Utility of strategic forest inventories for developing indicators of regional change

Jeremy S. Fried and Vicente Monleon

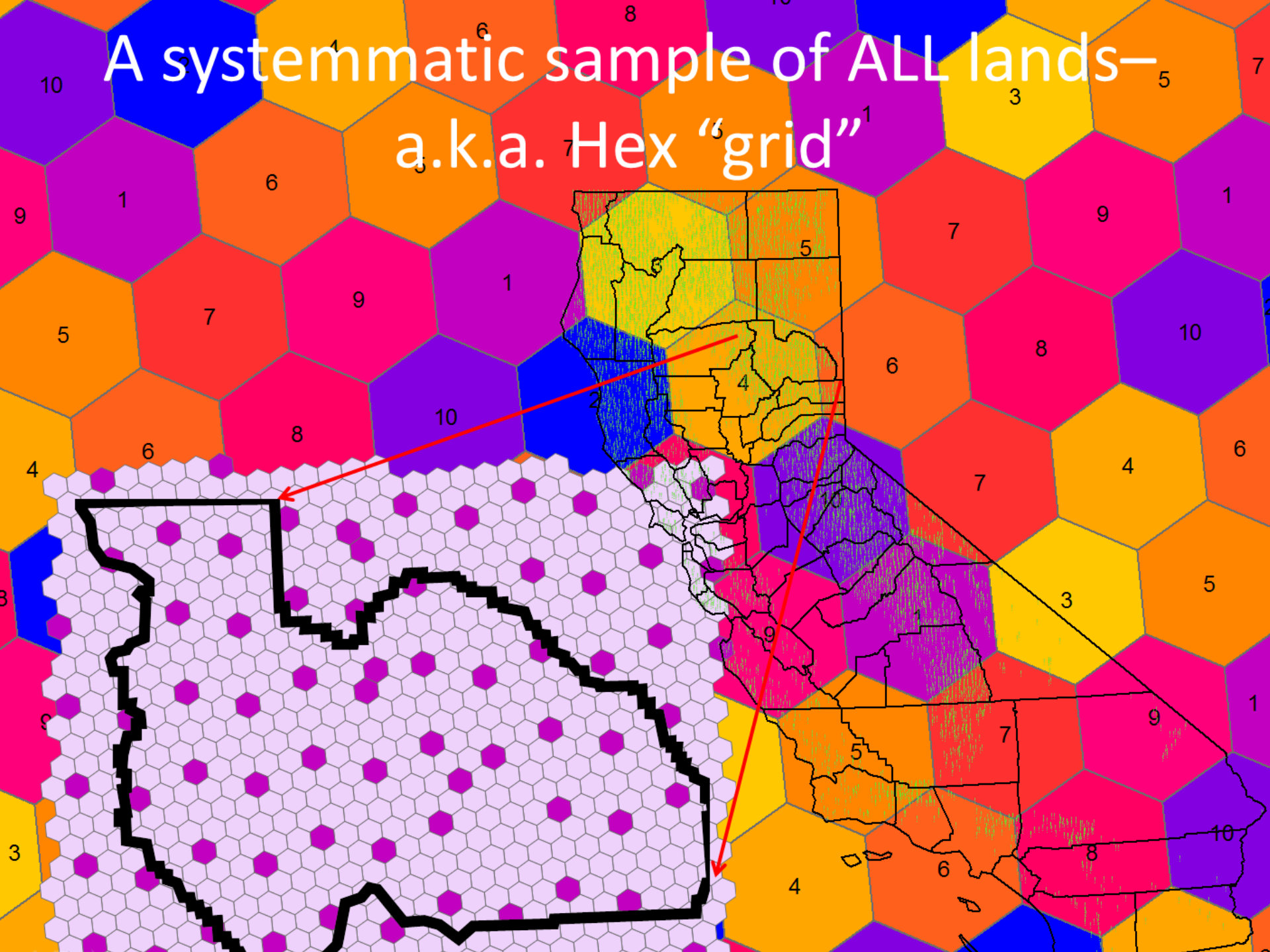
USFS Pacific Northwest Research Station

PNW-FIA: Forest Inventory and Analysis

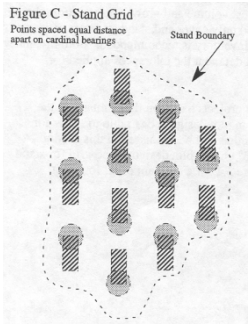
Forest Inventory & Analysis

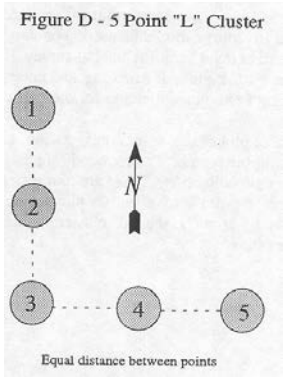
- A national, comprehensive, forest survey since 1928
- Focus was timber; ecological attributes came later
- Statistical approach evolved from maps+plots to a spatially balanced sample of systematically placed plots
- 1998 Farm Bill mandated:
  - ❖ Consistent, national design: 4 fixed radius subplots
  - ❖ 1 plot per 6000 acres across all forest lands
  - ❖ Complete, systematic, annual sample of each state
  - ❖ Confidentiality & FOIA exclusion for plot integrity, preservation of representativeness, and landowner protection

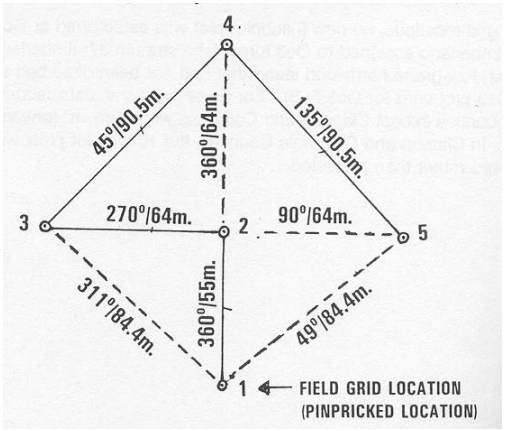
A systemmatic sample of ALL lands– a.k.a. Hex "grid"

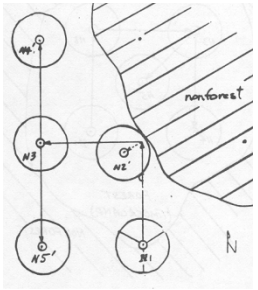


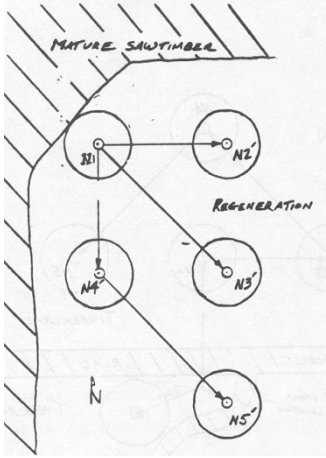
Pre-1998 plot designs

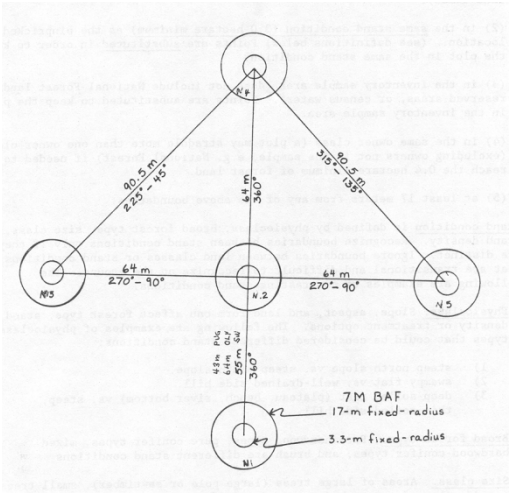


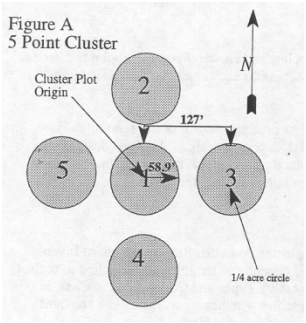


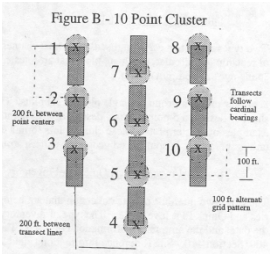


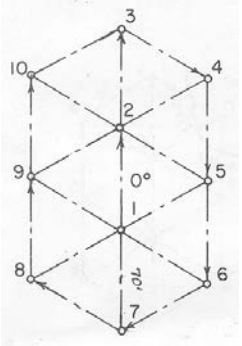


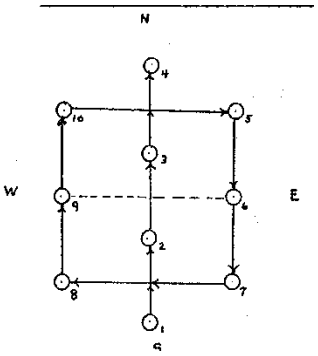






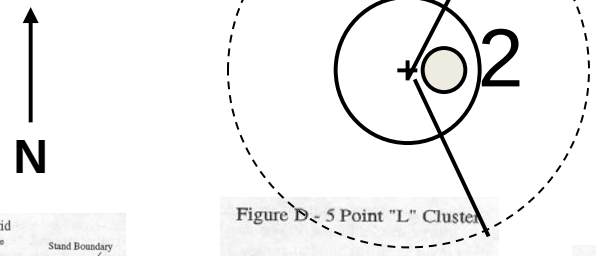


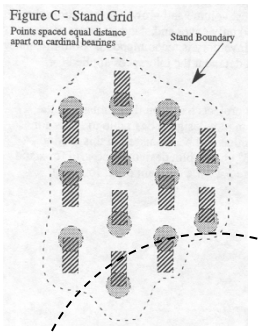


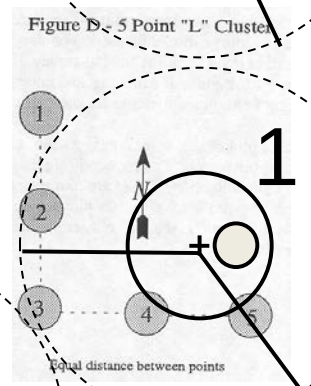


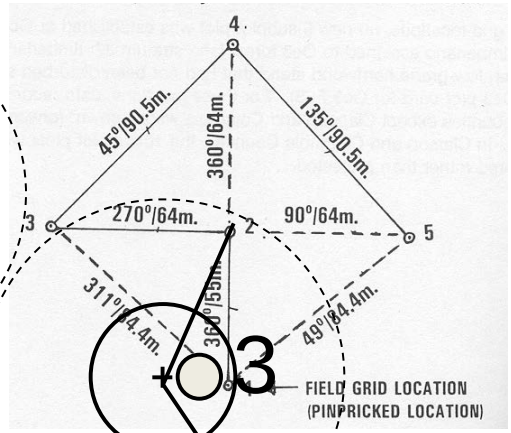
4-subplot, PNW-FIA Annual Plot "Footprint"

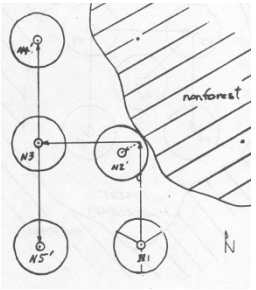
Pre-1998 plot designs

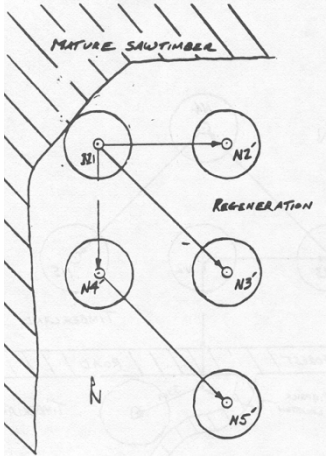


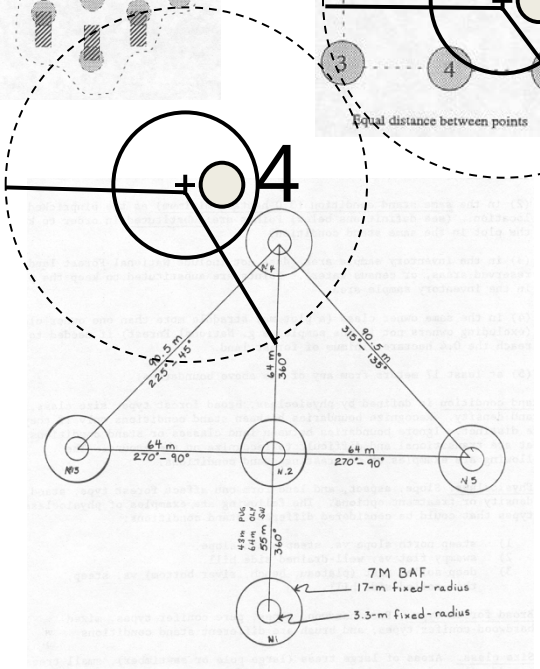


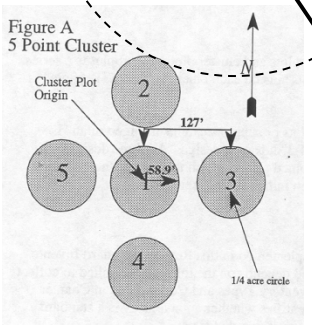


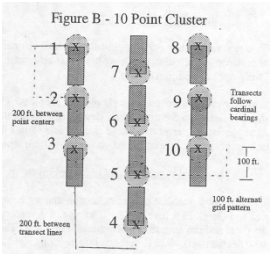


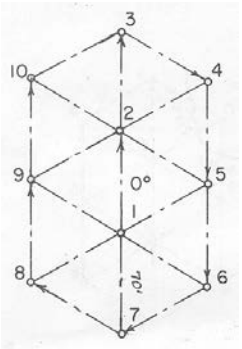


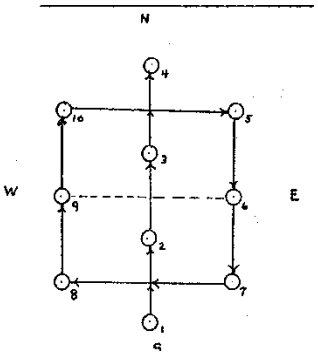




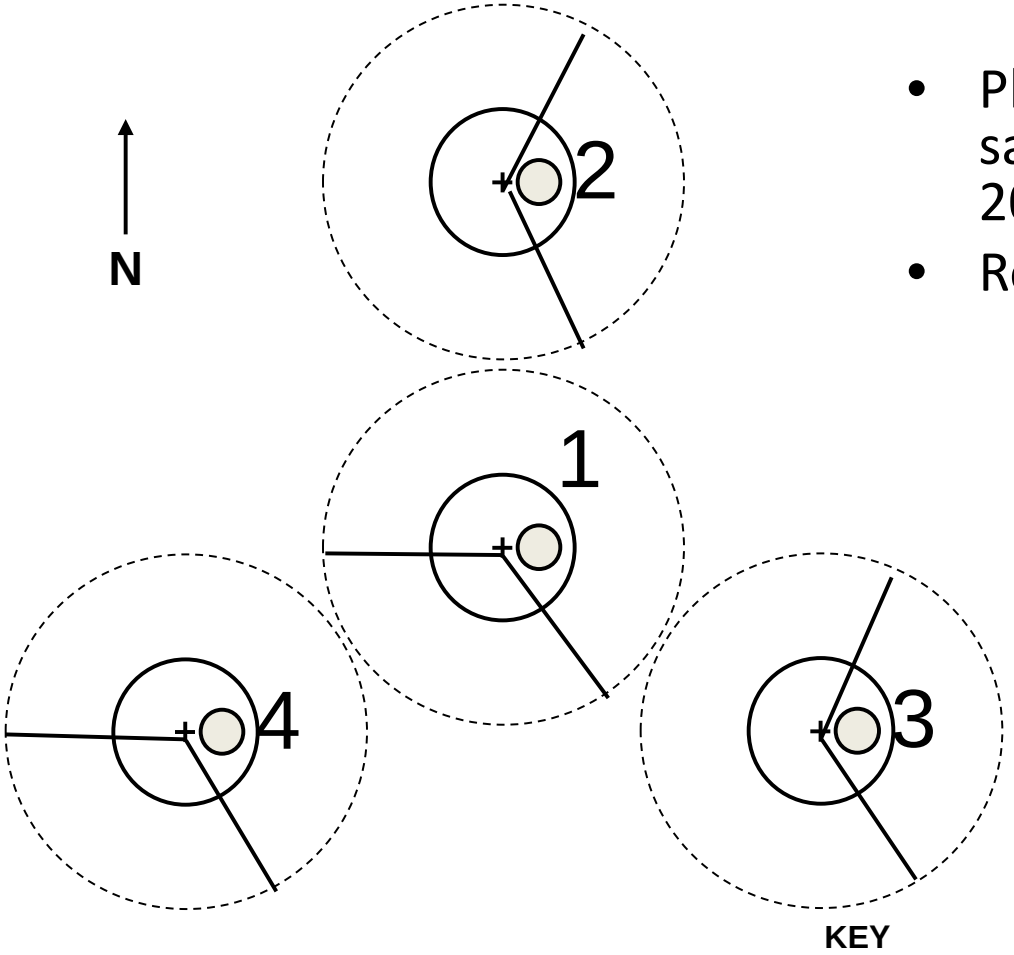








4-subplot, PNW-FIA Annual Plot "Footprint"



- Plots using this design were sampled in California starting in 2001
- Remeasurement began in 2011

distance between subplot centers=120' (36.6 m)

Attributes assessed in the field

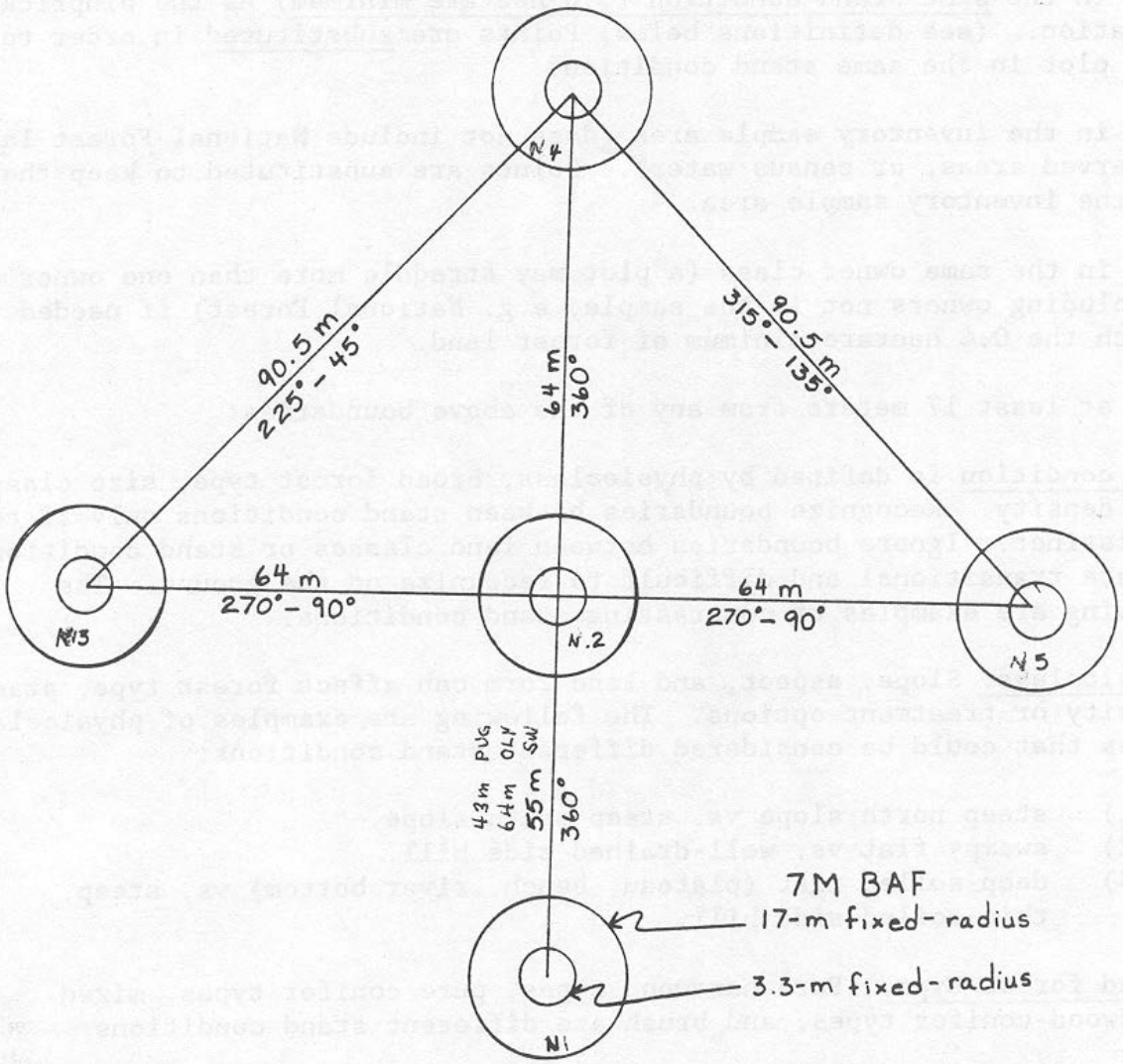
- Trees (live/dead status, species, diameter, height, crown ratio, damage, decay class…)
- Down wood (size, decay class, counts…)
- Understory vegetation (height, cover, species..)
- Location (lat, lon, elevation, ecoregion…)
- Owner, reserve status, land use…
- Slope, aspect, proximity to water, site trees…
- Disturbance and treatment history

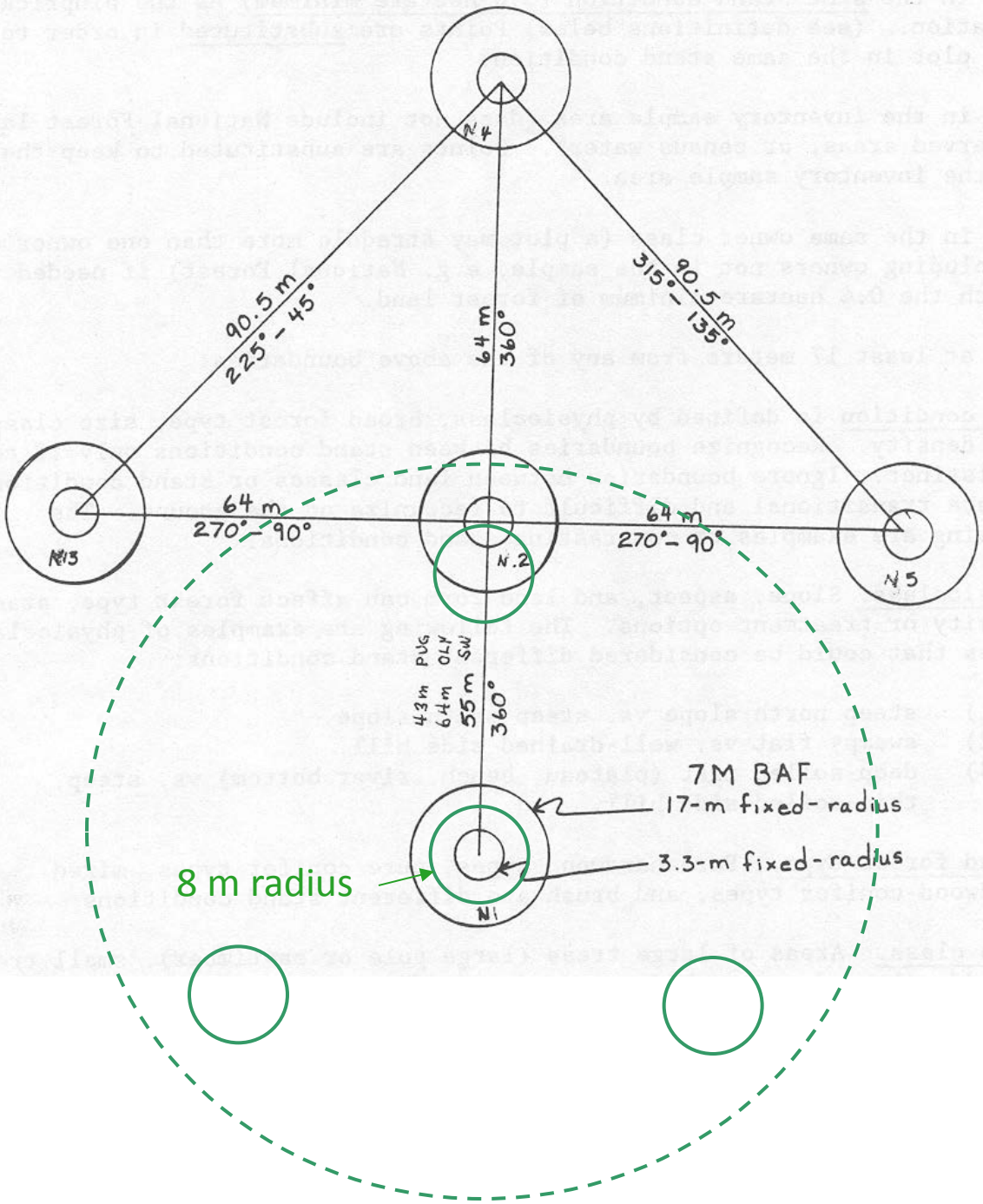
Standard attributes calculated

- Volume, biomass, carbon of trees & dead wood
- Forested area
- Forest type, size class, density class
- Site class, stocking
- Down wood loading by size class
- Tree density (Basal area, trees per acre)

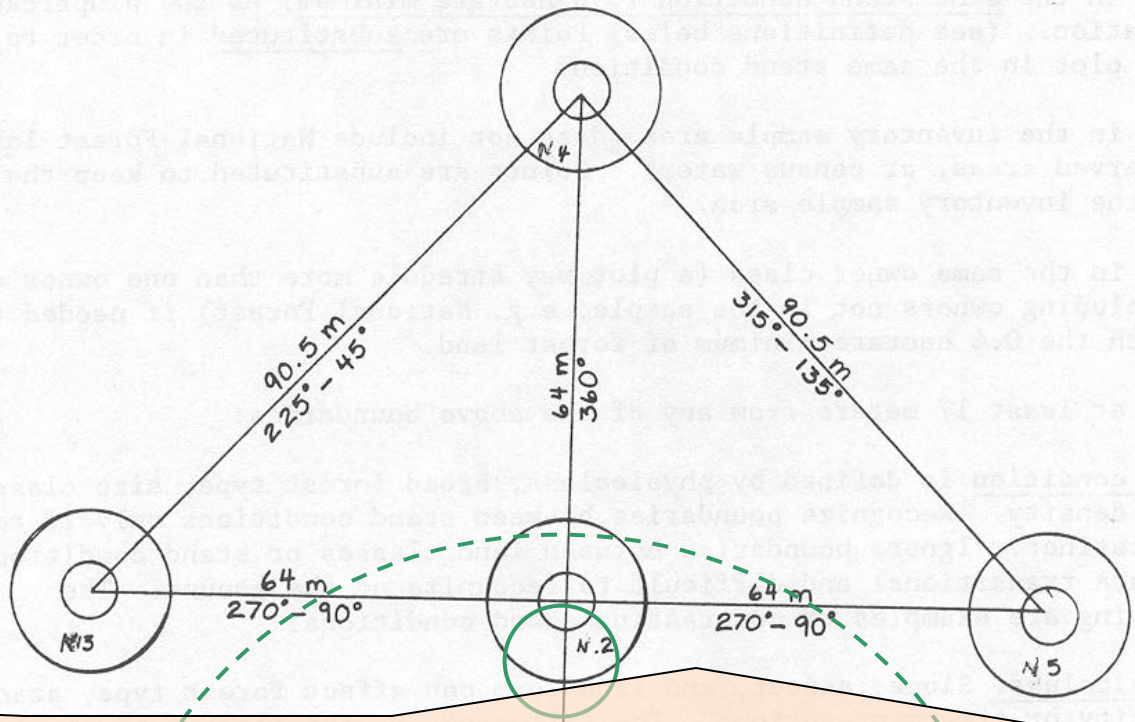
Regional Change Analysis is a Challenge

- Statistical sampling framework required for
  - Controlling noise and confounding signals
  - Enabling formal hypothesis testing & error bars
  - A truly scientific, evidentiary foundation
- Genuine remeasurement essential but rare; beware of noisemakers & bias traps:
  - "remeasures" of non-monumented plots
  - Remeasures that are not tree-level
  - Pixel-based change estimates

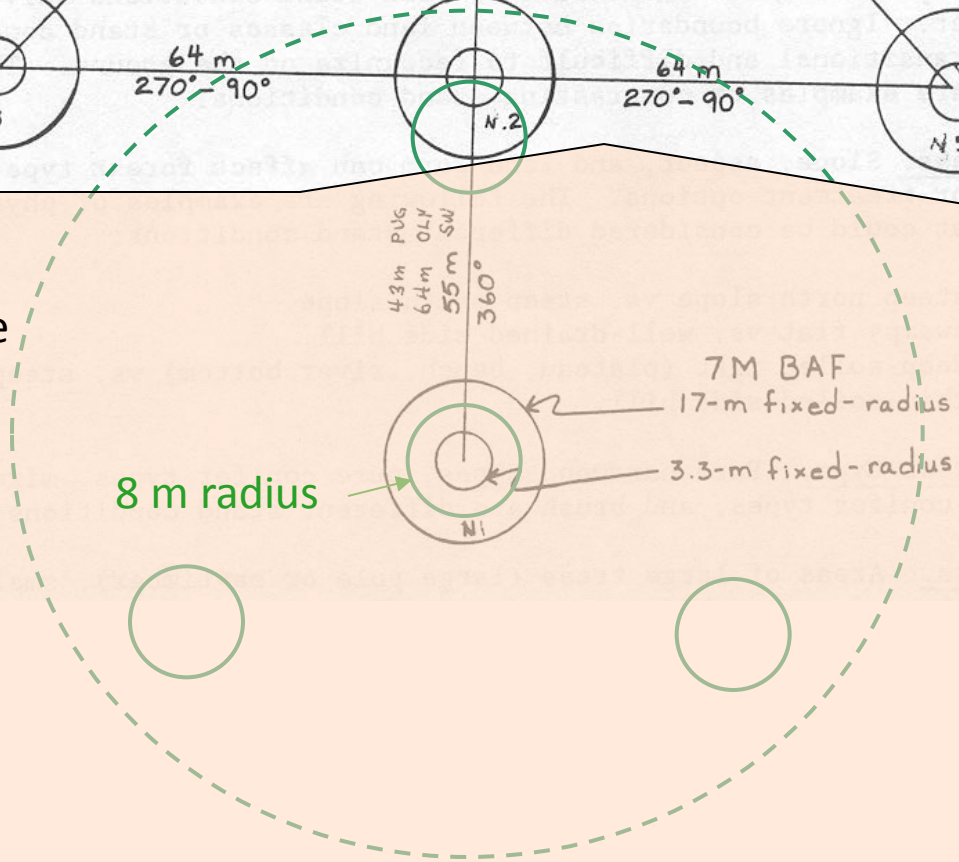

N4
90.5 m
225° - 45°
64 m
360°
315° - 135°
90.5 m
64 m
270° - 90°
64 m
270° - 90°
N3
N.2
N5
43m PUG
64m OLY
55m SW
360°
7M BAF
17-m fixed-radius
3.3-m fixed-radius
N1


N4
90.5 m
225° - 45°
64 m
360°
90.5 m
315° - 135°
64 m
270° - 90°
64 m
270° - 90°
N3
N2
N5
43m PVG
64m OLY
55m SW
360°
7M BAF
17-m fixed-radius
3.3-m fixed-radius
8 m radius
N1

Old Growth



Regeneration due to fire or harvest



8 m radius

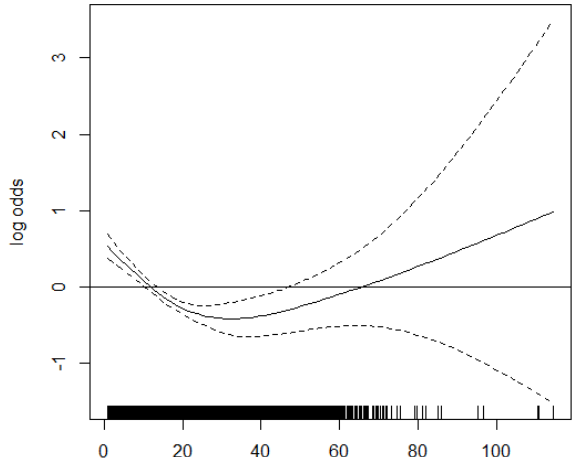
C flux Tg/yr in California National Forests

NFS All			NFS Reserved			NFS Unreserved			Analysis
Mean	SE		Mean	SE		Mean	SE		
-3.33	ns		-2.96	ns		-0.63	ns		**Periodic to Annual (6 panels) Plot-level (1992 – 2004)**
0.31	0.44		0.66	1.12		0.06	0.58		**Separate Annual Samples (2002 – 2005, 2 sets of 3 panels)**
0.27	0.17		-0.36	0.41		0.45*	0.18		**Accelerated Annual (4 panels) Subplot-level (2003 – 2008)**
0.50*	0.12		-0.14	0.319		0.71*	0.12		**Annual to Annual (3 panels) Tree-level (2002 – 2012)**

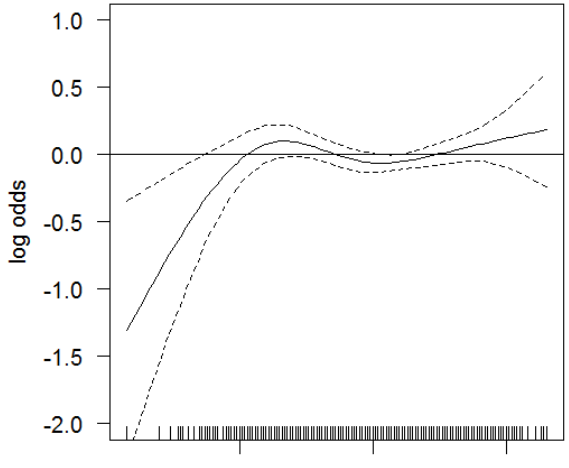
Forest Inventory Indicator Options

- Mortality
  - Well defined (binary response), but
  - Rare event so large supporting population needed
- Growth
  - Complicated by stand dynamics & ownership, but
  - Much more data
- Regeneration
  - Small sample, and
  - No tracking until DBH=1”

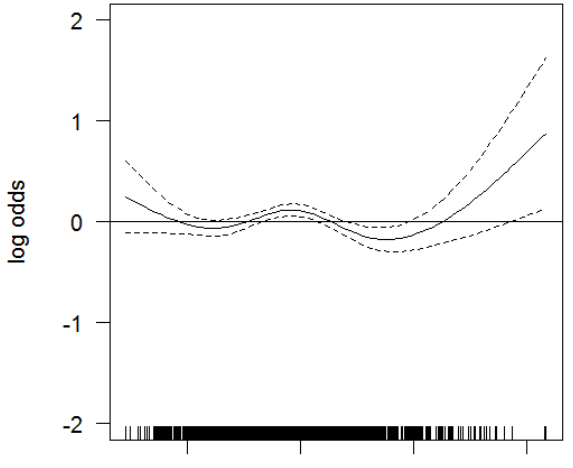
Lots of factors influence mortality



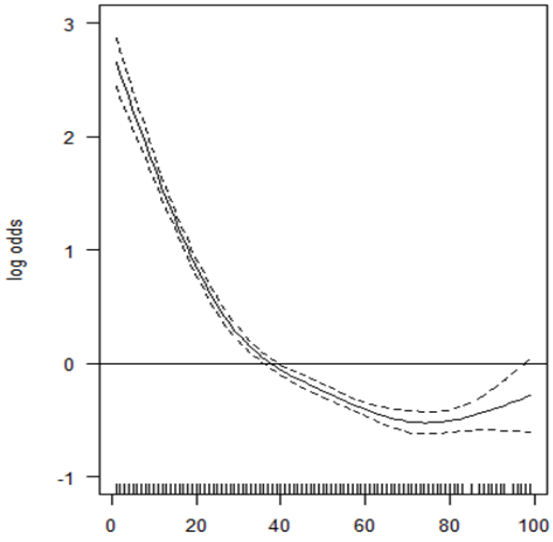
Tree Diameter



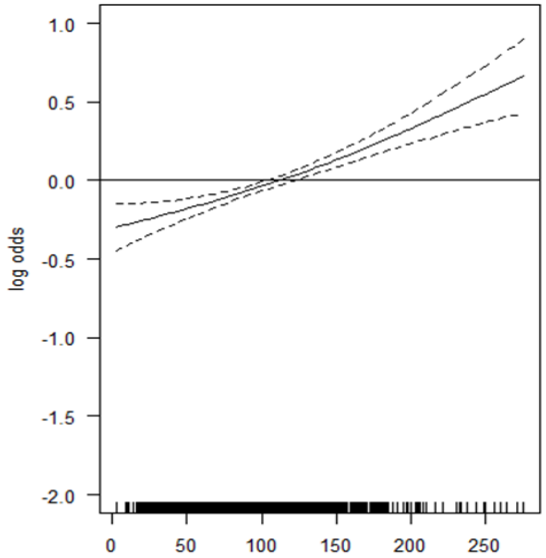
Mean Ann. Temperature



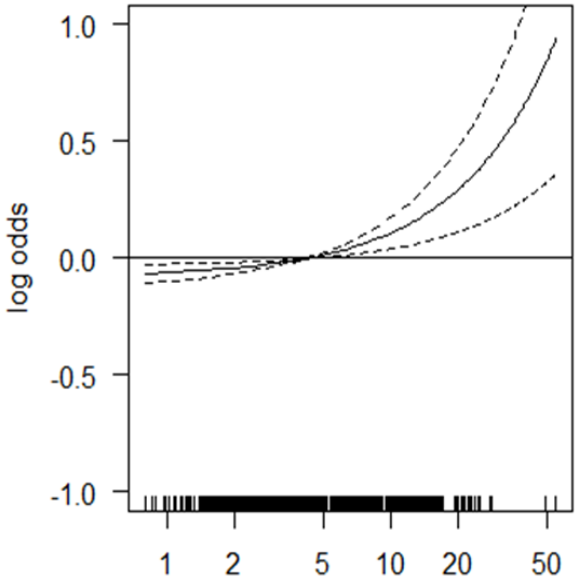
Cumulative Moisture Deficit



Live Crown Ratio

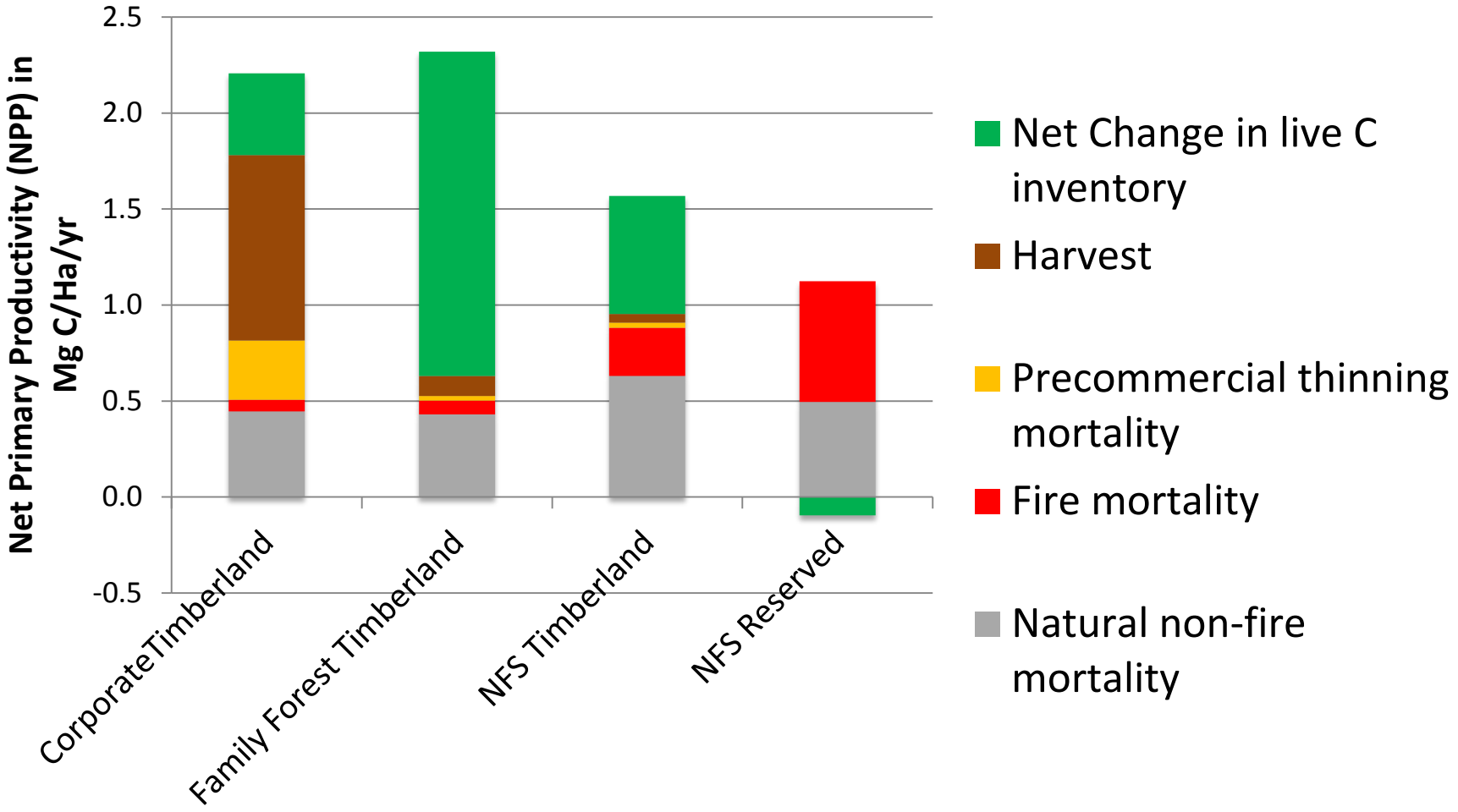


Site Quality (MAI)



Nitrogen Deposition

Allocation of Net Primary Production in California Forests 2002-2012



Much interest in species migration but artifacts mar analyses

- Chen and others (Science, 2011) did a meta-analysis of many taxonomic groups (mostly animals) around the world:
  - 23 taxonomic groups × region for latitudinal range shifts
  - 31 taxonomic groups × region for elevational range shifts
  - Estimated a median elevational shift of 11.0 m up/decade and a median latitudinal shift of 16.9 km poleward/decade
- Studies compared arbitrarily selected samples, taken at different times and sites, for different purposes, and without a formal sampling design.
  - Geographic bias, species selection bias, detectibility issues
  - Very strong assumptions needed to justify inference to a population
- A study in California (Science 331: 324, 2011) compared historic and contemporary data and reported that plant species were migrating **downhill**.
  - It was noted that the historic plots were to the south of the contemporary plots.

RESEARCH ARTICLE

January 29, 2015

Evidence of Tree Species' Range Shifts in a Complex Landscape

Vicente J. Monleon[1*], Heather E. Lintz[2]

PLOS ONE

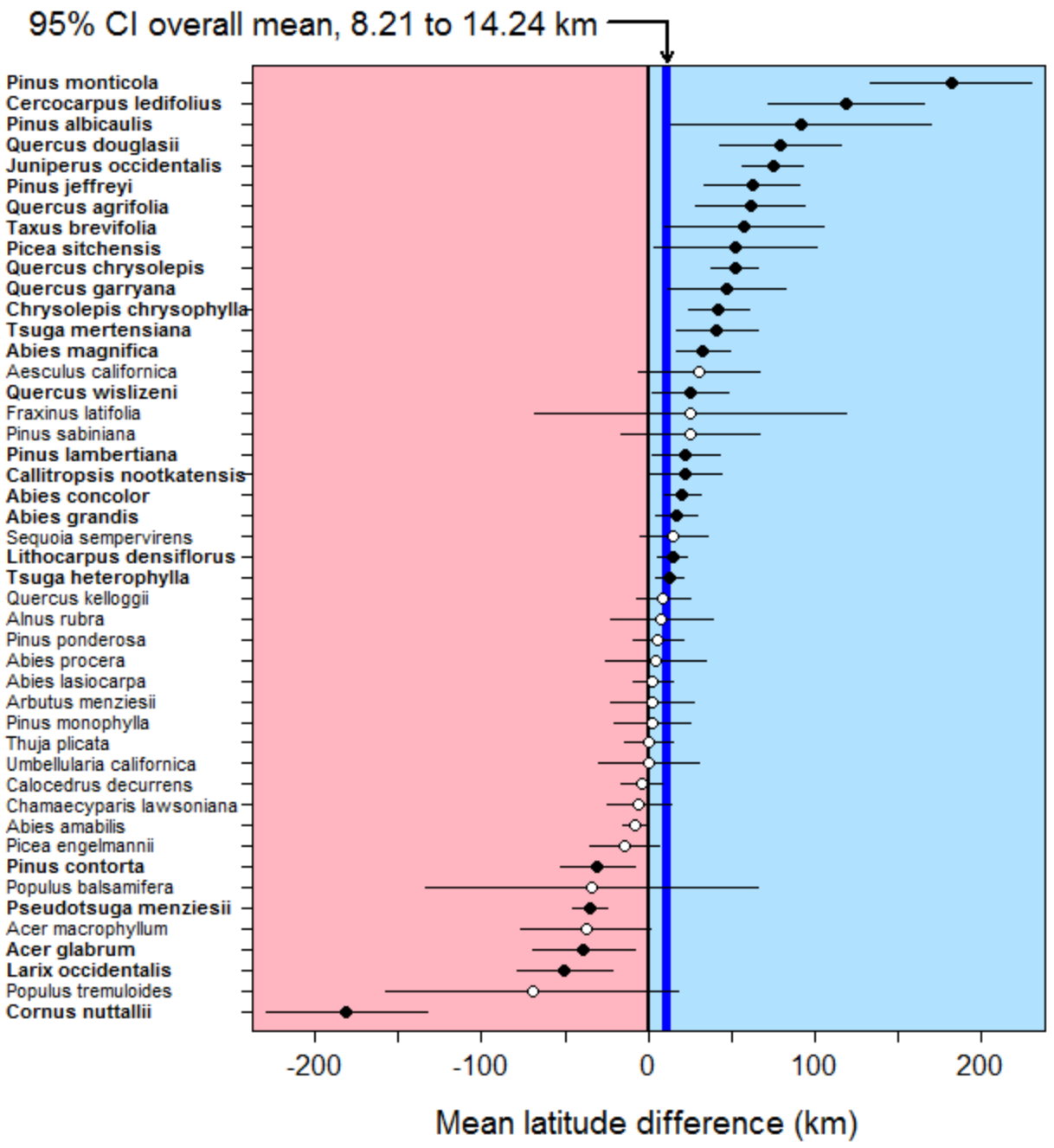
- Used a probability, spatially balanced sampling design across all lands – 1 FIA plot/24.0 km^2 to compare the mean latitude, elevation and temperature of the range of seedlings to that of mature trees
- Included species tallied on >25 plots as trees and seedlings: 46 species total
- Sampled 13,985 forested plots in CA, OR and WA

LATITUDE

Overall difference:

Seedlings 11.23 km north of trees

(95% CI from 8.21 to 14.24 km)

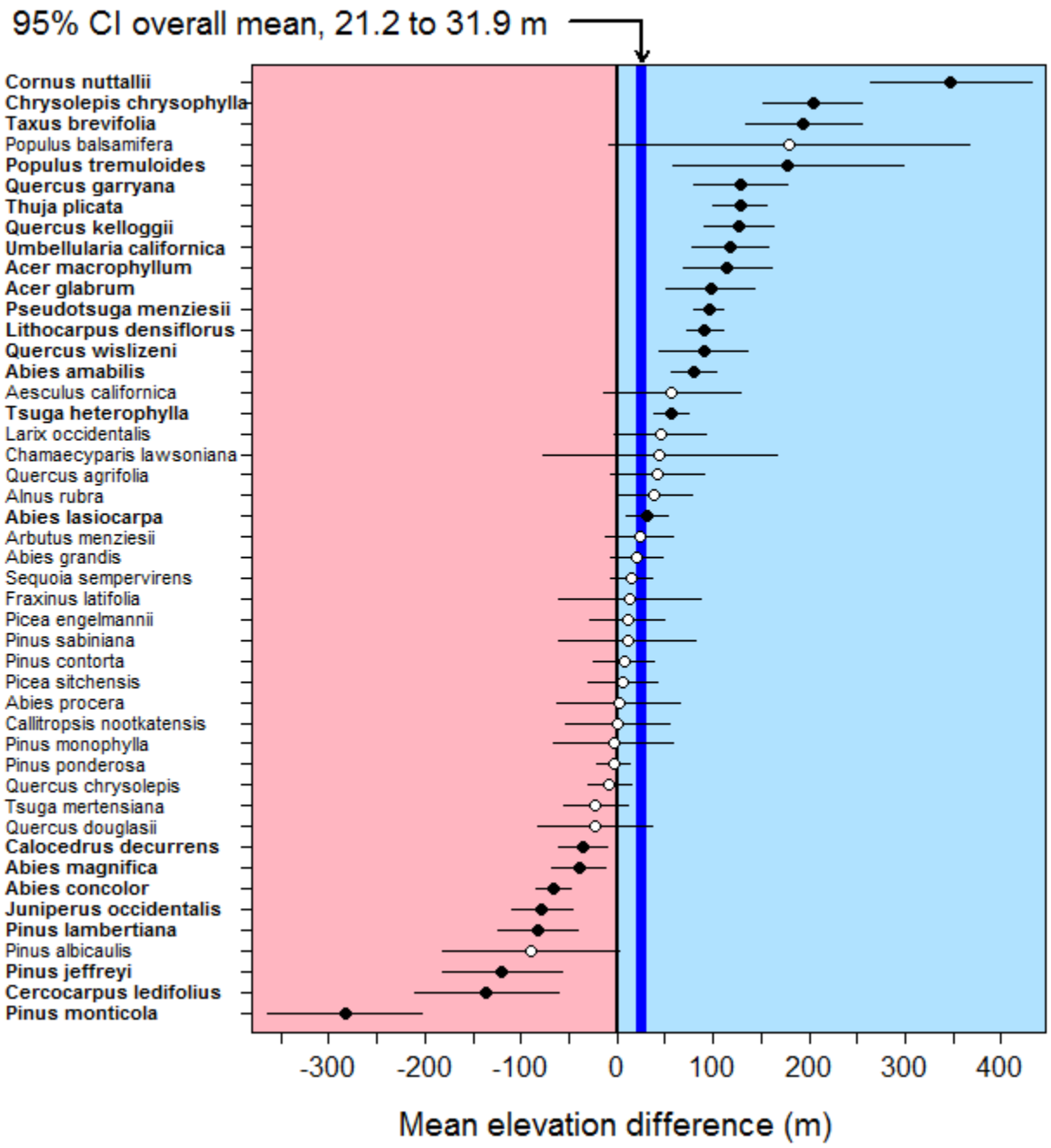


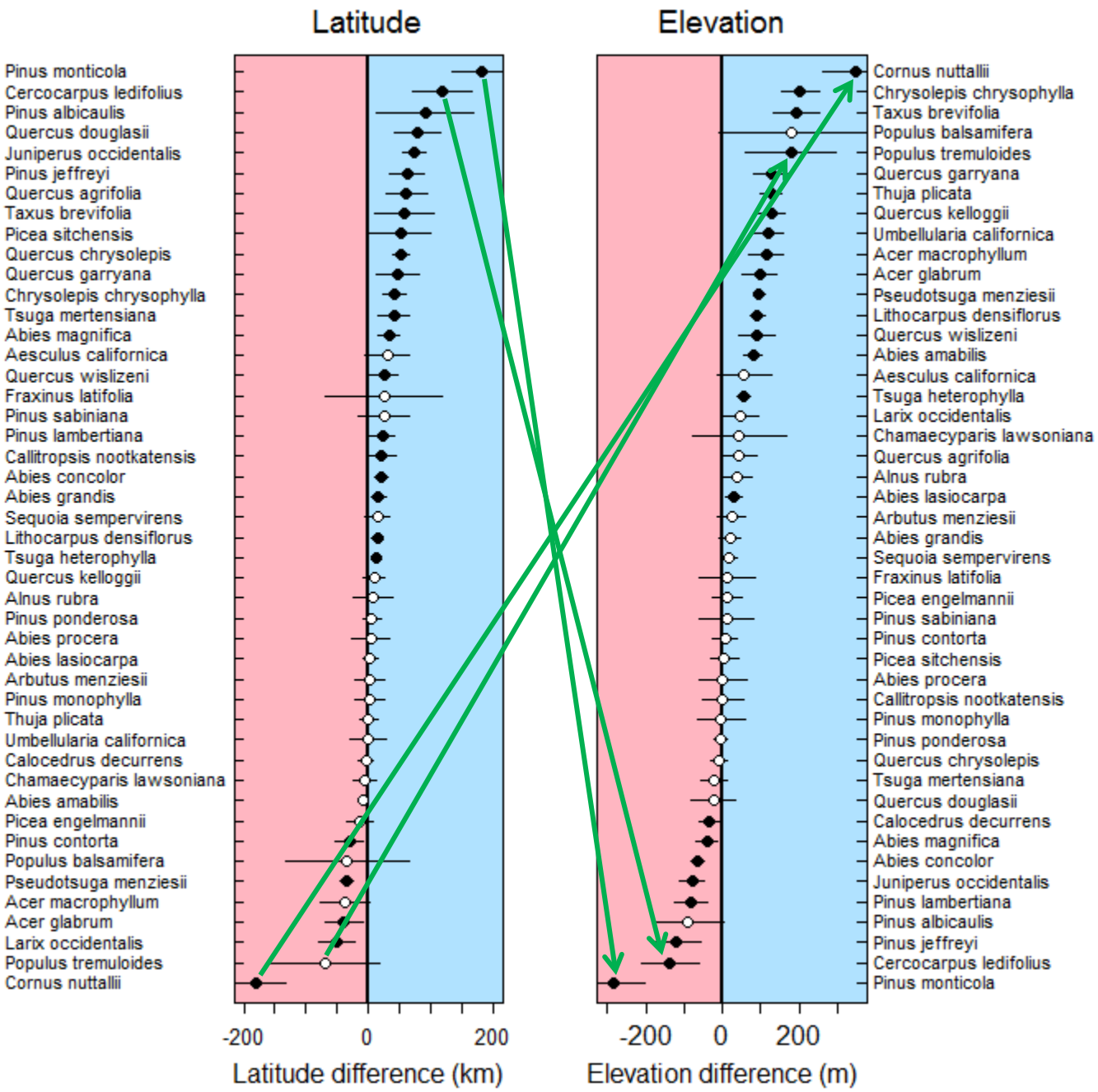
ELEVATION

Overall difference:

Seedlings 26.6 m higher than trees

(95% CI from 21.2 to 31.9 m)





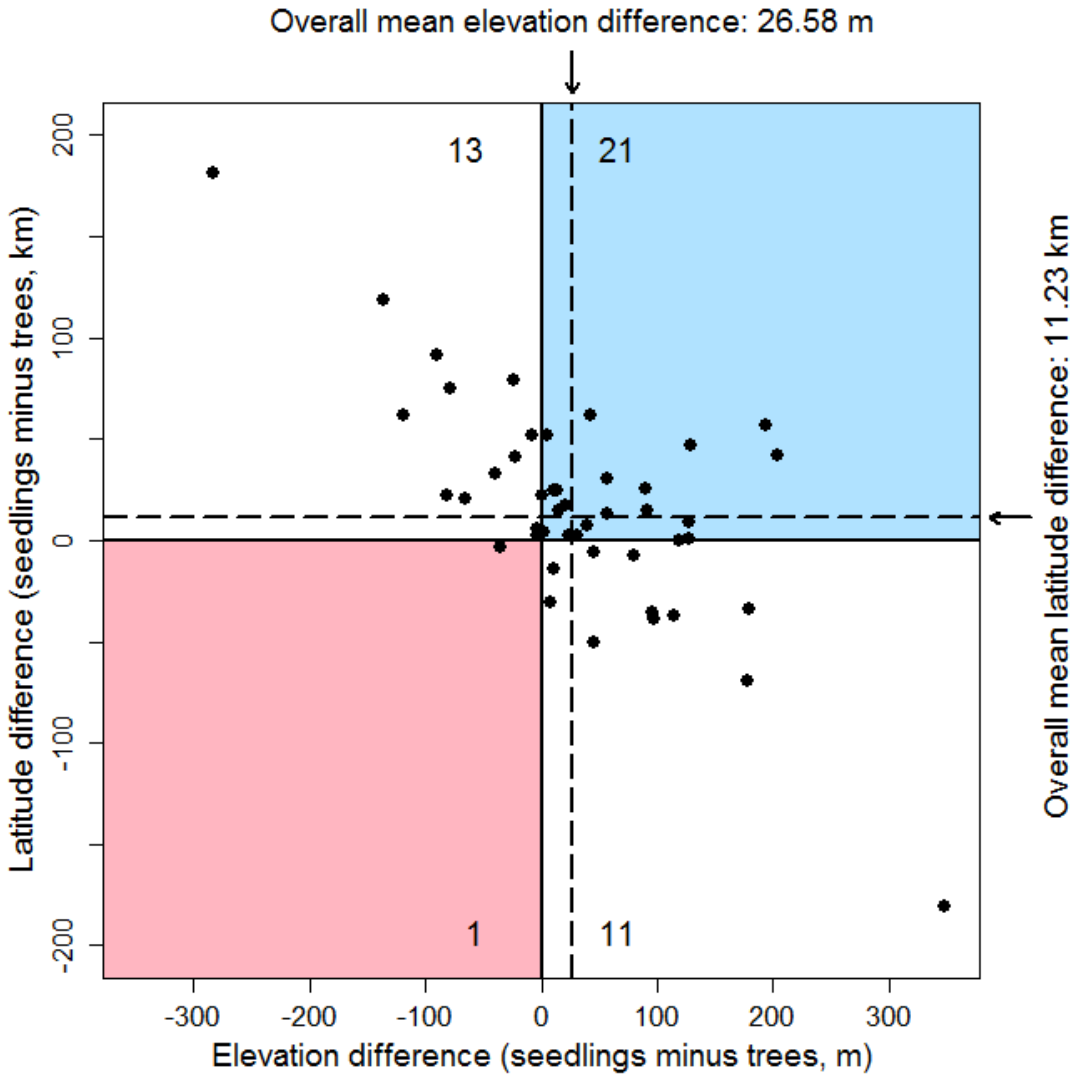
Western white pine

Mountain mahogany

Pacific dogwood

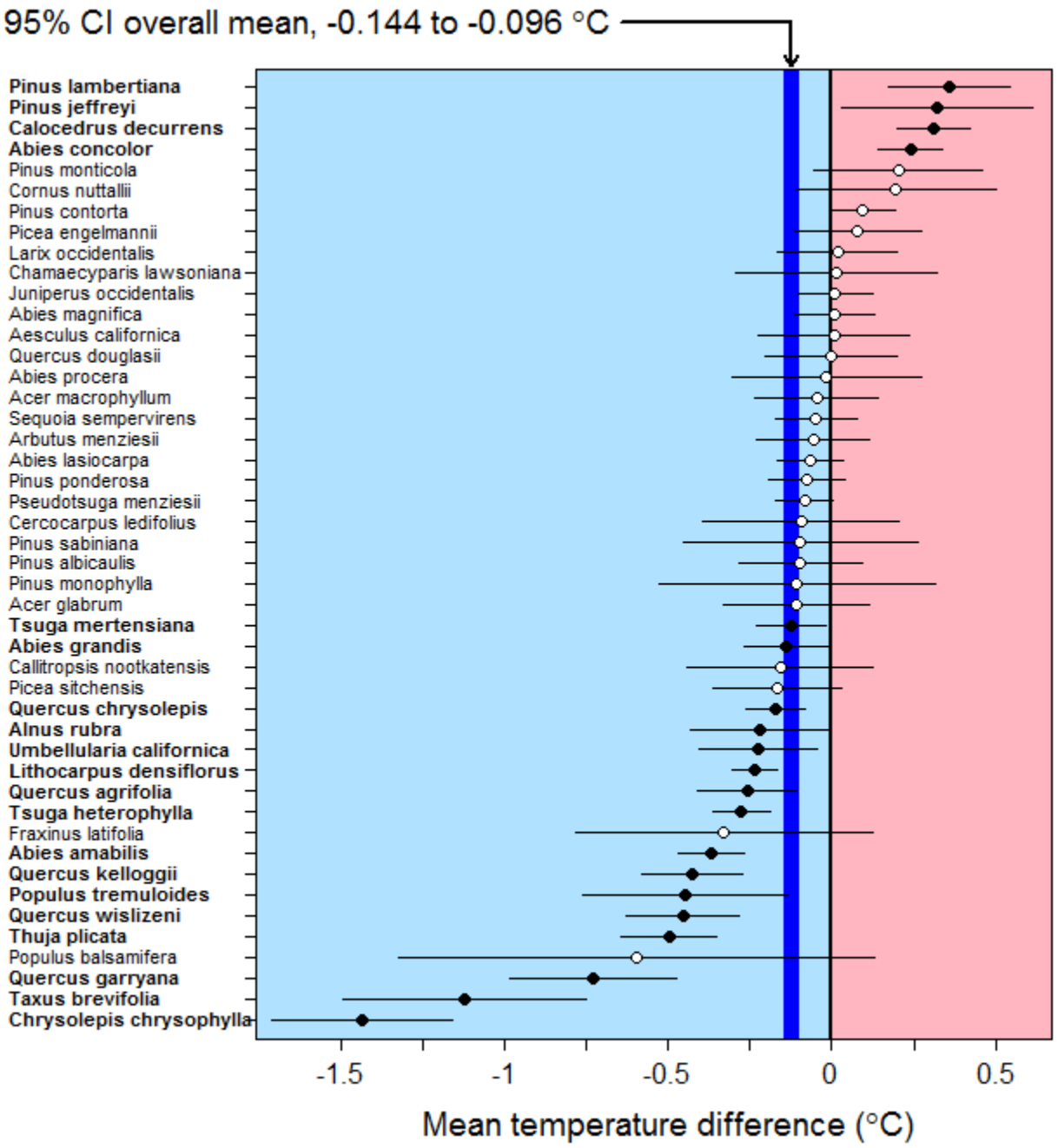
Quaking aspen

- How do we interpret the response of species with contradictory elevational and latitudinal responses?
- For example, seedlings of whitebark pine are 91 km north and 95 m lower than mature trees – what is the response to the warming trend?
- Can we look at elevational and latitudinal changes separately?



TEMPERATURE:
Overwhelming evidence that the mean temperature of the range of seedlings is colder than that of the range of trees.

The estimated difference is 0.120 °C colder (95% CI, 0.096 to 0.144 °C colder)



Lessons from species migration analysis

- Start with theory; test predictions (e.g., response to temperature)
  - Vegetation sees climate not geographic location so tailor analyses to that
- Confounding variables & many drivers of species distribution
  - Fire suppression→ true fir explosion and expanded juniper area
  - Some studies drop areas with disturbance, but fire suppression IS disturbance
    - Removing plots is a slippery slope– representativeness lost
  - Low elevation forests converted to agriculture; today's potential habitat impacted by human habitation
  - Douglas-fir plantations affect range of the rest of the tree species
- Hard to prove/generalize from one location or species
- Can't prove climate change as cause
  - Could be part of normal drought cycle; repeat measures may help
  - Have species long been shifting due to local drought patterns?

FIA Data Promising for Indicators

- Spatially balanced, annual sample of all forest lands, with precise tracking of trees and forested area (though not down wood)
- Lessons learned (almost) from 87 years of tweaking/”improving” the inventory, but at the expense of monitoring validity- best if we can keep protocols frozen for a long time!
- If long-term commitment to funding this effort with this protocol holds, it makes for an unparalleled, and unprecedented monitoring resource
- More info at http://pnwfia.info