STRUCTURED DECISION ANALYSIS TO INVESTIGATE DAM PASSAGE ALTERNATIVES FOR SPRING CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) IN THE MIDDLE FORK OF THE WILLAMETTE RIVER

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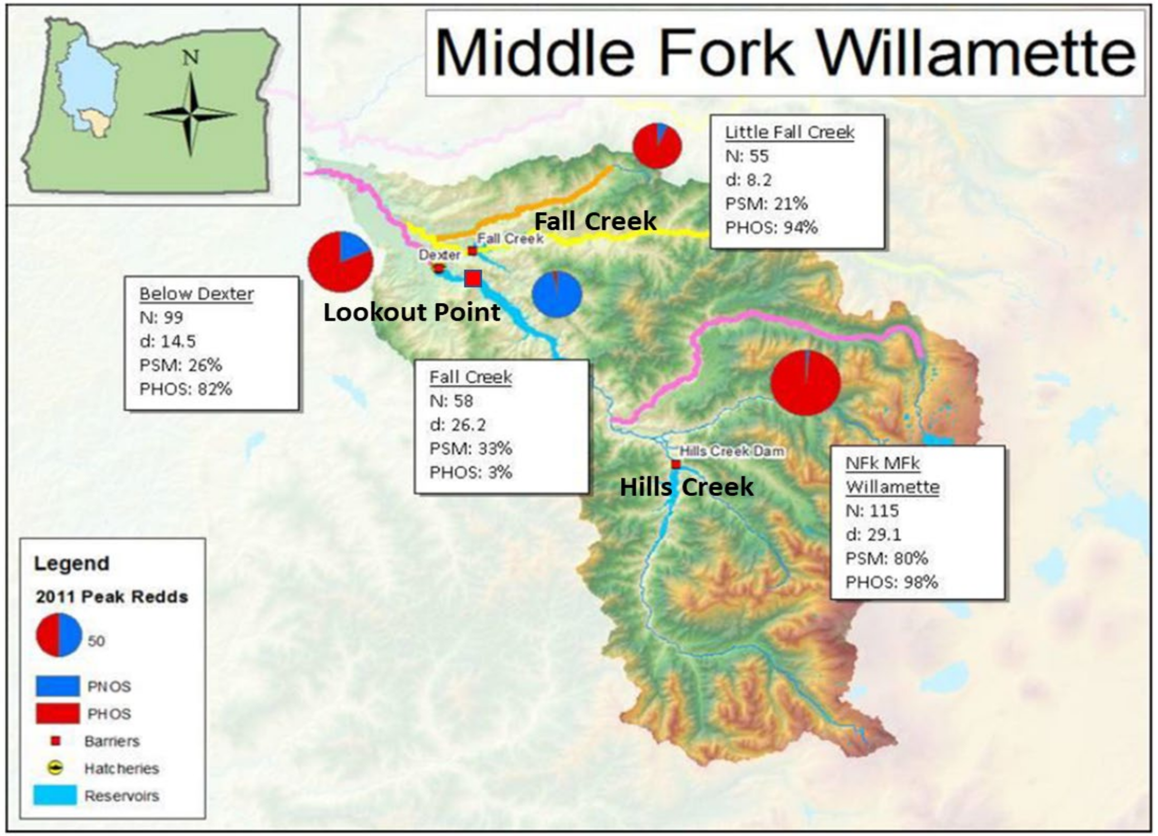
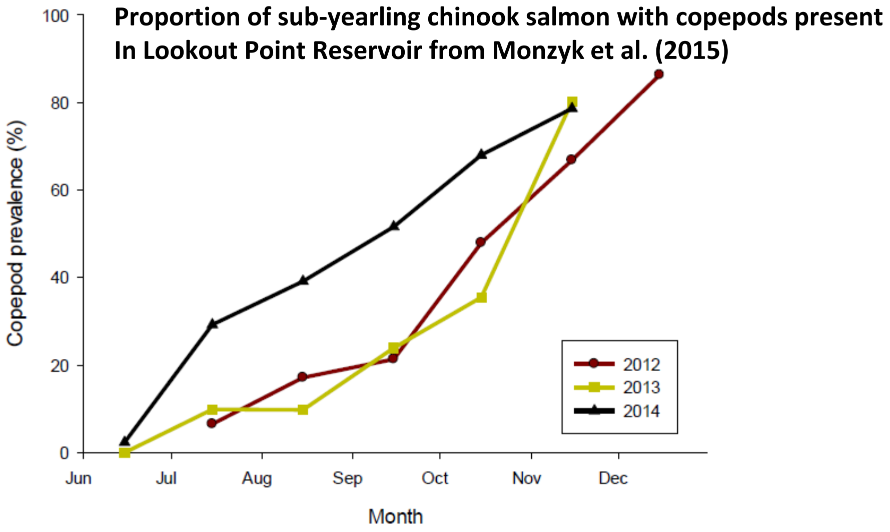


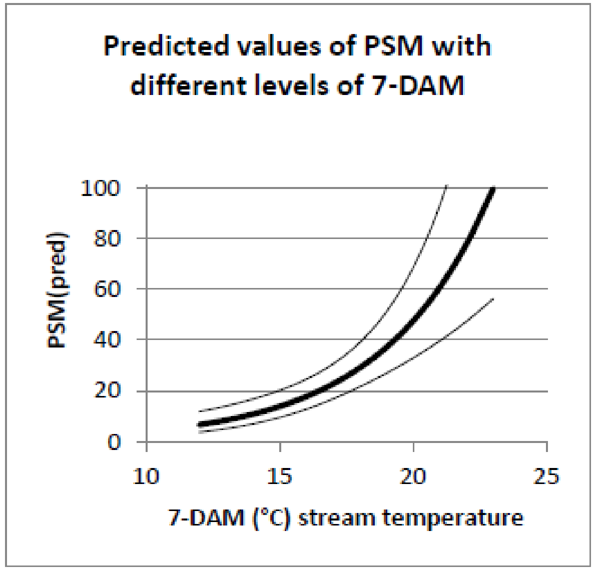
Hatchery Baseline Monitoring. Sharpe et al. (2013)

Integrated Passage Assessment

Achievement of successful dam passage faces several uncertainties

- **In-reservoir juvenile Chinook salmon survival rates**
- **Dam passage survival rates (DPS) for each juvenile life history type under each passage option**
- **Outmigration and smolt-adult survival rates**
- **Pre-spawn mortality (PSM) rates in returned adults**
- **Experiments and studies**
  - ***Liss et al. 2020, Kock et al. 2019; Murphy et al. 2020***
  - ***Enable hypotheses to be formulated on how passage options might work***





From Roumasset 2012

Choice of a set of passage options for the Middle Fork not straightforward

- **Difficult to predict how different candidate passage options could work**
- **The different passage options entail large trade-offs**
  - ***Can be costly to implement and maintain***
  - ***May involve reductions in power generation or other values, e.g., recreational***
- **Difficult to predict how hatchery operations should be adjusted to facilitate reestablishment of Natural Origin (NO) populations**
  - ***Due to low number of NO adults, hatchery adults needed for transplants***
  - ***High densities of juvenile and adult hatchery origin fish can negatively affect NO fish***

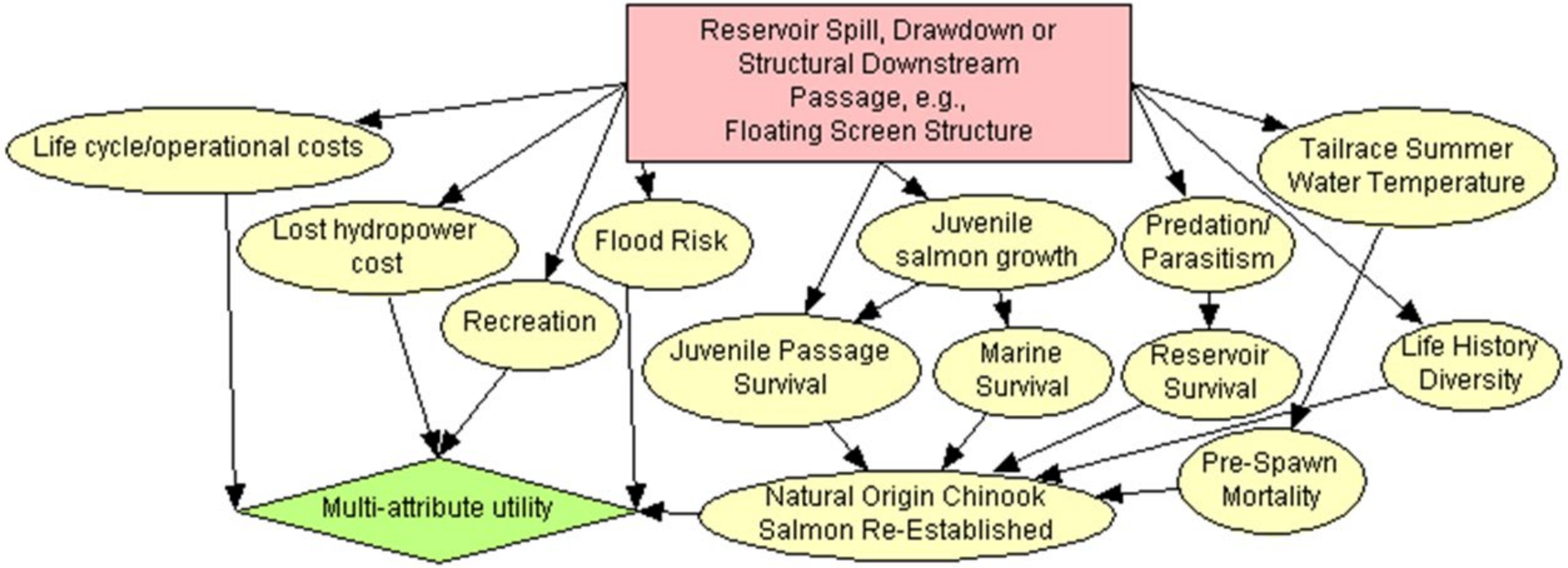
In 2019 Structured Decision Analysis (SDA) initiated to evaluate dam passage alternatives for spring chinook salmon in the Middle Fork

- **Raiffa 1968; Hilborn and Walters 1992; Punt and Hilborn 1996; Punt et al. 2016**
- **The aim of SDA is**
    - ***Not to make decisions***
    - ***Not to be prescriptive***
- **Aim is to inform decision makers about the potential consequences of the actions that can be taken**
- **SDA addresses the question**
    - ***How likely will management objectives be met under each potential course of action?***
- **An important feature of SDA is to test the sensitivity of outcomes of actions to uncertainties**
    - ***Adaptive management options can also be evaluated using SDA (Punt et al. 2016; Licandeo et al. 2020)***
- **Can rank actions according to**
    - ***Whether and how well objectives can be met***
    - ***Whether the trade-offs made are acceptable***
    - ***Their robustness to different uncertainties***

Steps of Structured Decision Analysis

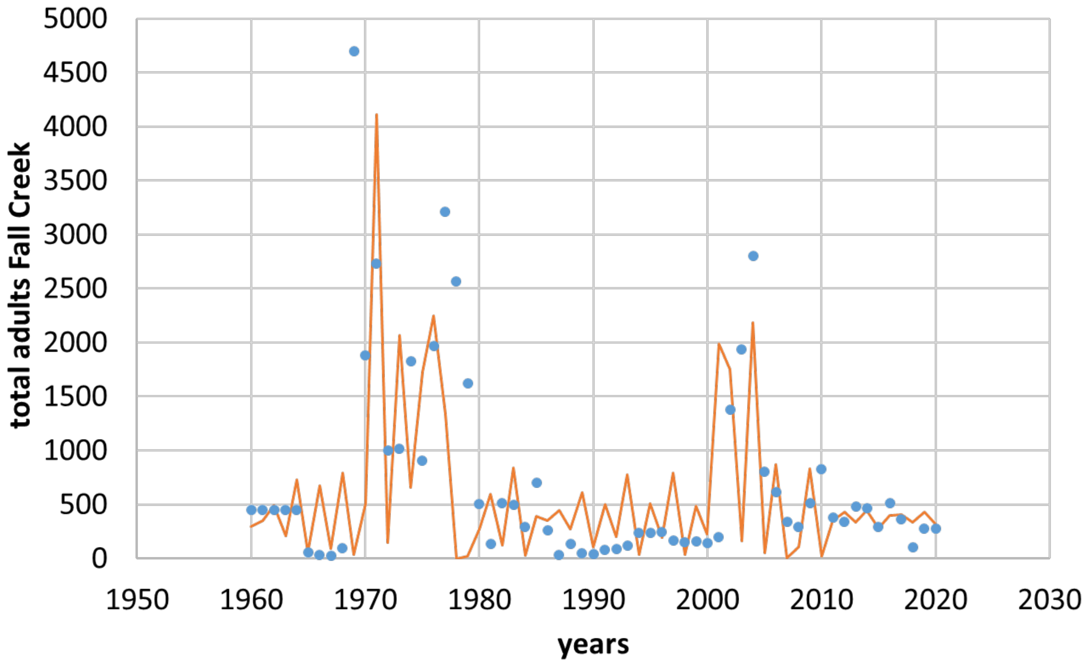
1. ***Identify a set of objectives to achieve, and associated performance metrics, O***
2. ***Identify a set of actions to evaluate, A, i.e., specific combinations from***
   - i. ***Reservoir operations, e.g., spill and drawdown options***
   - ii. ***Juvenile collection options***
   - iii. ***Predation and parasite controls***
   - iv. ***Fish facility, fish handling and dam modifications***
3. ***Identify uncertainties, represented by alternative scenarios (e.g., hypothesized states of nature), S***
4. ***Assign a probability, P, to each scenario S, to represent the credibility of each S.***
5. ***Calculate the potential outcome $O_{A,S}$ of each action A under each unique scenario, S***
6. ***Calculate the expected outcome $E(O_A)$ of each action across all of the alternative scenarios***

A Bayesian Decision Network for an Evaluation of Passage Options using Hugin BBN Software



Progress with SDA Steps for the Middle Fork

- **September 2019, Salem, Middle Fork SDA Workshop I**
  - ***Outlined the SDA approach, roles of participants***
  - ***Identified short and long term operational objectives, population objectives***
  - ***Identified alternative candidate passage options***
  - ***Identified sources of uncertainty***
- **February 2020, Corvallis, Middle Fork SDA Workshop II**
  - ***Reviewed operational and population objectives***
  - ***Formulated performance metrics***
  - ***Reviewed alternative actions***
  - ***Reviewed uncertainties***
  - ***Presented initial versions of Chinook salmon population dynamics models***



Model fit for spring chinook salmon in Fall Creek

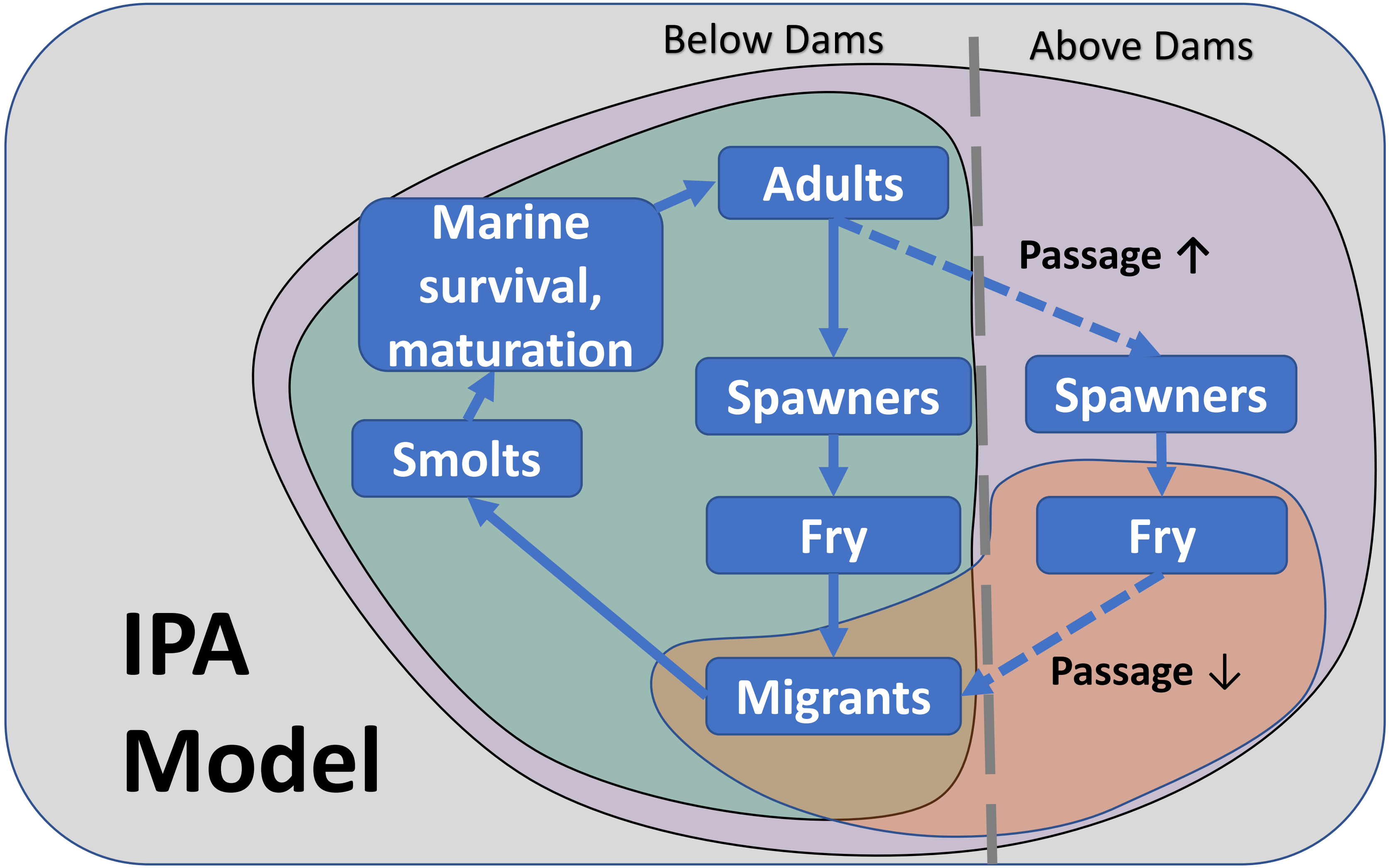
Long-term population-level objectives

Implement a passage approach (i.e., combination actions) such that the natural origin population that returns to the LOP/Dexter complex

1. ***Has a replacement rate of no less than 1 (average spawner to spawner ratio $\geq$ 1) for two generations***
2. ***Has a positive recovery signal (average spawner to spawner ratio >3) within four generations***
3. ***Has a spawner abundance exceeding 5% of carrying capacity by four generations***
4. ***Can sustain a commercial and recreational harvest program on natural origin fish after five generations***
   - ***e.g., recruits/spawner >2 where recruits = abundance just prior to the fishery***
5. ***Has a Viable Salmon Population (VSP) score > 3 (very low extinction risk)***

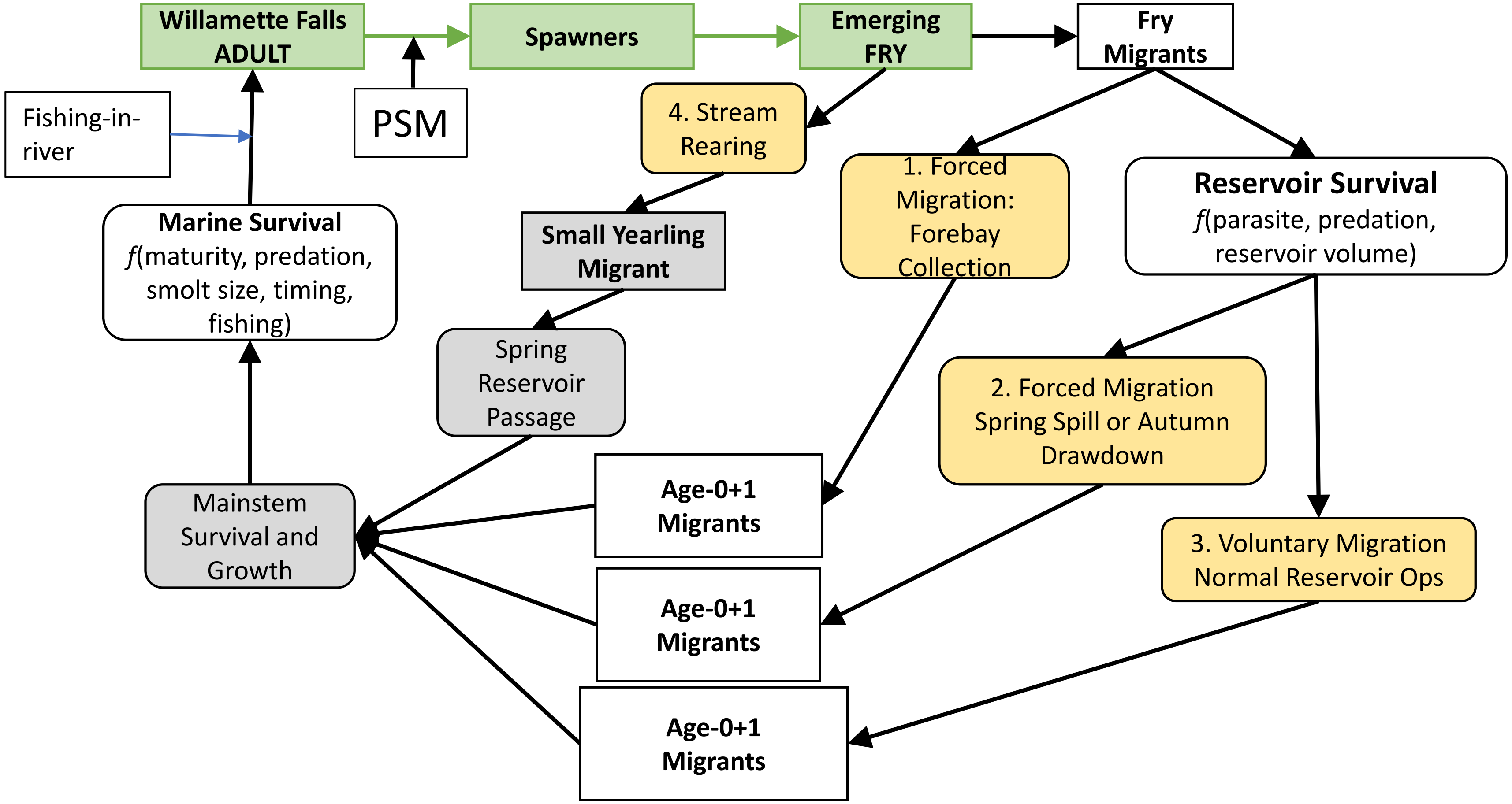
Integrated Passage Assessment (IPA) Model for Willamette Spring Chinook Salmon

- **Corps Fish Benefits Workbook (FBW) used to inform juvenile dam passage survival rates**
- **Previous studies used to inform**
  - ***Juvenile survival rates***
  - ***Spawner carrying capacity***
  - ***Egg-fry density dependence***
  - ***Smolt-adult survival (SAS) rates***
  - ***Pre-spawn mortality rates***
- **Water year type effects derived from PIT tag results and FBW-Resim outputs**



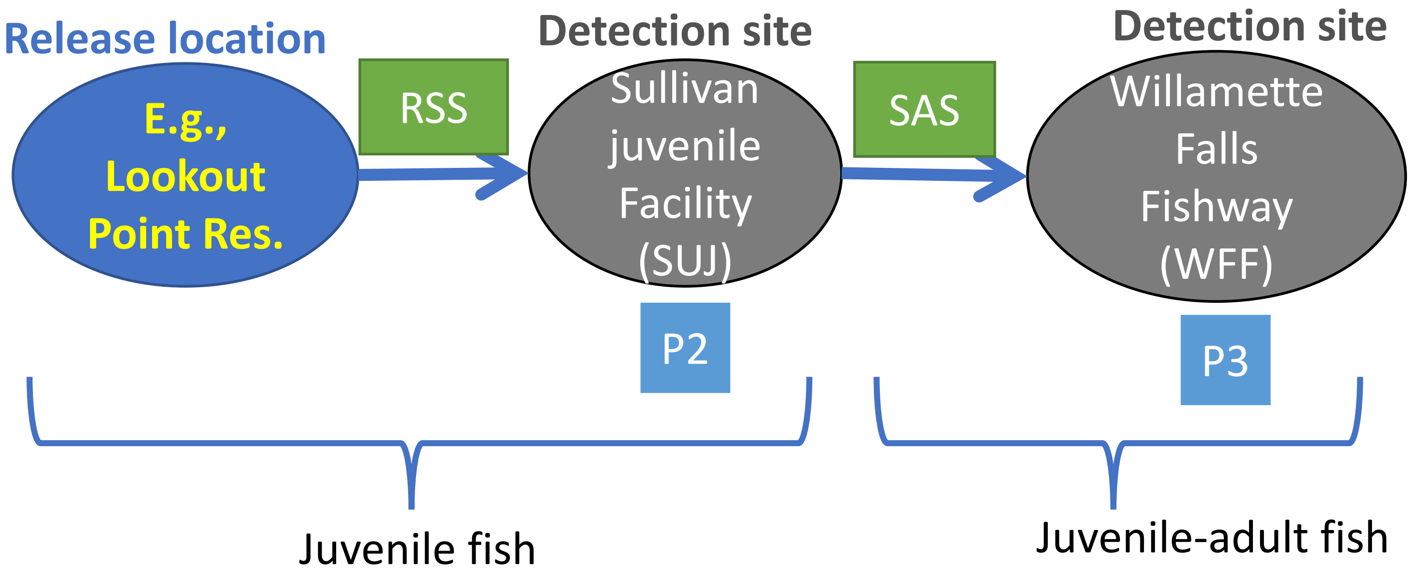
Life Cycle Model within Integrated Passage Assessment Model (IPA)

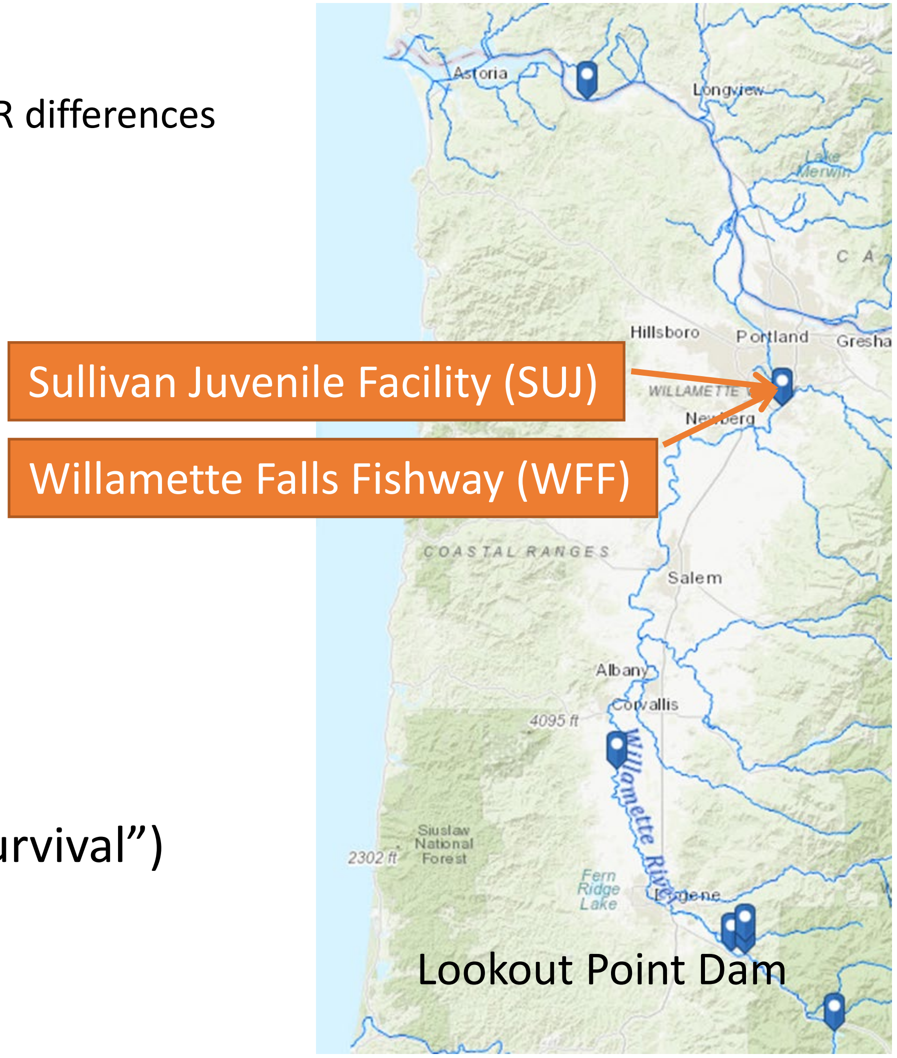
- **Includes main life history types for Spring Chinook Salmon**
- **Survival rates in multiple life history stages**
- **Density dependence in survival rates**



Estimation of stage-based survival rates

- Fitting Cormack-Jolly-Seber model to PIT tag release and detection records from the Middle Fork
- Bayesian approach
  - Prior distributions for detection rates, tag induced mortality, tag loss, NOR-HOR differences
  - Posterior distributions for survival rates used to parameterize IPA model





RSS: Survival rate from the release location to SUJ ("release-smolt survival")

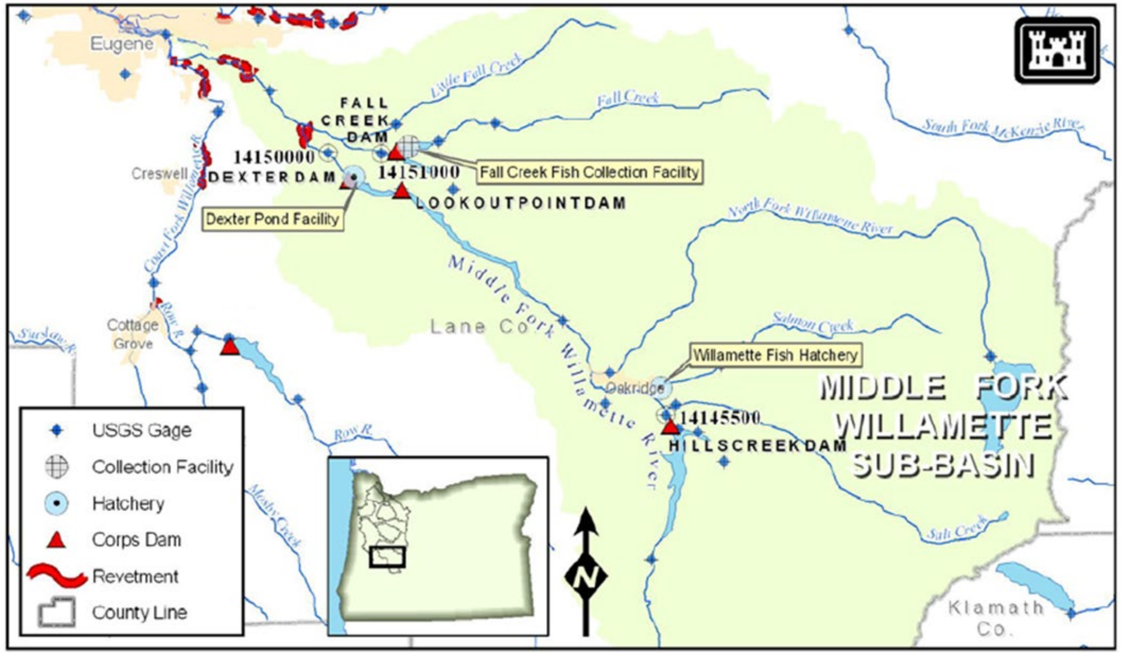
SAS: Survival rate from SUJ to WFF ("smolt-adult" survival)

P2: Detection rate at SUJ

P3: Detection rate at WFF

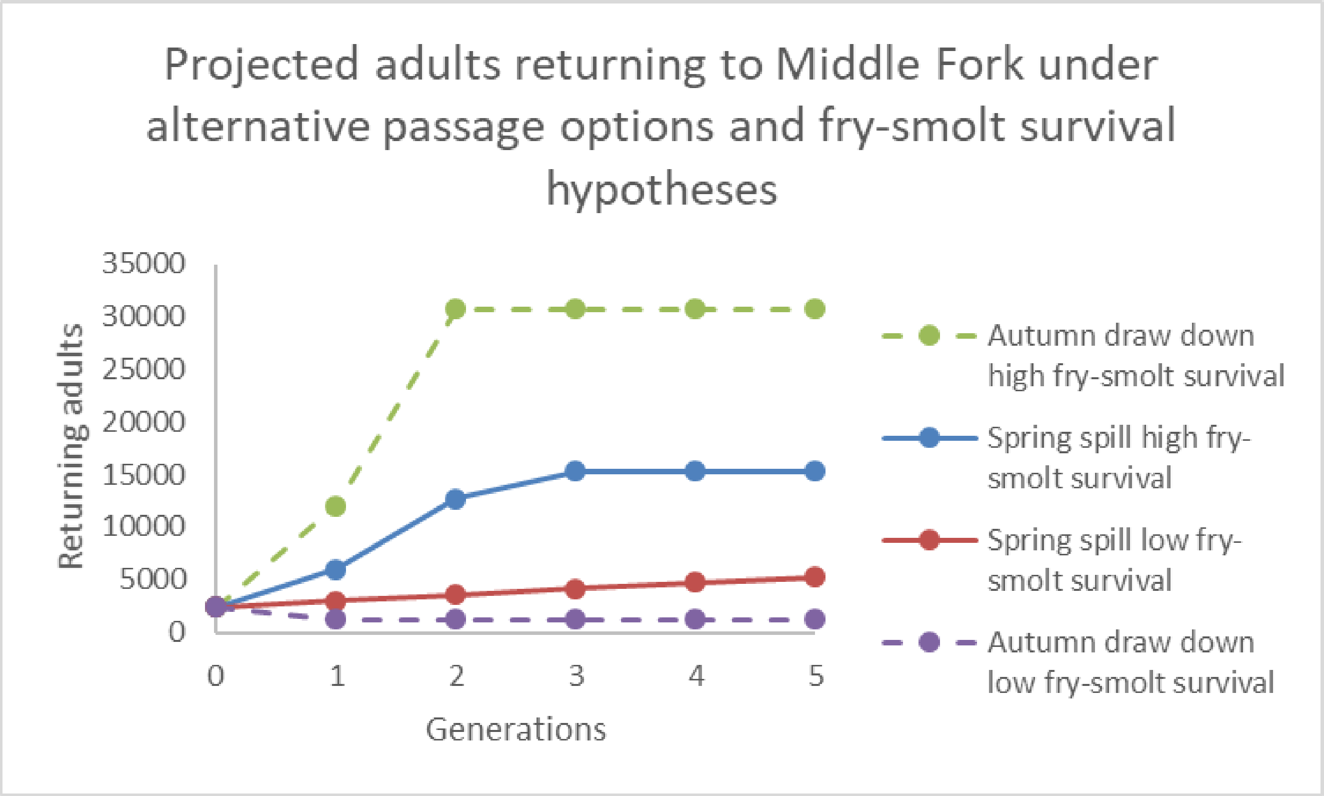
Illustration of IPA calculations to evaluate alternative passage options in the Middle Fork

- **Evaluation of two alternative passage options for the Lookout Point Reservoir**
    1. ***Spring Spill***
    2. ***Autumn drawdown***
- **Uses estimates of survival rates obtained from PIT tag experiments**
    1. ***Paired release experiments 2011-2014 in the Middle Fork***
    2. ***Single release experiment in Fall Creek Reservoir in 2013***
- **Applies adjustments to apparent survival rate estimates**
    - ***Tag induced mortality, tag loss, differences between hatchery and wild fish***
- **Assumes initiation of an "aggressive" re-introduction effort**
    - ***Implementation every year of each option as water conditions allow***
- ***Focuses on uncertainty in fry-smolt survival rates associated with each passage option***
    - ***Spring spill: fry-smolt survival will depend on the frequency of conditions for good spring spill***
    - ***Autumn drawdown: in-reservoir survival rates could be enhanced if predation/parasitism reduced***



Example IPA: Spring spill vs Autumn Drawdown for Lookout Point Reservoir

- **Transplant a minimum of 2450 adults/ year above the Lookout Point Reservoir**
- **Beverton-Holt density dependence in egg-fry survival**
- **Average pre-spawn mortality rate of 35%**
- **Average smolt-adult survival rate of 3.4%**
- **Projected for five generations**



Example Decision Table: Spring spill vs Autumn drawdown for Lookout Point Reservoir

	Hypotheses		
Fry-Smolt Survival	low	high	
Probability	0.5	0.5	Expected Value
Spring Spill	5744	15,316	10,530
Autumn drawdown	1200	30,682	15,941

- **Table shows the expected number of <u>returning adults</u> in the fifth generation**
- **Long-term population objectives 1-4 <u>could</u> be met by either spring spill or autumn drawdown**
- **Autumn drawdown has highest expected value but could be inferior if fry-smolt survival turns out be low**
- **Value of information high: 2272 adults or 14% of total expected value of apparent best action**

Conclusions: Structured Decision Analysis

1. **Provides a collaborative approach for the evaluation of dam passage options**
2. **Requires agreement on the operational and long-term population objectives to be achieved**
3. **Allows different sources of uncertainty to be explicitly addressed**
   - ***Allows quantification of the value of information for different passage options***
4. **Allows the alternative passage options to be ranked according to**
   - ***Whether and how well each of the objectives can be met***
   - ***Whether the trade-offs made are acceptable***
   - ***Robustness to different uncertainties***

Acknowledgments

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