Steelhead Overshoot Update

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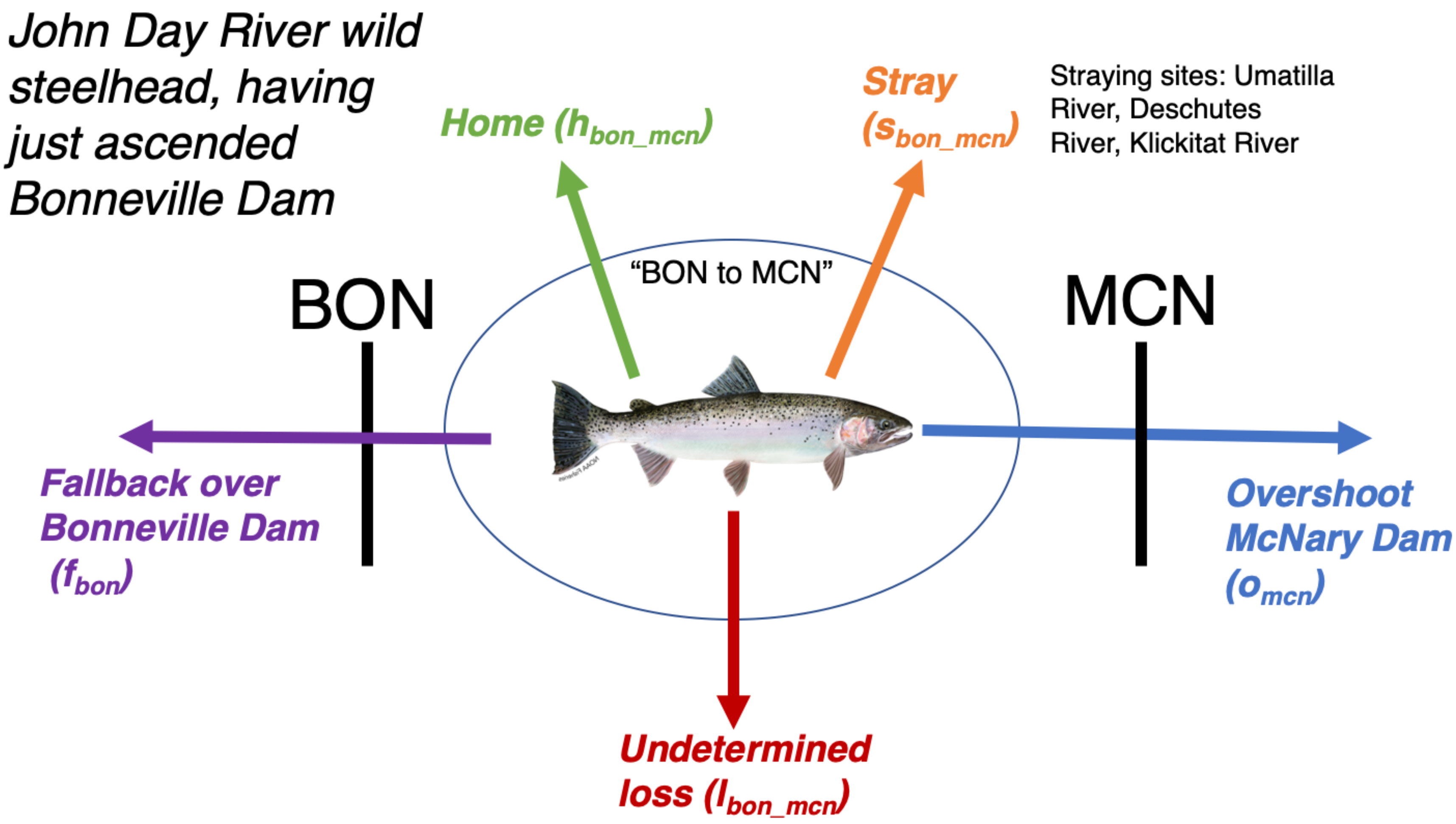
4/7/2022

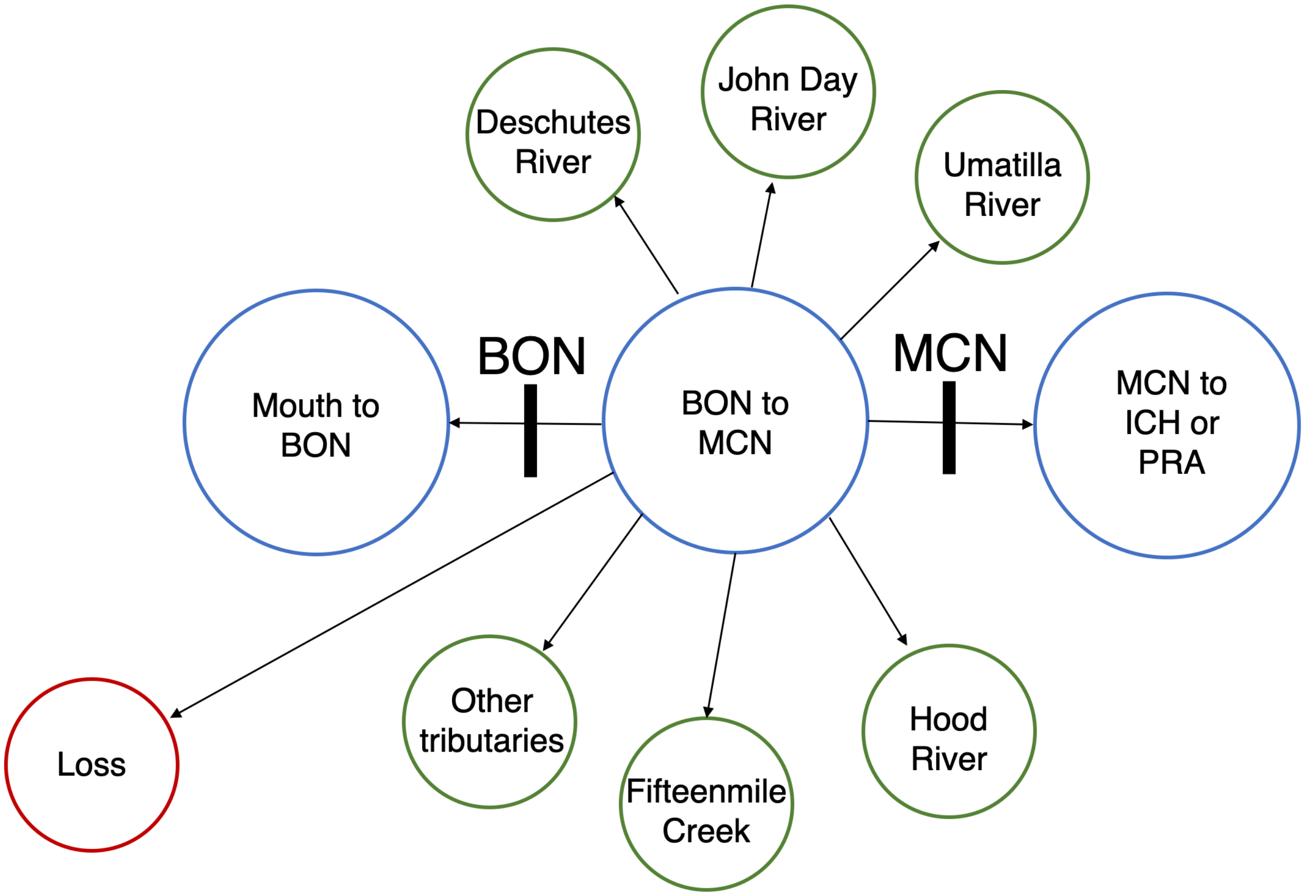
Changes to model

Expanding the number of states



Expanding the number of states

An individual in the BON to MCN state now has these movement options:



Previous approach: Multinomial likelihood

- Get a vector of probabilities *p* with length *K*, where *K* is the number of unique observed detection histories
- In the John Day River dataset, *K* = 169 (169 unique detection histories)
- Example:

$$n_7 = f_{bon} * o_{bon} * f_{bon} * o_{bon} * h_{bon\_mcn} * l_{nat\_trib}$$
$$p[7] = n_7$$

Previous approach: Multinomial likelihood

```
p <- c(n1, n2, n3, ... n169)

# Evaluate counts, where y are the counts of
# the number of times each of the unique detection
# histories was observed

# 2121 are the number of fish
y[1:N] ~ dmulti(p[1:N], 2121)
```

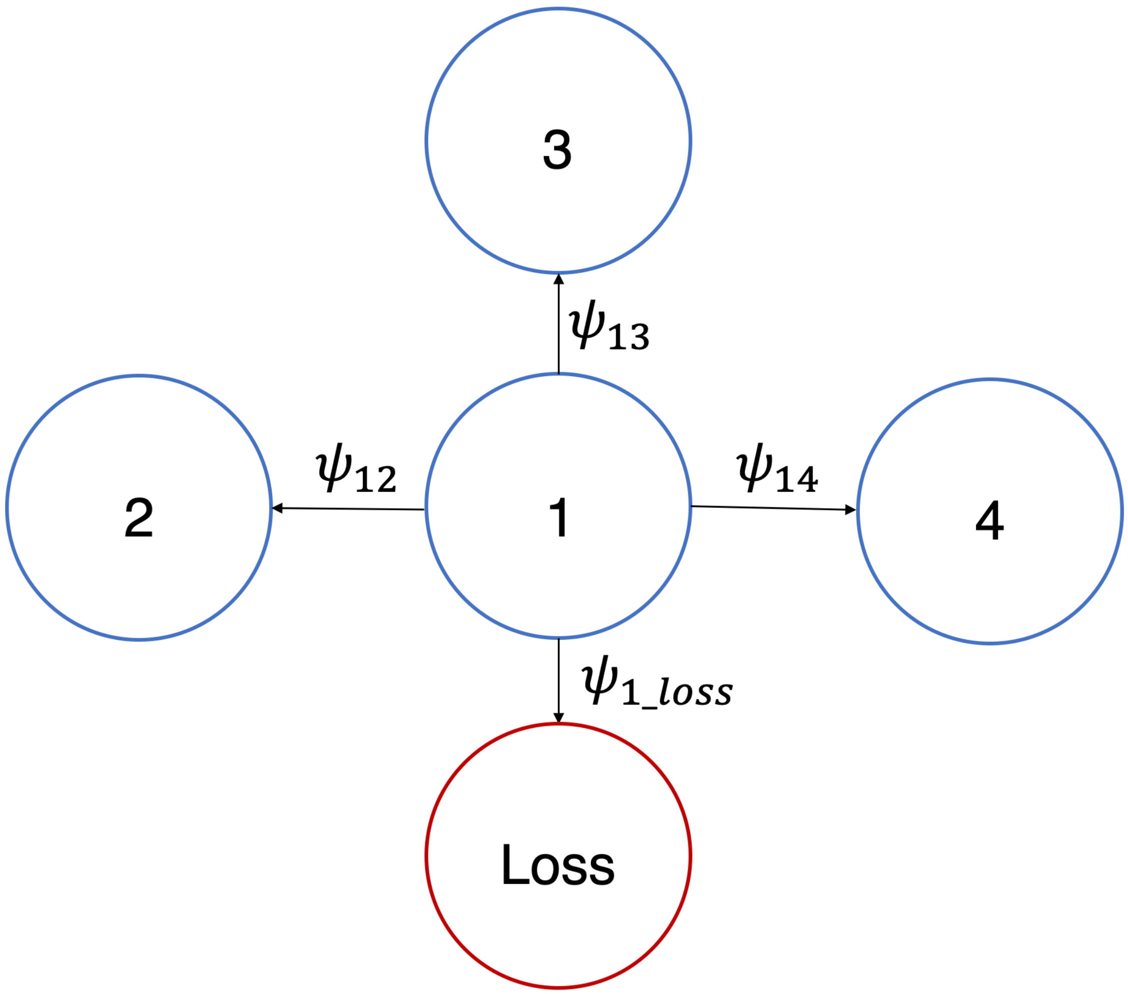
Multinomial likelihood no longer works with covariates

For fish *i* at location *l* at time *t*:

$$\psi_{12} = f(temperature_{l,t}, origin_i)$$

- Each movement probability is different for each individual fish, depending on the unique combination of covariates that it is experiencing
- Therefore, a multinomial likelihood, or using an m-array approach to summarize detection histories, becomes untenable, or at least very complicated

Moving to an individual-based model



Moving to an individual-based model

```
for(i in 1:n.ind){ # Loop through all individuals
  for(j in 1:n.encounters){ # Loop through the encounters (detections)
    psi_12 <- f(origin[i], temperature[j])
    psi_13 <- f(origin[i], temperature[j])
    psi_14 <- f(origin[i], temperature[j])
    psi_1_loss <- 1 - psi_12 - psi_13 - psi_14

    # Likelihood: evaluate multinomial with single trial (categorical)

    # Get a vector of probabilities
    p <- c(psi_12, psi_13, psi_14, psi_1_loss)

    # y is an array, with dimensions (number of fish) X
    # (number of possible states) X (number of encounters)

    # y[i,,j] is the vector containing all possible next states for a fish
    y[i,,j] ~ dmulti(p, 1)
  }
}
```

Example: y[i, ,] matrix

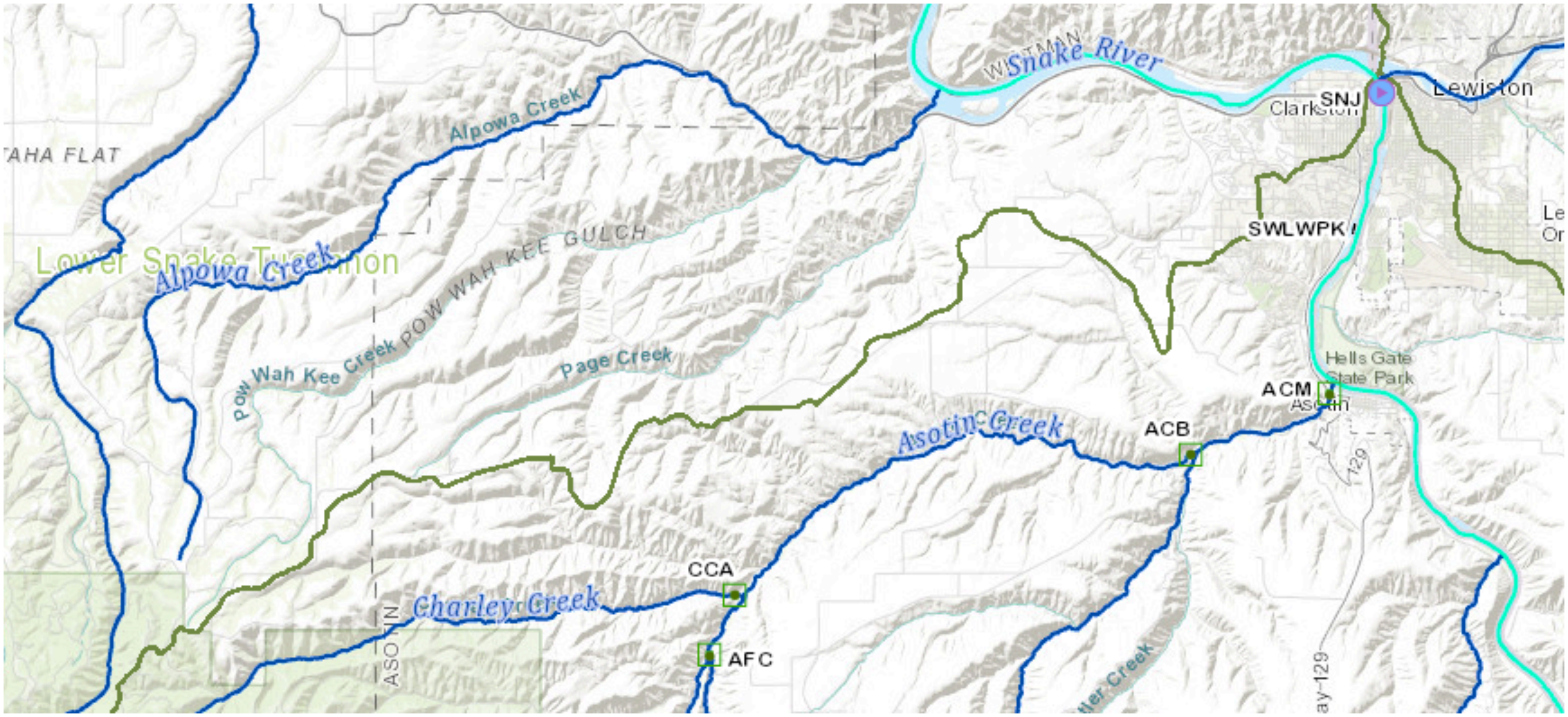
```
##                               [,1] [,2] [,3] [,4] [,5]
## mainstem, mouth to BON           0    0    0    0    0
## mainstem, BON to MCN             1    0    1    0    0
## mainstem, MCN to ICH or PRA      0    1    0    0    0
## mainstem, PRA to RIS             0    0    0    0    0
## mainstem, RIS to RRE             0    0    0    0    0
## mainstem, RRE to WEL             0    0    0    0    0
## mainstem, upstream of WEL        0    0    0    0    0
## mainstem, ICH to LGR             0    0    0    0    0
## mainstem, upstream of LGR        0    0    0    0    0
## Asotin Creek                     0    0    0    0    0
## Clearwater River                 0    0    0    0    0
## Deschutes River                  0    0    0    0    0
## Entiat River                     0    0    0    0    0
## Fifteenmile Creek                0    0    0    0    0
## Grande Ronde River               0    0    0    0    0
## Imnaha River                     0    0    0    0    0
## John Day River                   0    0    0    1    0
## loss                             0    0    0    0    1
```

Including covariates

- Enforcing sum to 1 constraint with covariates via the multinomial logit

$$\psi_{12} = \frac{\exp(\beta_{0,12} + \beta_{temp,12} * temp + \beta_{origin,12}[origin])}{1 + \exp(\beta_{0,12} + \beta_{temp,12} * temp + \beta_{origin,12}[origin]) + \exp(\beta_{0,13} + \beta_{temp,13} * temp + \beta_{origin,13}[origin]) + \exp(\beta_{0,14} + \beta_{temp,14} * temp + \beta_{origin,14}[origin])}$$

Detection probabilities - auxiliary likelihoods?

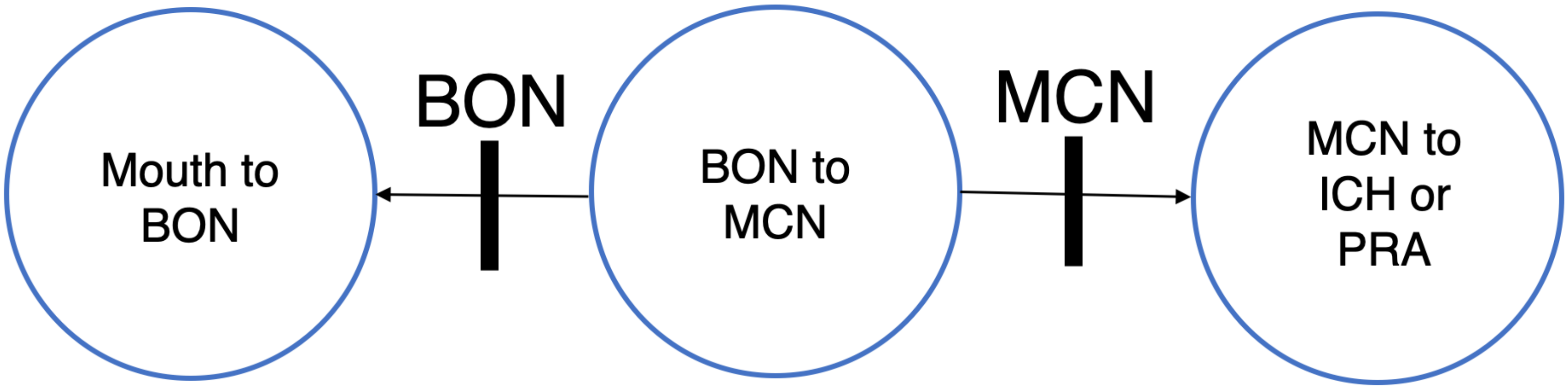


New approach to covariate time window

Old approach and issues:

- Old approach: Determine the median travel time from one dam to the next dam for each month and each natal origin; get the average value of the variable (e.g., temperature) for the weeklong window around that time
- This works well for upstream travel, but with downstream travel, we don’t typically know when individuals entered states because of the low detection probability with downstream travel

Old approach and issues:



- Our state-based model also doesn't assume the direction a fish is traveling when in a given state, so calculating a median travel time (either upstream or downstream) is problematic

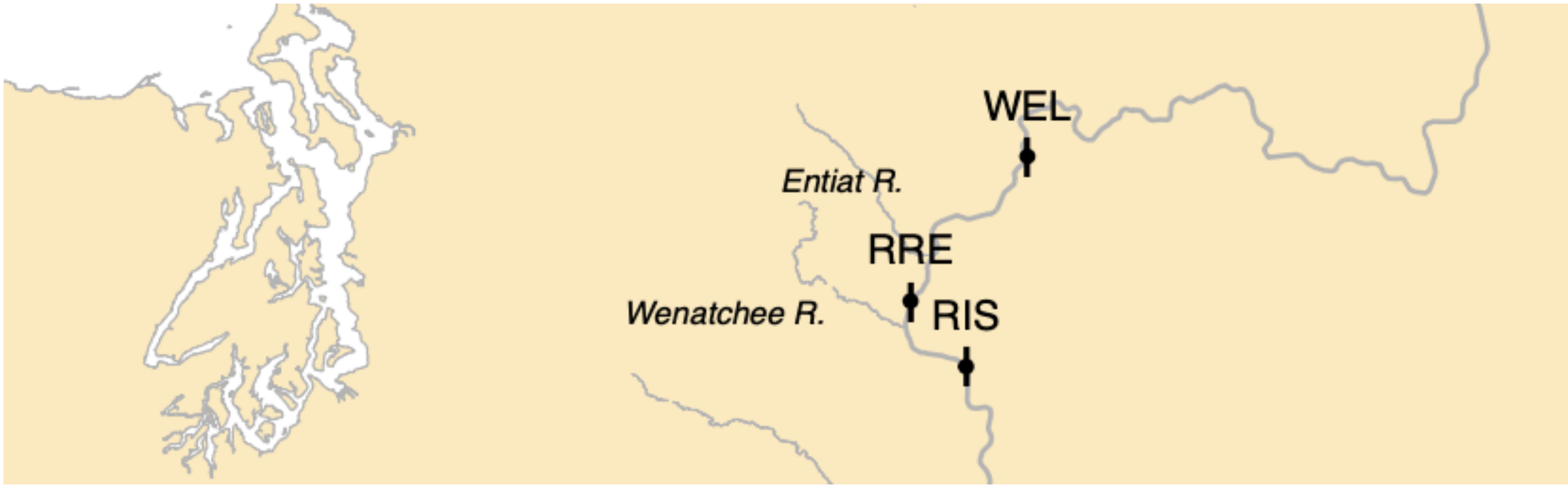
New approach:

- Calculate an “experience date”, from the time at arrival in state 1 and the time at arrival at state 2, which are typically known (e.g., the date + time that an individual was seen in the adult fish ladder at a dam)
- Calculate the time spent in this state as (time at arrival in state 2) - (time at arrival in state 1)
- Get the “experience date” by dividing the time spent in the state by 2 (this is equivalent to the median time in the state)

```
##               state     pathway arrival_date   exp_date
## 1        BON to MCN BON (adult)   2010-07-24 2010-08-23
## 2 MCN to ICH or PRA MCN (adult)   2010-09-22       <NA>
```

New approach:

- If the arrival time in a state is not known (i.e., the site visit was implicit), then take the halfway point between two known site arrivals as the arrival time in the implicit state
- If there were N implicit site visits between known arrival times, divide the time between the two known arrival times by N+1 to estimate the time spent in each state




```
##              state           date_time     pathway   date_source arrival_date
## 1       RRE to WEL 2011-05-03 09:23:37 RRE (adult) known_arrival   2011-05-03
## 2       RIS to RRE                <NA>    implicit  interpolated   2011-05-07
## 3 Wenatchee River 2011-05-11 04:09:47   WEN_sites known_arrival   2011-05-11
```

New approach: Example detection history

```
##                 state             pathway arrival_date   exp_date
## 1          BON to MCN         BON (adult)   2010-07-24 2010-08-23
## 2 MCN to ICH or PRA         MCN (adult)   2010-09-22 2010-09-25
## 3          PRA to RIS         PRA (adult)   2010-09-28 2010-09-30
## 4          RIS to RRE         RIS (adult)   2010-10-02 2011-01-09
## 5          RRE to WEL         RRE (adult)   2011-04-18 2011-04-22
## 6          RIS to RRE RRE_fallback_arrays   2011-04-27 2011-04-30
## 7          RRE to WEL         RRE (adult)   2011-05-03 2011-05-05
## 8          RIS to RRE            implicit   2011-05-07 2011-05-09
## 9     Wenatchee River           WEN_sites   2011-05-11 2011-05-11
```

Indexing to covariate by state (location) and "experience date"

```
##        state              pathway arrival_date   exp_date
## 5 RRE to WEL          RRE (adult)   2011-04-18 2011-04-22
## 6 RIS to RRE RRE_fallback_arrays   2011-04-27 2011-04-30
```

```
##         date ICH.to.LGR BON.to.MCN PRA.to.RIS RIS.to.RRE RRE.to.WEL
## 1 2011-04-22     8.4292     8.0042     6.4667     6.3833     6.3043
## 2 2011-04-23     8.5250     8.1417     6.5750     6.4042     6.4333
## 3 2011-04-24     8.8083     8.2917     6.6292     6.5292     6.6417
## 4 2011-04-25     8.8750     8.5125     6.7875     6.6875     6.7667
## 5 2011-04-26     9.0458     8.6417     6.9000     6.7958     6.8417
## 6 2011-04-27     9.3375     8.6833     6.9542     6.9083     6.9083
## 7 2011-04-28     9.5792     8.7500     7.1478     7.0261     6.9909
## 8 2011-04-29     9.6583     8.7708     7.2042     7.0792     7.0542
## 9 2011-04-30     9.6083     8.7417     7.2125     6.2500     6.9417
```

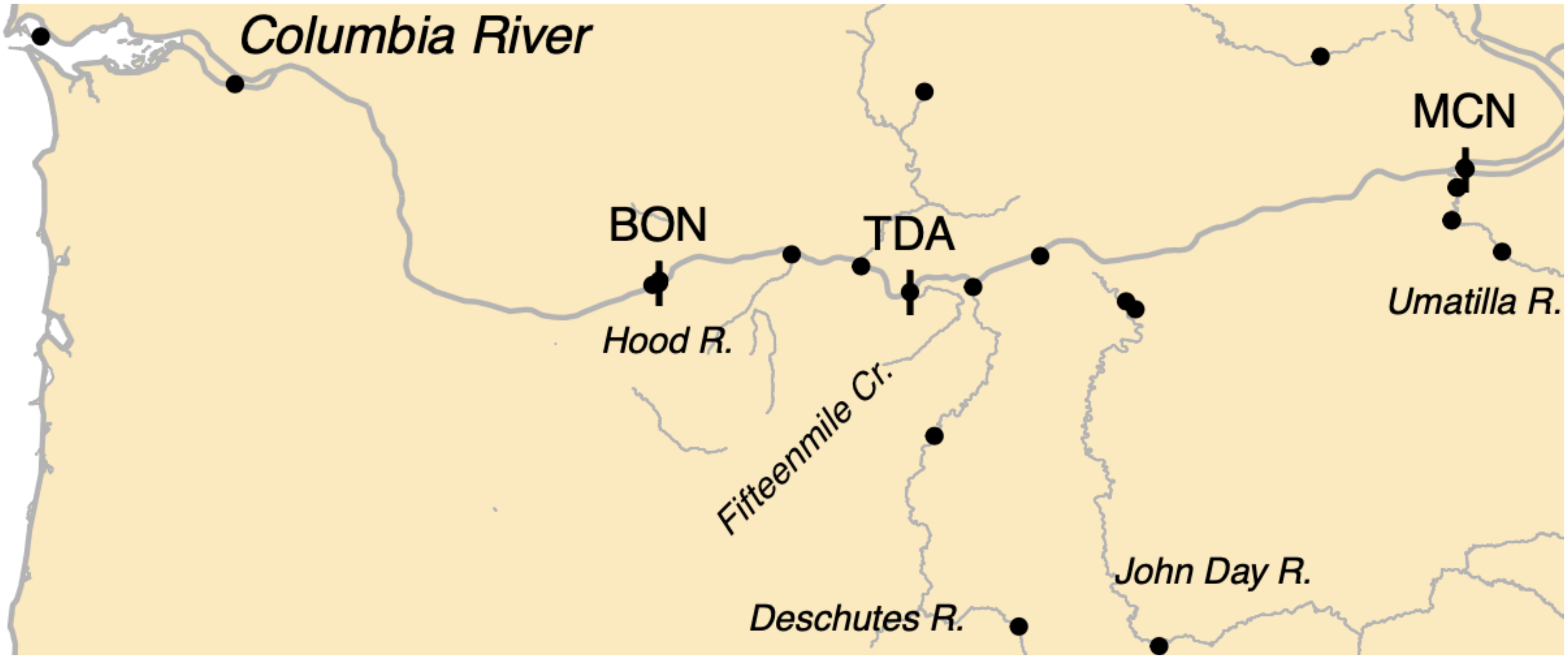
Problem: What to do at branching states?

MCN to PRA or ICH

- Two dams with covariate data at this state: PRA tailrace and ICH tailrace
- Potential solution could be to include the covariates (temperature, spill, flow) at both dams as covariates for just this state
- Could have temperature at PRA tailrace be covariate for ascending PRA, and temperature at ICH tailrace be covariate for ascending ICH

New potential covariate: time in a state

For individuals who are in the “mainstem, BON to MCN” state, how long does it take them to reach the next state?



Time in a state: directionality issue

Individuals in BON to MCN state who just ascended BON

```
## # A tibble: 8 × 2
##   next_state                    `median time (days)`
##   <chr>                                        <dbl>
## 1 Umatilla River                               126. 
## 2 John Day River                                79.5
## 3 BON to MCN other tributaries                  21  
## 4 mainstem, MCN to ICH or PRA                   14  
## 5 Deschutes River                                7  
## 6 Fifteenmile Creek                              7  
## 7 Hood River                                     4  
## 8 mainstem, mouth to BON                         0  
```

Time in a state: directionality issue

Individuals in BON to MCN state who did not just ascend BON

```
## # A tibble: 6 × 2
##   next_state                        `median time (days)`
##   <chr>                                            <dbl>
## 1 John Day River                                    64  
## 2 BON to MCN other tributaries                      62  
## 3 Umatilla River                                    51  
## 4 mainstem, mouth to BON                            46  
## 5 Deschutes River                                    5.5
## 6 mainstem, MCN to ICH or PRA                        1
```

Note: no individuals entered Hood River or Fifteenmile Creek next

Missing covariate data

- How do we handle missing covariate data?
- Does missing covariate data indicate no flow?