A General Overview of the Fall Chinook Salmon Life Cycle Production Model

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Yreka, California

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Scope of Fall Chinook Model

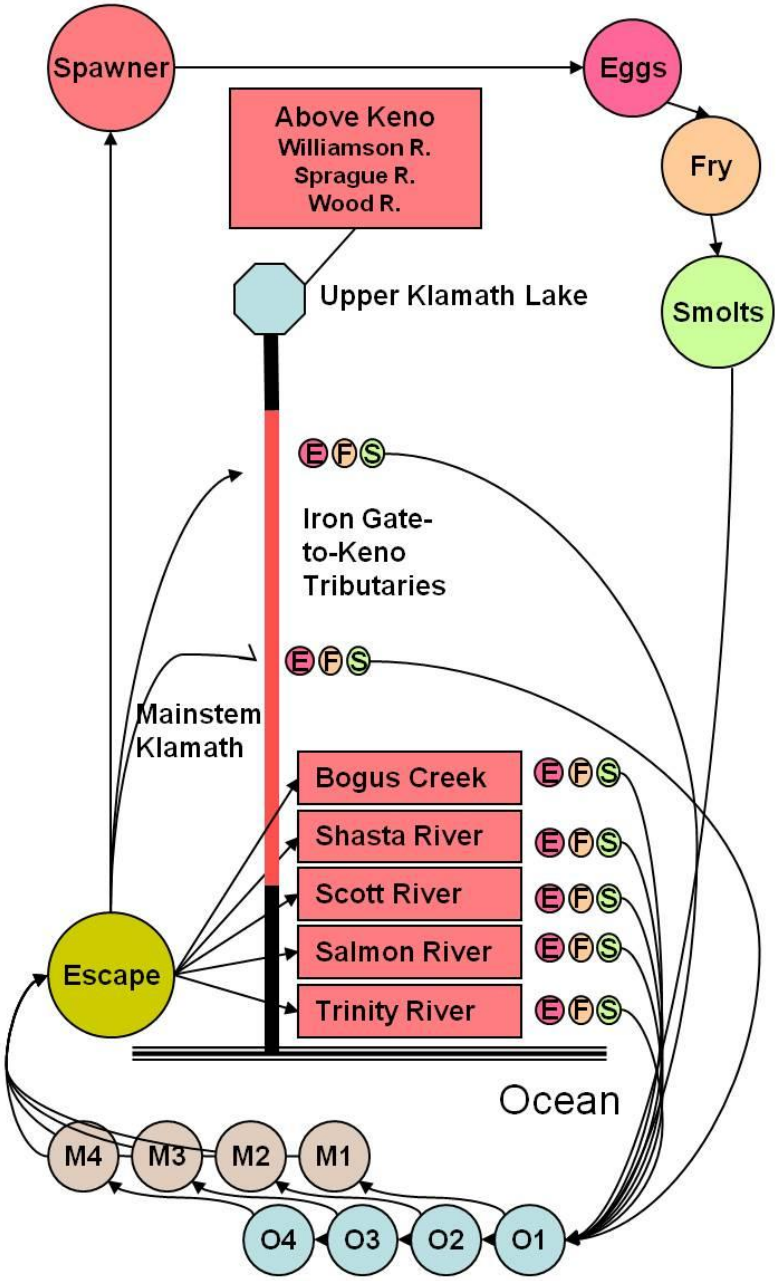
- Develop a Klamath River fall-run Chinook model capable of providing annual forecasts of stage specific abundances with uncertianty.

- Evaluate two management alternatives on the Klamath River:
  - the removal of four mainstem dams (Iron Gate, Copco I, Copco II, and JC Boyle) and KBRA restoration actions
  - Status Quo –upstream limit of fall-run Chinook is Iron Gate Dam

- Explicitly incorporate environmental and parameter uncertainty in abundance forecasts.

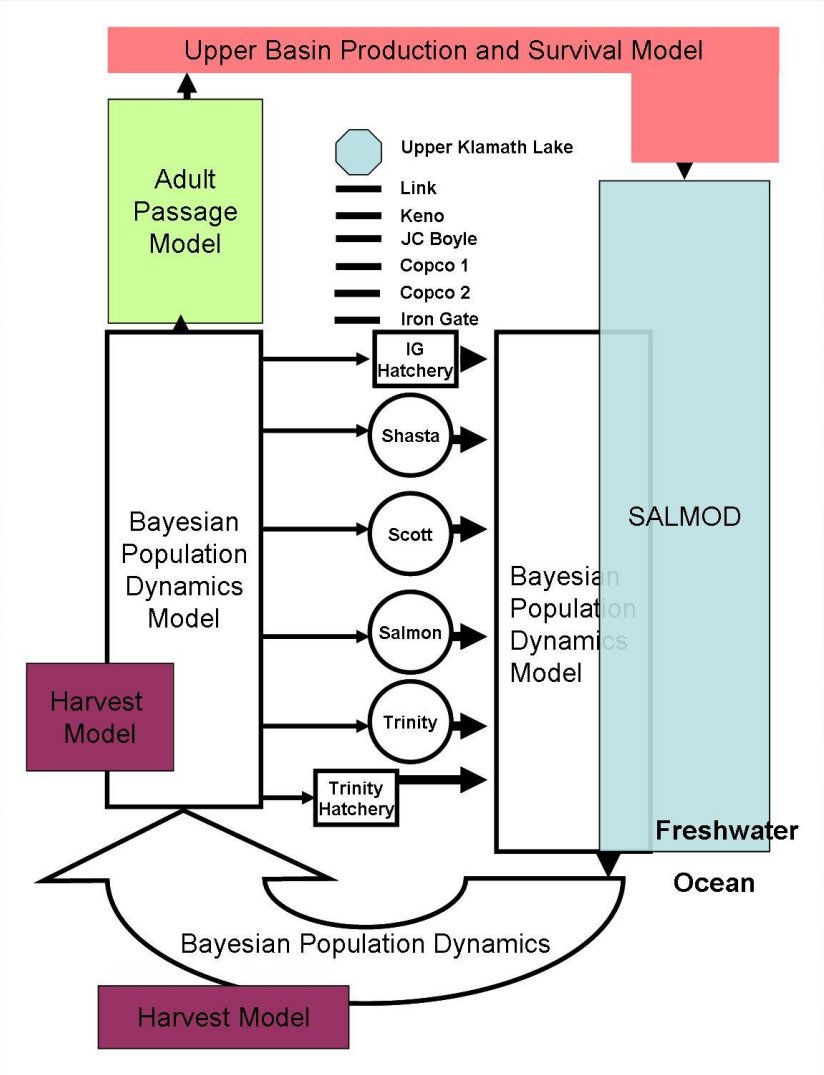
Life History

- Escapement and Production
  - Tributaries
  - Mainstem
  - Upper Basin
- Outmigration
  - Upper Basin
  - Mainstem
  - Lower Klamath River
- Ocean
  - Age structure of returns



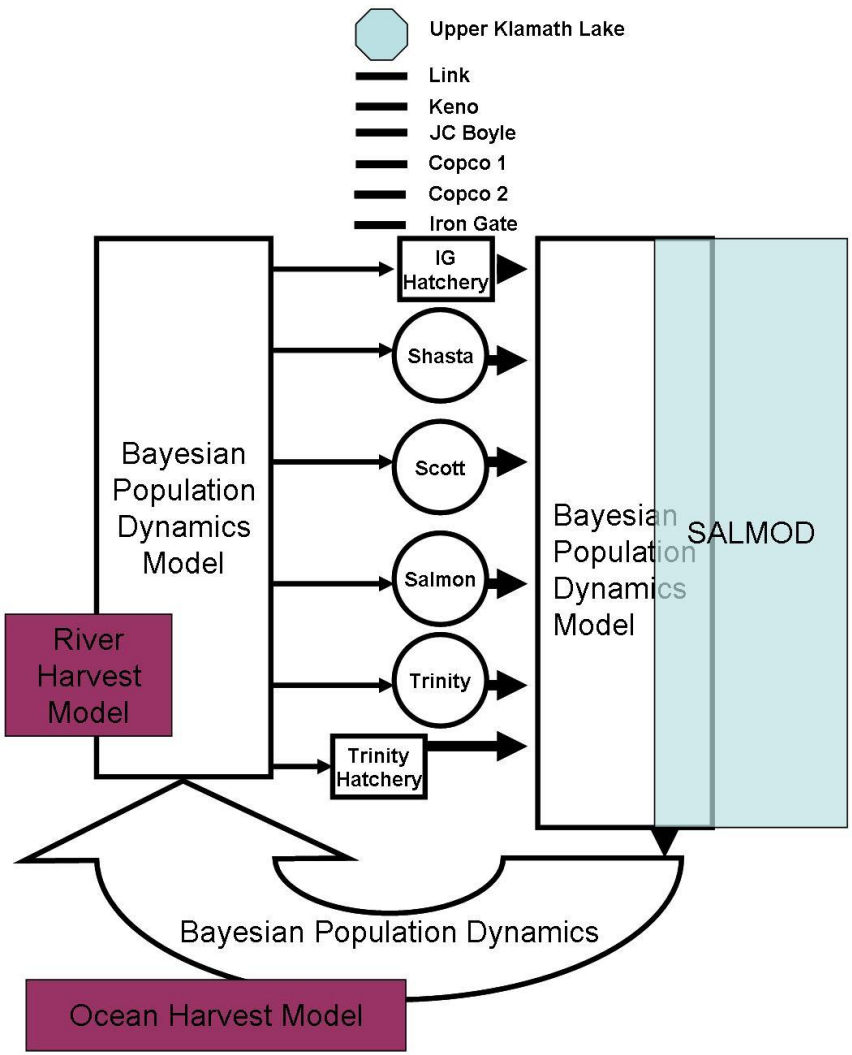
Production Model: Components

- Bayesian Population Dynamics Model
  - Estimate lower river juvenile, ocean, and adult migration survival rates
- Adult Passage Model
  - Simulate survival to the Upper Klamath Basin spawning grounds
- Upper Basin Production and Survival
  - Simulate production in Upper Klamath Basin and survival to Link River Dam
- Harvest Model
  - Estimate harvest rates for Klamath River fall-run Chinook



Status Quo

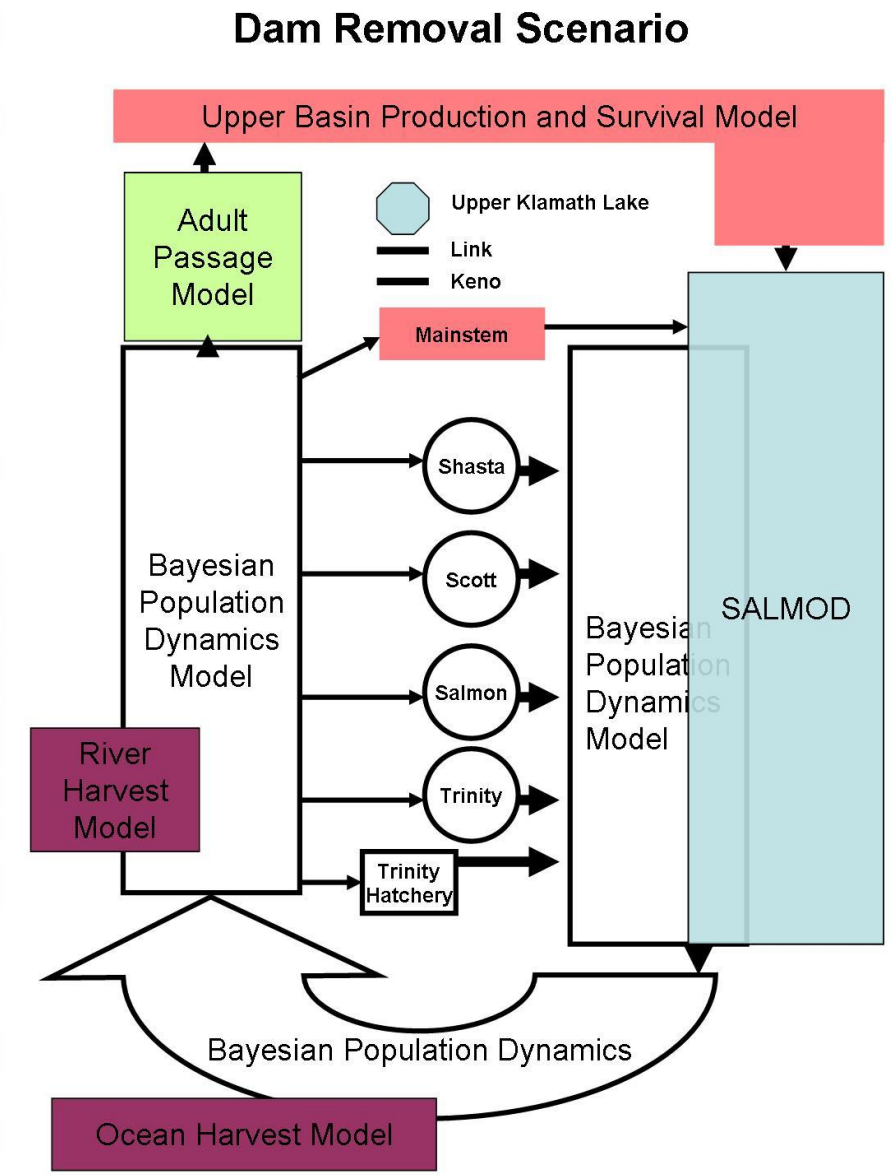
- Bayesian Population Dynamics
  - Lifecycle model for tributaries and IG Hatchery
- SALMOD
  - IG to Ocean survival
- Harvest Model



Dam Removal

in addition…

- Adult Passage
  - Timing
  - Water quality
- Upper Basin and mainstem production
  - Carrying Capacity
  - UKL conditions
- SALMOD
  - Disease
  - Water quality



Types of Uncertainty

- Environmental – the environment changes from year to year thus affecting population vital rates. For example, river flows will vary from year to year.
- Demographic – the population vital rates themselves are uncertain, or *random variables.* For example, effect of temperature on disease is uncertain.

Incorporating Demographic Uncertainty

- Explicitly incorporate demographic uncertainty into the forecasts through Monte Carlo simulations of model coefficients specified by probability distributions.
- Distributions will be derived from Bayesian analyses of empirical data where available.
- Additional distributions for coefficient values derived from:
  - literature values,
  - additional models/analyses
  - expert panel,
  - stake holder consensus

Incorporating Environmental Uncertainty

- Incorporate the environmental data into functions that define population vital rates
  - For example, mortality increases as a function of temperature; thus, higher temperatures lead to higher mortality.
- Model uncertainty in hydrology by developing multiple flow trajectories for each management scenario.

Monte Carlo Simulation for Incorporating Uncertainty

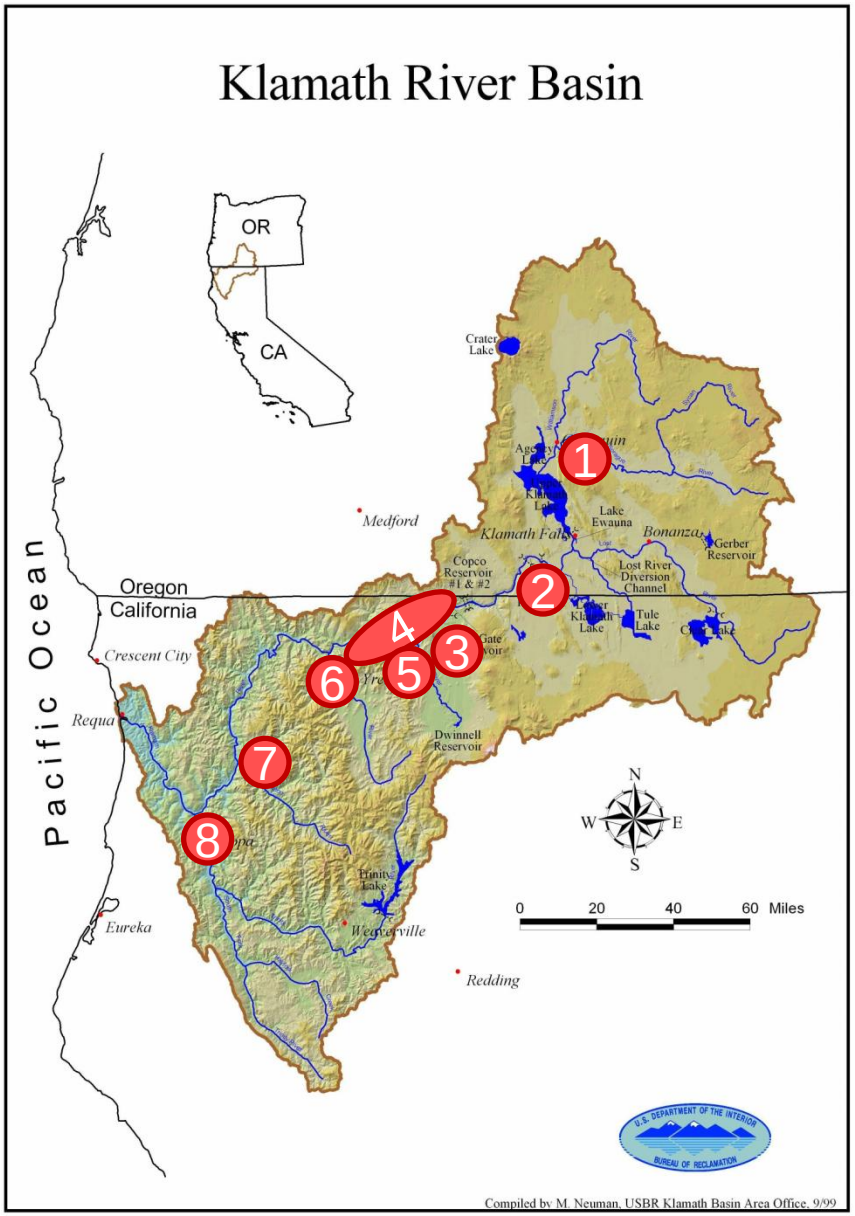
- Construct a deterministic model
- Run the deterministic model many times with different parameter values
- Parameter values drawn from probability distributions using random number generation
- Output of Monte Carlo simulation is a distribution of outcomes from the model (e.g, annual abundances)

FALL CHINOOK MODEL OVERVIEW

Spawning Reaches

8 spawning reaches

1. Above Keno (Sprague, Williamson, Wood)
2. Iron Gate-to-Keno (Spencer, Shovel, Jenny, Fall)
3. Bogus
4. Klamath Mainstem
5. Shasta
6. Scott
7. Salmon
8. Trinity

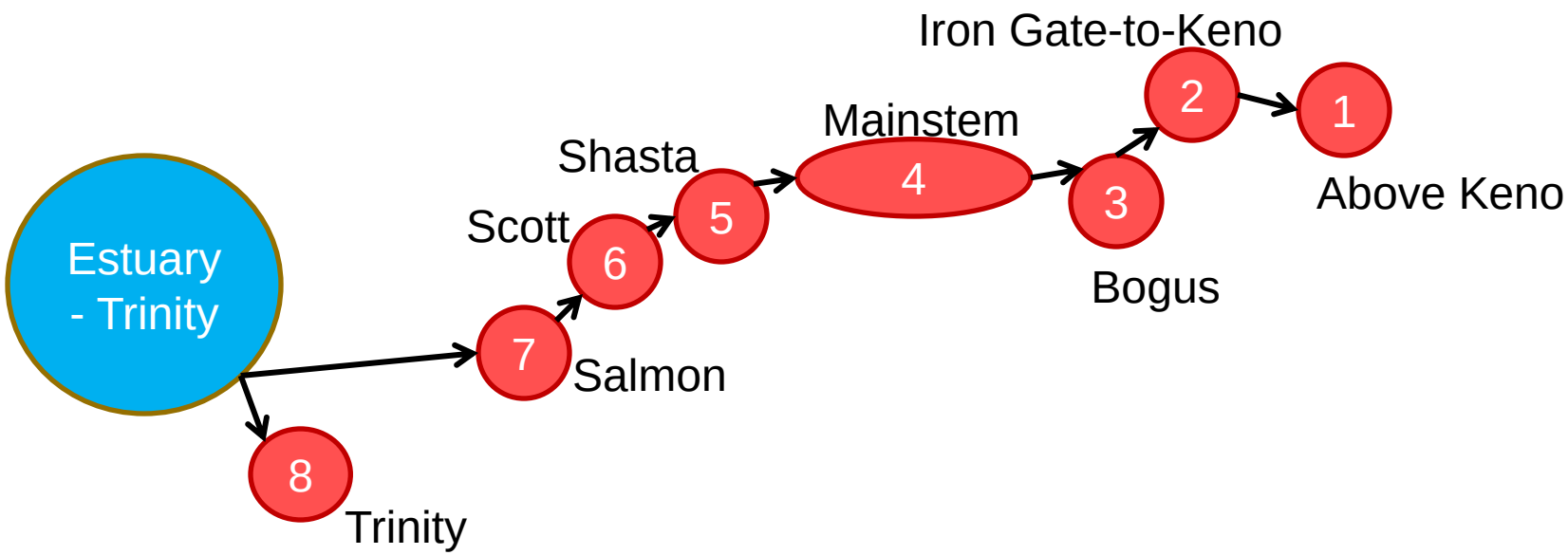


Elements

- Adult Migration – adults returning to spawn
- Production – production of outmigrants from spawners
- Downstream Survival – survival of outmigrants
- Harvest and Ocean – harvest of 3 to 5 year olds
- Disease – factors affecting juvenile survival
- Starting Conditions – stocking and dam removal

ADULT MIGRATION

- Adult migration broken into 2 phases
  - Below Trinity
  - Above Trinity migration to spawning reaches



Below Trinity Section

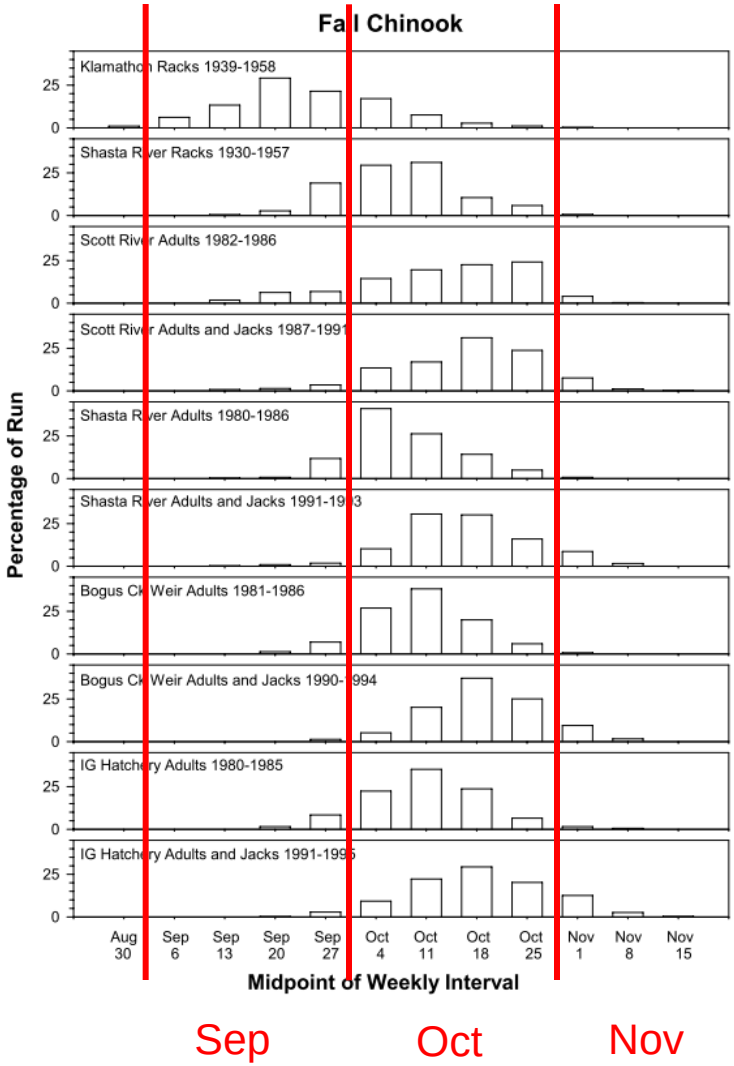
- Factors affecting survival below Trinity: pre-spawn mortality based on 2002 event
  - Total Abundance
  - Flow
  - Temperature
  - Fishing Mortality
- Factors affecting movement
  - Weekly Temperature *(Strange 2010, unpub. tagging data)*
    - Threshold of 23 C for Trinity fish
    - Threshold of 20 - 22 C for Klamath fish
  - Straying among spawning regions of ~ 5%

Above Trinity Section - survival

- Factors affecting survival
  - Reach specific mortality related to:
    - Temperature relative to optimum *(Huntington and Dunsmoor 2006)*
  - Trap and haul for Upper Basin
    - 3 – 7% trapping mortality *(Pacificorp, Malone whitepaper)*
    - 10 – 20% post-release mortality *(Stuart 2005)*

Above Trinity Section - Timing

- Mid-Oct. peak
- Migrate to maintain existing timing – calculate rate to meet objective
- Unless migration rates become improbable
- Migration rate estimates for comparison
  - J. Strange tagging data (12.8 km/d [5.4 – 27])
  - Values from literature



(Huntington and Dunsmoor 2006)

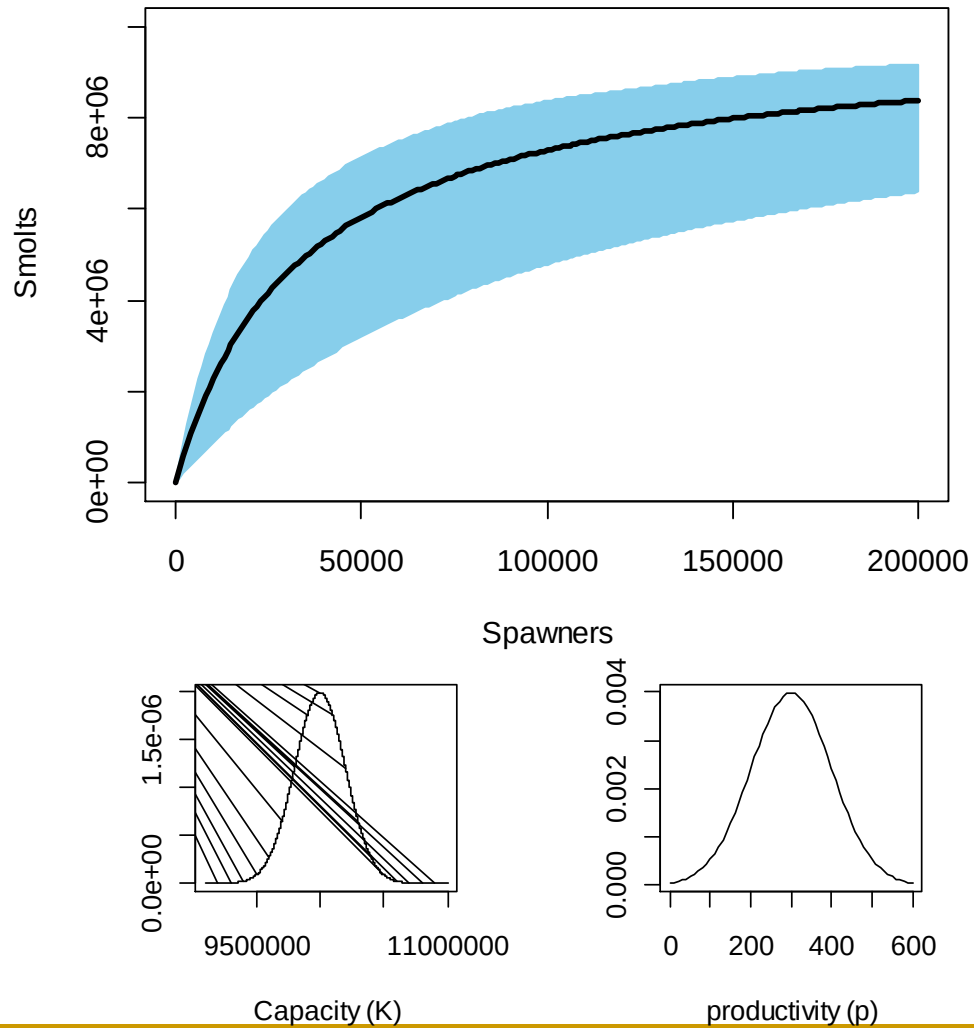
PRODUCTION

- Approach:
  - Use Beverton-Holt (BH) stock production functions for all spawning reaches, except Trinity
  - Use parameters based on statistical analysis of Klamath populations
- Incorporating change over time
  - KBRA actions incorporated into BH function in the 50 year simulations
  - Climate change incorporated through flow variabilityin the 50 year simulations

Beverton – Holt stock recruitment

Tributary specific Beverton – Holt stock production functions, except for Trinity (Ricker model)

$$R = \frac{S}{\frac{1}{p} + \frac{S}{K}}$$



Lower Basin stock production functions

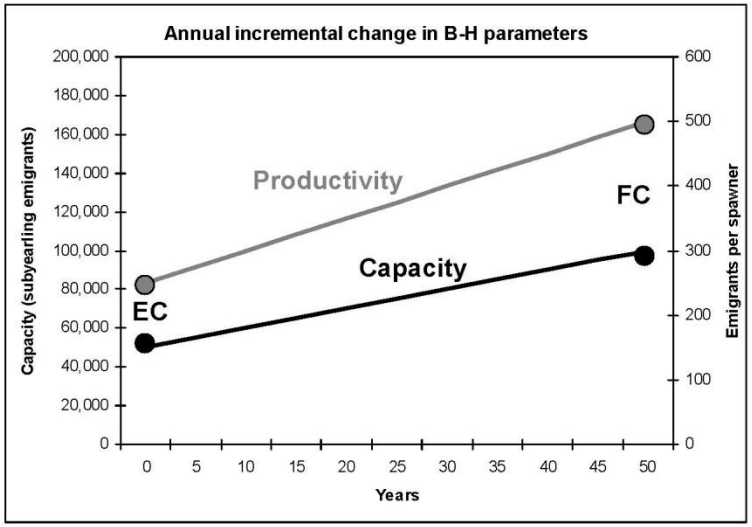
- Stock Recruit Analysis *(Perry, USGS)*
  - Trinity
  - Scott
  - Shasta
  - Bogus
  - Incorporated flow covariates on productivity
- Estimates of capacity based on watershed size *(Parken et al. 2006)*

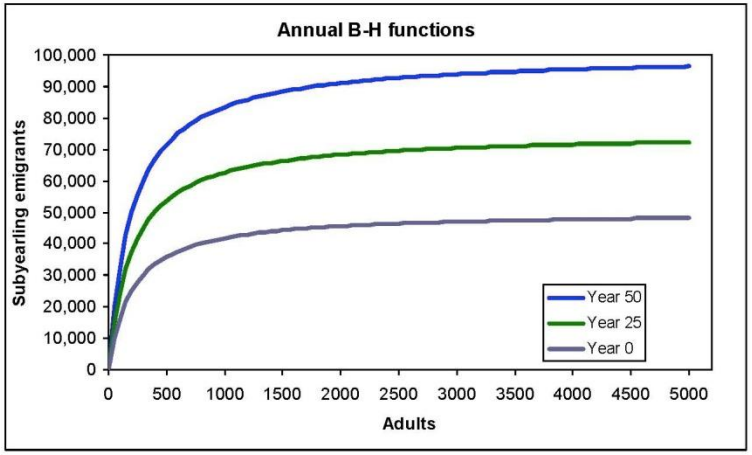
Upper Basin stock production function

- Productivity distribution:
  - Results of lower basin analysis
  - Literature review of fall Chinook juvenile productivity
  - Disease effect in Williamson
- Capacity distribution:
  - Results of EDT modeling
  - Watershed size estimate *(Parken et al. 2006)*

KBRA effects on production

- Increase in production over 50 year simulation
- Staged effects of KBRA actions:





DOWNSTREAM SURVIVAL

- Upper Basin – Upper Klamath Lake and Lake Ewauna survival
  - Timing of outmigration – thermal units and rearing opportunities (*Huntington EDT analysis*)
- SALMOD – Keno to Estuary
  - Tracks 8 spawning populations
  - Survival a function of
    - Flow
    - Temperature
    - Disease
  - Provides numbers of smolts at the estuary

Upper Klamath Lake and Lake Ewauna survival

- Survival distribution constructed from the following sources of information:
  - Boxcar survival studies
  - Reservoir survival on Columbia
  - Survival estimates of fall Chinook through lake Washington
  - Evaluation of sources of predation

SALMOD – brief overview

- Calculates mortality and growth of juveniles from Keno to Estuary as function of temperature and flow
- Weekly time step
- Habitat based model (WUA curves)
- Parameters:
  - Mortality parameters
  - Growth parameters
  - Movement parameters
- Inputs
  - Number of spawners in mainstem
  - Size and abundance of juveniles at 7 other spawning reaches

SALMOD - dependencies

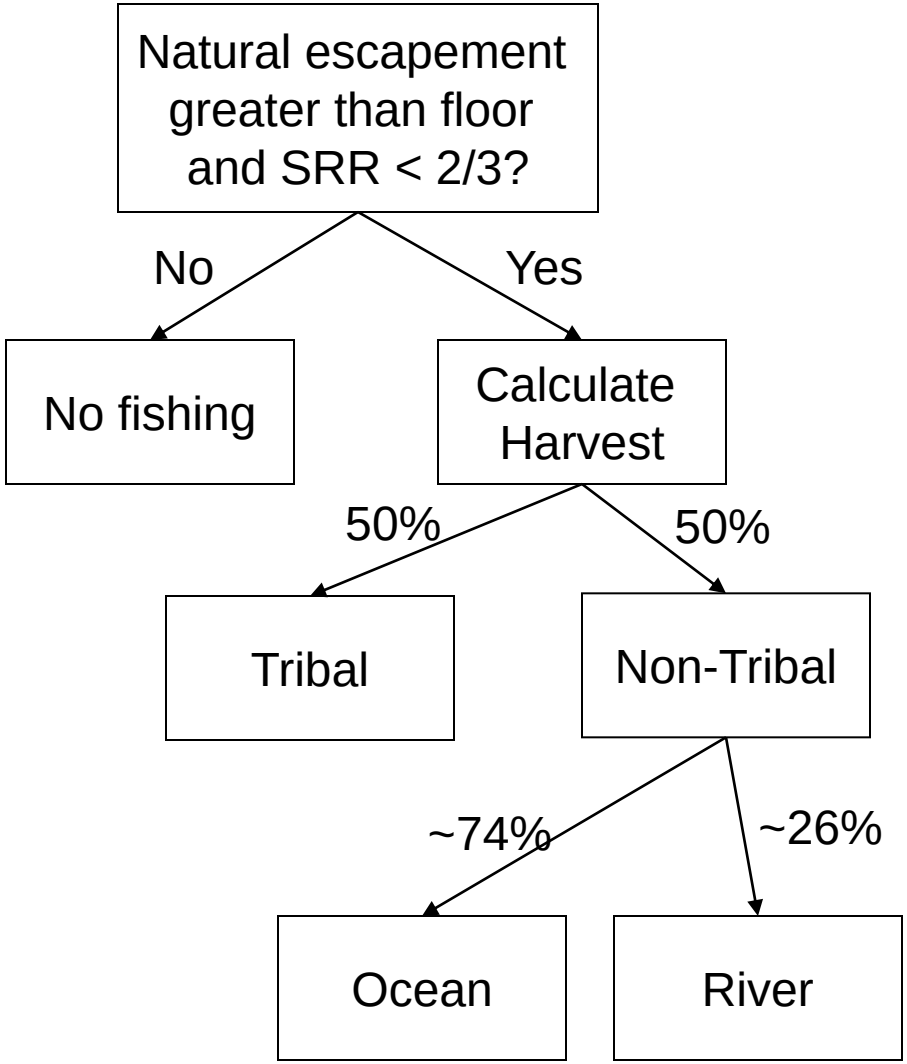
- SALMOD 2 development – Heasley and Perry
- Flow – USBR hydrology
- Temperature - Campbell
- Growth functions via EDT analyses – Huntington
- Disease scalar – Foote and Bartholomew
- WUA curves – Hardy et al.

HARVEST

- Klamath Harvest Rate Model developed by M. Mohr, NMFS
- Determines optimal harvest in each year
- Proportions harvest among:
  - Tribal
  - Non-Tribal
  - Commercial
  - Recreational
- Constraints based on spawner reduction and coastal Chinook

Harvest - General Approach

1) Calculate escapement and SRR
2) Floor met?
3) Find ocean and river harvest rates to meet floor
4) Additional constraints – age 4 harvest rate < 0.16
5) Apportion harvest



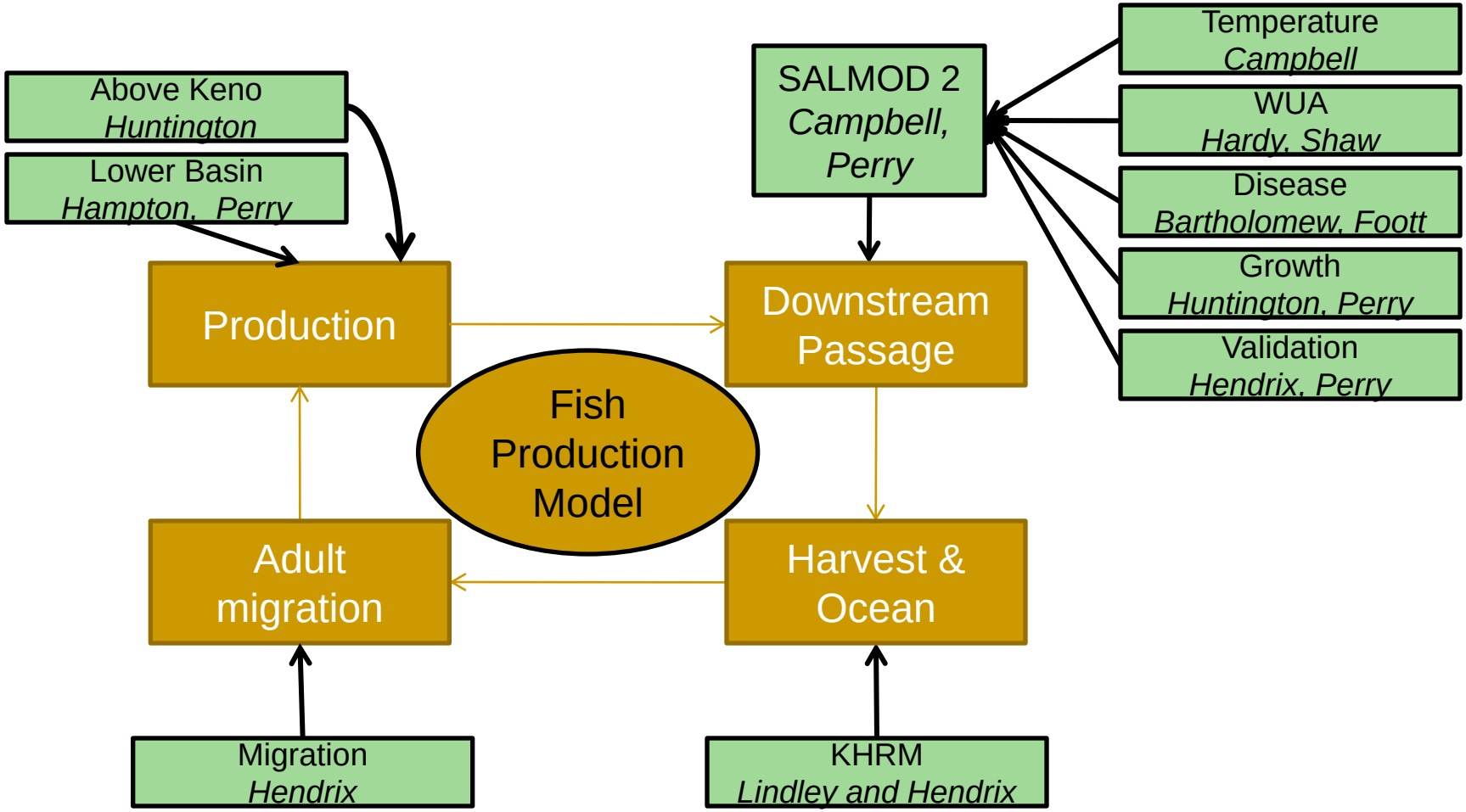
DISEASE

- Disease a function of:
  - Temperature during outmigration
  - Flows in the previous year
  - Flow in the current year
  - Reach specific disease potential (adult carcasses, intermediate host habitat)
- Disease Incorporated into SALMOD
- Potential for disease in Williamson River – affect production in the upper basin

STARTING CONDITIONS

- Abundance for lower basin tributaries - Current estimates
- Upper basin tributaries - seeded with fry to capacity at time of dam removal
- Dam removal affects spawners in mainstem and potential for affecting first year of outmigrants

FPM components and analyses



QUESTIONS?

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Current Model Status

Status of Model Components I

- Harvest – 95% Complete
  - R Code provided by M. Mohr
- Adult Migration – 75% Complete
  - R Code for tracking populations 80% complete
  - Temperature files needed
- Production – 70% Complete
  - Productivity values estimated
  - KBRA effects estimated
  - EDT analyses for capacity above Keno require hydrology

Status of Model Components II

- Downstream Migration – 50% Complete
  - SALMOD 2 up and running
  - WUA Curves generated
  - USBR hydrology for flow
  - HEC5Q for temperature
  - Calibration / Statistical fitting
- Disease – 90% Complete
  - Minor tweaks to mortality functions to match expectations

Schedule for Fish Production Model

- From point of hydrology finalization –
  - Roughly 6 weeks of work by modeling team
- Assuming hydrology finalized in next week:
  - FPM making deterministic forecasts of abundance by Nov. 15
  - FPM providing forecasts of abundance with uncertainty by Nov. 30.
  - Draft results to expert panel by mid-December
  - Reviewed results by mid – January 2011