



Barber Revisited: Aggregate Analysis in Harvest Schedule Models



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The Aggregation of Age Classes in Timber Resources Scheduling Models: Its Effects and Bias



- Richard L. Barber (1985)
- Summary
 - Efficient solution to scheduling problems typically requires aggregation into age-classes
 - Harvests are represented as a single event occurring once every multi-year planning period
 - Two sources of bias:
 - Size of the age-class interval
 - Age corresponding to the interval harvest and its associated volume
 - Conclusions:
 - Bias increases with aggregation interval width
 - Bias minimized when yields attributed to the oldest age within the interval
 - Volume bias is negative



Why revisit this topic?



- Inherent assumptions are often taken for granted
 - Age-class aggregation is important yet commonly overlooked issue in forest planning
- Barber's work is cited as justification for model assumptions.
- Planners often fail to recognize that Barber employed area and volume control methods
- Can Barber's results be broadened to LP-based planning frameworks?



Aggregate Analysis



- Age Class Width
 - The number of *ages* combined into a single age class
 - Assumptions drawn around initial age class age
- Planning Period Width
 - The length of *time* each planning period represents
 - Assumptions drawn around timing of harvest within the period
- In literature, convention sets age class width equal to planning period width

Aggregate Analysis

$$\text{harvest age} = \left[a_u - \delta_1 \left(\frac{c_w}{2} \right) \right] + \left[p_w t - \delta_2 \left(\frac{p_w}{2} \right) \right]$$

where:

a_u = age equal to the upper end of the age-class

c_w = age-class width (years)

p_w = planning period width (years)

t = harvest period

δ_1 = 1 if assumed initial age is class mid-point, 0 otherwise

δ_2 = 1 if assumed harvest timing is period mid-point, 0 otherwise

Methods

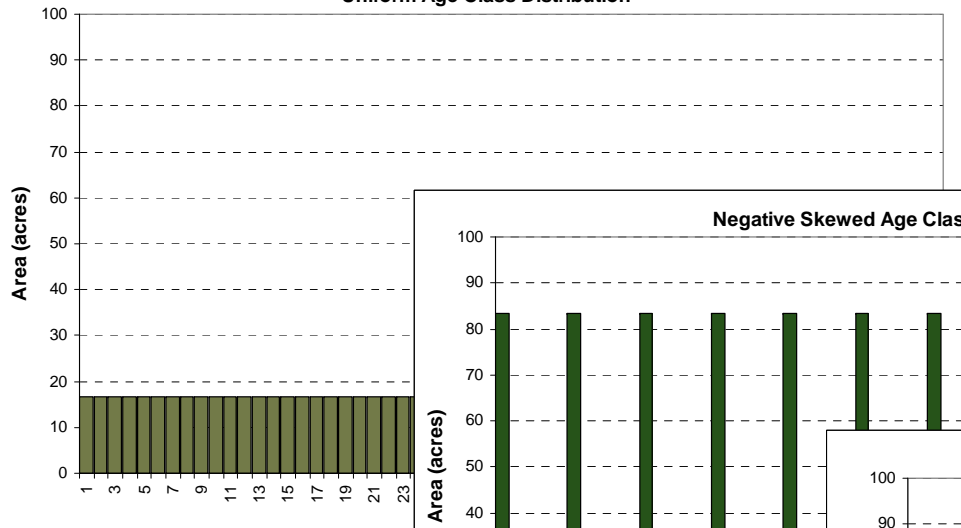


- Where possible, tried to mimic Barber (1985)
- Hypothetical 1,000-acre forest
 - All stands Douglas Fir plantations
 - Planting density 360 trees per acre
 - Douglas Fir site index of 140
 - Three initial age class distributions
 - Uniform
 - Negative Skew
 - Positive Skew

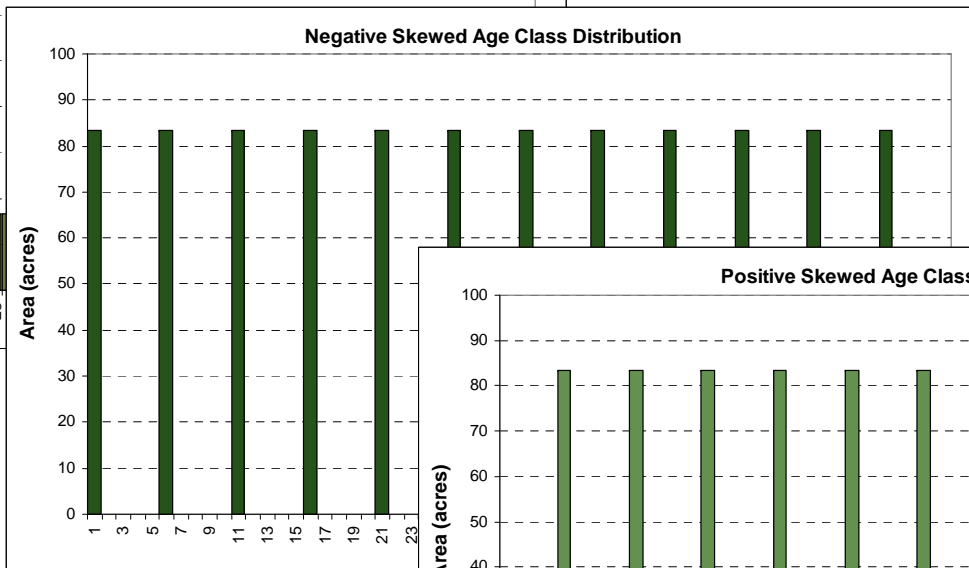
Methods



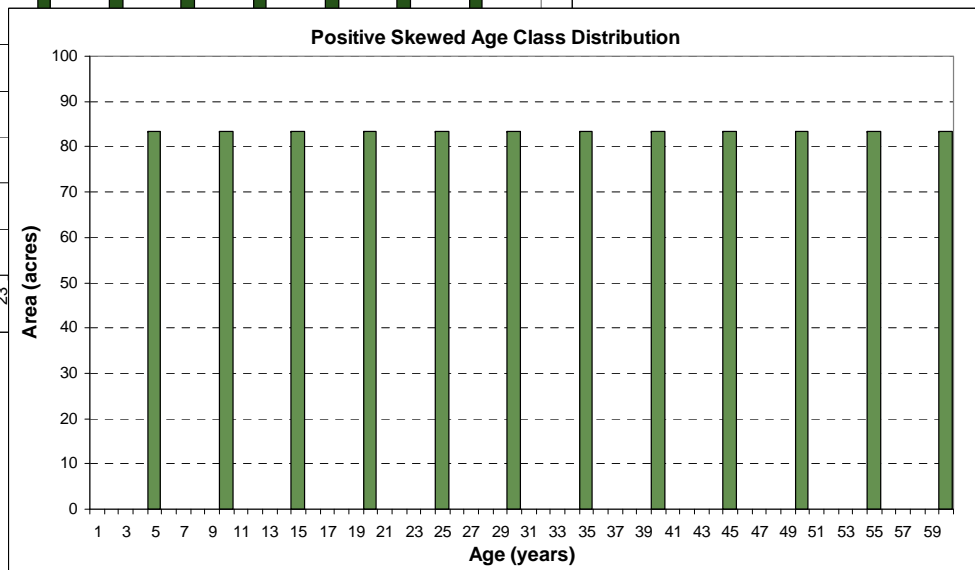
Uniform Age Class Distribution



Negative Skewed Age Class Distribution



Positive Skewed Age Class Distribution

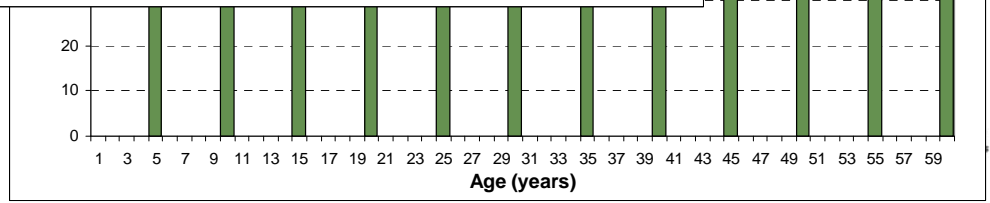
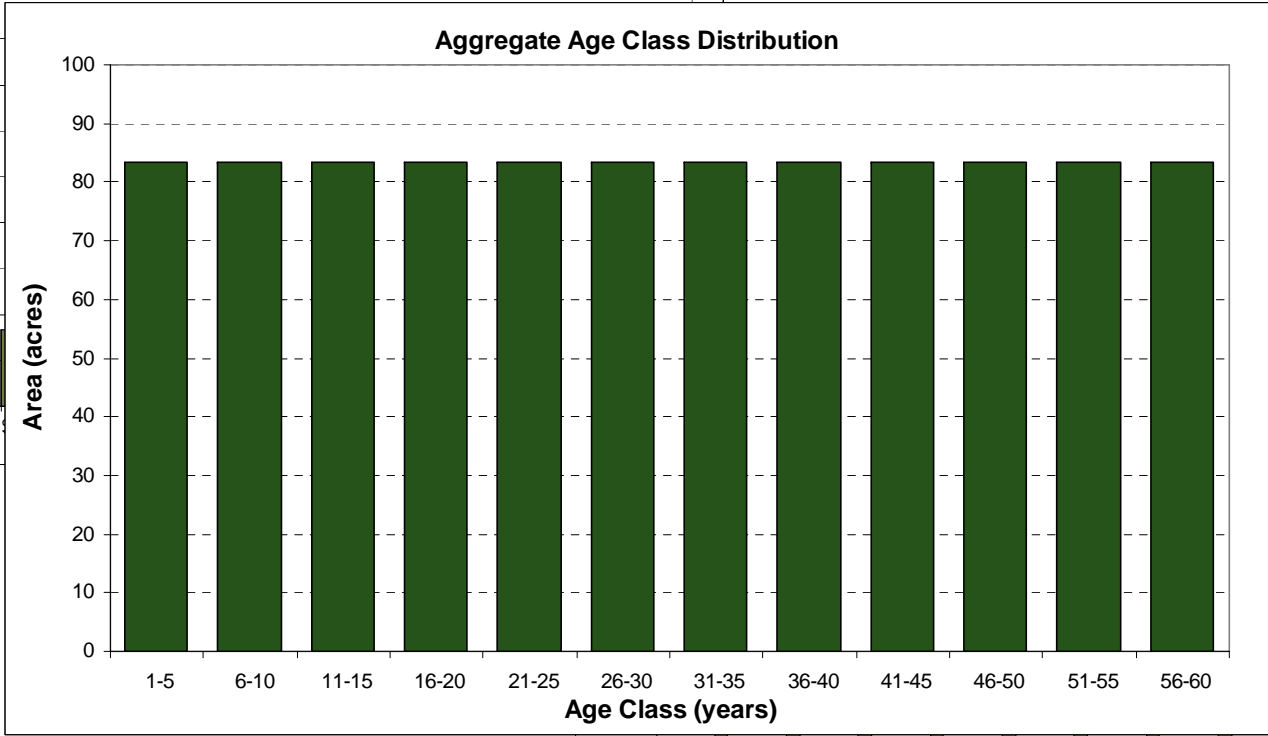
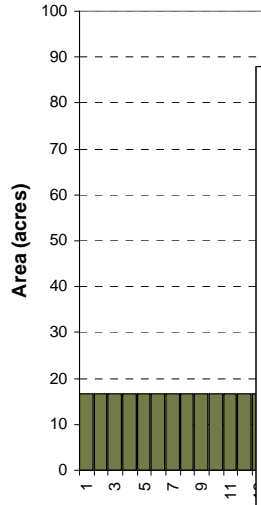


Methods



Uniform Age Class Distribution

Aggregate Age Class Distribution





Methods



- Harvest schedules
 - Model II LP formulation
 - Maximize NPV (6% real)
 - All harvested stands must be replanted
 - Same forest type & planting density as before
 - Even flow harvest volume
 - Yield data developed with FORSim PNW implementation of ORGANON model

Test Cases

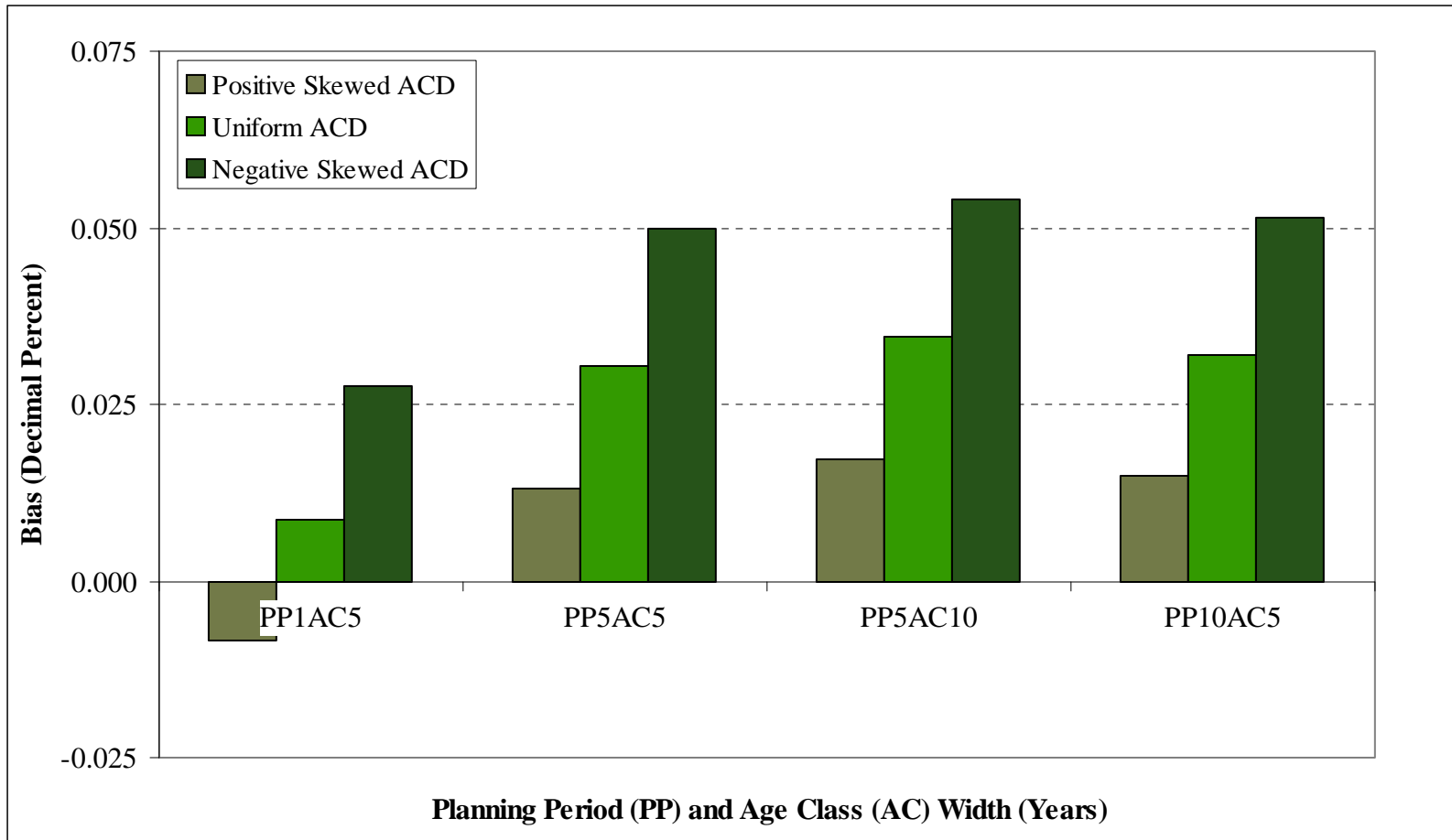


Planning Period Width	Age-class Width	Initial Age (Within Age-class)	Harvest Timing (Within Planning Period)	Abbreviation
<i>1-year planning period width, 5-year age-class width (PP1AC5##)</i>				
1	5	Mid-point	End-point	PP1AC5ME
1	5	End-point	End-point	PP1AC5EE
<i>5-year planning period width, 5-year age-class width (PP5AC5##)</i>				
5	5	Mid-point	Mid-point	PP5AC5MM
5	5	Mid-point	End-point	PP5AC5ME
5	5	End-point	Mid-point	PP5AC5EM
5	5	End-point	End-point	PP5AC5EE
<i>5-year planning period width, 10-year age-class width (PP5AC10##)</i>				
5	10	Mid-point	Mid-point	PP5AC10MM
5	10	Mid-point	End-point	PP5AC10ME
5	10	End-point	Mid-point	PP5AC10EM
5	10	End-point	End-point	PP5AC10EE
<i>10-year planning period width, 5-year age-class width (PP10AC5##)</i>				
10	5	Mid-point	Mid-point	PP10AC5MM
10	5	Mid-point	End-point	PP10AC5ME
10	5	End-point	Mid-point	PP10AC5EM
10	5	End-point	End-point	PP10AC5EE

Results - Harvest Volume Bias

Case	Initial Age Class Distribution		
	Uniform	Negative Skew	Positive Skew
PP1AC5ME	0.009	0.028	-0.008
PP1AC5EE	0.025	0.044	0.008
PP5AC5MM	0.03	0.05	0.013
PP5AC5ME	0.056	0.076	0.038
PP5AC5EM	0.056	0.076	0.038
PP5AC5EE	0.071	0.091	0.053
PP5AC10MM	0.035	0.054	0.017
PP5AC10ME	0.051	0.071	0.034
PP5AC10EM	0.075	0.095	0.057
PP5AC10EE	0.09	0.11	0.071
PP10AC5MM	0.032	0.051	0.015
PP10AC5ME	0.072	0.093	0.055
PP10AC5EM	0.049	0.069	0.031
PP10AC5EE	0.087	0.108	0.069

Results - Harvest Volume Bias



Results - Harvest Age Bias

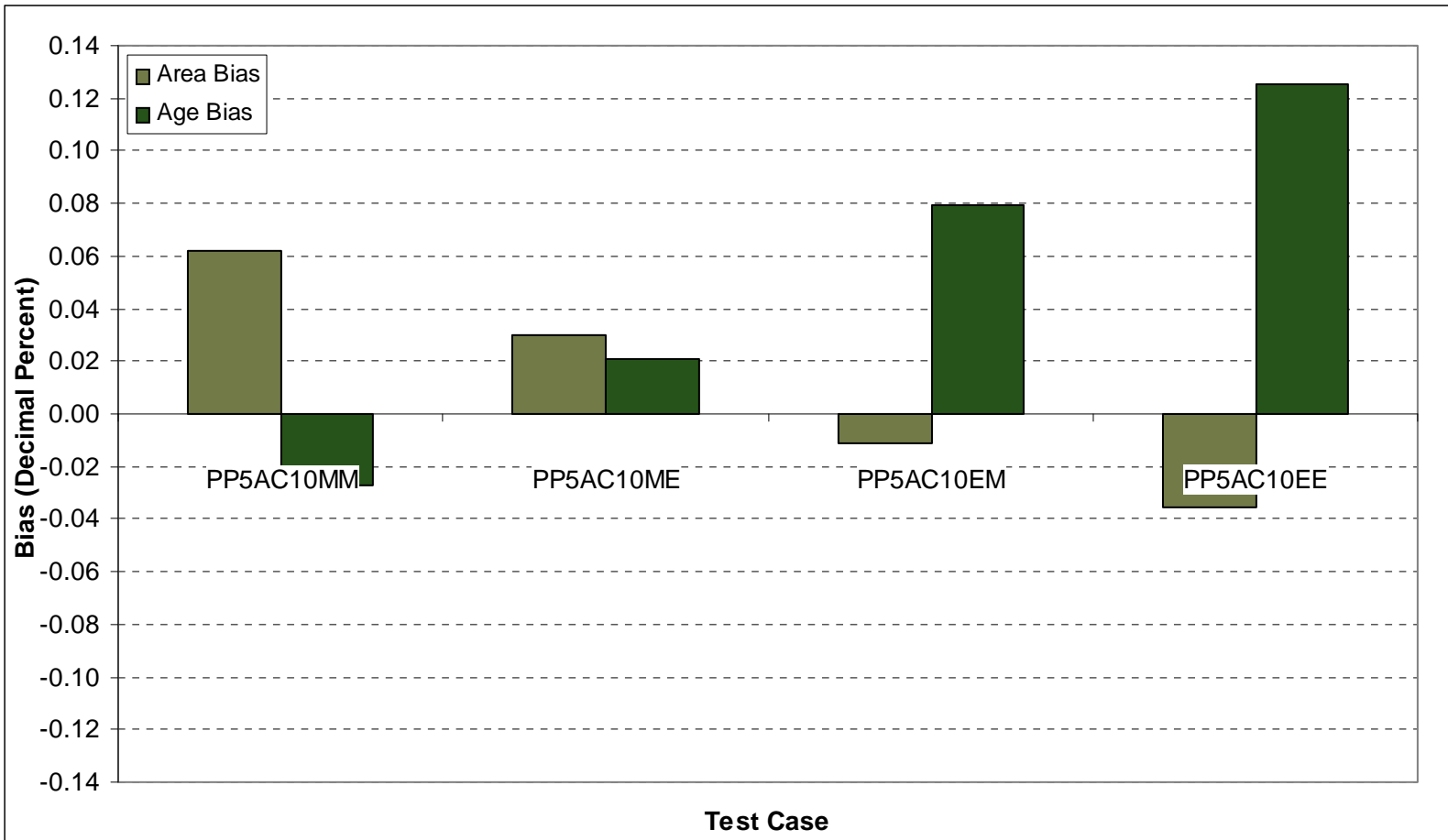
Case	100-year Subset			1-period Subset		
	Uniform	Negative Skew	Positive Skew	Uniform	Negative Skew	Positive Skew
PP1AC5ME	0.016	0.063	-0.025	-0.024	0.045	-0.025
PP1AC5EE	0.064	0.113	0.021	0.017	0.089	0.017
PP5AC5MM	-0.031	0.014	-0.071	-0.006	0.064	-0.007
PP5AC5ME	0.029	0.077	-0.013	0.038	0.111	0.037
PP5AC5EE	0.076	0.126	0.032	0.081	0.157	0.08
PP5AC10MM	-0.027	0.018	-0.067	-0.041	0.027	-0.042
PP5AC10ME	0.021	0.068	-0.021	0.043	0.116	0.042
PP5AC10EM	0.079	0.129	0.035	0.001	0.071	0
PP5AC10EE	0.126	0.178	0.08	0.084	0.161	0.083
PP10AC5MM	-0.025	0.02	-0.065	-0.009	0.061	-0.01
PP10AC5ME	0.079	0.129	0.035	0.035	0.108	0.034
PP10AC5EM	0.021	0.069	-0.02	0.08	0.156	0.079
PP10AC5EE	0.127	0.179	0.081	0.124	0.203	0.123

Results - Harvest Area Bias



Case	100-year Subset			1-period Subset		
	Uniform	Negative Skew	Positive Skew	Uniform	Negative Skew	Positive Skew
PP1AC5ME	-0.014	-0.044	0.014	0.025	-0.027	0.009
PP1AC5EE	-0.04	-0.069	-0.013	0.007	-0.044	-0.008
PP5AC5MM	0.068	0.035	0.097	0.037	-0.016	0.021
PP5AC5ME	0.02	-0.011	0.049	0.009	-0.042	-0.007
PP5AC5EE	-0.007	-0.037	0.021	-0.008	-0.059	-0.024
PP5AC10MM	0.062	0.029	0.091	0.07	0.016	0.053
PP5AC10ME	0.03	-0.002	0.058	0.051	-0.003	0.034
PP5AC10EM	-0.011	-0.042	0.016	0.023	-0.029	0.007
PP5AC10EE	-0.035	-0.065	-0.009	0.006	-0.046	-0.01
PP10AC5MM	0.058	0.025	0.087	0.034	-0.019	0.017
PP10AC5ME	-0.013	-0.043	0.015	-0.013	-0.064	-0.029
PP10AC5EM	0.028	-0.004	0.056	0.014	-0.038	-0.002
PP10AC5EE	-0.038	-0.067	-0.011	-0.03	-0.08	-0.046

Results - Harvest Area Bias



Results - Harvest Schedule Feasibility



Case	Test Case Volume	Annual Volume	Fall Down
PP1AC5EE	1,485,147	1,448,591	2.50%
PP5AC5EE	1,551,975	1,432,616	8.30%
PP5AC10EE	1,578,577	1,448,589	9.00%
PP10AC5ME	1,553,557	<i>Infeasible</i>	-----



Conclusions



- Results contradict Barber (1985)
 - Barber notes negative volume bias
- Constrained models with aggregated age-classes consistently exhibit positive volume bias
- Assumptions which minimize volume bias do not always minimize area bias
- Which should we minimize, volume or area bias?
 - Generally, use annual models with annual age classes
 - Annual planning periods with 5-year age classes (PP1AC5) provides a good alternative



Thank you.



Questions?



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