USGS
science for a changing world

The Value of Time and the Perils of Aggregation in PIT Tag Survival Analyses

Dalton Hance, Russell Perry, Adam Pope, John Plumb, Ken Tiffan and Mike Dodrill

USGS Western Fisheries Research Center

Columbia River Research Lab

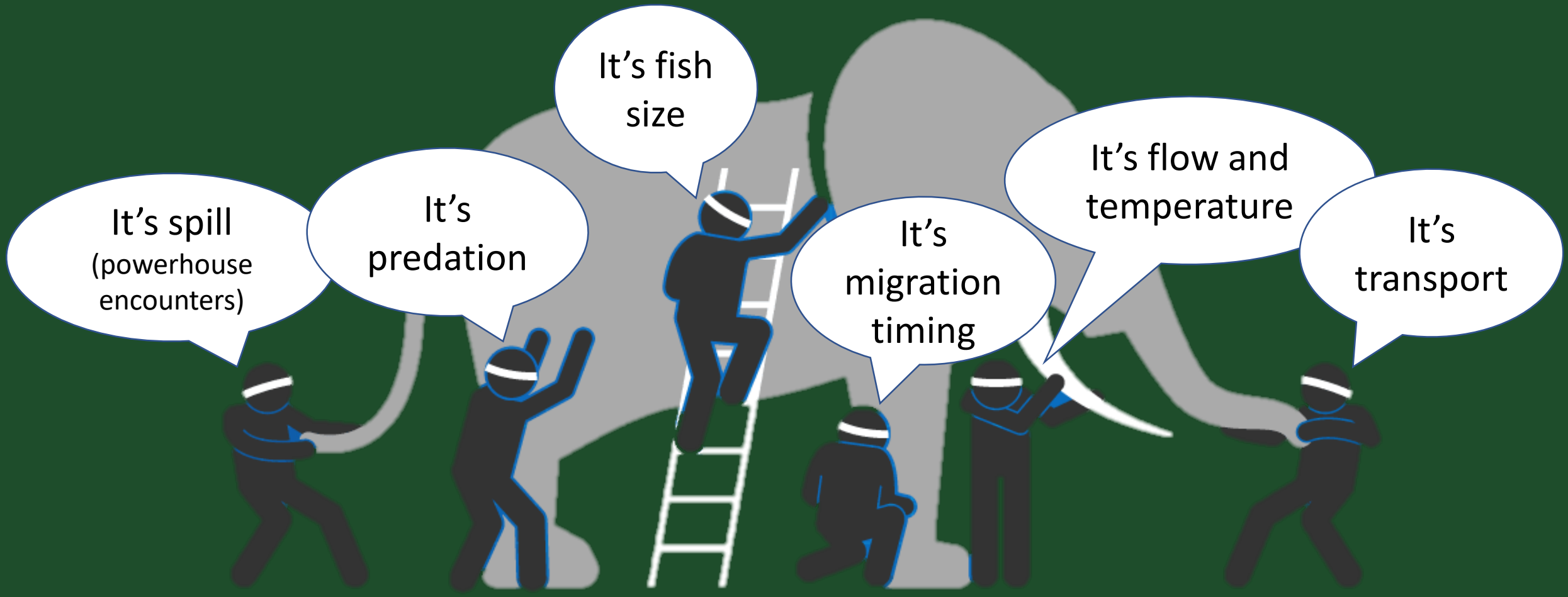
Quantitative Ecology Section

Image credit: wikipedia.com

The elephant in the room: smolt freshwater survival and apparent carryover effects

USGS

Image credit: planbox.com



Gosselin, J.L., Buhle, E.R., Van Holmes, C., Beer, W.N., Iltis, S., Anderson, J.J., 2021. Role of carryover effects in conservation of wild Pacific salmon migrating regulated rivers. Ecosphere 12. https://doi.org/10.1002/ecs2.3618

Faulkner, J.R., Bellerud, B.L., Widener, D.L., Zabel, R.W., 2019. Associations among Fish Length, Dam Passage History, and Survival to Adulthood in Two At-Risk Species of Pacific Salmon. Trans Am Fish Soc 148, 1069–1087. https://doi.org/10.1002/tafs.10200

Wilson, S.M., Moore, J.W., Ward, E.J. *et al.* Phenological shifts and mismatch with marine productivity vary among Pacific salmon species and populations. *Nat Ecol Evol* **7**, 852–861 (2023). https://doi.org/10.1038/s41559-023-02057-1

Payton, Q., Evans, A.F., Hostetter, N.J., Roby, D.D., Cramer, B., Collis, K., 2020. Measuring the additive effects of predation on prey survival across spatial scales. Ecological Applications 30, e02193. https://doi.org/10.1002/eap.2193

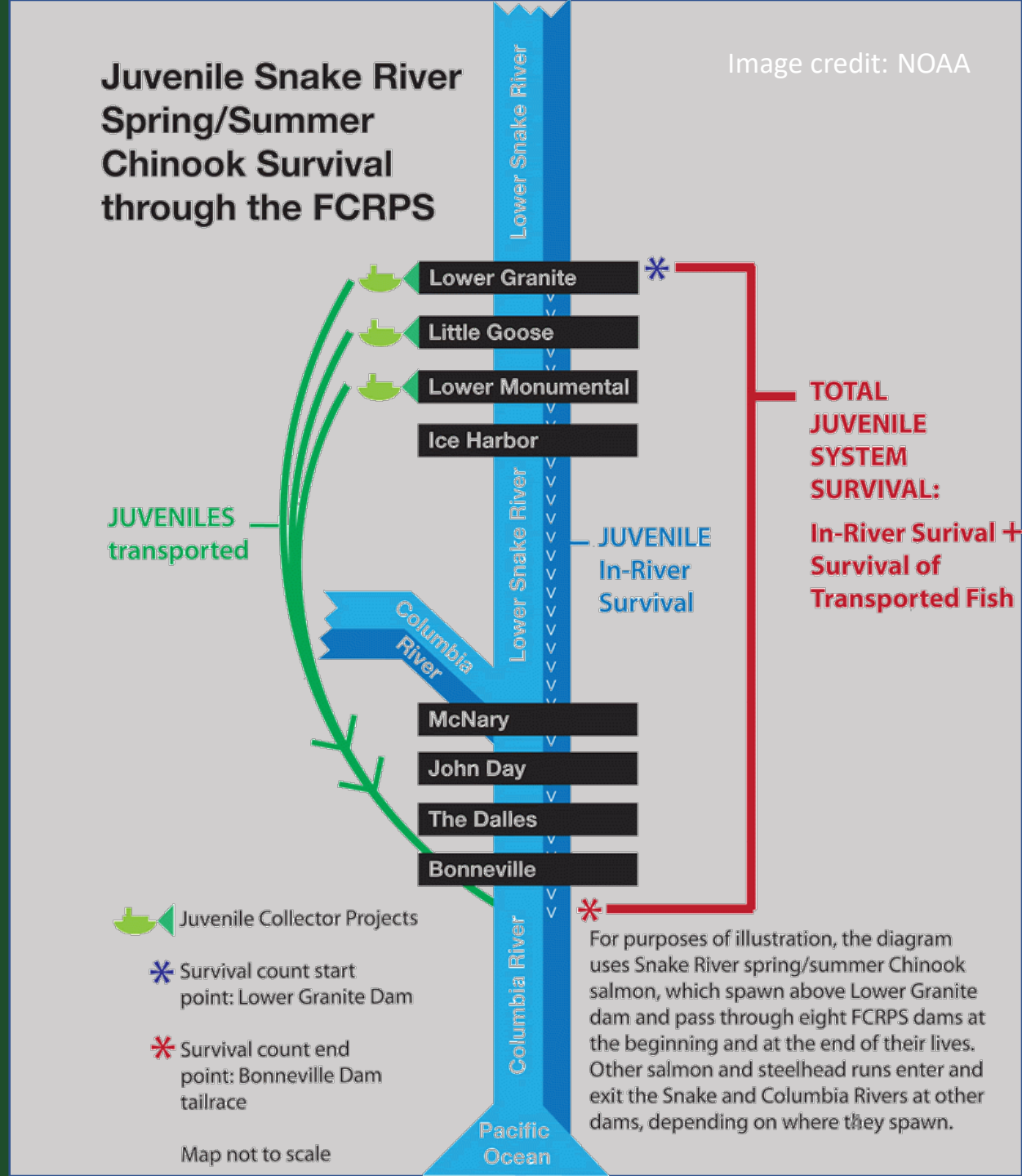
USGS

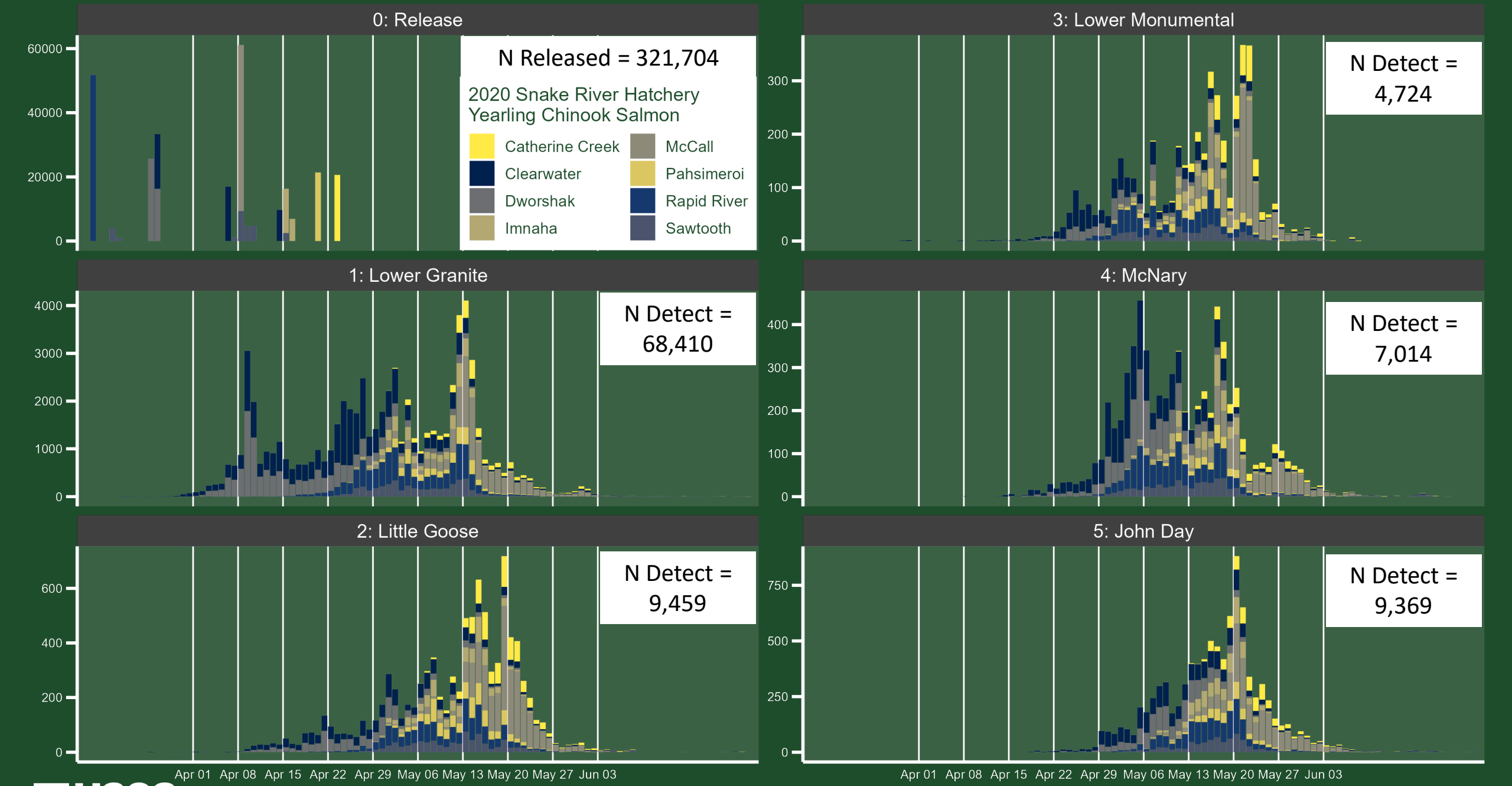
How do we know what we think we know about smolt survival?

Space-for-Time CJS Survival Models

USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

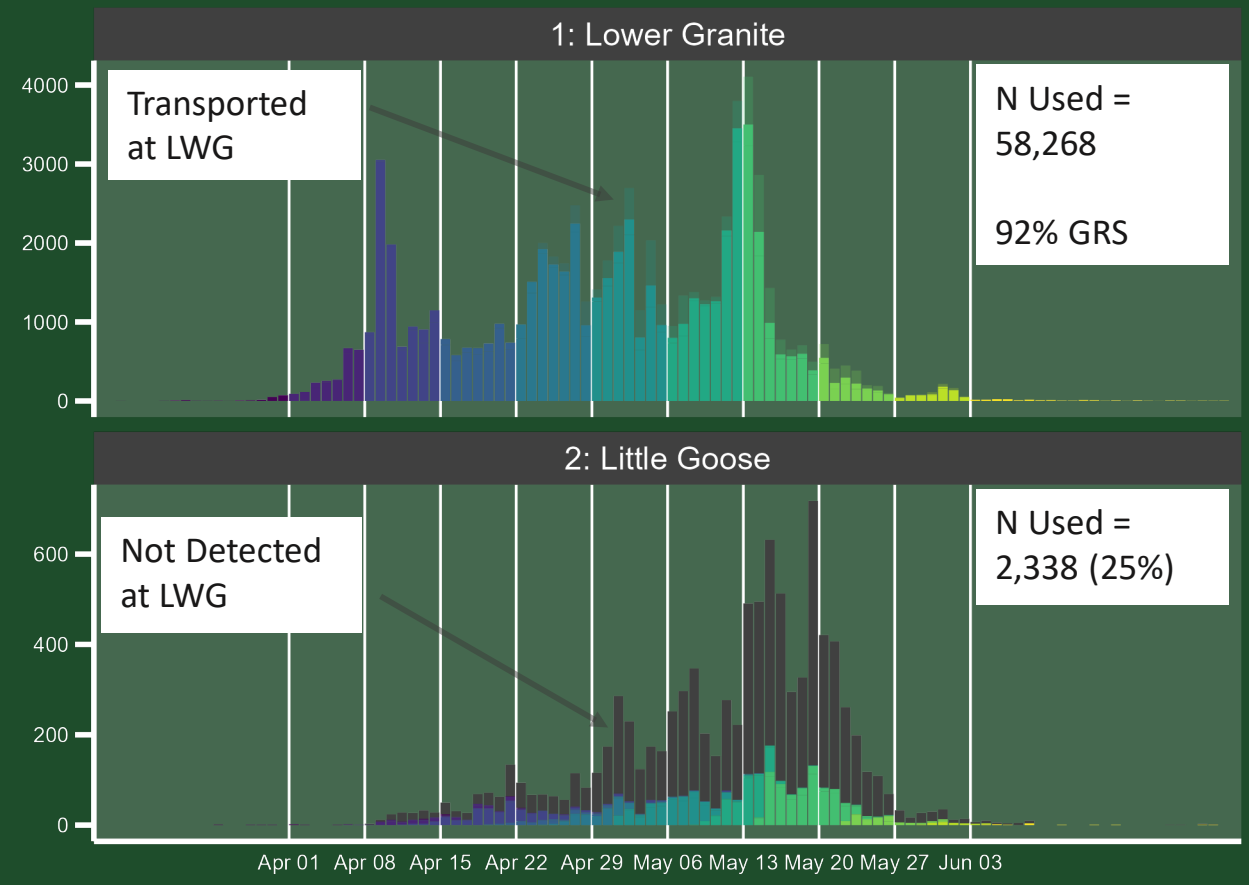


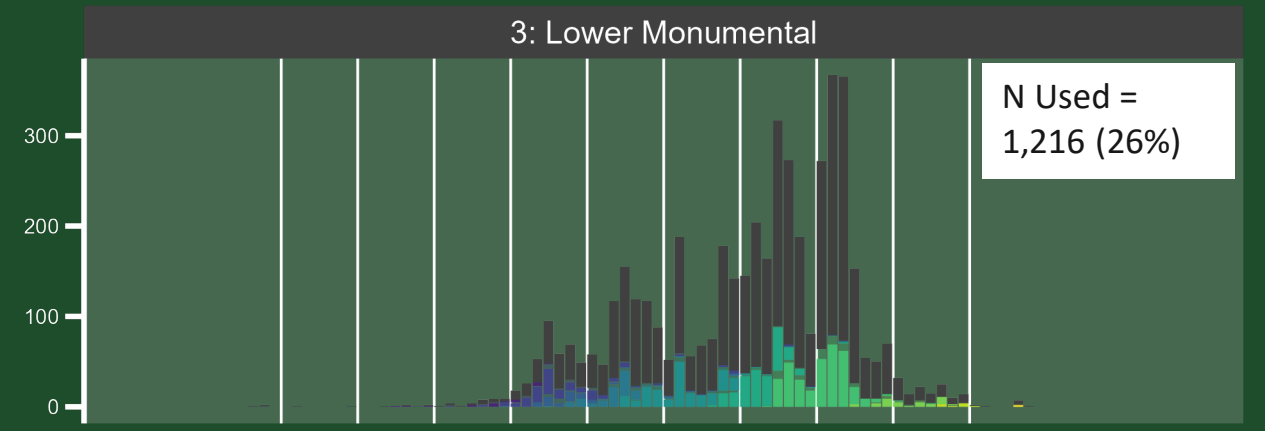


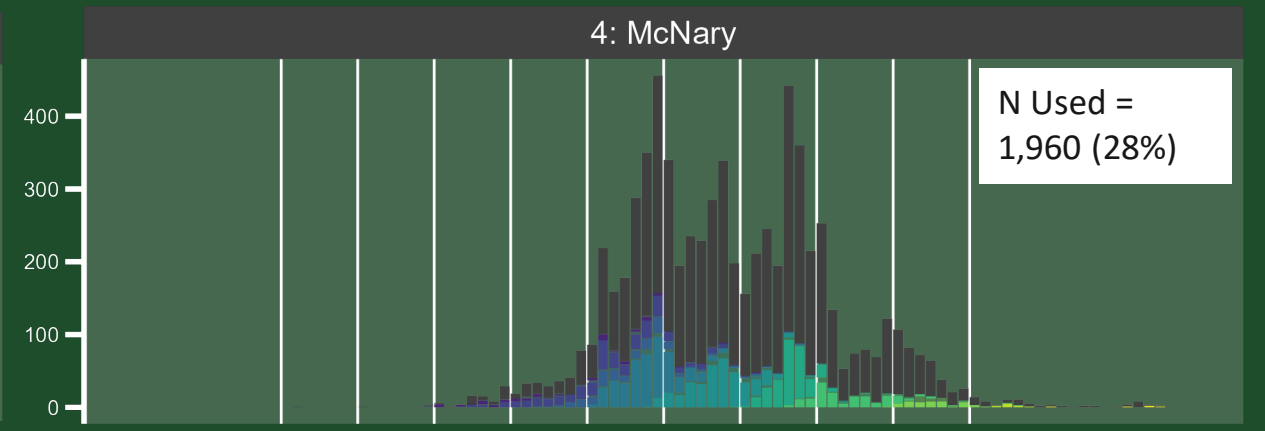
USGS

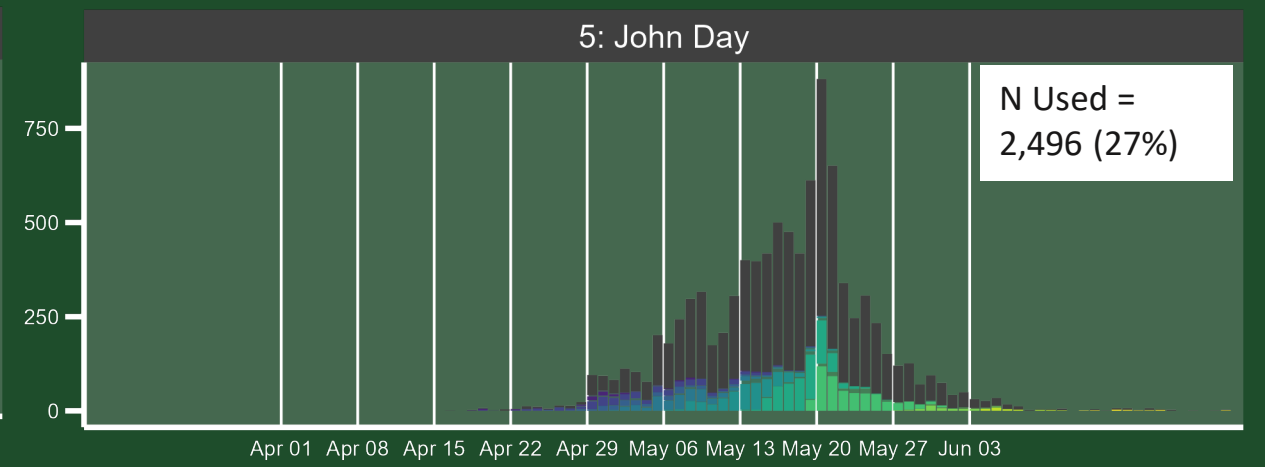
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

The Traditional Approach to Evaluating Time Varying Survival: Virtual Release Cohorts

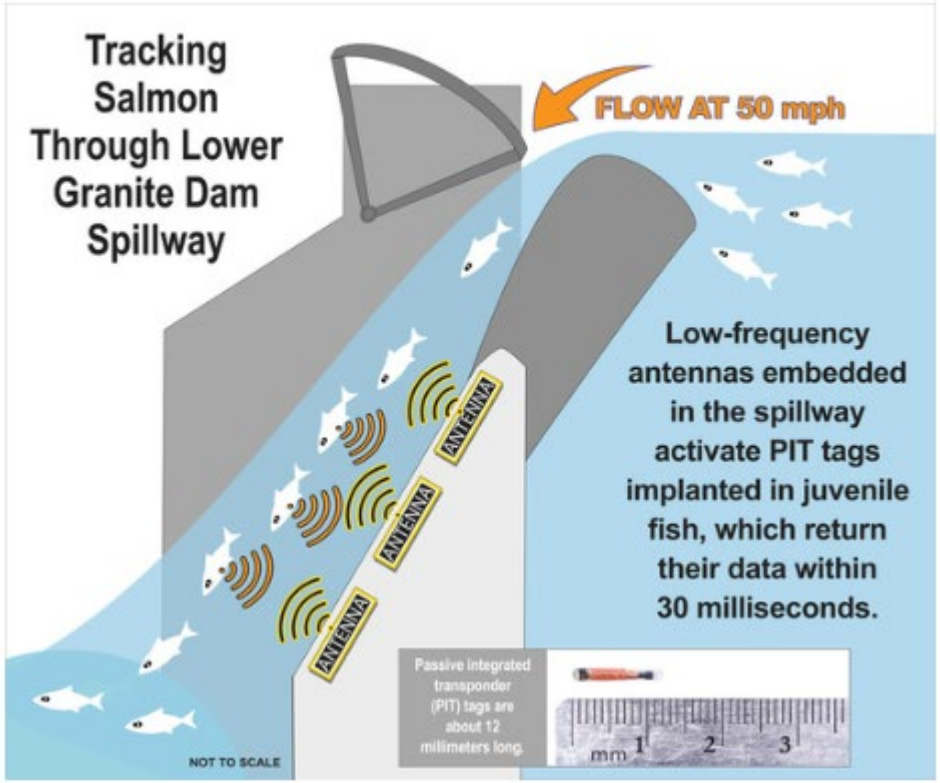








USGS



WITH HIGHER SPILL AT DAMS, DETECTING SURVIVAL OF PIT-TAGGED JUVENILE SALMON, STEELHEAD EXTREMELY ELUSIVE, CREATING KEY DATA GAP

JANUARY 5TH, 2024
HYDRO

https://cbbulletin.com/

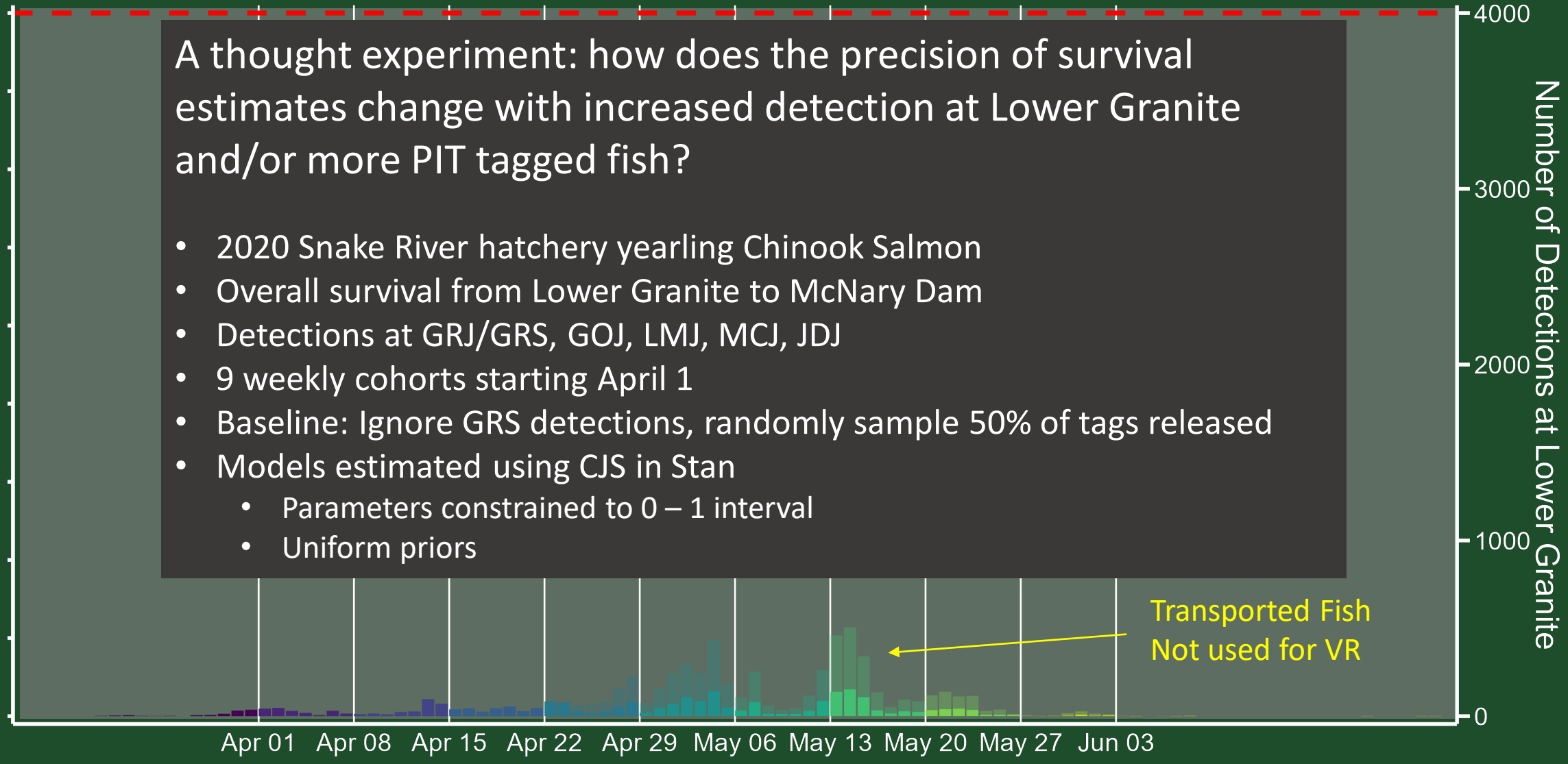
High Spill = Low Detection = Increased Uncertainty

- Traditional virtual release cohort methods have struggled with flex spill operations
- Has led to calls to increase detection capabilities and/or increase sample sizes
- What do increased detection and/or sample sizes buy us?

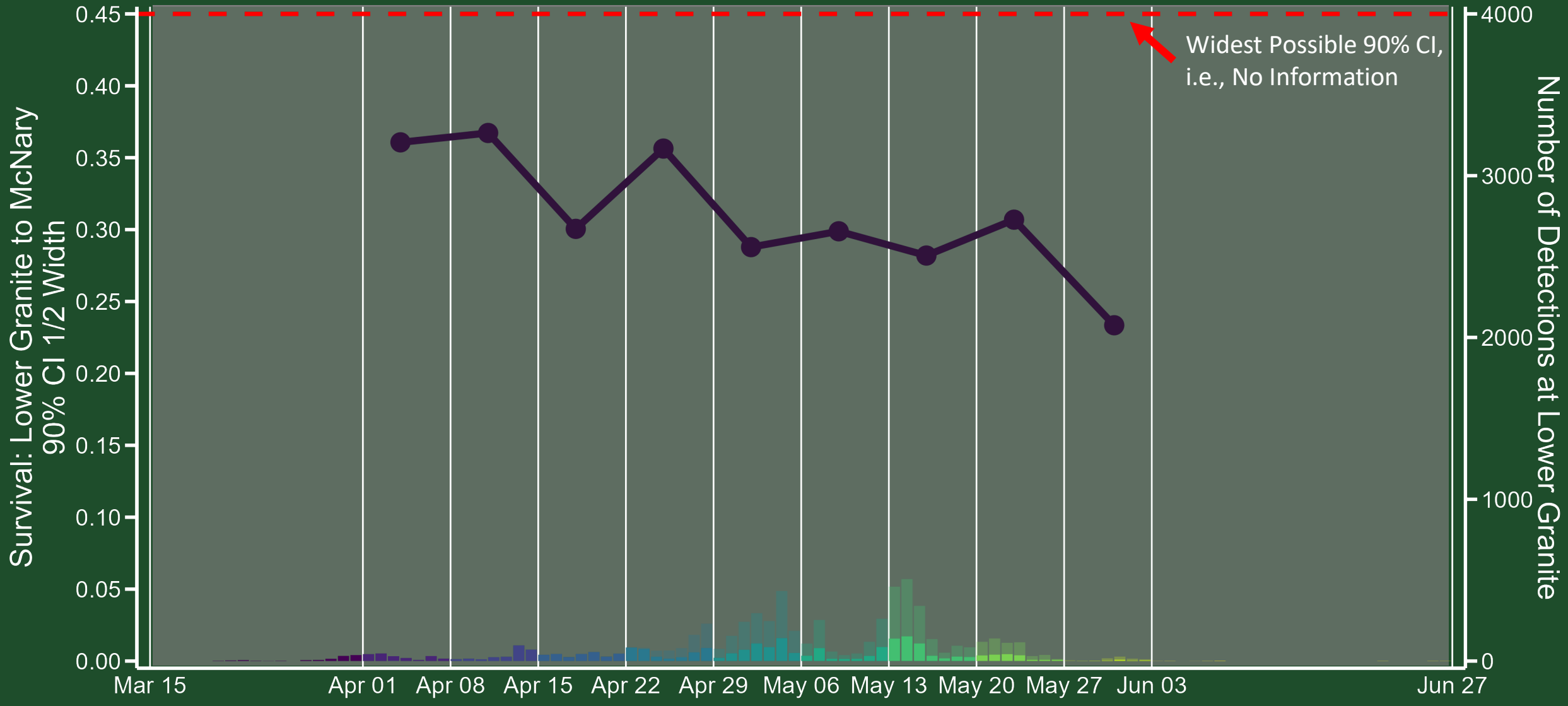
USGS

A thought experiment: how does the precision of survival estimates change with increased detection at Lower Granite and/or more PIT tagged fish?

- 2020 Snake River hatchery yearling Chinook Salmon
- Overall survival from Lower Granite to McNary Dam
- Detections at GRJ/GRS, GOJ, LMJ, MCJ, JDJ
- 9 weekly cohorts starting April 1
- Baseline: Ignore GRS detections, randomly sample 50% of tags released
- Models estimated using CJS in Stan
  - Parameters constrained to 0 – 1 interval
  - Uniform priors

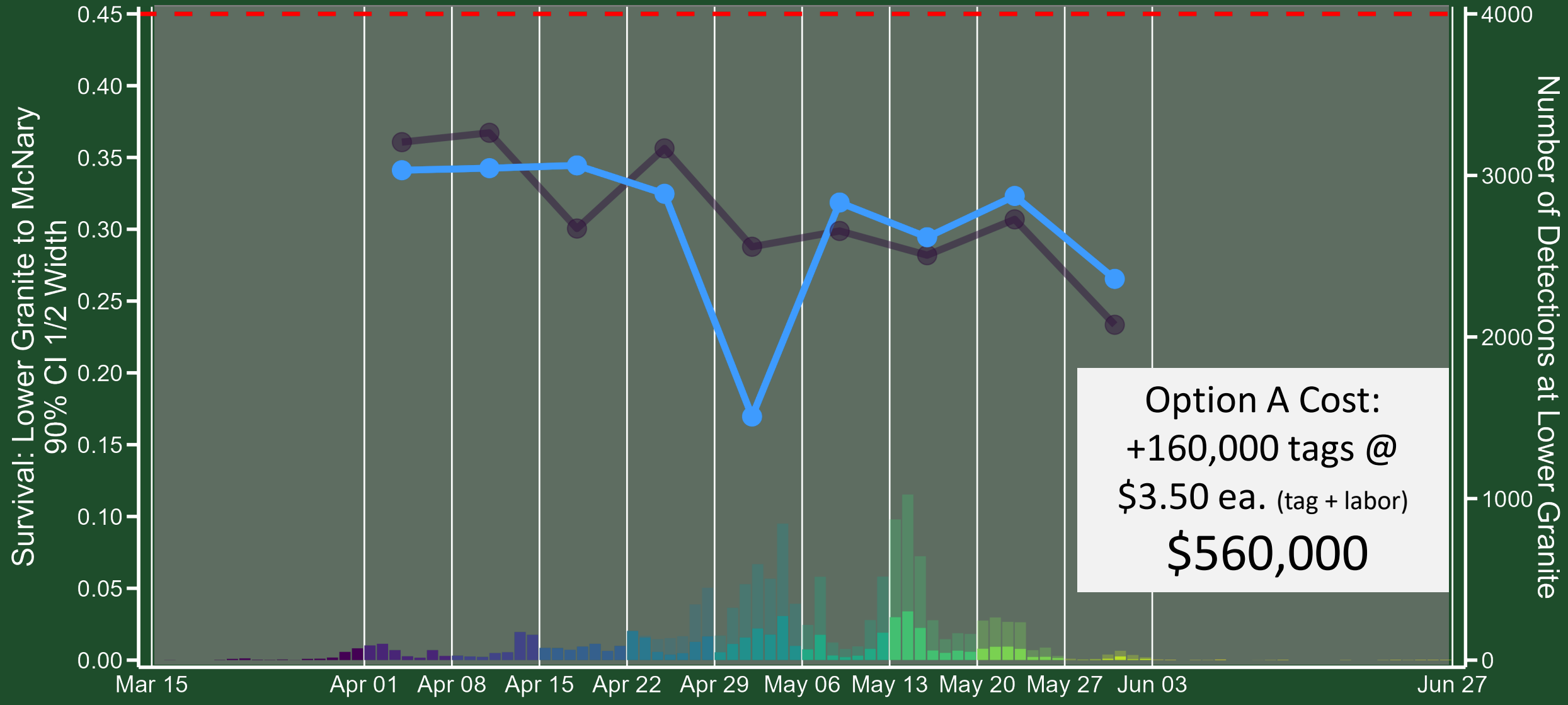


USGS



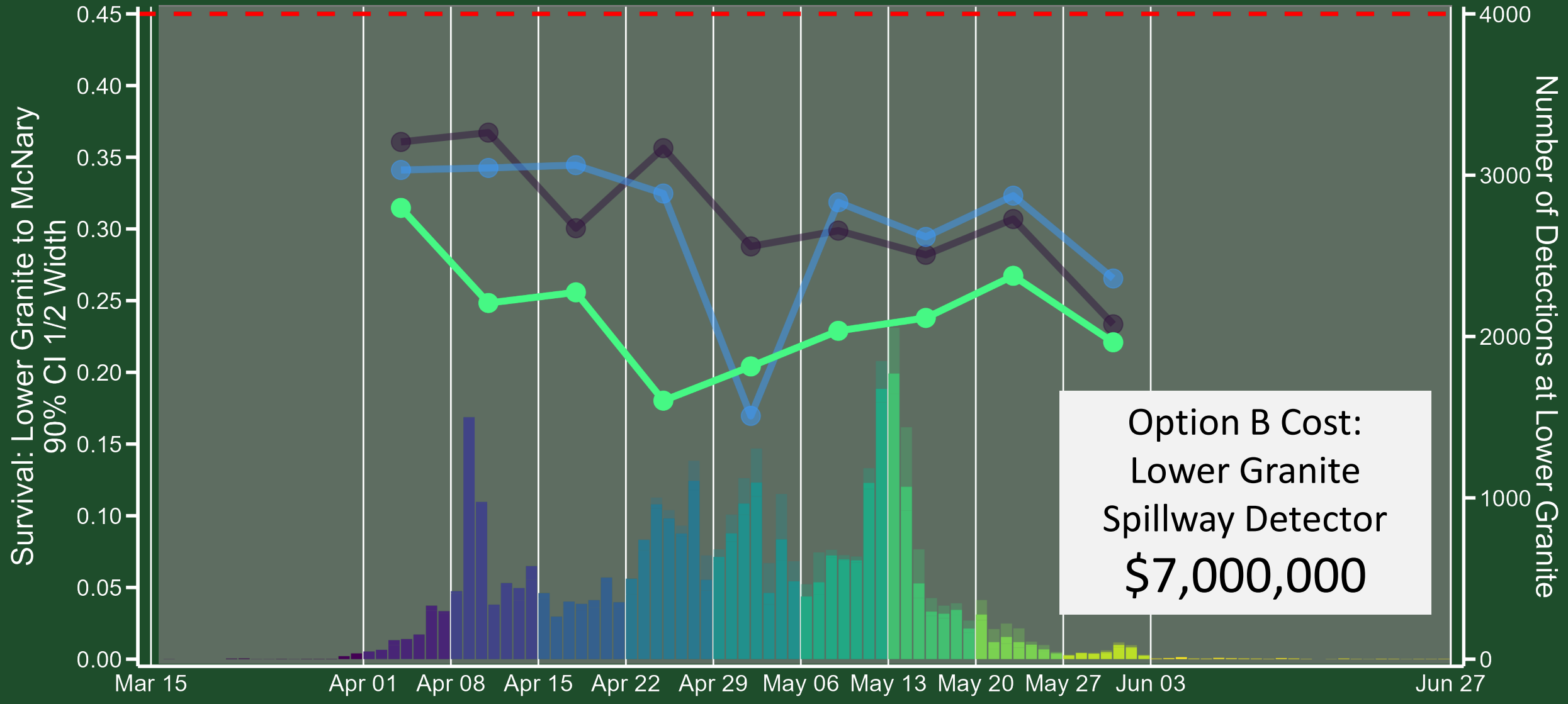
USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

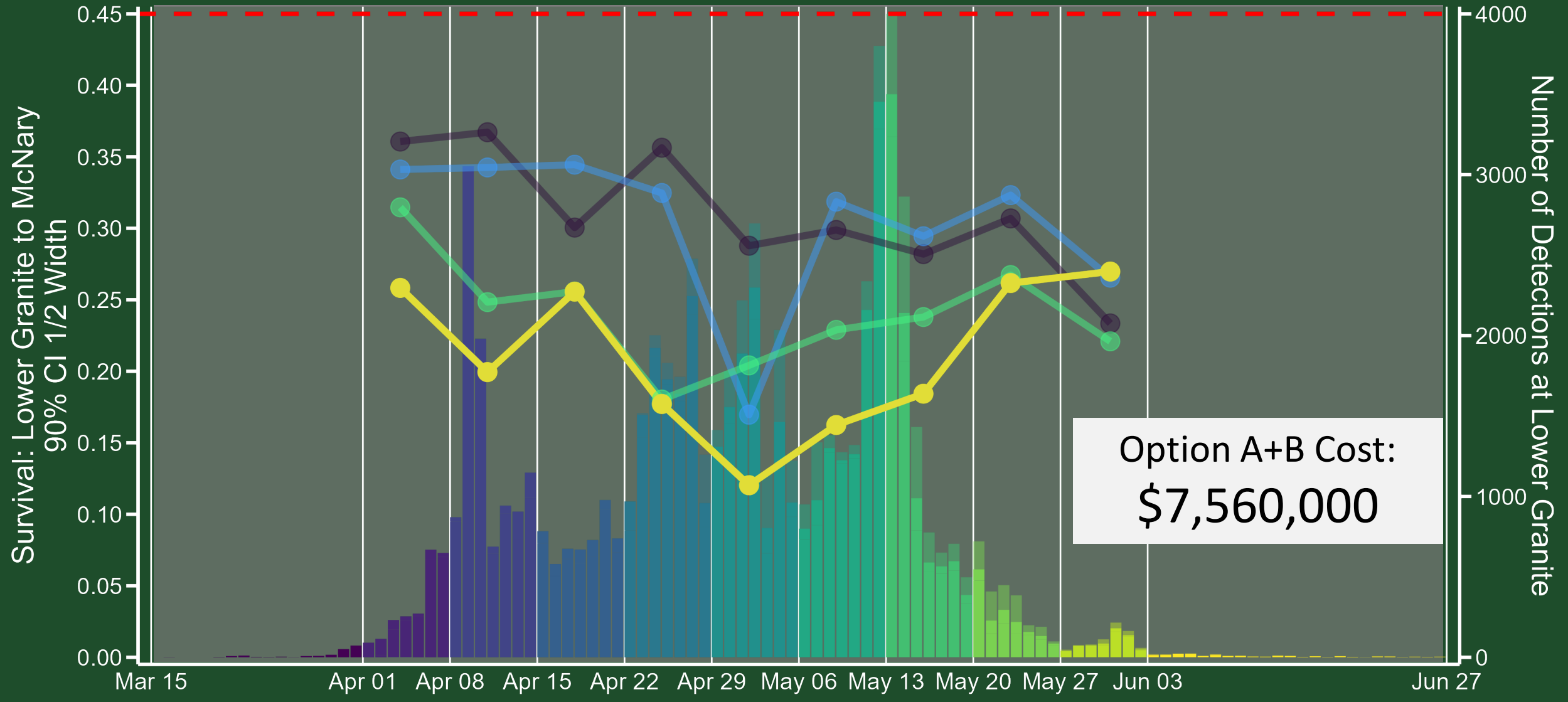


Survival Estimation Option

Baseline
Option A: Double Tags
Option B: Increase Detection

USGS

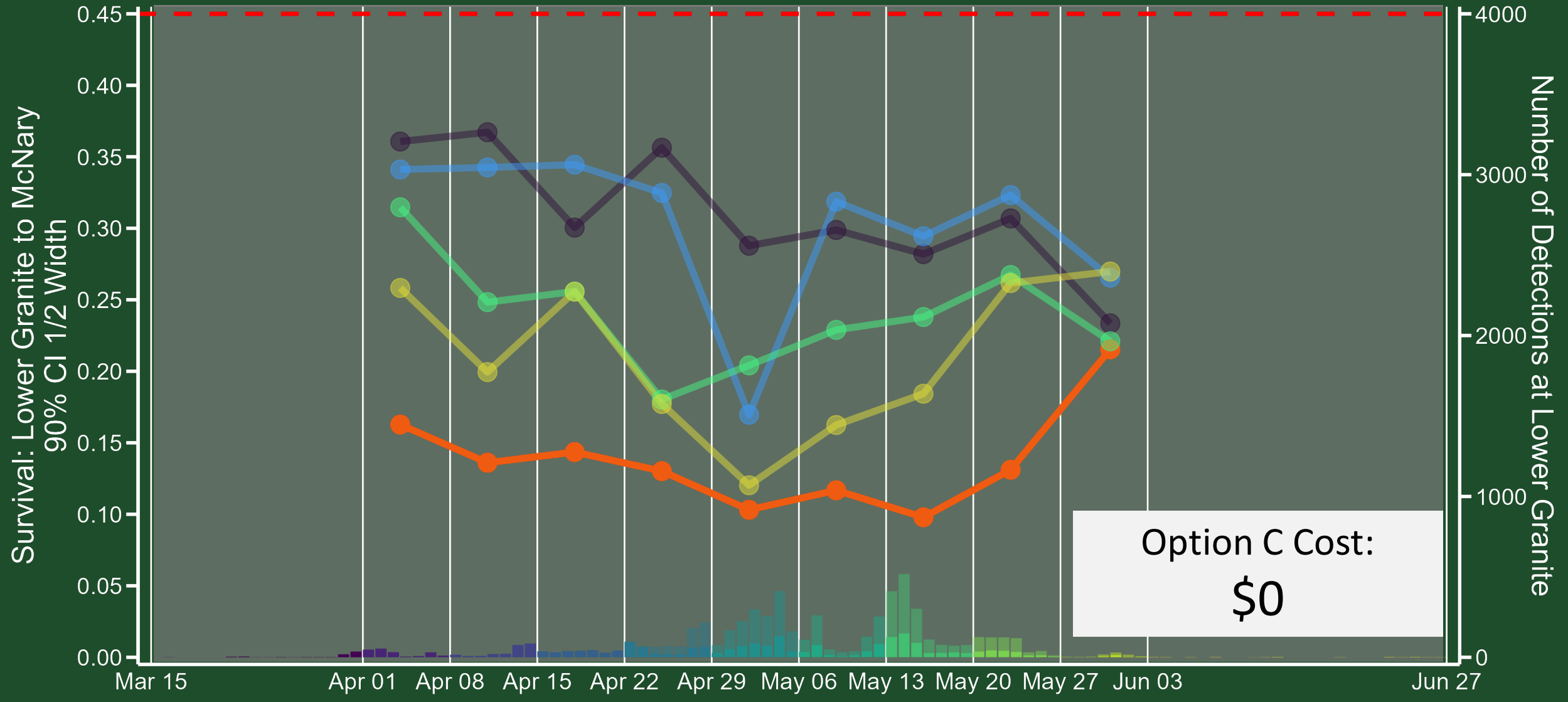
Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



Survival Estimation Option

Baseline
Option A: Double Tags
Option B: Increase Detection
Option A + B

USGS



Survival Estimation Option

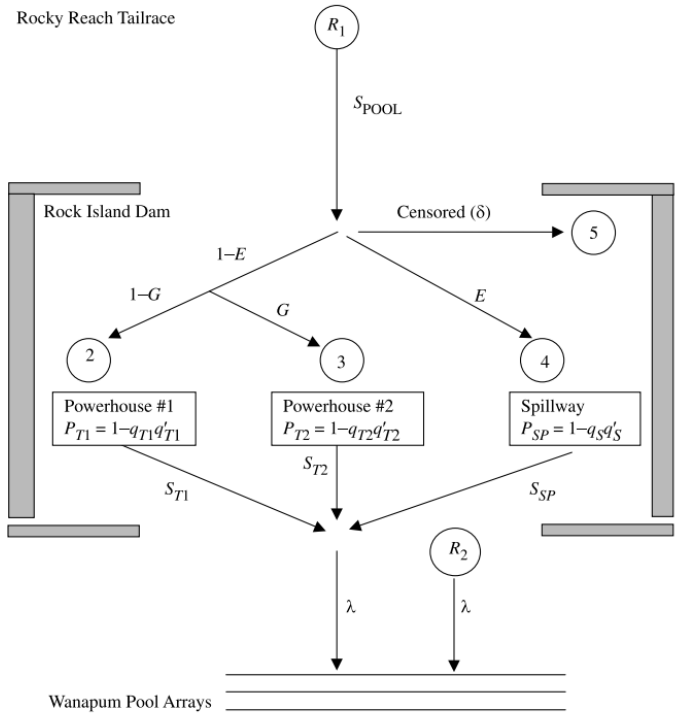
Baseline
Option A: Double Tags
Option B: Increase Detection
Option A + B
Option C: TSCJS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

Option C: Time as a "state"

Route as State: Skalski et al. (2002)

Fig. 2. Schematic of route-specific passage and survival through the Rock Island project based on Rocky Reach (R_1) and Rock Island (R_2) tailrace releases.



Skalski, J. R., R. Townsend, J. Lady, A. Giorgi, J. R. Stevenson, C. M. Peven, and R. D. McDonald. 2002. Estimating route-specific passage and survival probabilities at a hydroelectric project from smolt radiotelemetry studies. Canadian Journal of Fisheries and Aquatic Sciences 59:1385–1393. https://doi.org/10.1139/f02-094

Perry et al. (2012)

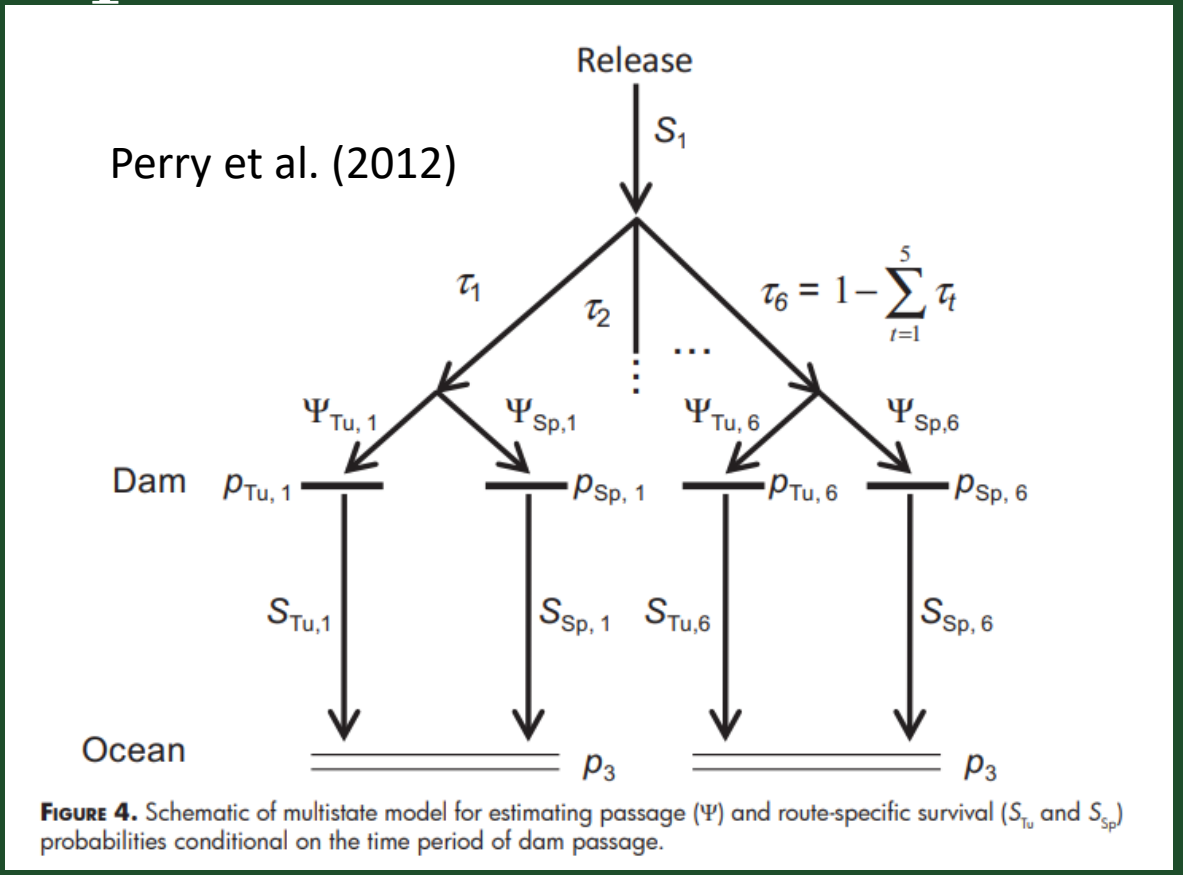


Figure 4. Schematic of multistate model for estimating passage (Ψ) and route-specific survival (S_{Tu} and S_{Sp}) probabilities conditional on the time period of dam passage.

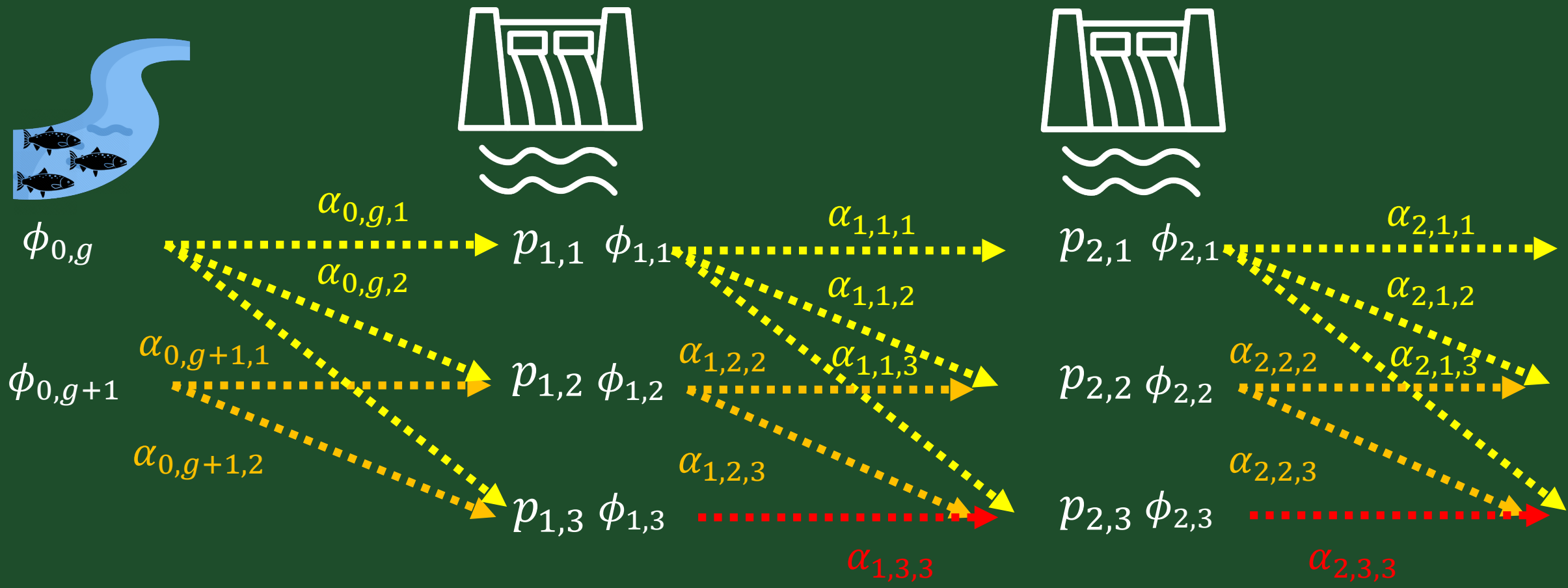
Perry RW, Castro-Santos T, Holbrook CM, Sandford BP. 2012. *Using Mark–Recapture Models to Estimate Survival from Telemetry Data, Telemetry Techniques: A User Guide for Fisheries Research*. American Fisheries Society: Bethesda, Maryland; 453–475.

Courter, I.I., Garrison, T.M., Kock, T.J., Perry, R.W., Child, D.B., Hubble, J.D., 2016. Benefits of Prescribed Flows for Salmon Smolt Survival Enhancement Vary Longitudinally in a Highly Managed River System: Benefits of Prescribed Flows for Salmon Survival. River Res. Applic. 32, 1999–2008. https://doi.org/10.1002/rra.3066

Perry, R.W., Pope, A.C., Romine, J.G., Brandes, P.L., Burau, J.R., Blake, A.R., Ammann, A.J., Michel, C.J., 2018. Flow-mediated effects on travel time, routing, and survival of juvenile Chinook salmon in a spatially complex, tidally forced river delta. Can. J. Fish. Aquat. Sci. 75, 1886–1901. https://doi.org/10.1139/cjfas-2017-0310

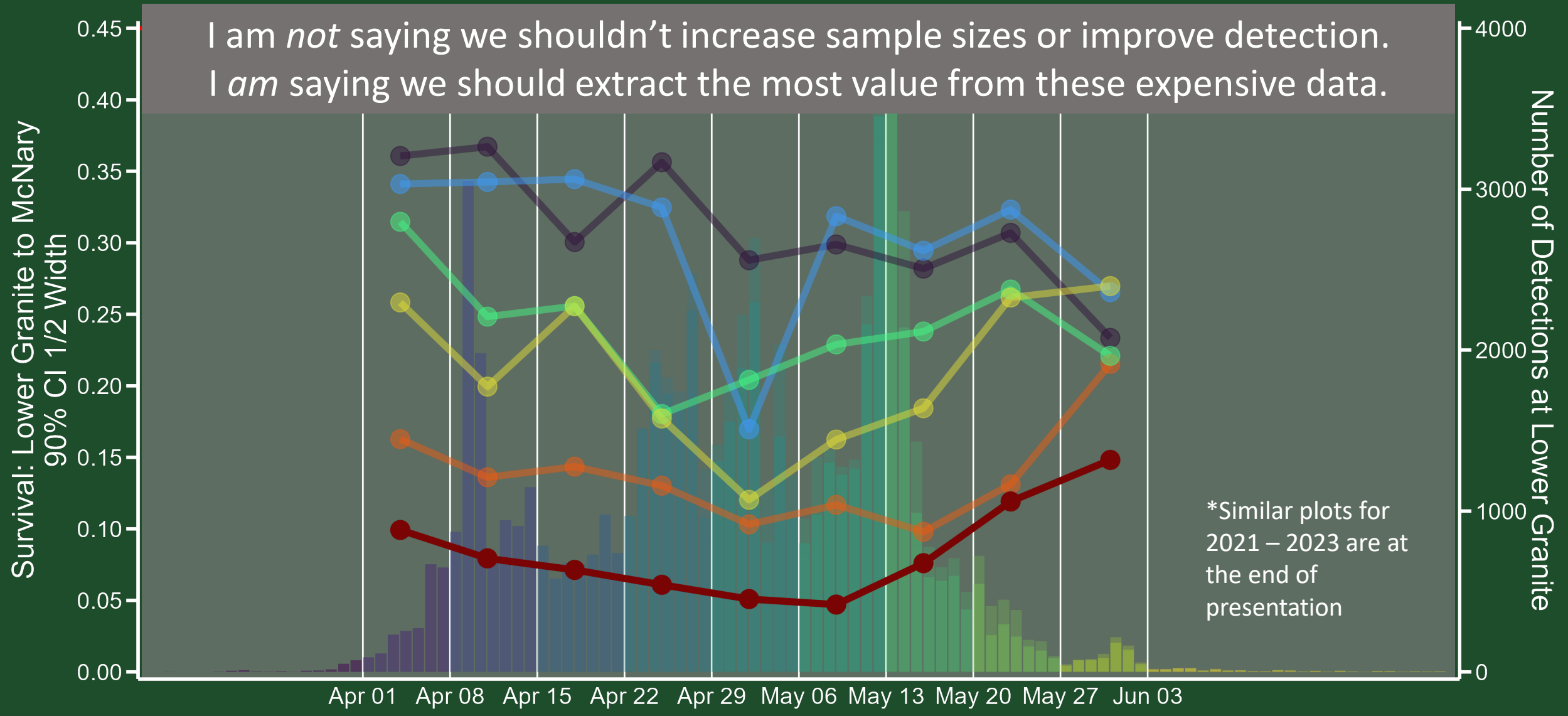
Hance, D.J., Perry, R.W., Plumb, J.M., Pope, A.C., 2020. A temporally stratified extension of space-for-time Cormack–Jolly–Seber for migratory animals. Biometrics 76, 900–912. https://doi.org/10.1111/biom.13171

Option C: Time as a "state"



Option C as depicted fit in Stan with uniform/non-informative priors.
Could be fit using MLE.

I am *not* saying we shouldn't increase sample sizes or improve detection.
I *am* saying we should extract the most value from these expensive data.



Survival Estimation Option

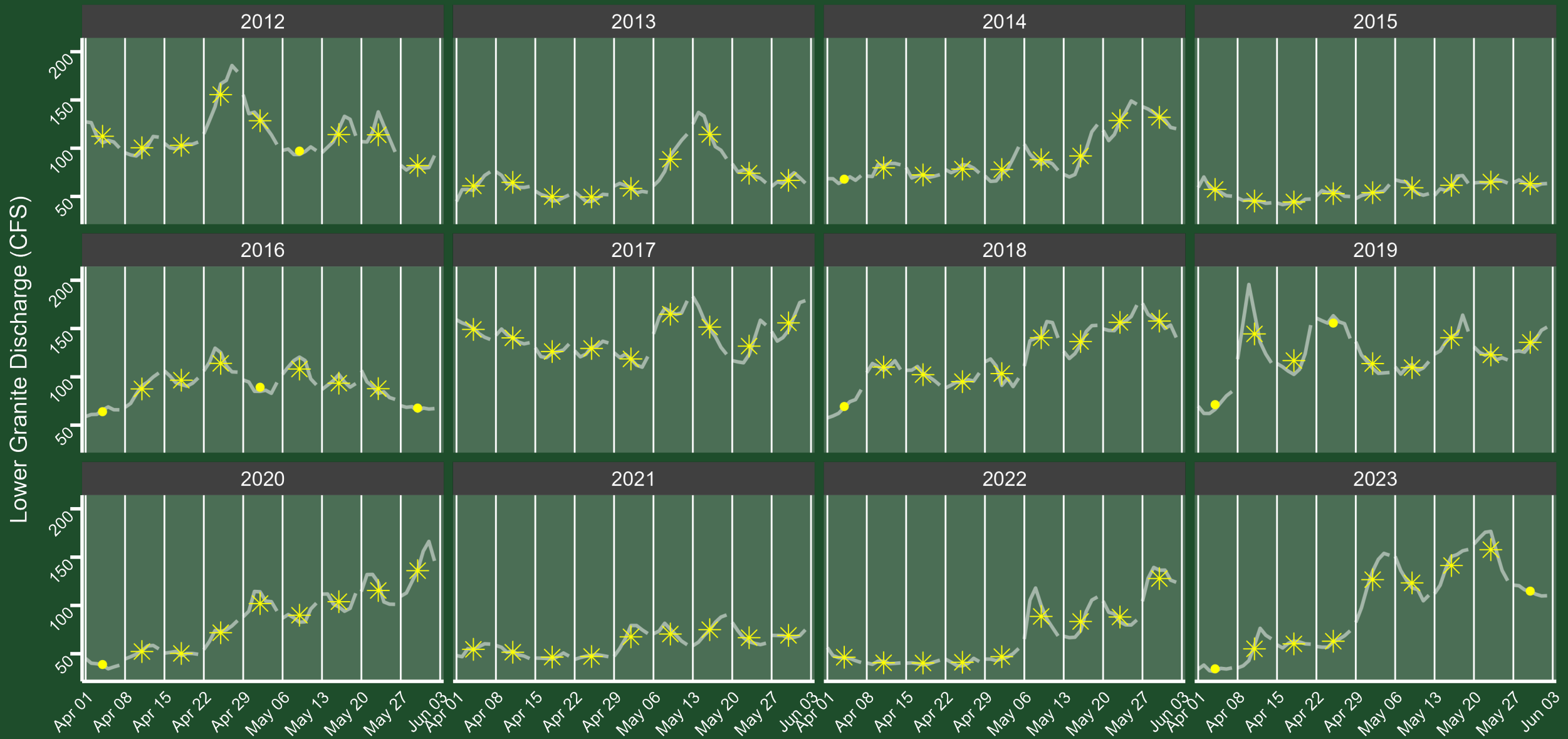
Baseline
Option A: Double Tags
Option B: Increase Detection
Option A + B
Option C: TSCJS
Option A + B + C

USGS

The Perils of Aggregation

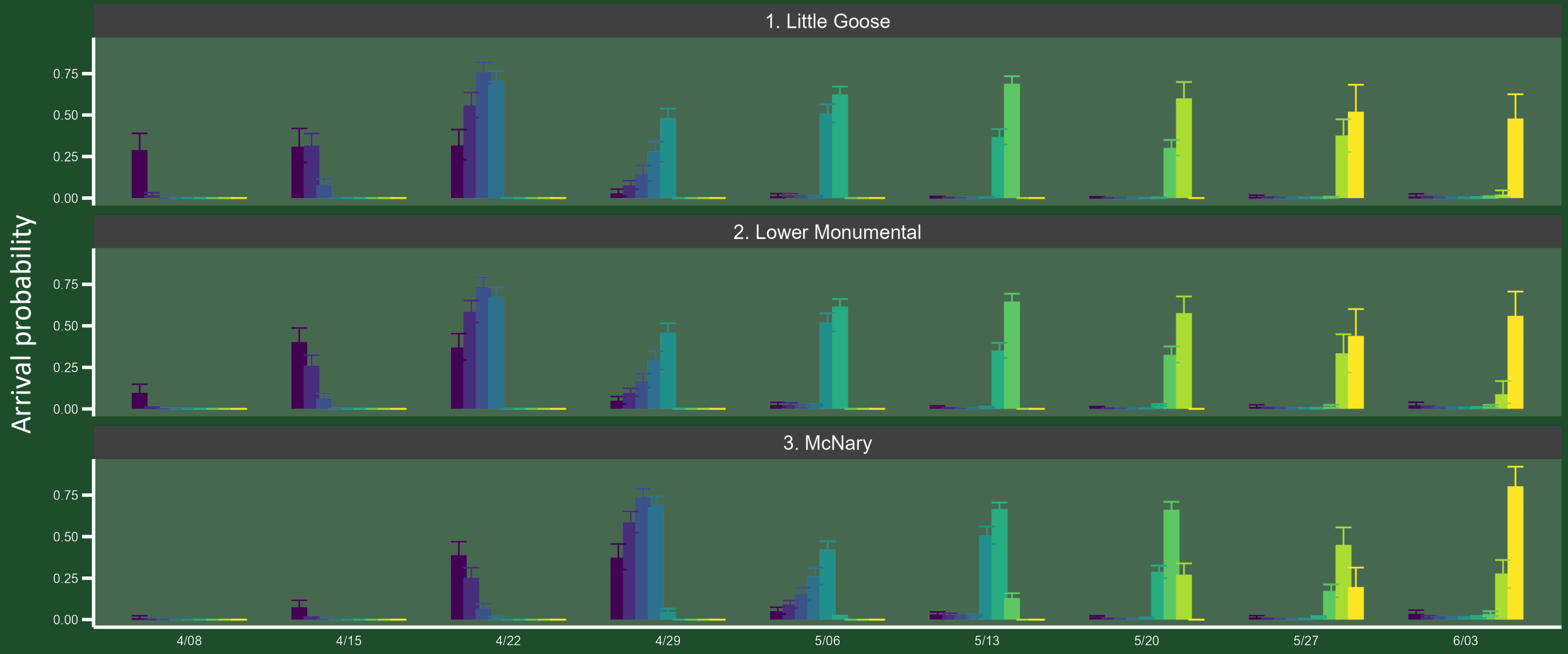
- A common management goal is to relate survival to environmental/operational conditions
- Using the VR cohort approach covariates are typically summarized over the temporal window
- For assessing survival over multiple reaches (e.g. LWG – MCN), summary covariates are usually applied based on detection date *at LWG*

Differences within cohorts can be greater than differences between cohorts



USGS

Fish don’t stay within their assigned cohort



Modelling Time as State

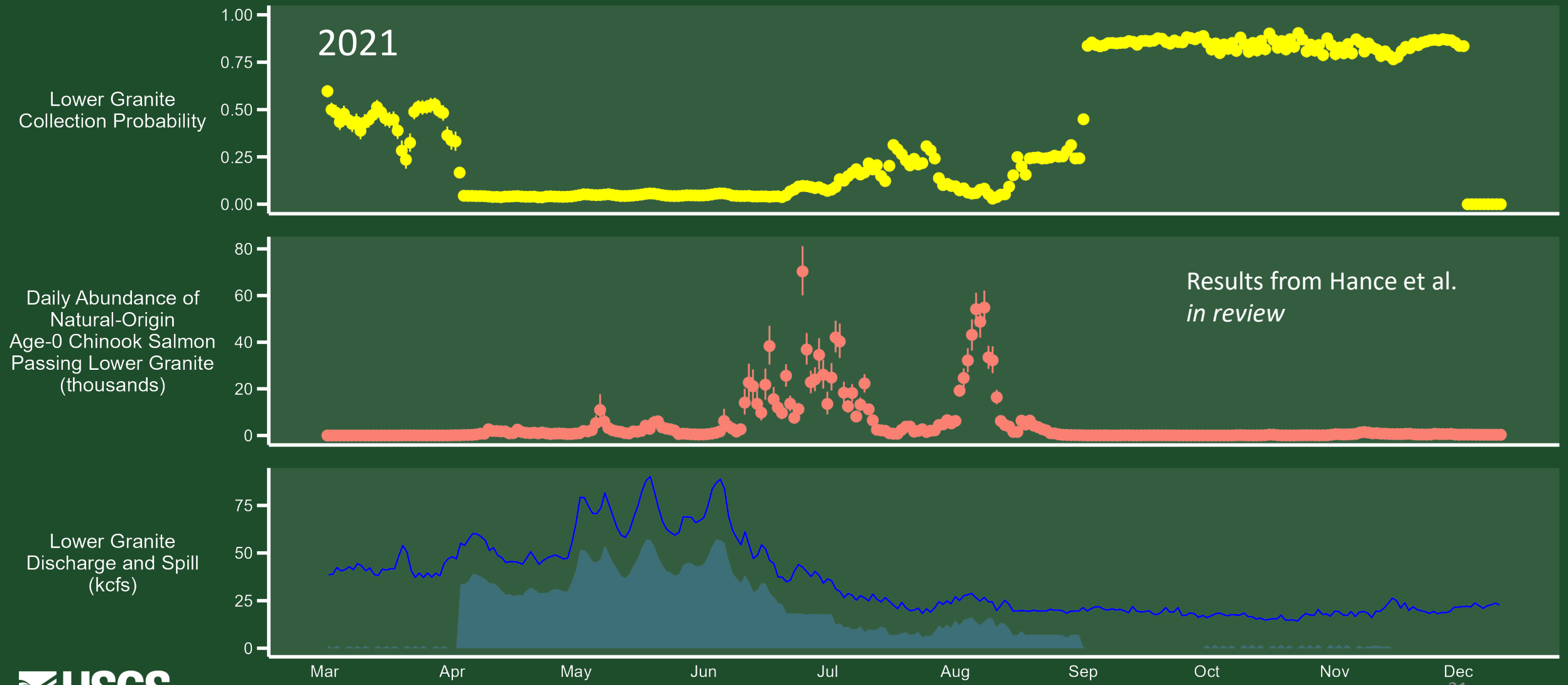
Advantages

- Increased precision at no additional cost for data collection
- Supports any level of stratification, mitigating the perils of aggregation
- Jointly models travel time and survival
  - Inference on travel time *not* conditioned on detected fish
- Many options in parameterization
  - Relatively simple and assumption light models do well

Disadvantages

- Many options in parameterization
  - Analysis paralysis is an occupational hazard
- Currently no plug and play software available
  - Come talk to me. What would be useful?

We'd like more and better data, yes, but we can also do more and better with the data we have



USGS

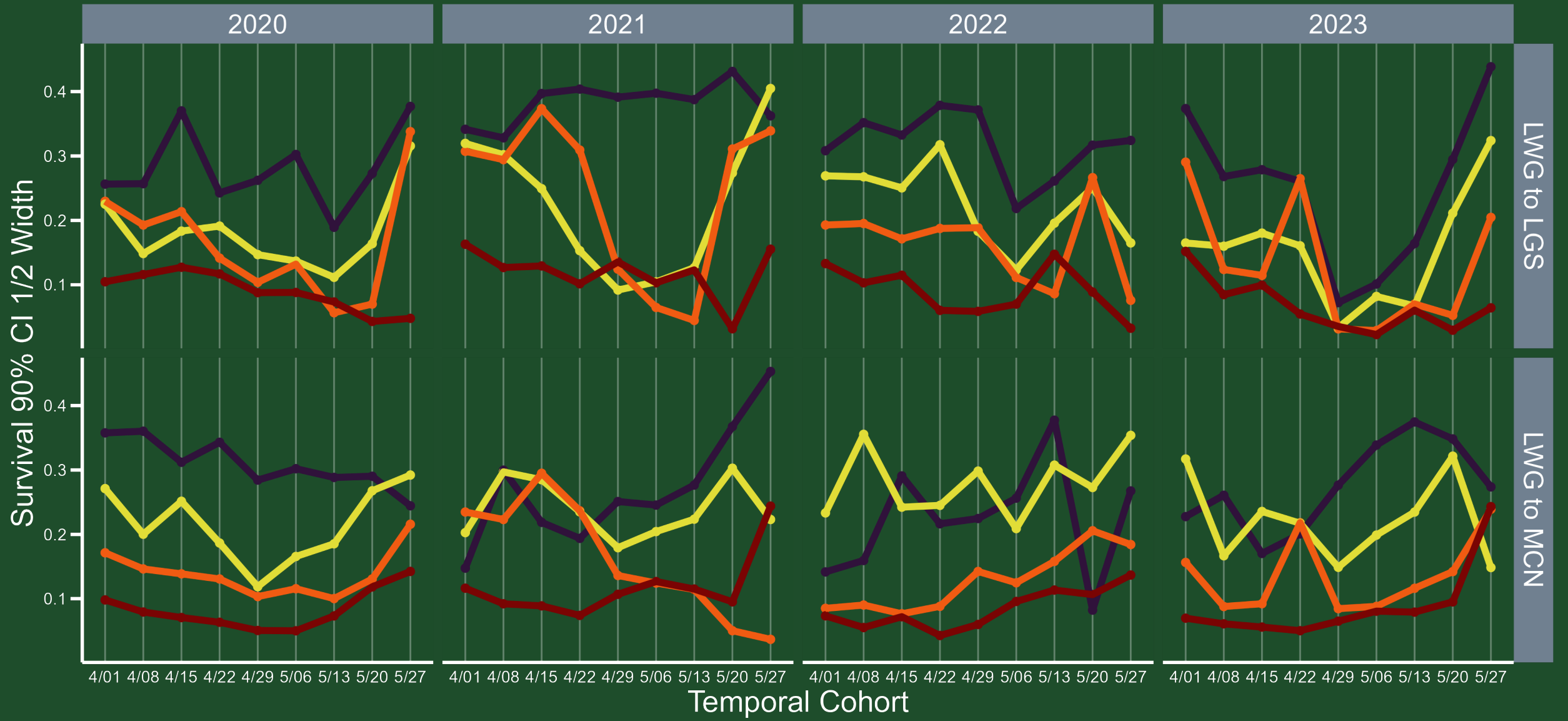
Questions?

Dalton Hance
Research Statistician
dhance@usgs.gov

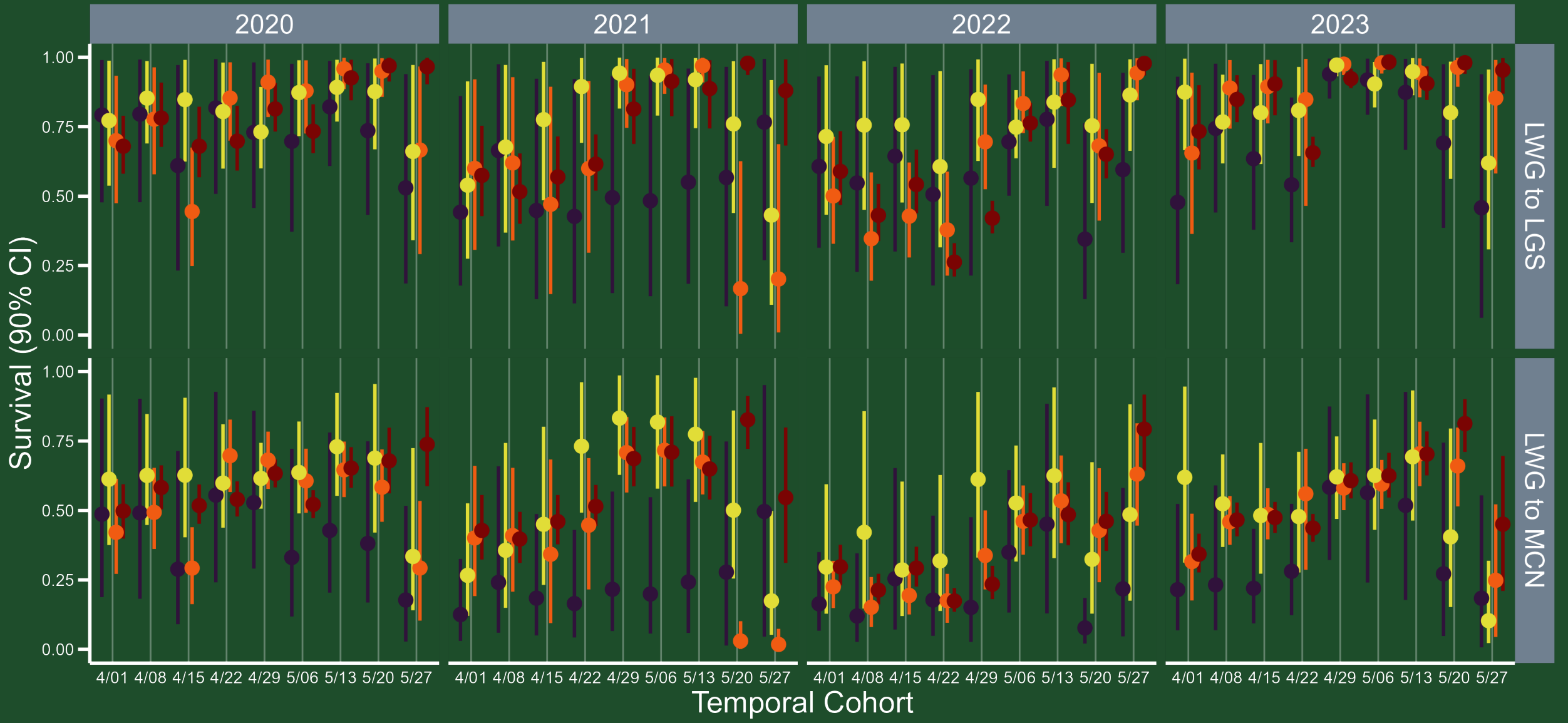
Funding for this research provided by:

Bonneville
POWER ADMINISTRATION

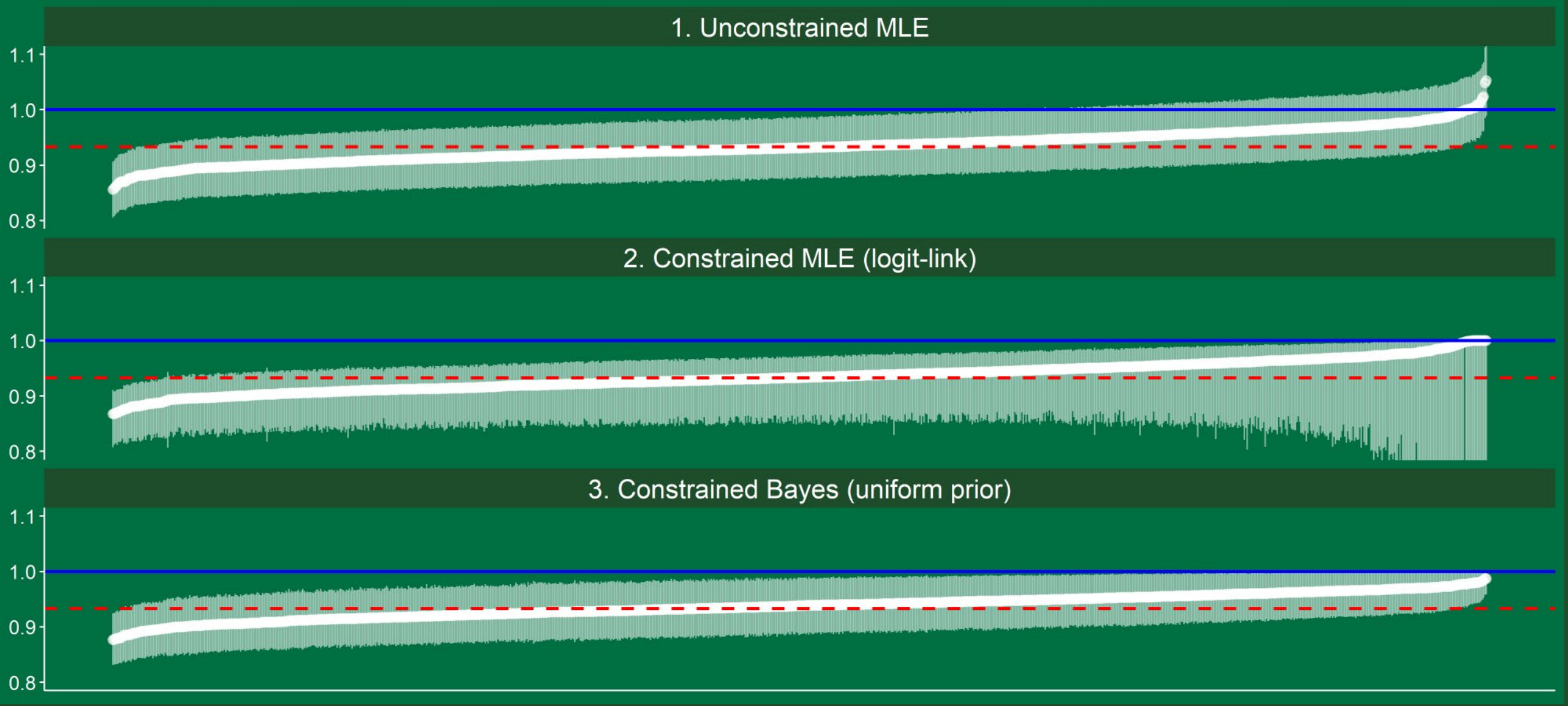
USGS



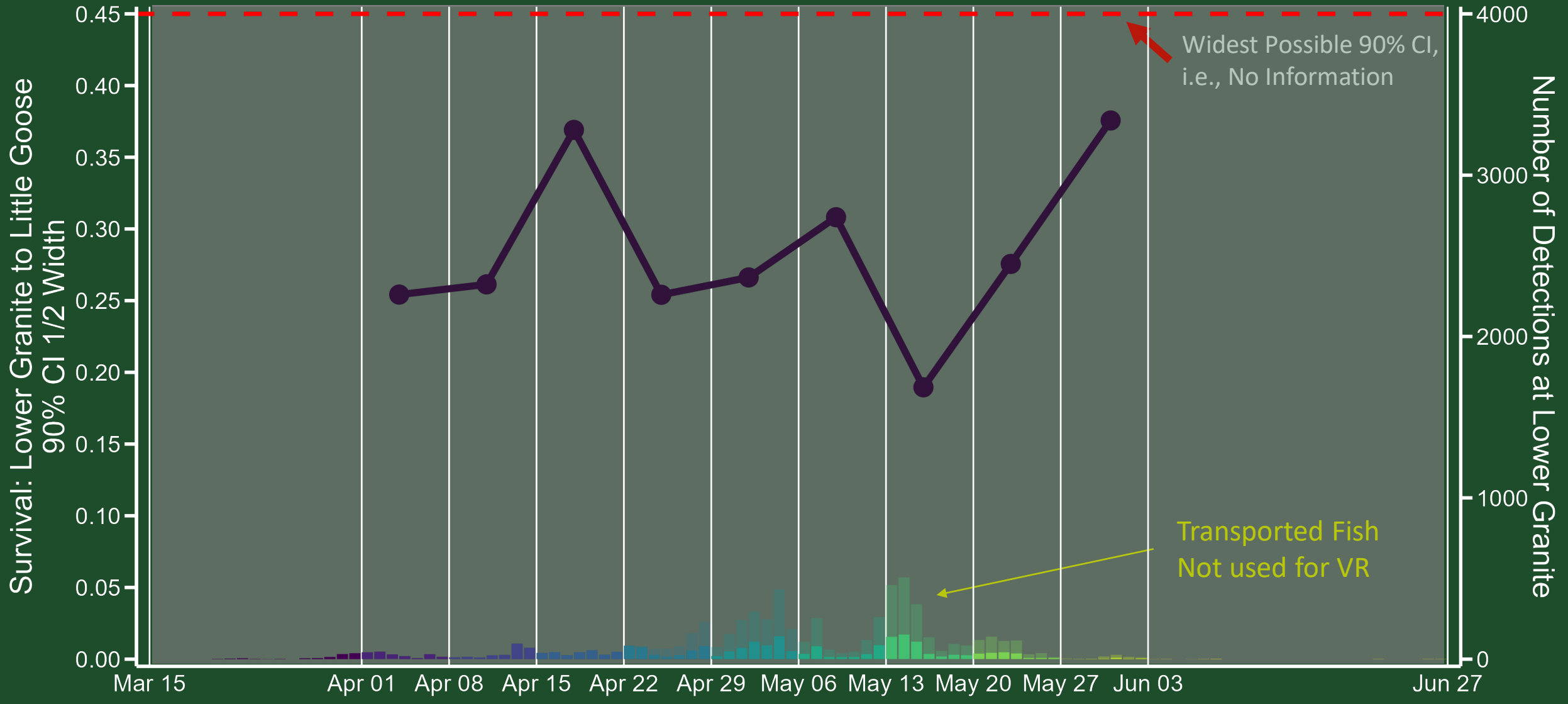
USGS



USGS



USGS

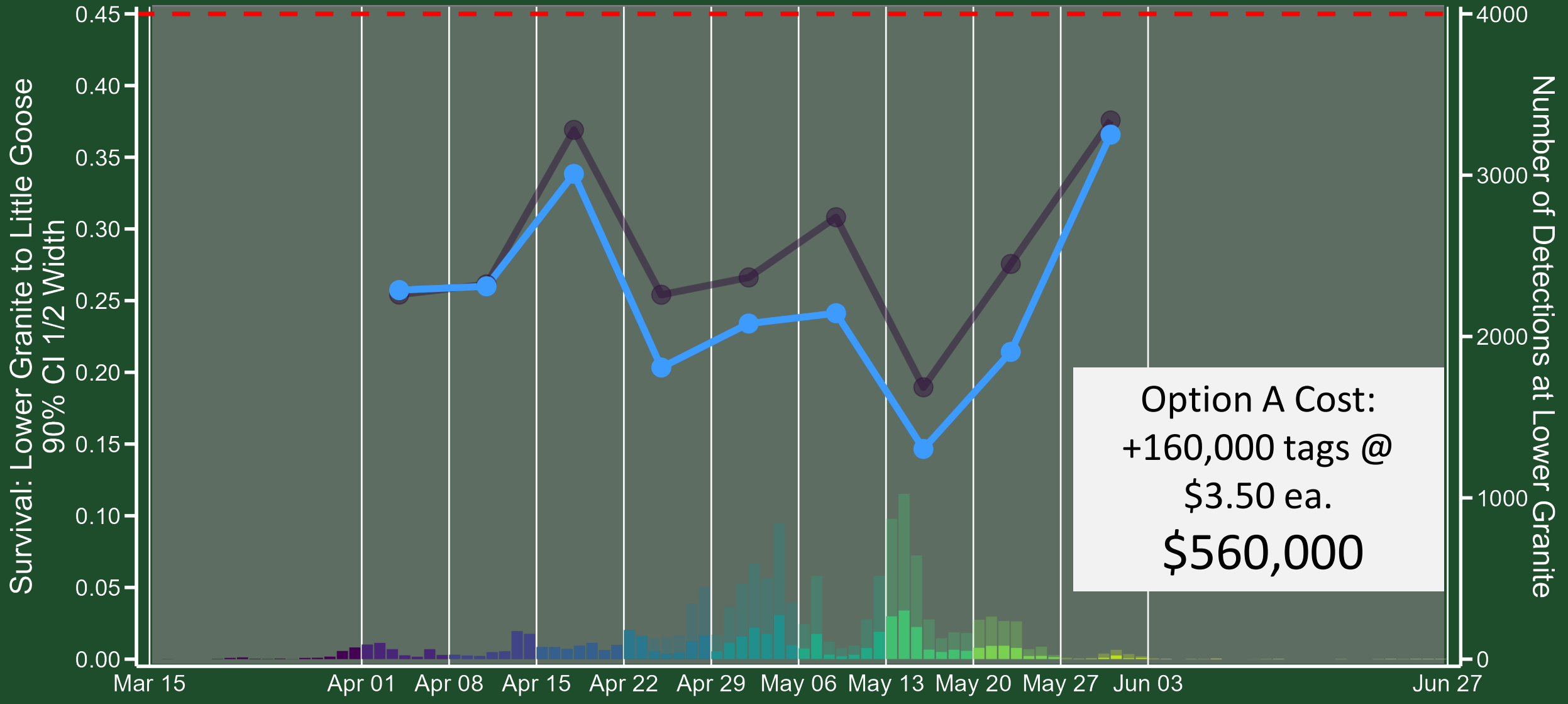


Survival Estimation Option

Baseline

USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



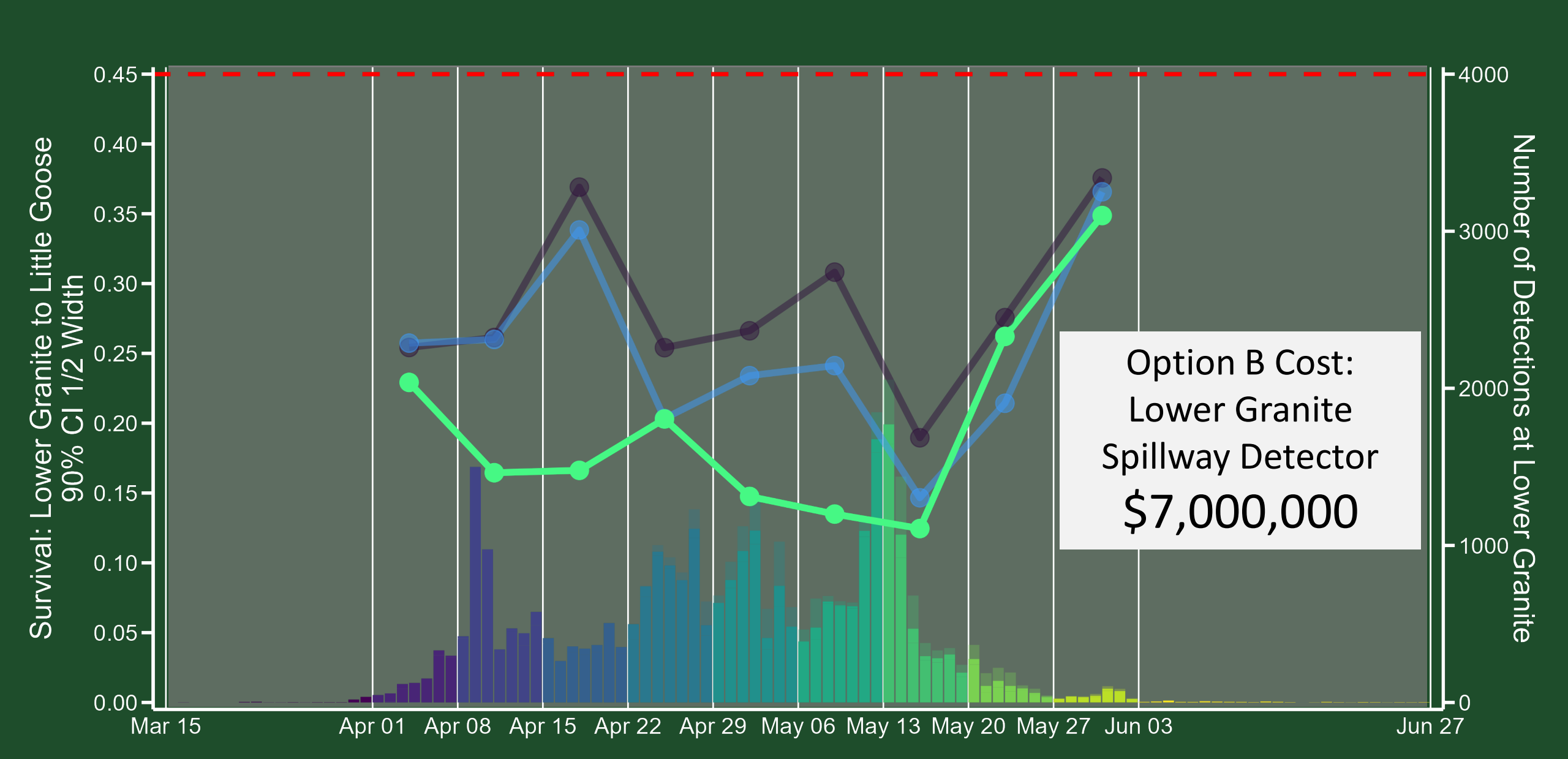
Survival Estimation Option

Baseline

Option A: Double Tags

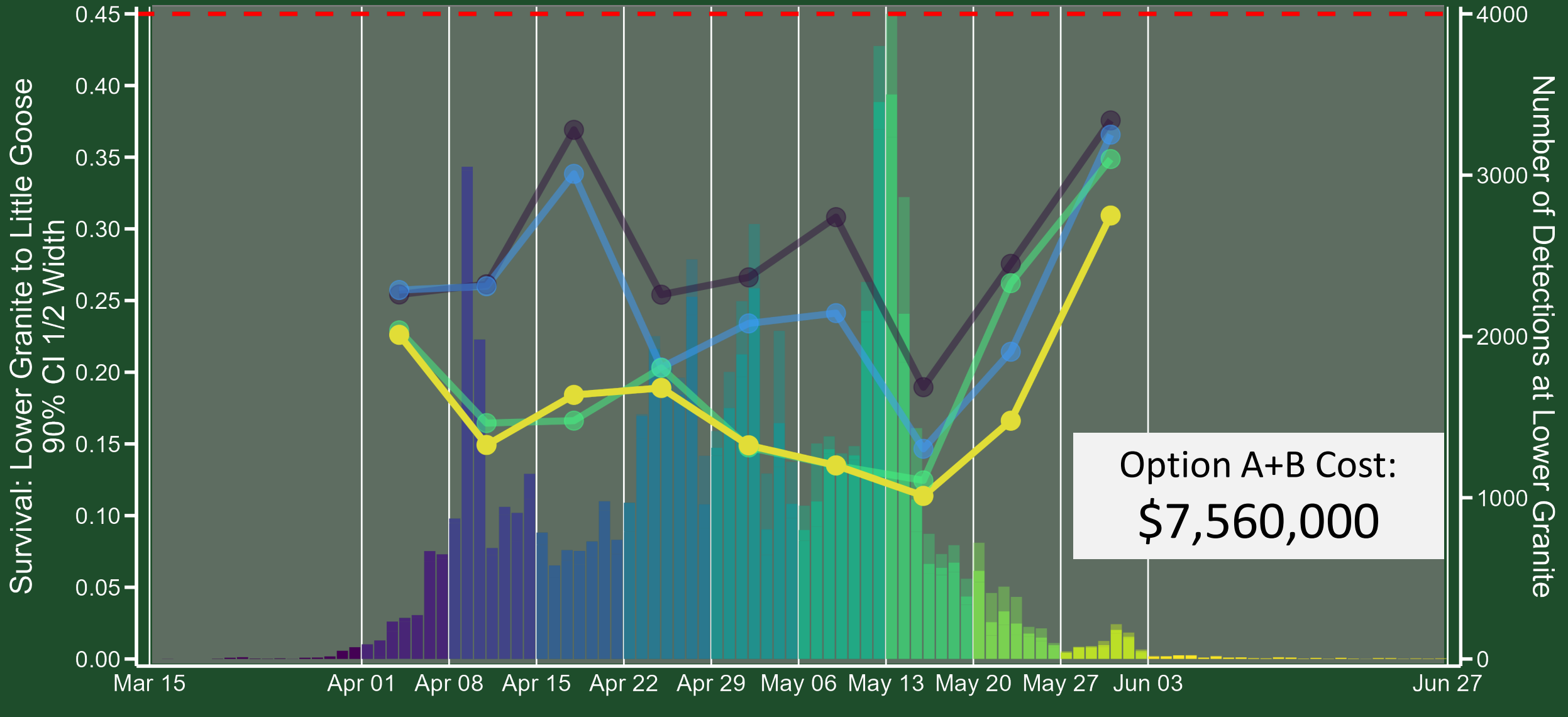
USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



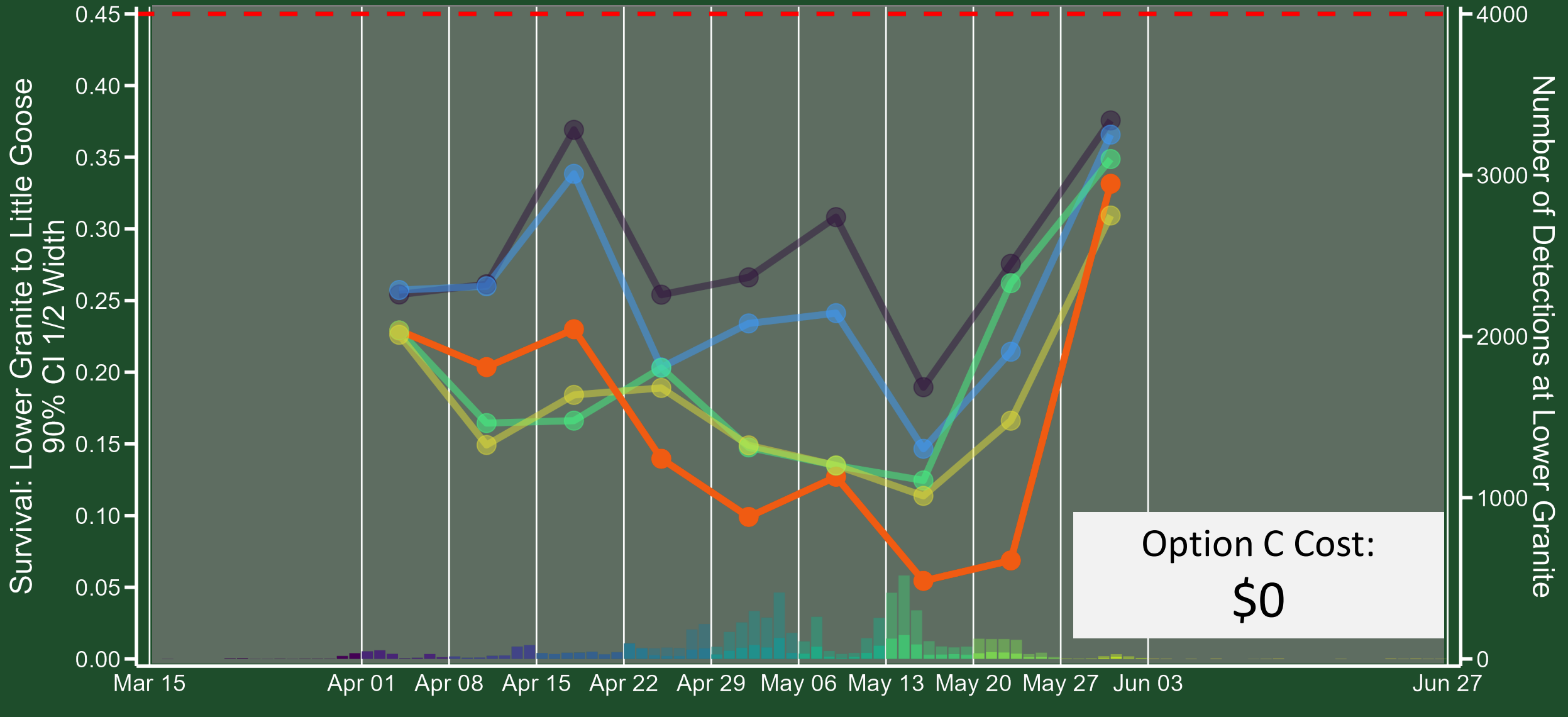
USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.



USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

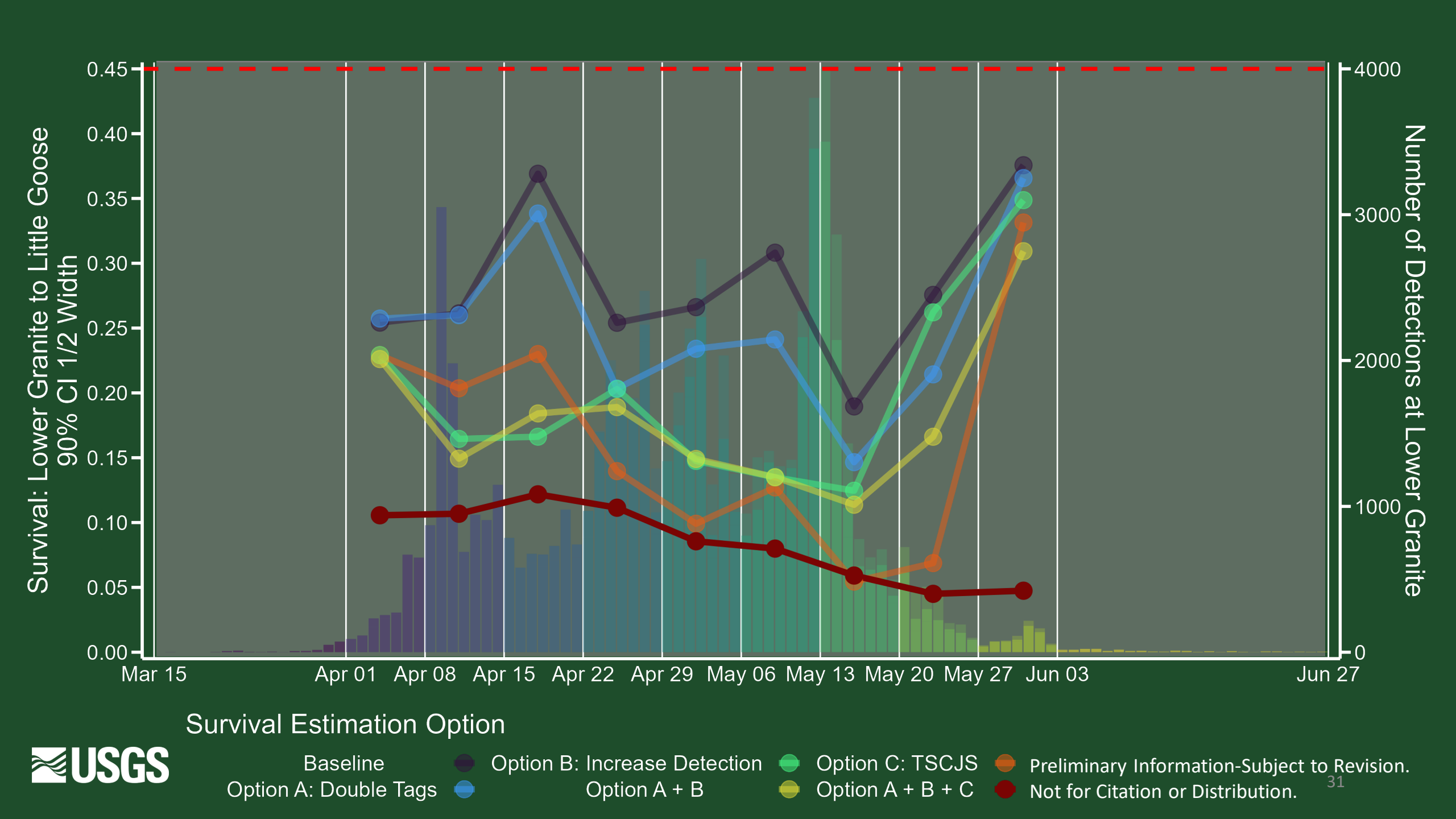


Survival Estimation Option

Baseline
Option A: Double Tags
Option B: Increase Detection
Option A + B
Option C: TSCJS

USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.


Survival: Lower Granite to Little Goose
90% CI 1/2 Width
Number of Detections at Lower Granite
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
4000
3000
2000
1000
0
Mar 15
Apr 01
Apr 08
Apr 15
Apr 22
Apr 29
May 06
May 13
May 20
May 27
Jun 03
Jun 27
Survival Estimation Option
Baseline
Option A: Double Tags
Option B: Increase Detection
Option A + B
Option C: TSCJS
Option A + B + C
Preliminary Information-Subject to Revision.
Not for Citation or Distribution.