



Riparian forest structure, stream light, and bottom-up drivers of fish production in forested headwaters

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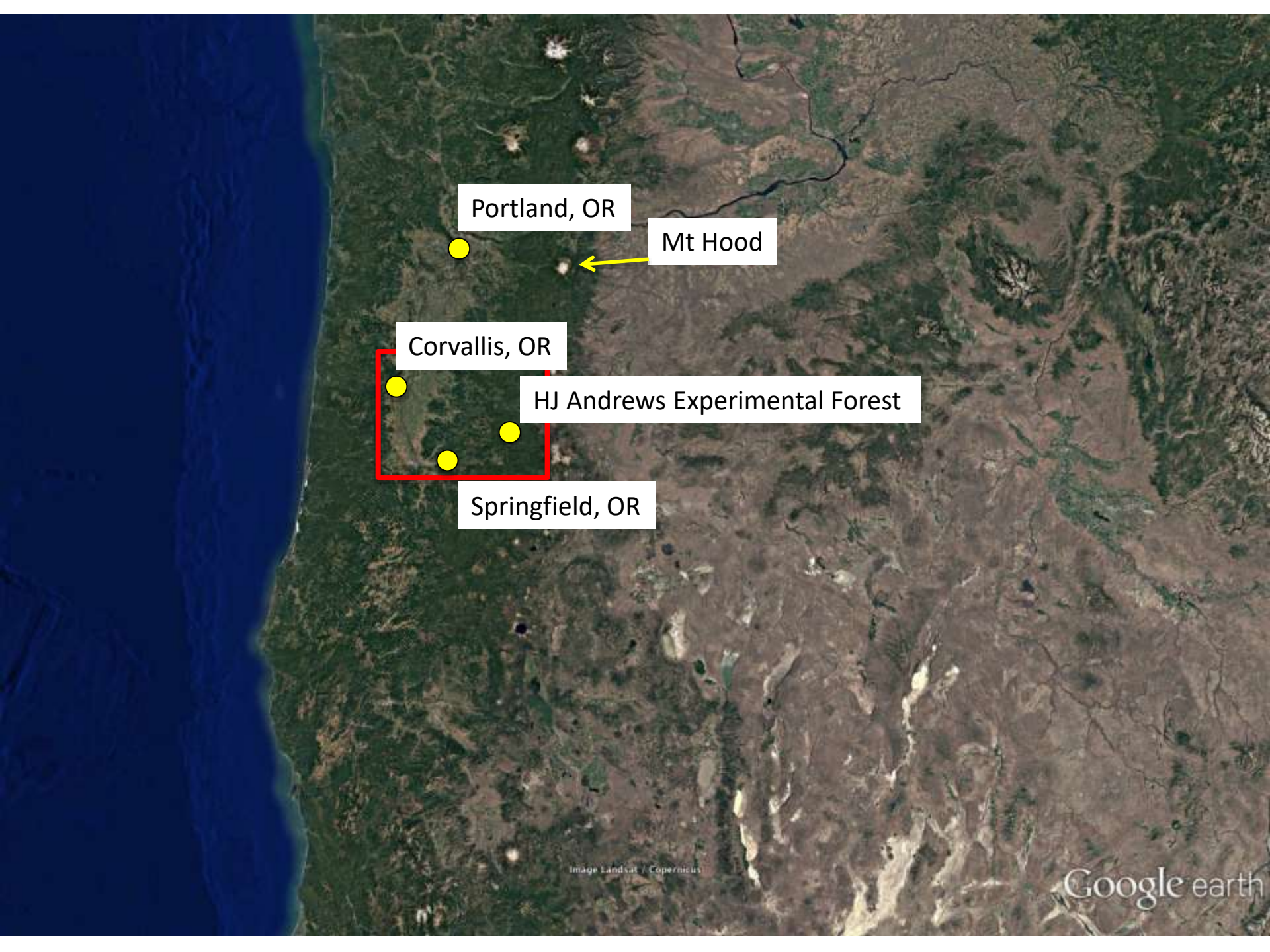
²*Dept. Fisheries and Wildlife, OSU*

³*Weyerhaeuser Co.*





Riparian forest structure,
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forested headwaters



Portland, OR

Mt Hood

Corvallis, OR

HJ Andrews Experimental Forest

Springfield, OR

Corvallis, OR



HJ Andrews Experimental Forest



Springfield, OR



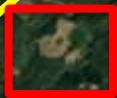
2016

HJ Andrews Experimental Forest

1986



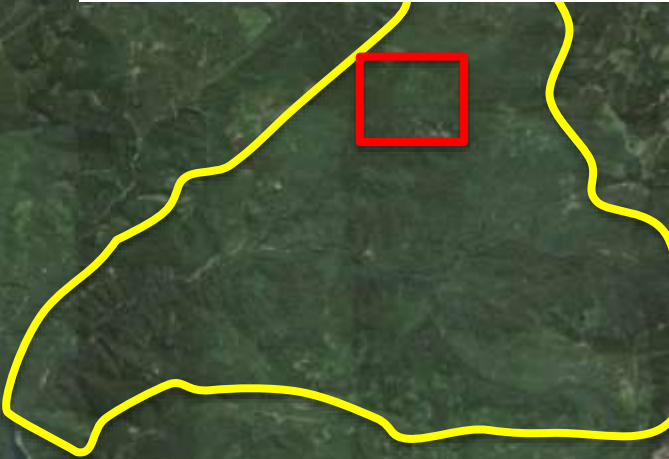
HJ Andrews Experimental Forest



2016



HJ Andrews Experimental Forest



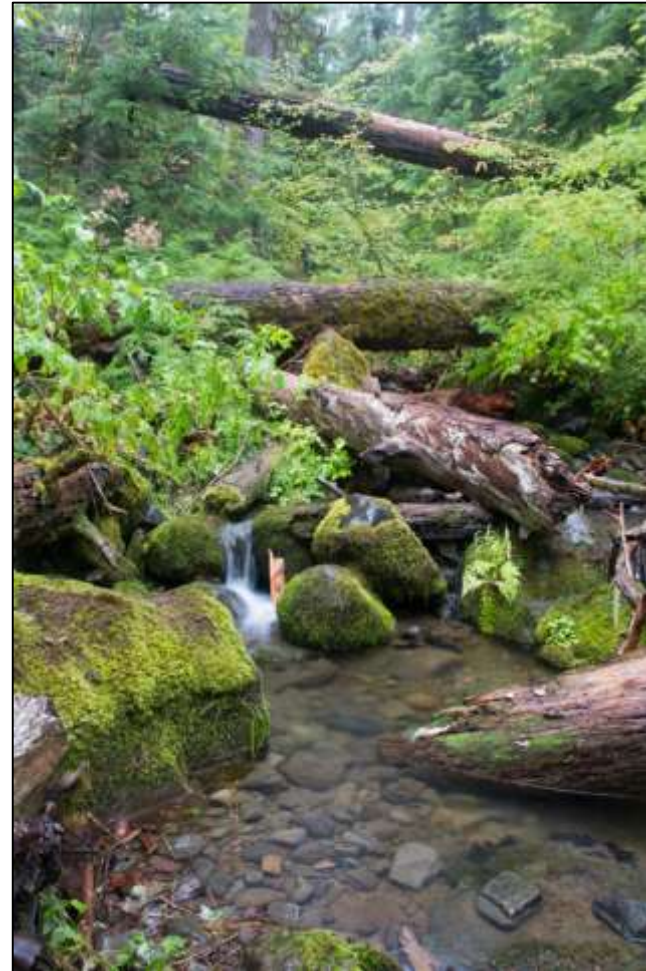
Headwater streams

- key areas for aquatic-terrestrial linkages

60+ yr second-growth forest

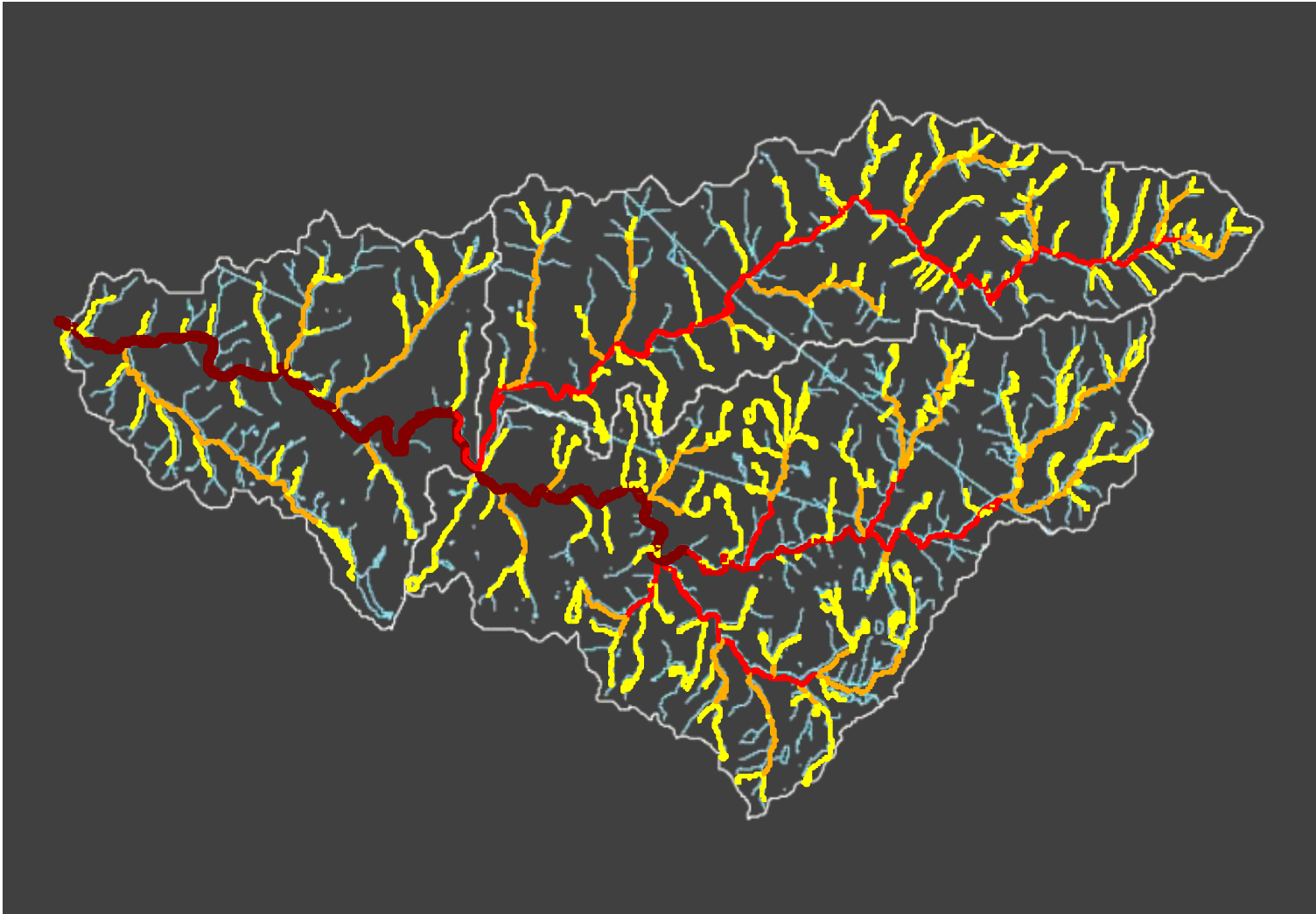


400+ yr old-growth forest



Headwater streams

- key areas for aquatic-terrestrial linkages
- Disproportionate amount of total stream length



Headwater streams

- key areas for aquatic-terrestrial linkages
- disproportionate amount of total stream length

60+ yr second-growth forest



400+ yr old-growth forest

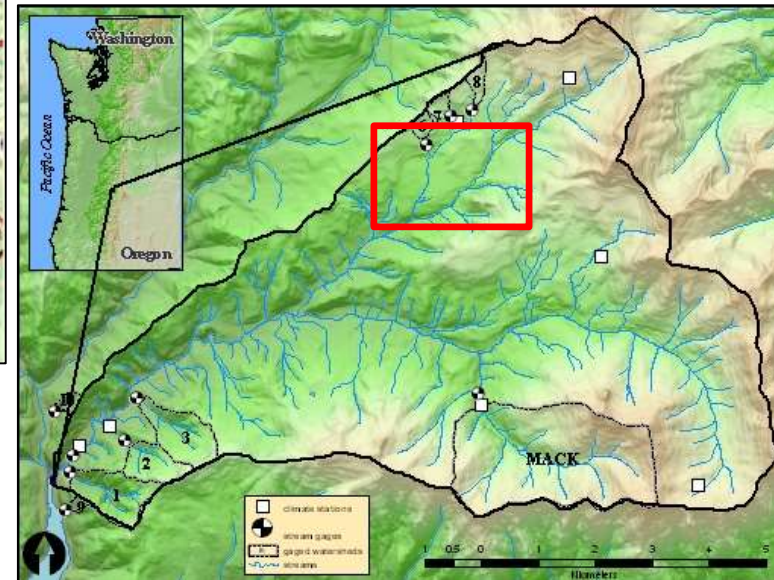
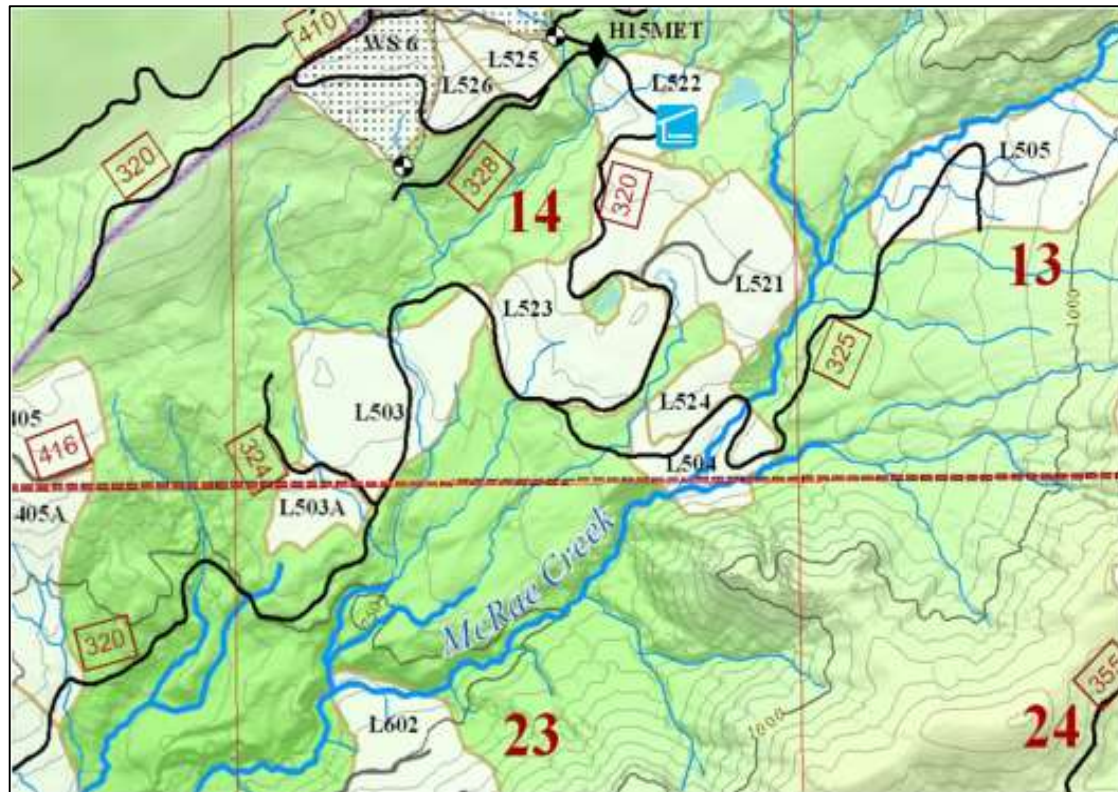


Stand development and aquatic-terrestrial linkages



Light quantification – HJ Andrews Experimental Forest:

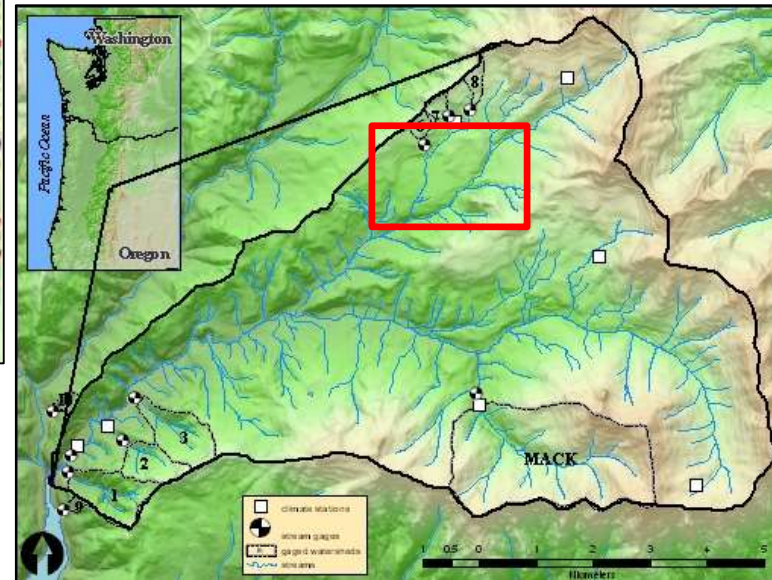
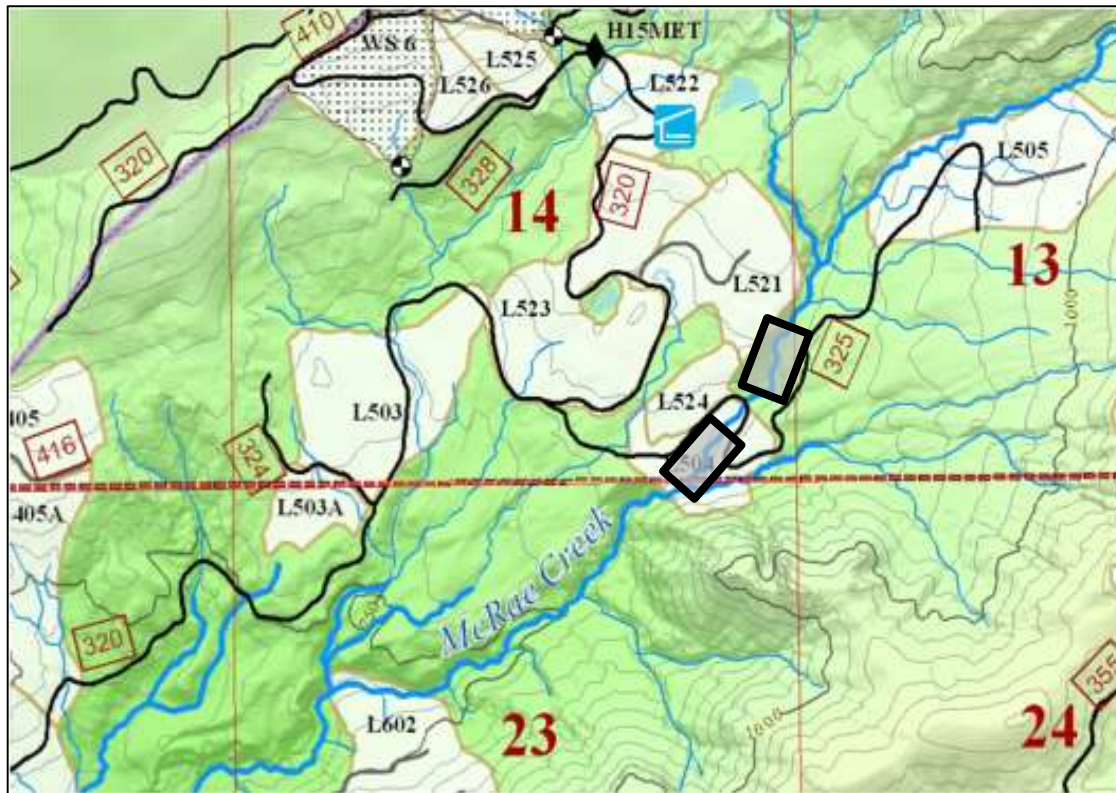
We used the unique management history of HJ Andrews Experimental Forest to select reach pairs with old-growth versus second-growth riparian forests



Forest age class comparison

Stream 1: upper third-order McRae Creek

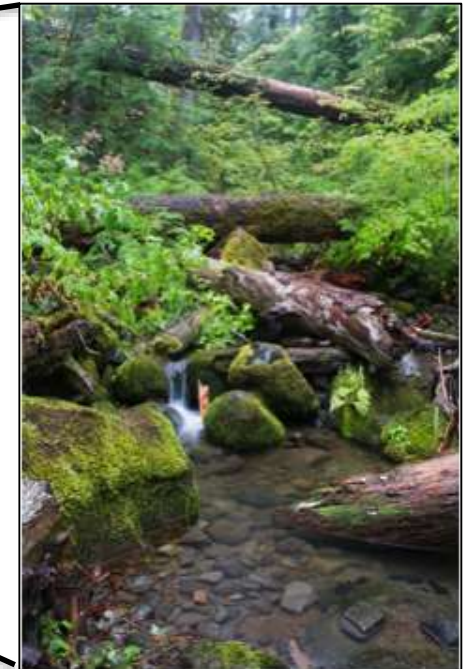
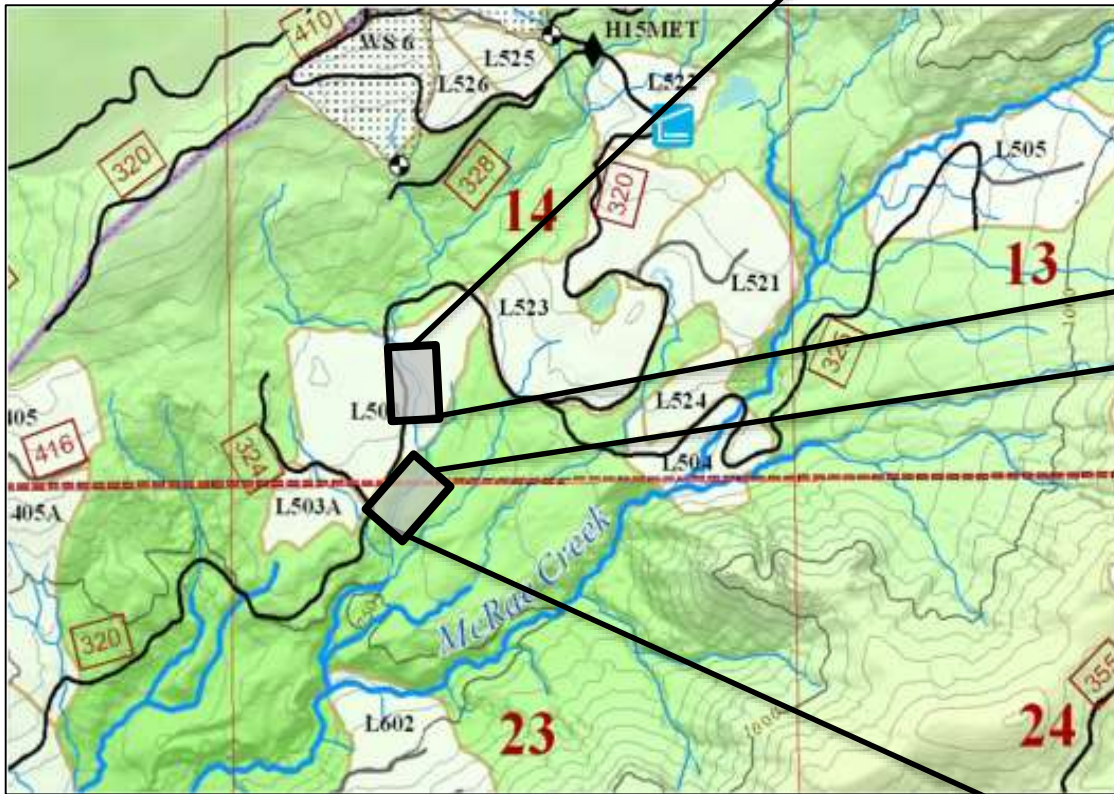
- 6.6 m bankfull width



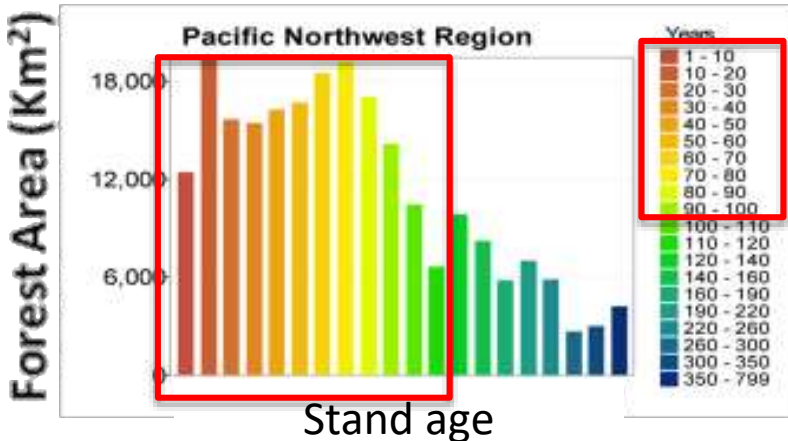
Forest age class comparison

Stream 2: McRae Creek Tributary – West

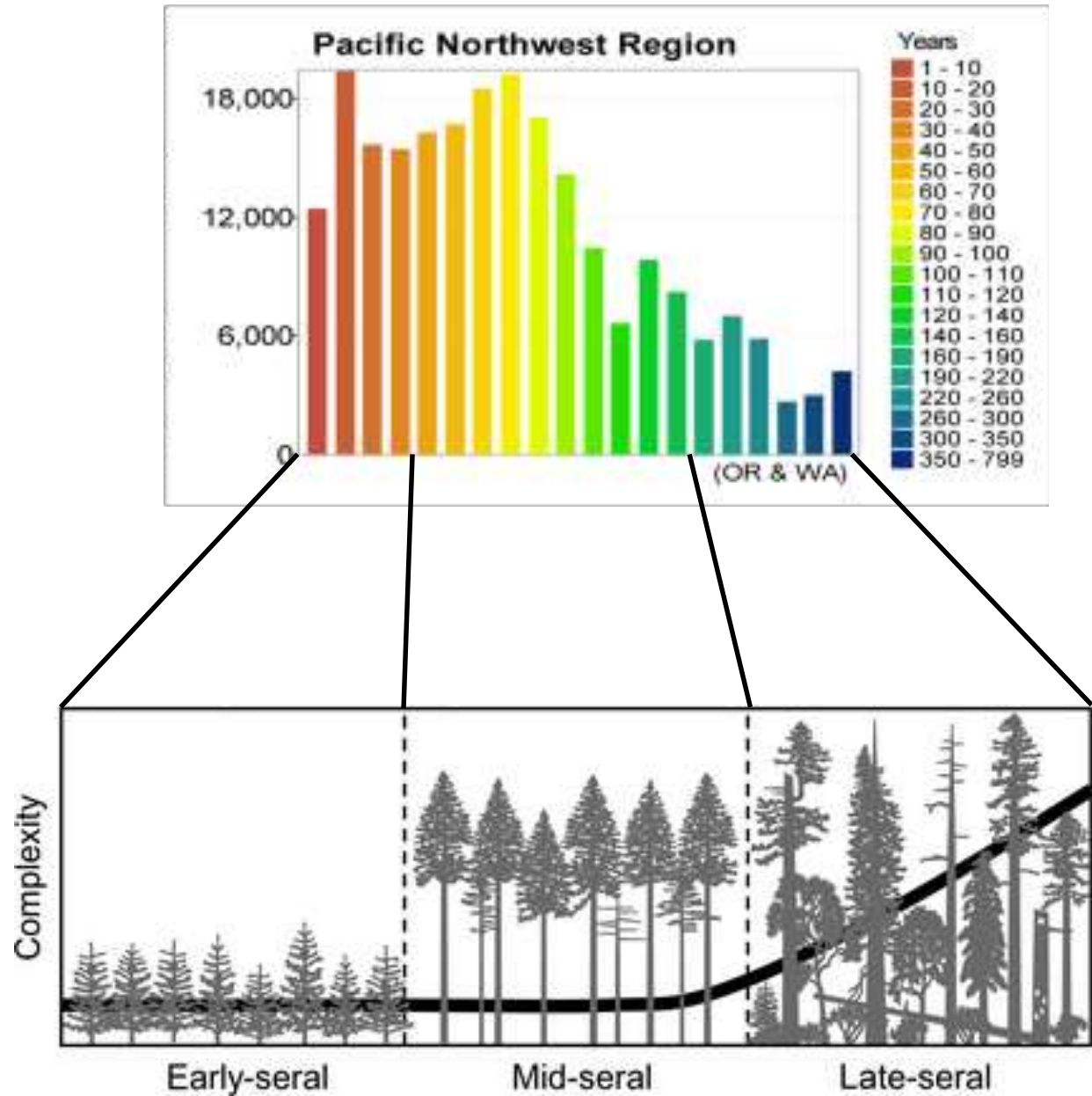
- 4.4 m bankfull width



Forests <100 yrs old dominate PNW landscapes



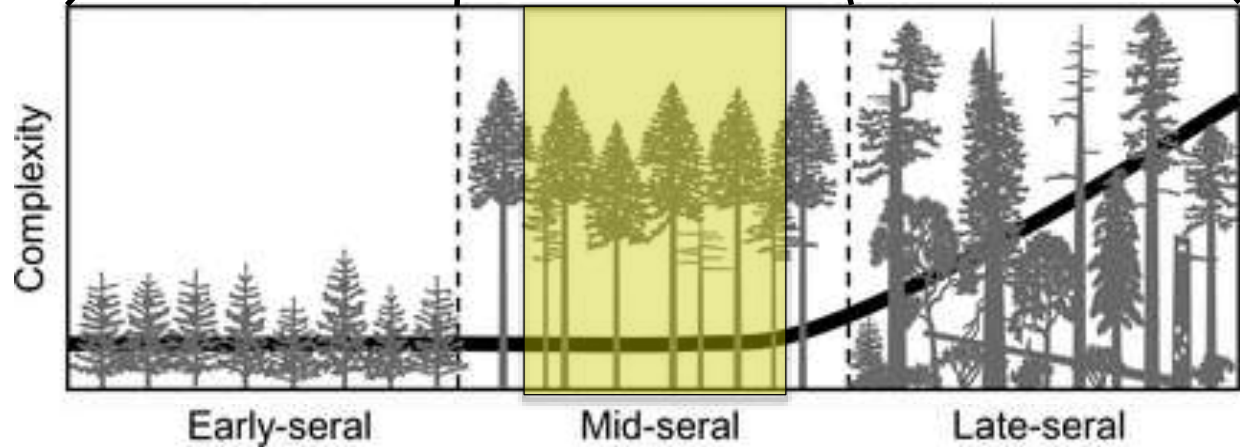
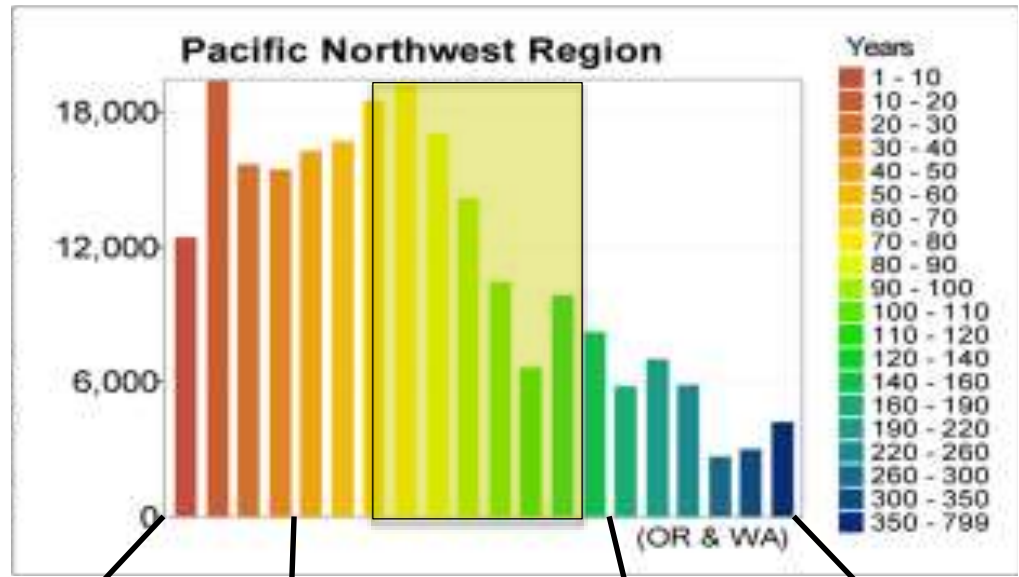
Few stands with complex forest structure



Pan et al. 2011

Donato et al. 2012

Forest Structure CHANGES over time



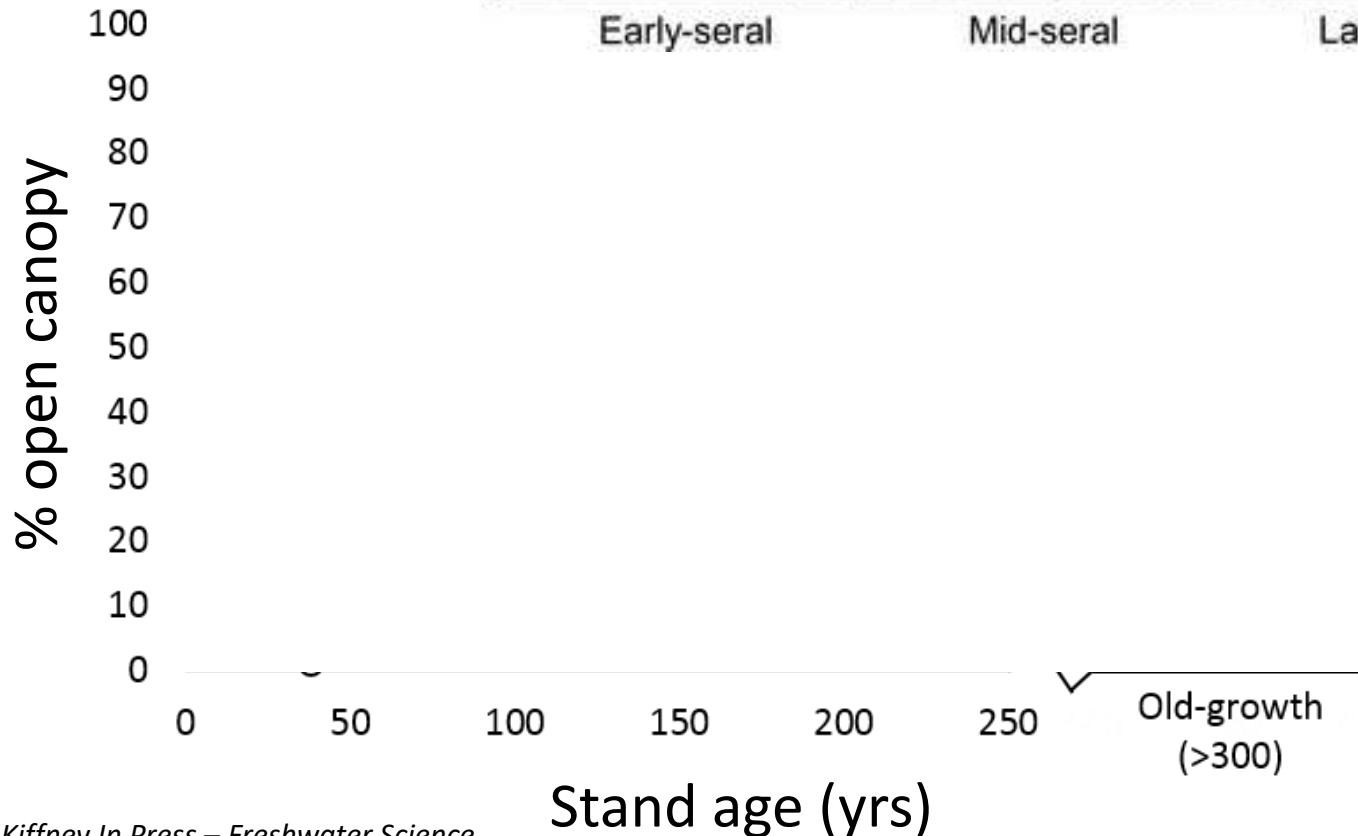
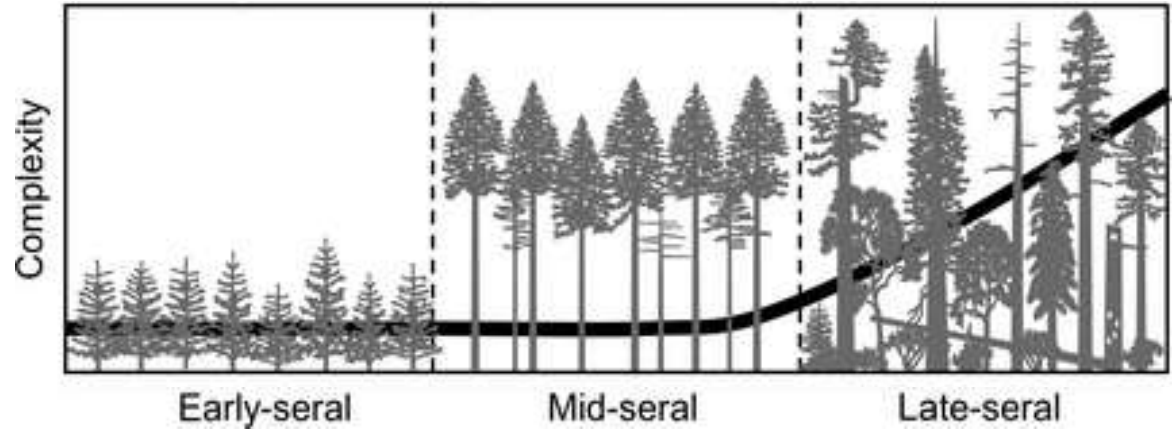
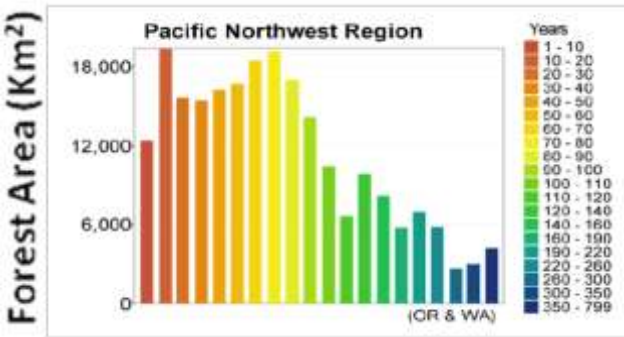
Pan et al. 2011
Donato et al. 2012



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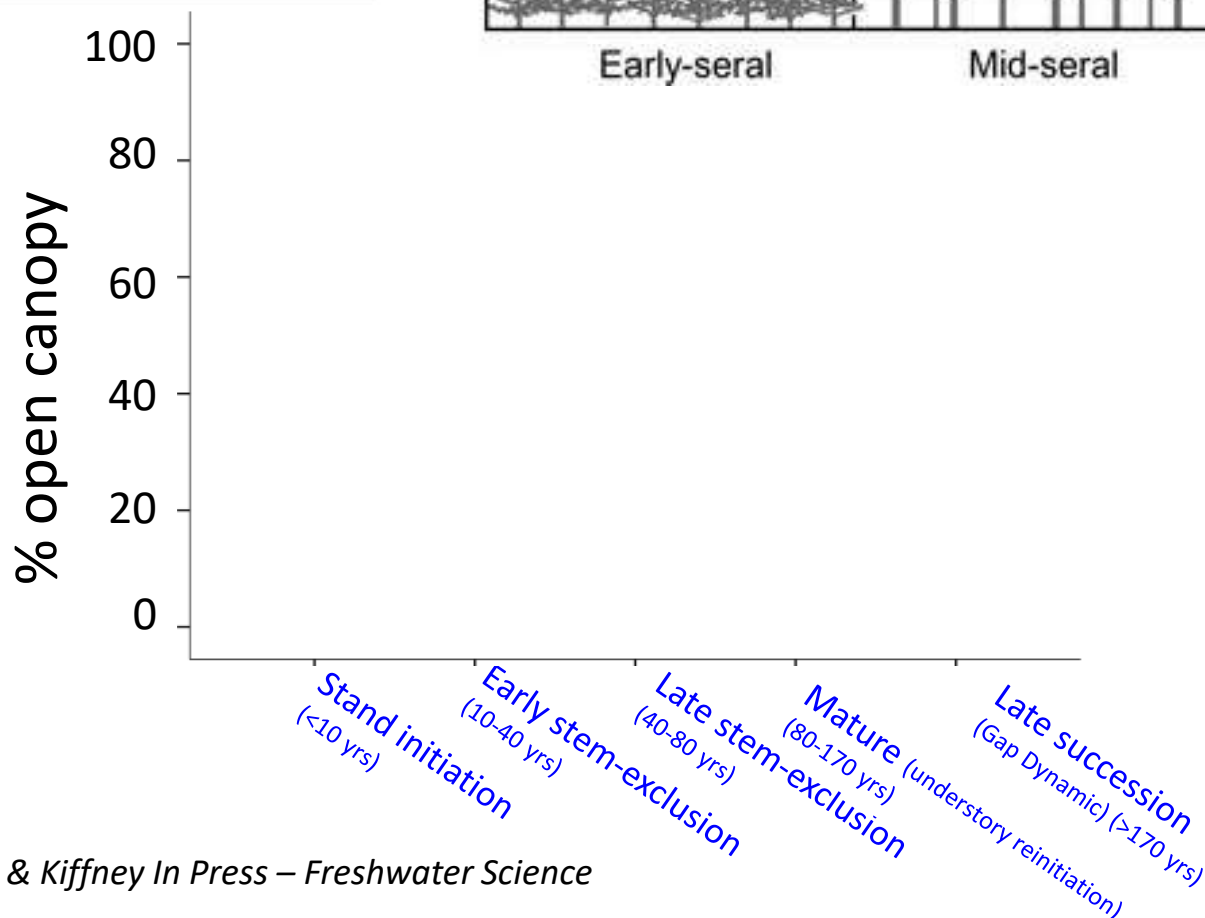
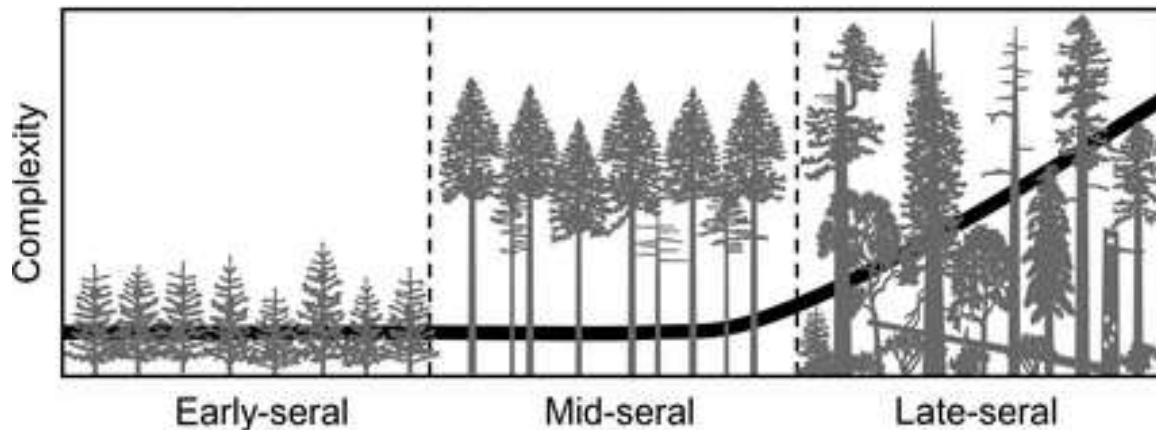
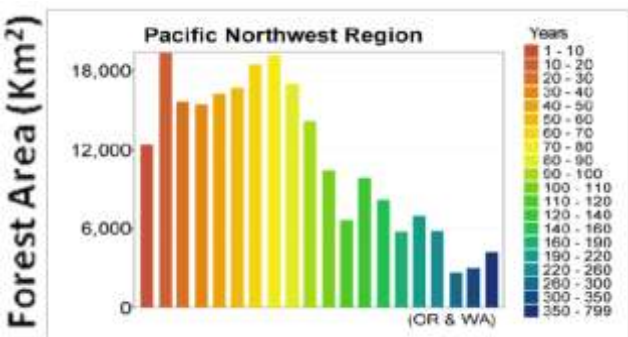
Stand development (*simplified*)

Donato et al. 2012

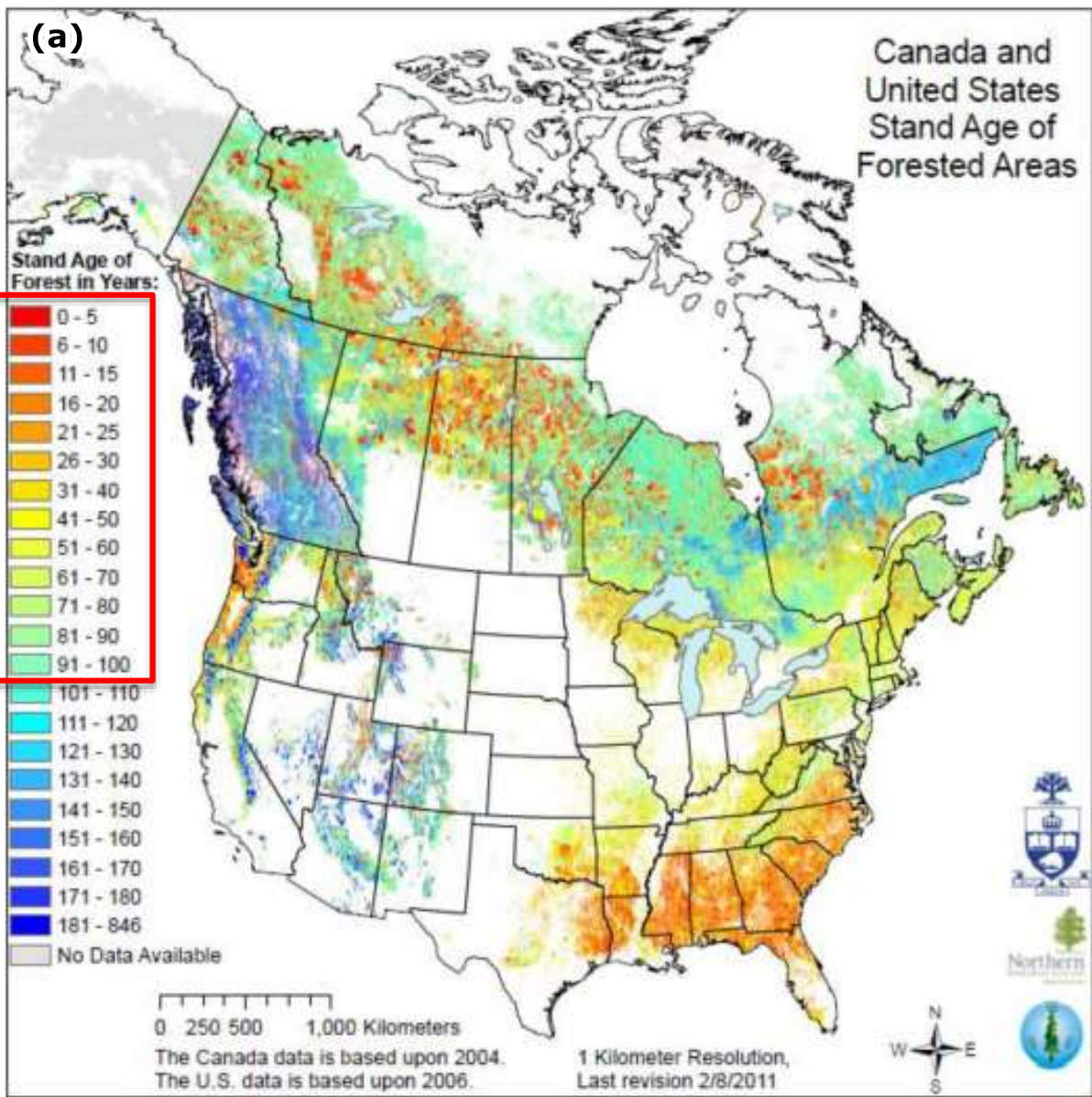
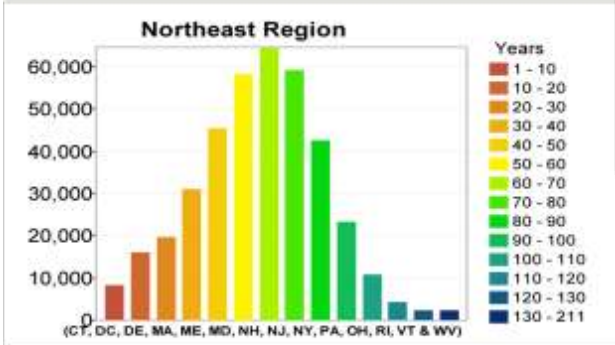
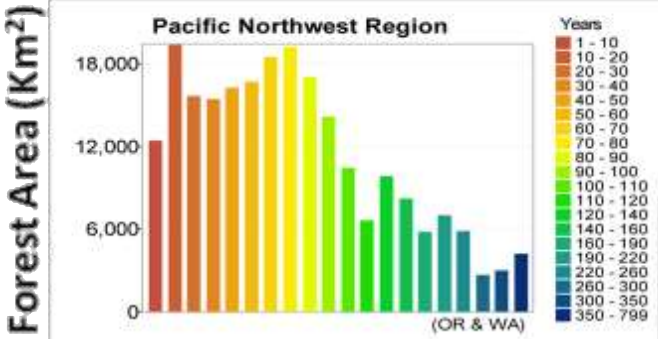


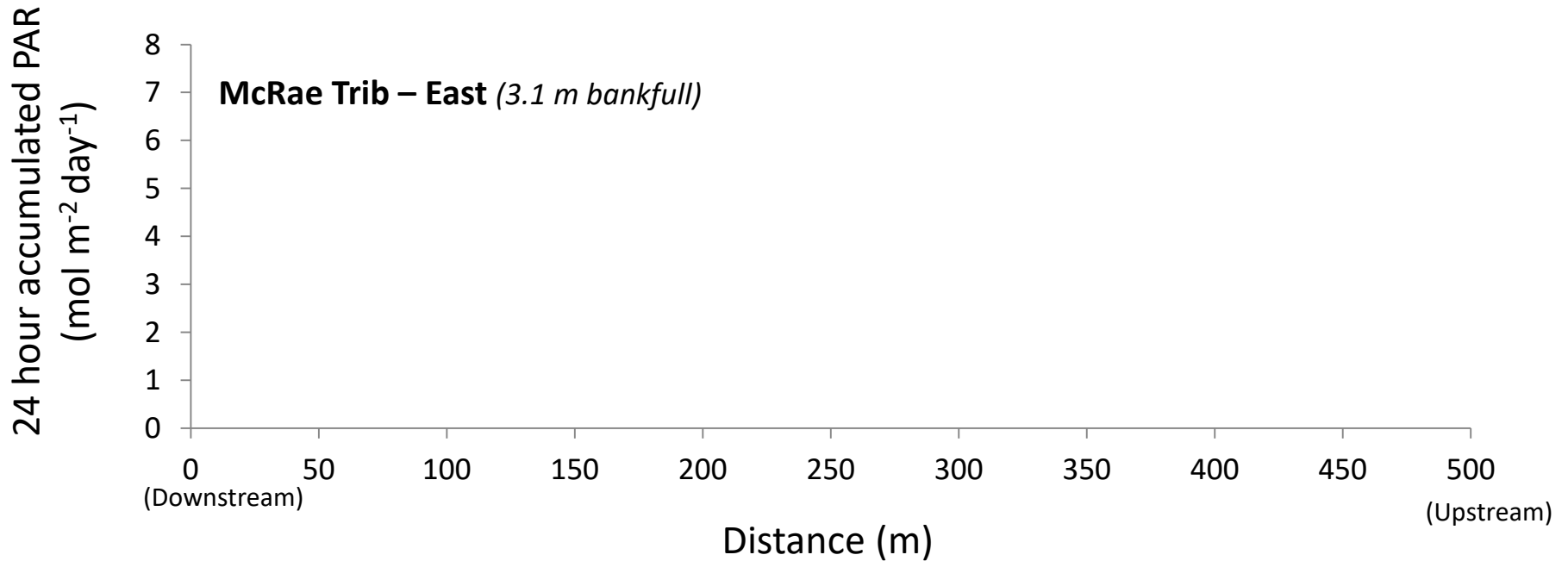
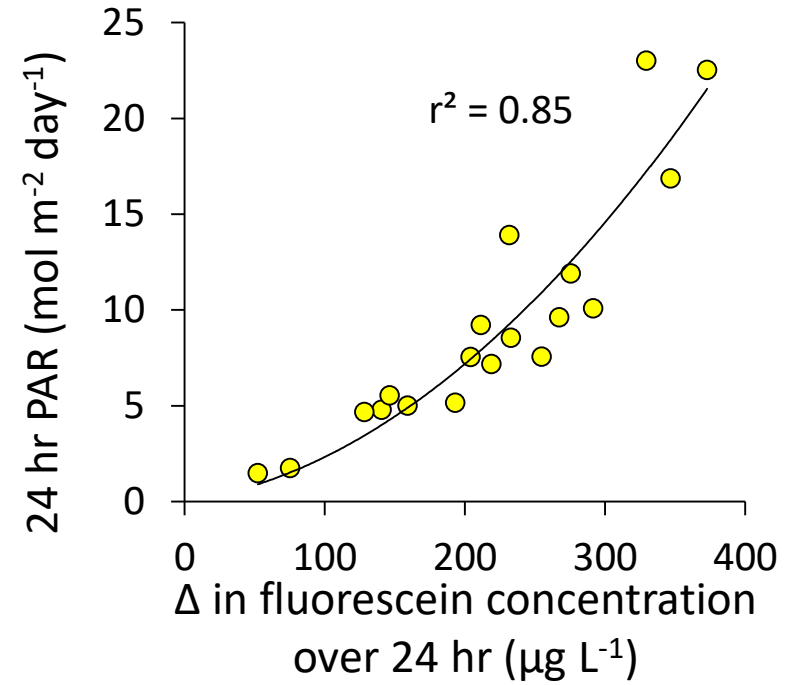
Stand development (*simplified*)

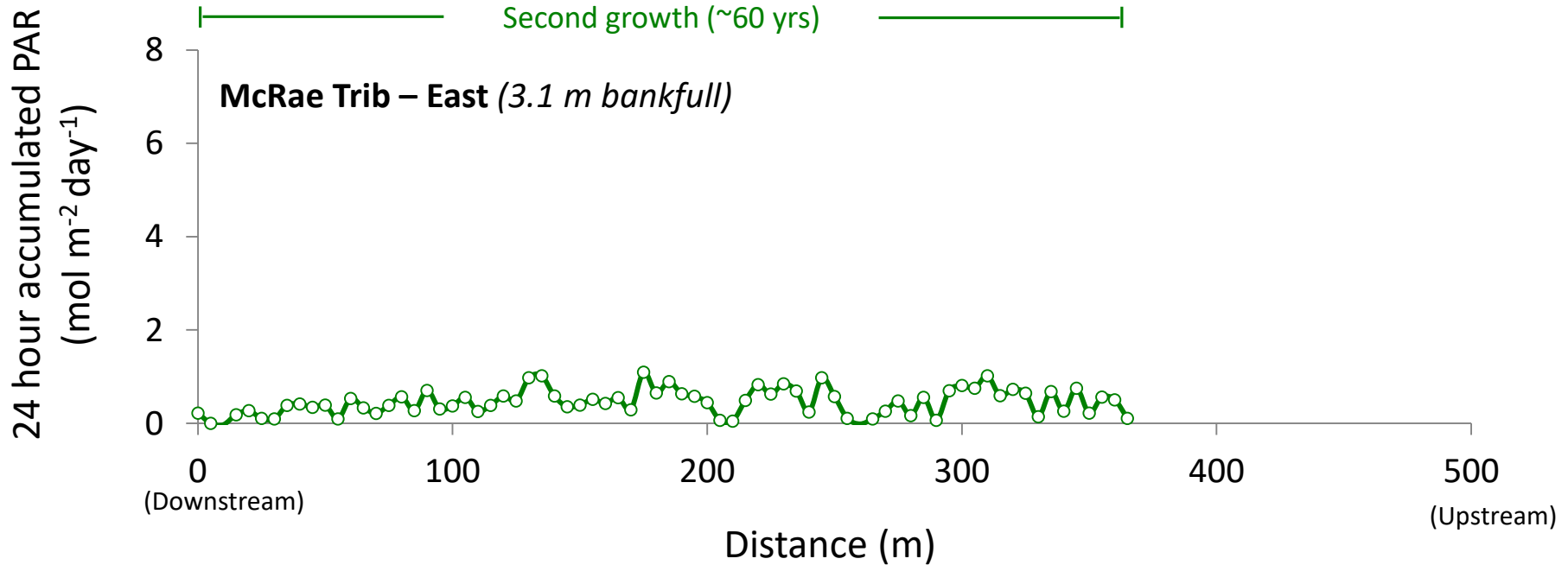
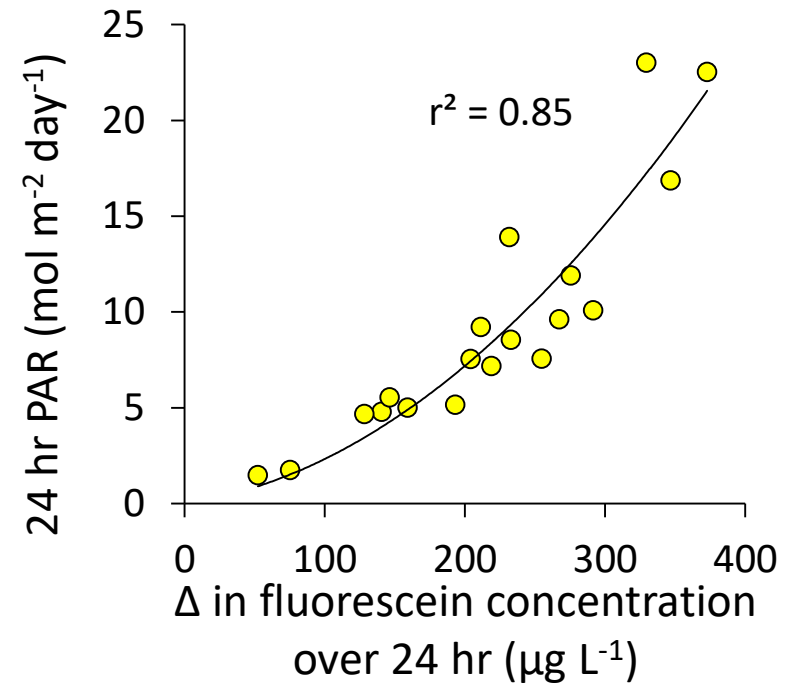
Donato et al. 2012

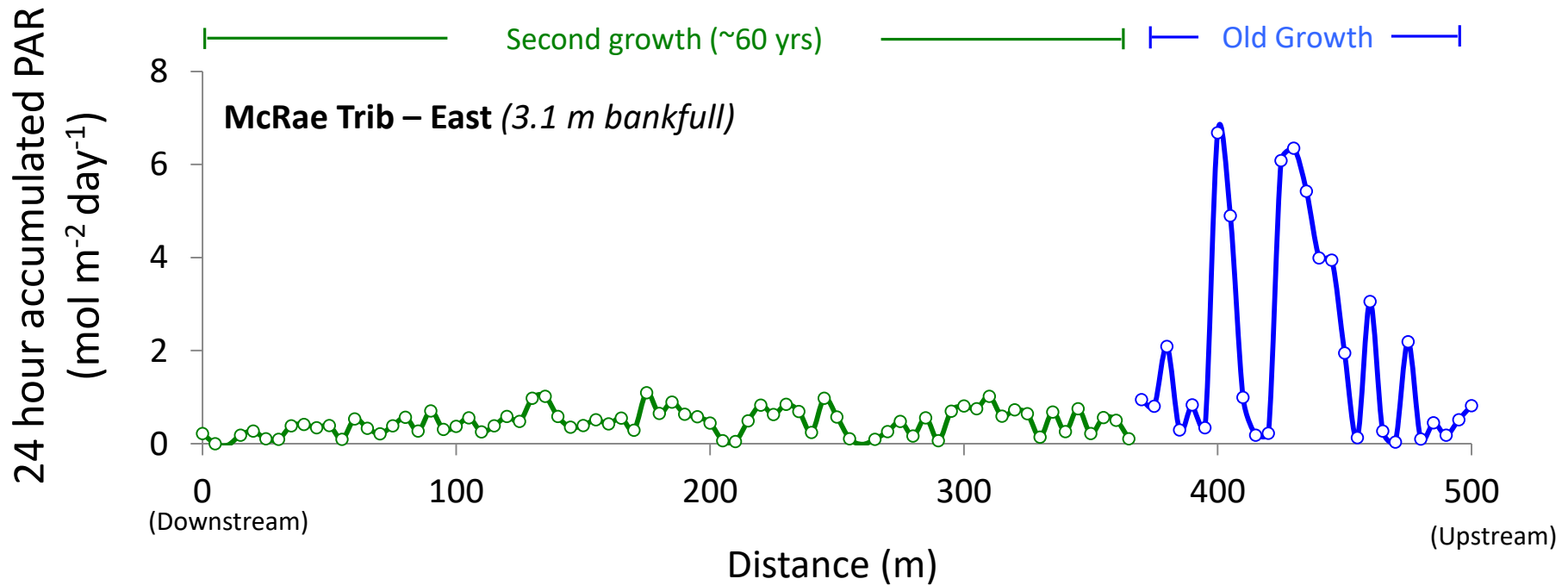
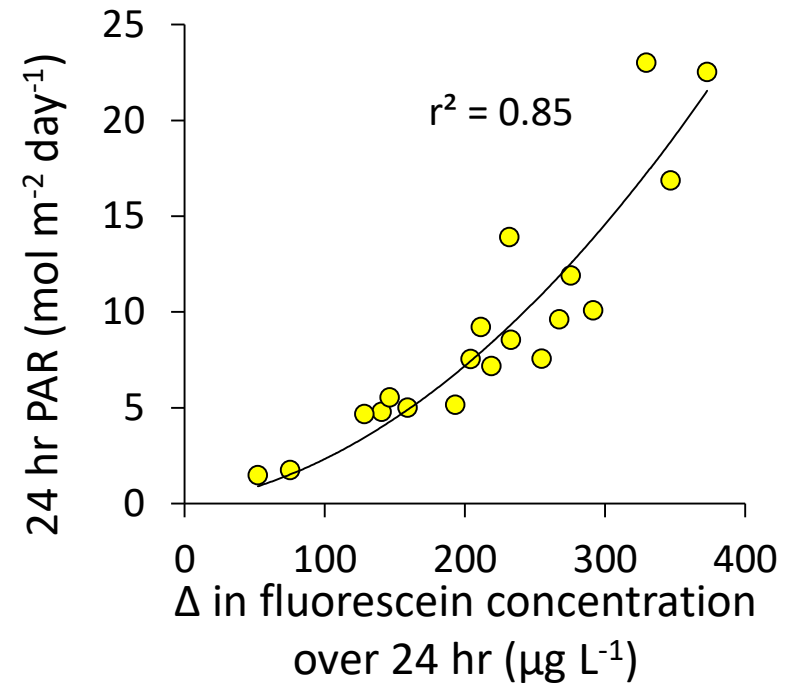


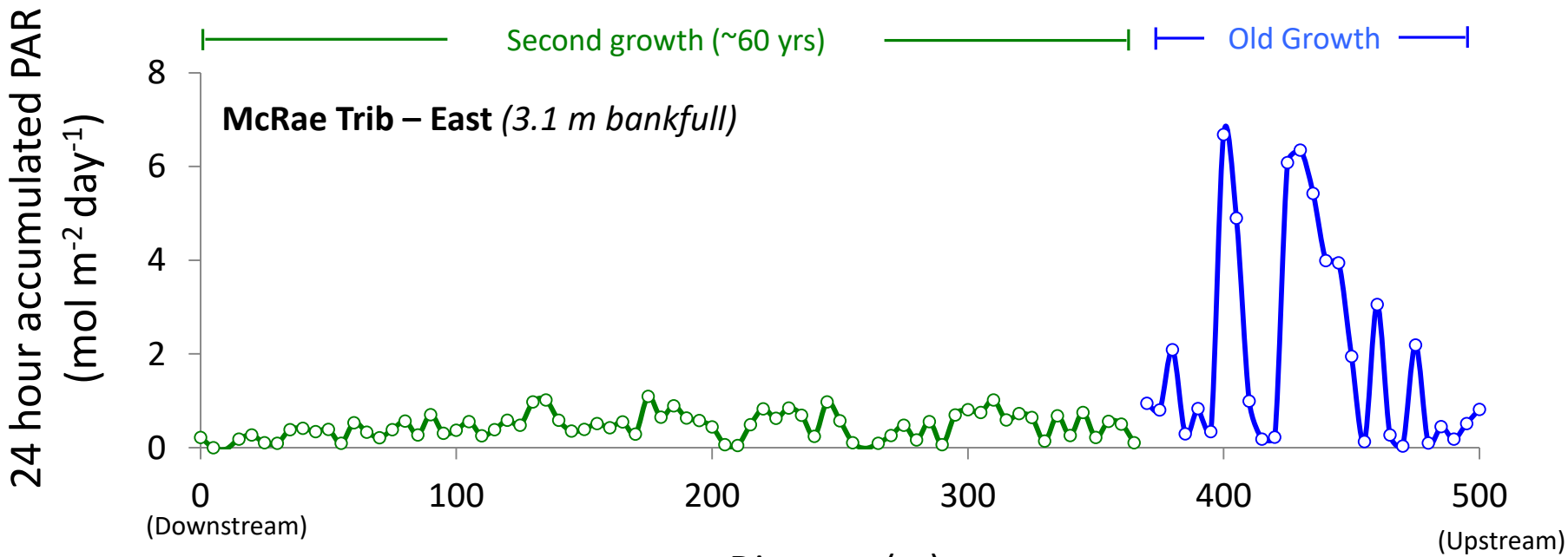
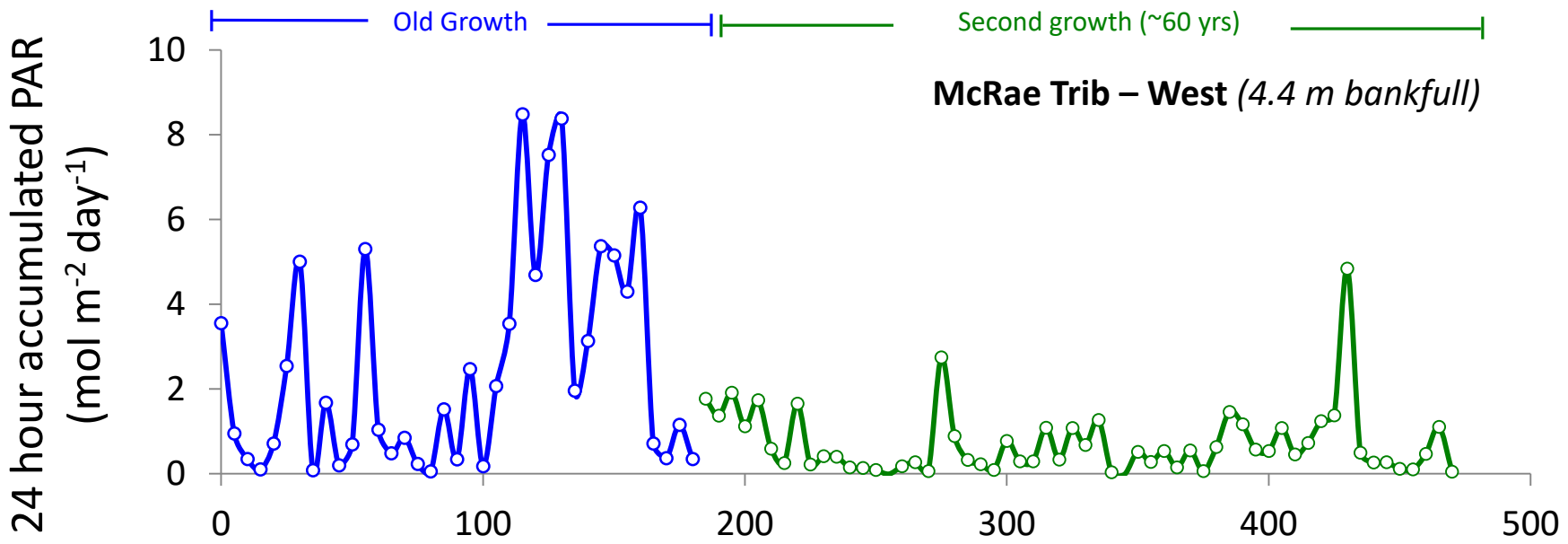
Forests <100 yrs old dominate North American landscapes

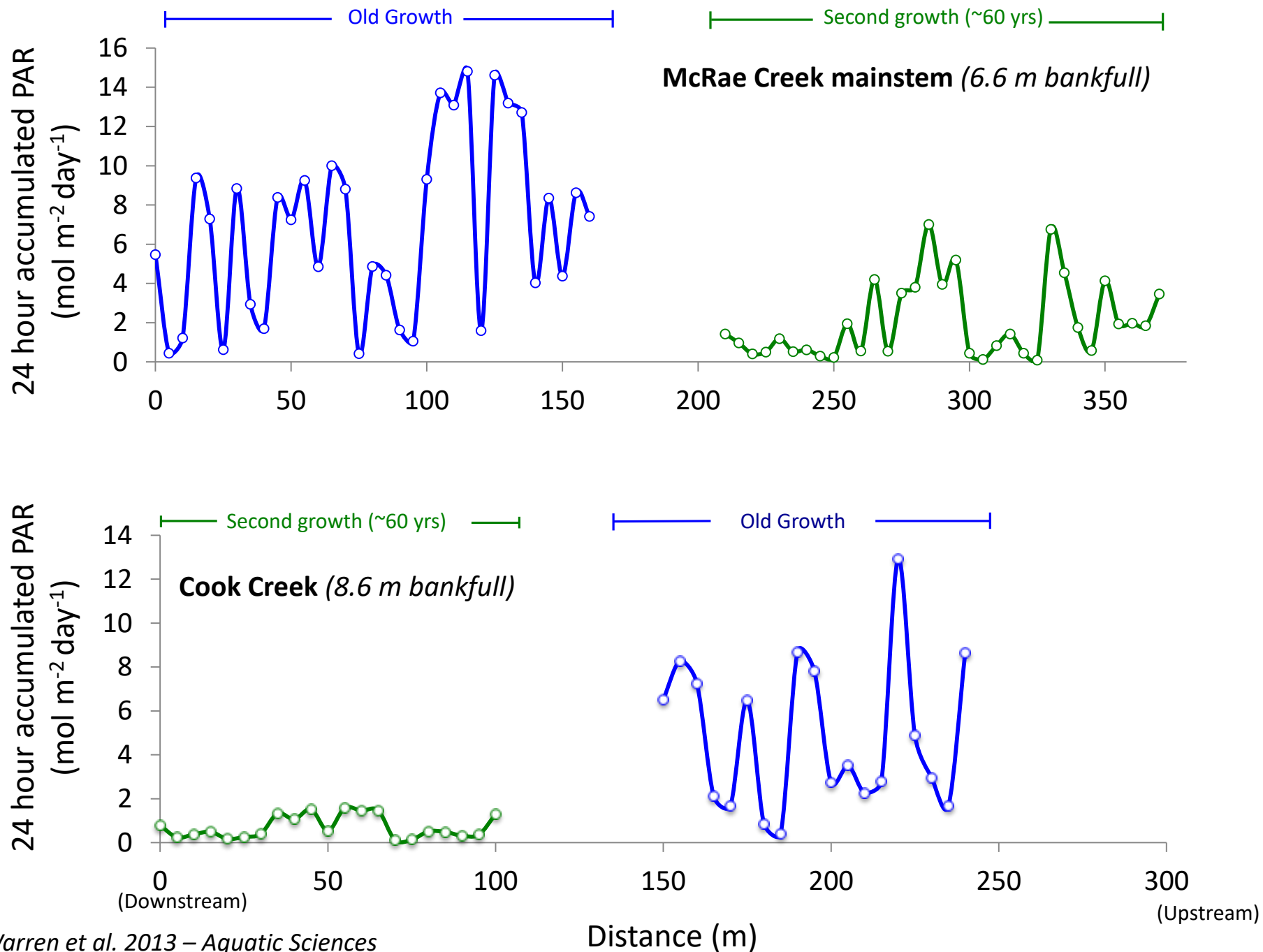




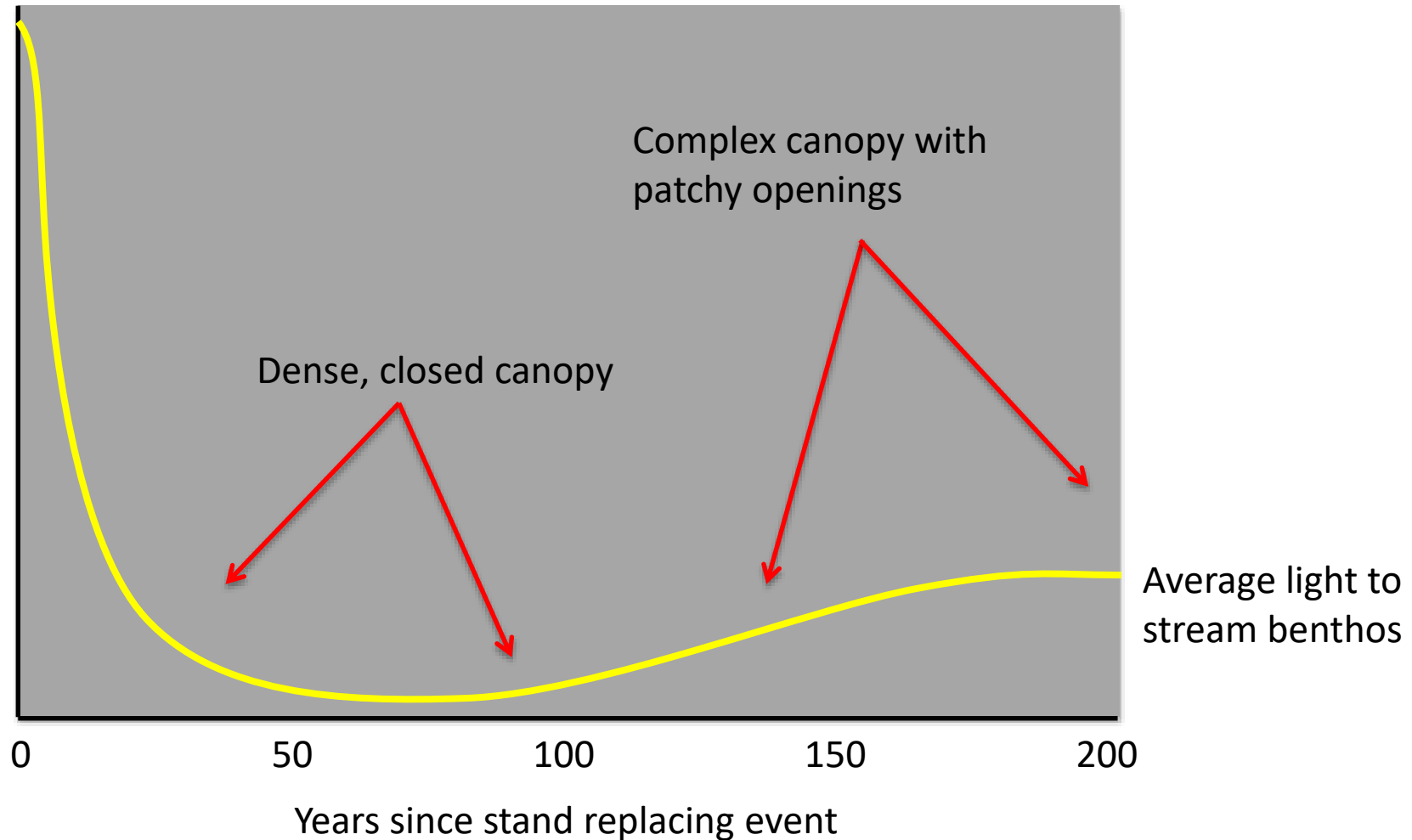








Conceptual model for changing **stream light** over time in a forested headwater stream

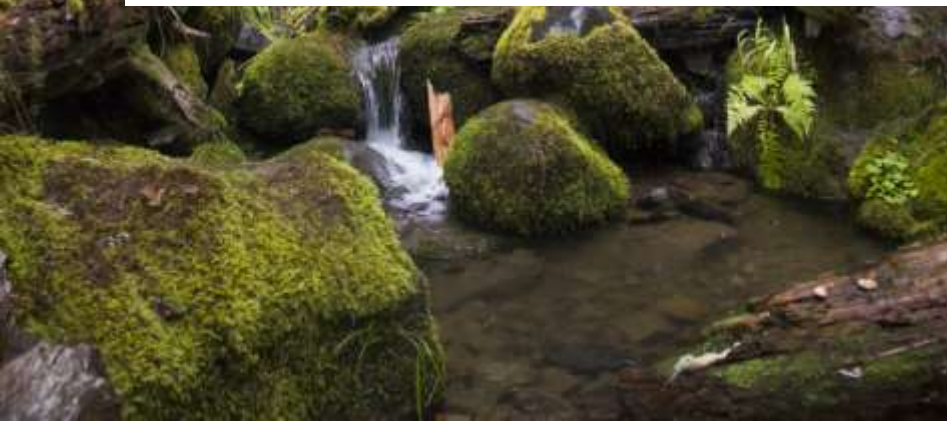




Riparian forest structure, stream light, and **bottom-up drivers of fish production in forested headwaters**

Food web components

- Primary production (algal accrual)
- Invertebrate biomass
- Fish biomass

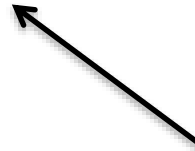


Primary production (algal accrual)

Do areas (patches) of elevated light along the stream have higher periphyton standing stocks?

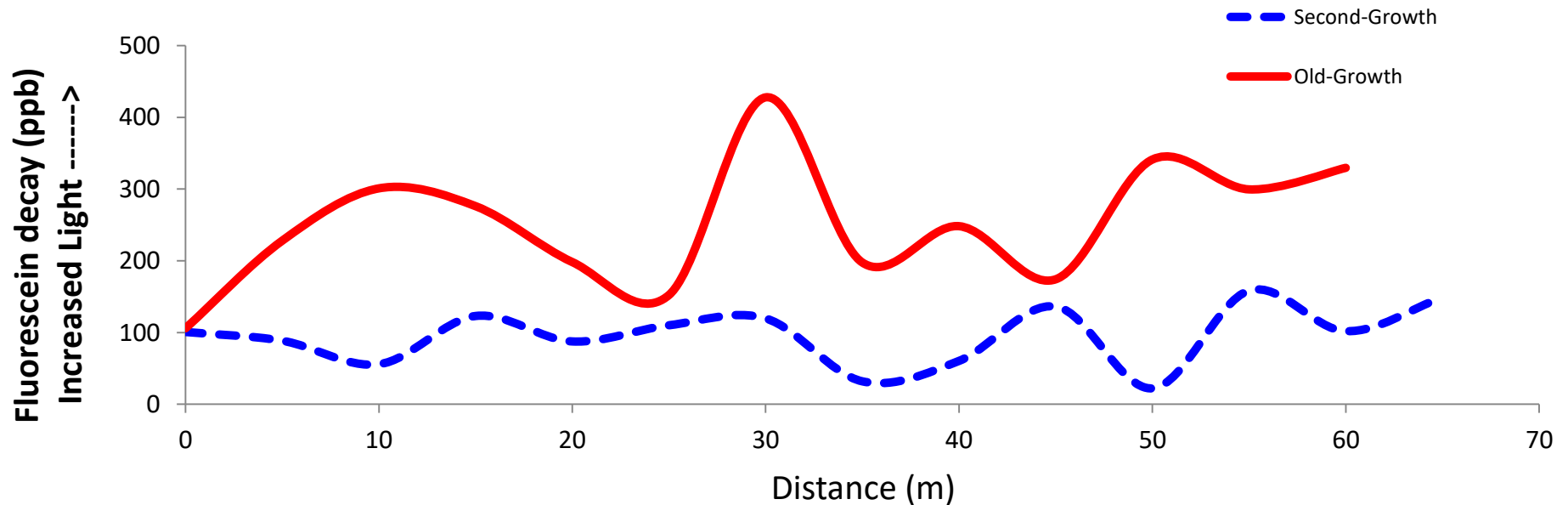
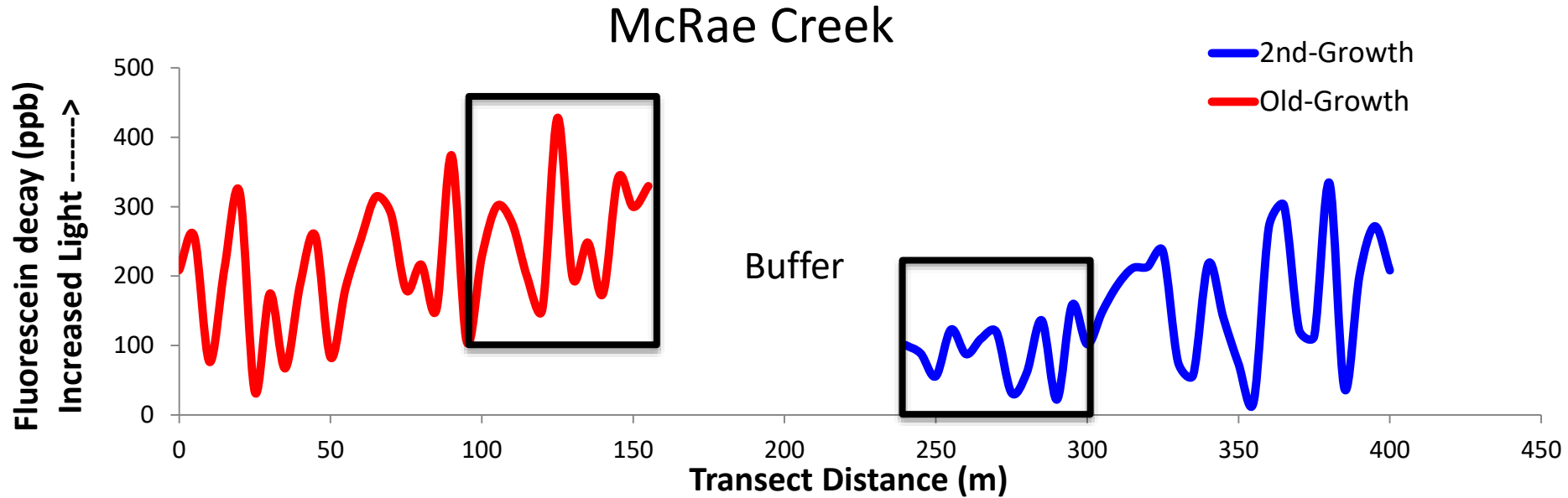
Primary production (algal accrual)

Do areas (patches) of elevated light along the stream have higher periphyton standing stocks?

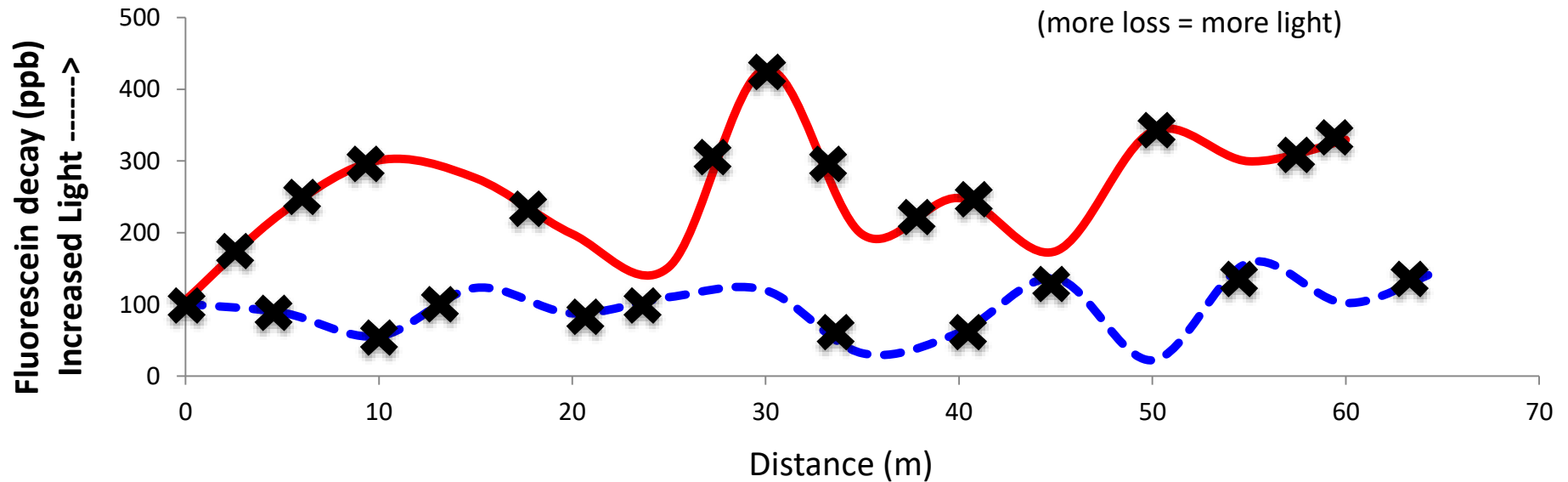
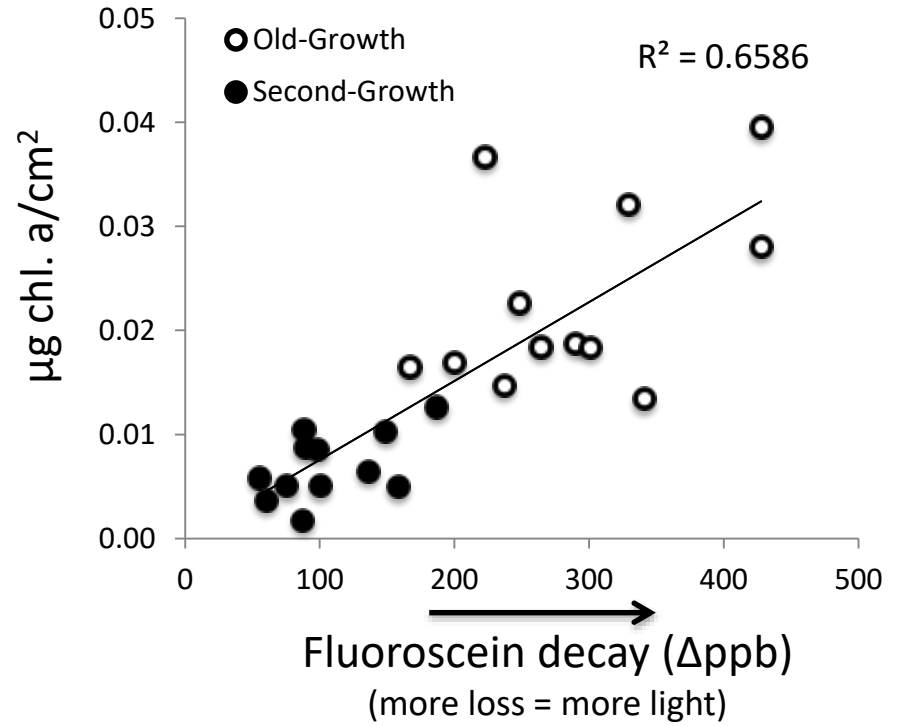


Mostly benthic algae, but also includes fungi and heterotrophic bacteria

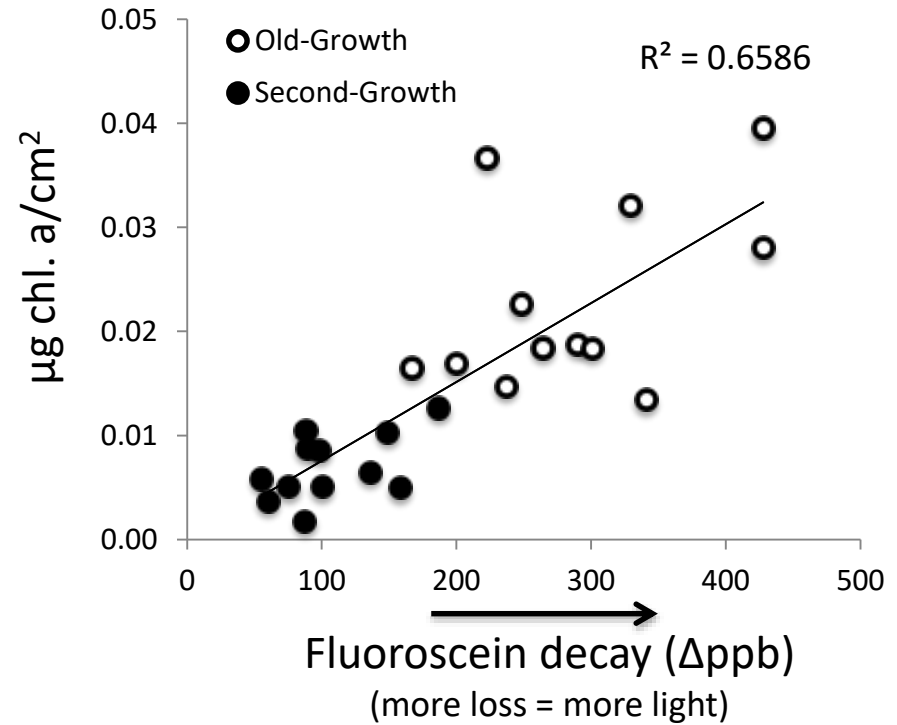
Is periphyton accrual affect by local light?



Is periphyton accrual affect by local light?



Is periphyton accrual affect by local light?

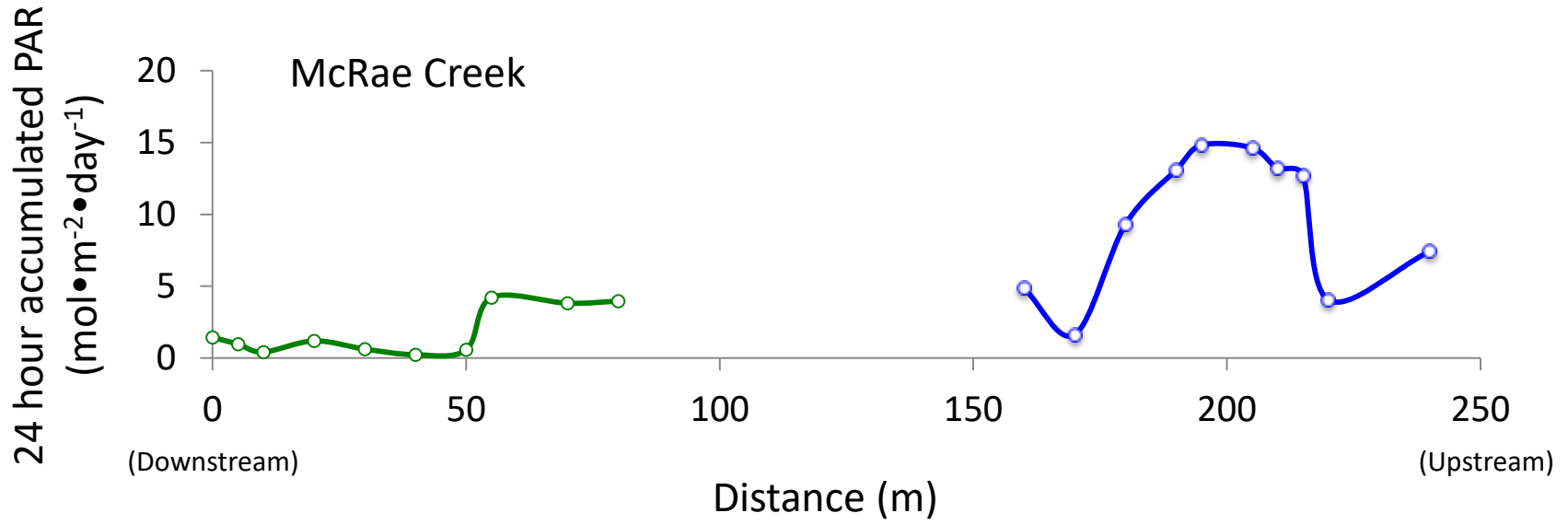


Yes!

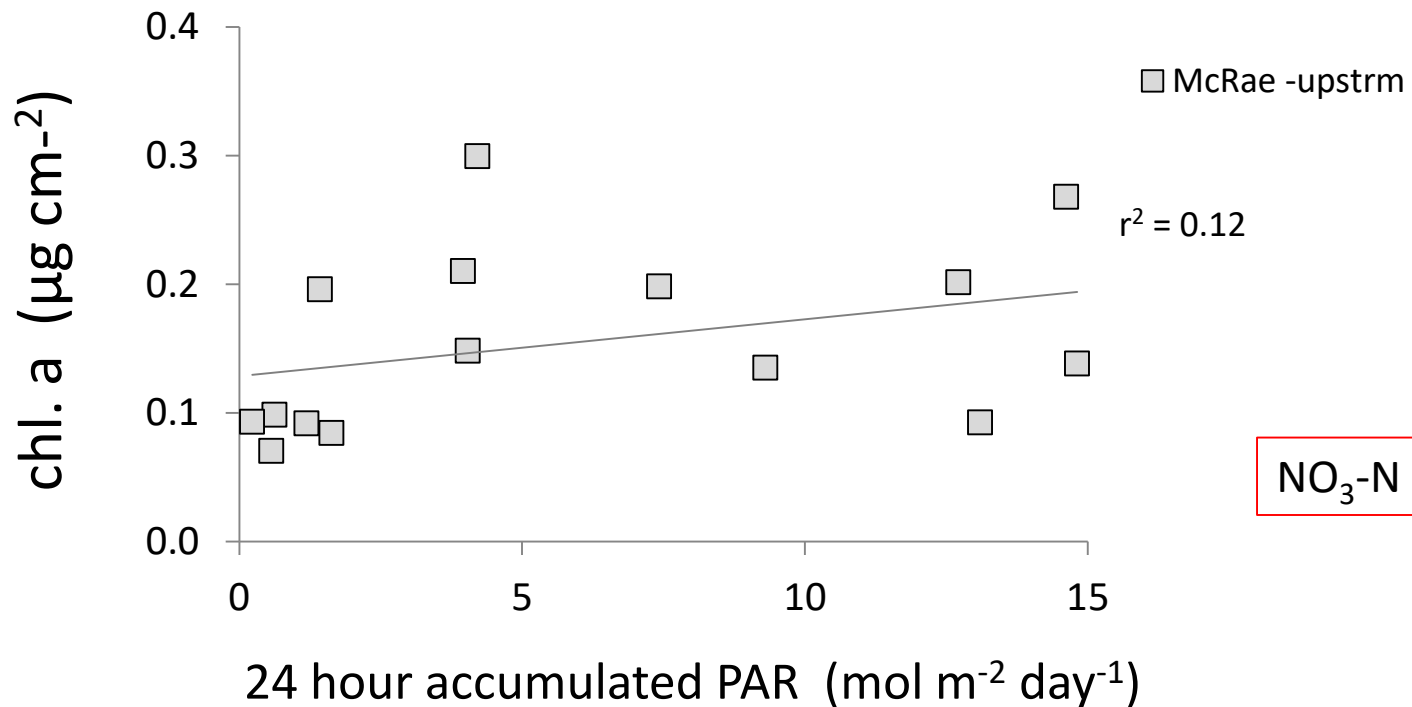
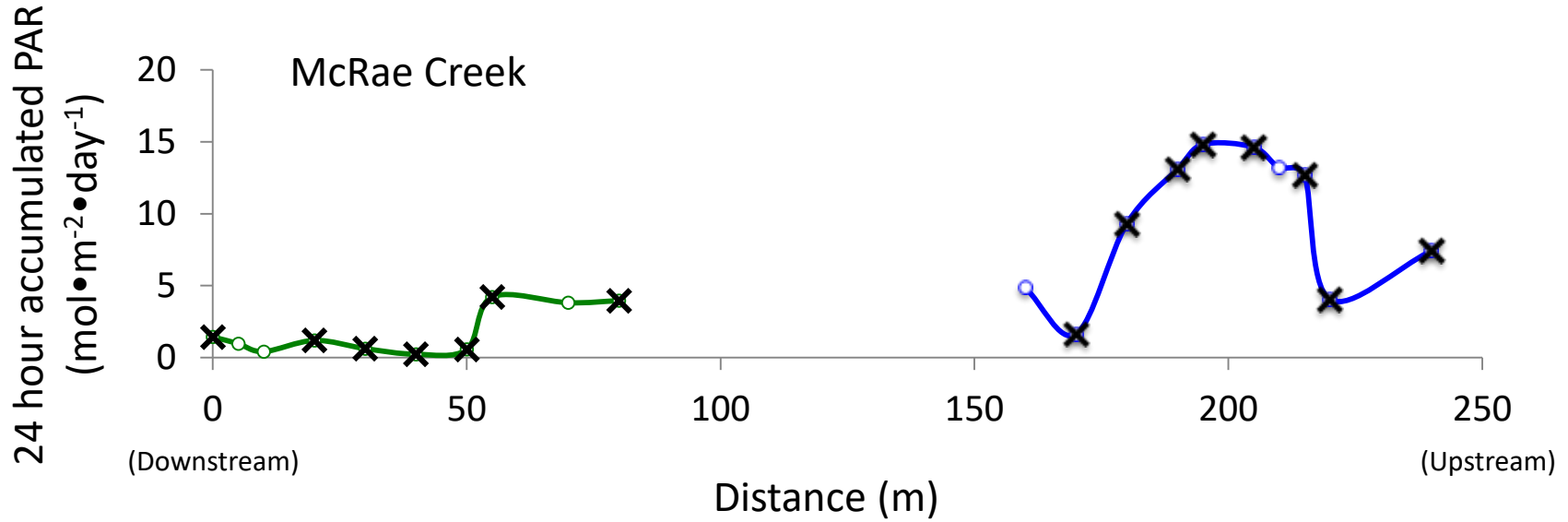
But. . .

How does light availability interact with nutrient availability?

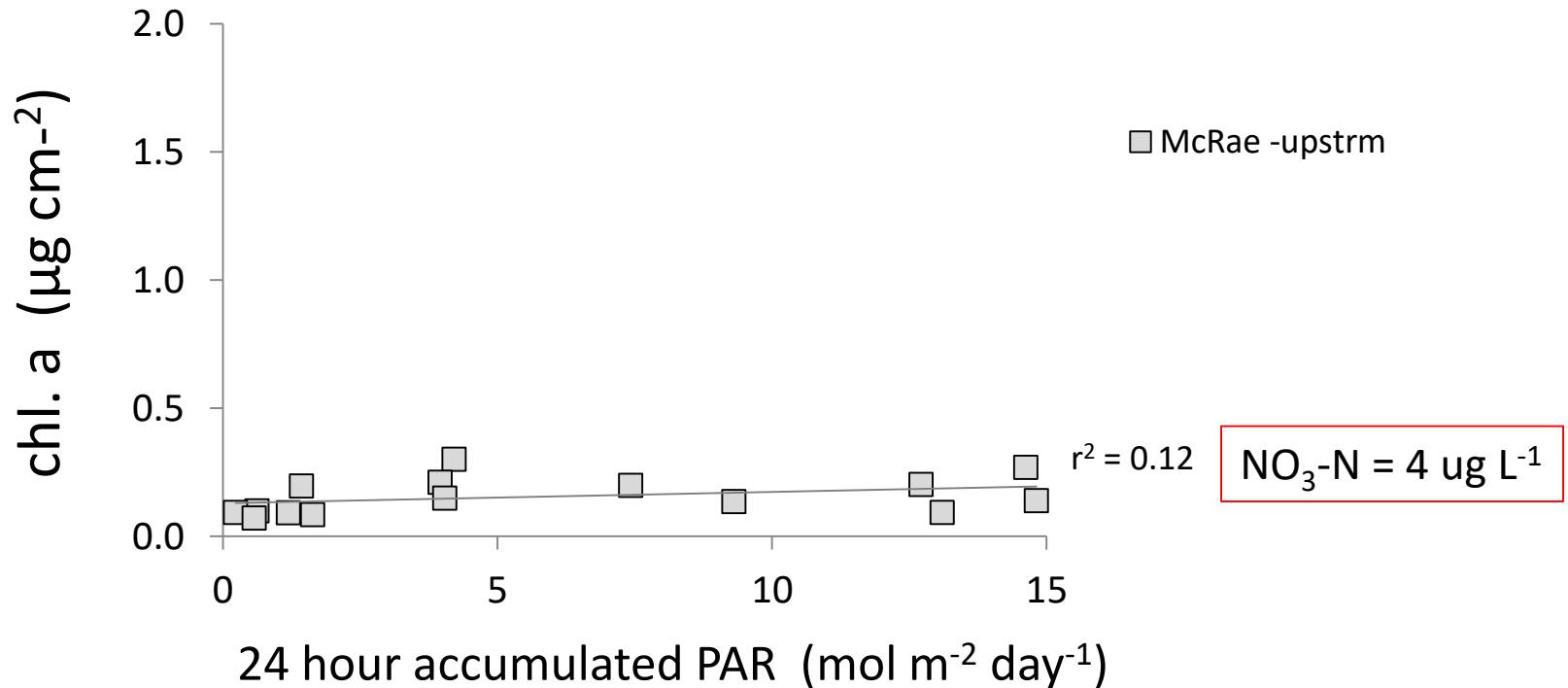
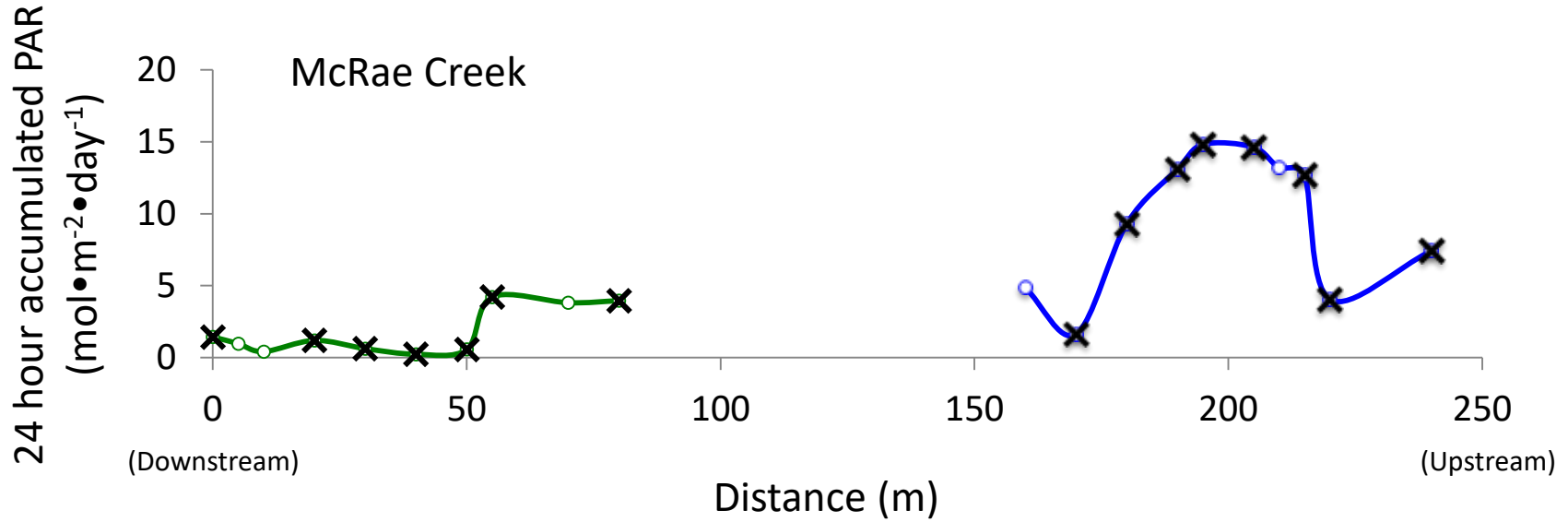
Primary production (algal accrual)



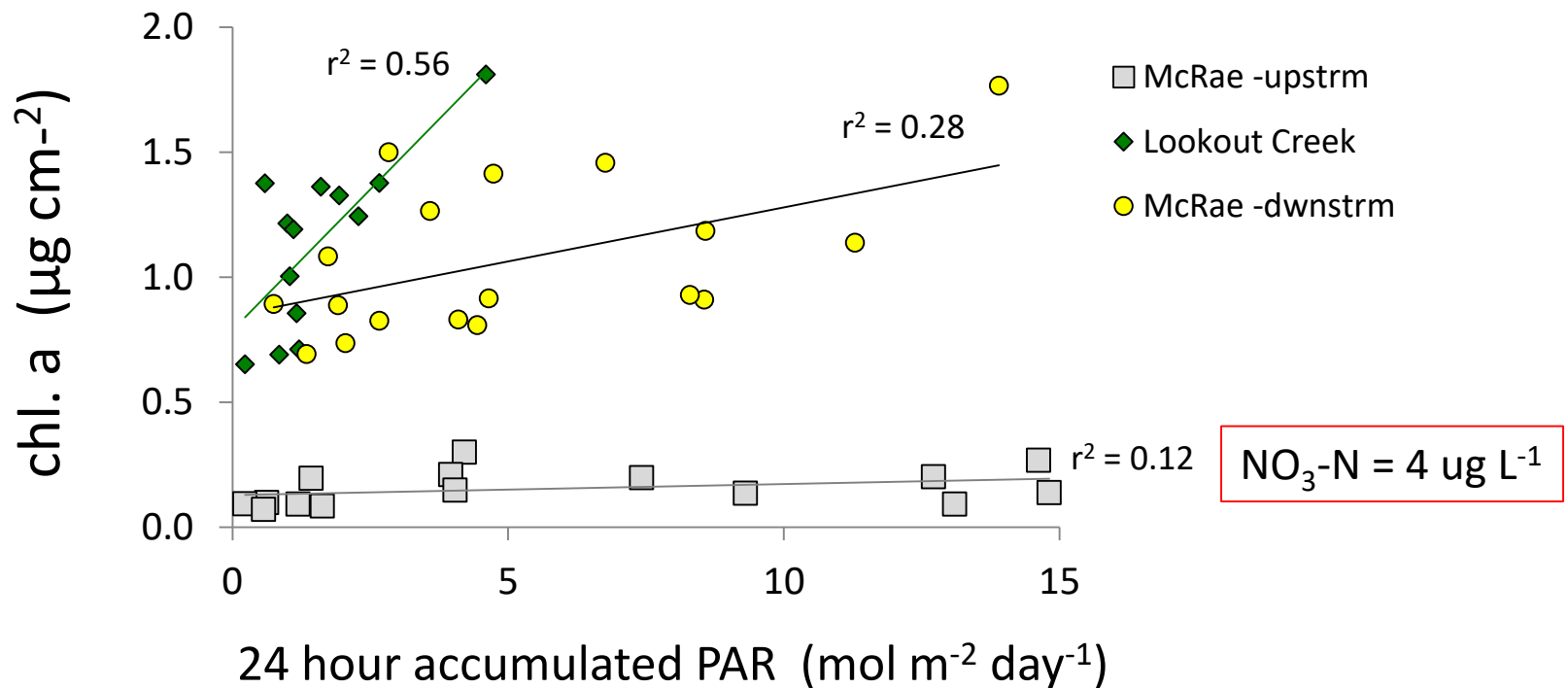
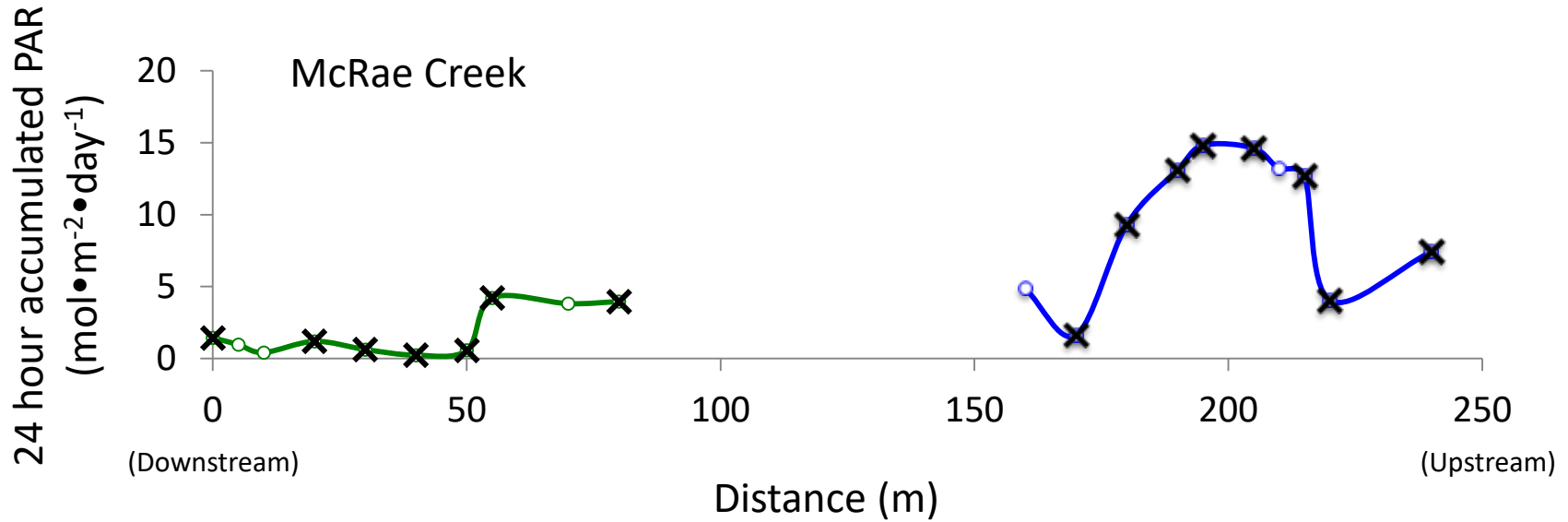
Primary production (algal accrual)



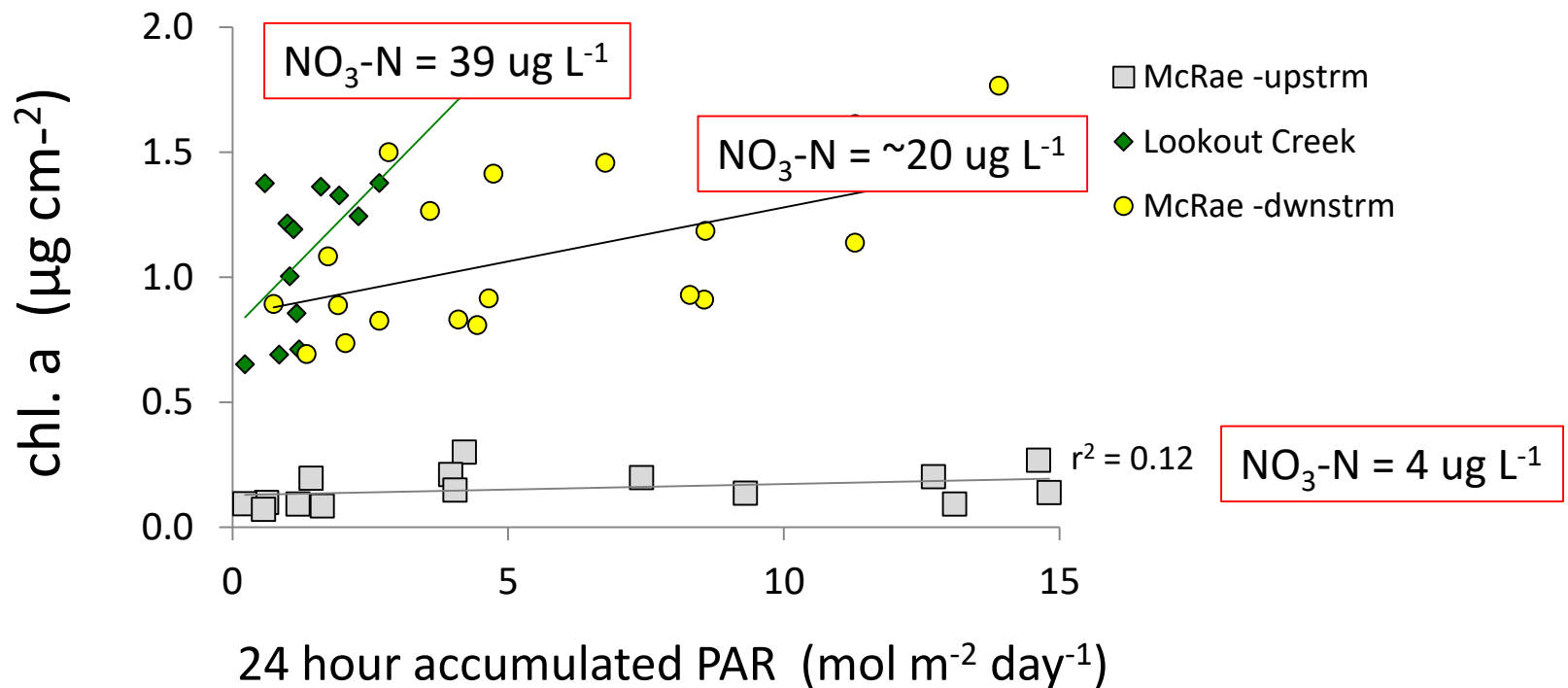
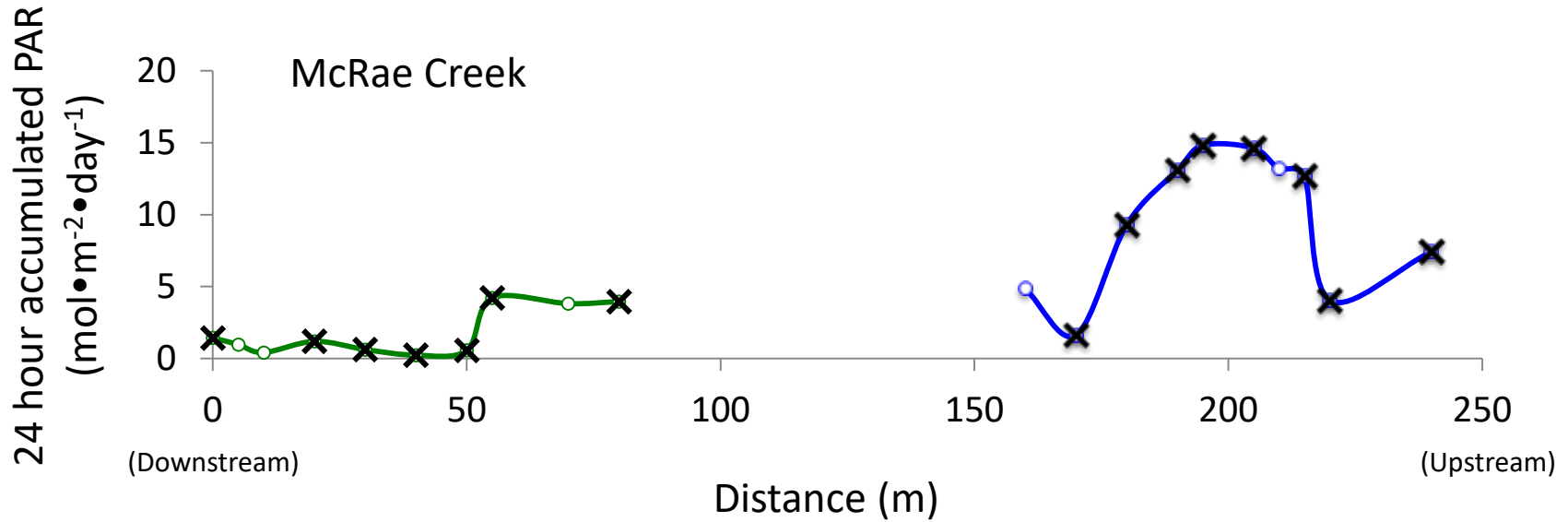
Primary production (algal accrual)



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Primary production (algal accrual)

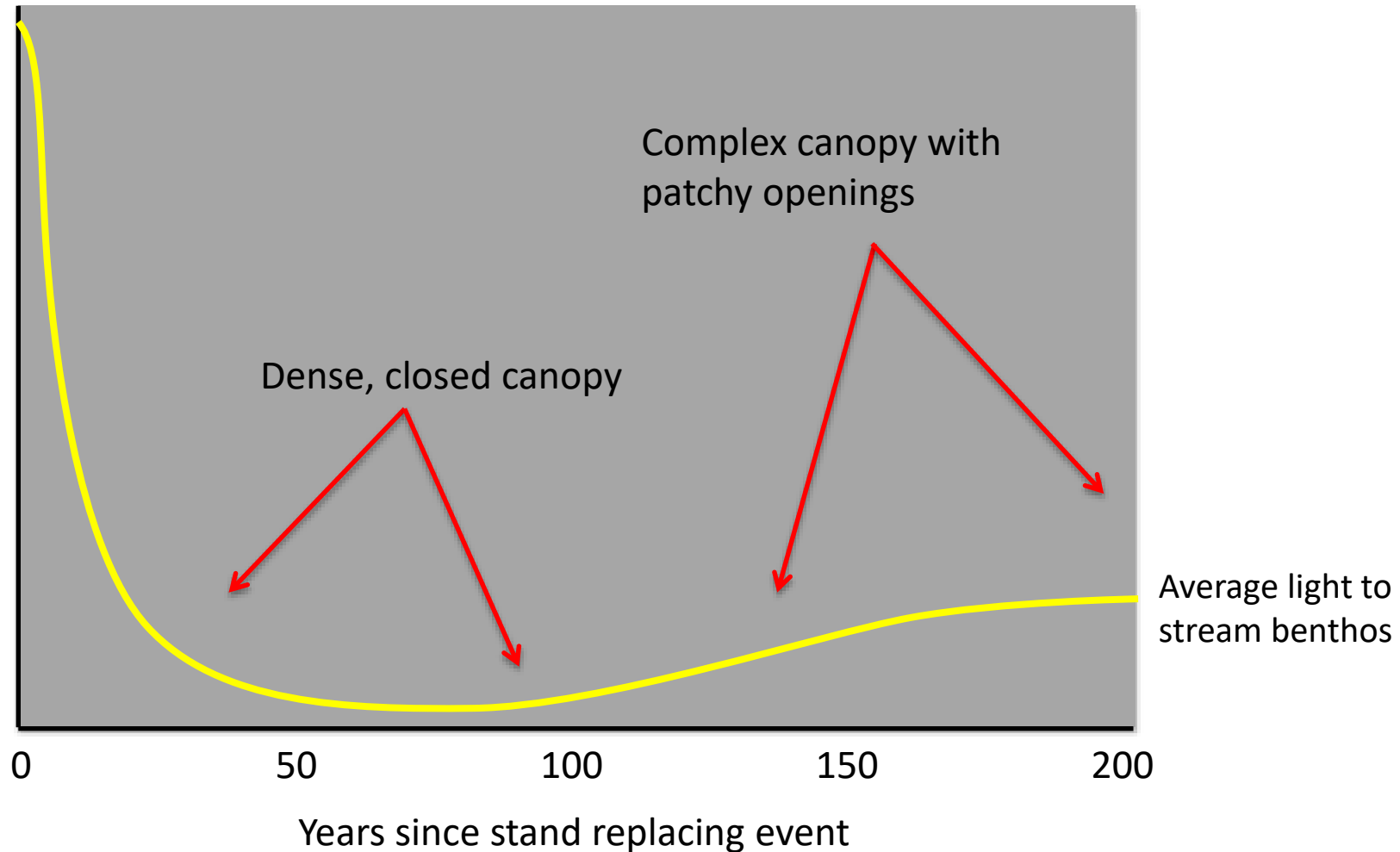


Primary production (algal accrual)

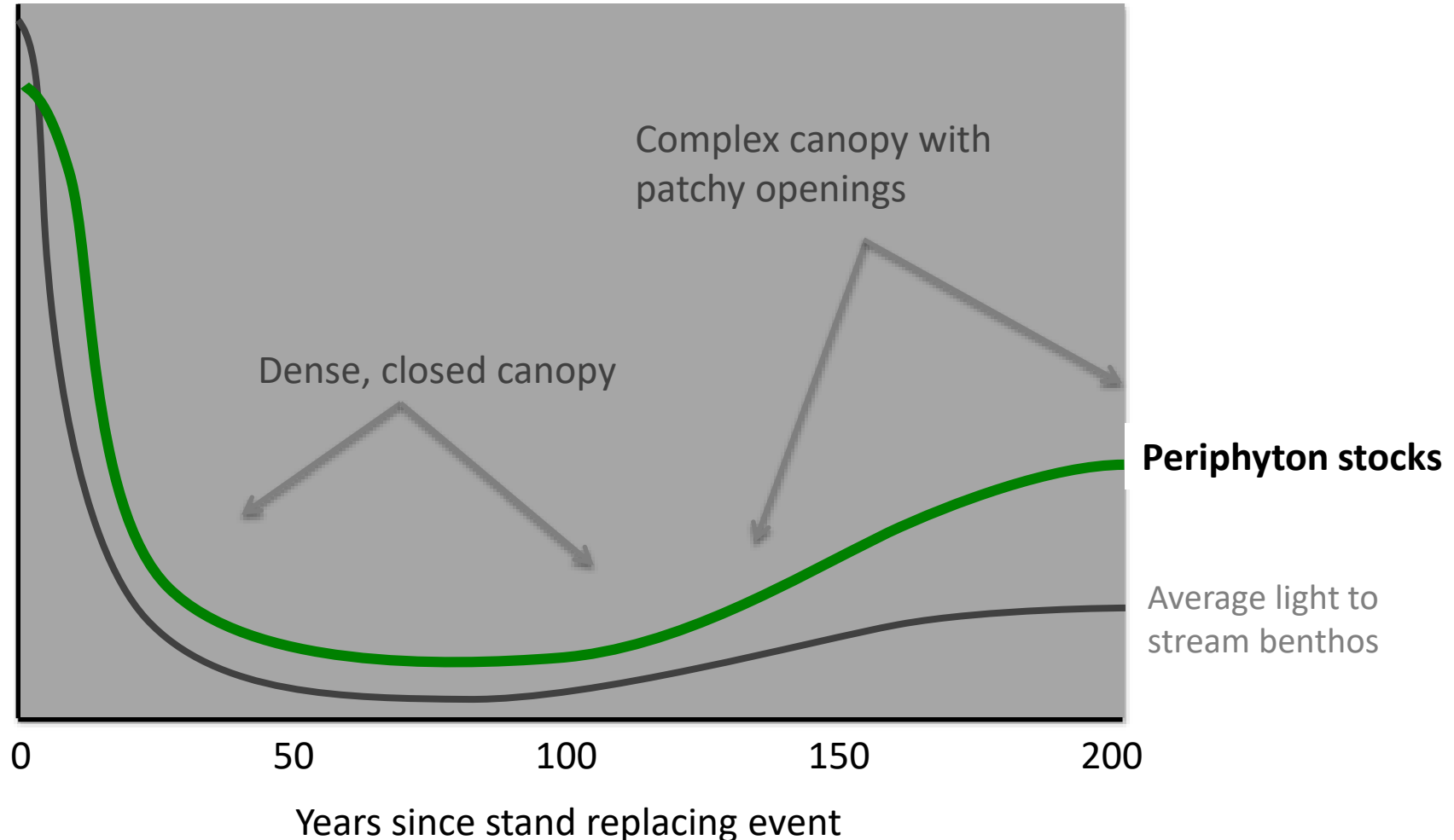
Do areas (patches) of elevated light along the stream have higher periphyton standing stocks?

Yes, - some of the time. . .

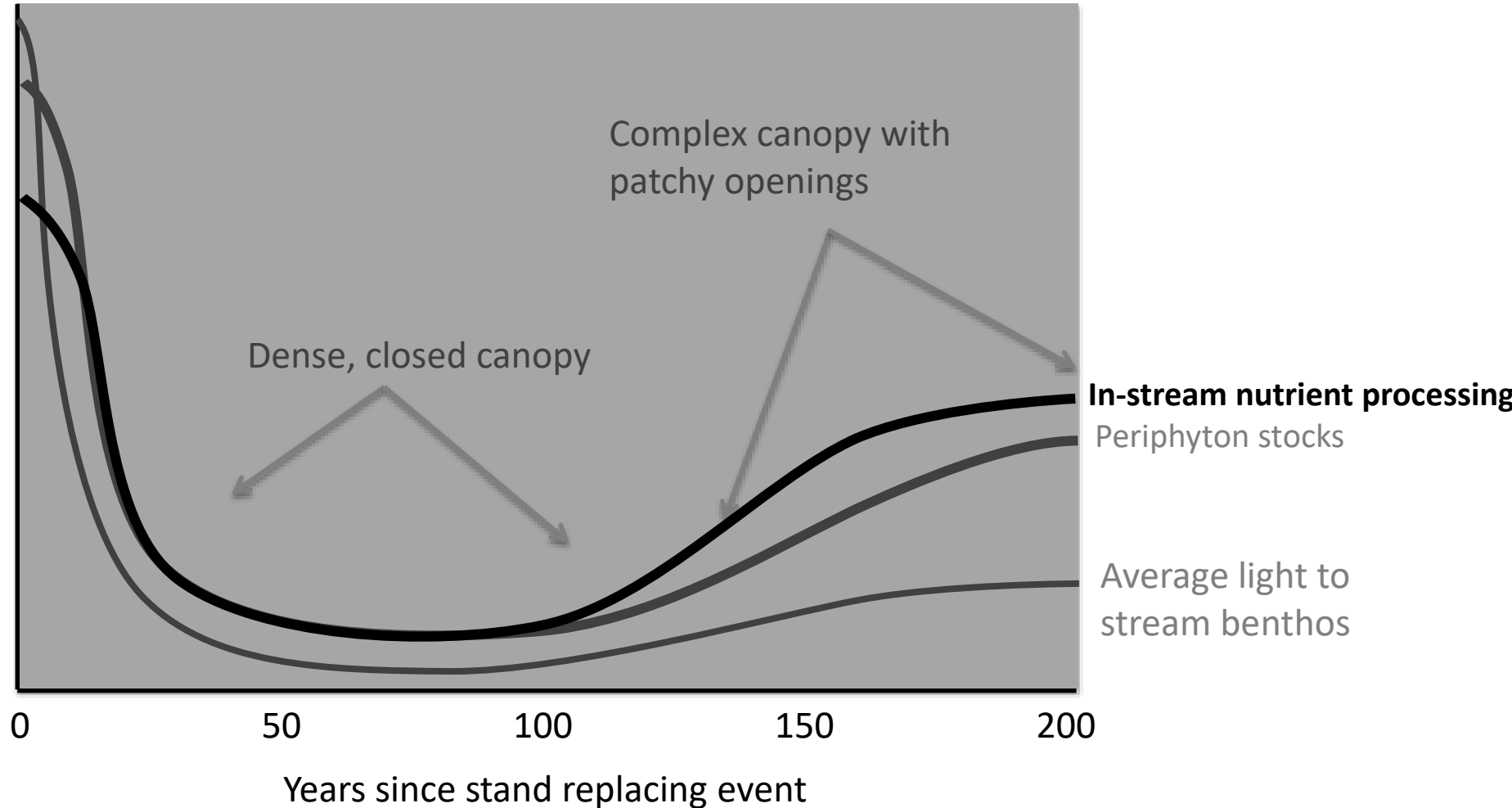
Conceptual model for changing **stream light** over time in a forested headwater stream



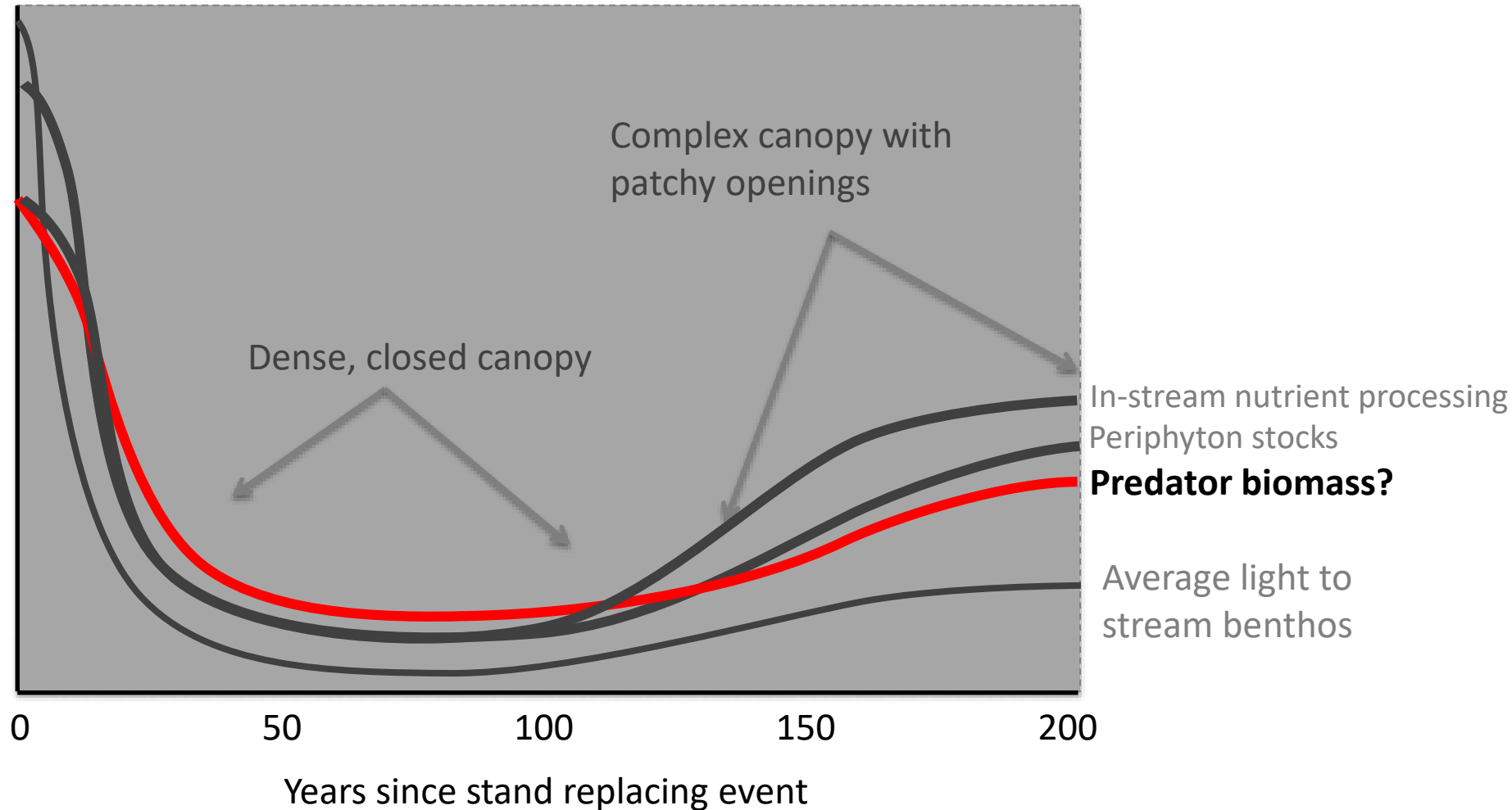
Conceptual model for changing **periphyton (GPP?)** over time in a forested headwater stream



Conceptual model for changing **N-cycling** over time in a forested headwater stream

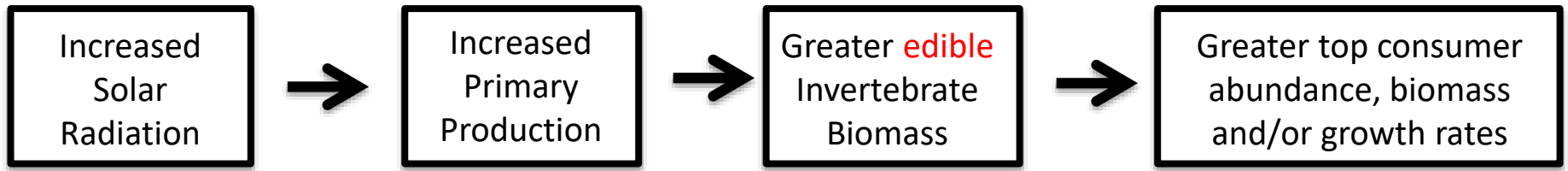


Conceptual model for changing **predator biomass** over time in a forested headwater stream



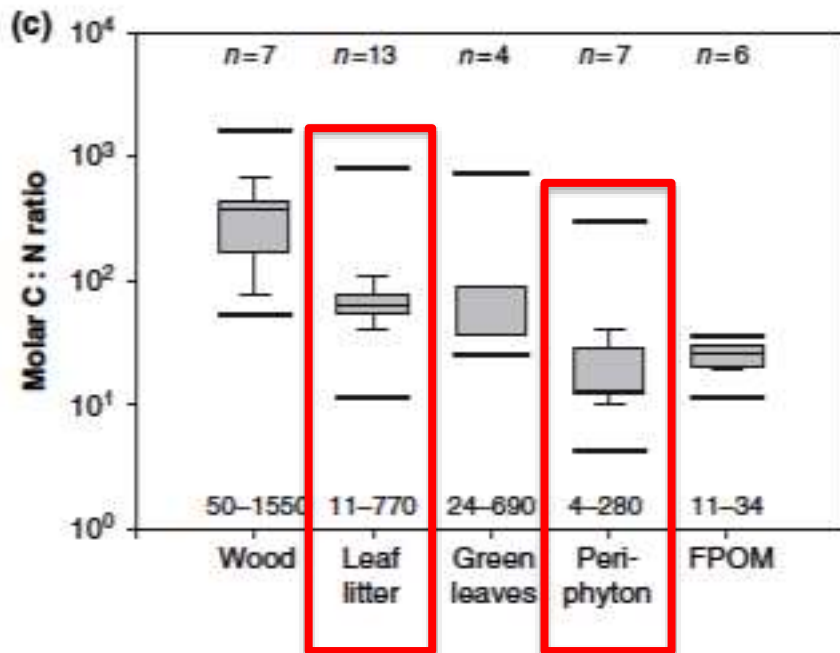
Conceptual framework

Forest structure influences stream predators via
‘Bottom-up’ drivers in the food web



Why would a small change in periphyton matter to stream predators?

- Algal material is “higher quality” food that most allochthonous material that enters streams (i.e. leaves)
- Therefore relatively small increases in primary production have the potential to disproportionately impact secondary production



Study Design: Study 1

(Matt Kaylor)

Set up 9 pairs of reaches with old-growth and second-growth riparian forests and evaluate relationships among the following metrics compare across streams for each stand type.

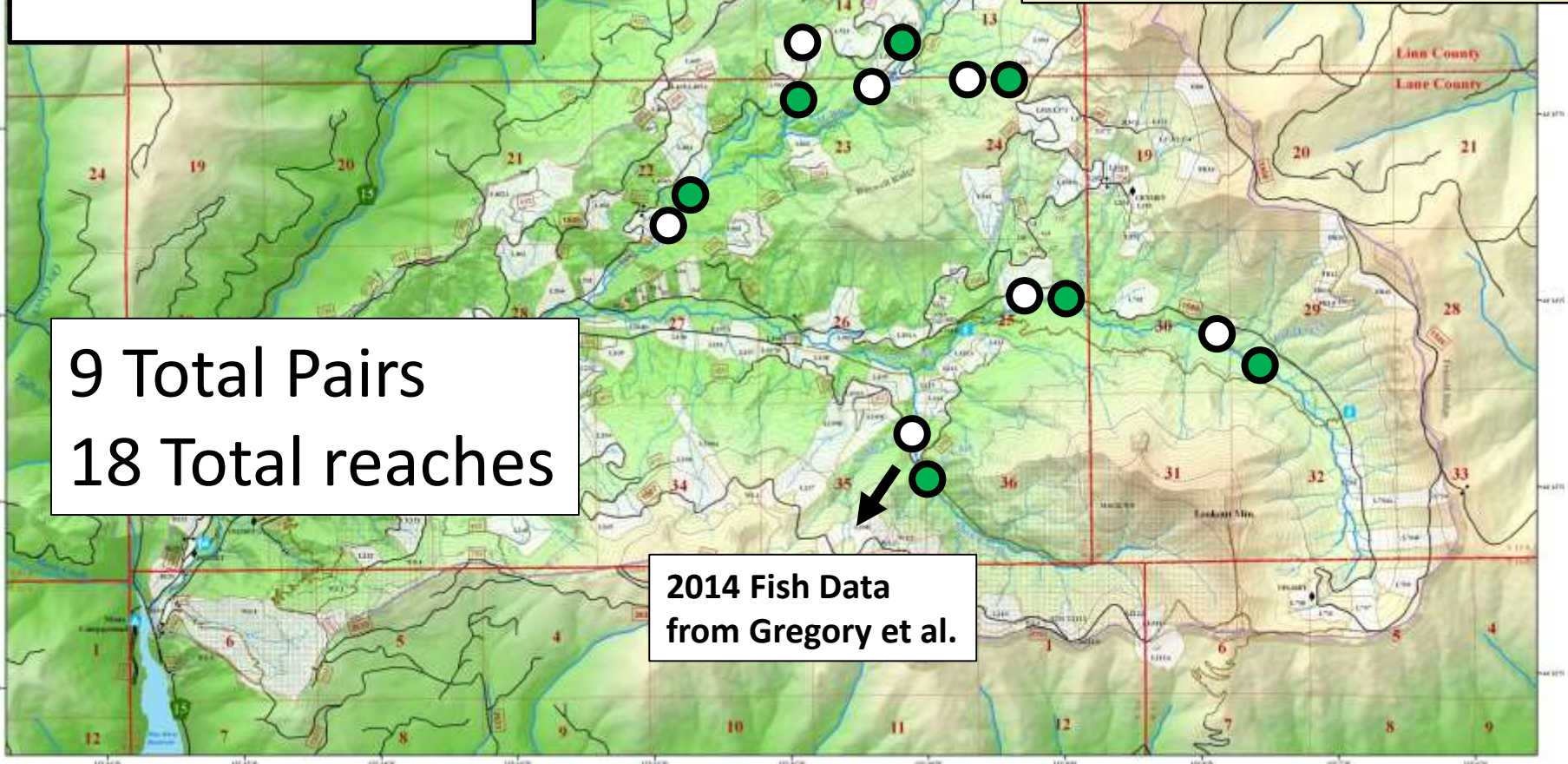
- Light/canopy cover
- Stream habitat
- Background nutrient concentrations
- Primary production (chlorophyll *a*)
- Macroinvertebrate biomass and community composition
- Fish abundance and biomass
- Salamander abundance and biomass



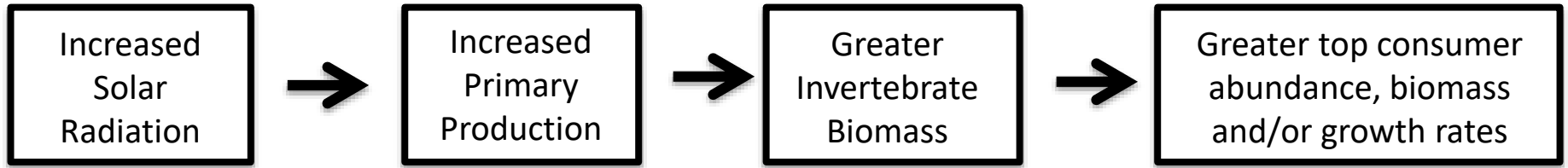
Study Design

H.J. Andrews Experimental Forest, OR

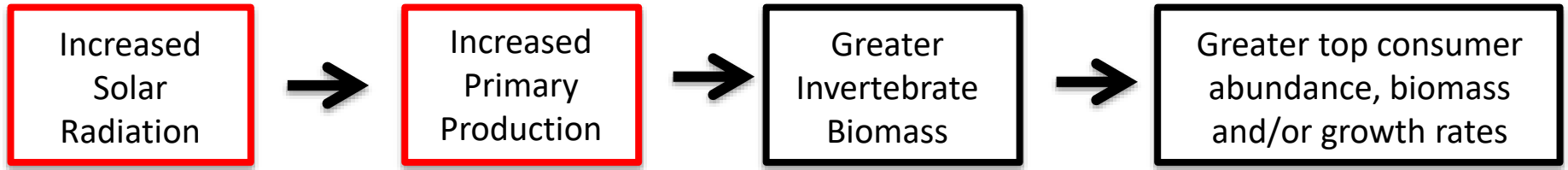
- Old-growth
- Previously Harvested



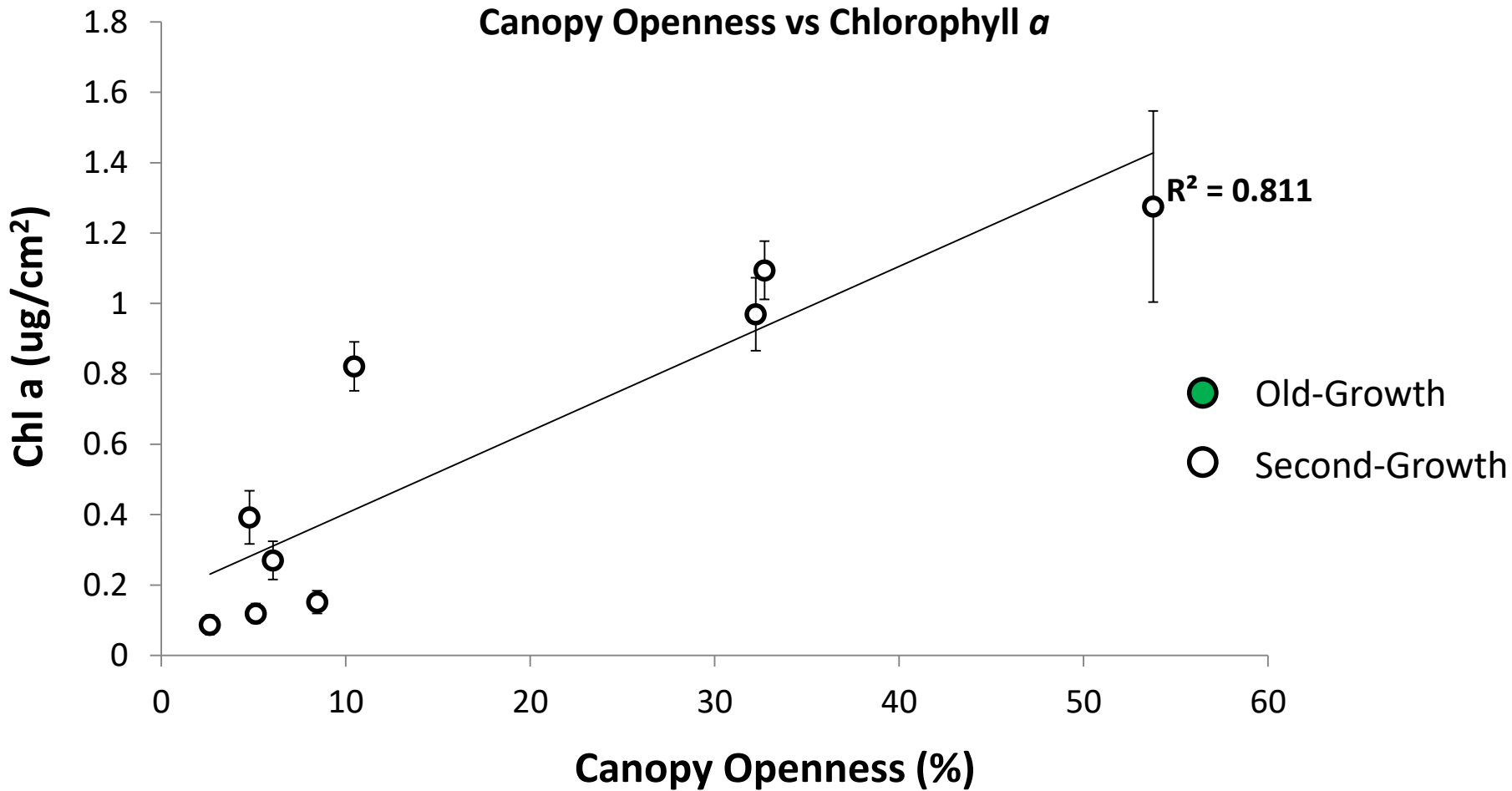
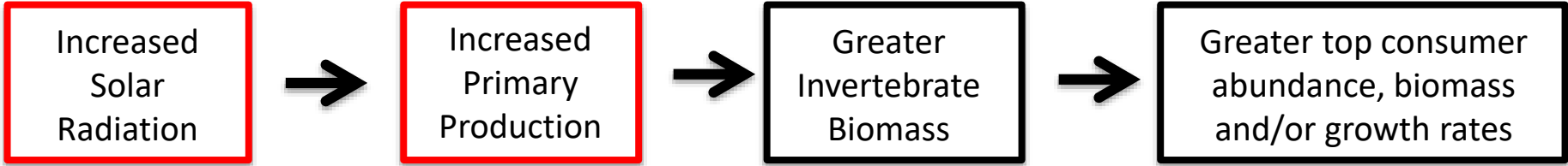
Results: Bottom-up Drivers?



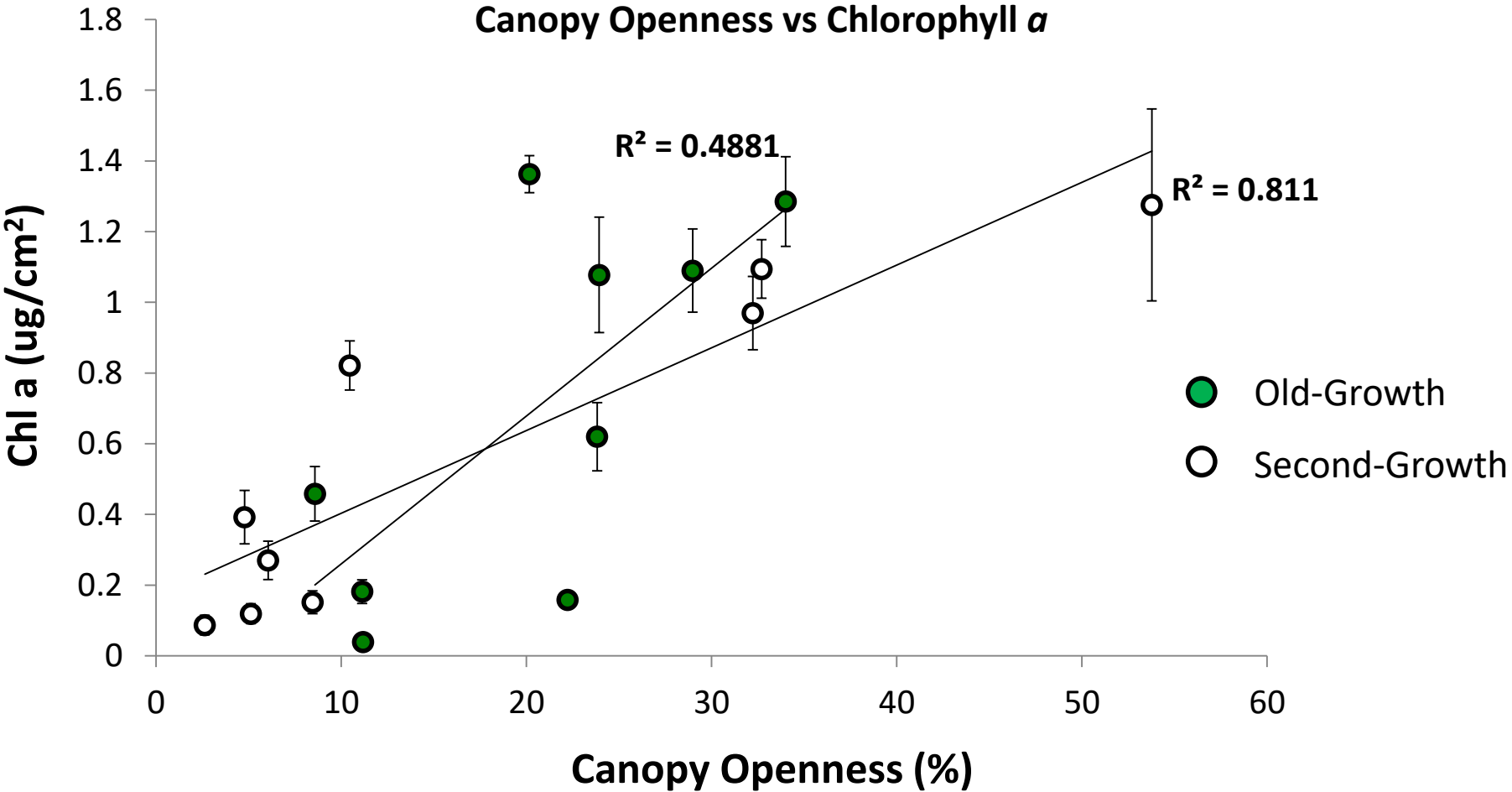
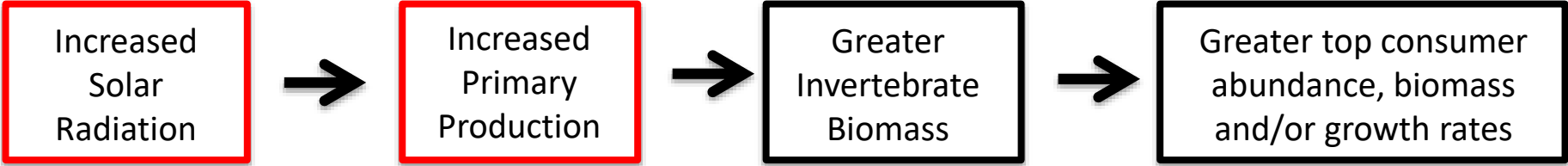
Results: Bottom-up Drivers?



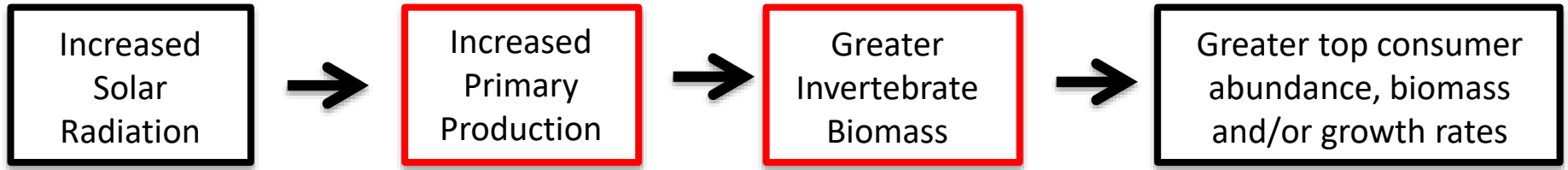
Results: Bottom-up Drivers?



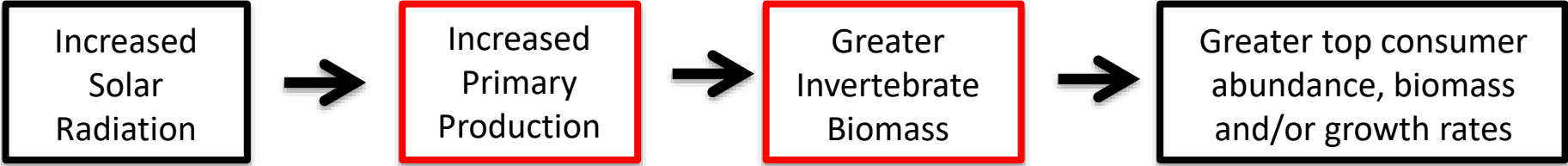
Results: Bottom-up Drivers?



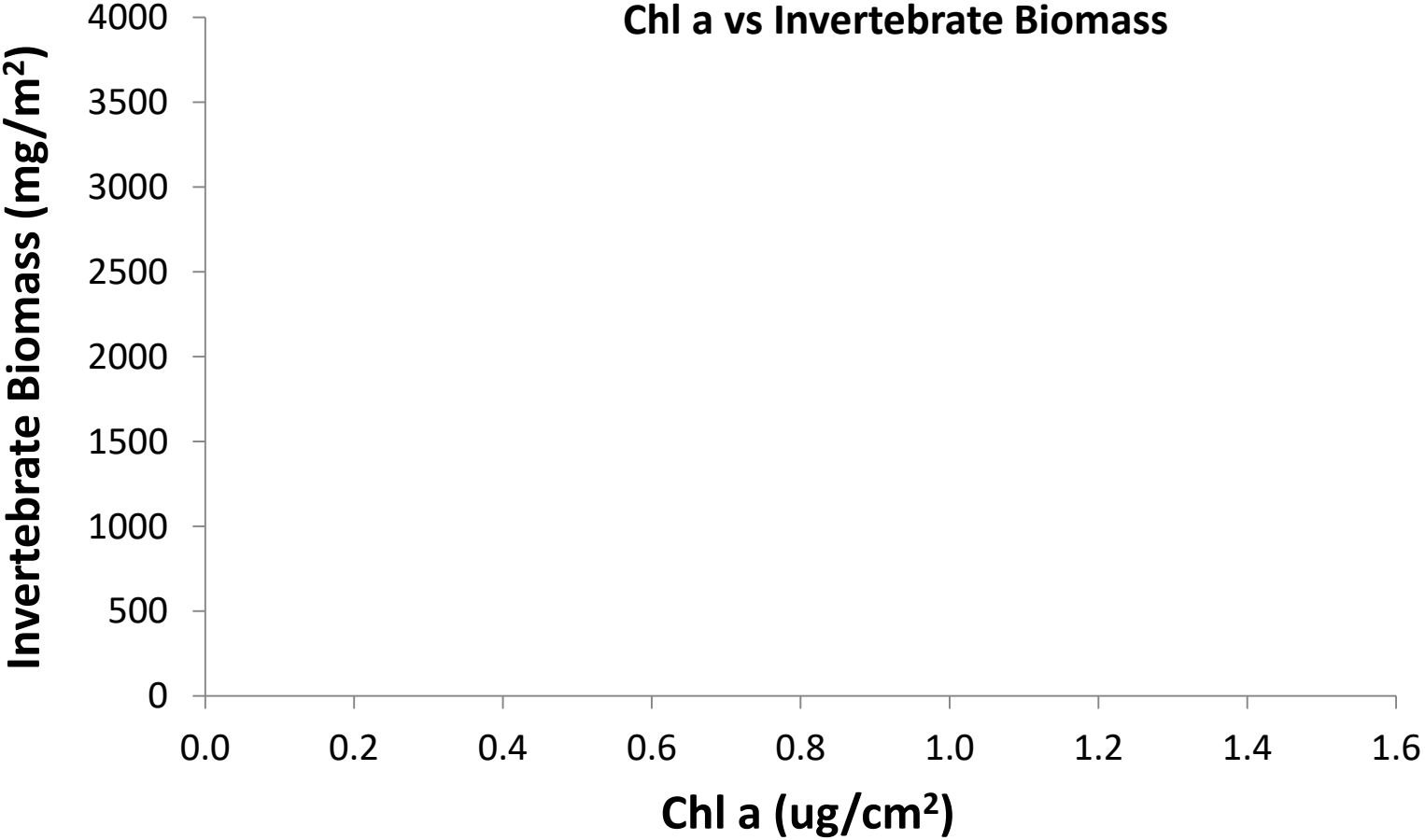
Results: Bottom-up Drivers?



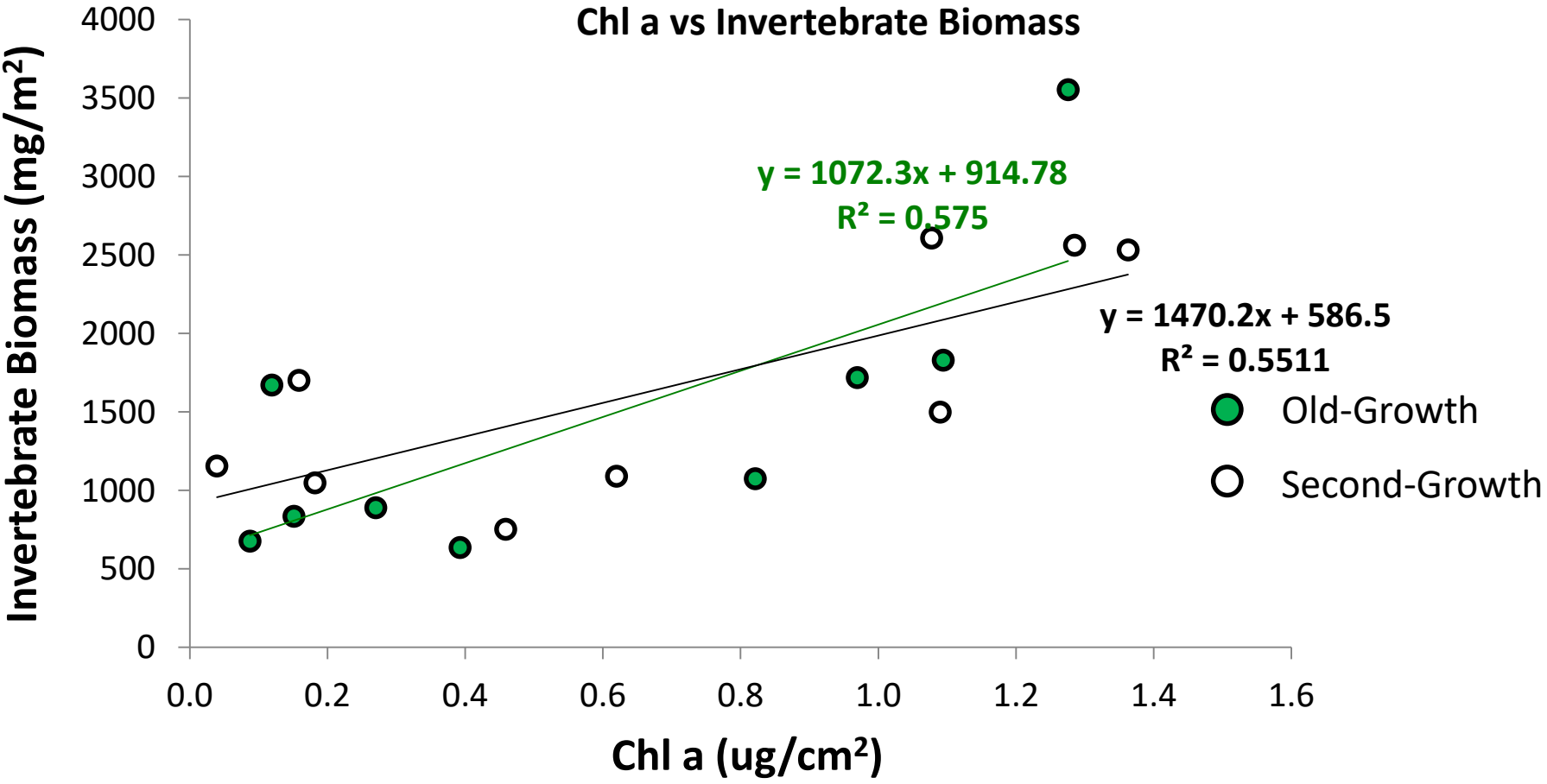
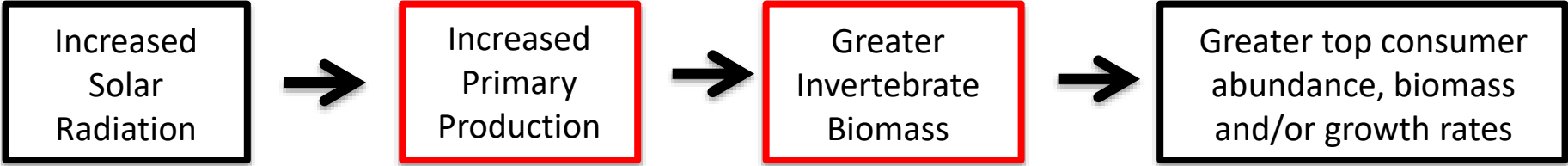
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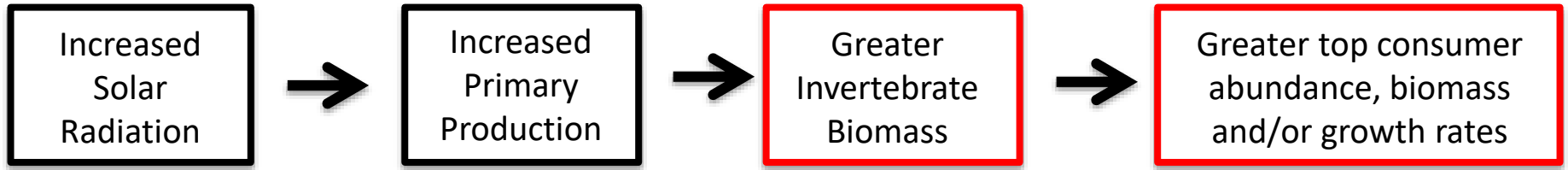
Chl a vs Invertebrate Biomass



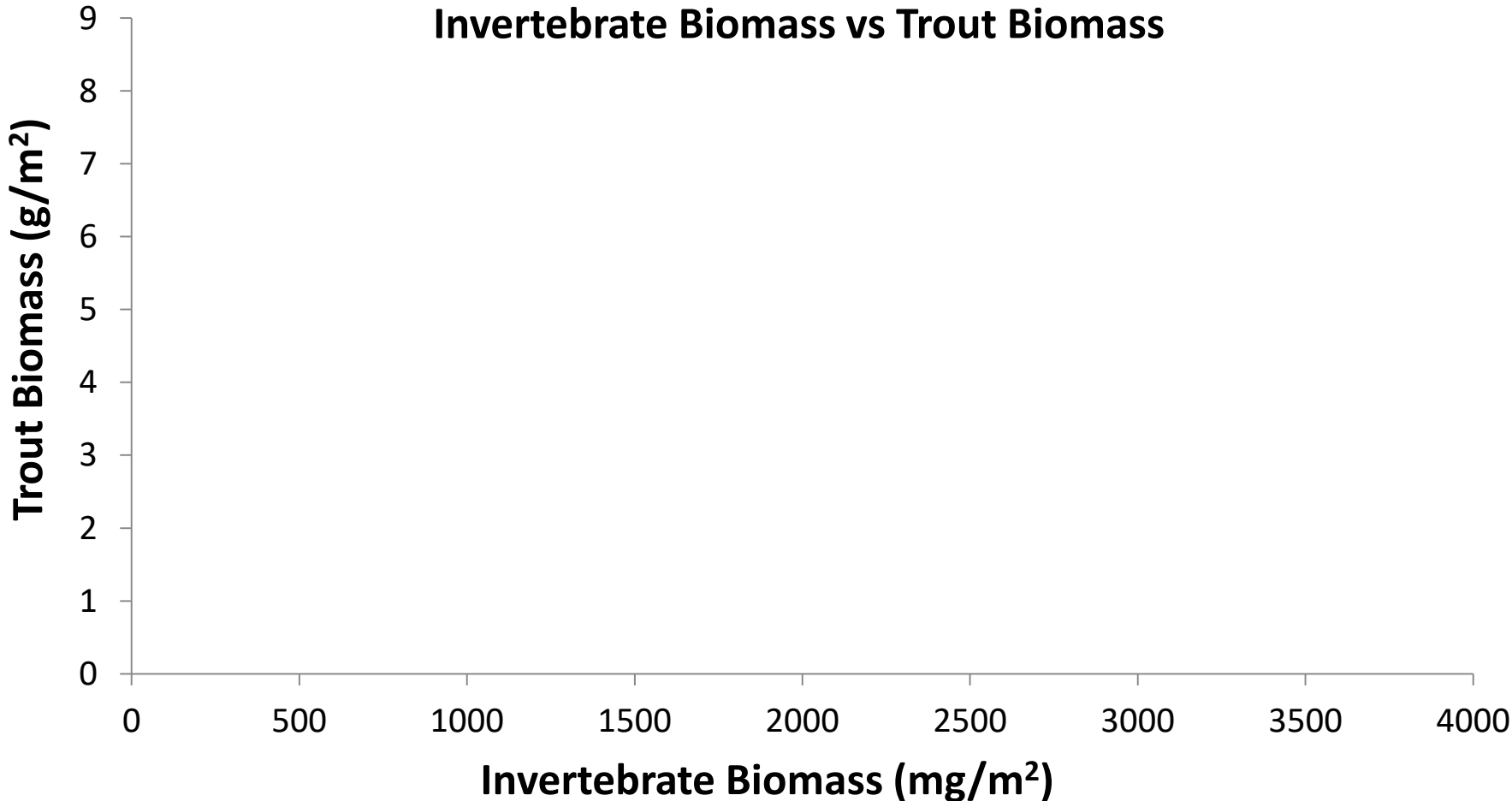
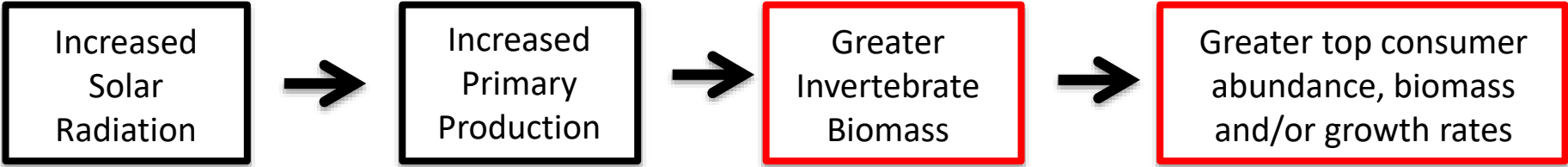
Results: Bottom-up Drivers?



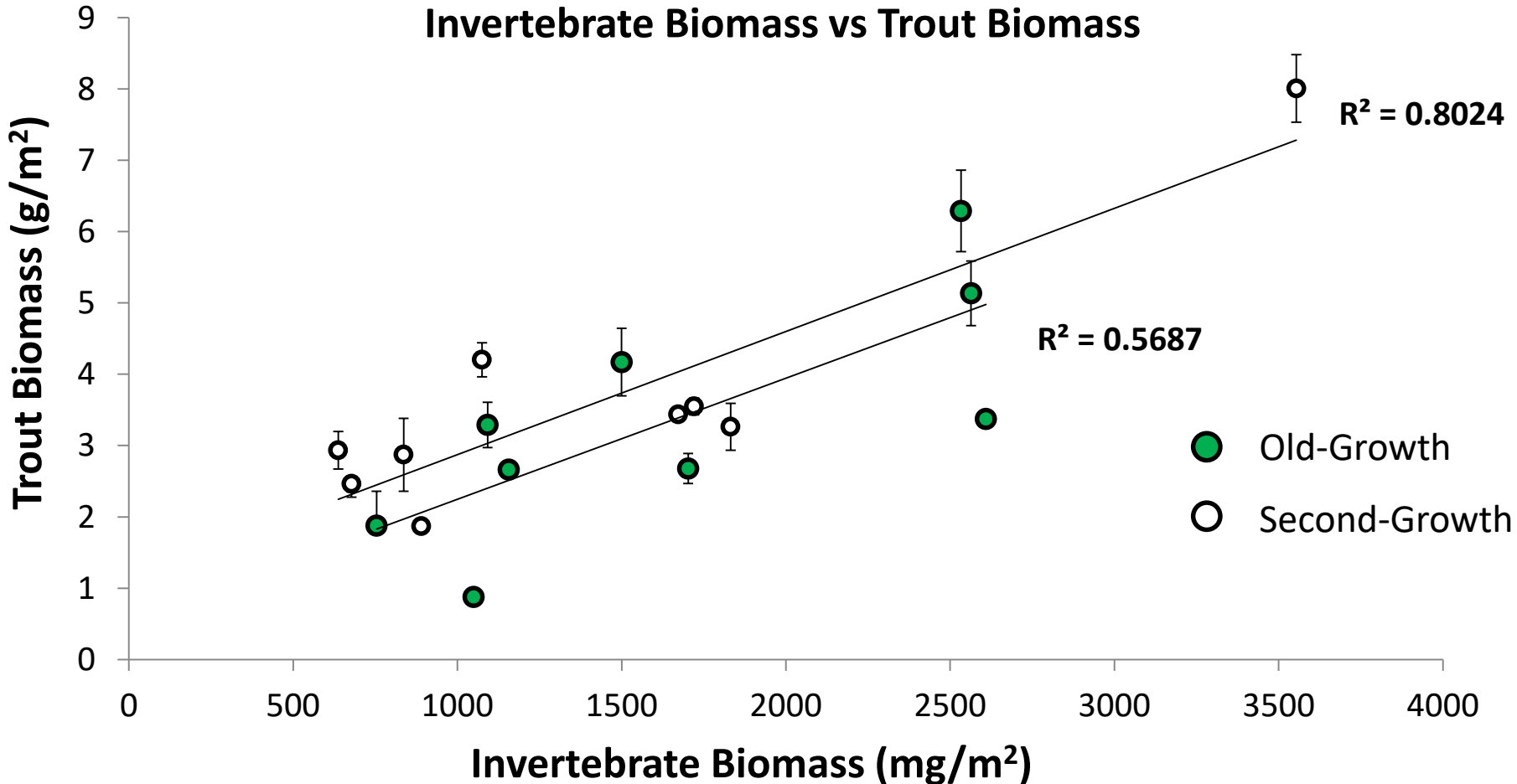
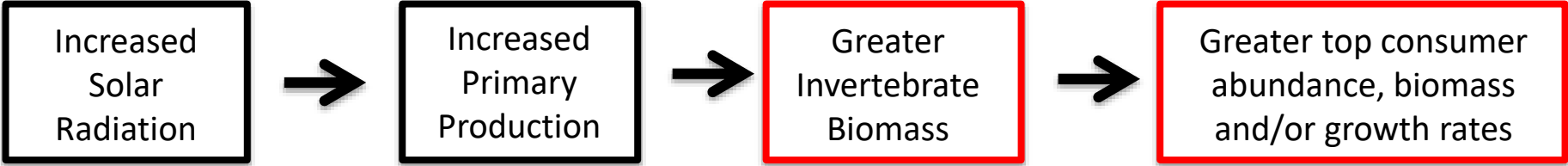
Results: Bottom-up Drivers?



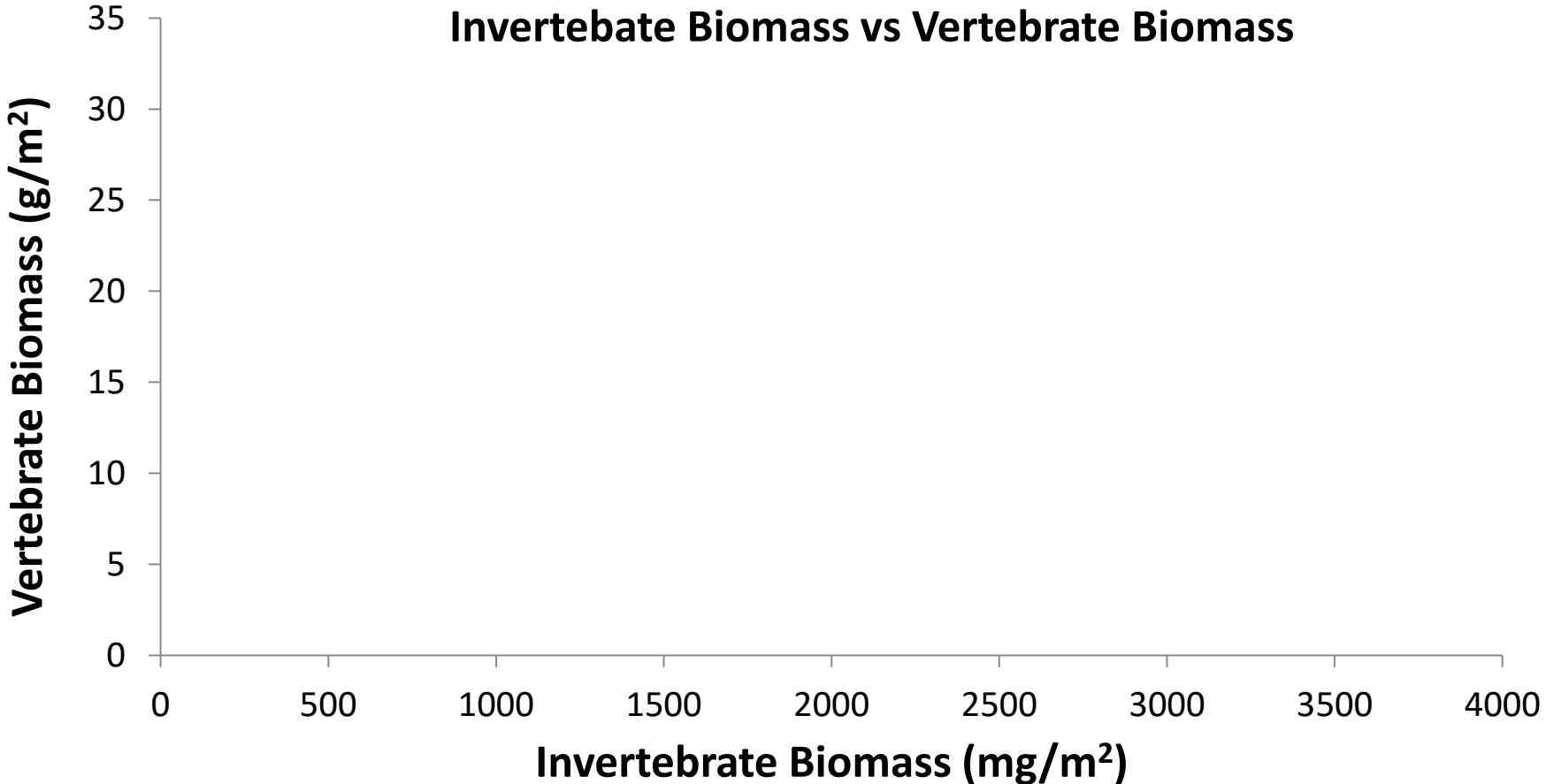
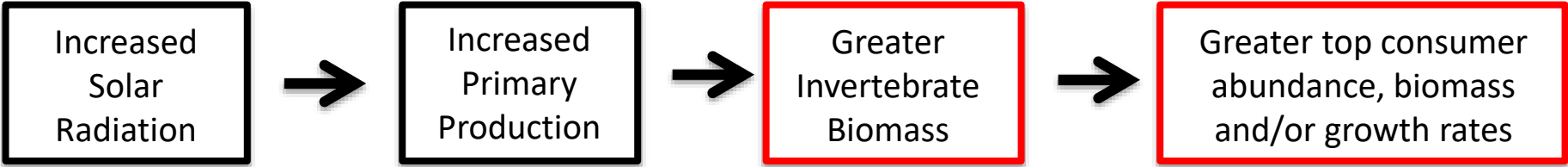
Results: Bottom-up Drivers?



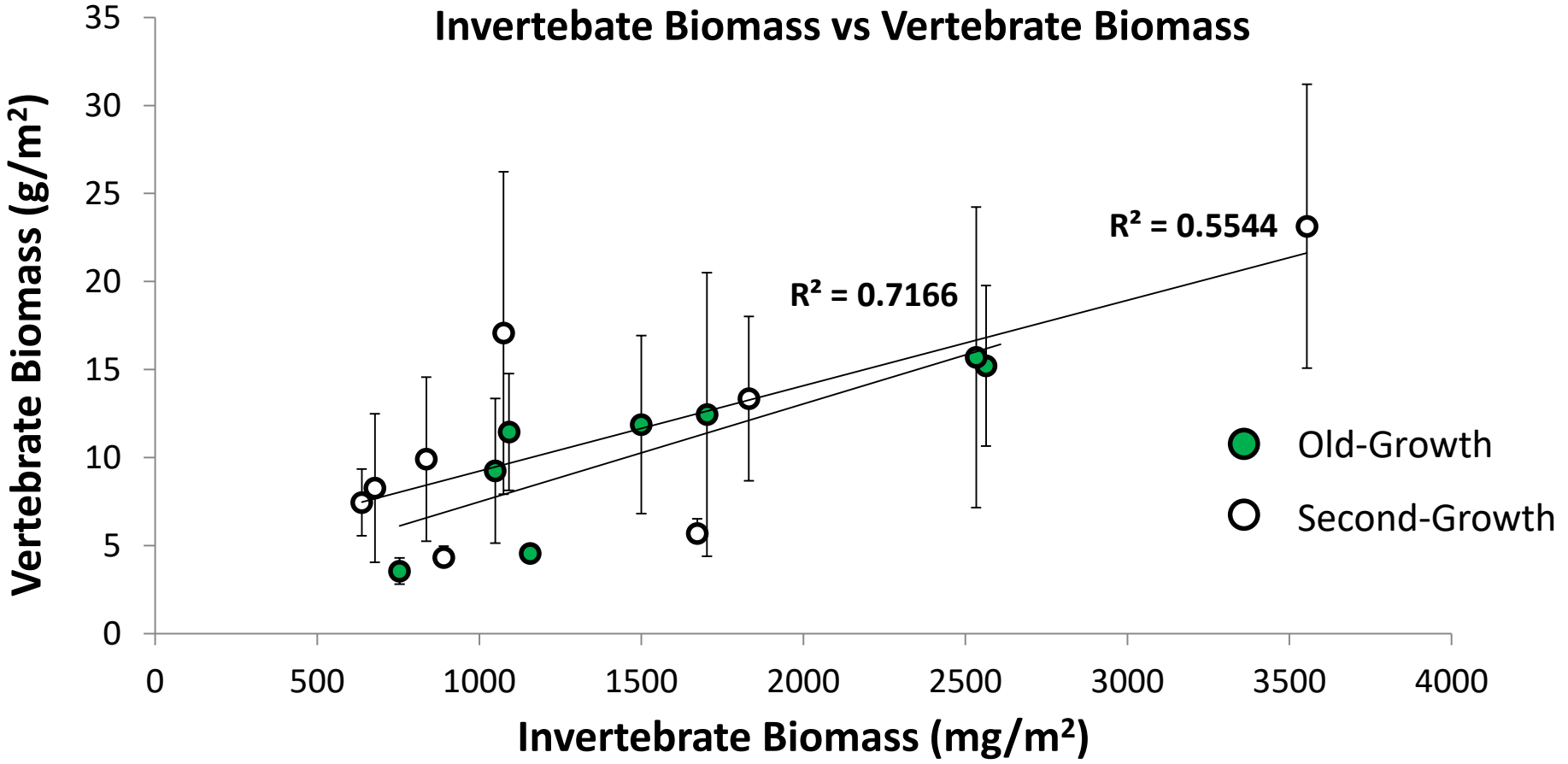
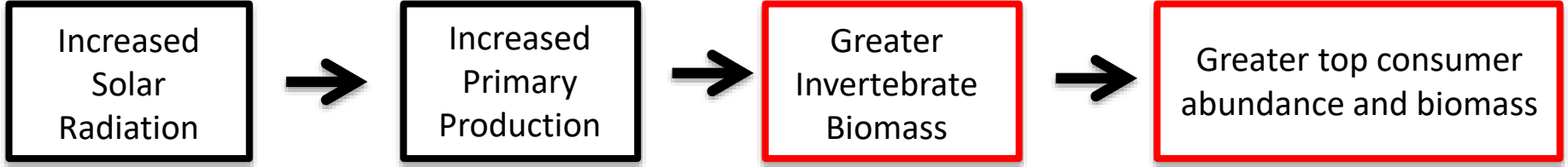
Results: Bottom-up Drivers?



Results: Bottom-up Drivers?



Results: Bottom-up Drivers?



Study Design



H.J. Andrews Experimental Forest, OR

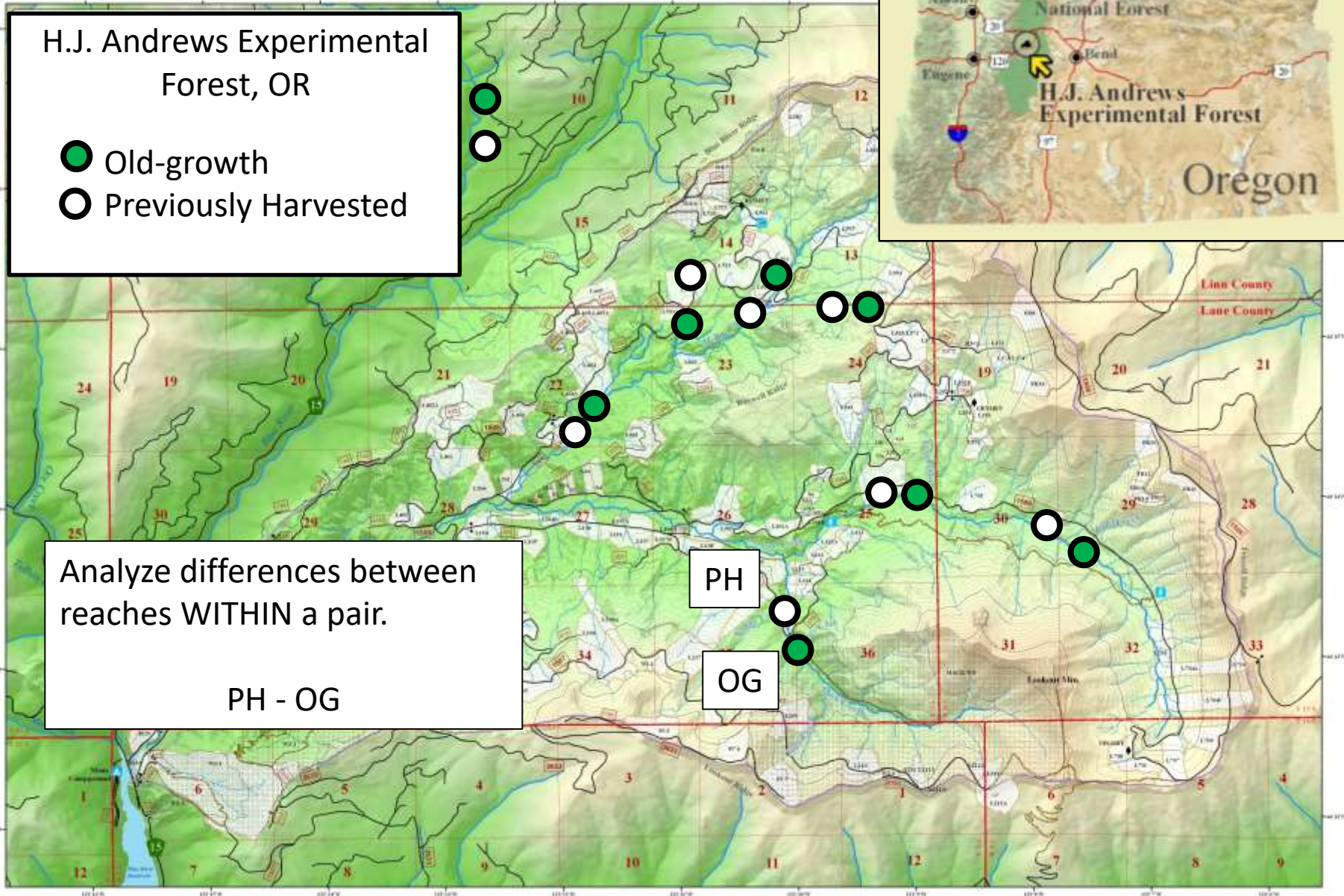
- Old-growth
- Previously Harvested

Analyze differences between reaches WITHIN a pair.

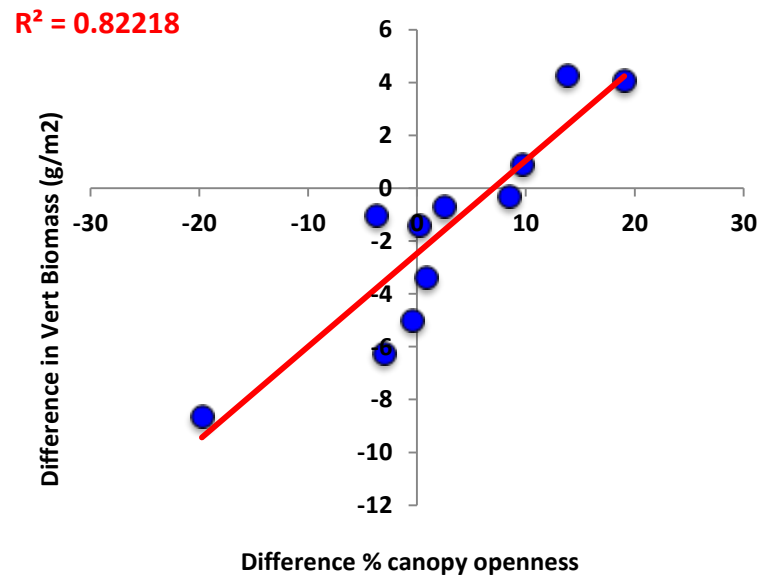
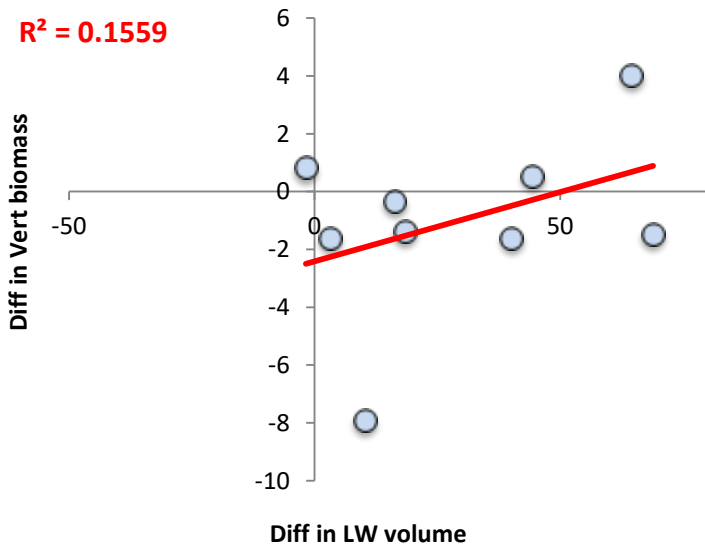
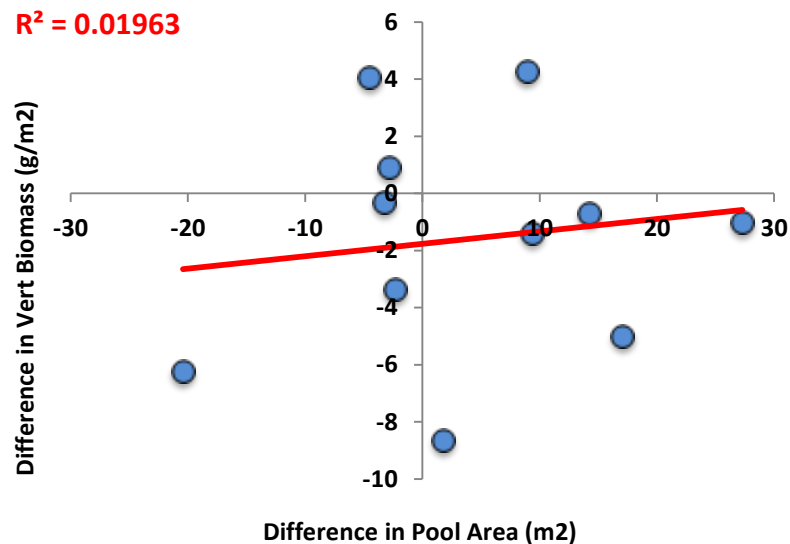
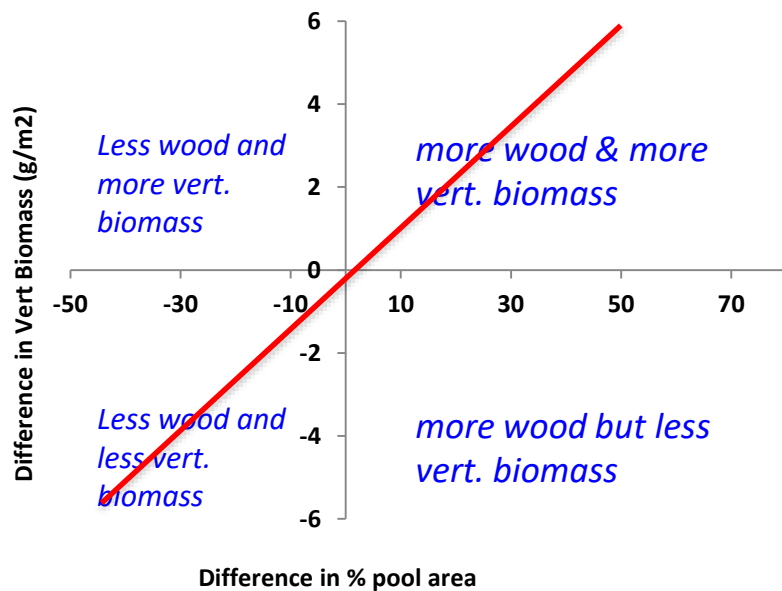
PH - OG

PH

OG



Analysis of differences



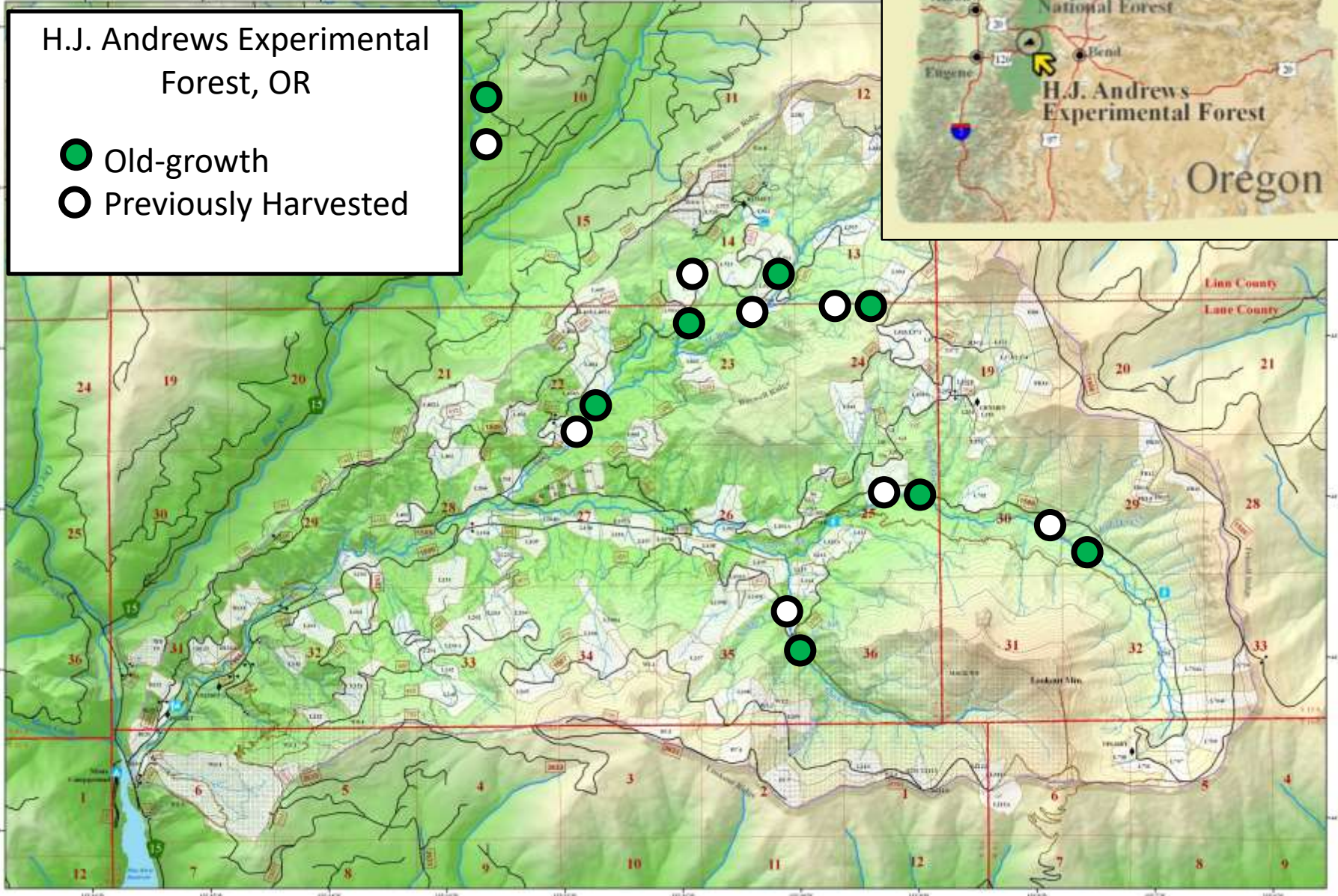
Consumer responses to changing forest structure

“Stand regeneration experiment” Study 2

- 1970's M. Murphy quantified effects of riparian forest harvest on stream food webs and stream habitat
 - *Fish*
 - *Canopy cover*
 - *Periphyton accrual (on tiles)*
 - *Predatory macroinvertebrates*
 - *Volume of large wood*
 - *Pool area*

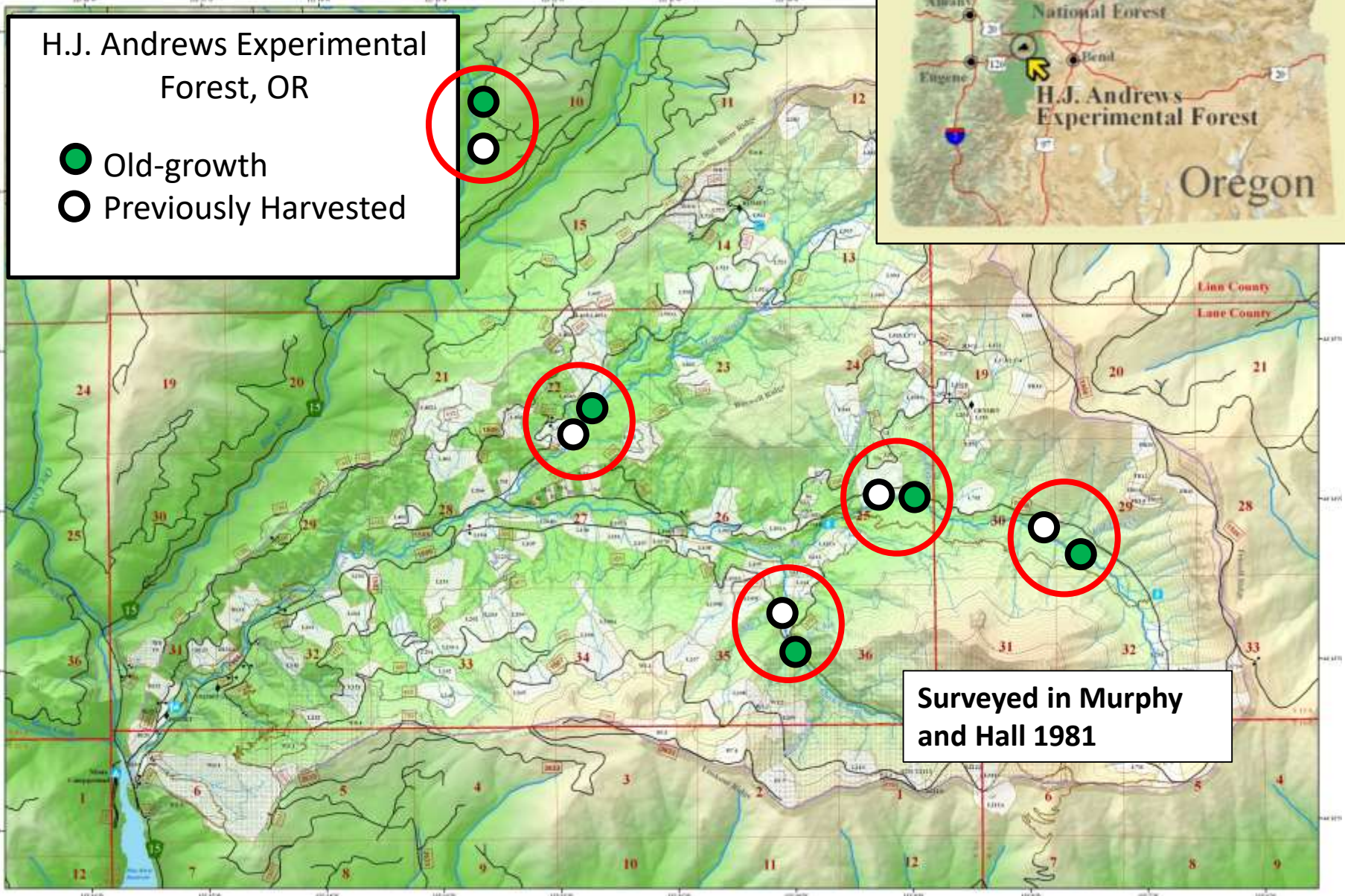
H.J. Andrews Experimental Forest, OR

- Old-growth
- Previously Harvested



H.J. Andrews Experimental Forest, OR

- Old-growth
- Previously Harvested

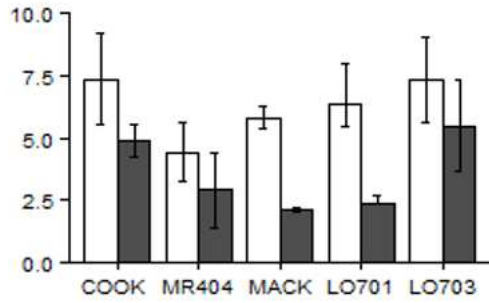


Surveyed in Murphy and Hall 1981

1976

Trout Biomass (g/m²)

(A)



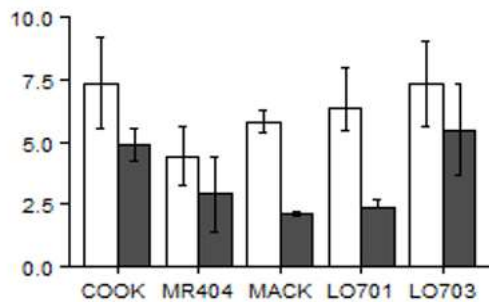
□ Harvested

■ Old-Growth

1976

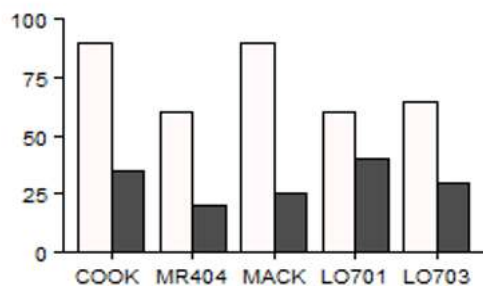
Trout Biomass (g/m²)

(A)



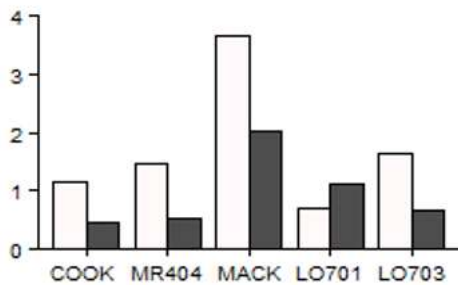
Canopy Openness (%)

(B)



Chlorophyll a (mg/cm²)

(C)



Stream

□ Harvested

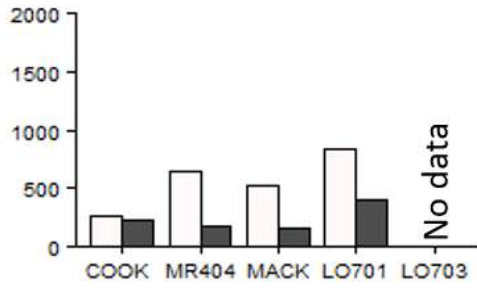
■ Old-Growth



1976

(A)

Predatory Invertebrate
Biomass (mg/m²)



□ Harvested

■ Old-Growth

Consumer responses to changing forest structure

“Stand regeneration experiment”

- 1970’s M. Murphy quantified effects of riparian forest harvest on stream food webs and stream habitat
- 2014’s M. Kaylor returned to these exact (or nearly exact) locations and re-assessed conditions in old-grown and regenerating forests after 38 yrs. of stand regeneration

H.J. Andrews Experimental Forest, OR

● Old-growth

○ Previously Harvested

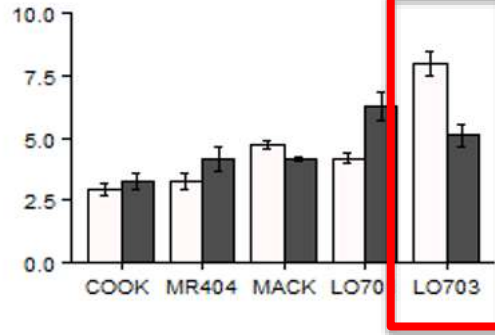
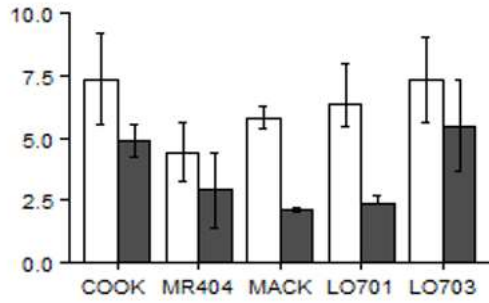


1976

2014

Trout Biomass (g/m²)

(A)



□ Harvested

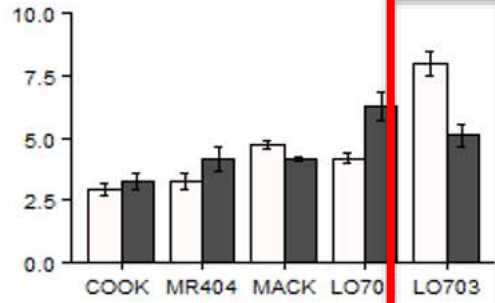
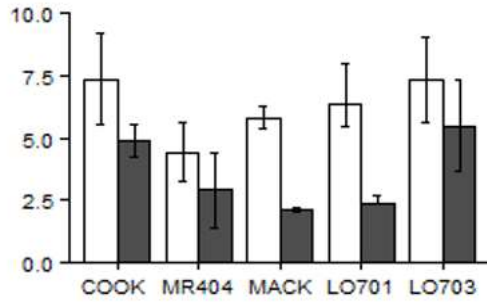
■ Old-Growth

1976

2014

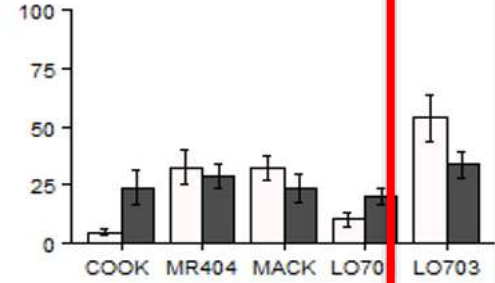
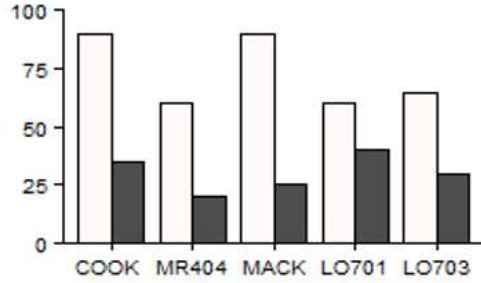
Trout Biomass (g/m²)

(A)



Canopy Openness (%)

(B)



□ Harvested

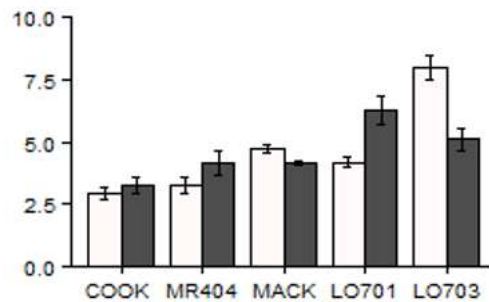
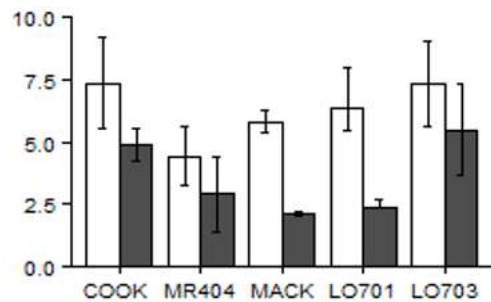
■ Old-Growth

1976

2014

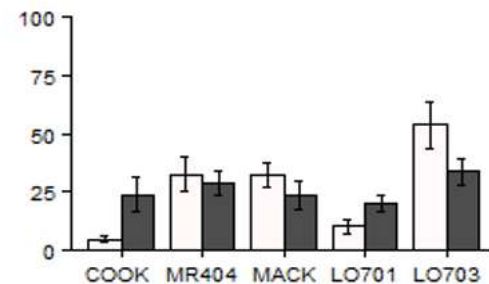
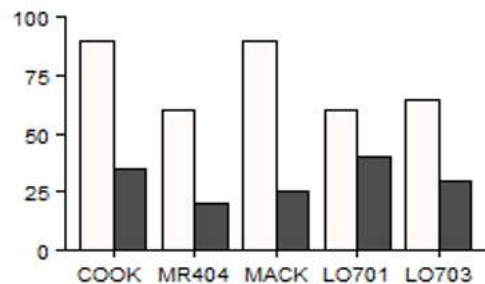
Trout Biomass (g/m²)

(A)

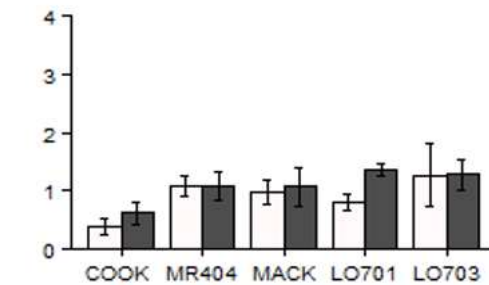
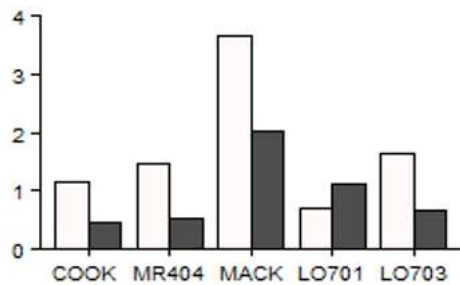


Canopy Openness (%)

(B)

Chlorophyll a (mg/cm²)

(C)



Stream

Stream

□ Harvested

■ Old-Growth

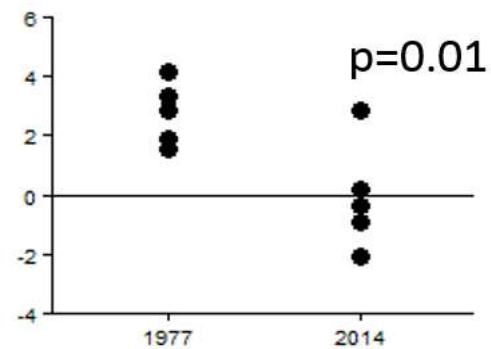
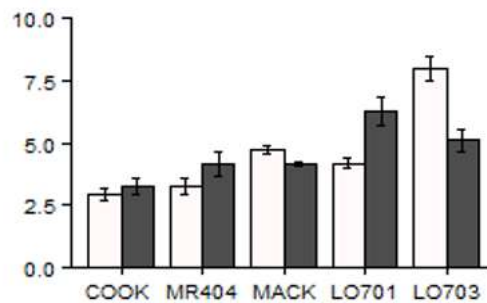
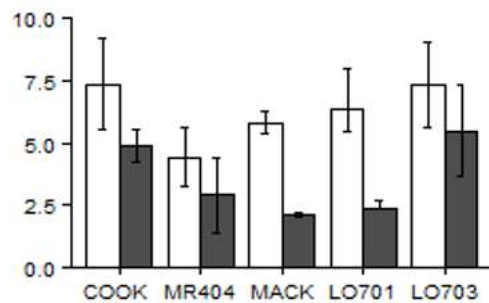
1976

2014

Reach Differences

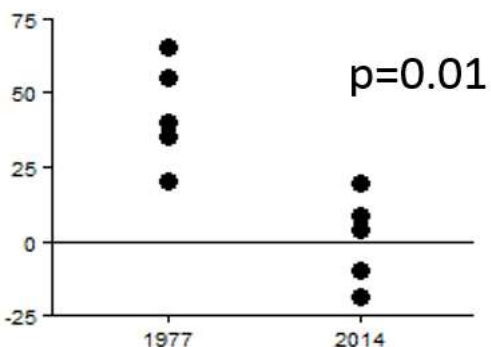
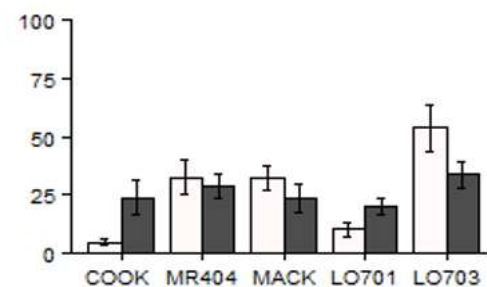
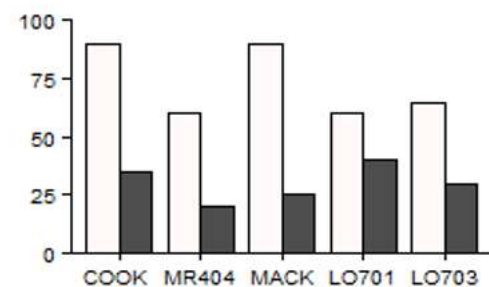
Trout Biomass (g/m²)

(A)

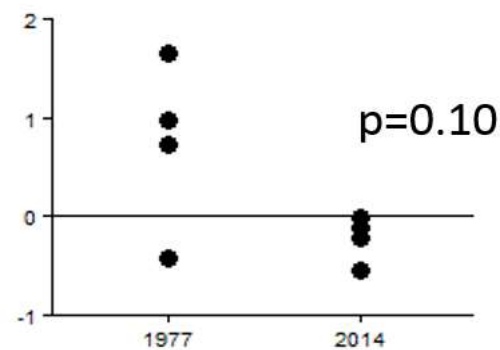
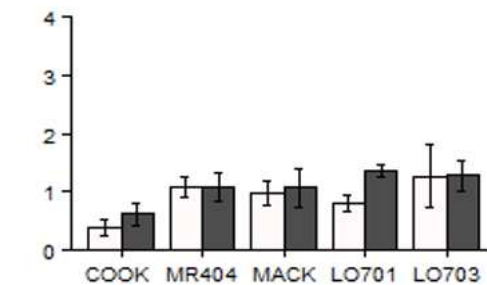
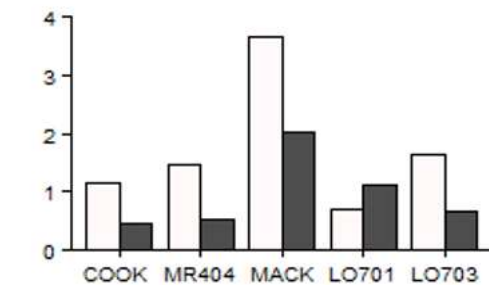


Canopy Openness (%)

(B)

Chlorophyll a (mg/cm²)

(C)



Stream

Stream

Year

□ Harvested

■ Old-Growth

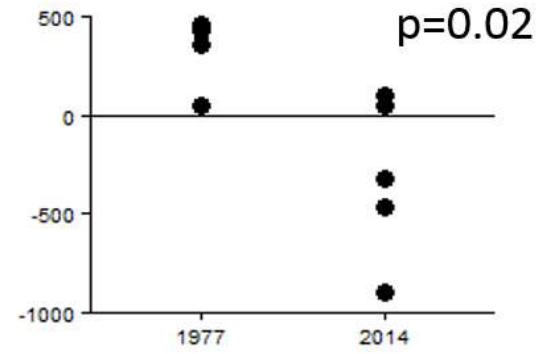
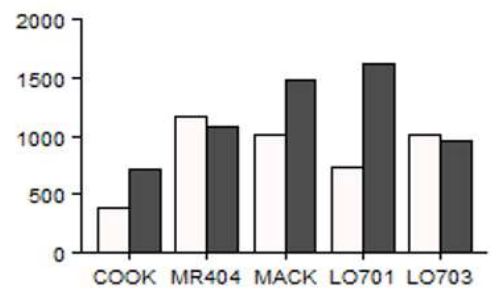
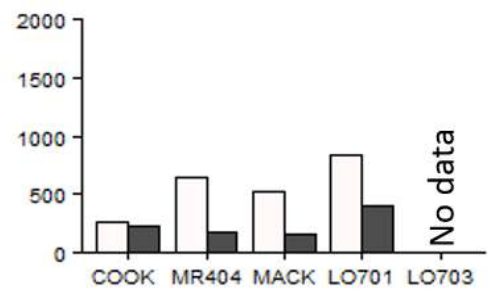
Predatory Invertebrate Biomass (mg/m²)

1976

2014

Reach Differences

(A)



□ Harvested ■ Old-Growth

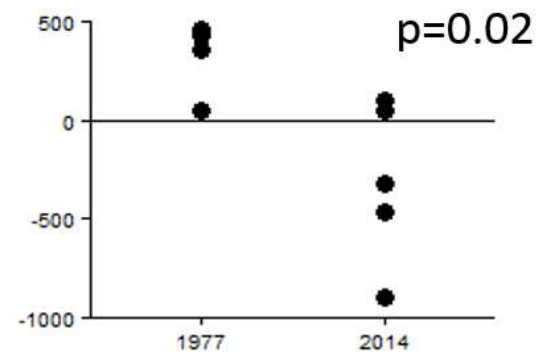
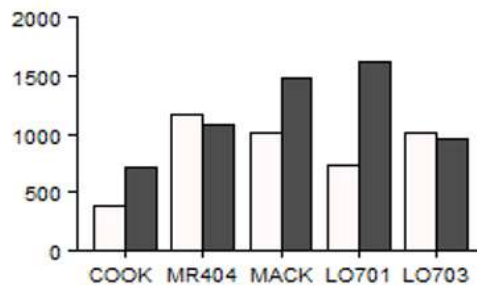
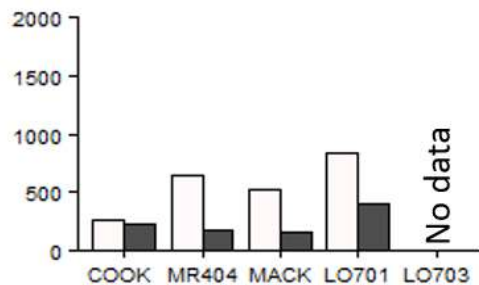
Predatory Invertebrate Biomass (mg/m²)

1976

2014

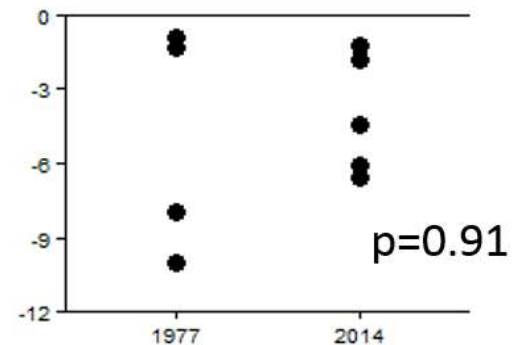
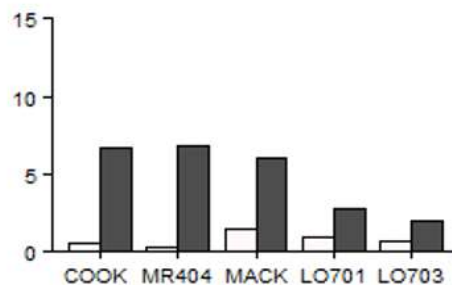
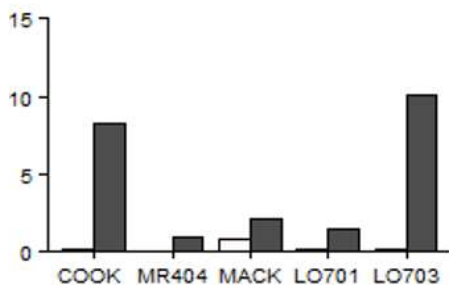
Reach Differences

(A)



Large Wood (m³/100m²)

(B)



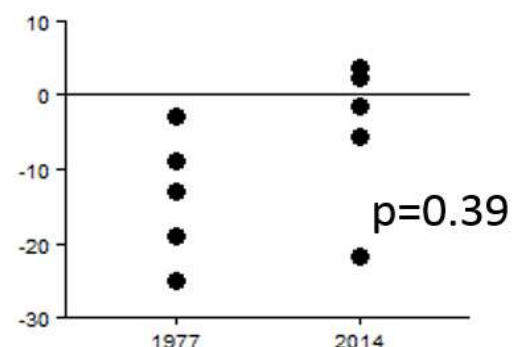
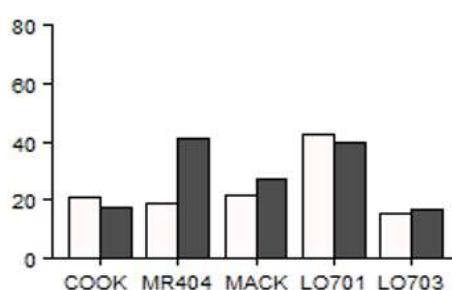
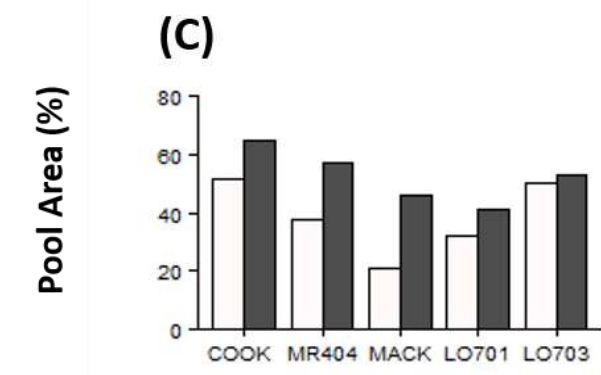
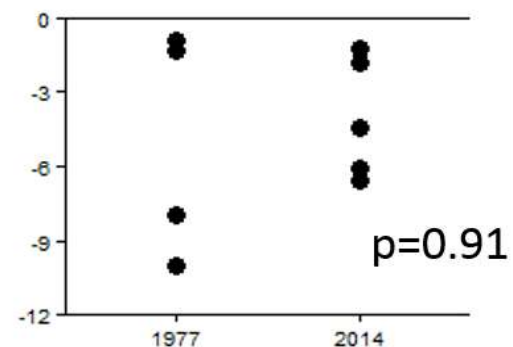
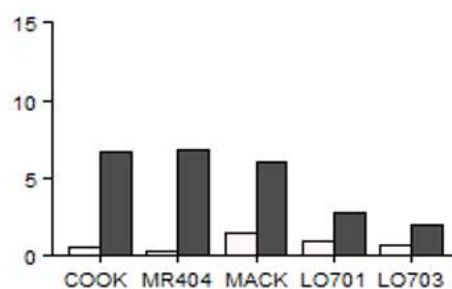
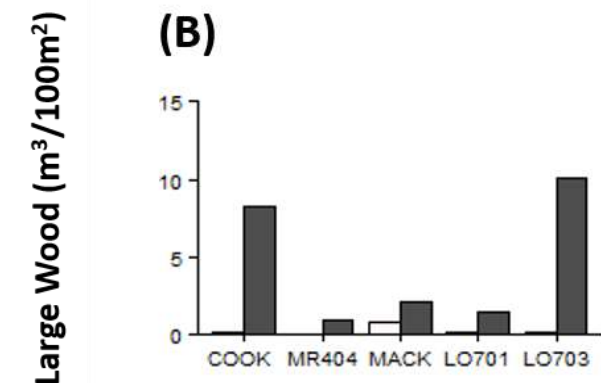
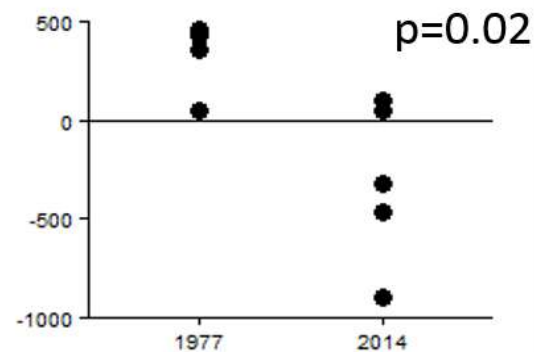
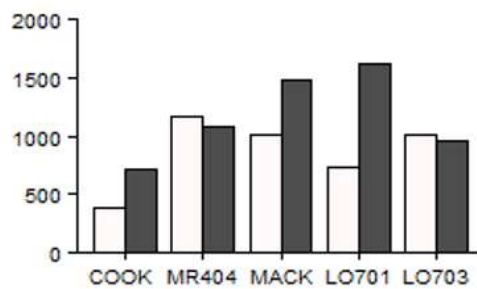
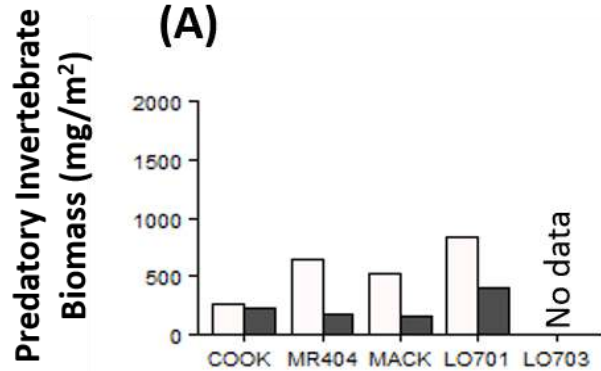
□ Harvested

■ Old-Growth

1976

2014

Reach Differences



Stream

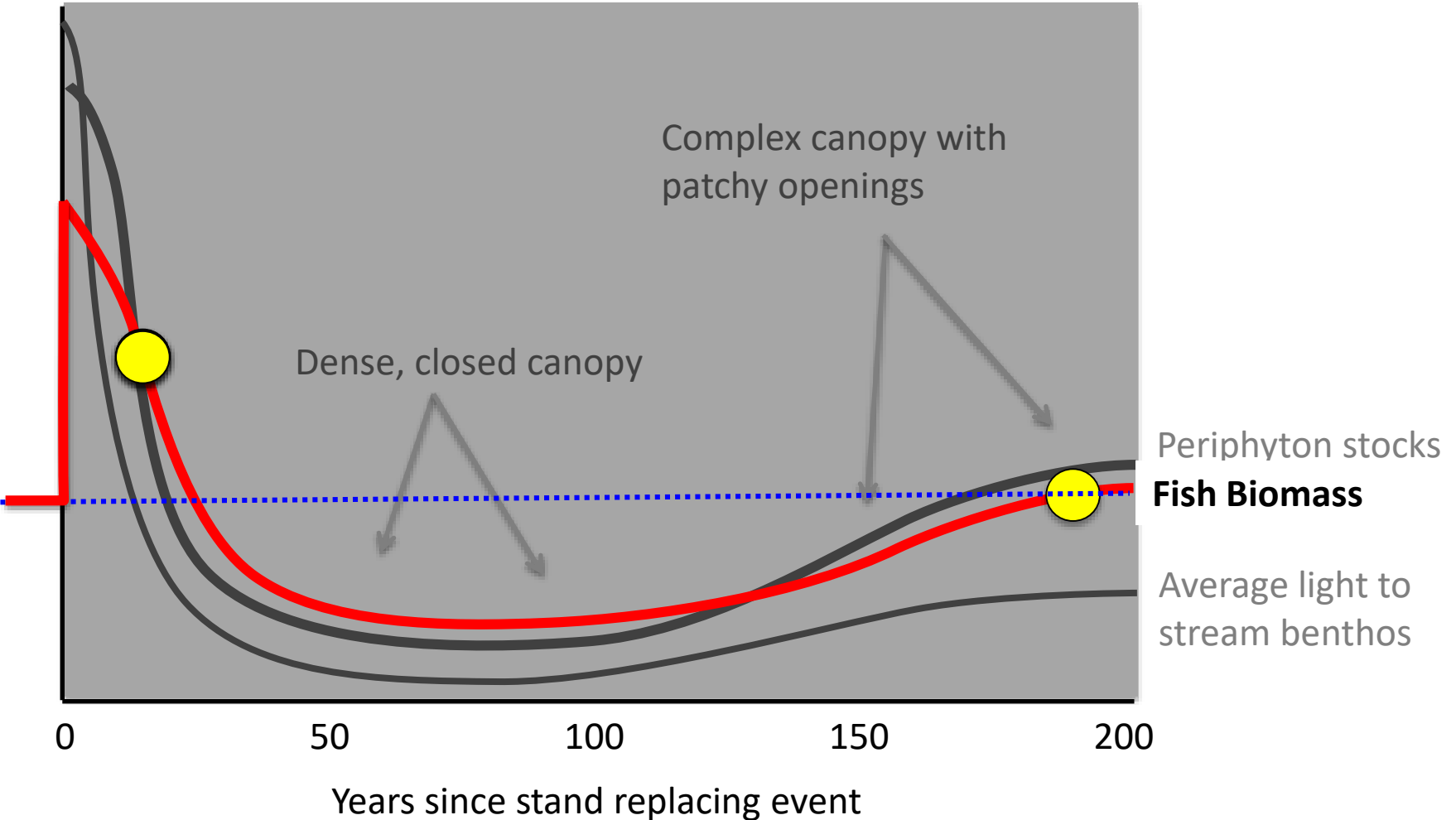
Stream

Year

□ Harvested

■ Old-Growth

Conceptual model for changing **vertebrate biomass** over time in a forested headwater stream



“Stream shading experiment”

Study 3

(Emily Heaston)

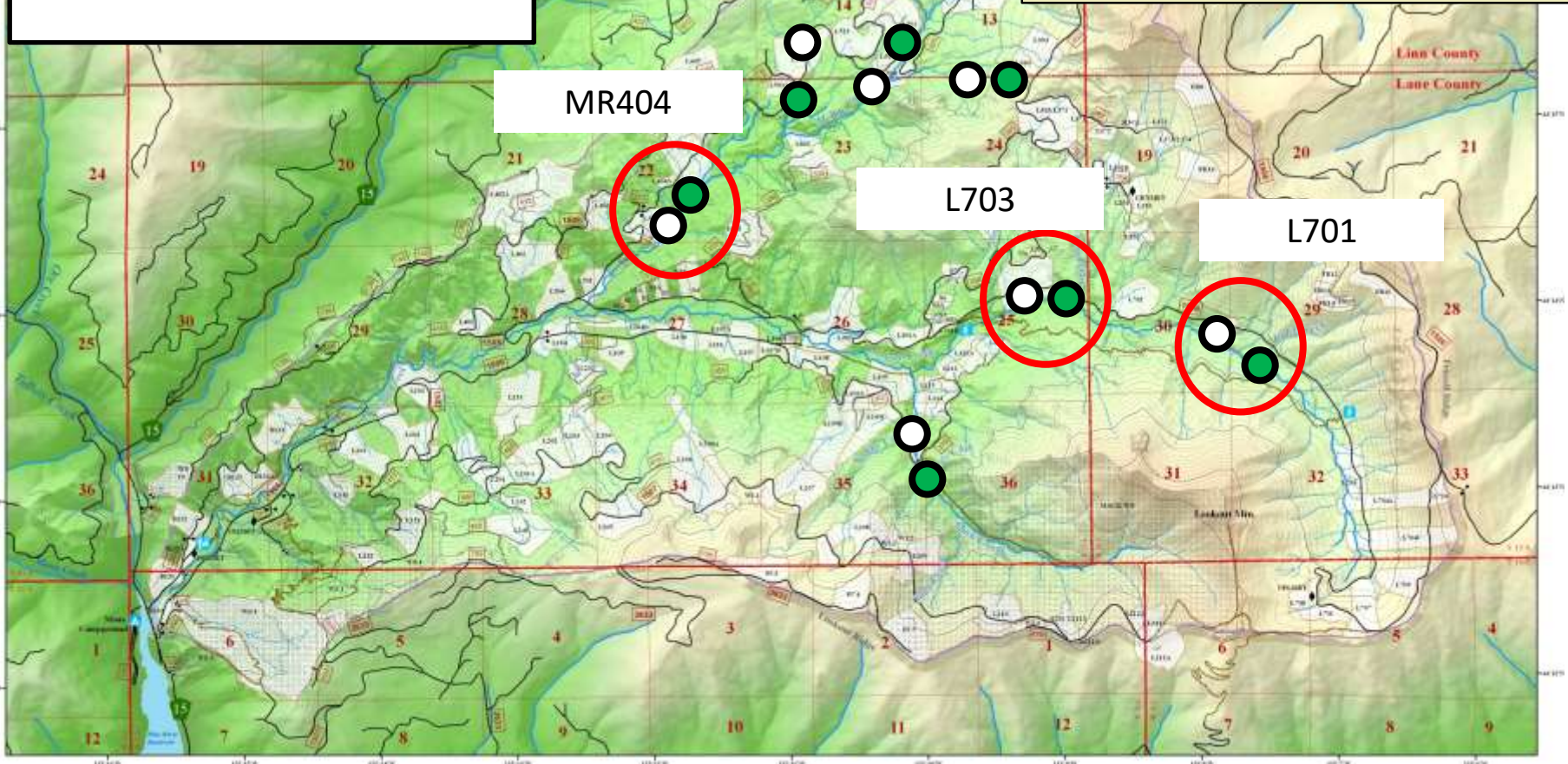
- Picked 3 of the reach pairs assessed by M. Kaylor in 2014 and shaded one of the reaches in each pair for one summer
- Determine if partial shading impacts primary production, invertebrates, fish and salamanders

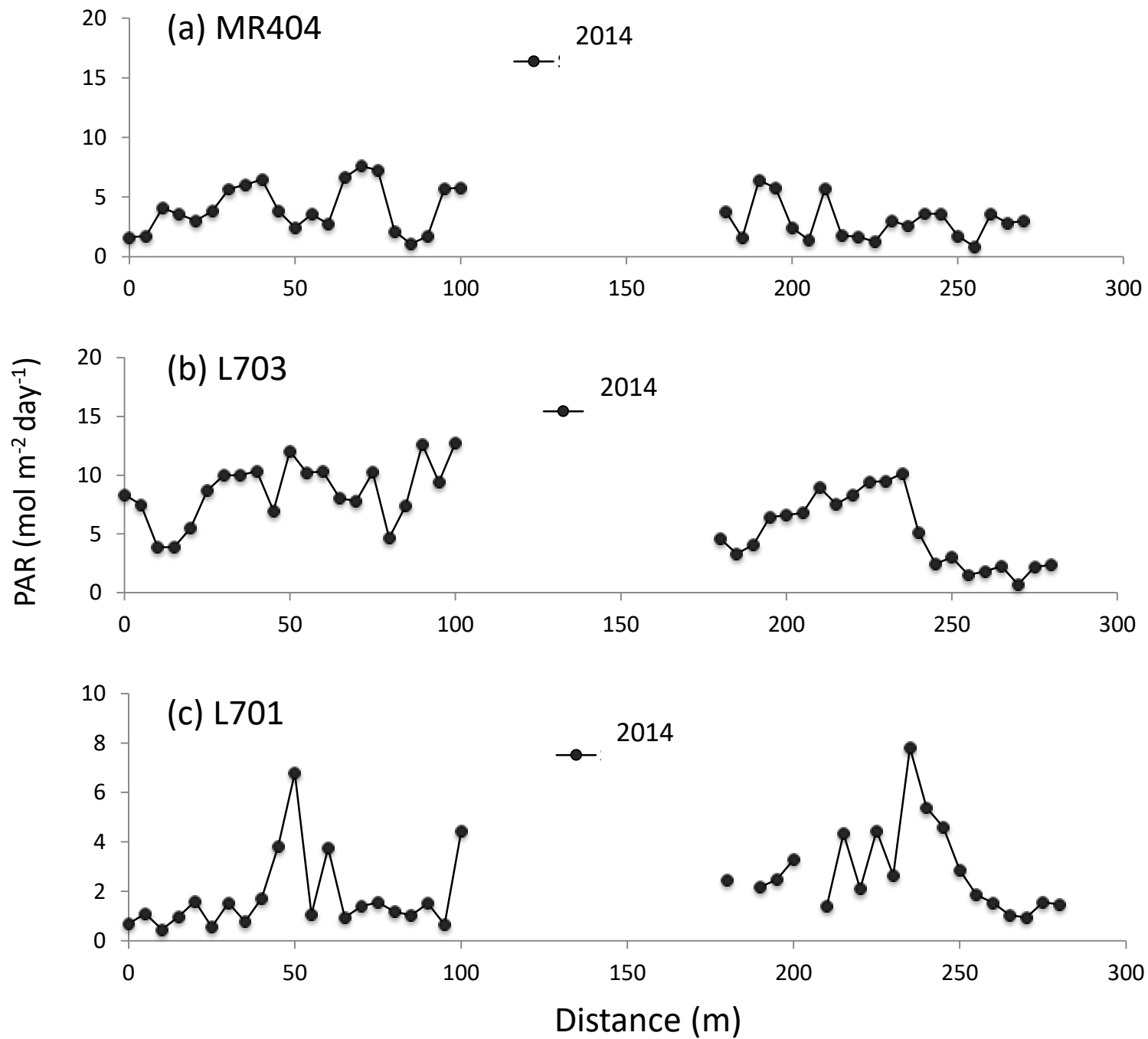


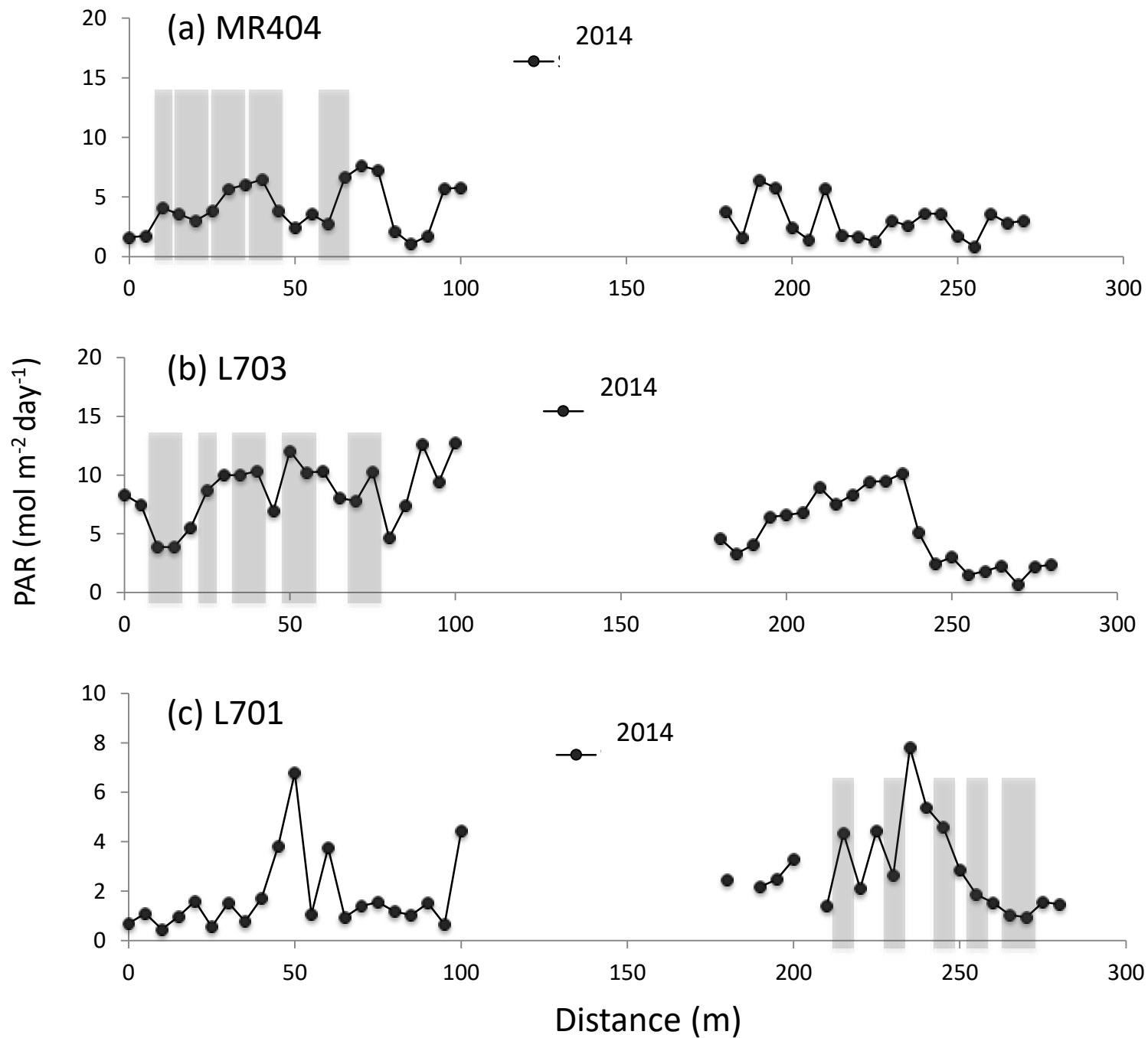
Study Design

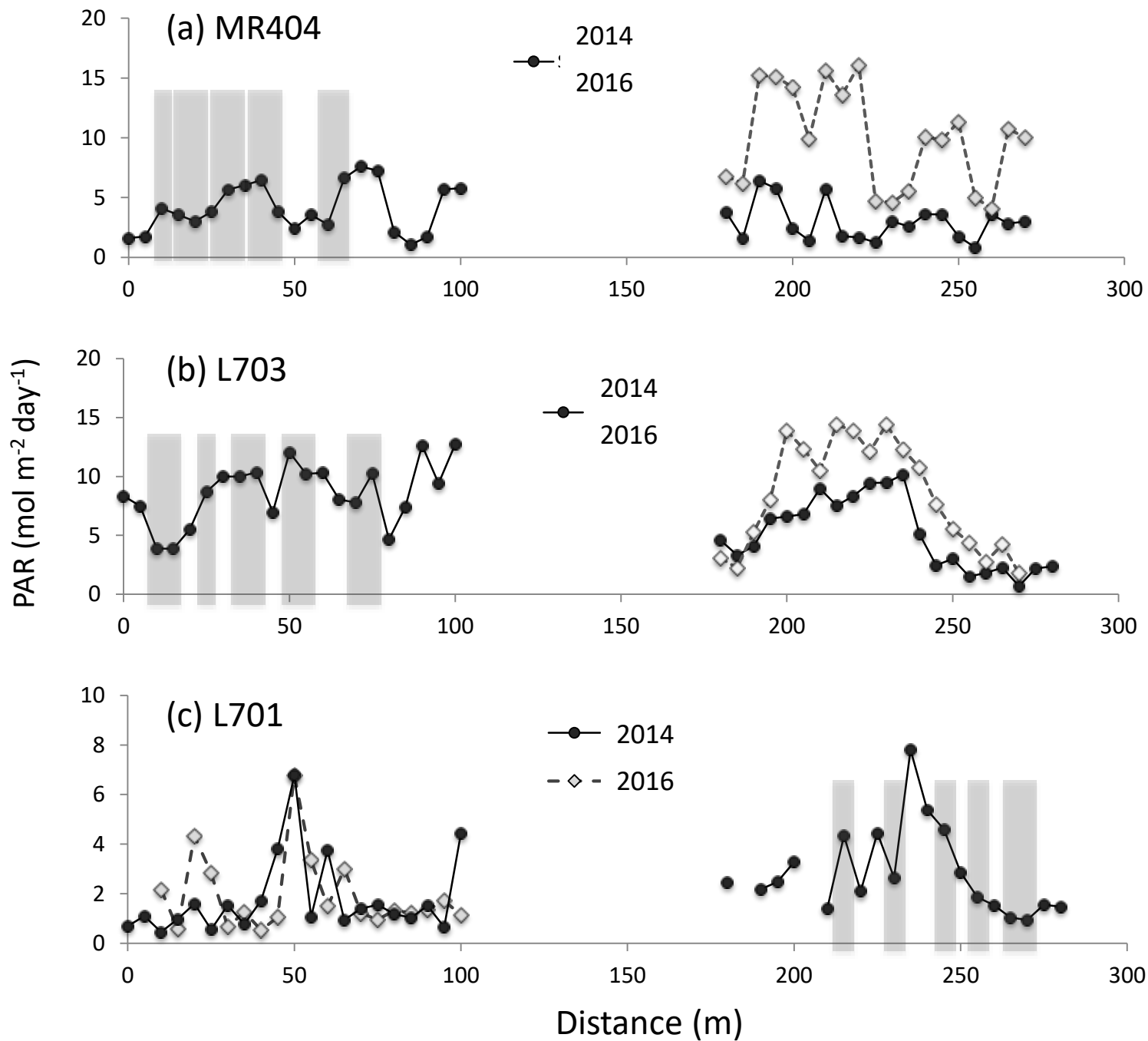
H.J. Andrews Experimental Forest, OR

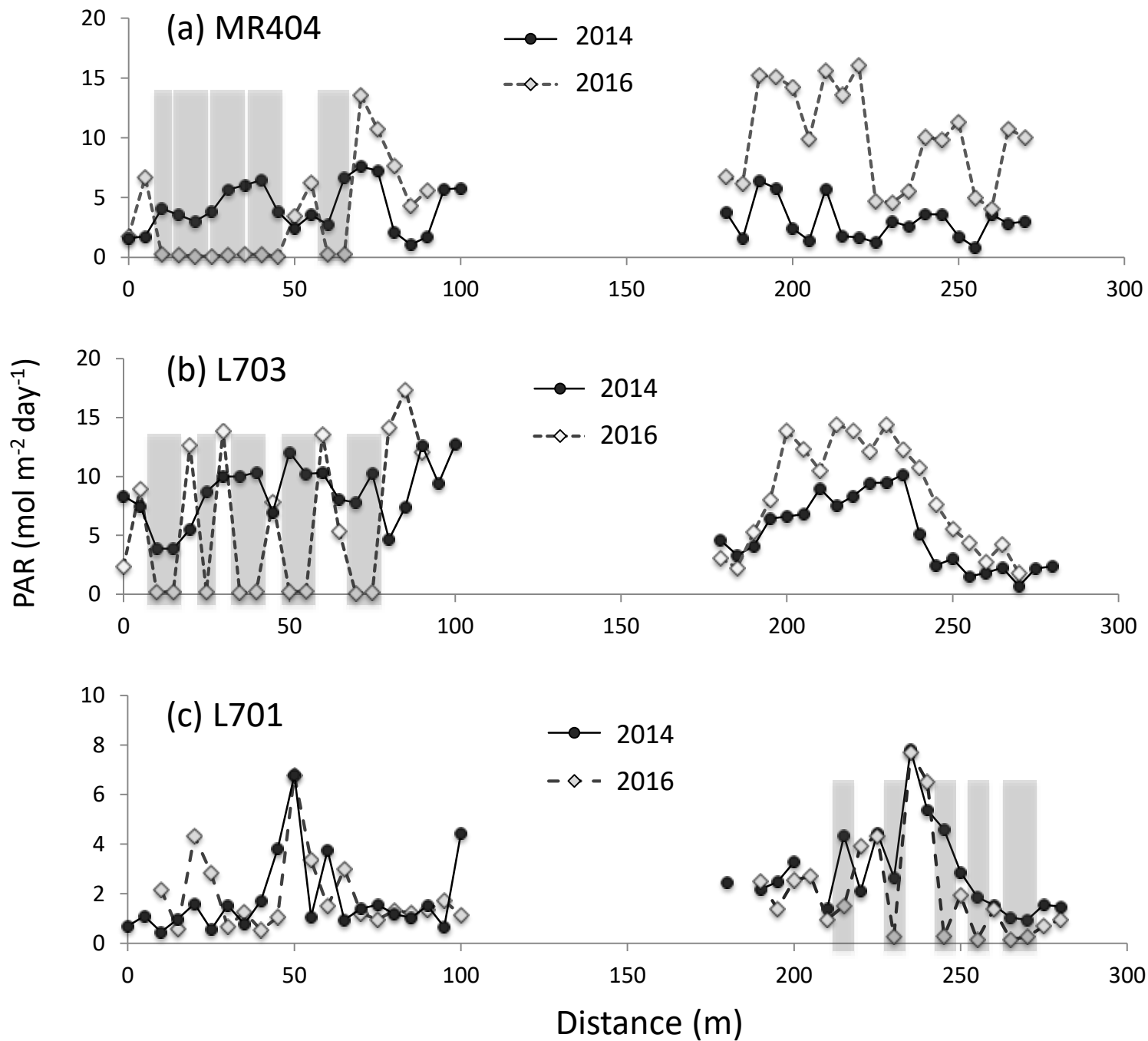
- Old-growth
- Previously Harvested

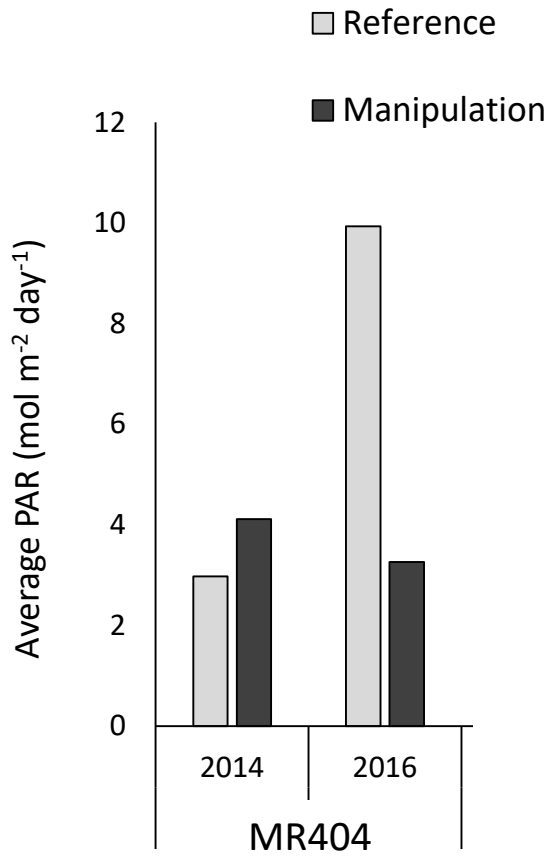


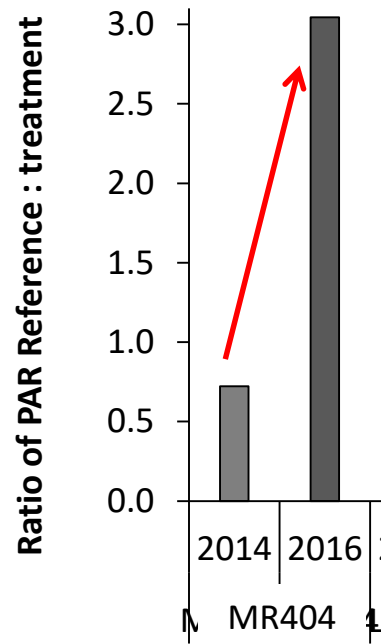
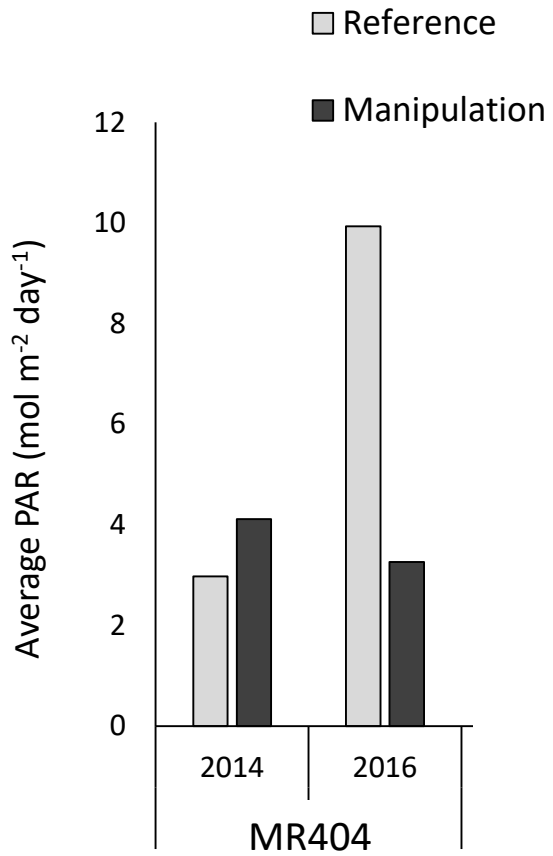


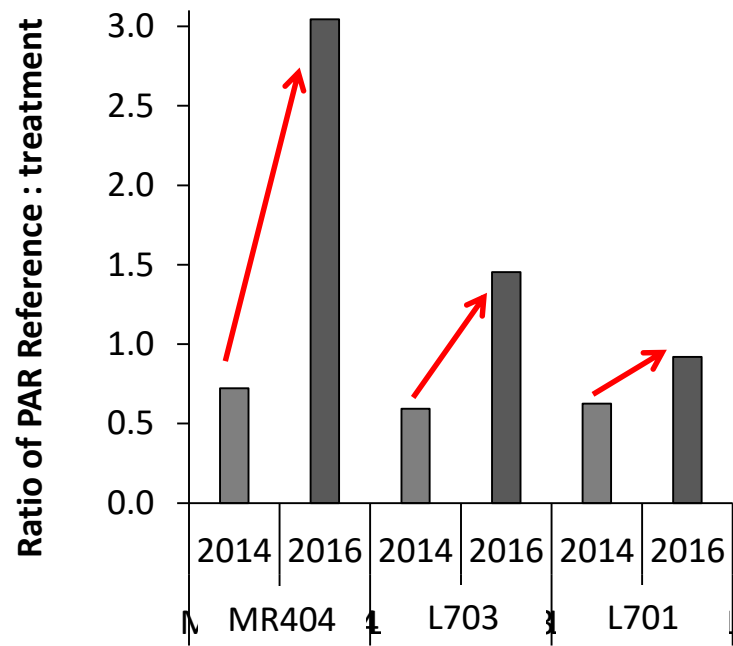
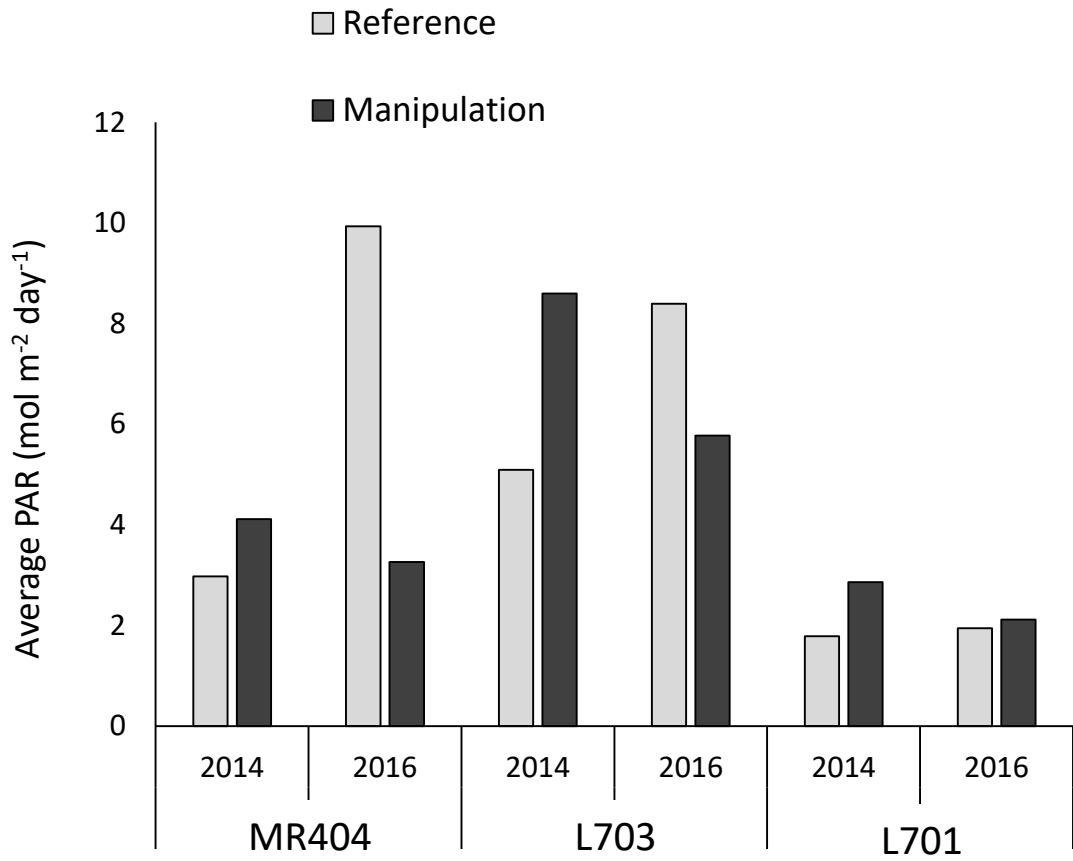


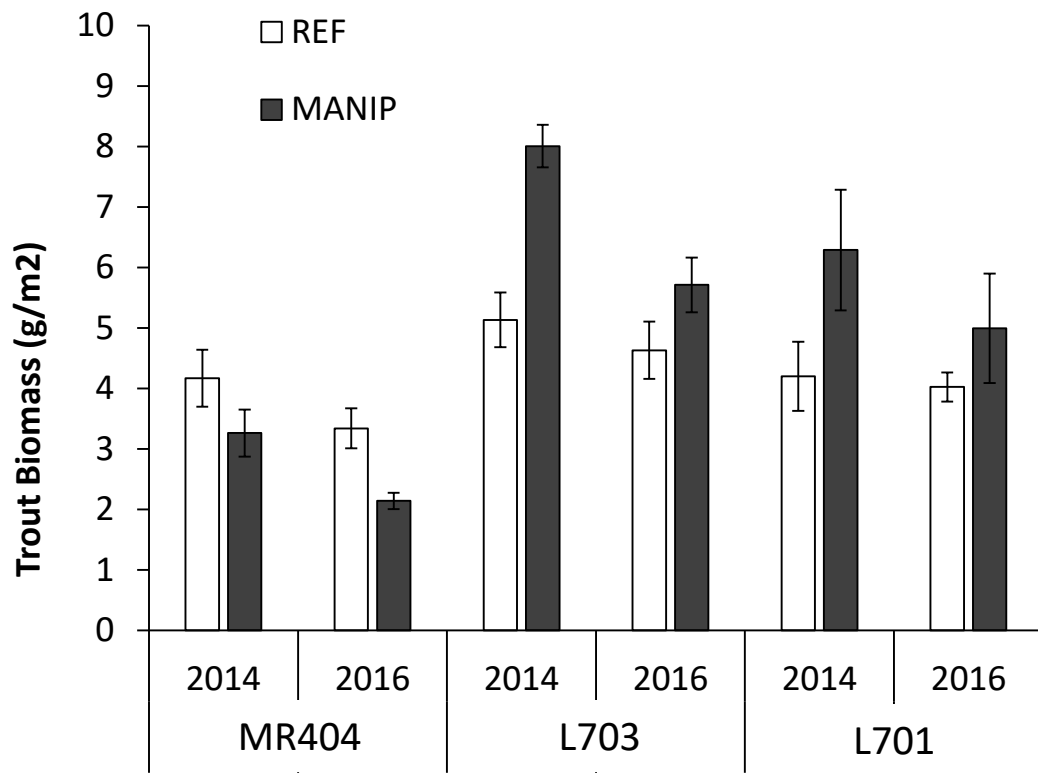


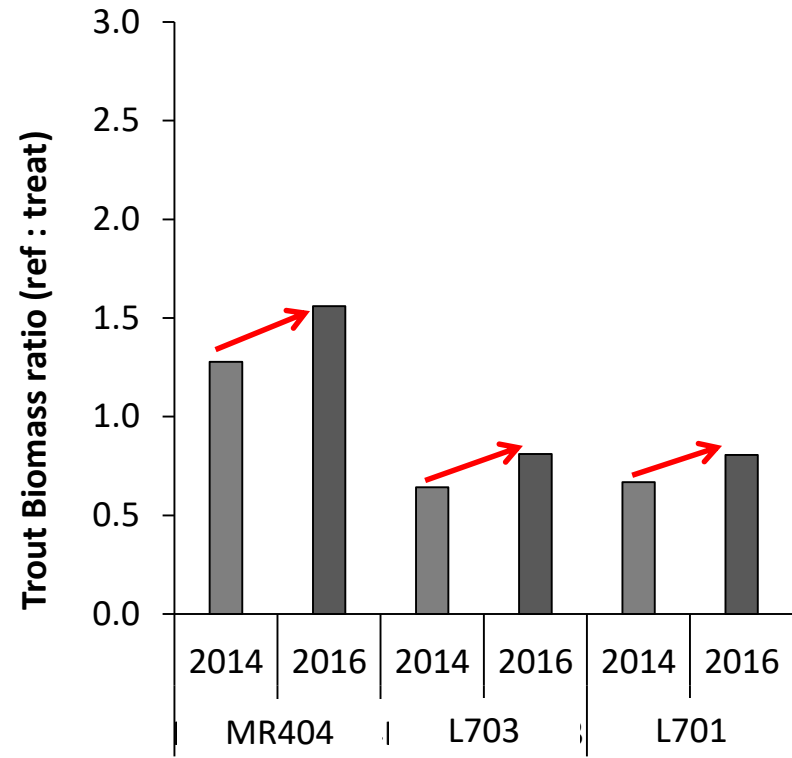
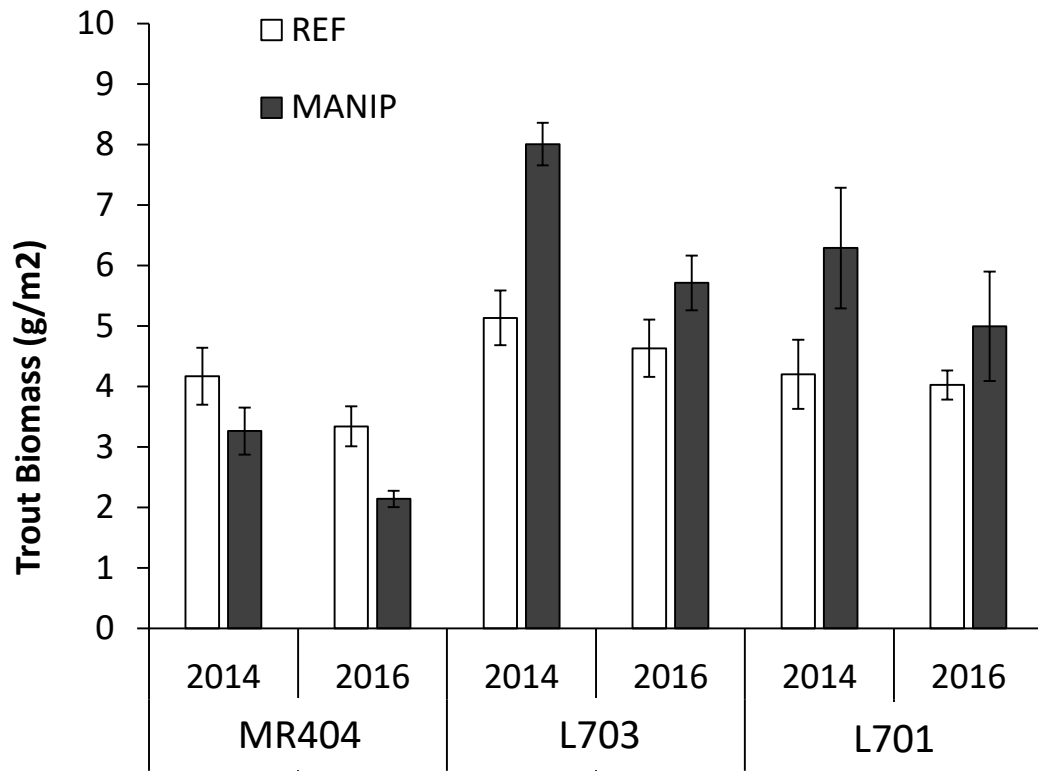


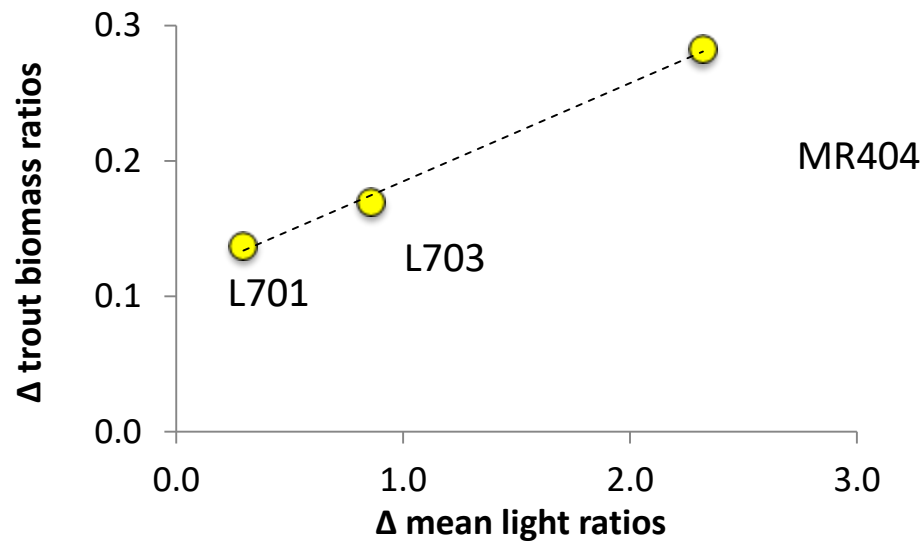
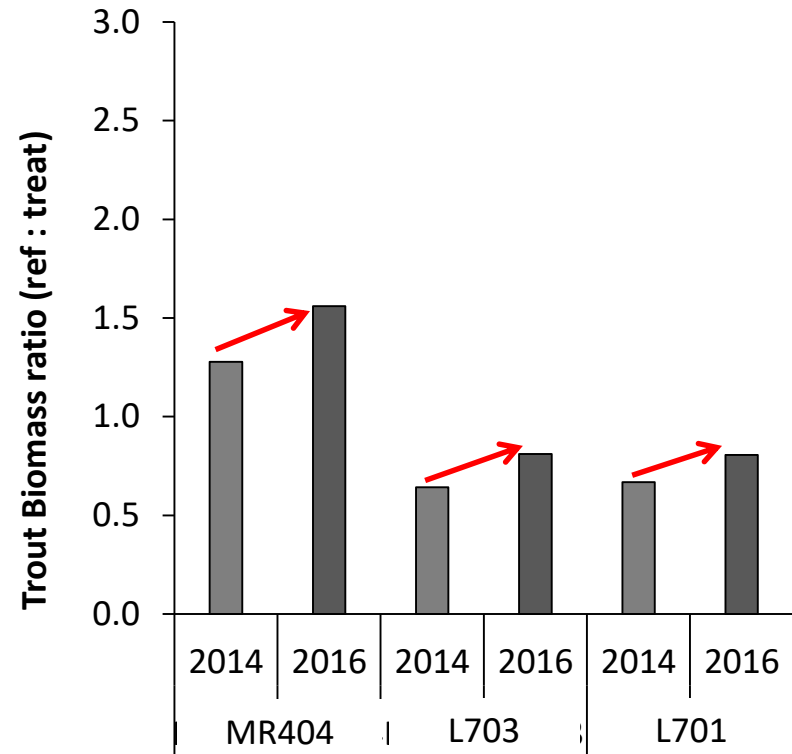
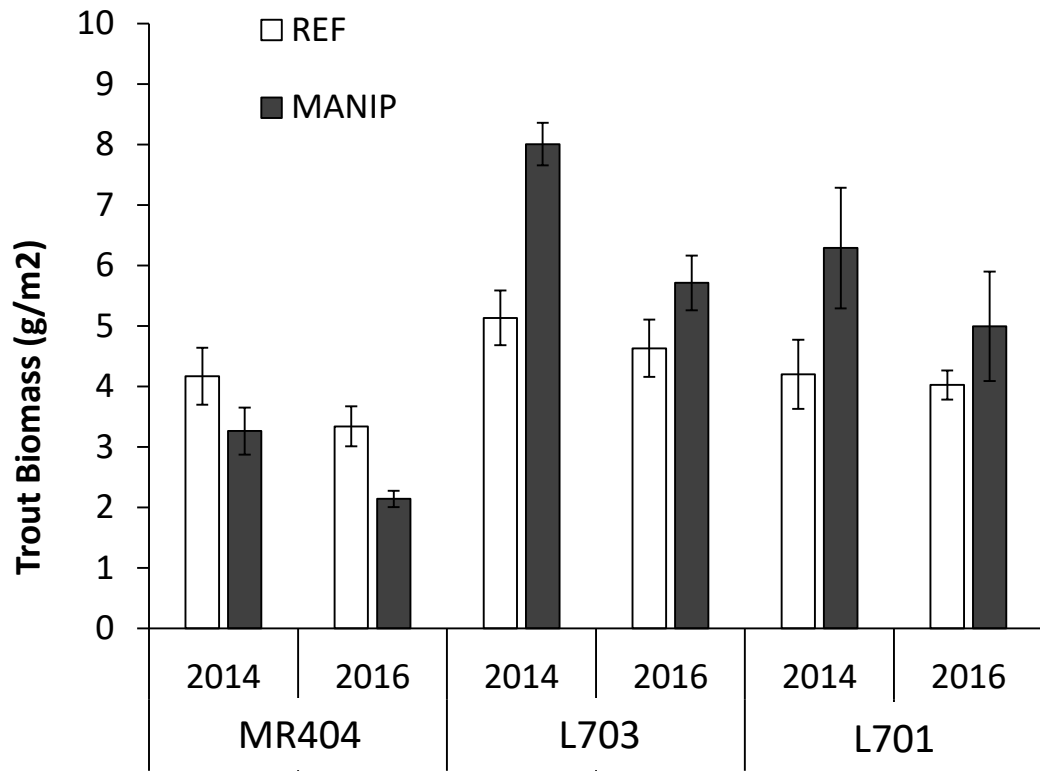


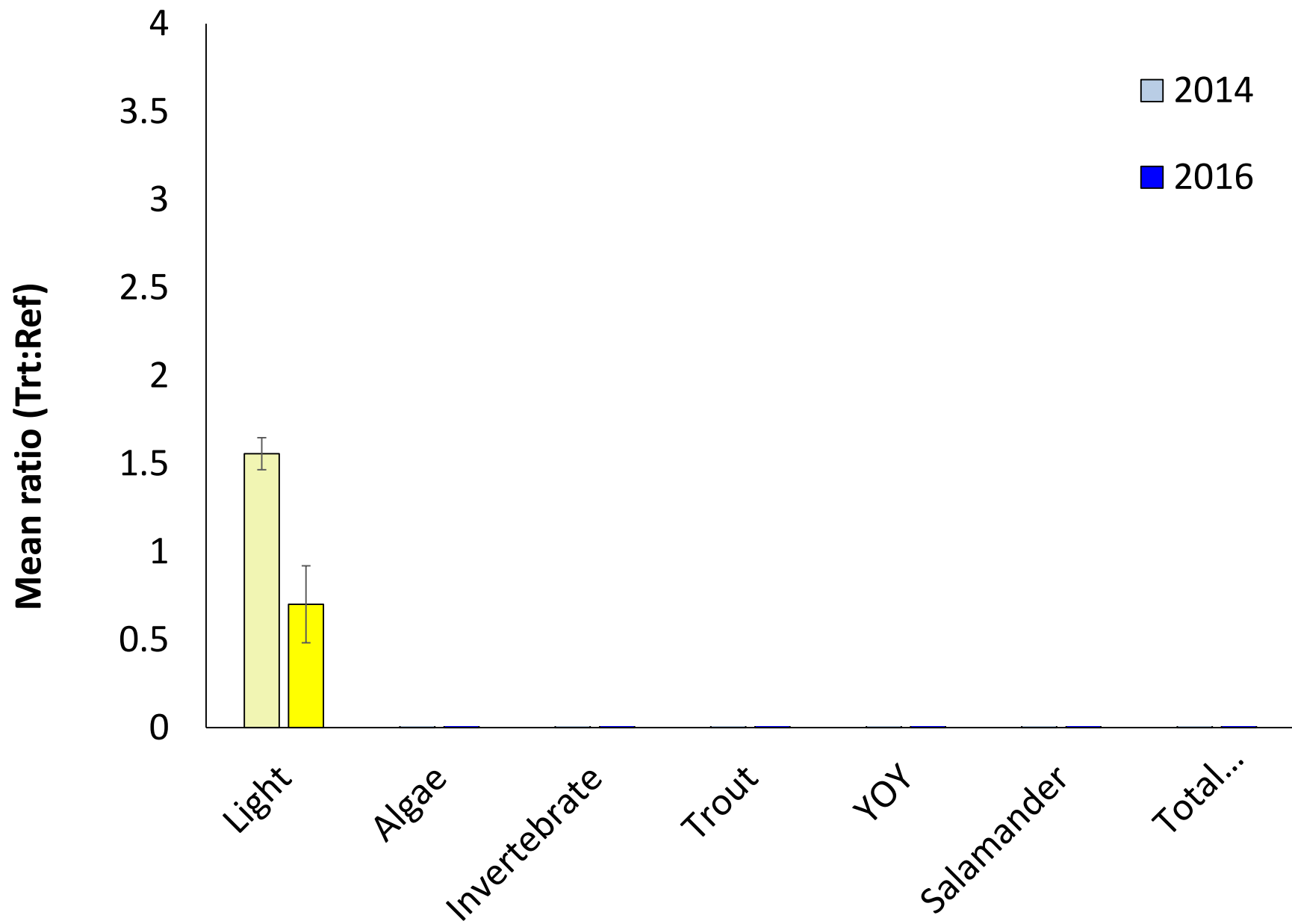


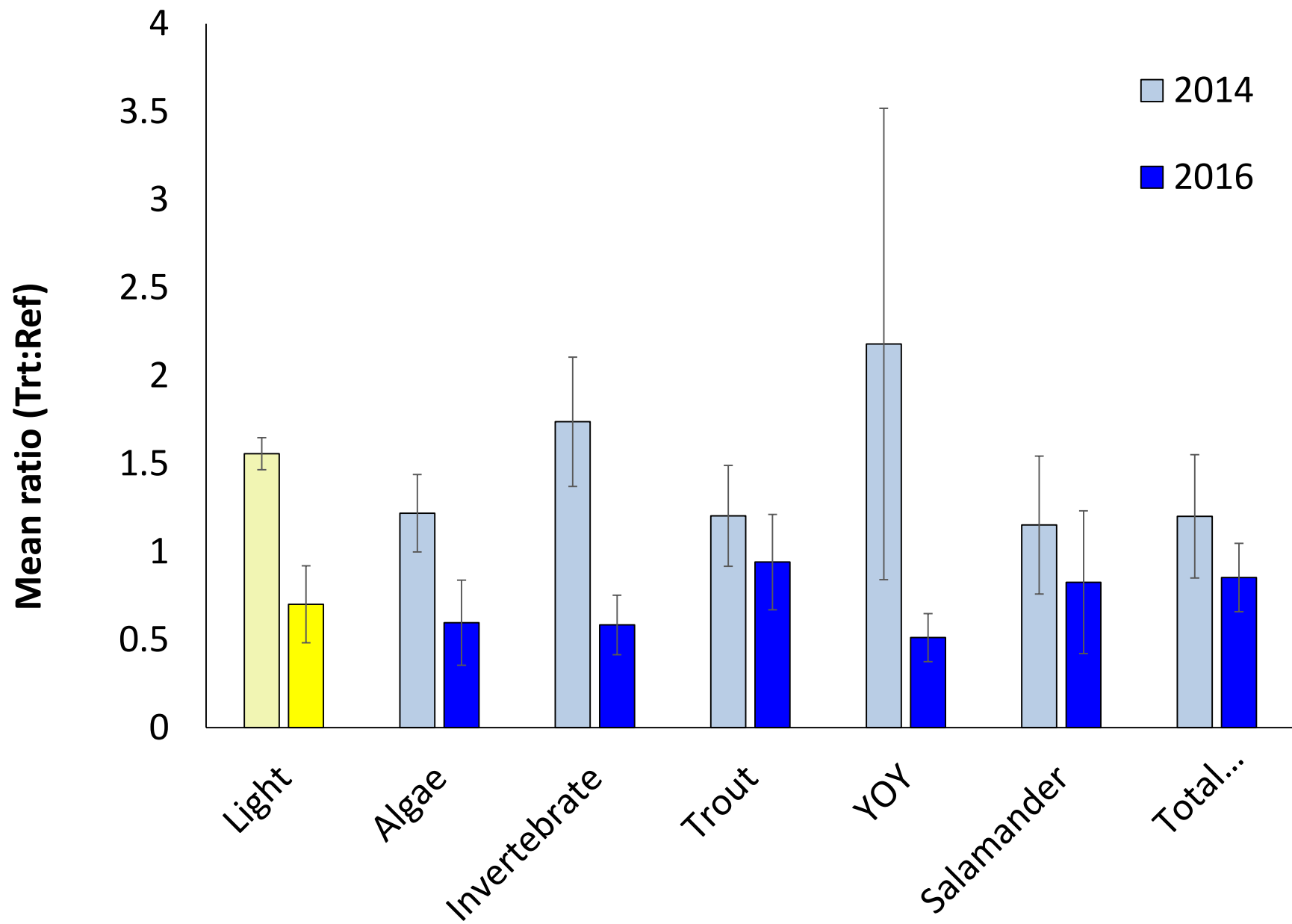


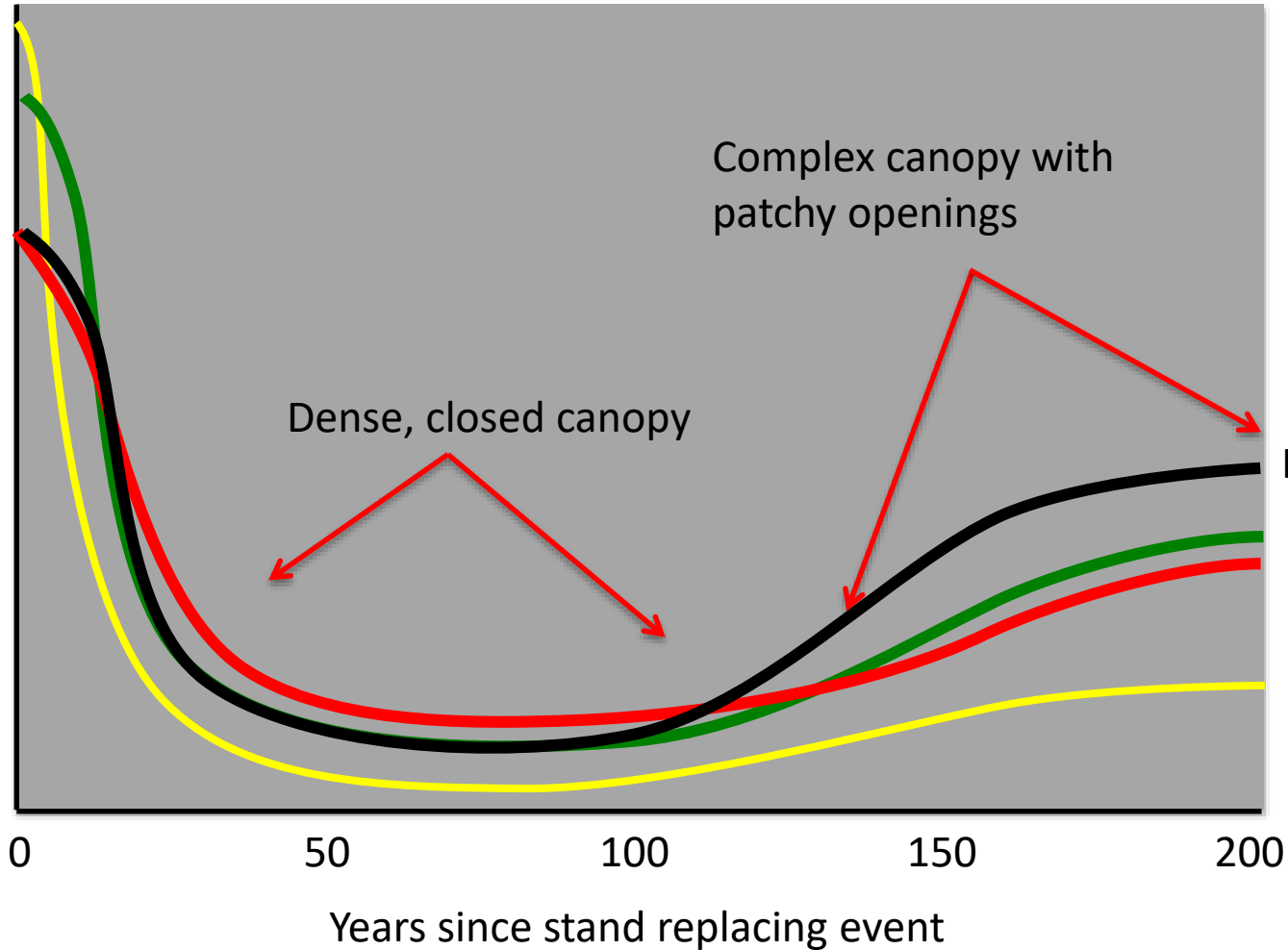
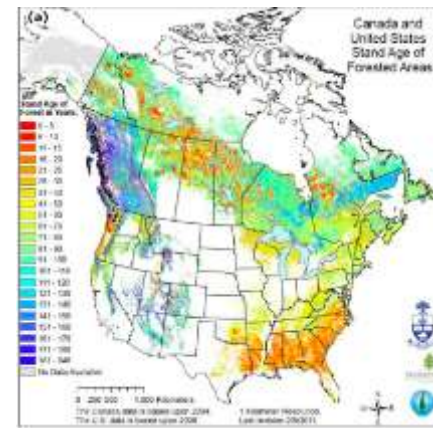












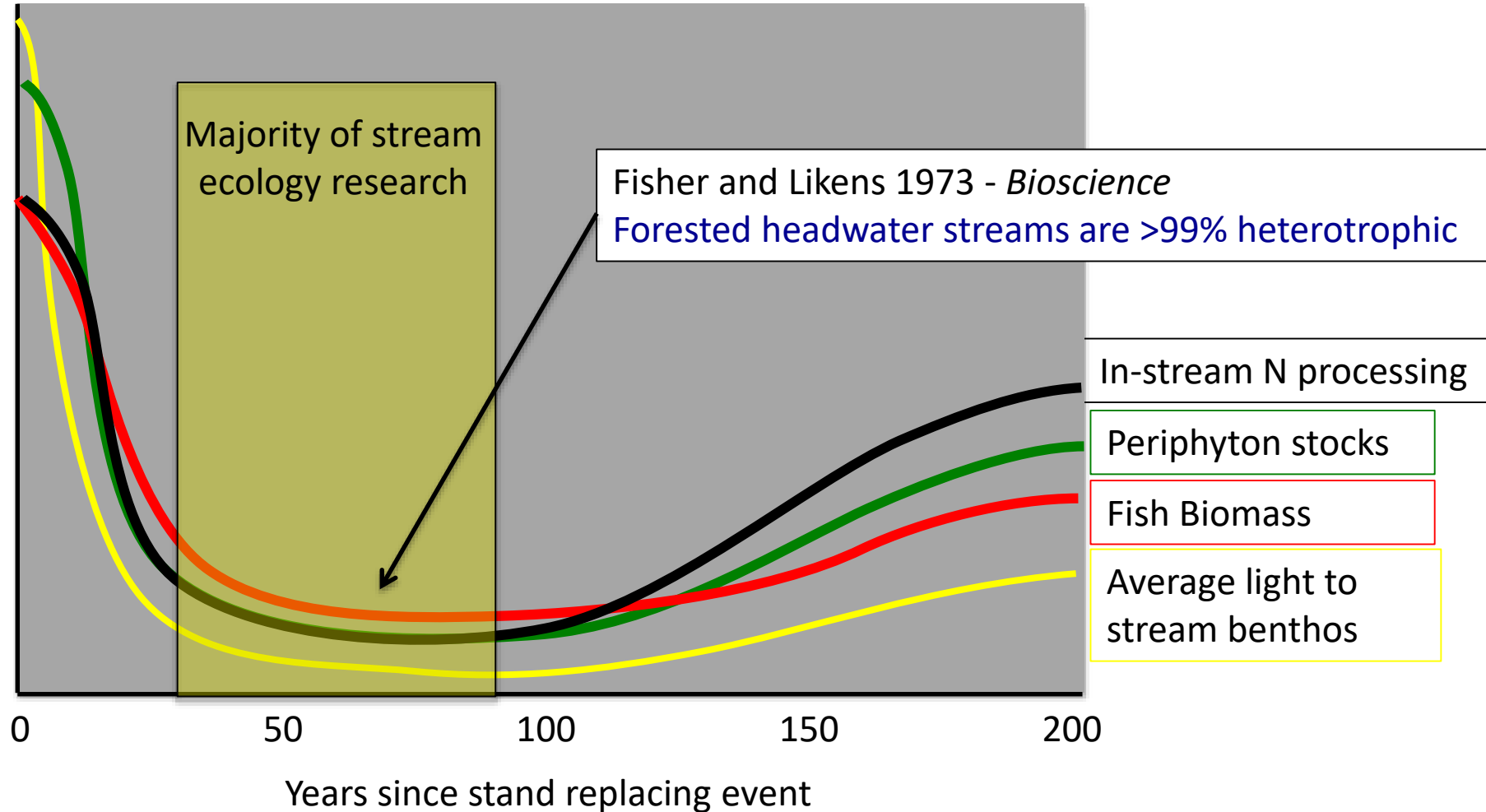
In-stream N processing

Periphyton stocks

Fish Biomass

Average light to stream benthos

Do we need to change our understanding of stream function and stream processes?



NEXT STEPS

Stream gap experiment (Allison Swartz)

- Cut gaps into a riparian zone with close-canopy second-growth forest

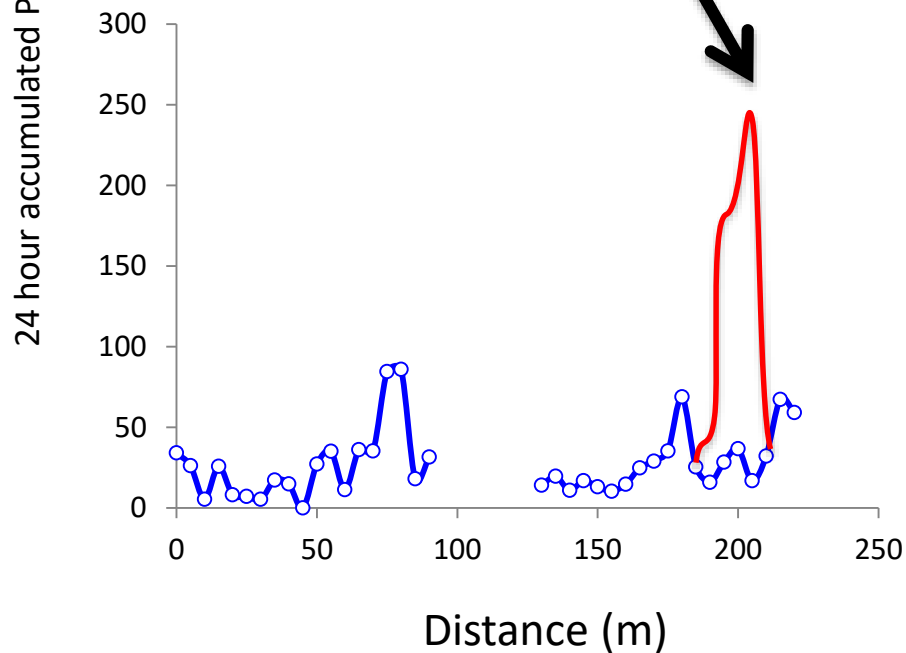
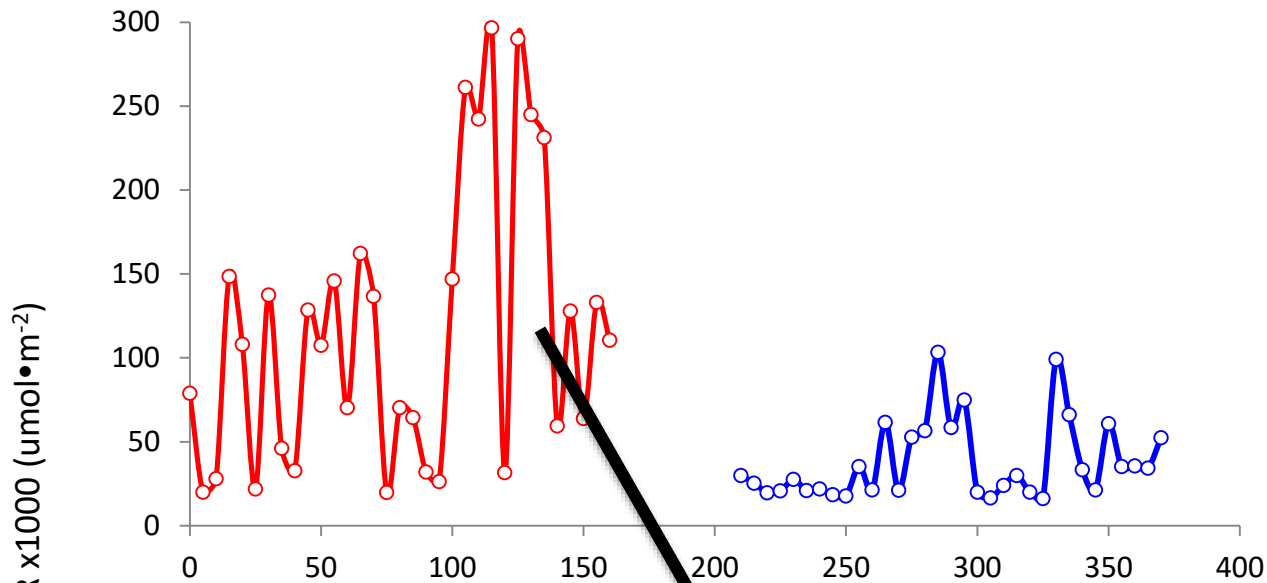
Study Questions:

How do fish, salamanders, and other stream biota respond to forest management that creates a localized area of open canopy adjacent to and over the stream?

Do localized riparian gaps impact stream water temperature in summer?

*Are riparian gaps beneficial such that they can be applied as a habitat **enhancement** tool in highly shaded systems?*

USFS Riparian gap project



3 years of pre-treatment fish data
2 years of pre-treatment invert data
2 years of pre-treatment chl a data
1 year of pre-treatment nutrient uptake

Loon Creek



McRae Tributary - East

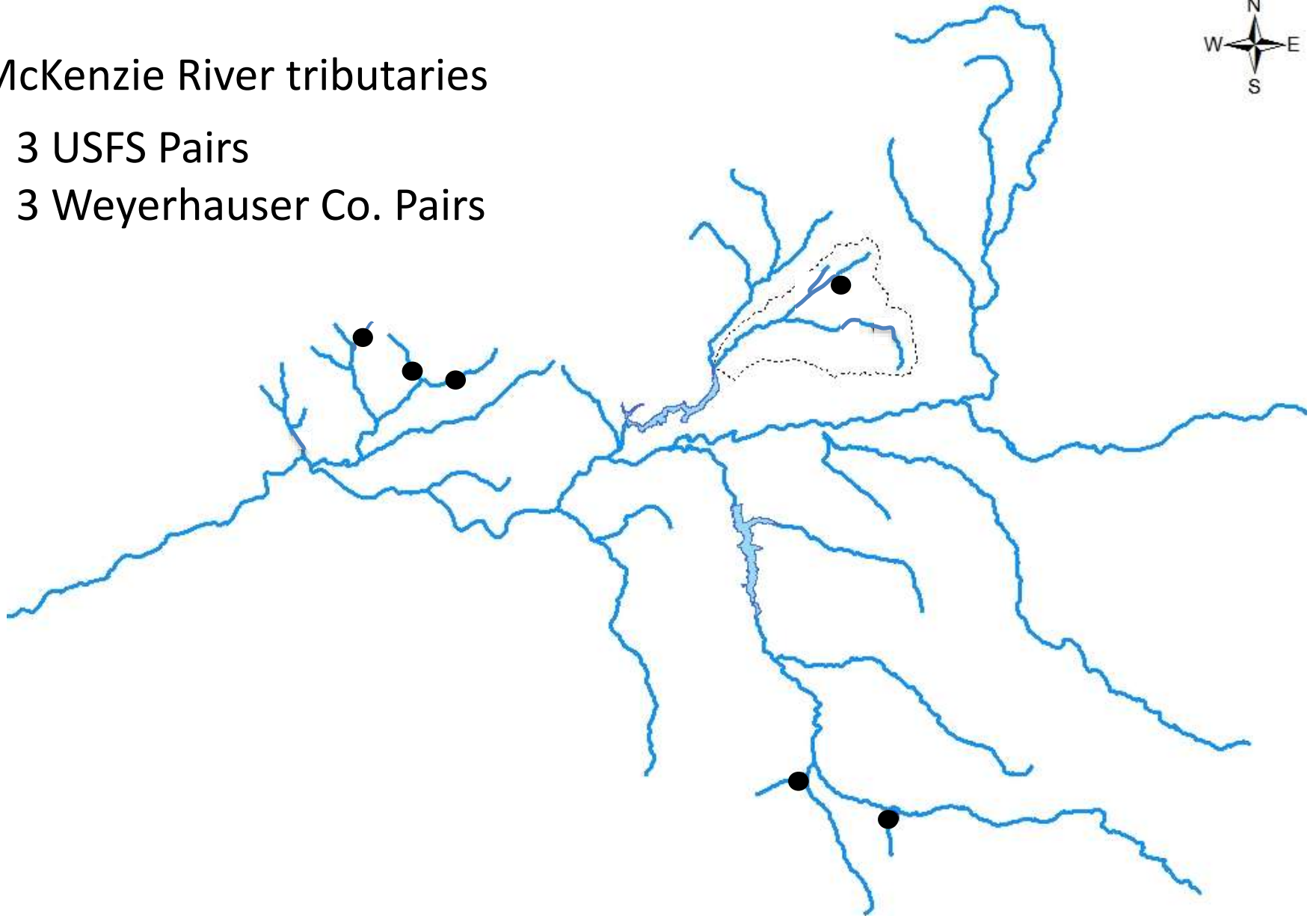


Study sites

McKenzie River tributaries

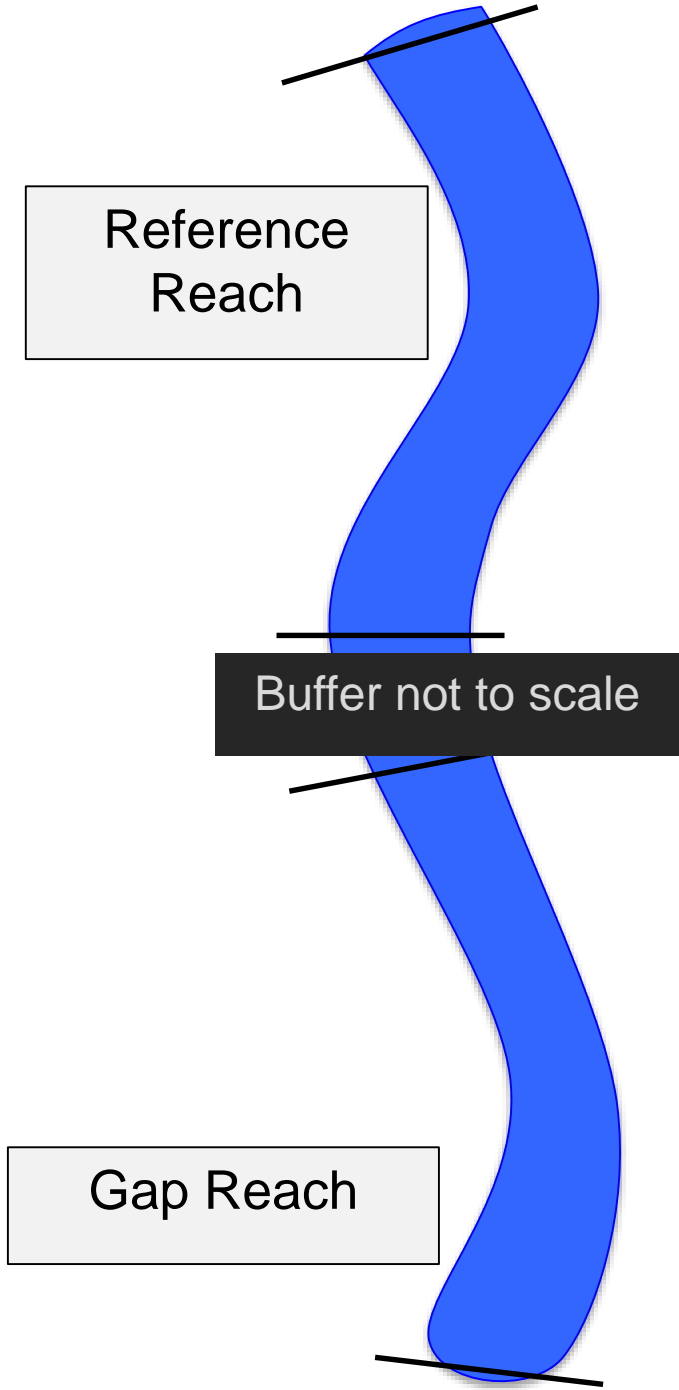
3 USFS Pairs

3 Weyerhaeuser Co. Pairs



Study Design

Before-after Control-impact
(BACI)



Reference
Reach

The diagram illustrates a river reach for a BACI study design. A blue, wavy river flows from top to bottom. Three horizontal black lines cross the river at different points. The top line is labeled 'Reference Reach' in a grey box. The middle line is labeled 'Buffer not to scale' in a black box. The bottom line is labeled 'Gap Reach' in a grey box. The river is wider at the top and bottom and narrower in the middle.

Buffer not to scale

Gap Reach

Study Design

At each reach collect:

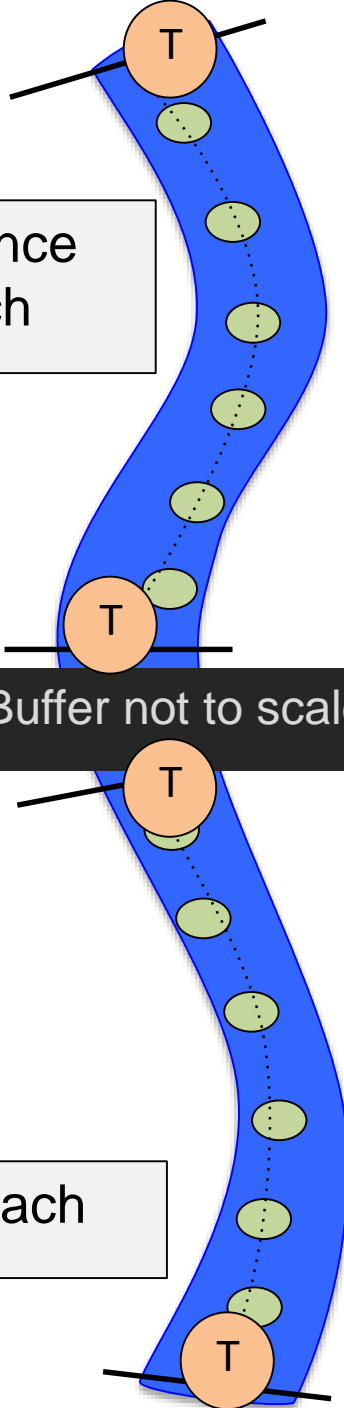
- Temperature – upstream and downstream
- Algal standing stocks
- Macroinvertebrates
- Nutrient demand
- Fish
- Salamanders

Collected but *not* analyzed

Reference
Reach

Buffer not to scale

Gap Reach





Thank you

Acknowledgements

Funding:

- HJ Andrews LTER
- NSF – Div. Env. Biol. (Ecosystems)
- Fish and Wildlife Habitat in Managed Forests Grant Program
- Bureau of Land Management (Eugene District)
- USFS Willamette National Forest (McKenzie Ranger District)

Fieldwork and data collection:

- Grad students: Matt Kaylor, Emily Heaston, Allison Swartz
- Field Technicians: Brian VerWey, Kate Pospisil
- Undergraduate students: Claire Hacker, Lauren Still, Gavin Jones, Chris Frisell

Other intellectual contributions:

- Lina DiGrigorio
- Cheryl Friesen
- Stan Gregory
- William Keeton
- Julie Pett-Ridge
- Mark Shultz