Modeling freshwater survival of wild juvenile steelhead

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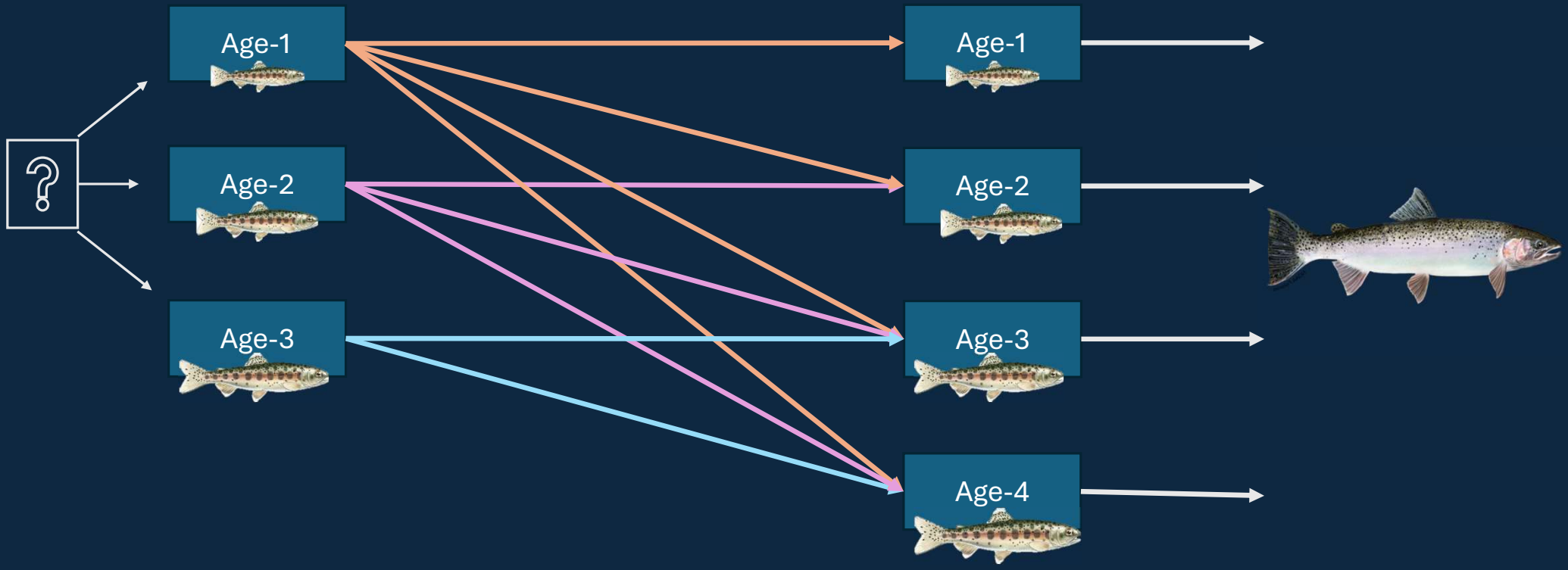
Objectives

- Develop a mark-recapture model for juvenile steelhead
  - Estimate age-specific survival
  - Life history contributions to smolt abundance
  - Relate survival to environmental and biotic factors


Age-1
Age-2
Age-3
Age-1
Age-2
Age-3
Age-4

Model details

- Mark-recapture model
- Observed data likelihood (Hance et al. 2020)
- Incorporates uncertainty in age using an age sub-model
- Includes covariates via GLM (generalized linear models)
- Bayesian (Stan)
- Flexible generalizability to other systems

RST

1st dam

2nd dam

Age

1 → 1 → 1

2 → 2 → 2

3 → 3 → 3

4 → 4

Age-1 survival = $\theta_{1-1} + \theta_{1-2} + \theta_{1-3} + \theta_{1-4}$

Age-2 survival = $\theta_{2-2} + \theta_{2-3} + \theta_{2-4}$

Age-3 survival = $\theta_{3-3} + \theta_{3-4}$

RST

1st dam

2nd dam

Age

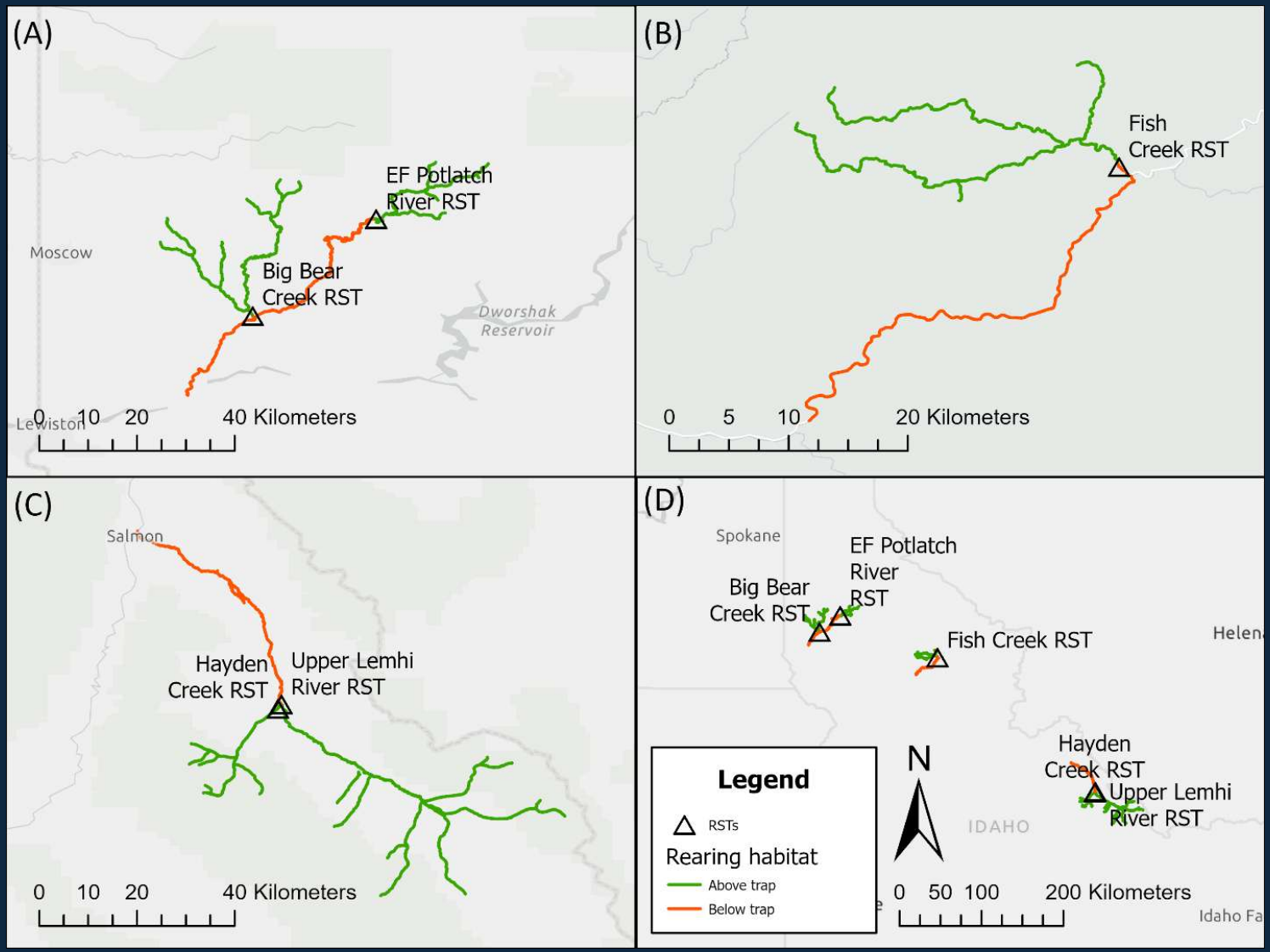
θ_{1-1} θ_{1-2} θ_{1-3} θ_{1-4} θ_{2-2} θ_{2-3} θ_{2-4} θ_{3-3} θ_{3-4}

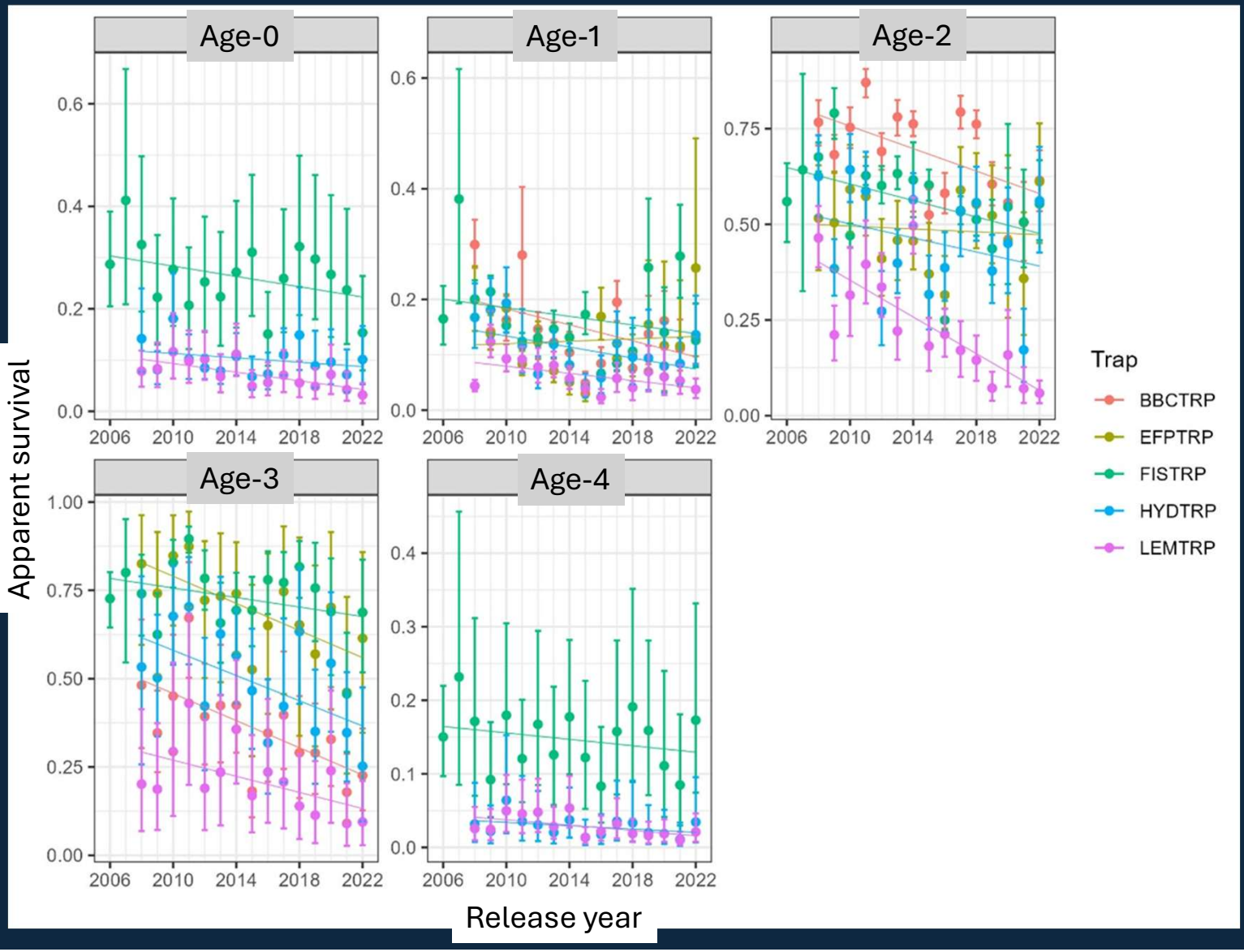
θ

p

What do you need

- Initial capture where fish are tagged (individually identifiable)
- At least two downstream recapture sites (i.e. PIT array)
- Auxiliary info on all fish (i.e. fork length)
- Ages for some fish


(A)
EF Potlatch
River RST
Moscow
Big Bear
Creek RST
Dworshak
Reservoir
Lewiston
0 10 20 40 Kilometers
(B)
Fish
Creek RST
0 5 10 20 Kilometers
(C)
Salmon
Hayden
Creek RST
Upper Lemhi
River RST
0 10 20 40 Kilometers
(D)
Spokane
EF Potlatch
River
RST
Big Bear
Creek RST
Fish Creek RST
Helen
Hayden
Creek RST
Upper Lemhi
River RST
IDAHO
Legend
RSTs
Rearing habitat
Above trap
Below trap
N
0 50 100 200 Kilometers
Idaho Fa

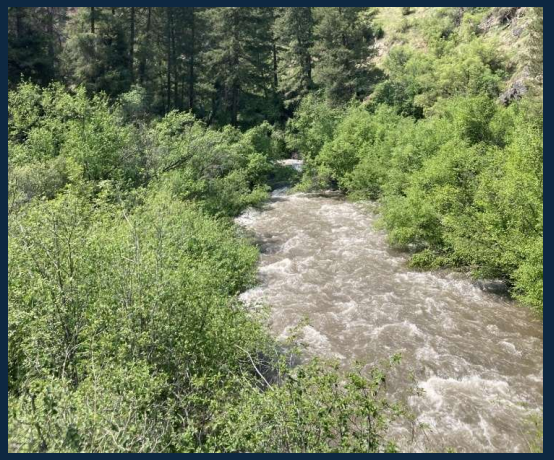

Age-0
Age-1
Age-2
Age-3
Age-4
Apparent survival
Release year
Trap
BBCTRP
EFPTRP
FISTRP
HYDTRP
LEMTRP
2006
2010
2014
2018
2022

Covariates

Biotic
- Female spawner abundance
- Juvenile abundance (at RST)

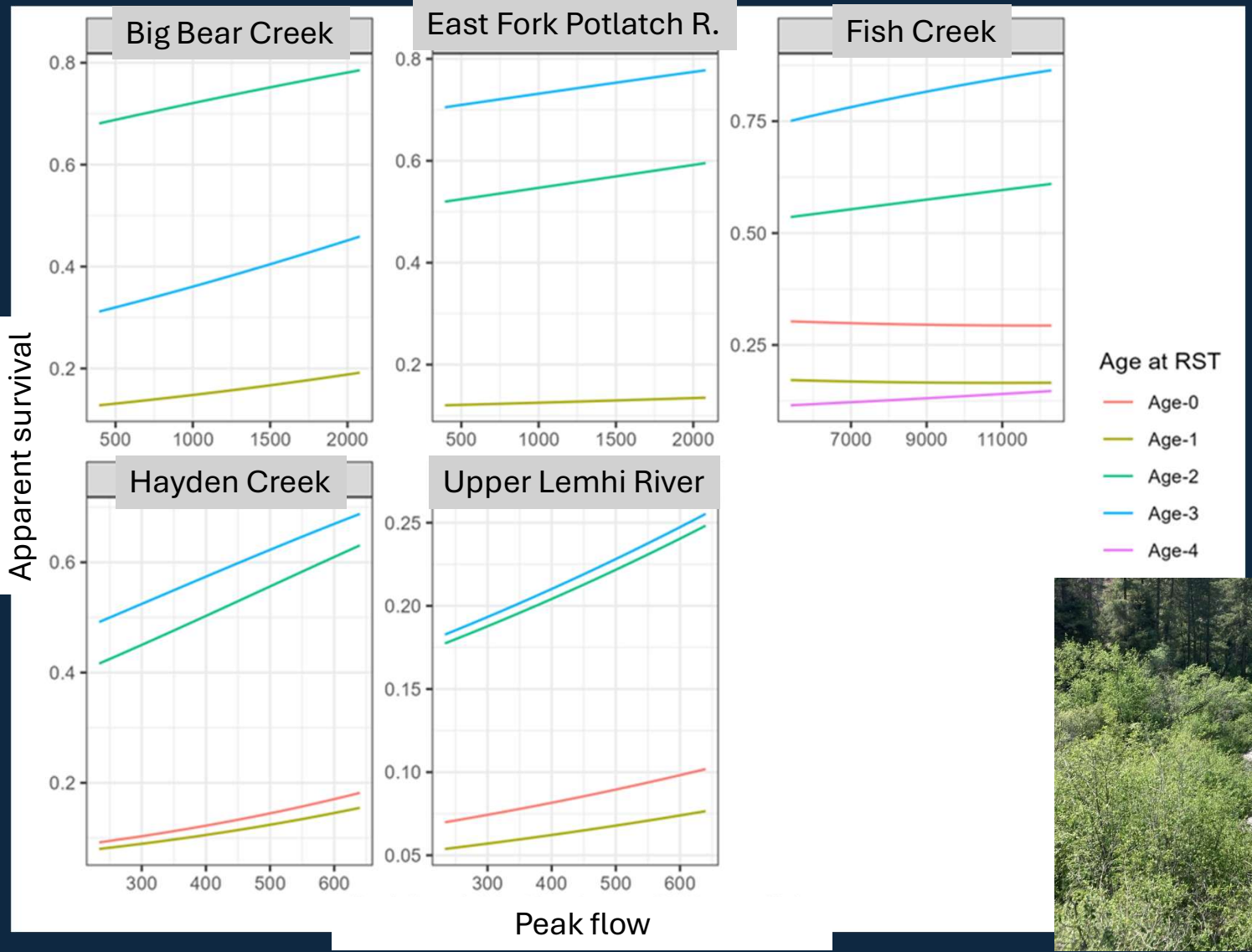
Environmental
- Peak flow (90% quantile of daily mean flow)
- Low flow (10% quantile of summer/fall flow)
- Stream temperature above RST
- Stream temperature below RST

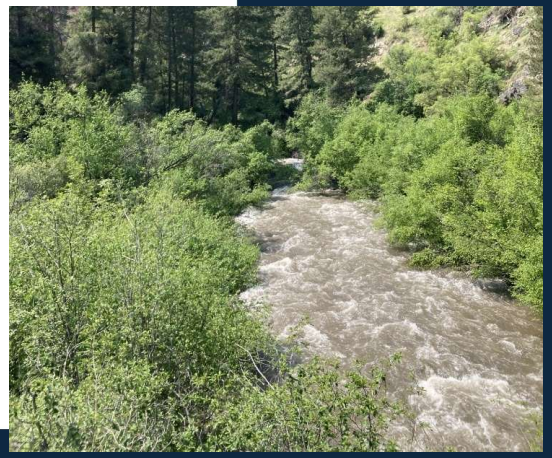
Individual
- Fork length

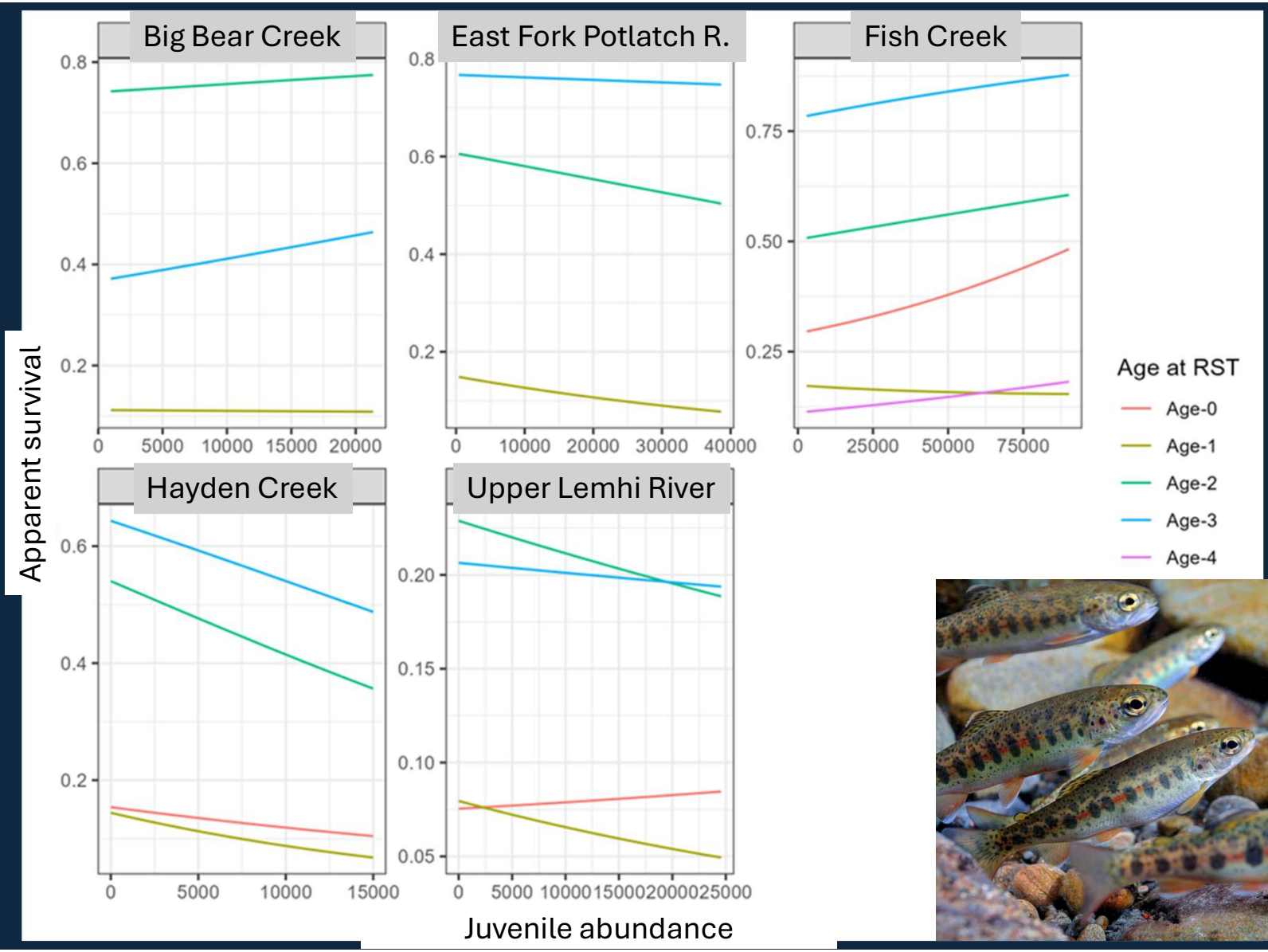


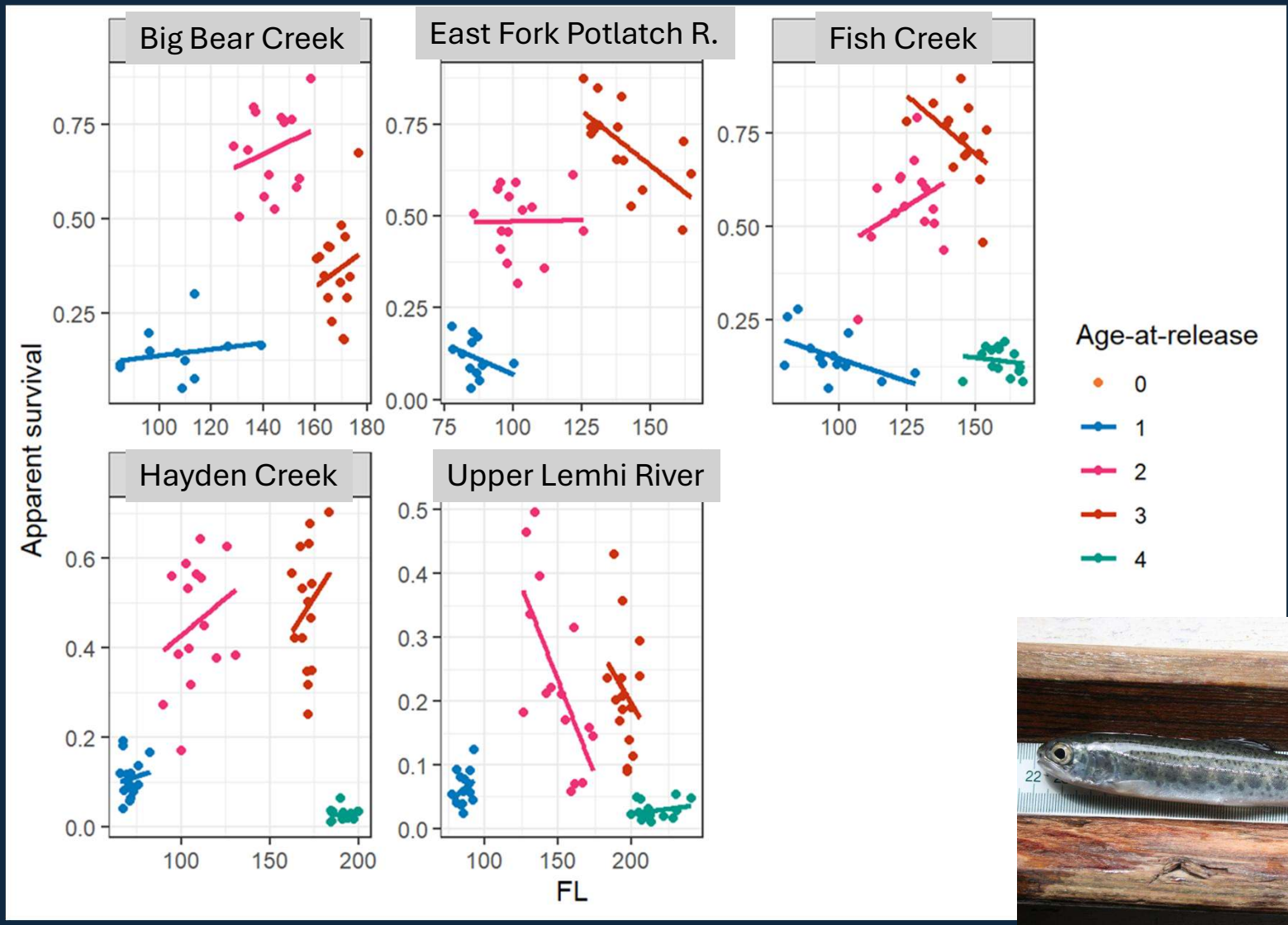
Model selection (preliminary)

- Fitted the full mark-recapture model
  - Fit covariates to the estimated cohort transition rates
- Evaluated a limited set of models with different combinations of 2 or 3 covariates
  - Best model included peak flow and juvenile abundance


Big Bear Creek
East Fork Potlatch R.
Fish Creek
Hayden Creek
Upper Lemhi River
Apparent survival
Peak flow
Age at RST
Age-0
Age-1
Age-2
Age-3
Age-4




Big Bear Creek
East Fork Potlatch R.
Fish Creek
Hayden Creek
Upper Lemhi River
Apparent survival
Juvenile abundance
Age at RST
Age-0
Age-1
Age-2
Age-3
Age-4


Big Bear Creek
East Fork Potlatch R.
Fish Creek
Hayden Creek
Upper Lemhi River
Apparent survival
FL
Age-at-release
0
1
2
3
4

Implications

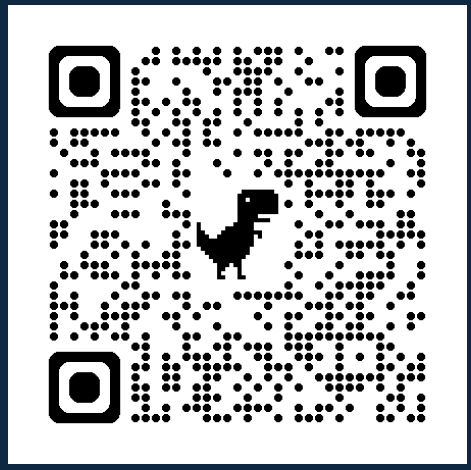
- Framework for estimating survival of emigrating juvenile steelhead
- Evaluate effects of conditions above and below traps on juvenile steelhead survival
- Watershed-specific limiting factors

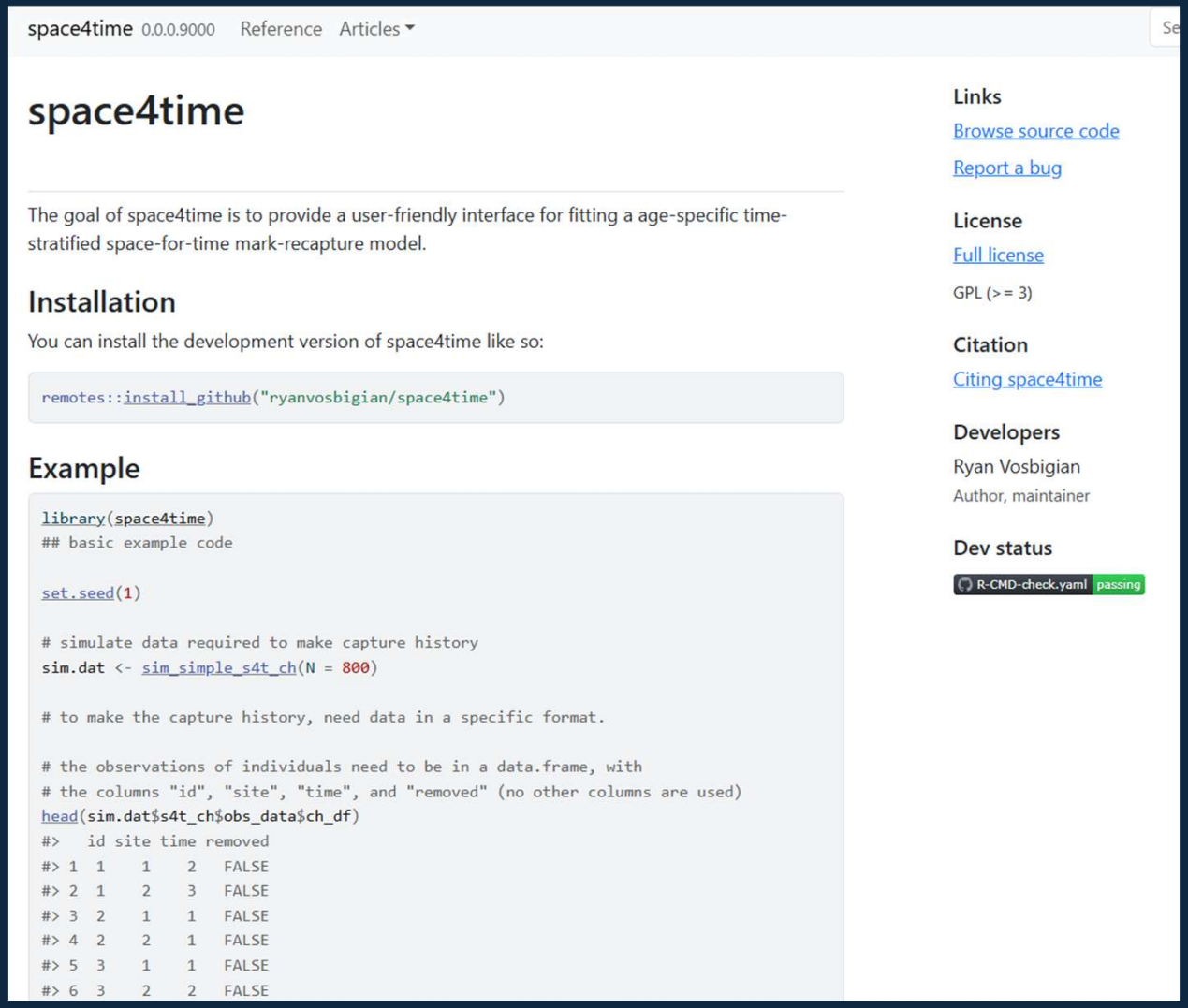
Package

- Generalizable
- Workflow for Columbia River salmon and steelhead

Available on GitHub

- ryanvosbigian/space4time




space4time 0.0.0.9000 Reference Articles
space4time
The goal of space4time is to provide a user-friendly interface for fitting a age-specific time-stratified space-for-time mark-recapture model.
Installation
You can install the development version of space4time like so:
remotes::install_github("ryanvosbigian/space4time")
Example
library(space4time)
basic example code
set.seed(1)
# simulate data required to make capture history
sim.dat <- sim_simple_s4t_ch(N = 800)
# to make the capture history, need data in a specific format.
# the observations of individuals need to be in a data.frame, with
# the columns "id", "site", "time", and "removed" (no other columns are used)
head(sim.dat$s4t_ch$obs_data$ch_df)
#> id site time removed
#> 1 1 1 2 FALSE
#> 2 1 2 3 FALSE
#> 3 2 1 1 FALSE
#> 4 2 2 1 FALSE
#> 5 3 1 1 FALSE
#> 6 3 2 2 FALSE
Links
Browse source code
Report a bug
License
Full license
GPL (>= 3)
Citation
Citing space4time
Developers
Ryan Vosbigian
Author, maintainer
Dev status
R-CMD-check.yaml passing

Example using PTAGIS queries

Source: vignettes/Example.Rmd

```
library(space4time)
library(dplyr)
#>
#> Attaching package: 'dplyr'
#> The following objects are masked from 'package:stats':
#>
#>     filter, lag
#> The following objects are masked from 'package:base':
#>
#>     intersect, setdiff, setequal, union
library(ggplot2)
```

This is an example workflow for implementing the model. This implementation uses data queried from Columbia Basin Research Data Access in Real Time (DART). The Columbia Basin Research has a query that was developed for use with the Basin TribPit software. However, the data can also be used by *space4time*.

We start with the observations of individuals from the East Fork Potlatch River Rotary Screw Trap, which has the site name: EFPTRP (previously POTREF). We'll use observations from 2015 to 2019 for this example. These data are from Idaho Department of Fish and Game's juvenile trapping database.

Here are some of the rows of a file that contain data on juvenile steelhead encountered at this rotary screw trap. Some of the columns (`id`, `obs_time`, and `ageclass`) are required to have those names. Any additional variables can be included. However, complete data for all variables (except `ageclass`) is required for any of the following analyses.

Acknowledgements

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