Delayed Conifer Tree Mortality Following Fire in California

Sharon Hood, Sheri Smith, and Daniel Cluck

Rocky Mountain Research Station, Fire Sciences Lab, Missoula, MT

Forest Health Protection
NE California Shared Services Area
USDA Forest Service, Region 5

Background

- Historically, fire-salvage marking guidelines used throughout California were based on Willis Wagener's "Guidelines for estimating the survival of fire-damaged trees in California" (1961)

- Based on concerns over salvage harvesting there was a need to reevaluate Wagener's guidelines

Background

- There still exists a general lack of information regarding fire injured tree survivability for California
- Mutch and Parsons (1998)
  - Very small size classes
- Stephens and Finney (2001)
  - Developed for prescribed fire applications
  - Smaller size classes (5-60 cm)

Current Needs of Land Managers

- To accurately evaluate fire injury and predict survivability of trees for planning rehabilitation and salvage operations
- To accurately assess residual fuels
- Fire marking guidelines which use variables that are easy to interpret, quick to apply and provide a relatively high degree of accuracy

Tree Mortality Study

- Assess fire injury on trees that initially survived fire

- Follow them through time (5 years)

- Develop mortality models to predict probability of tree death after fire
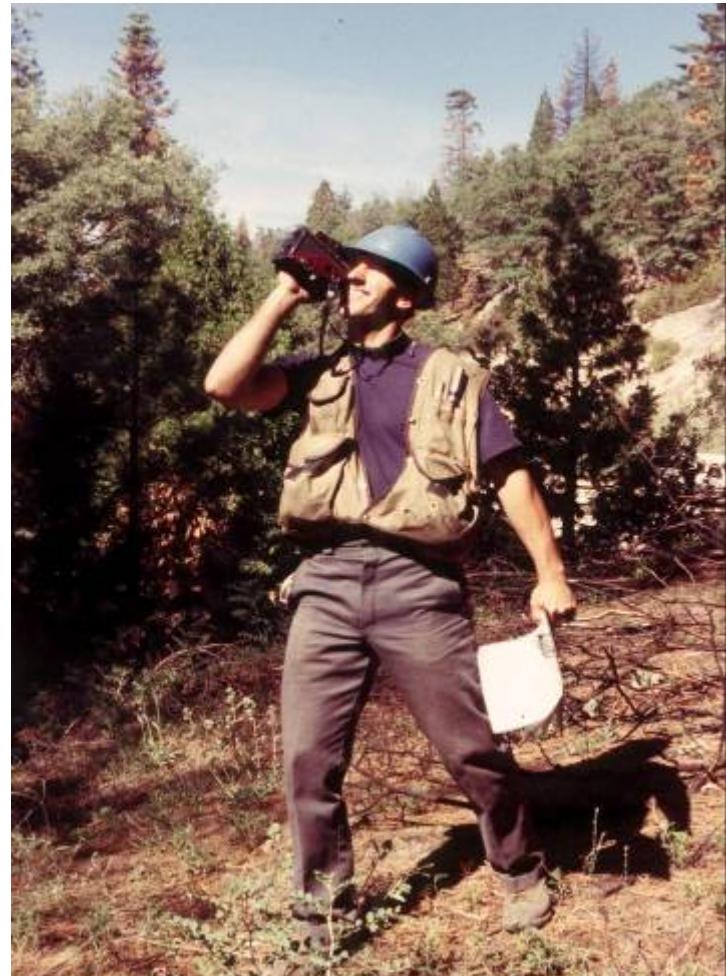
Study Sites

- Five wildfires (1999-2002)
- 5,246 trees
- Species:
  - Red fir
  - White fir
  - Ponderosa and Jeffrey pine
  - Incense cedar
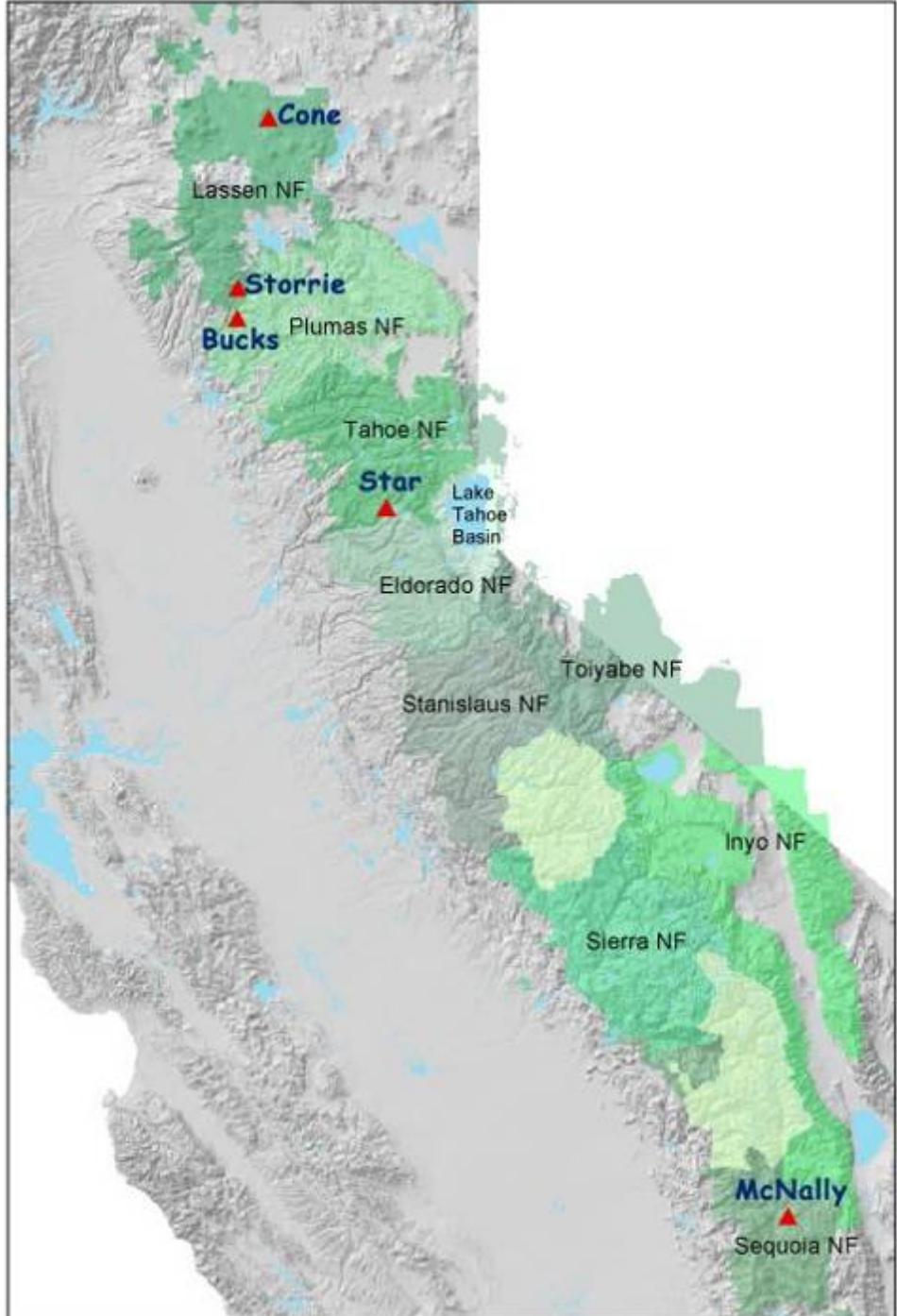
Fires in Study

Fire	Month & Year Burned	Elevation (m)	Forest Type	Mean annual Precipitation (cm)
Bucks	September, 1999	1400-1500	Mixed conifer	152-178
Cone	August, 2002	1750-1800	Eastside Pine	50-75
McNally	July, 2002	1700-2750	Mixed conifer	50-75
Star	August, 2001	1550-1950	Mixed conifer	152-178
Storrie	August, 2000	1650-1950	Mixed conifer	152-178

Species by fire

| Fire	Red Fir	White Fir	Incense Cedar	Yellow Pine
Bucks	112	124	-	-
Cone	-	-	-	923
McNally	-	1866	781	1046
Star	-	199	-	-
Storrie	94	101	-	-
Total	**206**	**2290**	**781**	**1969**

Methods

- Tagged live trees in summer following fire
- Assessed:
  - DBH
  - Tree height
  - Pre/post crown base height
  - Crown injury
  - Cambium injury
 - Beetle attacks

Crown Injury

- Percent crown length killed
- Percent crown volume killed (McNally and Cone fires)
- Percent crown length scorched (yellow pine only)
- Percent crown volume scorched (yellow pine only)

Original (pre-fire) crown length* (A)

Estimated length* of remaining green foliage or live crown (B)

Fire-scorched or killed
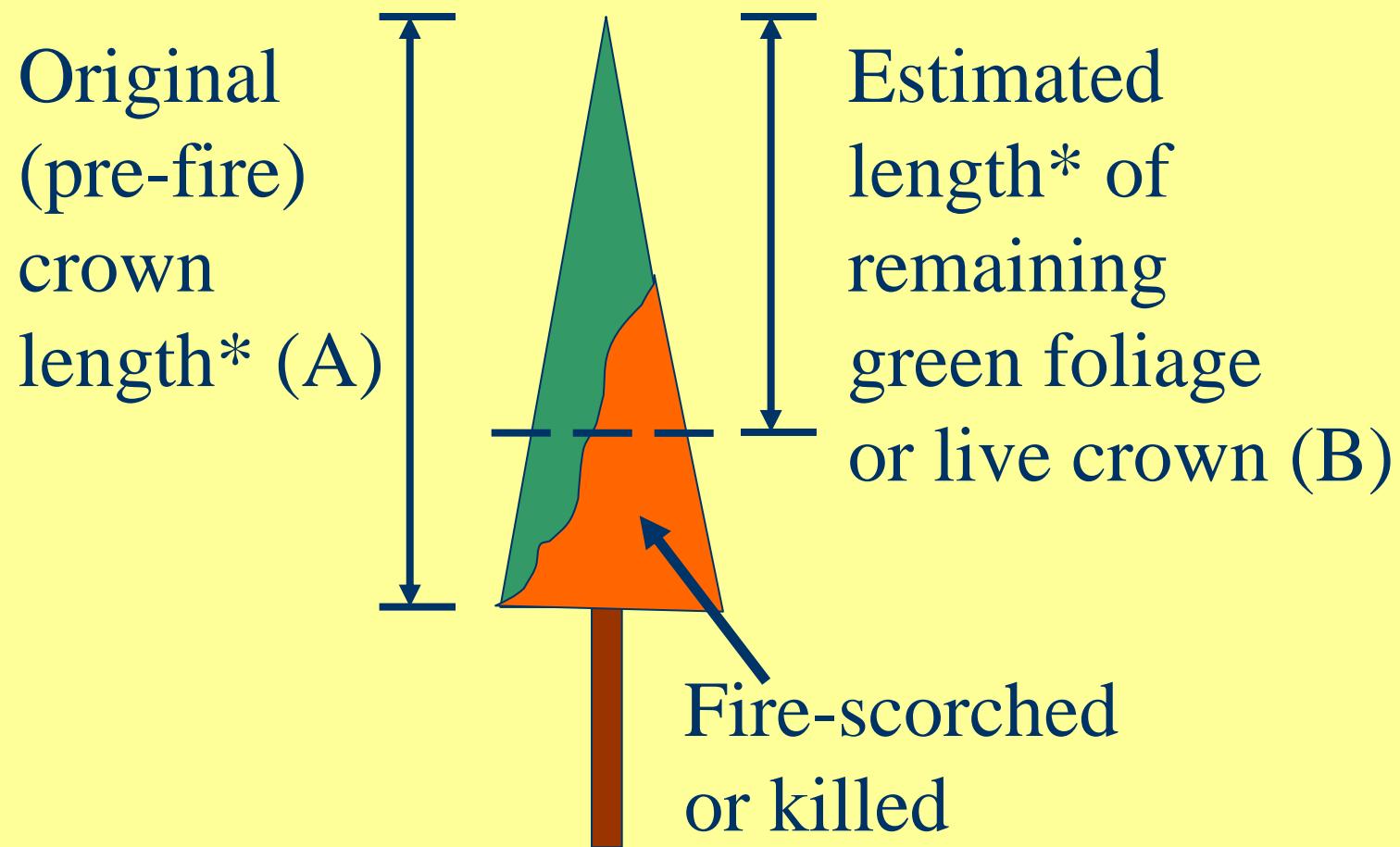
B/A*100 = Percent remaining green foliage or live crown

*Estimating length not volume

Crown Injury – Volume vs. Length
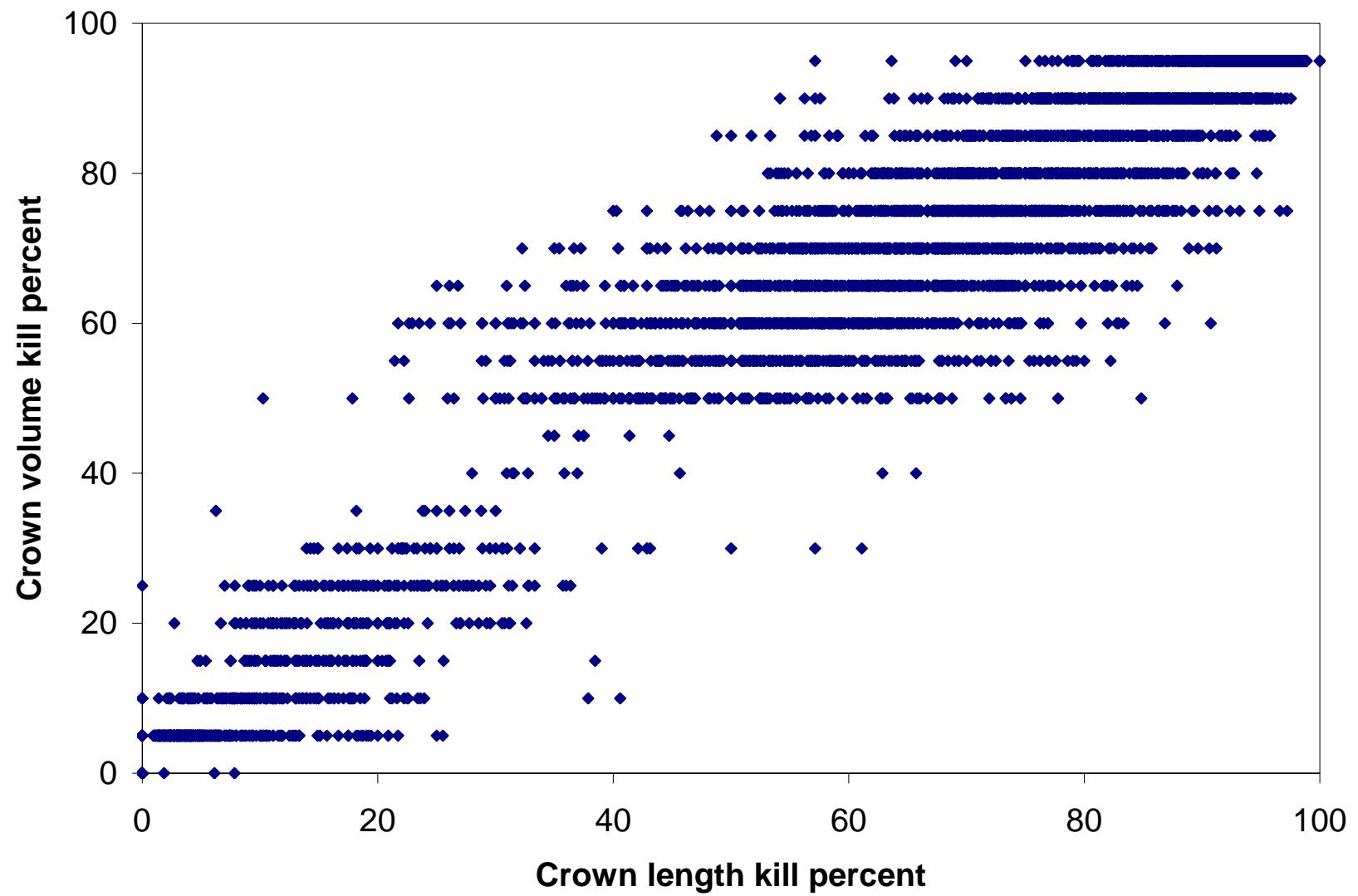
Green, healthy needles

Crown Scorch -

Needles killed but buds alive

Crown Kill -

Needles and buds killed

Cambium Injury

- Direct cambium sampling on 4 sides of tree
- Indirect sampling using bole char codes (Ryan 1982)
  - McNally Fire
  - Cone Fire

Indirect vs. Direct Cambium Sampling

- Bark Char Codes
  - Unburned
  - Light
  - Moderate
  - Deep
- Majority of quadrant
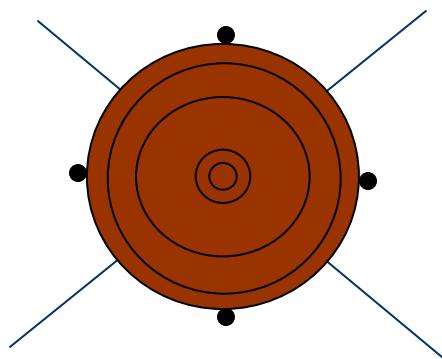
Beetle Attacks

- Ambrosia Beetle - % of bole circumference with boring dust

- Red Turpentine Beetle - # of pitch tubes

Data Analysis

- Compare bark char codes to cambium status
- Used logistic regression for mortality modeling
- Potential variables
  - Percent crown length killed (PCLK)
  - Cambium kill rating (CKR)
  - DBH
 - Presence/absence of beetles

Bark Char Codes
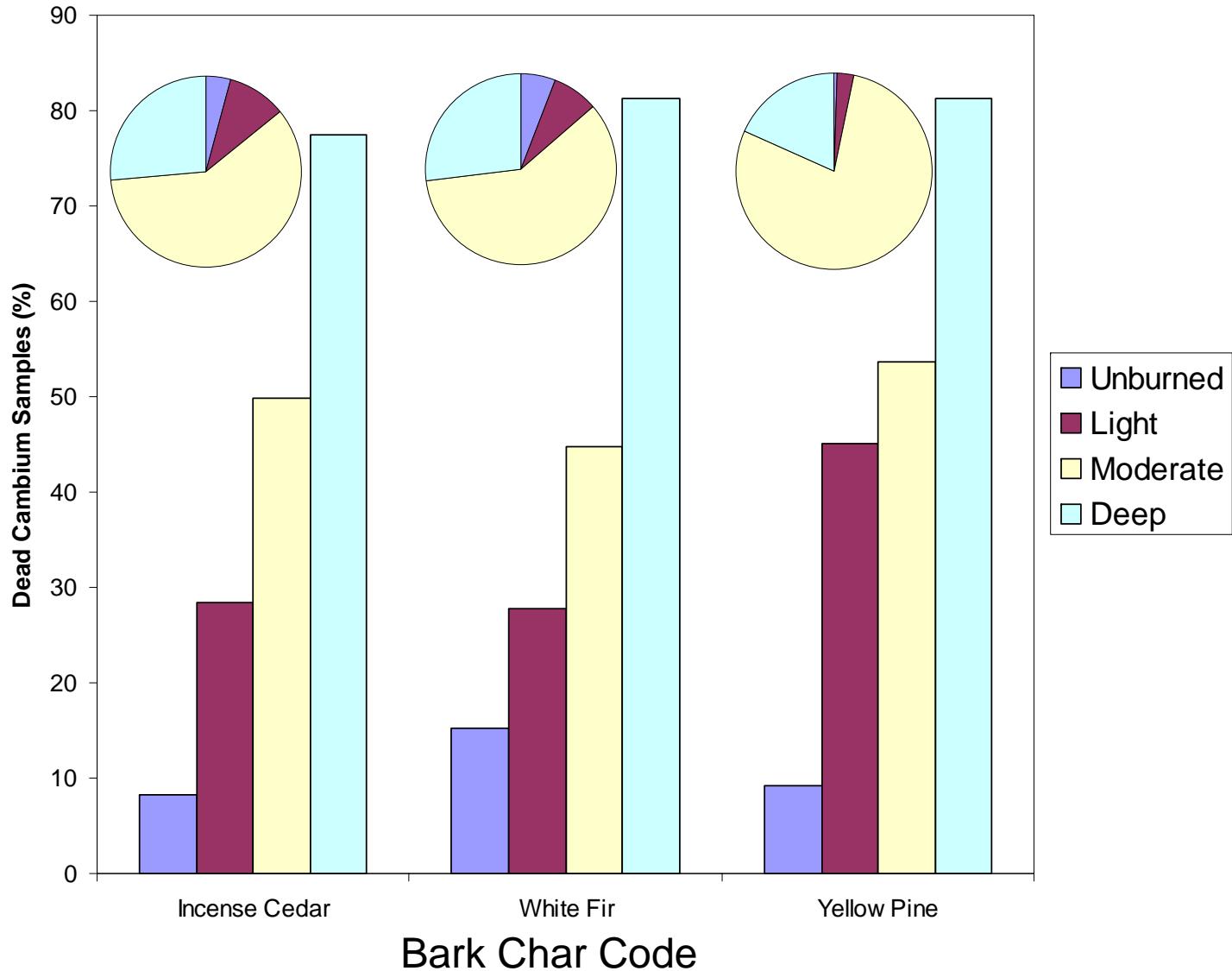
RED FIR

- Four year mortality model
- Significant variables
  - Crown length kill
  - Cambium kill rating
  - Ambrosia beetle

$$Pm = \frac{1}{1 + \left[e^{-\left(-4.2066 \, + \, 0.0330PCLK \, + \, 0.8702CKR \, + \, 0.4619AB\right)} \right]}$$

RED FIR – ambrosia beetle absent
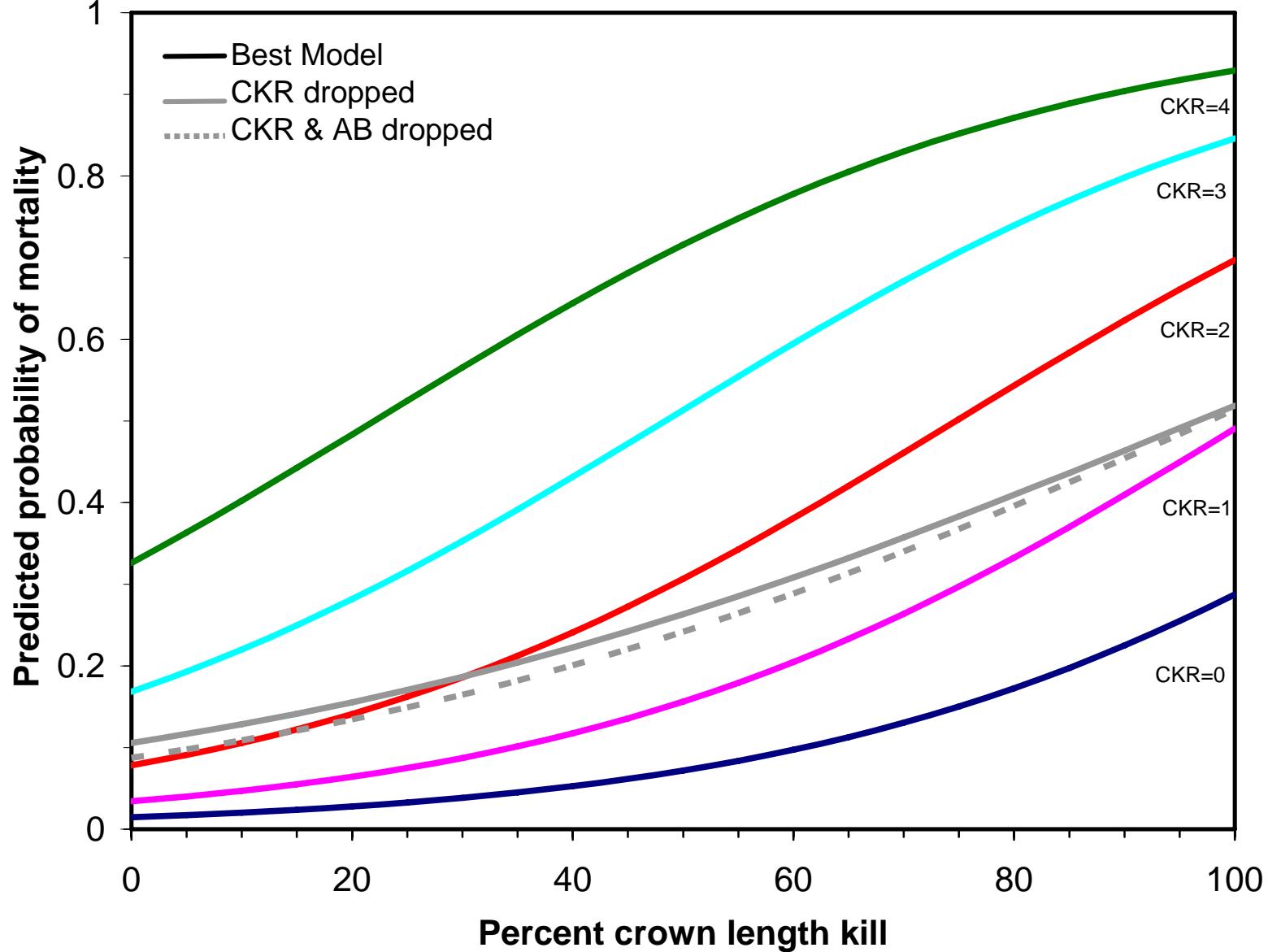
RED FIR – ambrosia beetle present
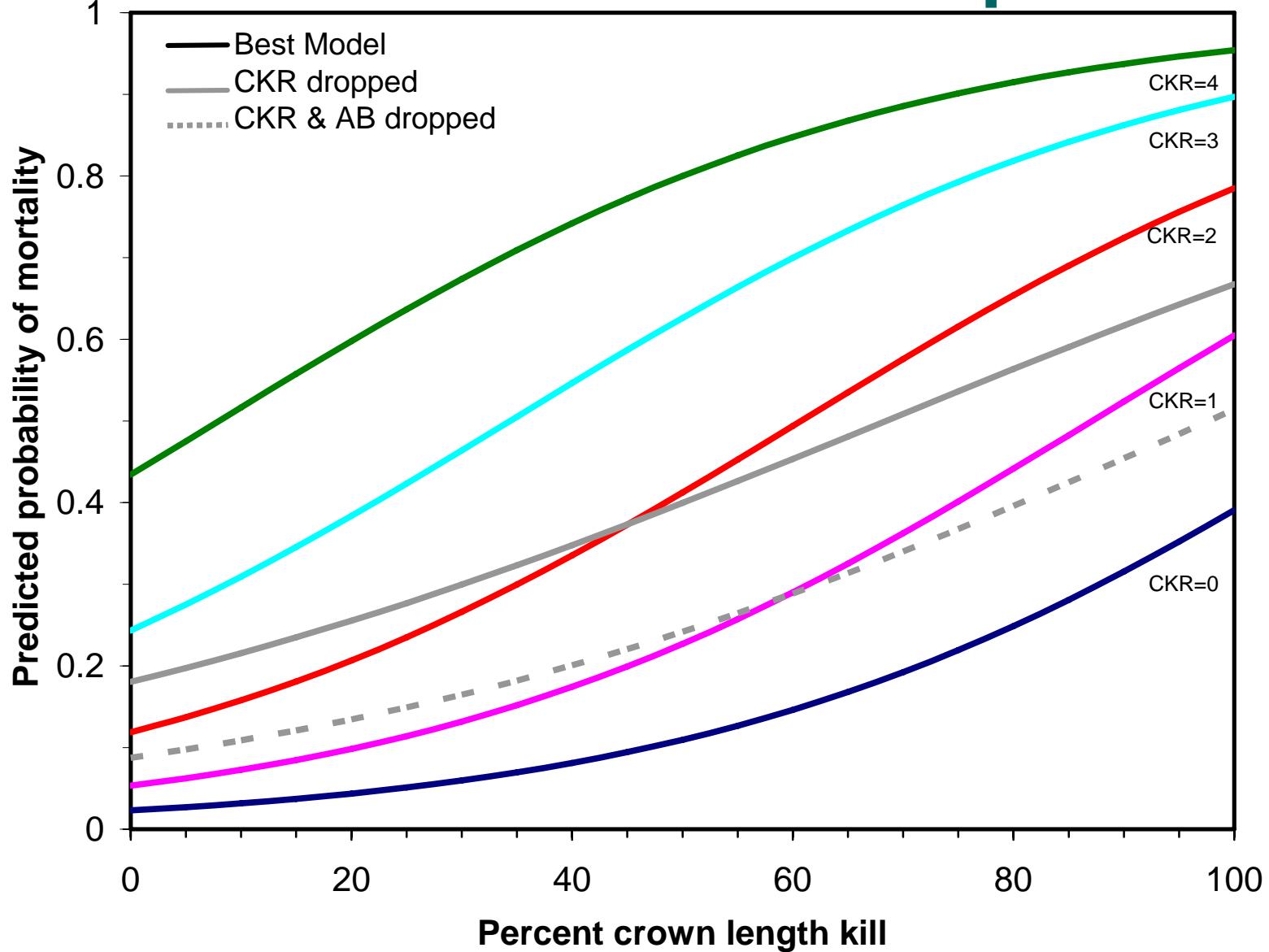
RED FIR Model Accuracy

ROC = 0.825

P_m	Correctly Predicted Mortality (%)	Correctly Predicted Survival (%)	Total Correct %
0.5	66.7	85.2	82.5
0.6	71.5	83.2	82.0
0.7	78.6	81.8	81.6
0.8	60	78.6	78.2
0.9	-	77.7	77.7
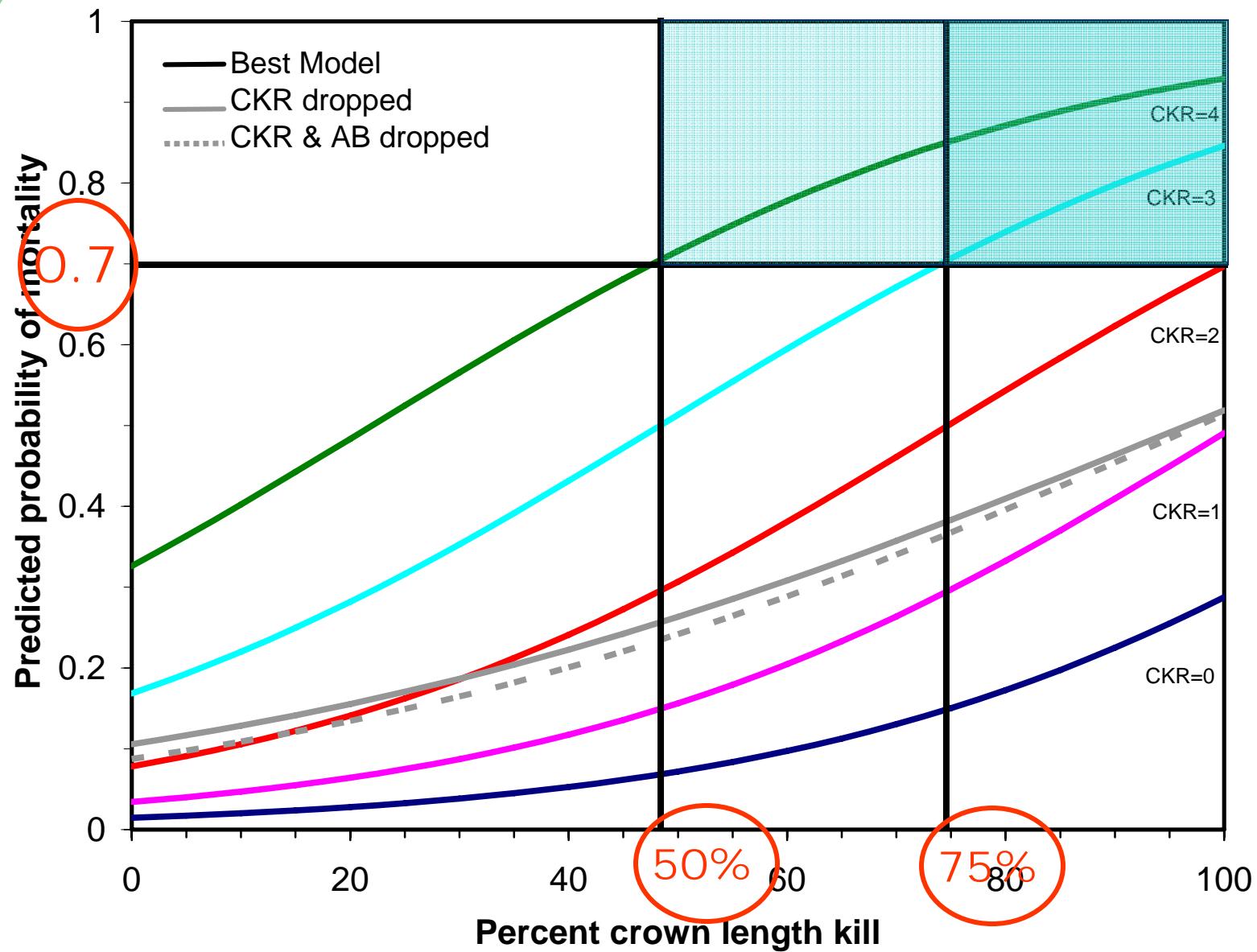
WHITE FIR

- Three year mortality model (preliminary)
- Significant variables
  - Crown length kill^3
  - Cambium kill rating
  - DBH
  - Ambrosia beetle

$$Pm = \frac{1}{1 + \left[e^{-\left(-5.3456 + 0.000006PCLK^3 + 0.6584CKR + 0.0367DBH + 0.5308AB\right)} \right]}$$

WHITE FIR – ambrosia beetle absent

DBH = 80 cm

Best Model
CKR dropped
CKR & AB dropped

Predicted probability of mortality

Percent crown length kill
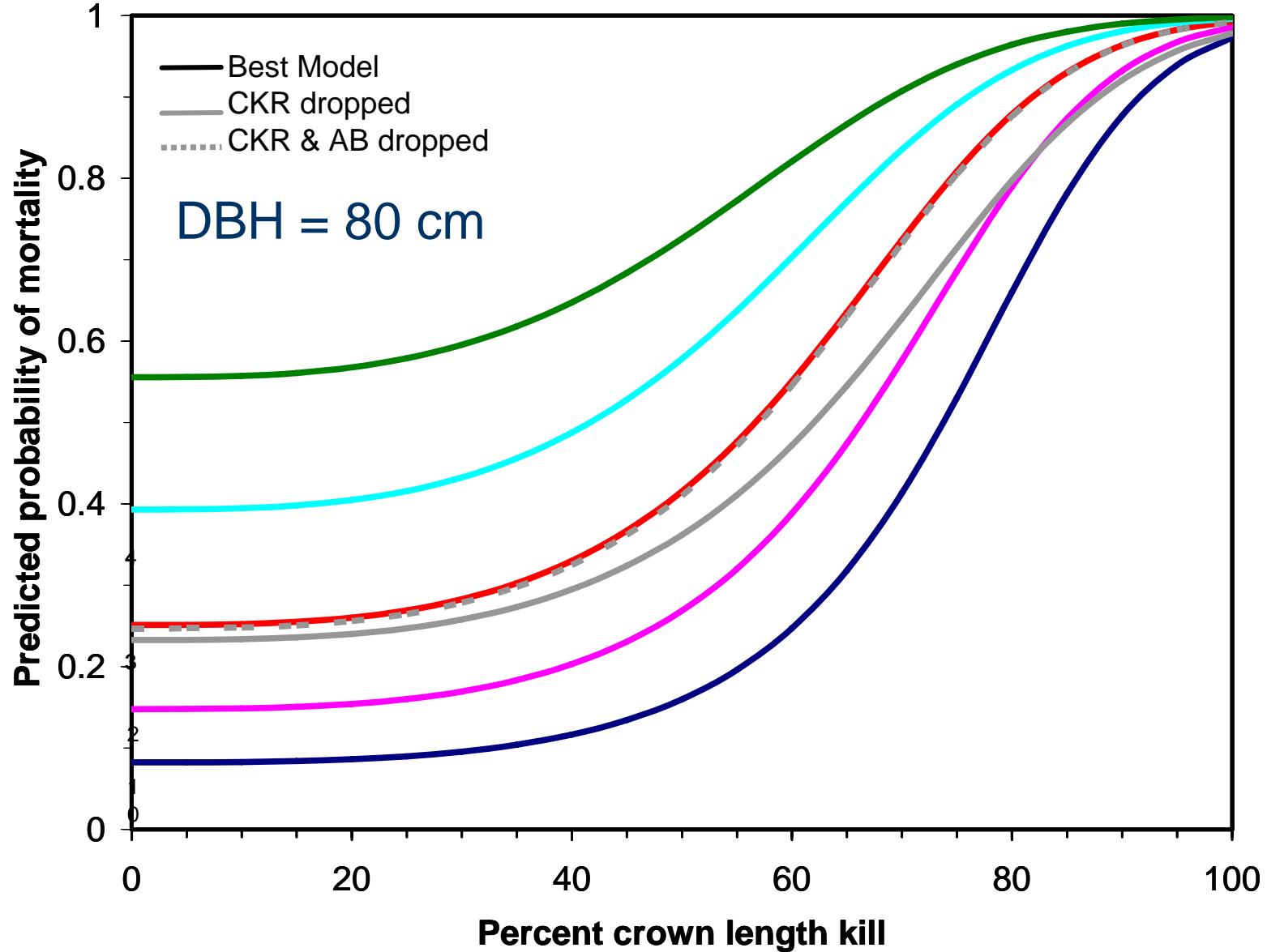
WHITE FIR – ambrosia beetle present
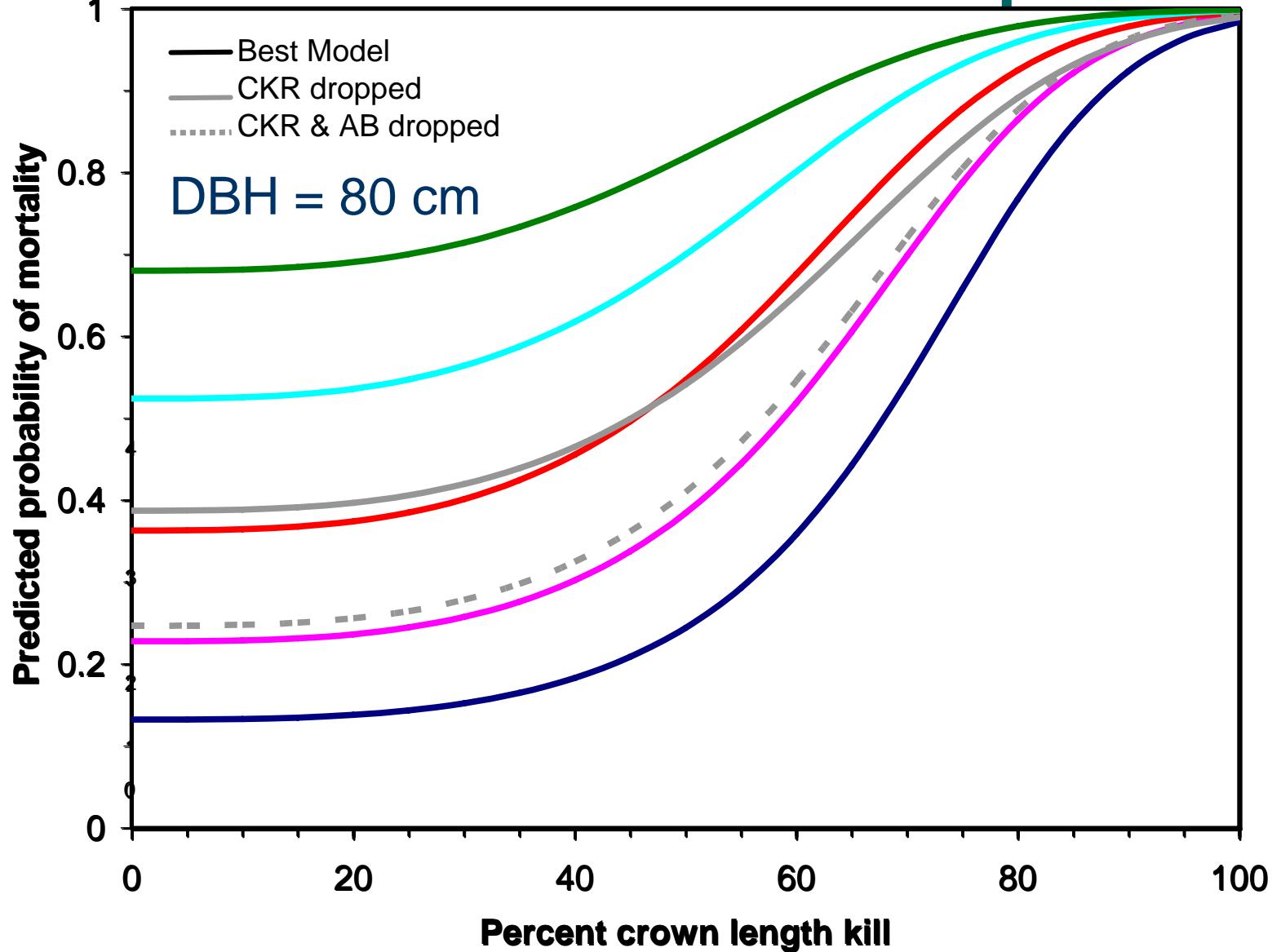
WHITE FIR Model Accuracy

ROC = 0.910

P_m	Correctly Predicted Mortality (%)	Correctly Predicted Survival (%)	Total Correct %
0.5	81.9	86.4	84.4
0.6	87.1	82.5	84.2
0.7	87.9	77.4	80.7
0.8	90.1	71.8	76.2
0.9	92.9	66.9	71.2

INCENSE CEDAR

- Two year mortality model (preliminary)
- Significant variables
  - Crown length kill^3
  - Cambium kill rating
  - DBH

$$Pm = \cfrac{1}{1 + \left[e^{-\left(-4.9639 + 0.0000068 PCLK^3 + 0.5398 CKR - 0.0143 DBH\right)} \right]}$$

INCENSE CEDAR
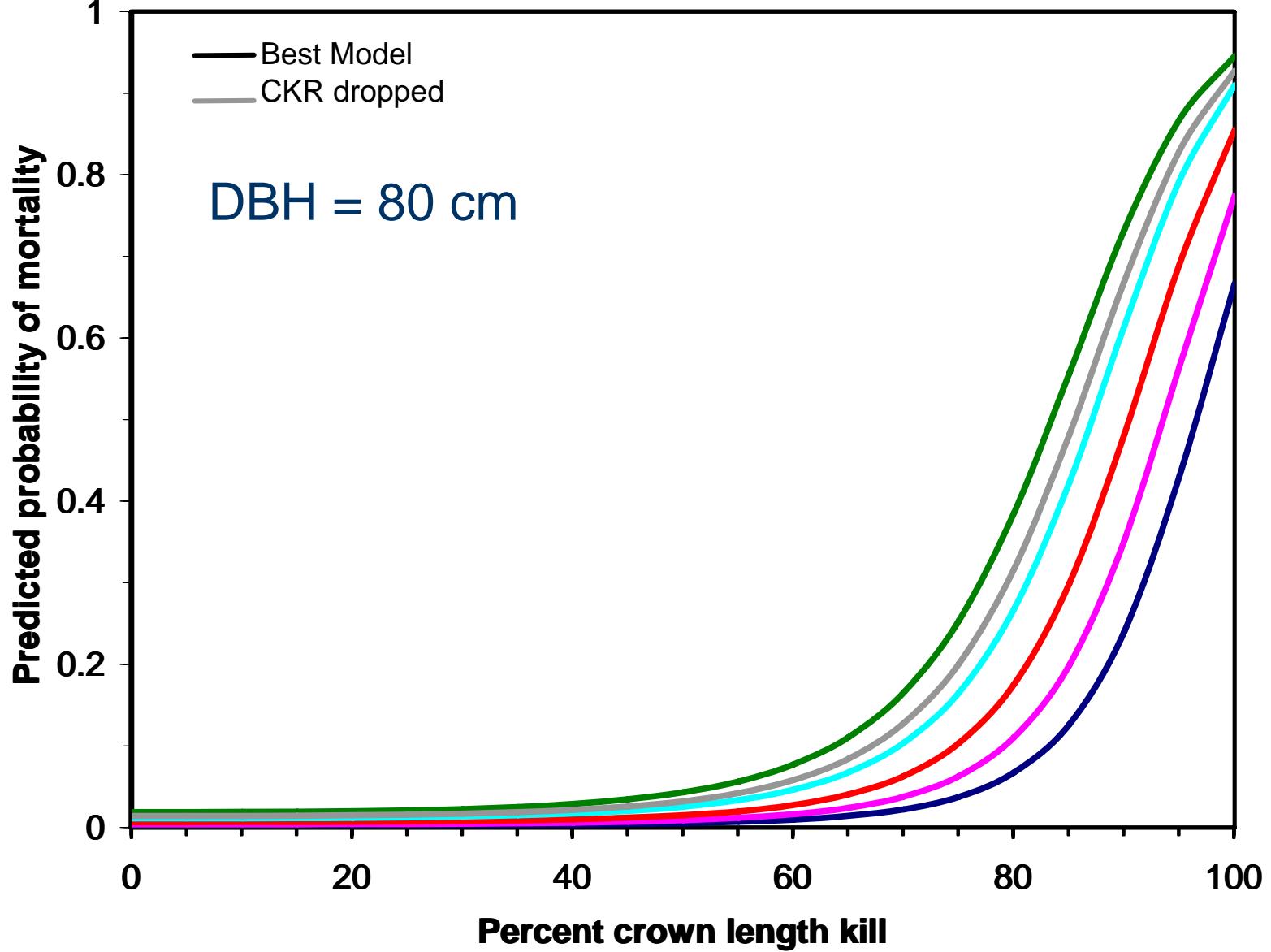
INCENSE CEDAR Model Accuracy

ROC = 0.924

P_m	Correctly Predicted Mortality (%)	Correctly Predicted Survival (%)	Total Correct %
0.5	66.7	93.1	90.9
0.6	72.5	92.3	91.0
0.7	77.8	91.3	90.7
0.8	90.5	90.3	90.3
0.9	83.3	88.6	88.6

YELLOW PINE – post-budbreak

- Two year mortality model (preliminary)
- Significant variables
  - Crown length kill^2
  - Cambium kill rating
  - DBH
  - Red turpentine beetle

$$Pm = \frac{1}{1 + \left[e^{-\left(-4.3202 + 0.000723 PCLK^2 + 0.4185 CKR - 0.0188 DBH + 0.9048 RTB\right)} \right]}$$

YELLOW PINE – no RTB attacks

DBH = 110 cm

Legend:
- Best Model (black line)
- CKR dropped (gray line)
- CKR & RTB dropped (gray dotted line)

Y-axis: Predicted probability of mortality (0 to 1)
X-axis: Percent crown length kill (0 to 100)
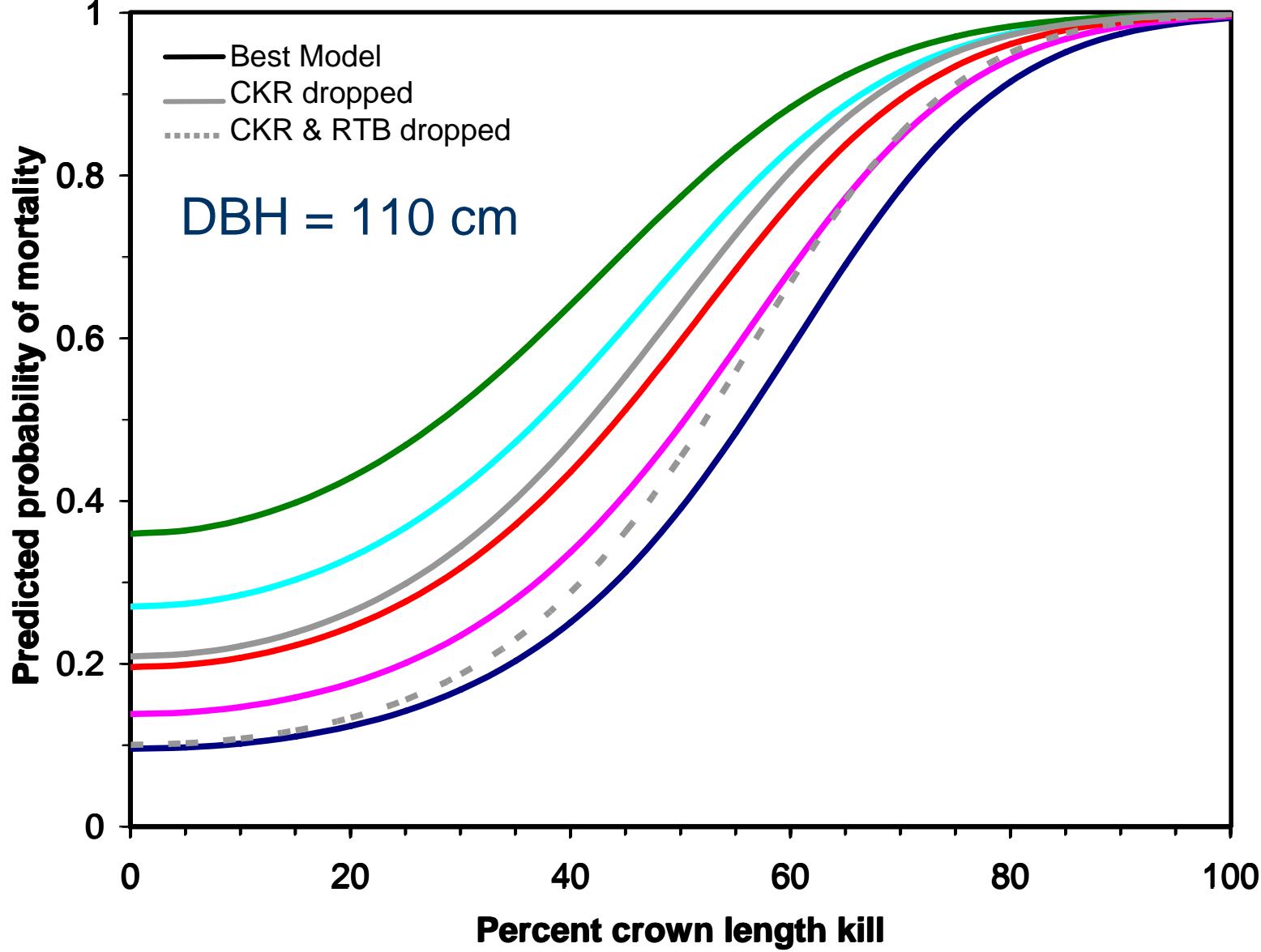
YELLOW PINE – with RTB attacks

DBH = 110 cm

Legend:
- Best Model
- CKR dropped
- CKR & RTB dropped

Y-axis: Predicted probability of mortality

X-axis: Percent crown length kill
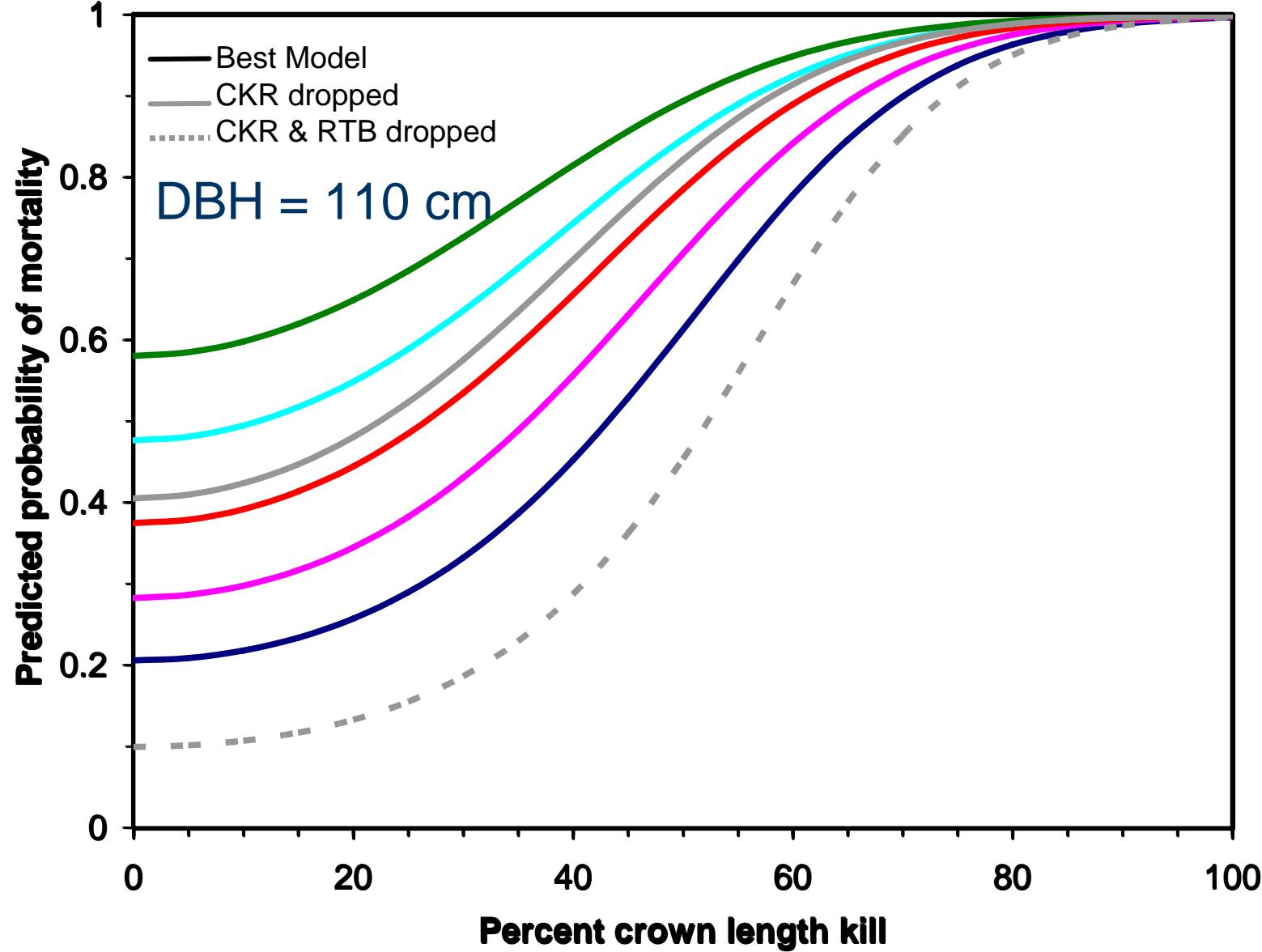
YELLOW PINE Model Accuracy

ROC = 0.924

P_m	Correctly Predicted Mortality (%)	Correctly Predicted Survival (%)	Total Correct %
0.5	86.4	80.6	84.6
0.6	89.3	76.2	84.5
0.7	91.2	70	82.3
0.8	93.8	64.3	79.4
0.9	98.0	55.9	72.5

YELLOW PINE – pre-budbreak

- Two year mortality model (preliminary)
- Significant variables
  - Crown length scorched^2
  - Cambium kill rating
  - DBH

$$Pm = \frac{1}{1 + \left[e^{-\left(-6.8243 + 0.000568 PCLS^2 + 0.6688 CKR - 0.0285 DBH \right)} \right]}$$

YELLOW PINE – scorched model
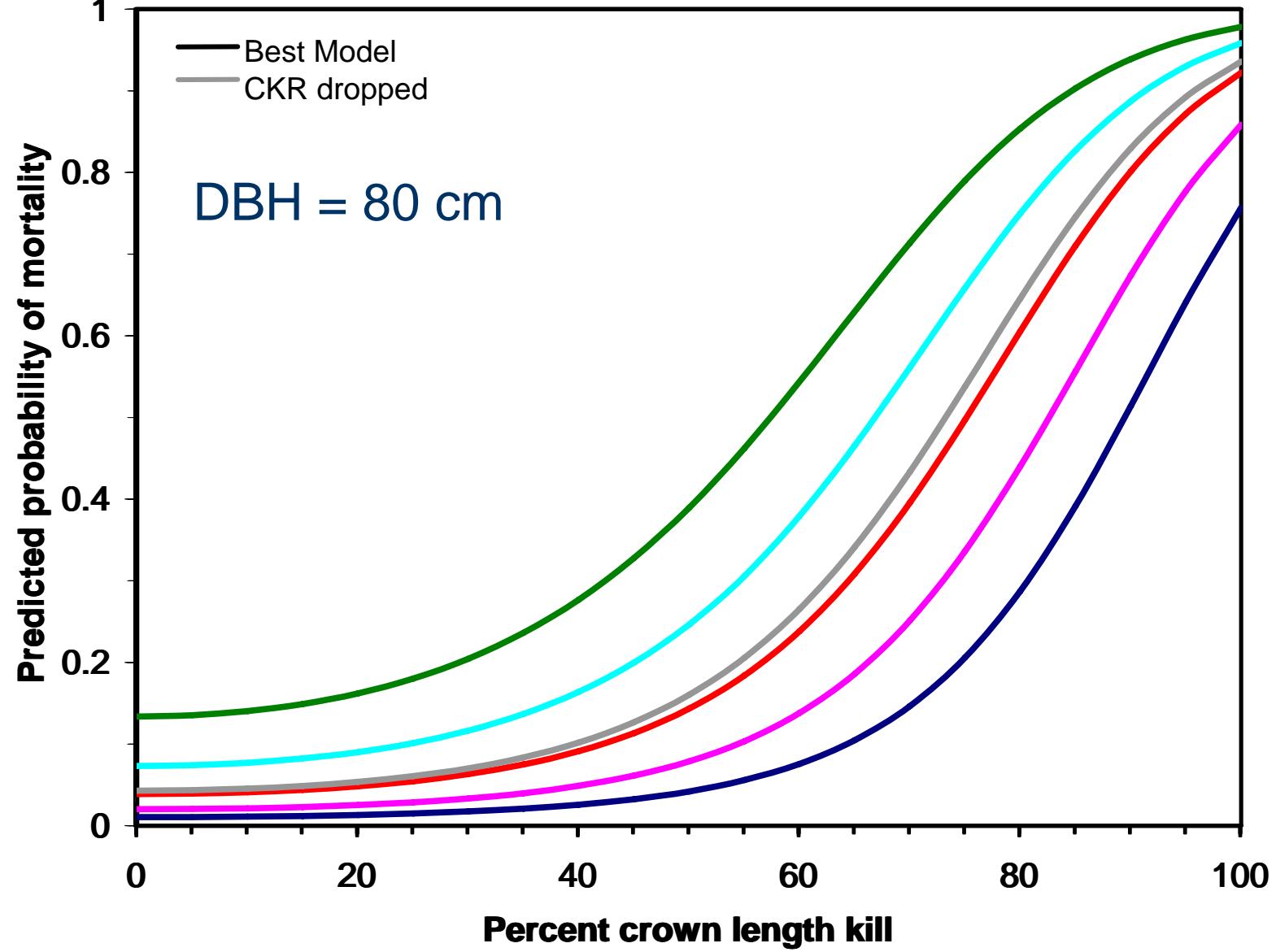
YELLOW PINE
Scorched Model Accuracy

ROC = 0.867

P_m	Correctly Predicted Mortality (%)	Correctly Predicted Survival (%)	Total Correct %
0.5	82.2	77.6	80.9
0.6	84.8	71.3	80.1
0.7	87.6	64.1	77.6
0.8	90.6	55.1	71.1
0.9	95.6	46.1	59.8

Conclusions – Bark Char Codes

- Light and deep bark char can be used to predict cambium condition

- Moderate bark char cannot be used

Conclusions – Mortality Models

- **Most Important Predictor Variables**
  - Crown length kill (%)
  - Cambium kill rating
  - Beetle attacks
- **Important Variable**
  - DBH

Future Plans

- Continue post-fire sampling this summer on all fires

- Use data to refine post-fire mortality models for Ponderosa and Jeffrey pines, White and Red firs, Incense Cedar and Sugar Pine

- Develop a management guide that interprets study results and assists land managers in developing site specific marking guidelines

From Models to Management

- Salvage marking guidelines developed for the Power Fire, El Dorado NF and the Grease and Boulder Fires, Plumas NF

- Probabilities of mortality utilized at the 0.5, 0.7 and 0.9 levels based on management objectives (artificial vs. natural regeneration) or harvest methods (e.g. helicopter vs. tractor logging)

Yellow Pine Guideline Example

0.5 predicted probability of mortality
- <20" DBH- 85% of the crown length scorched
- 20-30" DBH- 70% of the crown scorched

0.7 predicted probability of mortality
- <20" DBH- 95% of the crown length scorched
- 20-30" DBH- 80% of the crown scorched

Acknowledgments

- Support and cooperation from the Lassen, Plumas, Sequoia and Tahoe National Forests
- Kevin Ryan
- Rudy King
- Michael Landram