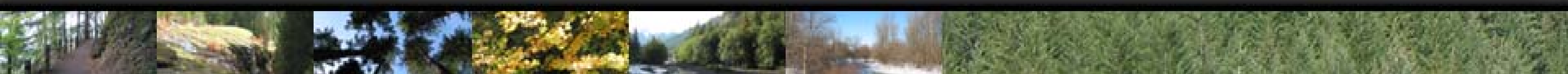
FORSight Resources LLC

Barber Revisited: Aggregate Analysis in Harvest Schedule Models



Steven D. Mills, Bruce L. Carroll & Karl R. Walters

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

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

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

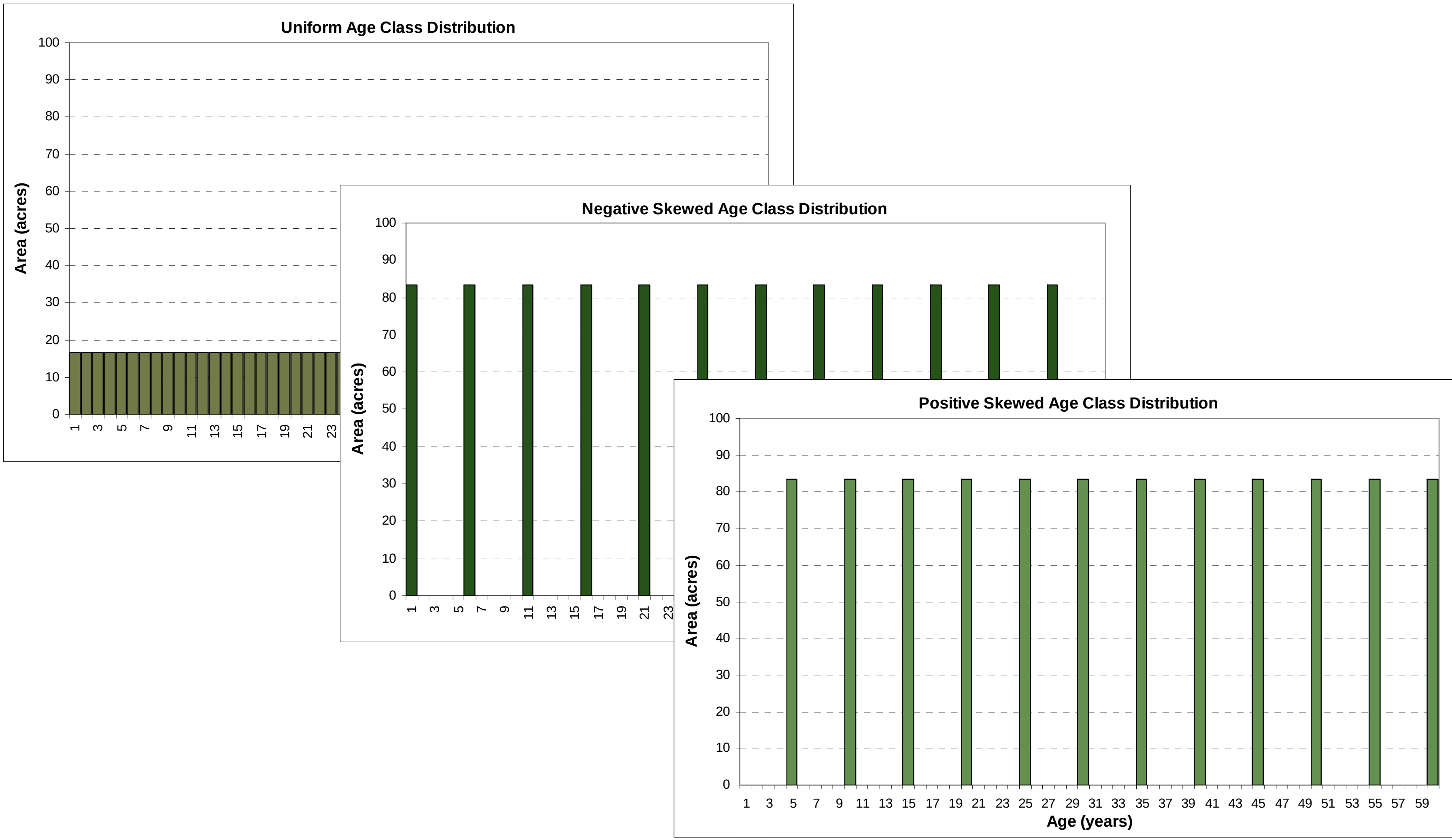
δ_2 = 1 if assumed harvest timing is period mid-point, 0 otherwise

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

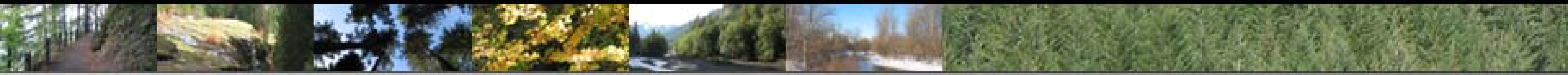
FORSight Resources LLC

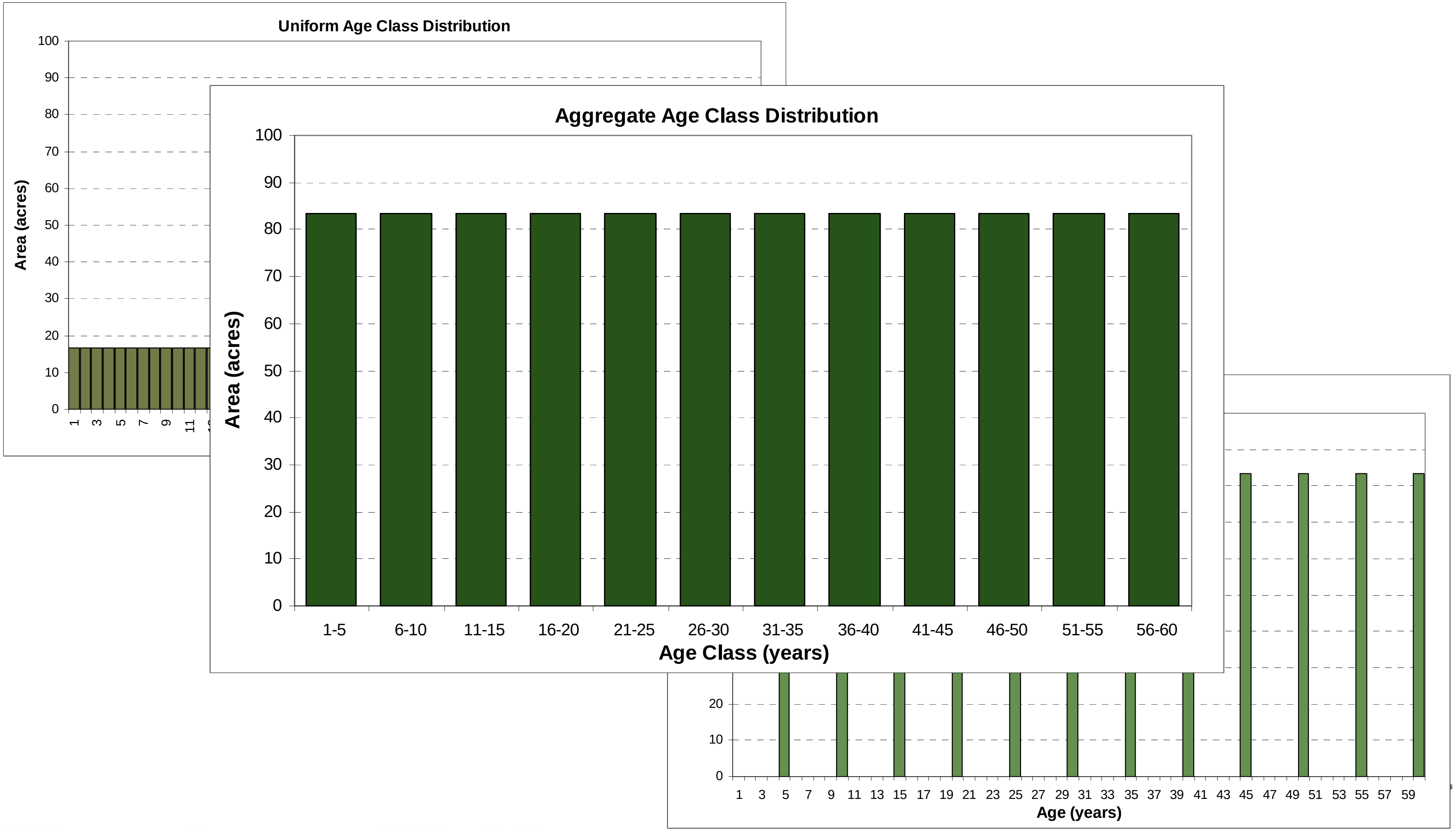
Methods



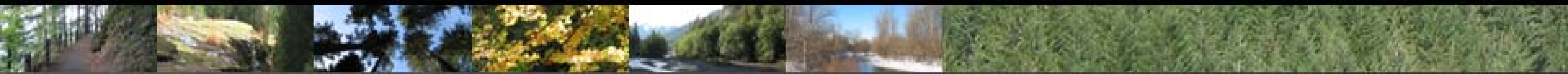
Uniform Age Class Distribution
Area (acres)
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23
Negative Skewed Age Class Distribution
Area (acres)
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23
Positive Skewed Age Class Distribution
Area (acres)
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
Age (years)

Methods




Uniform Age Class Distribution
Area (acres)
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
Aggregate Age Class Distribution
Area (acres)
100
90
80
70
60
50
40
30
20
10
0
1-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
Age Class (years)
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
Age (years)

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

FORSight Resources LLC

Test Cases

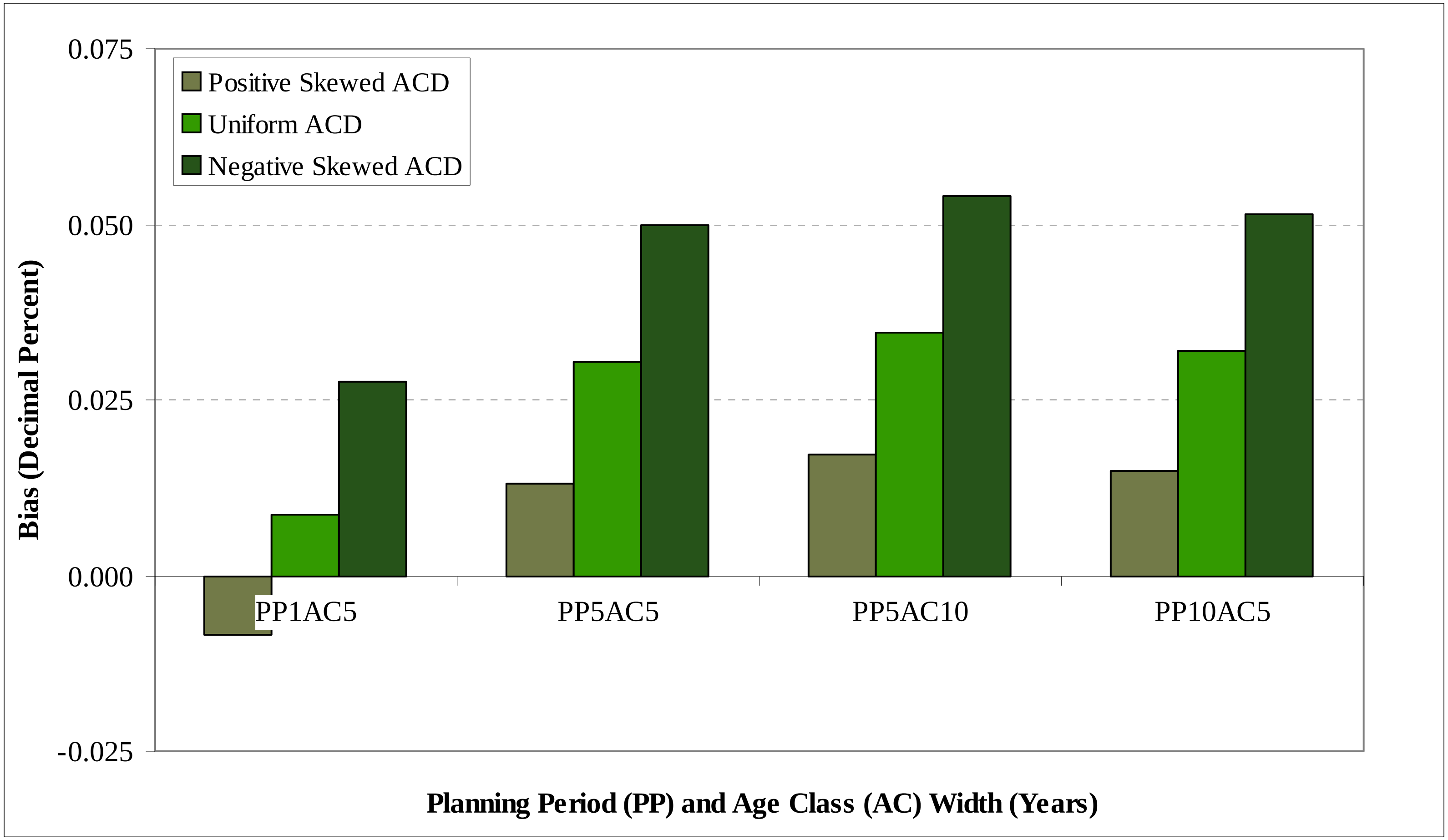
Planning Period Width	Age-class Width	Initial Age (Within Age-class)	Harvest Timing (Within Planning Period)	Abbreviation
1-year planning period width, 5-year age-class width (PP1AC5##)				
1	5	Mid-point	End-point	PP1AC5ME
1	5	End-point	End-point	PP1AC5EE
5-year planning period width, 5-year age-class width (PP5AC5##)				
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
5-year planning period width, 10-year age-class wdith (PP5AC10##)				
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
10-year planning period width, 5-year age-class width (PP10AC5##)				
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

	Initial Age Class Distribution		
Case	**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

FORSight Resources LLC

Results – Harvest Volume Bias



Results – Harvest Age Bias

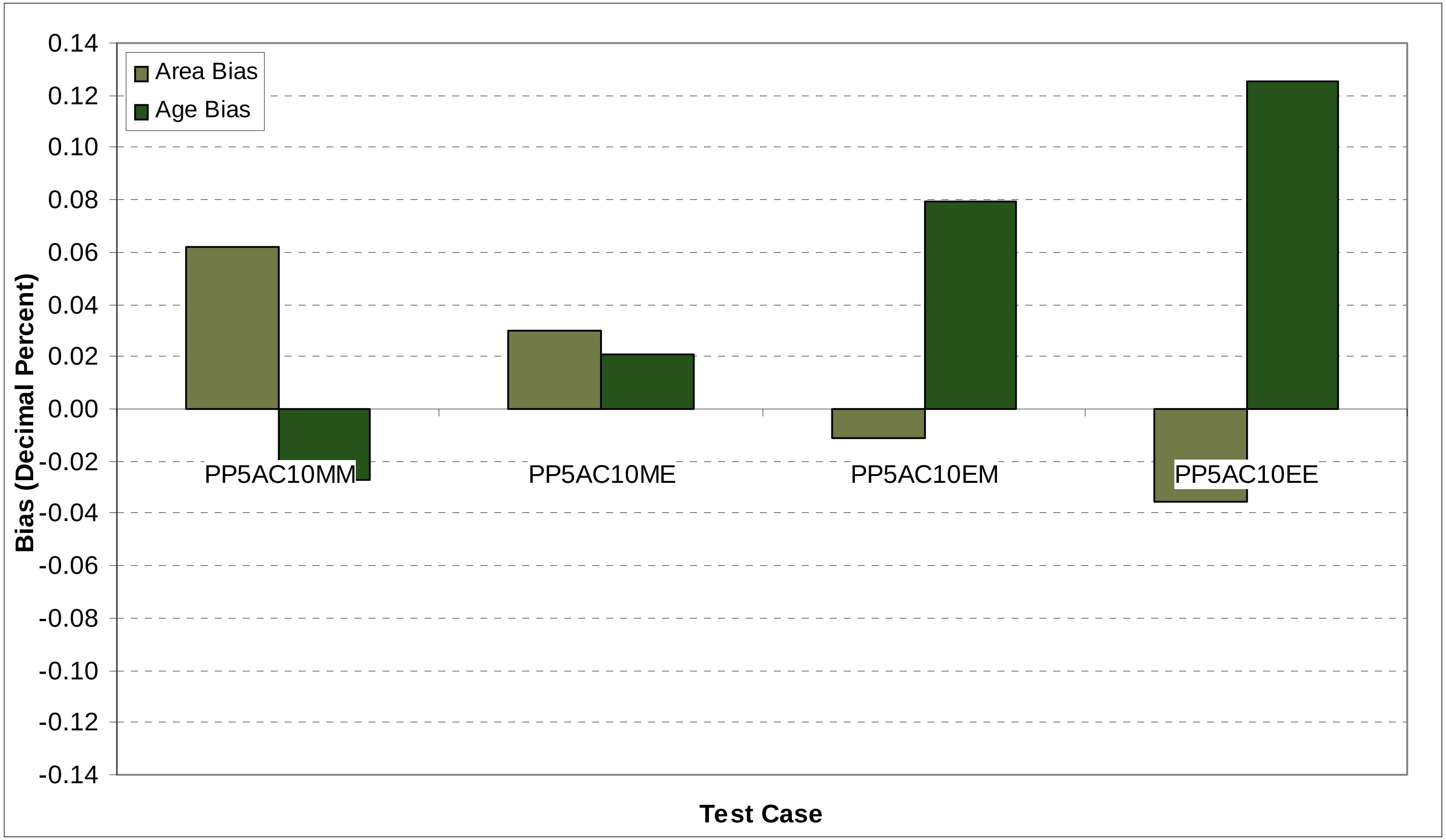
Case	100-year Subset			1-period Subset		
	Uniform	Negative Skew	Positive Skew	Uniform	Negative Skew	Positive Skew
PP1AC5ME	**0.016**	**0.063**	-0.025	-0.024	**0.045**	-0.025
PP1AC5EE	0.064	0.113	**0.021**	**0.017**	0.089	**0.017**
PP5AC5MM	-0.031	**0.014**	-0.071	**-0.006**	**0.064**	**-0.007**
PP5AC5ME	**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

FORSight Resources LLC

Results – Harvest Area Bias

	100-year Subset			1-period Subset		
Case	**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



FORSight Resources LLC

Results – Harvest Schedule Feasibility

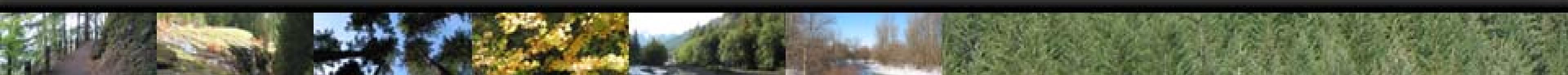
Case	Test Case Volume	Annual Volume	Fall Down
PP1AC5EE	1,485,147	1,448,591	2.50%
PP5AC5EE	1,551,975	1,432,616	8.30%
PP5AC10EE	1,578,577	1,448,589	9.00%
PP10AC5ME	1,553,557	*Infeasible*	-----

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

FORSight
Resources
LLC

Thank you.



Questions?

Corresponding Author: Bruce Carroll
FORSight Resources, LLC
8761 Dorchester Rd, Suite 102
North Charleston, SC 29420
Bruce.Carroll@FORSightResources.com
www.FORSightResources.com