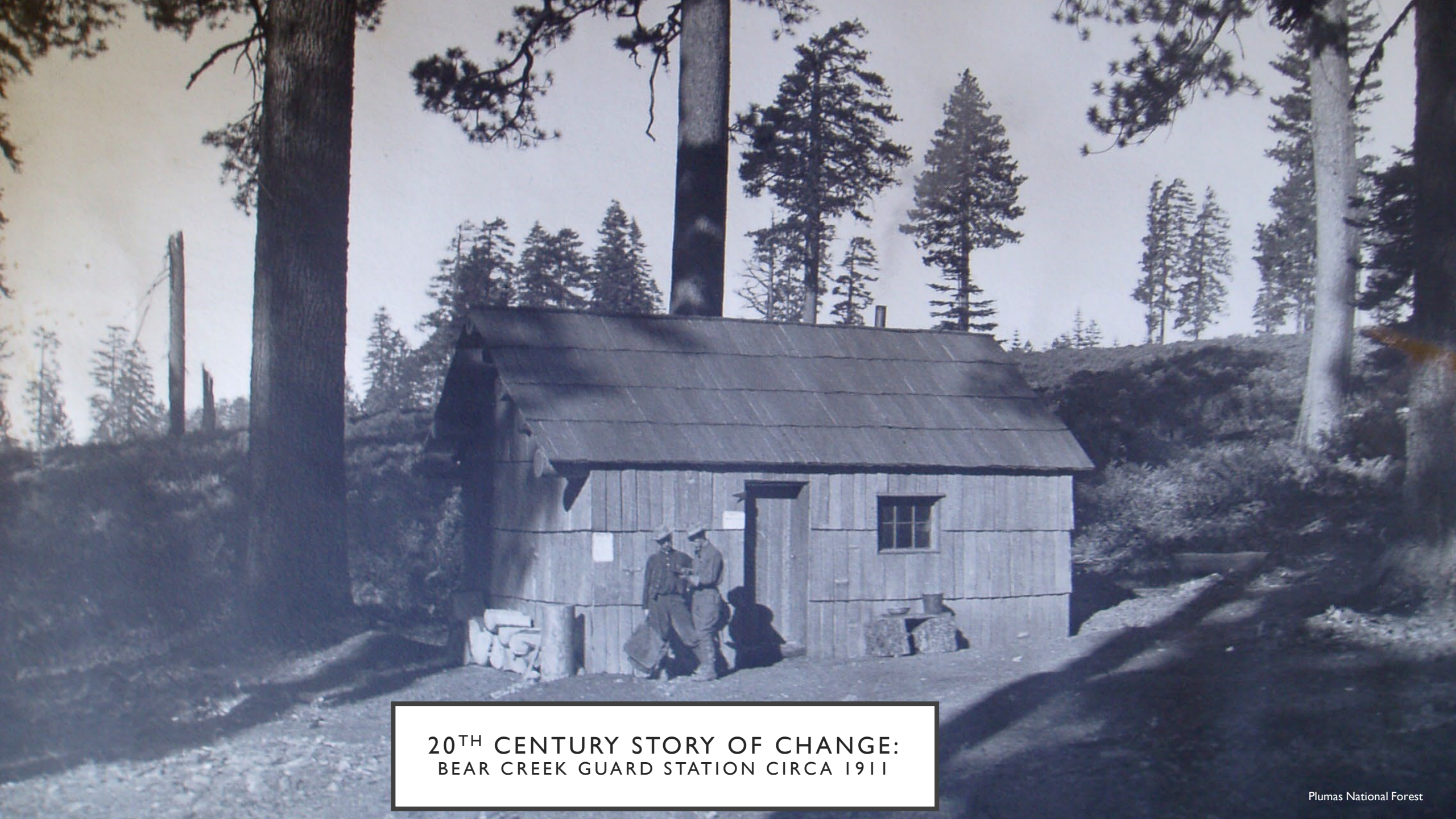

20TH CENTURY STORY OF CHANGE:
BEAR CREEK GUARD STATION CIRCA 1911

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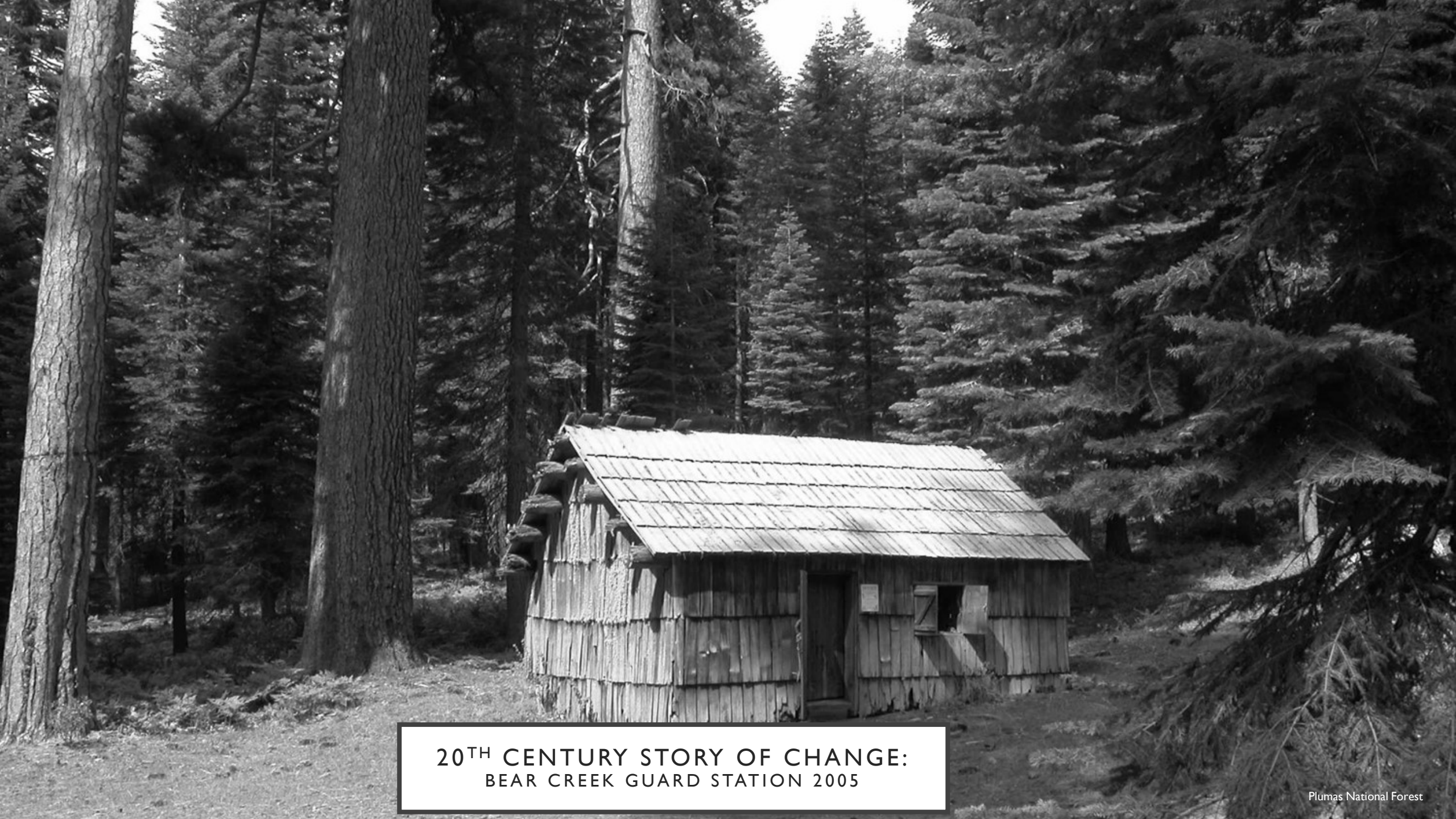


20TH CENTURY STORY OF CHANGE:
BEAR CREEK GUARD STATION 2005

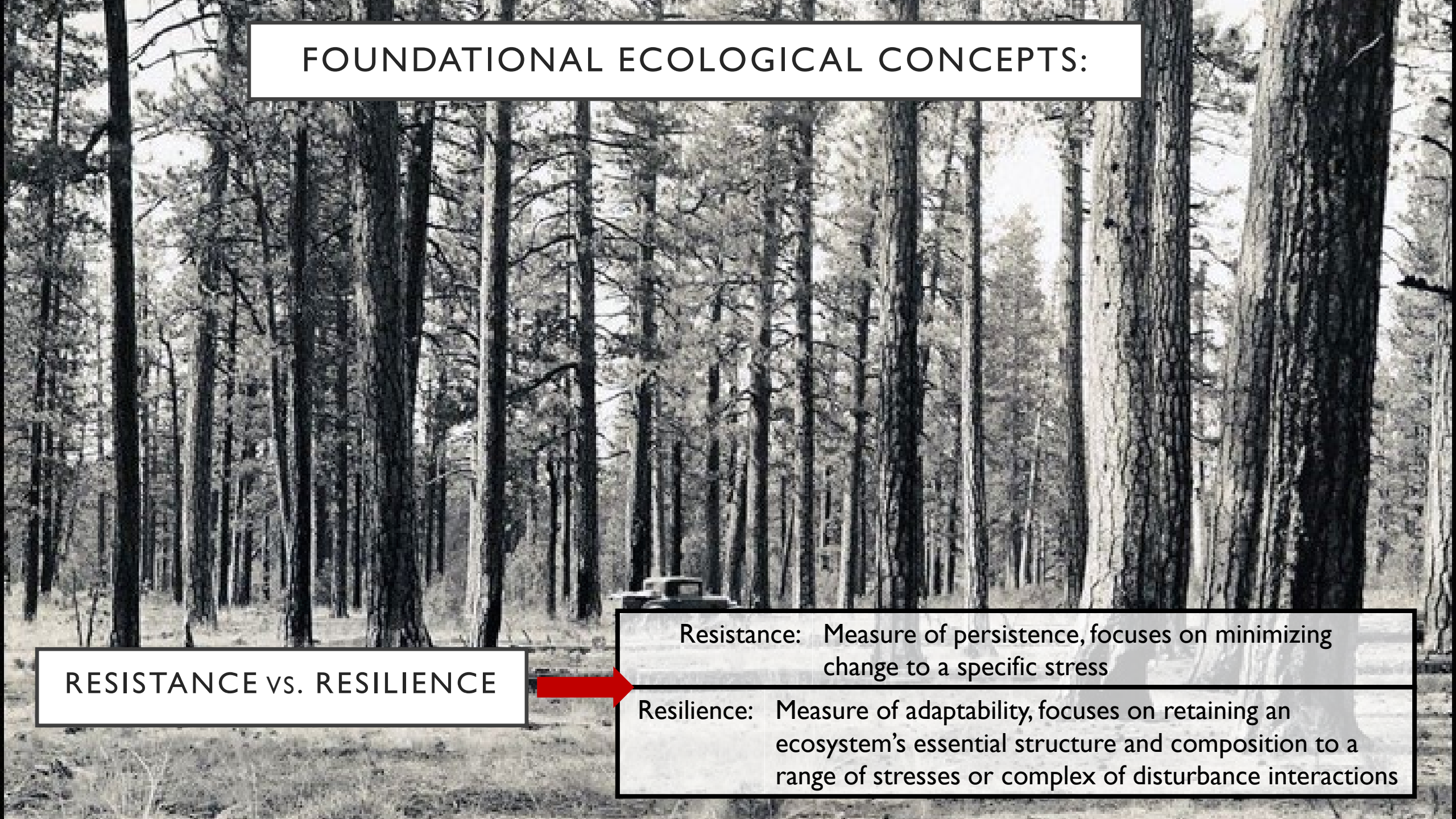
Plumas National Forest

Photo: Plumas County Search and Rescue/KRCR

21ST CENTURY SHIFTS IN DISTURBANCE REGIMES:

ALIGNMENT OF DROUGHT WITH LANDSCAPE LEVEL FOREST DENSITY & FUELS

FOUNDATIONAL ECOLOGICAL CONCEPTS:



RESISTANCE vs. RESILIENCE

Resistance: Measure of persistence, focuses on minimizing change to a specific stress

Resilience: Measure of adaptability, focuses on retaining an ecosystem's essential structure and composition to a range of stresses or complex of disturbance interactions

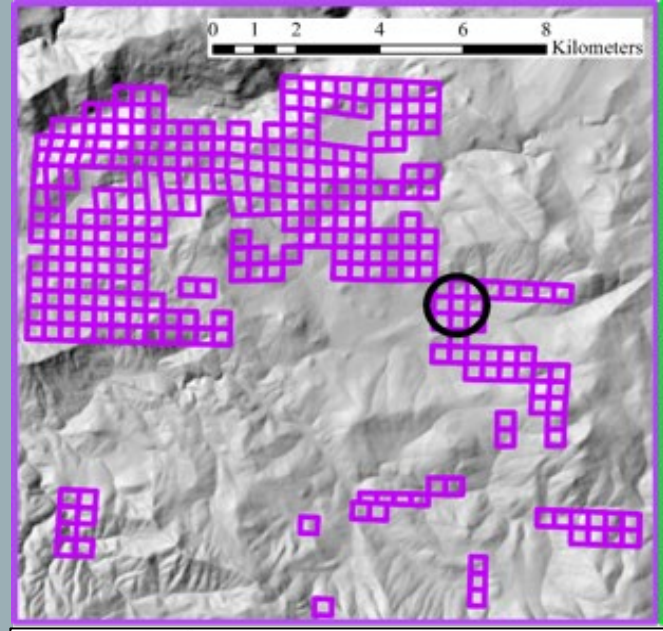
RESILIENCE STUDY DESIGN

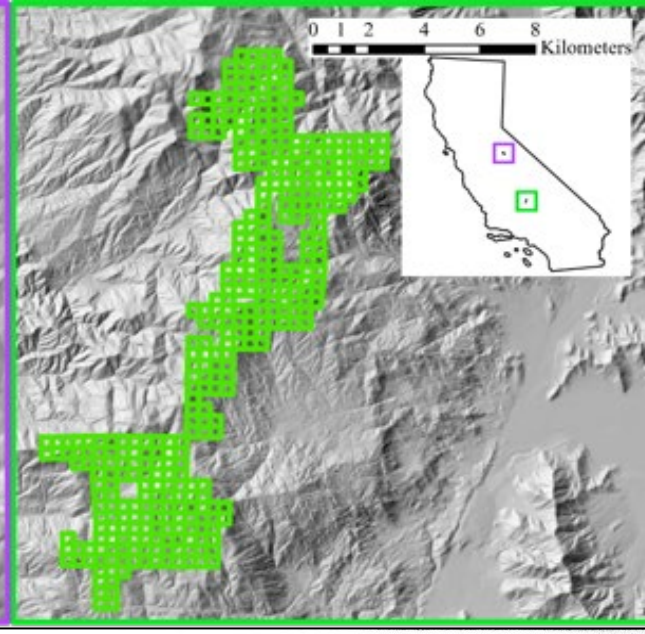
Utilized1911 Forest Inventory data from Stanislaus & Sequoia National Forests (Collins et al. 2015 & Stephens et al. 2015)

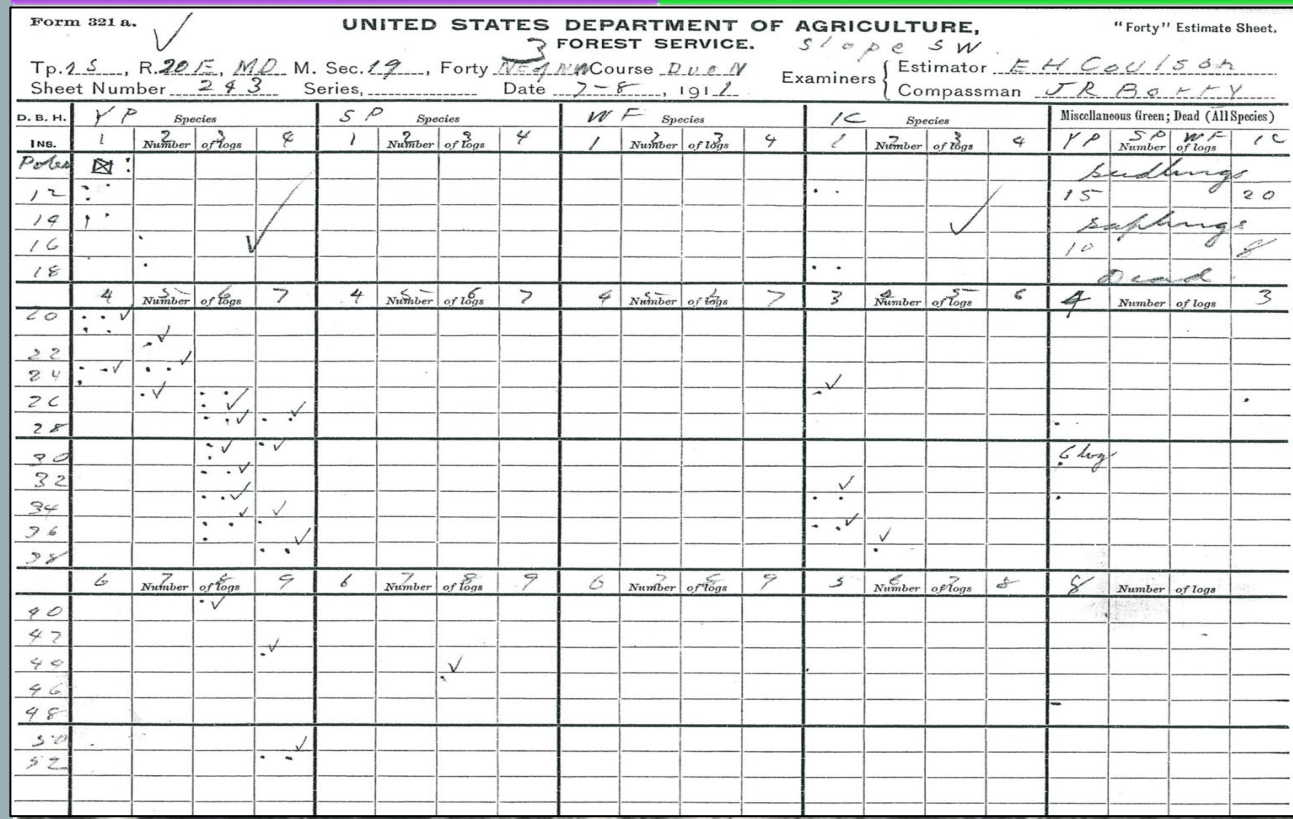
- Total of 644, Quarter-Quarter sections covering over 24,000 acres
- Belt transects 1-2 chains x 20 chains
- 5-10% sample intensity
- Trees > 6.0 inches
- Canopy Covers 12-28% for forested stands

2011 forest conditions assessed with USFS F3 data: FIA, FVS, & FastEmap. (Huang et al 2018)

Examined 3 Forest Types based on historical data	
Pine Mixed Conifer	> 50% pine
Xeric Mixed Conifer	≤ 50% pine & ≤ 50% fir
Mesic Mixed Conifer	> 50% fir






Form 321 a.

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.

"Forty" Estimate Sheet.

Tp. 1 S, R. 20 E, MD M. Sec. 19, Forty NE¼ NW¼ Course Due N Slope SW

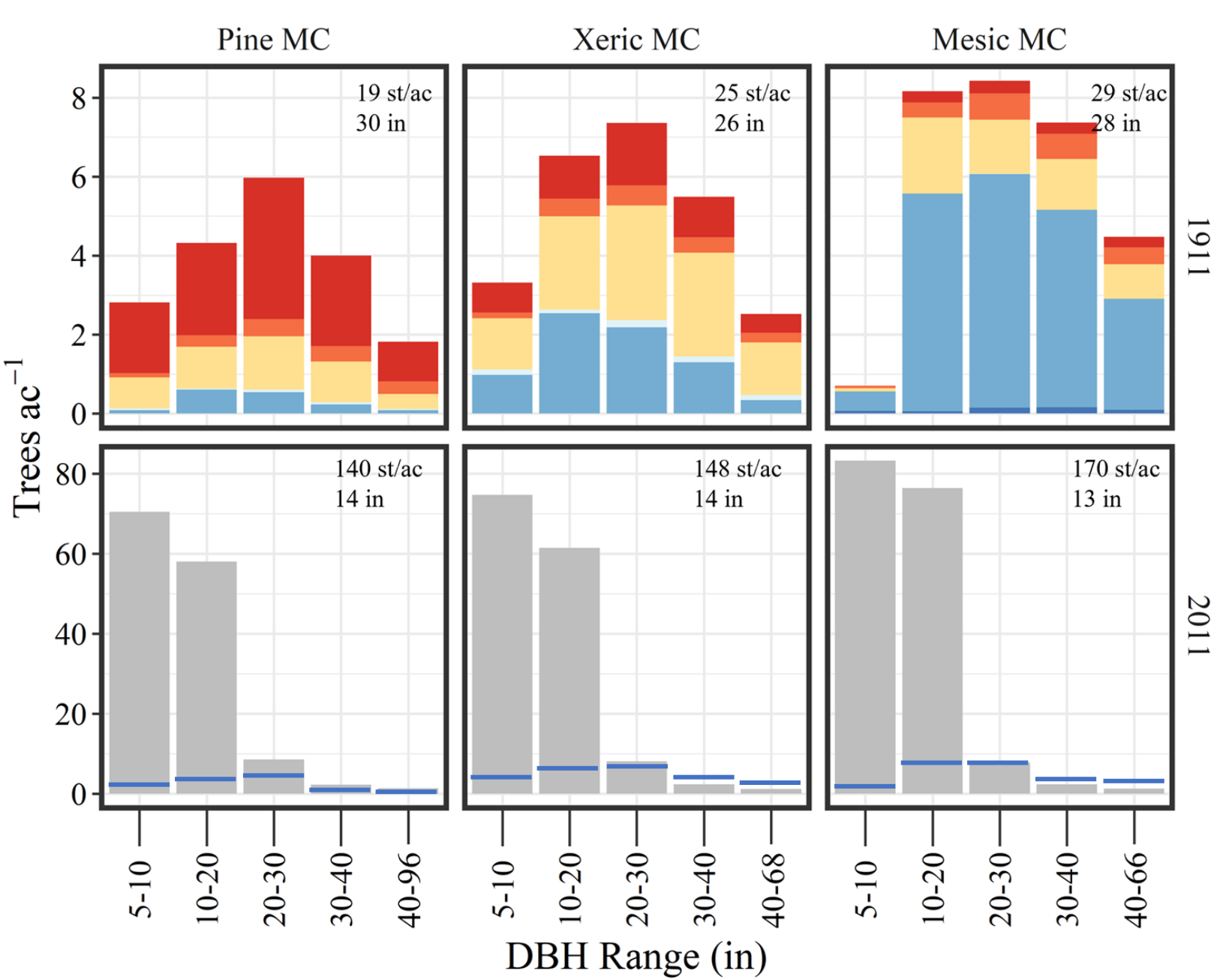
Sheet Number 243 Series, Date 7-8, 1911

Examiners { Estimator E H Coulson
Compassman J R Beatty

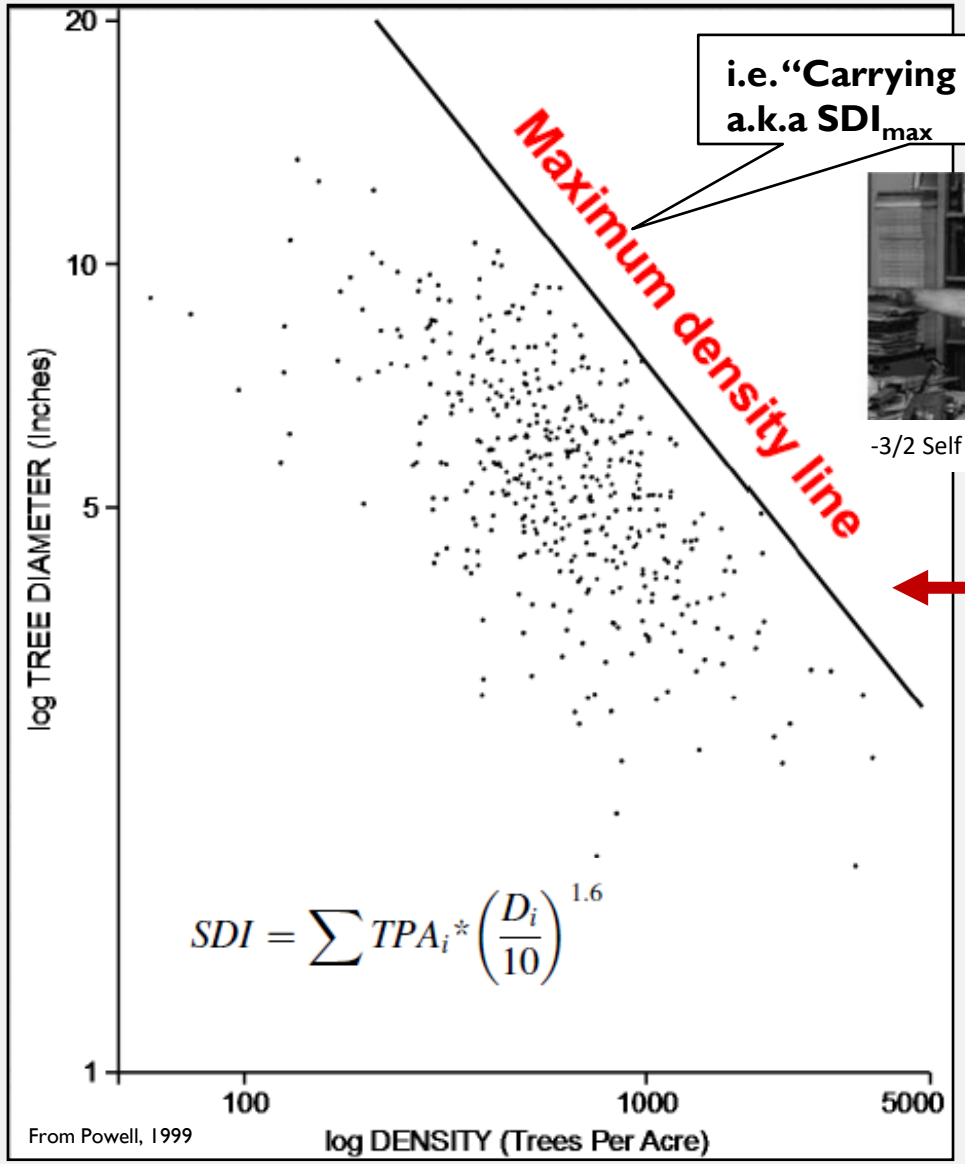
D. B. H.	YP Species				SP Species				WF Species				IC Species				Miscellaneous Green; Dead (All Species)			
INS.	1	2 Number	3 of logs	4	1	2 Number	3 of logs	4	1	2 Number	3 of logs	4	1	2 Number	3 of logs	4	YP	SP Number	WF of logs	IC
Poles																	saplings			
12																	15			20
14																	saplings			
16																	10			
18																	dead			
	4	5 Number	6 of logs	7	4	5 Number	6 of logs	7	4	5 Number	6 of logs	7	3	4 Number	5 of logs	6	4	Number	of logs	3
20																				
22																				
24																				
26																				
28																				
30																	6 logs			
32																				
34																				
36																				
38																				
	6	7 Number	8 of logs	9	6	7 Number	8 of logs	9	6	7 Number	8 of logs	9	5	6 Number	7 of logs	8	8	Number	of logs	
40																				
42																				
44																				
46																				
48																				
50																				
52																				


1911


2005

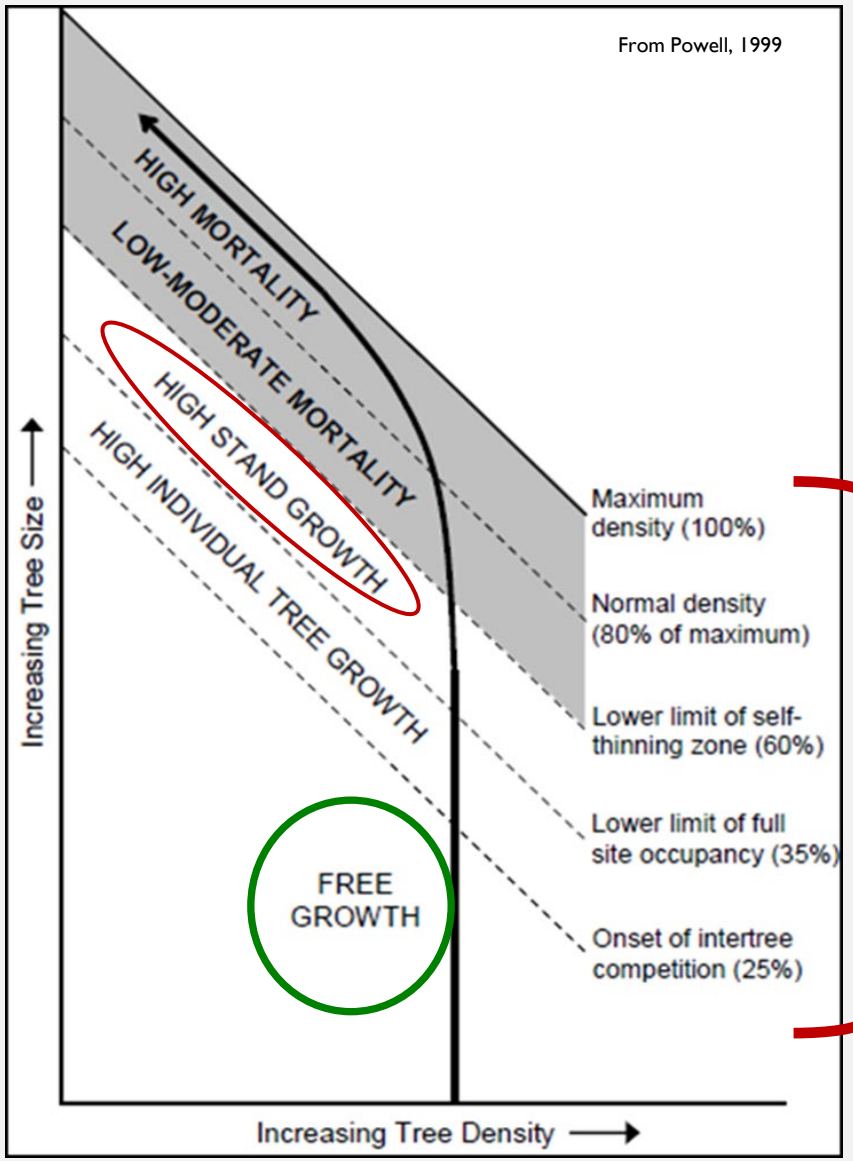

Pine MC
Xeric MC
Mesic MC
19 st/ac
30 in
25 st/ac
26 in
29 st/ac
28 in
140 st/ac
14 in
148 st/ac
14 in
170 st/ac
13 in
1911
2011
Trees ac^{-1}
0
2
4
6
8
0
20
40
60
80
5-10
10-20
20-30
30-40
40-96
40-68
40-66
DBH Range (in)
PIPO
PILA
CADE
PSME
ABCO
ABMA
NA

ECOLOGICAL IMPORTANCE OF RELATIVE STAND DENSITY:
CHARACTERIZING COMPETITION & GROWTH

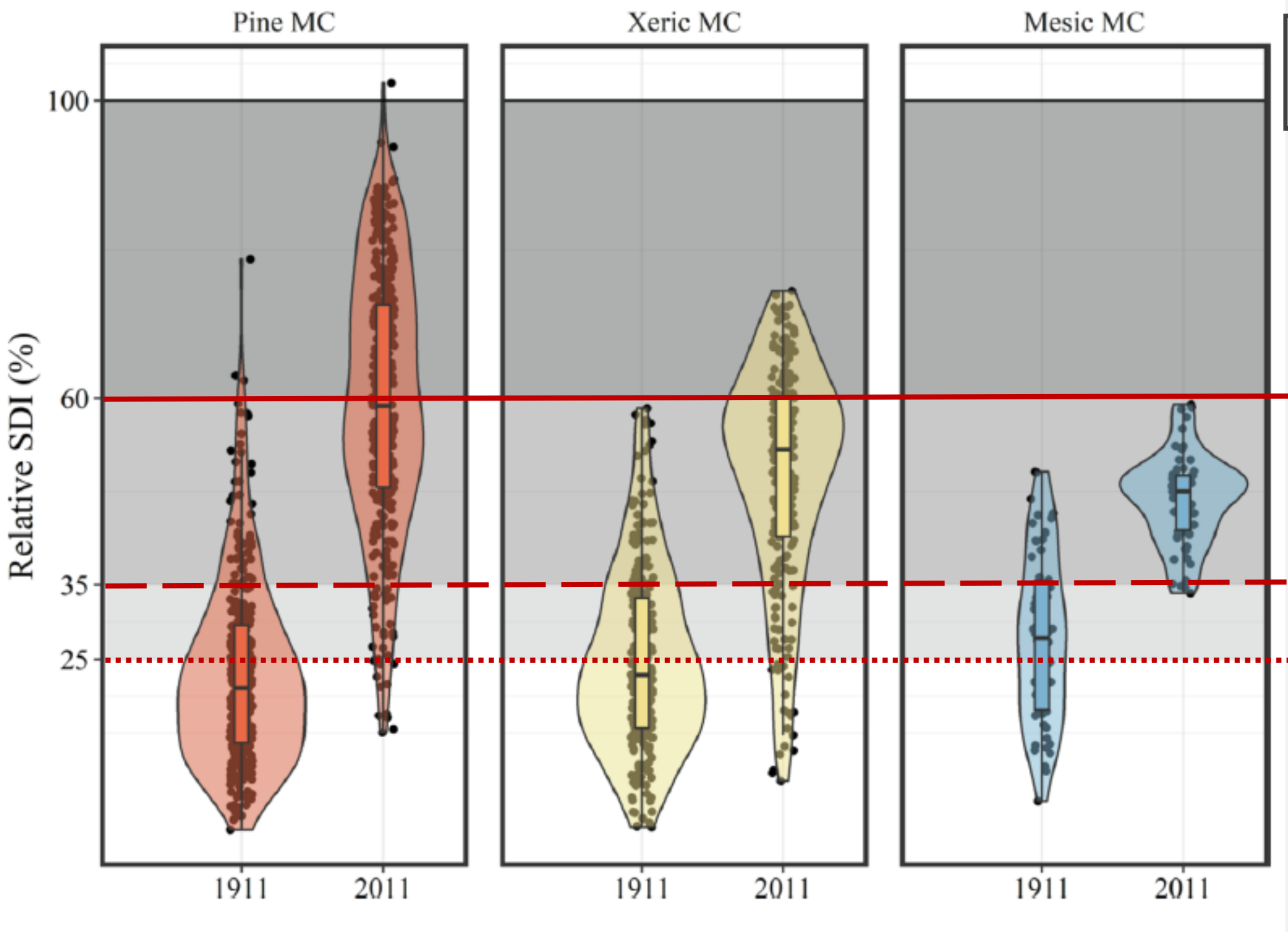


-3/2 Self Thinning Law (Yoda 1963)

Stand Density Index (Reinecke 1933)



Drew & Flewelling 1979 & Long 1985



RELATIVE DENSITY ECOLOGICAL THRESHOLDS OF COMPETITION

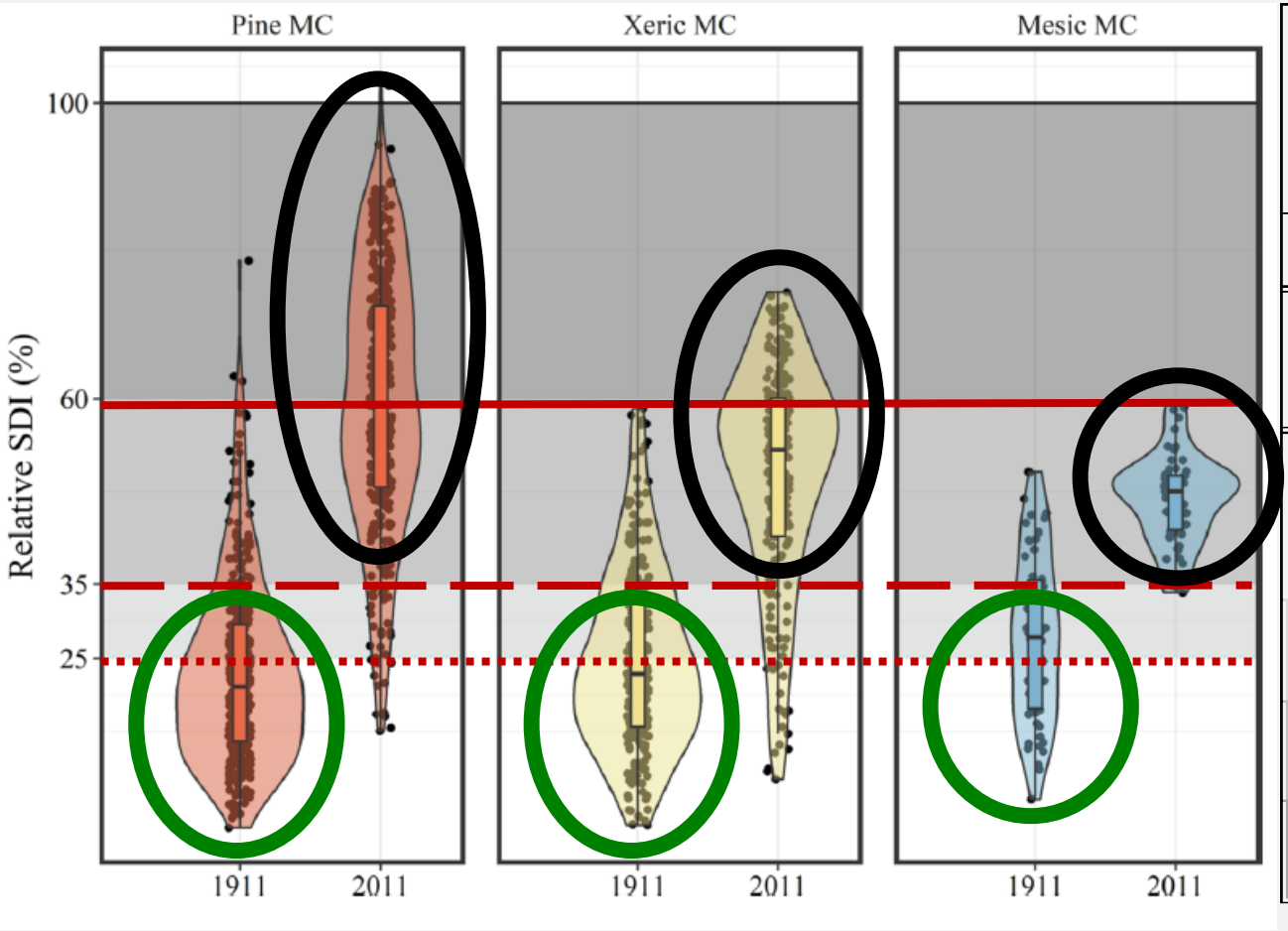
ZONE OF IMMINENT MORTALITY !!!!!

Full Site Occupancy
(a.k.a. full competition)

Onset of Competition
(a.k.a. partial competition)

Free of Competition
(a.k.a. Free Growth)

SHIFTS IN THE COMPETITIVE ENVIRONMENT
RELATIVE DENSITY AS A RESILIENCE METRIC

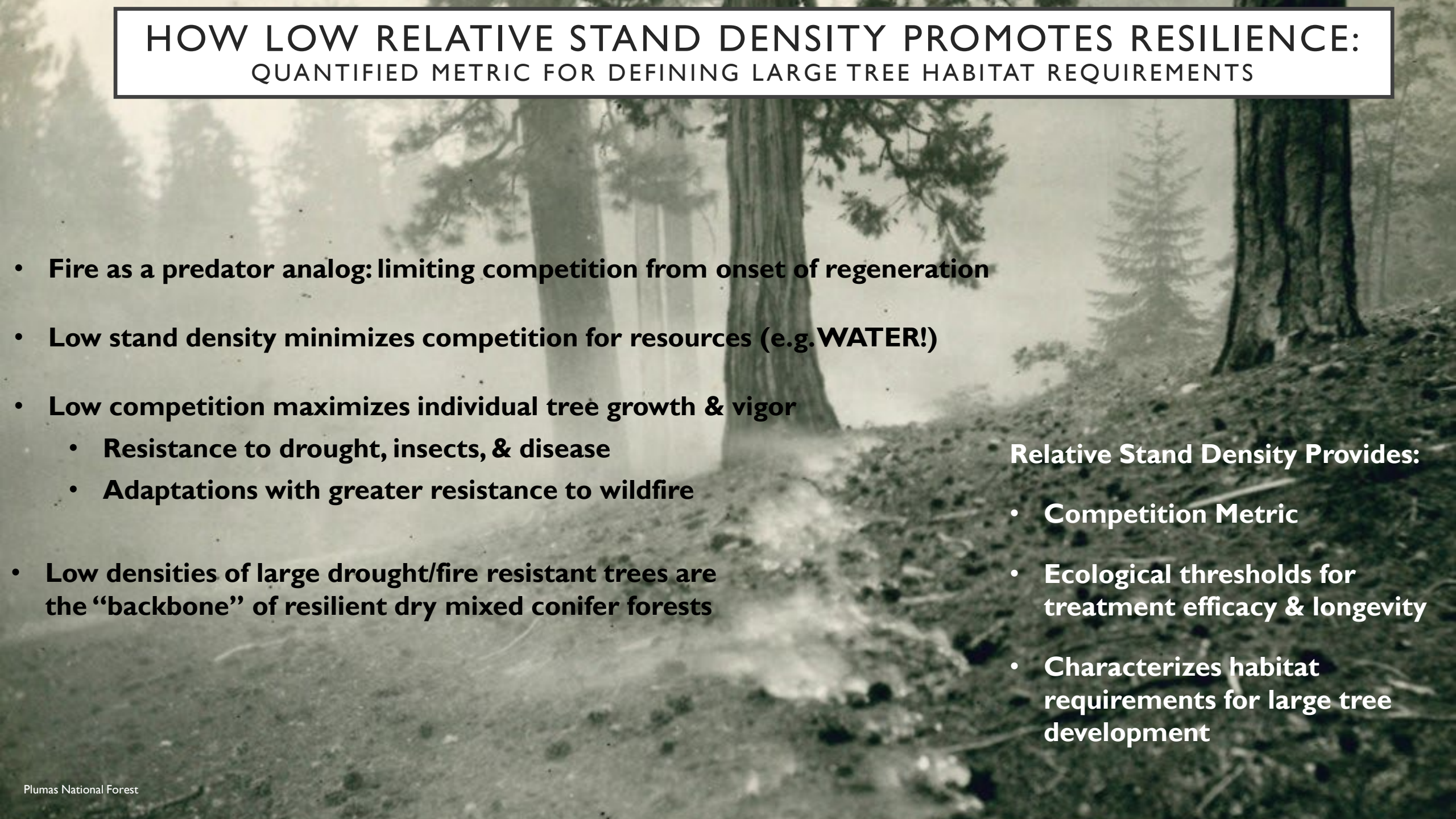


	Pine MC		Xeric MC		Mesic MC	
A) Absolute SDI						
	1911	2011	1911	2011	1911	2011
SDI_{metric}	206 (123-267)	535 (433-655)	275 (175-370)	551 (462-668)	378 (247-483)	632 (575-674)
$SDI_{english}$	83 (50-108)	216 (174-265)	111 (71-150)	223 (187-270)	153 (100-196)	256 (233-273)
B) Relative SDI (% of SDI_{max})						
Mean (Range)	23 (14-30)	59 (48-73)	25 (16-33)	50 (42-60)	28 (18-36)	46 (42-50)
C) % of Relative SDI Observations In Each Competitive Benchmark						
Free (<25% SDI_{max})	64	4	58	9	44	0
Partial (25-34% SDI_{max})	21	6	21	9	29	5
Full (35-59% SDI_{max})	14	42	20	57	27	95
IM (≥60% SDI_{max})	<1	48	0	25	0	0

In historic Forests (1911): 73-85% of stands were below full occupancy (free of competition or partial competition)

In contemporary Forests (2011): 82-95% of stands were in full competition or in the zone of imminent mortality

HOW LOW RELATIVE STAND DENSITY PROMOTES RESILIENCE:
QUANTIFIED METRIC FOR DEFINING LARGE TREE HABITAT REQUIREMENTS



- **Fire as a predator analog: limiting competition from onset of regeneration**
- **Low stand density minimizes competition for resources (e.g. WATER!)**
- **Low competition maximizes individual tree growth & vigor**
  - **Resistance to drought, insects, & disease**
  - **Adaptations with greater resistance to wildfire**
- **Low densities of large drought/fire resistant trees are the "backbone" of resilient dry mixed conifer forests**

Relative Stand Density Provides:

- **Competition Metric**
- **Ecological thresholds for treatment efficacy & longevity**
- **Characterizes habitat requirements for large tree development**

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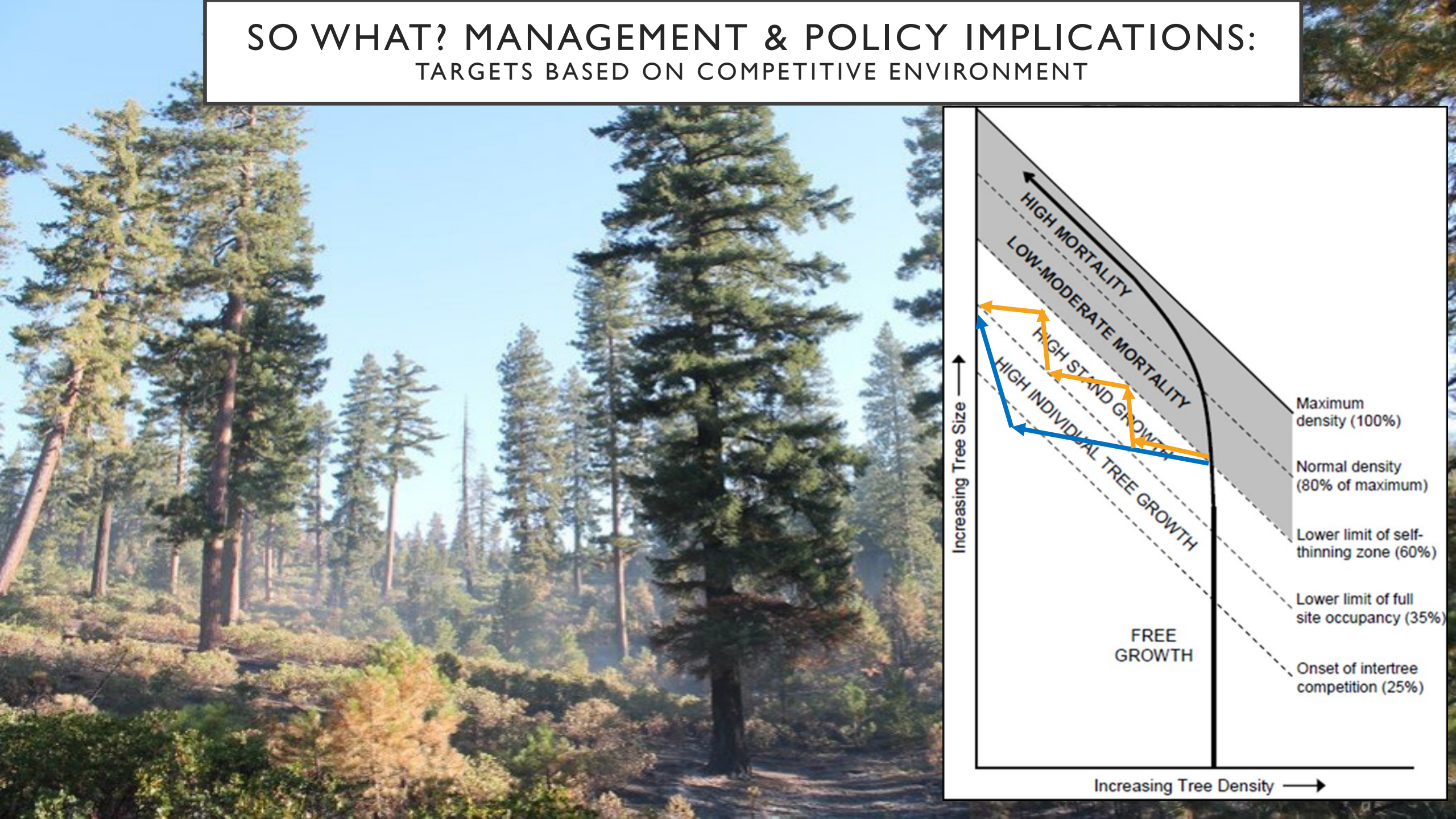
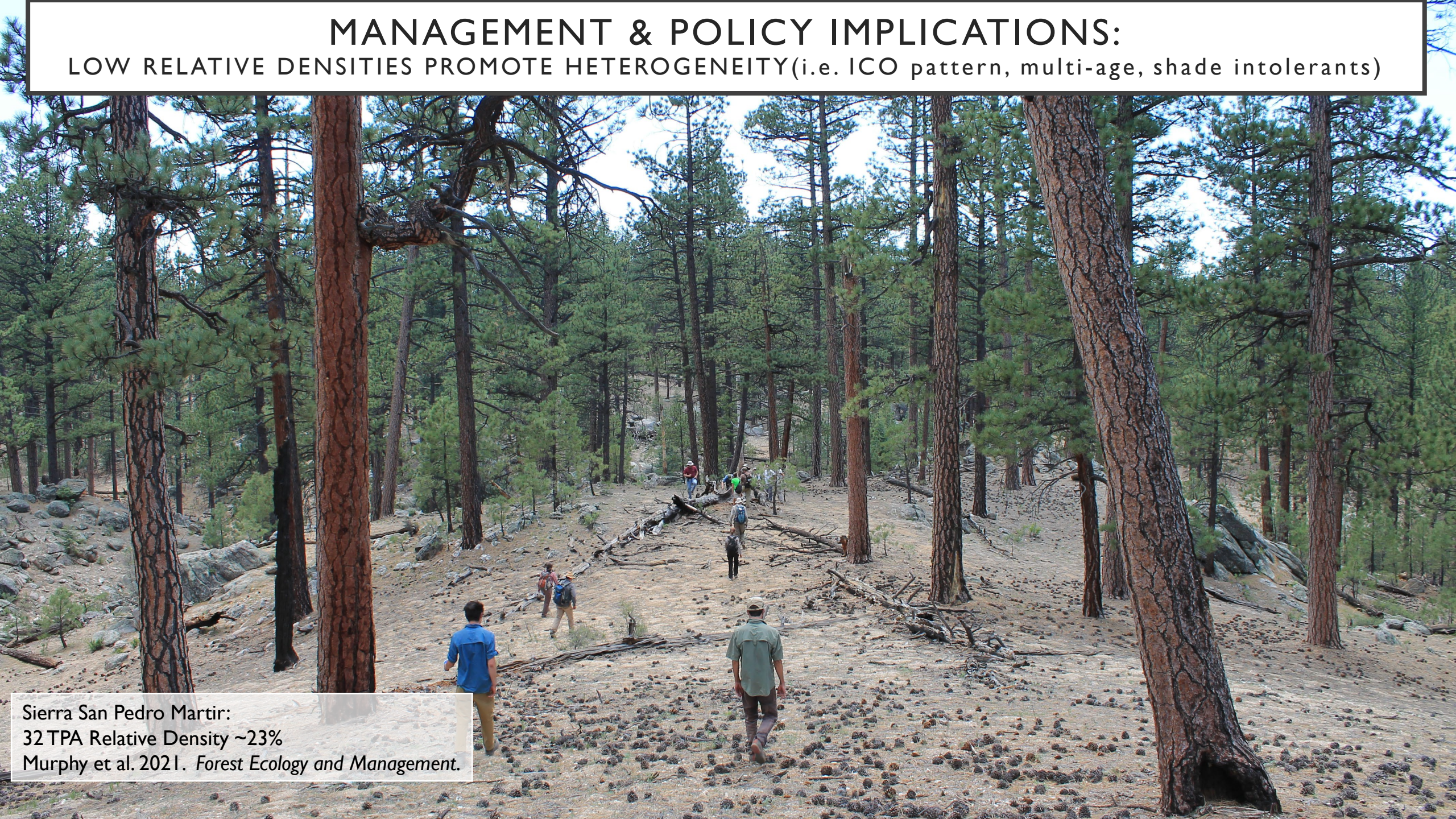
SO WHAT? MANAGEMENT & POLICY IMPLICATIONS:
TARGETS BASED ON COMPETITIVE ENVIRONMENT



MANAGEMENT & POLICY IMPLICATIONS:

LOW RELATIVE DENSITIES PROMOTE HETEROGENEITY(i.e. ICO pattern, multi-age, shade intolerants)



Sierra San Pedro Martir:
32 TPA Relative Density ~23%
Murphy et al. 2021. *Forest Ecology and Management.*

MANAGEMENT& POLICY IMPLICATIONS:

RESTORATION OF BOTH STRUCTURE + PROCESS IS CRITICAL TO RESTORATION OF ECOLOGICAL FUNCTION

Structure only: Mechanical thinning…

…low intensity burn in Dixie Fire

Relative Density ~30%

MANAGEMENT& POLICY IMPLICATIONS:

RESTORATION OF BOTH STRUCTURE + PROCESS IS CRITICAL TO RESTORATION OF ECOLOGICAL FUNCTION

Structure only: Mechanical thinning

Relative Density~48%

…Intense burning conditions in Dixie Fire

MANAGEMENT& POLICY IMPLICATIONS:

RESTORATION OF BOTH STRUCTURE + PROCESS IS CRITICAL TO RESTORATION OF ECOLOGICAL FUNCTION

Process only: RxFire 3 times in 20 years

Relative Density~76%

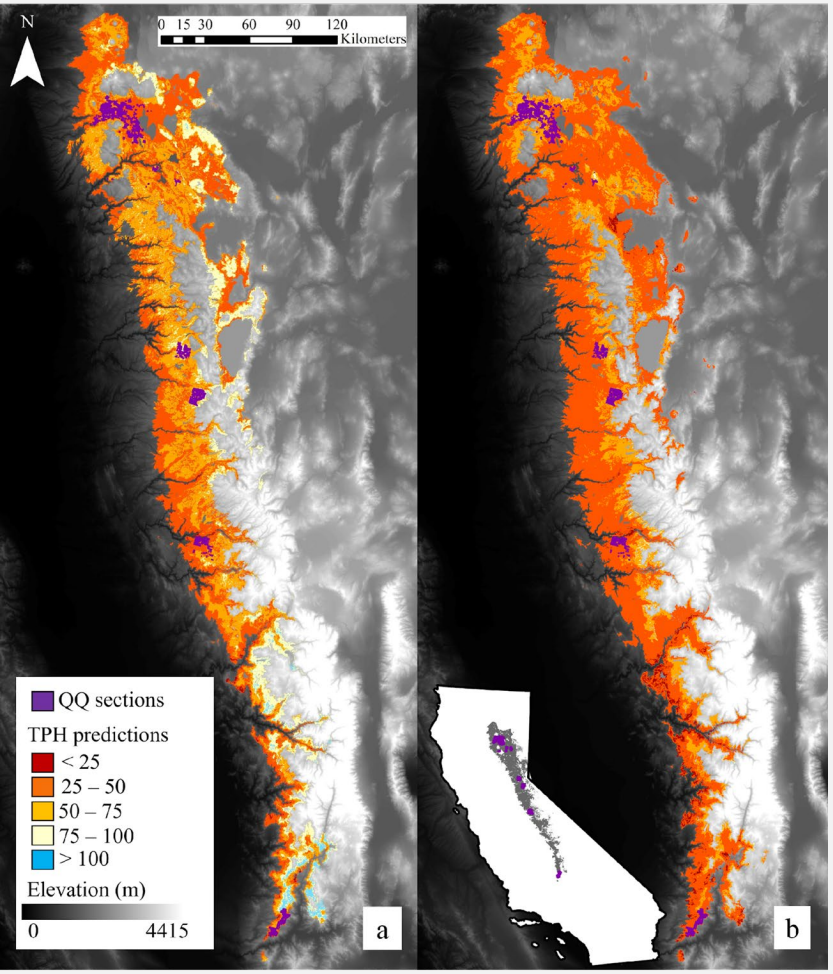
Structure + Process: Thinning & Gap Harvest + 1 RxFire

Relative Density~34%

WHAT DOES RESILIENCE LOOK LIKE IN THE FUTURE?

Bernal et al. 2022; Environmental Research Letters

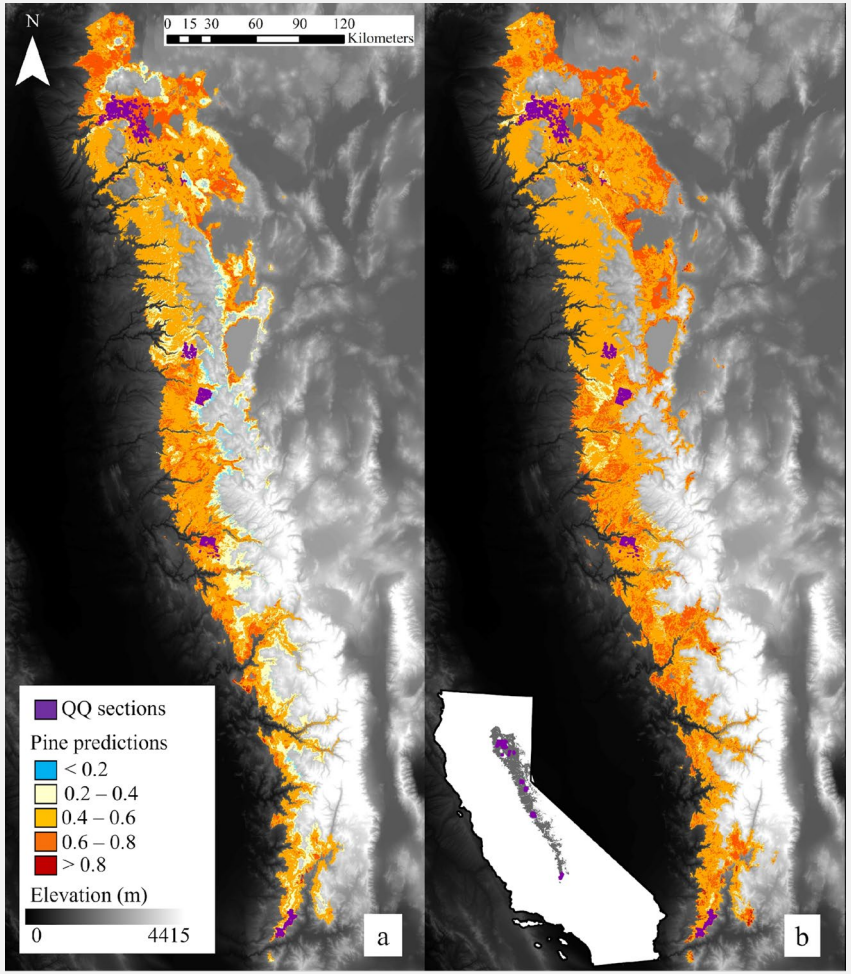
Low tree densities (low end of NRV)



Historical (1911-1936)

Future (2040-2069)

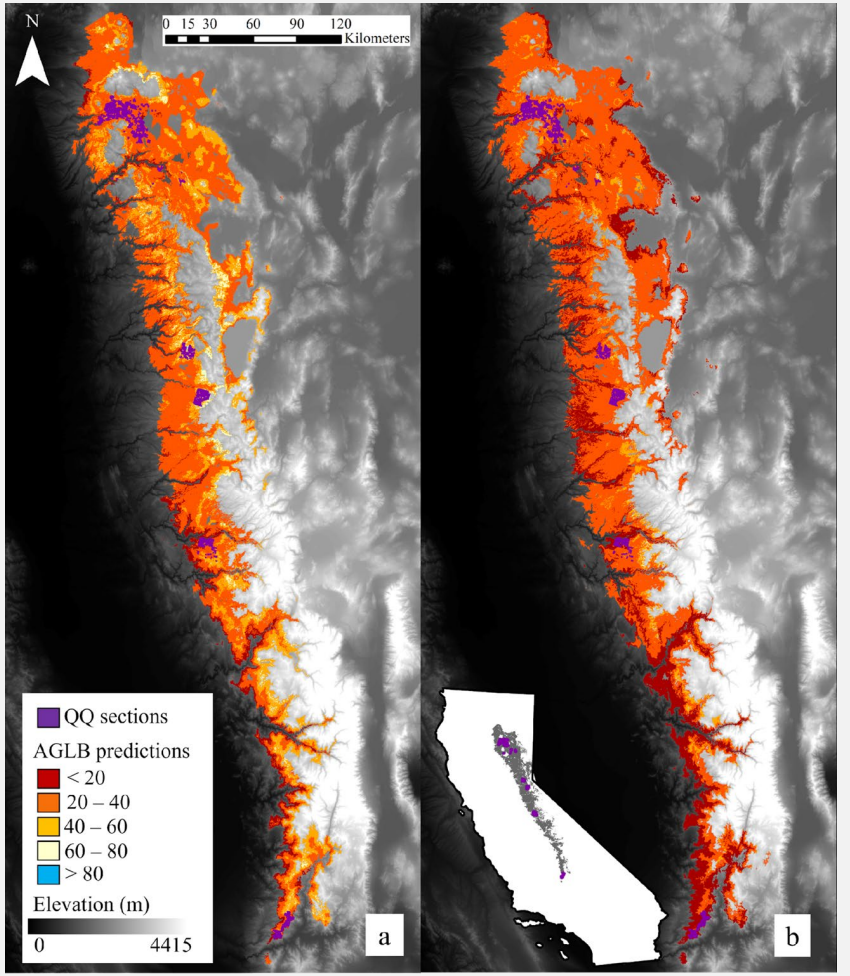
Higher Pine Dominance



Historical (1911-1936)

Future (2040-2069)

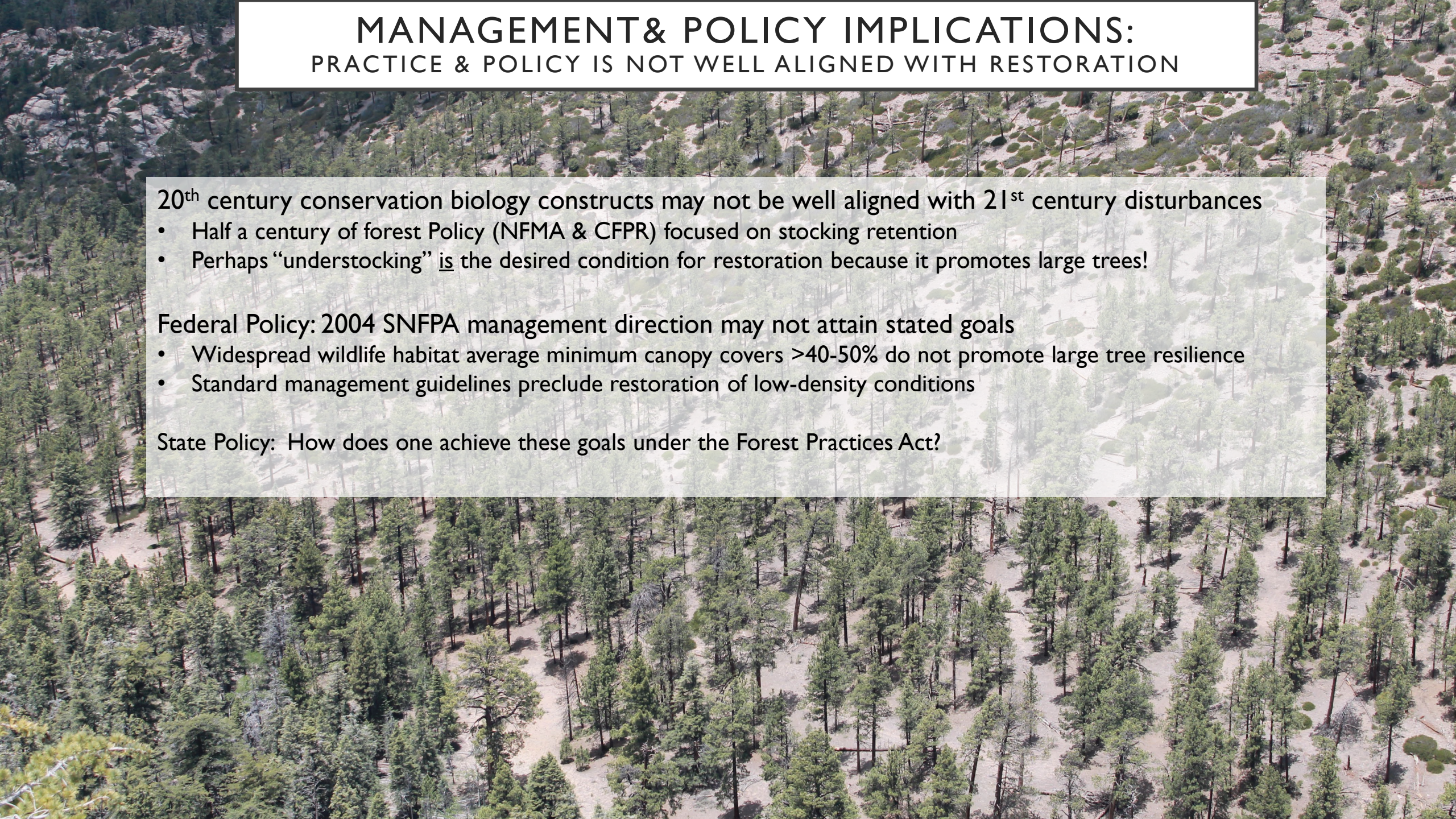
Supports <25% of current AGLB



Historical (1911-1936)

Future (2040-2069)

MANAGEMENT& POLICY IMPLICATIONS:
PRACTICE & POLICY IS NOT WELL ALIGNED WITH RESTORATION



20th century conservation biology constructs may not be well aligned with 21st century disturbances

- Half a century of forest Policy (NFMA & CFPR) focused on stocking retention
- Perhaps "understocking" is the desired condition for restoration because it promotes large trees!

Federal Policy: 2004 SNFPA management direction may not attain stated goals

- Widespread wildlife habitat average minimum canopy covers >40-50% do not promote large tree resilience
- Standard management guidelines preclude restoration of low-density conditions

State Policy: How does one achieve these goals under the Forest Practices Act?

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