A hierarchical approach to joint estimation of juvenile salmonid abundance and detection efficiency

Rethinking methods for quantifying snorkel survey detection efficiency

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Oregon Chapter AFS Meeting

B. Staton[1], C. Justice[1], S. White[1], T. Sedell[2], L. Burns[1], M. Kaylor[3]

[1]Fisheries Science, Columbia River Inter-Tribal Fish Commission
[2]Oregon Department of Fish and Wildlife
[3]Department of Fish and Wildlife, Oregon State University

Snorkel Surveys

What are they?

- Basically what they sound like
- Intended to count juvenile salmonids
- Summer base-flow counts
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Types of observation errors

(1) Partial Detectability (*individual fish may not be seen*)

(2) Misclassification

- Double, triple, etc. counting
- Incorrect species assignment
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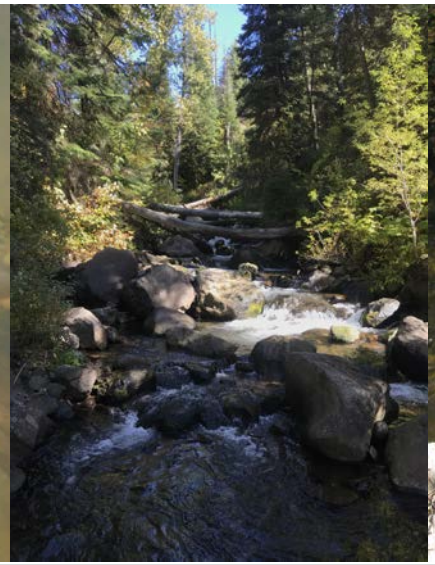
(3) Transcription (*counts may be incorrectly recorded*)



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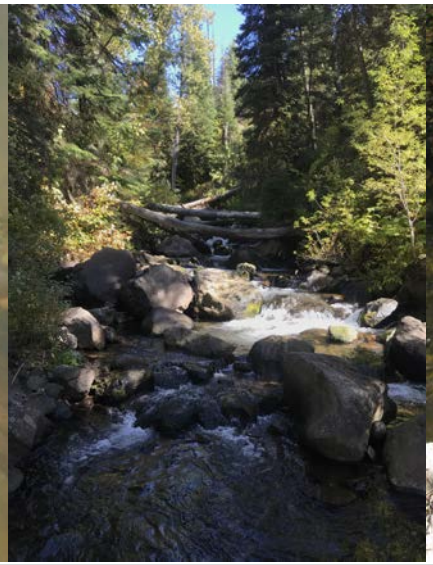

Partial Detectability in Snorkel Surveys

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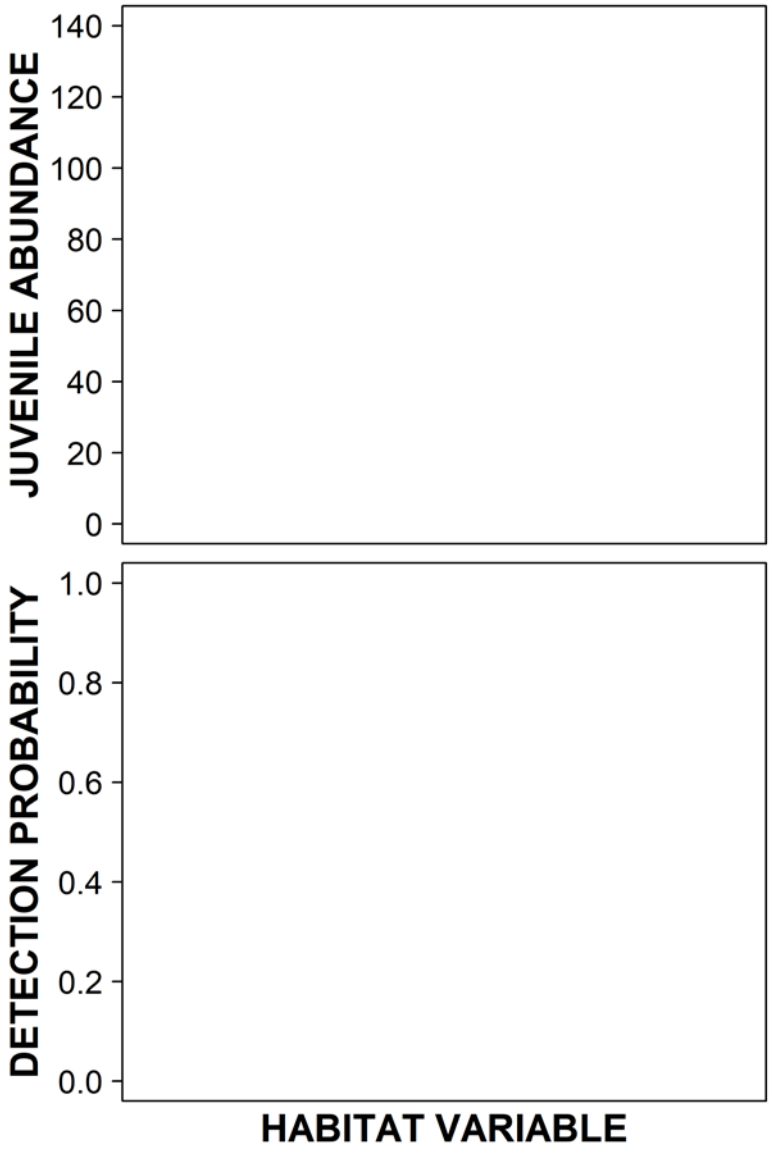

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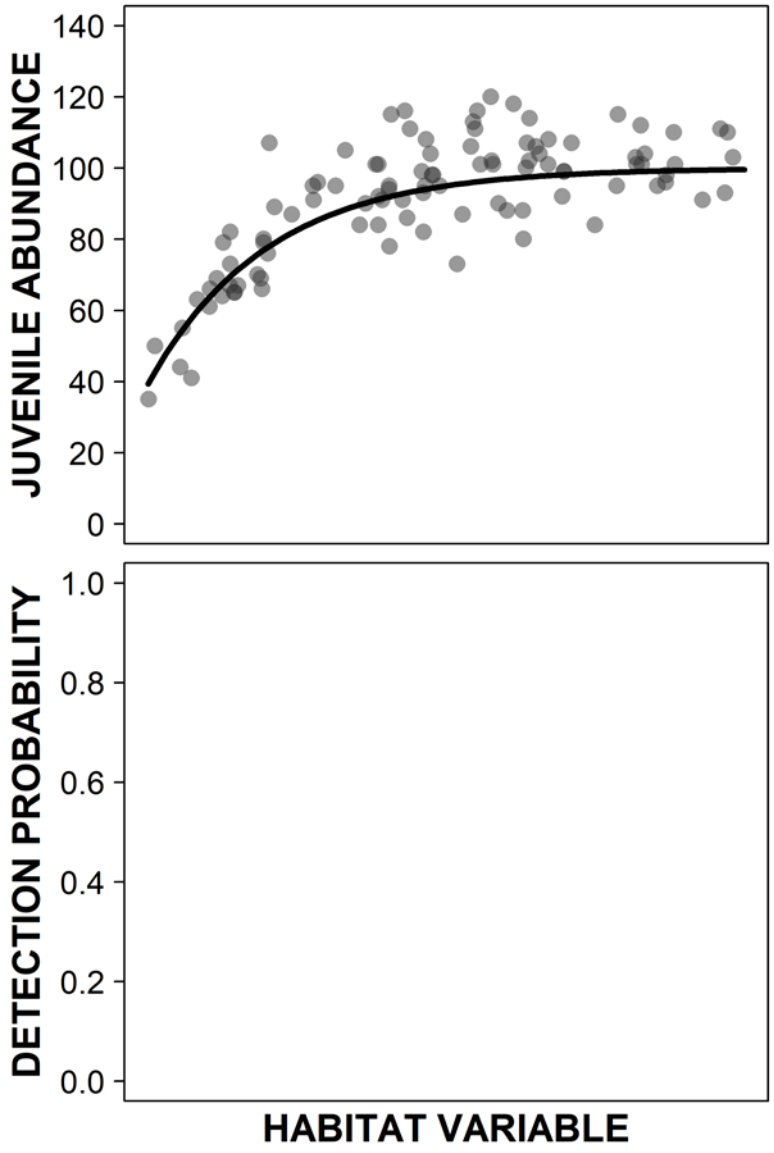

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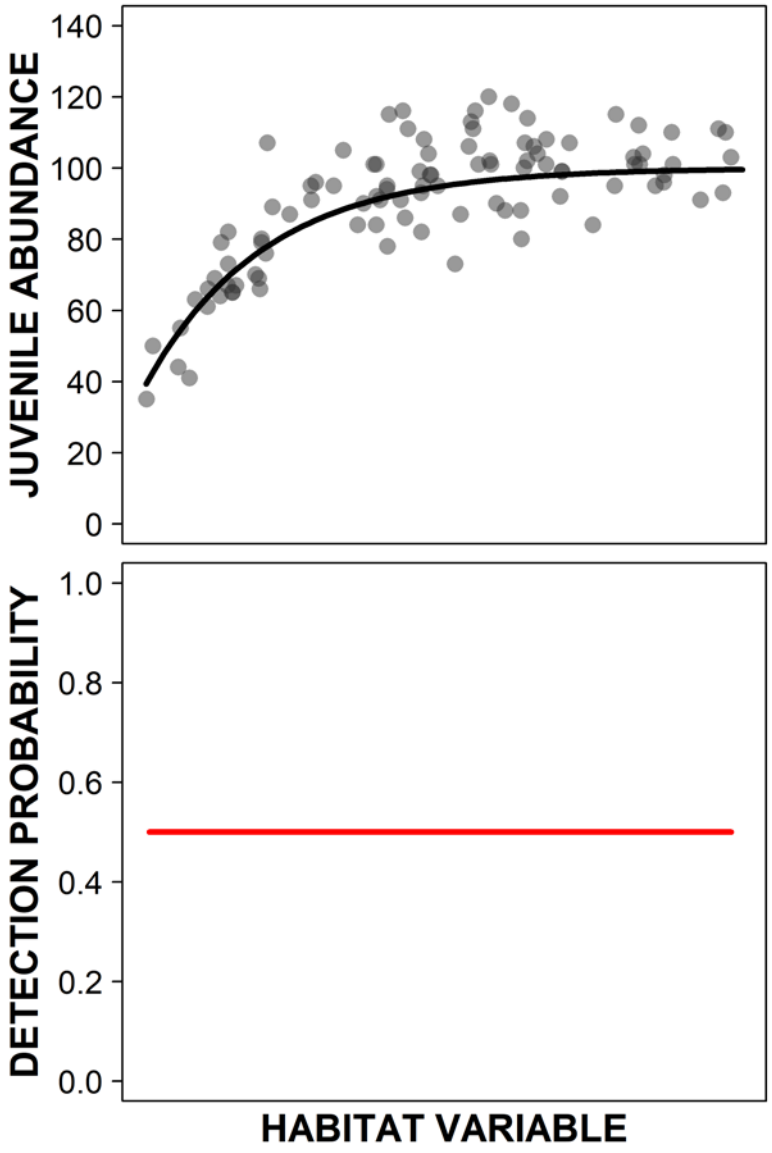

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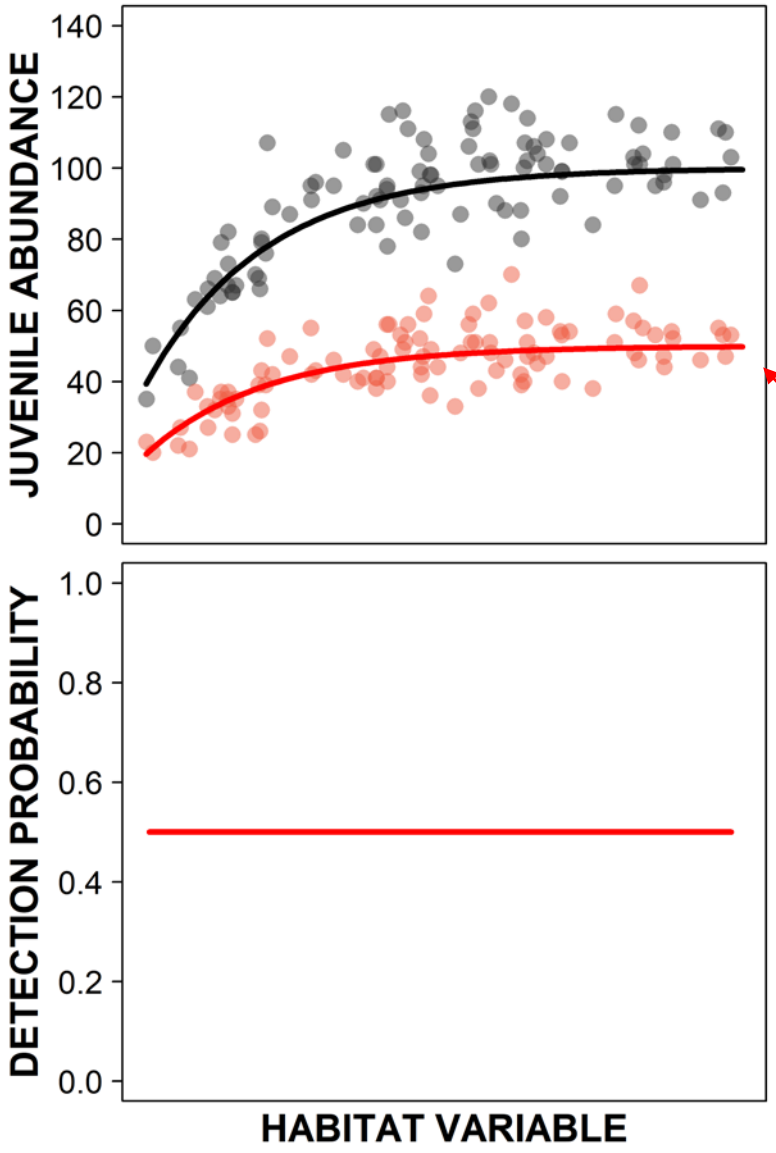

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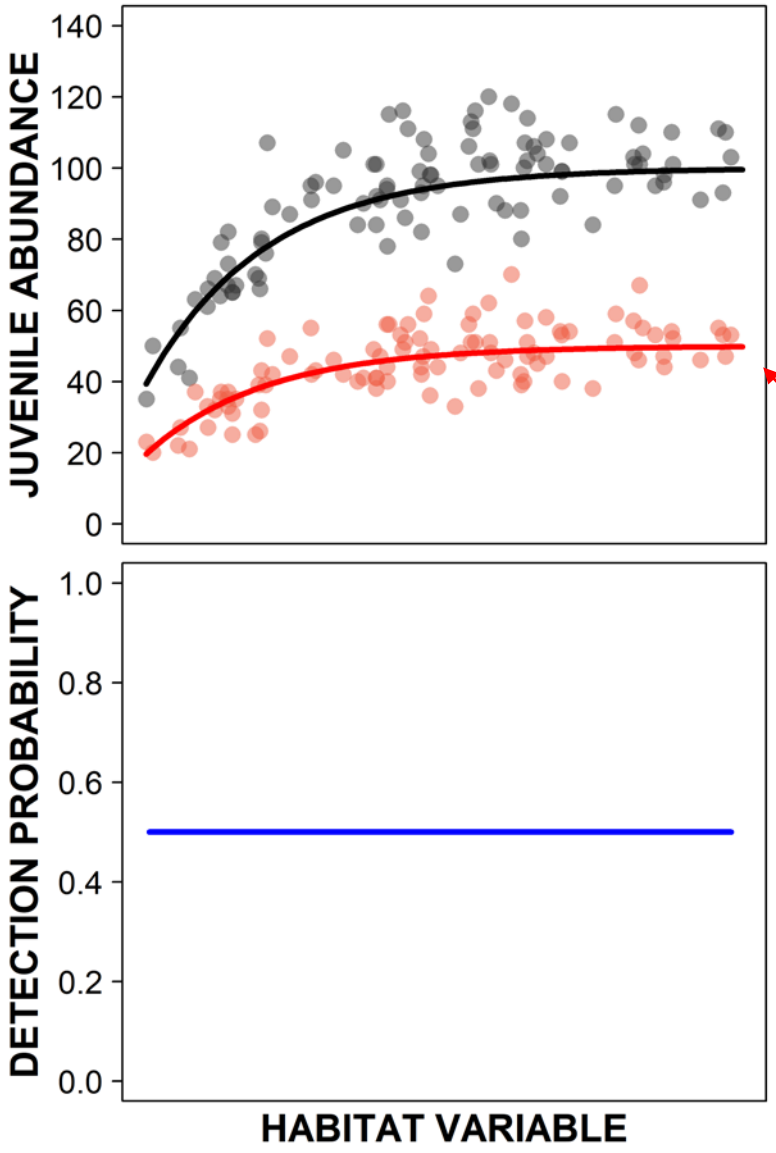

Counts are a **biased representation** of abundance but can be corrected

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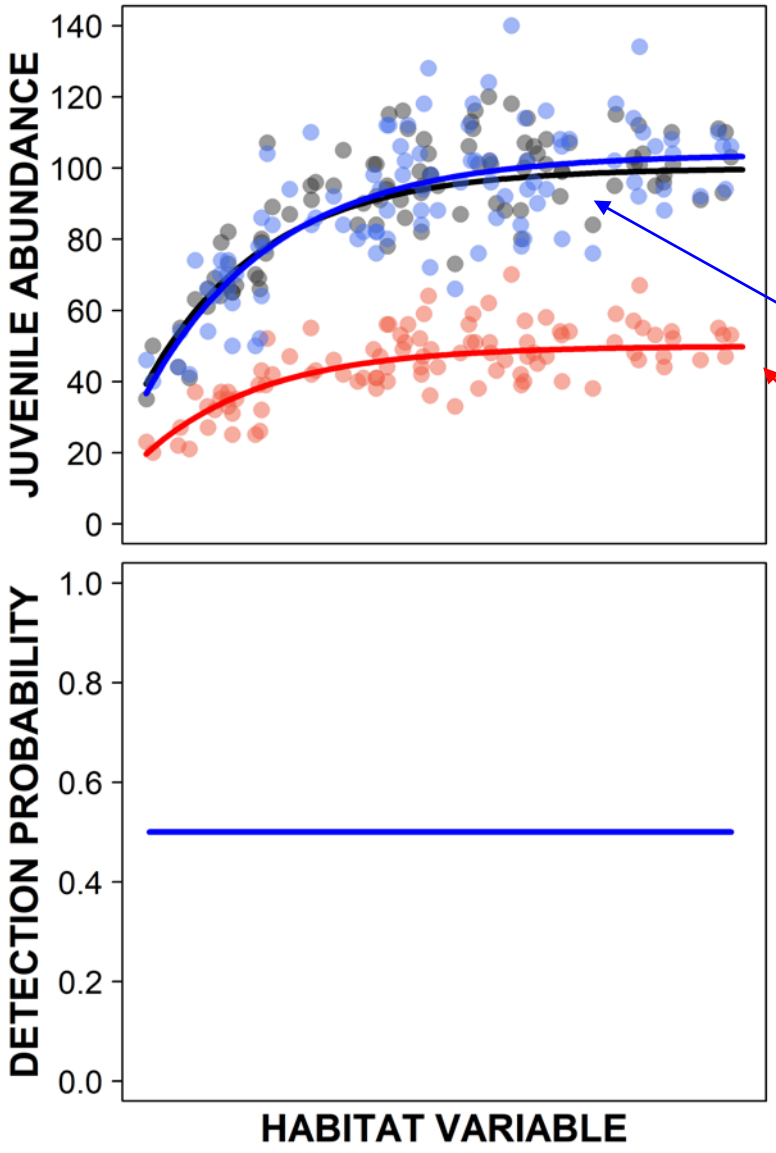

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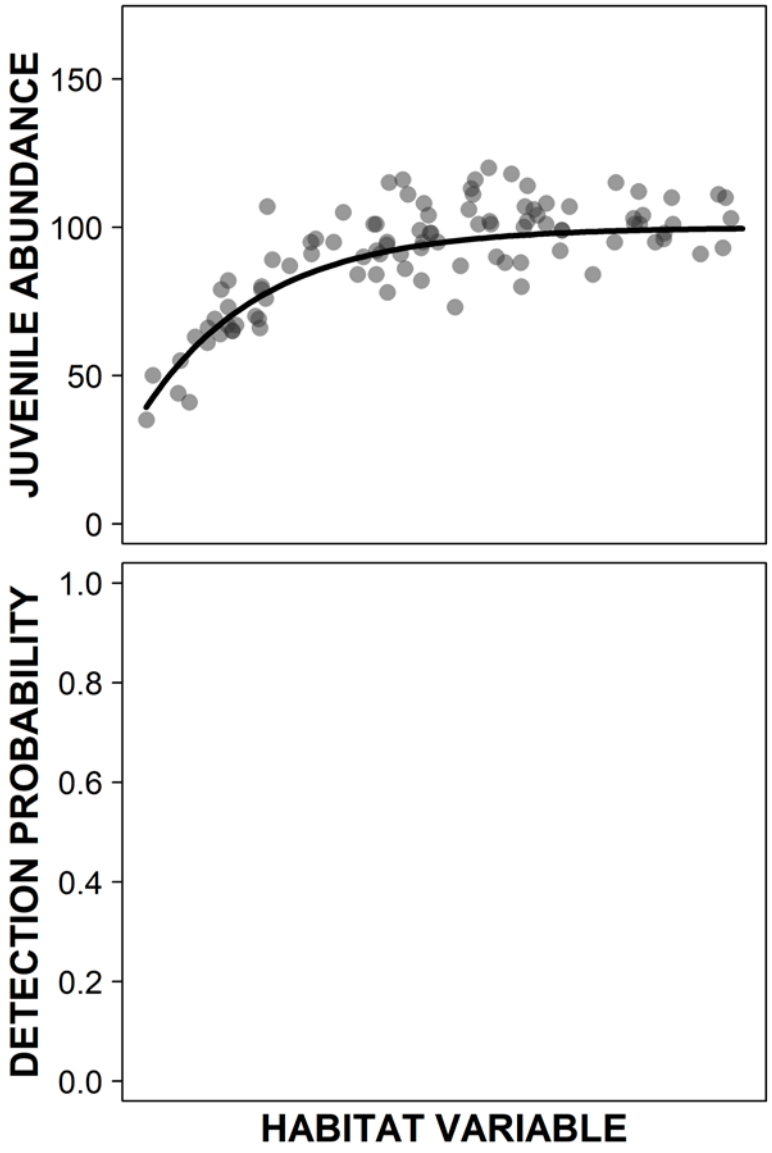

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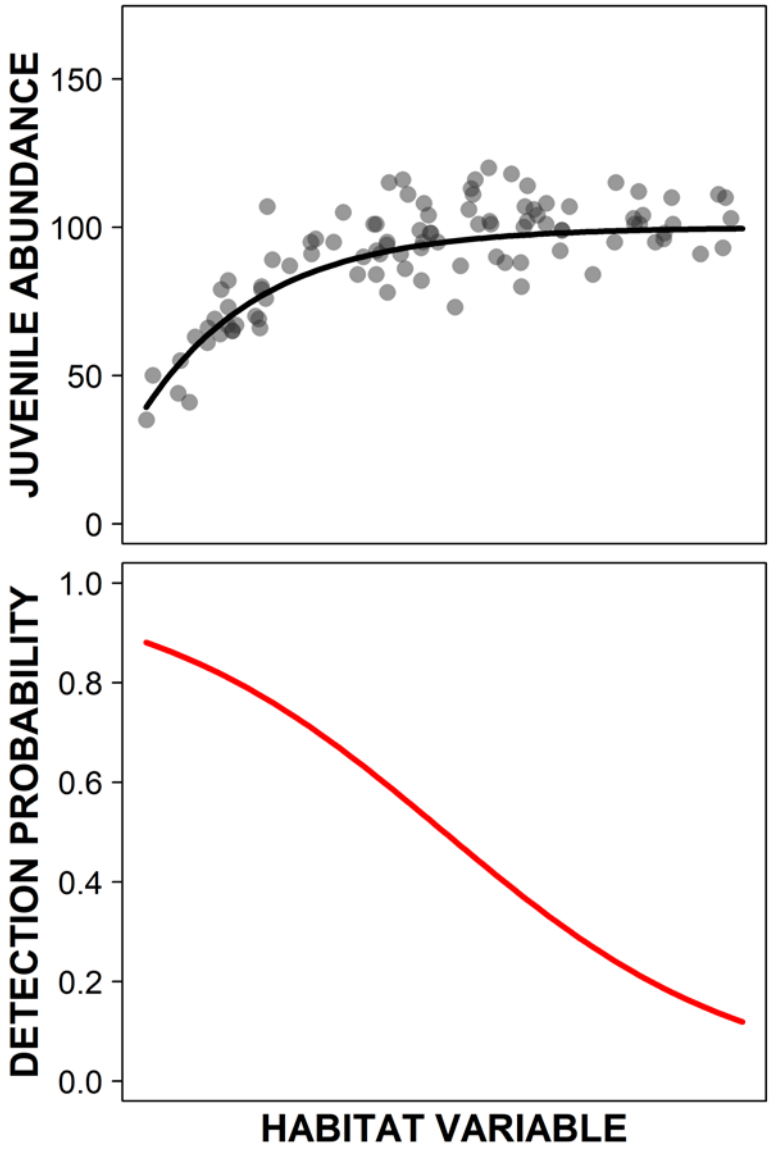

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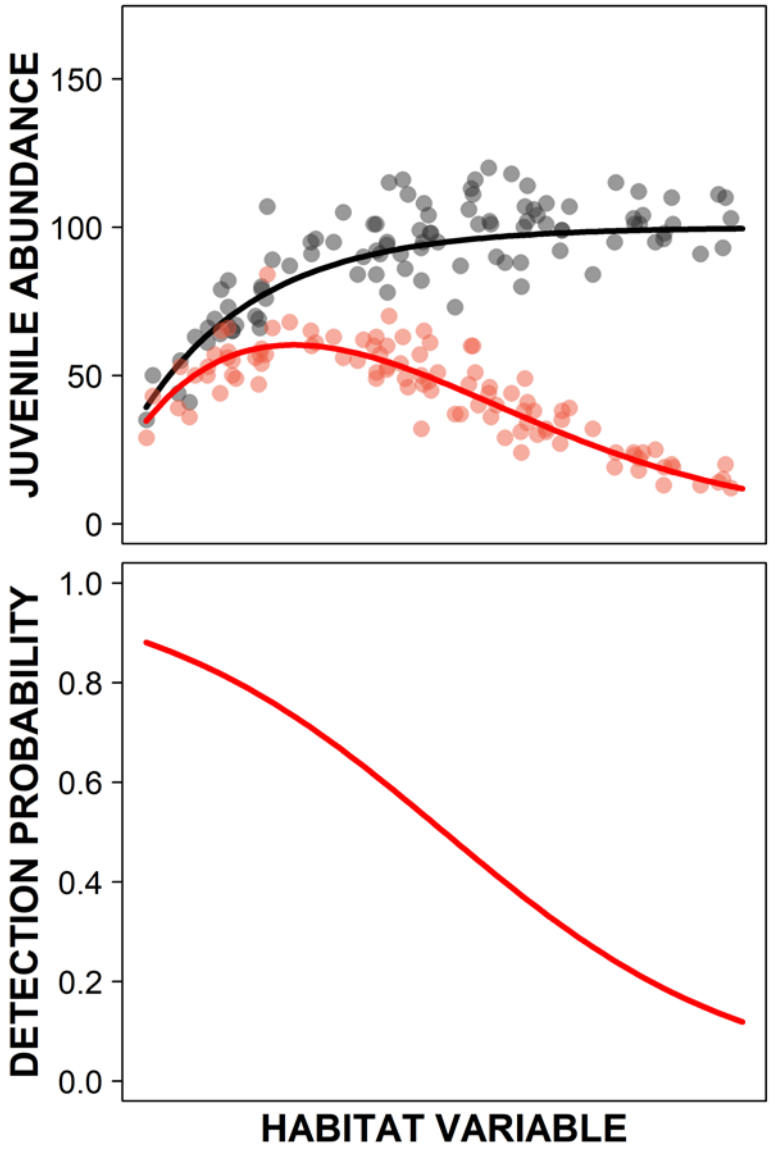

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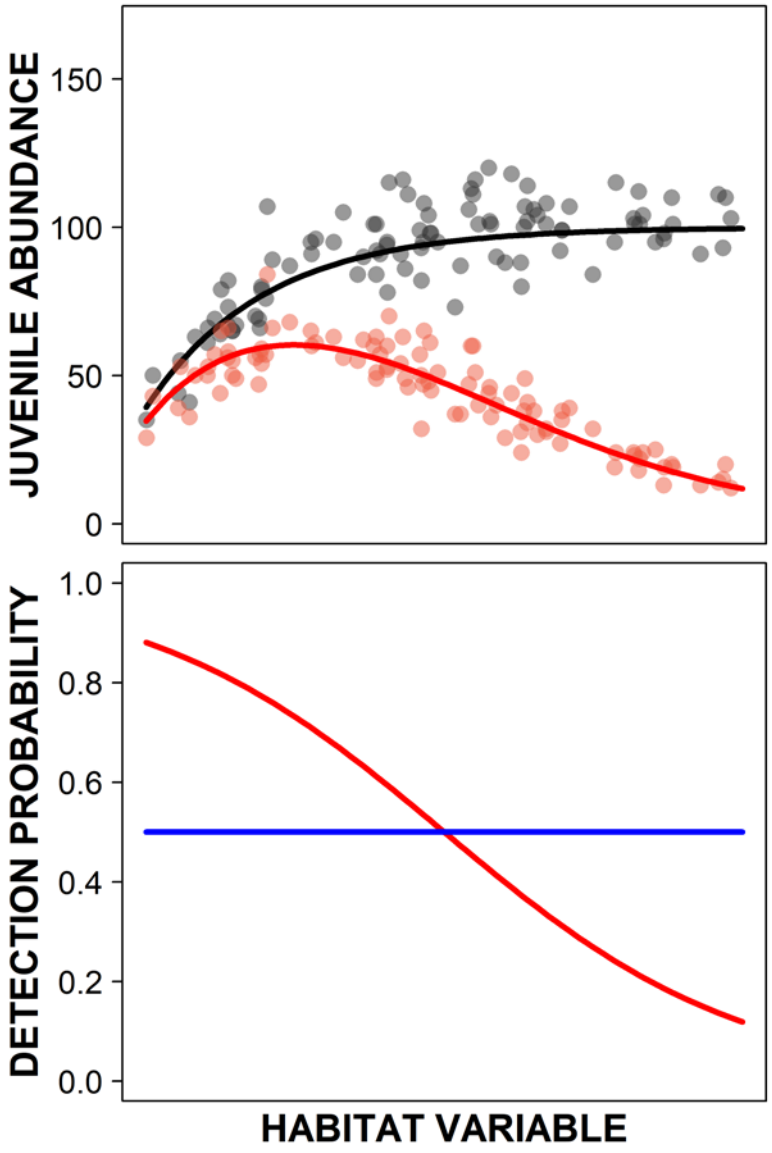

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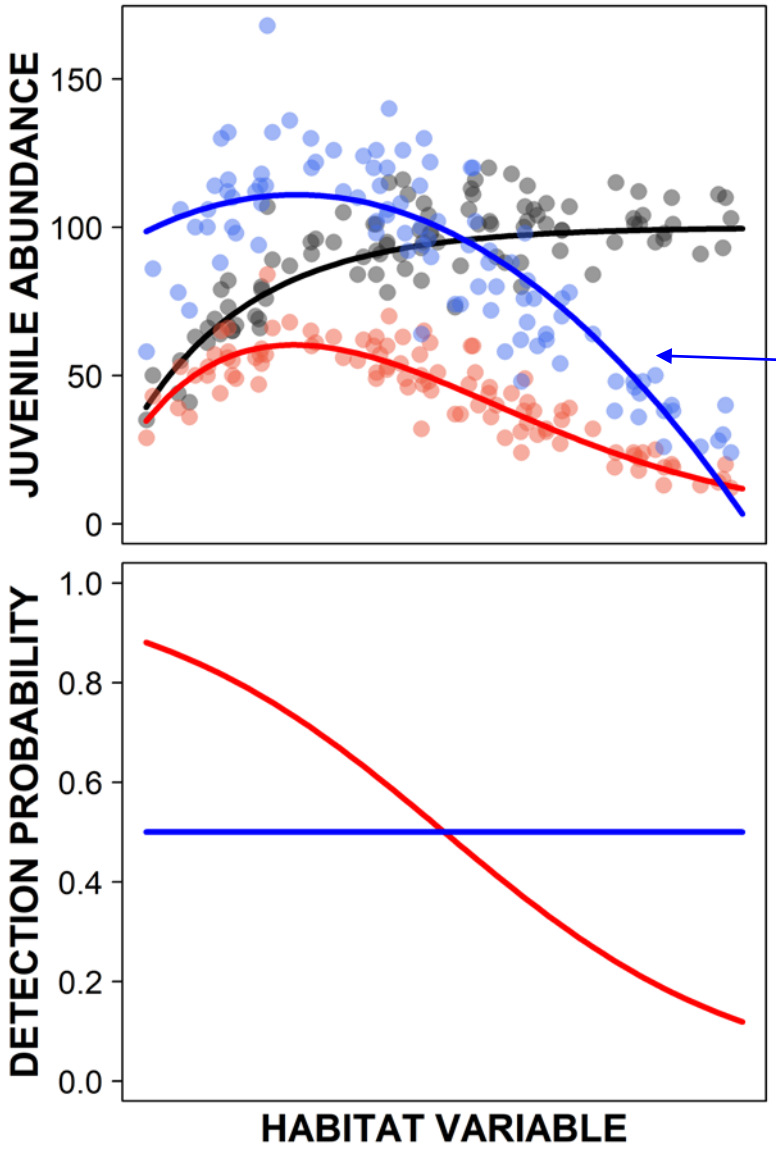

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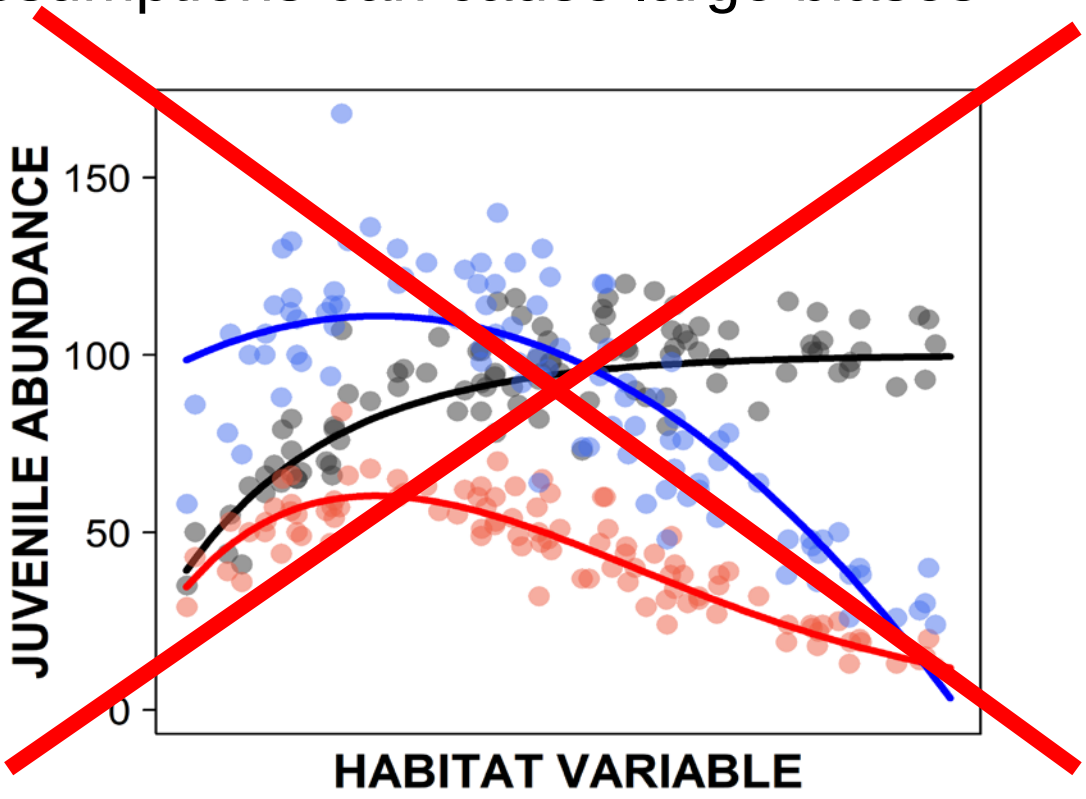

Partial Detectability in Snorkel Surveys

What can we do about it?

- Make assumptions about factors, direction, and magnitude
  - Bad assumptions can cause large biases

- Conduct **directed studies** to quantify it
  - Must have pairs of snorkel counts and abundance

- How to obtain abundance?
  - Depletion estimators (*keep removing fish until you don't catch any more*)
  - Repeated count estimators (*N-mixture models*)
  - Mark-recapture estimators (*based on fraction of population with marks*)

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What can we do about it?

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  - Must have pairs of snorkel counts and abundance
  - Count/abundance = efficiency -> link to habitat

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  "Middle ground" on these

Quantifying Partial Detectability

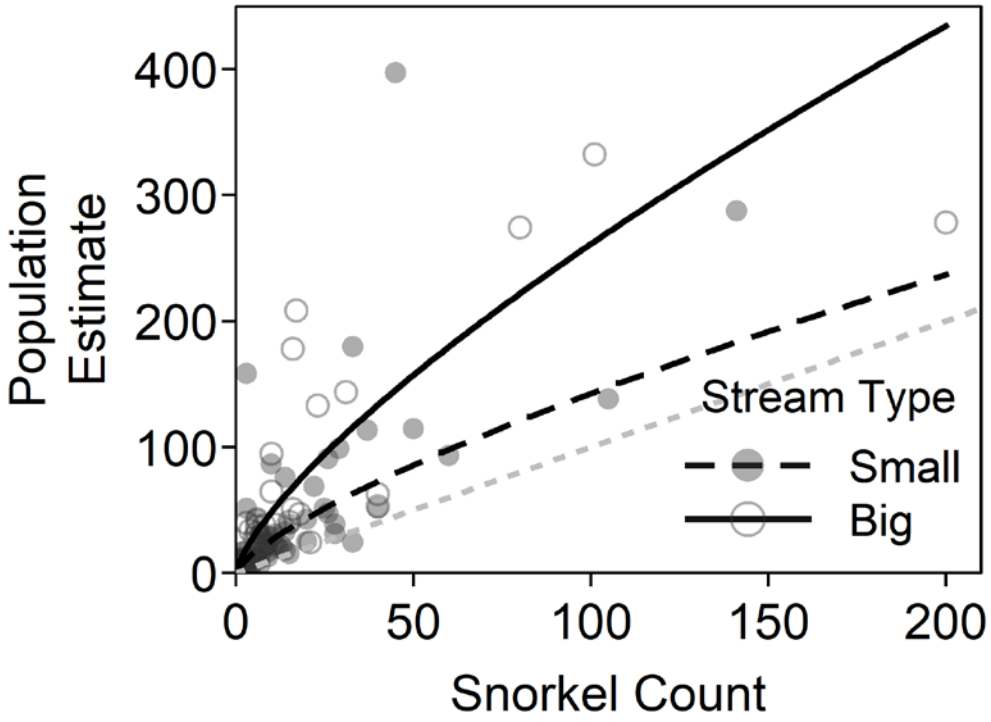
ODFW/CRITFC study

- Summers of 2012/2015; Grande Ronde Basin
- At a wide variety of habitat types:
  (1) Snorkel the channel unit
  (2) Insert block nets
  (3) Capture fish and mark them *(electrofishing + fin clips)*
  (4) Allow population to mix
  (5) Capture fish and count recaptures + novel captures
  (6) Remove block nets
- Obtain a statistical relationship for correcting snorkel counts for partial detectability
- ~100 paired snorkel counts and abundance estimates

Quantifying Partial Detectability

The current approach

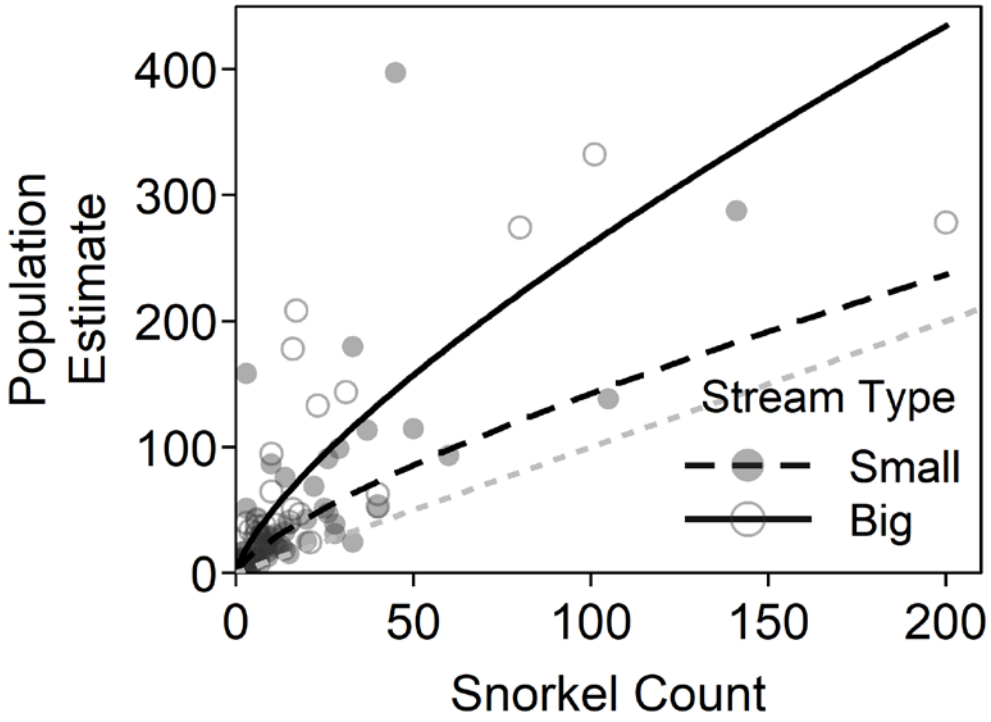
- Regression: predict total salmonid abundance directly from snorkel count
- Same count gives different abundance in small vs. large streams



Quantifying Partial Detectability

***Potential problems** with the current approach*

- The population estimate is highly uncertain, ignored
- Assumes stream size (binary) is the only factor impacting detection
- Assumes all salmonids are equally detectable



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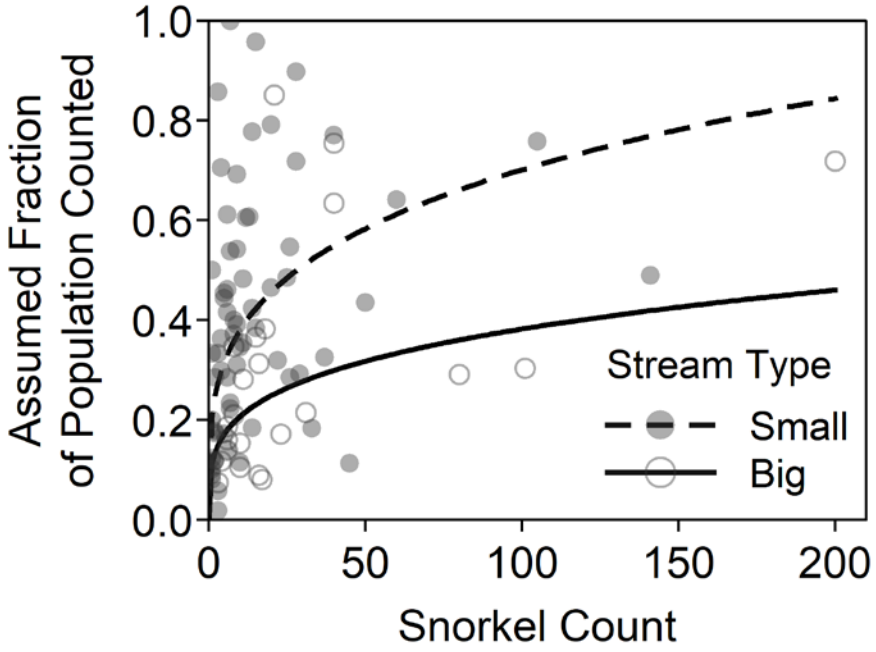
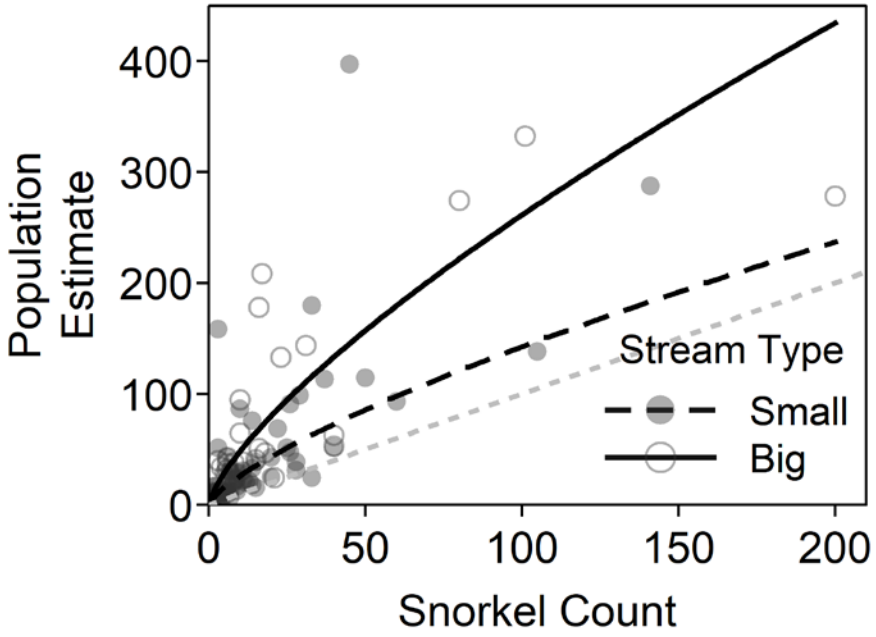
- Assumes detection probability is a function of count





Rethinking Partial Detectability

As a binomial process

- *N* fish in channel unit *j*
  - Outcome 1: individual *i* is seen (with probability p_j)
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- p_j is a complex function of
  - Habitat conditions, fish behavior, snorkeler aptitude
- If *N* is known, we can estimate *p* as a function of these covariates via logistic regression

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PROBLEM

N is not known! Mark-recapture provides an estimate of *N*, with substantial uncertainty due to sampling variability

SOLUTION

Treat *N* as a latent parameter and apply a joint likelihood to explain both mark-recapture and snorkel data

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Layout of hierarchical model

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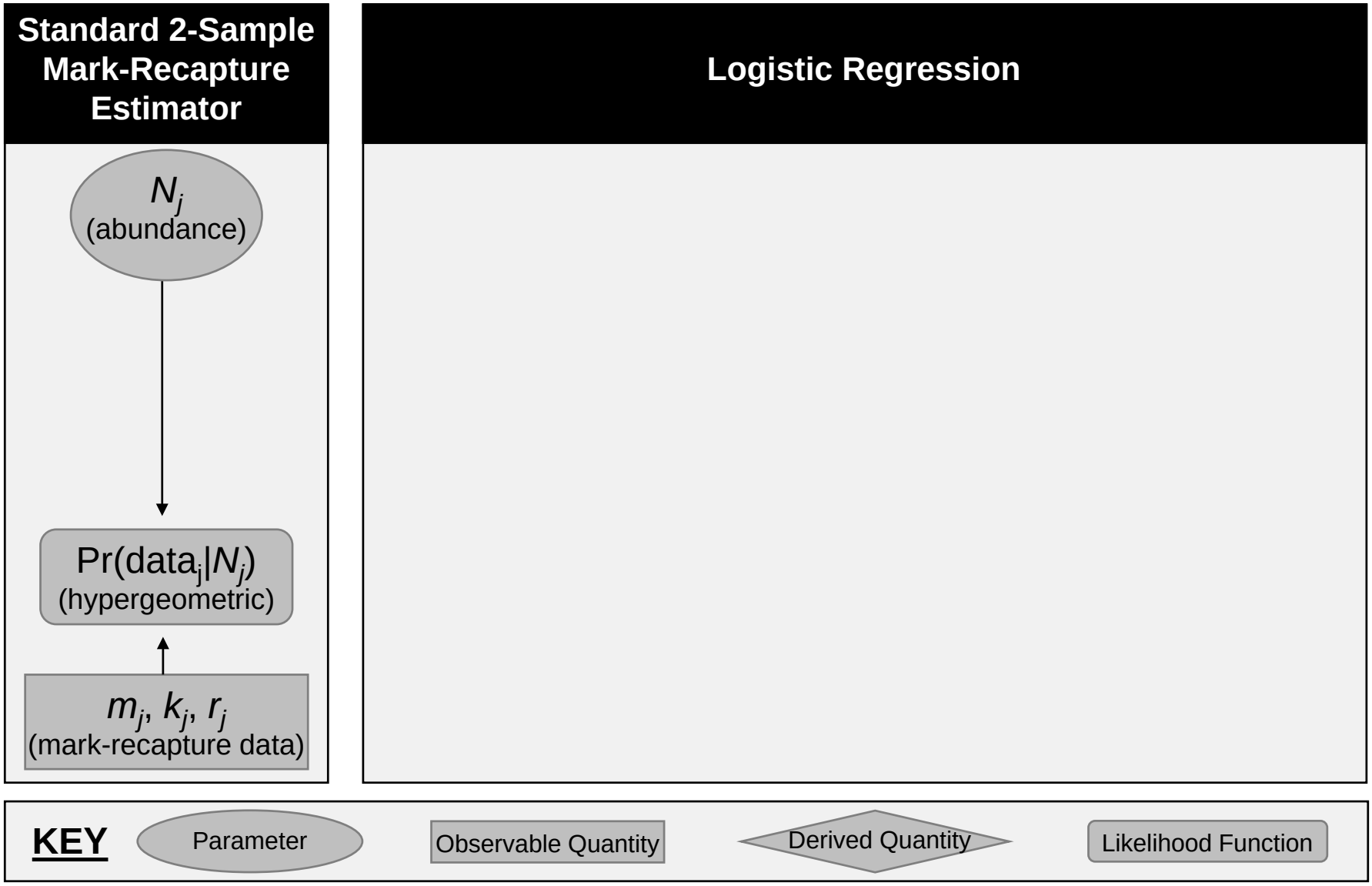

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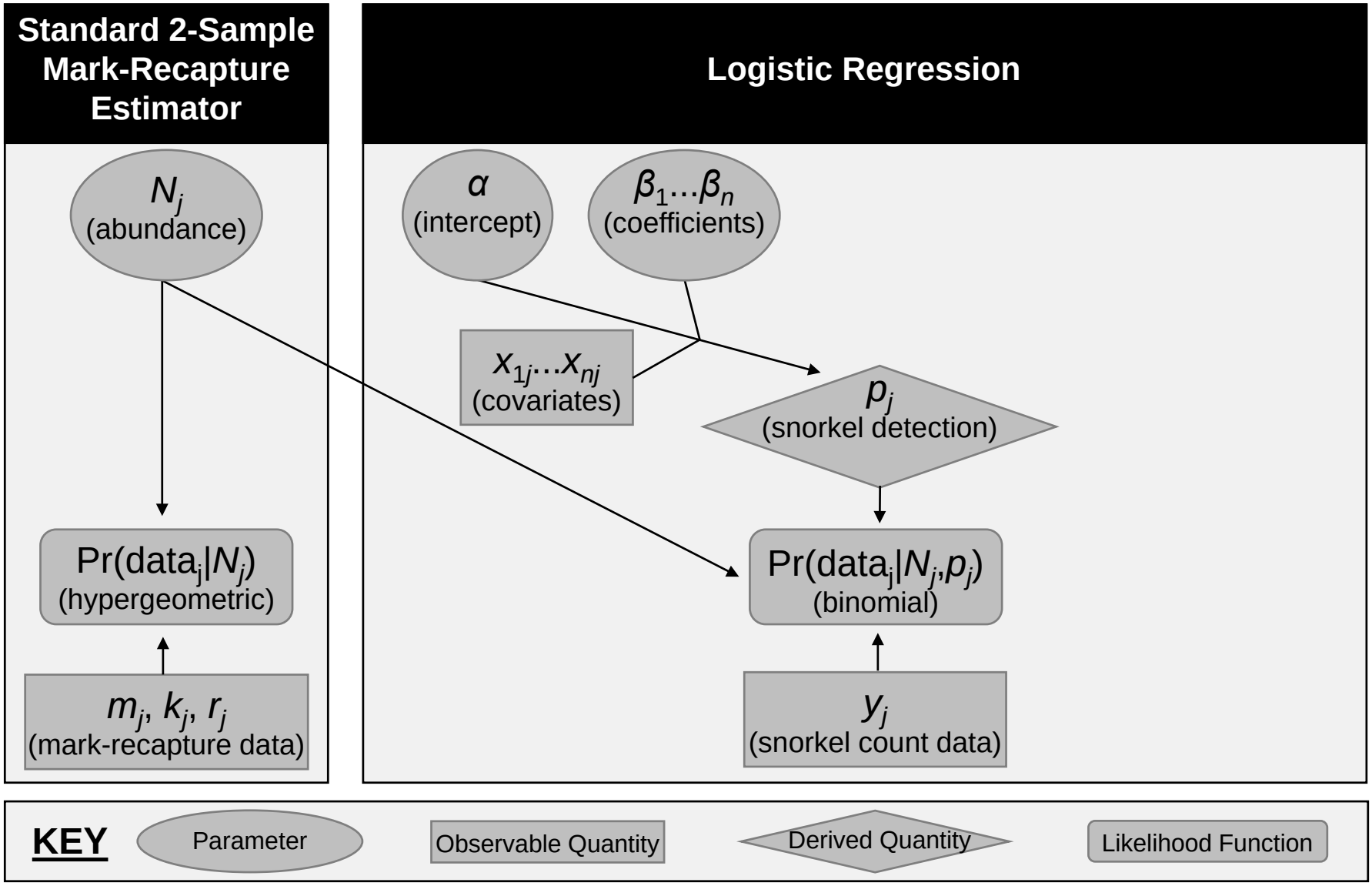

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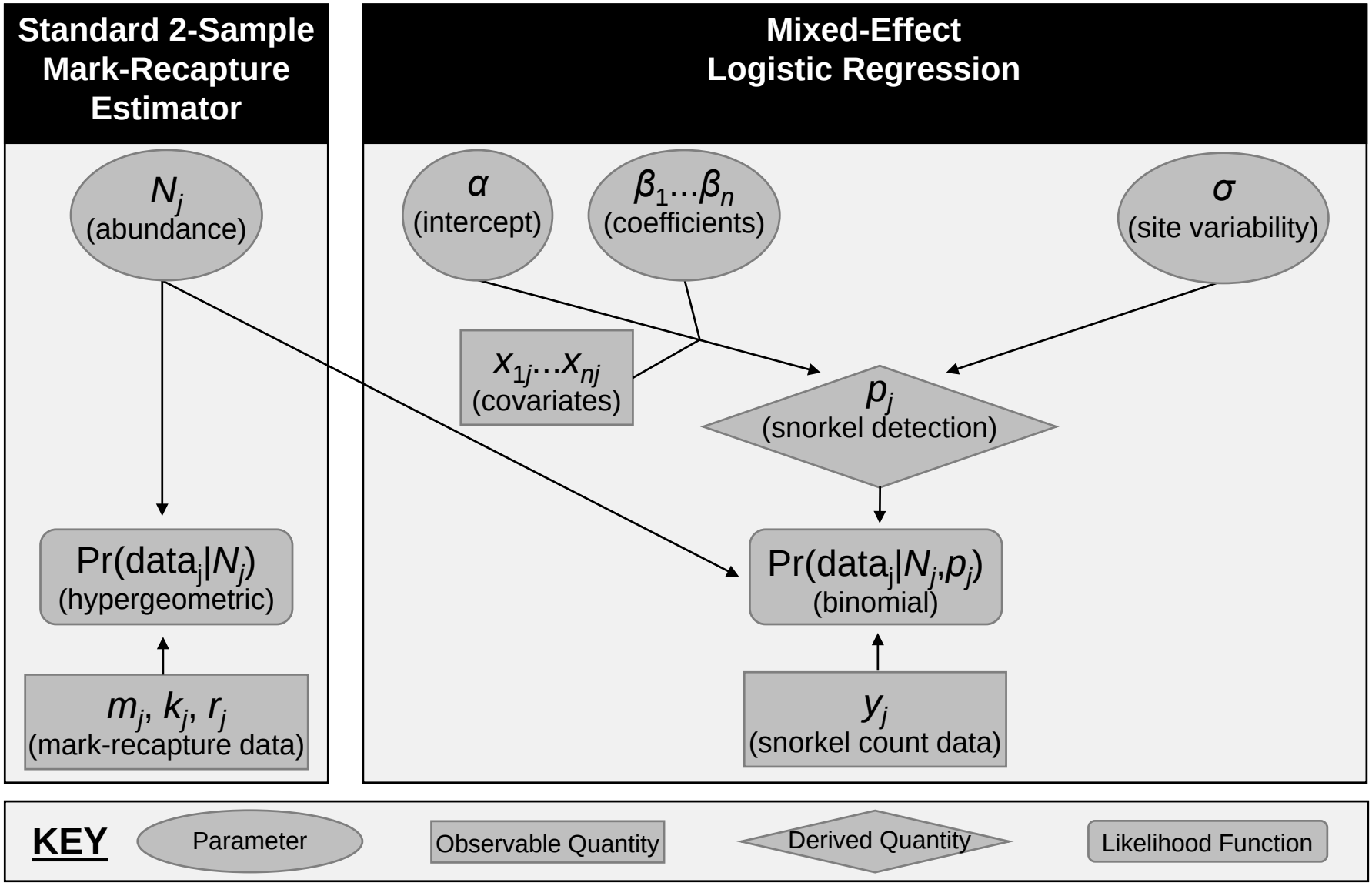

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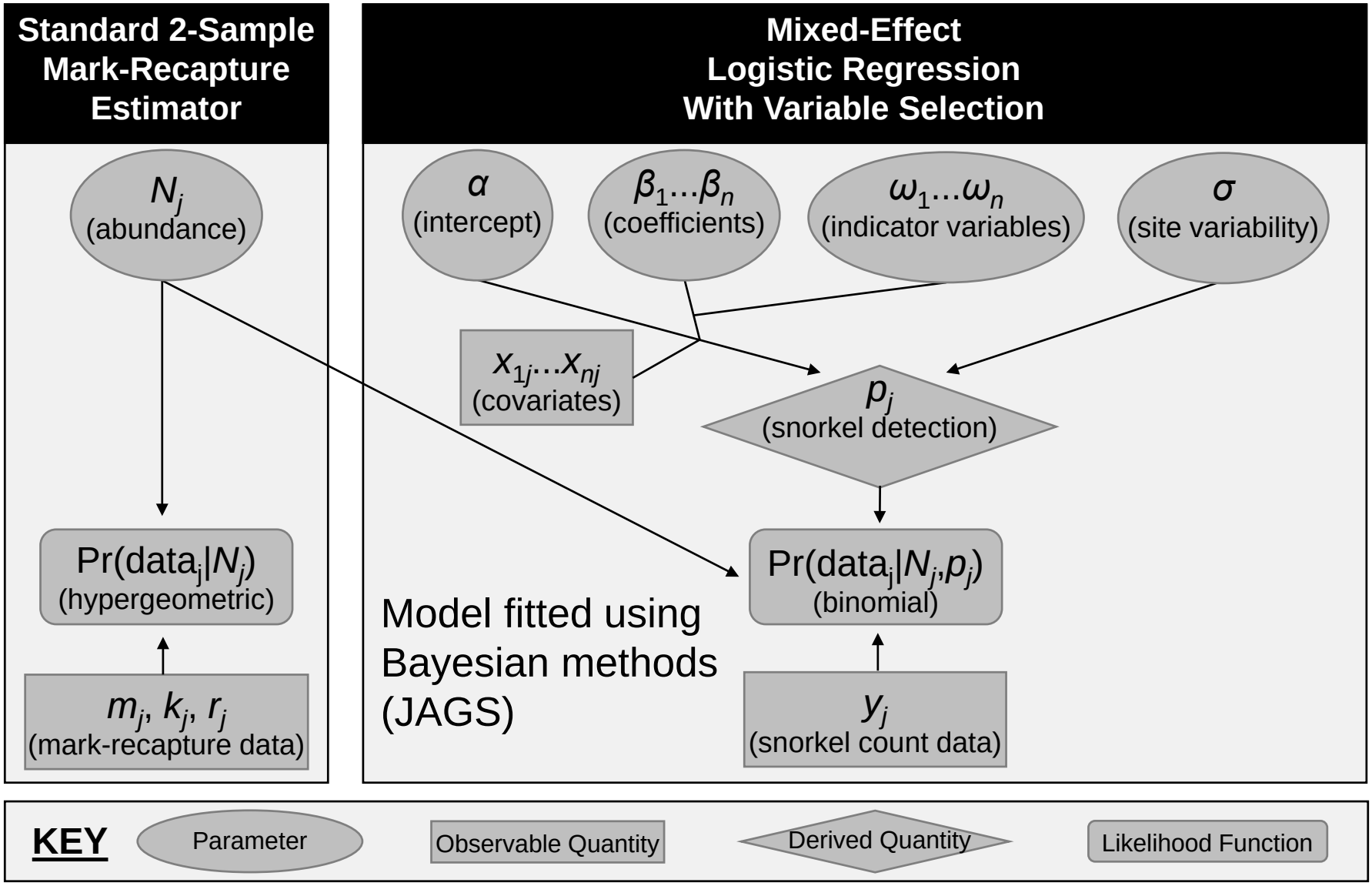

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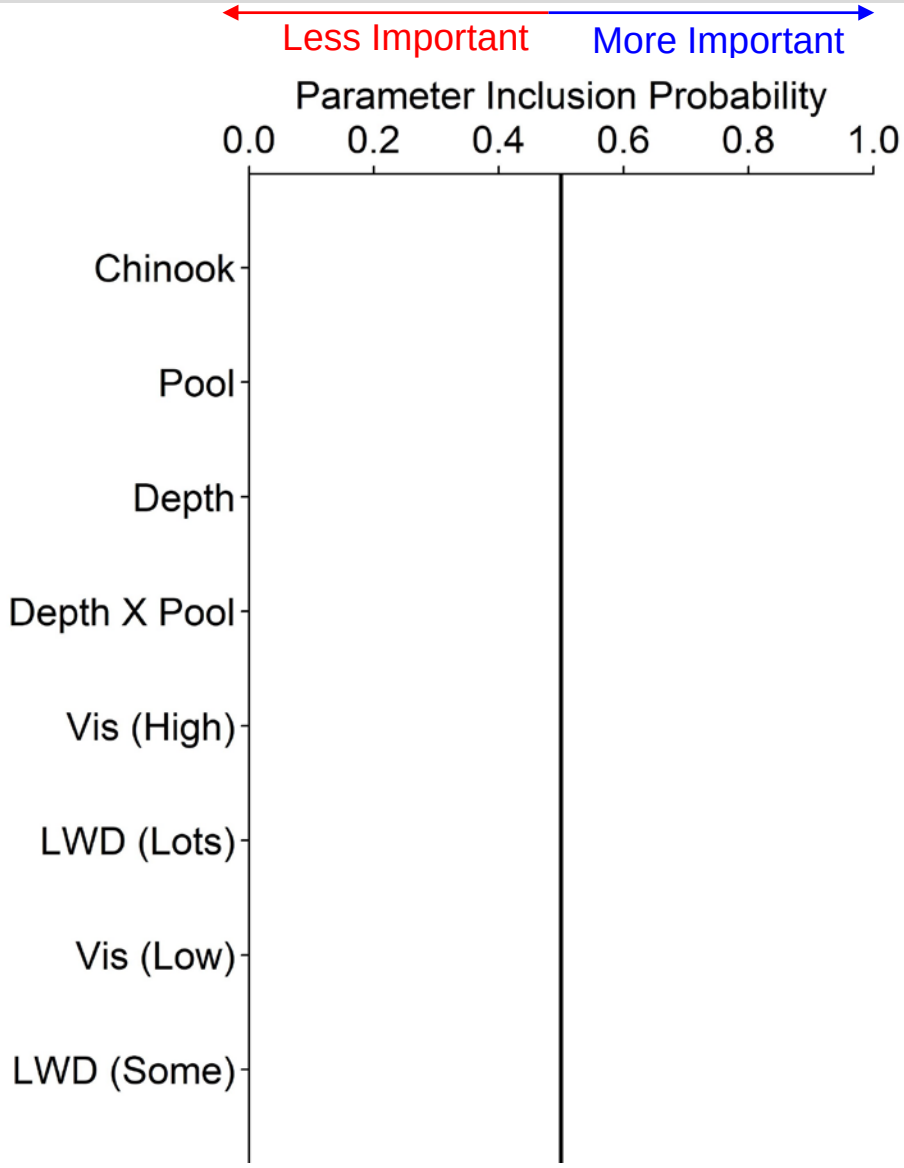
Variable importance: parameter inclusion probability



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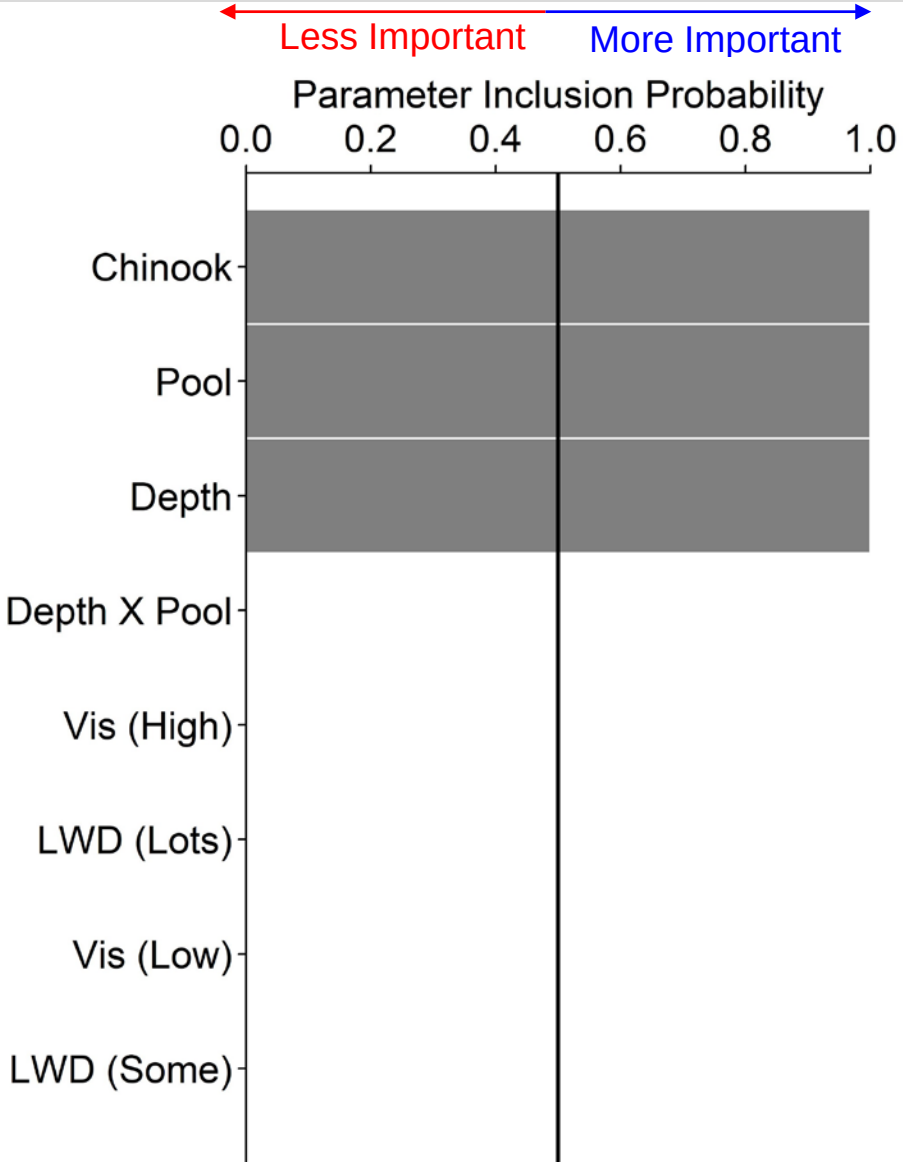

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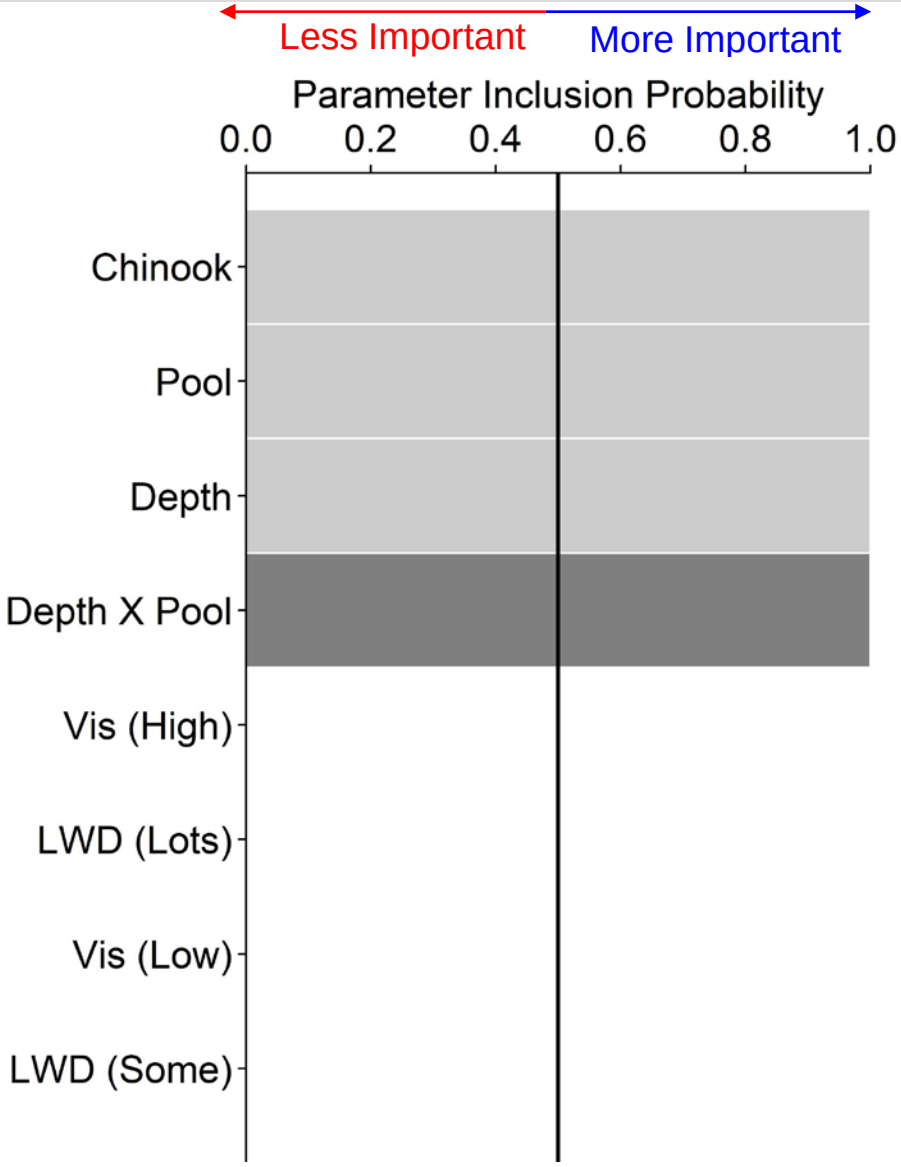

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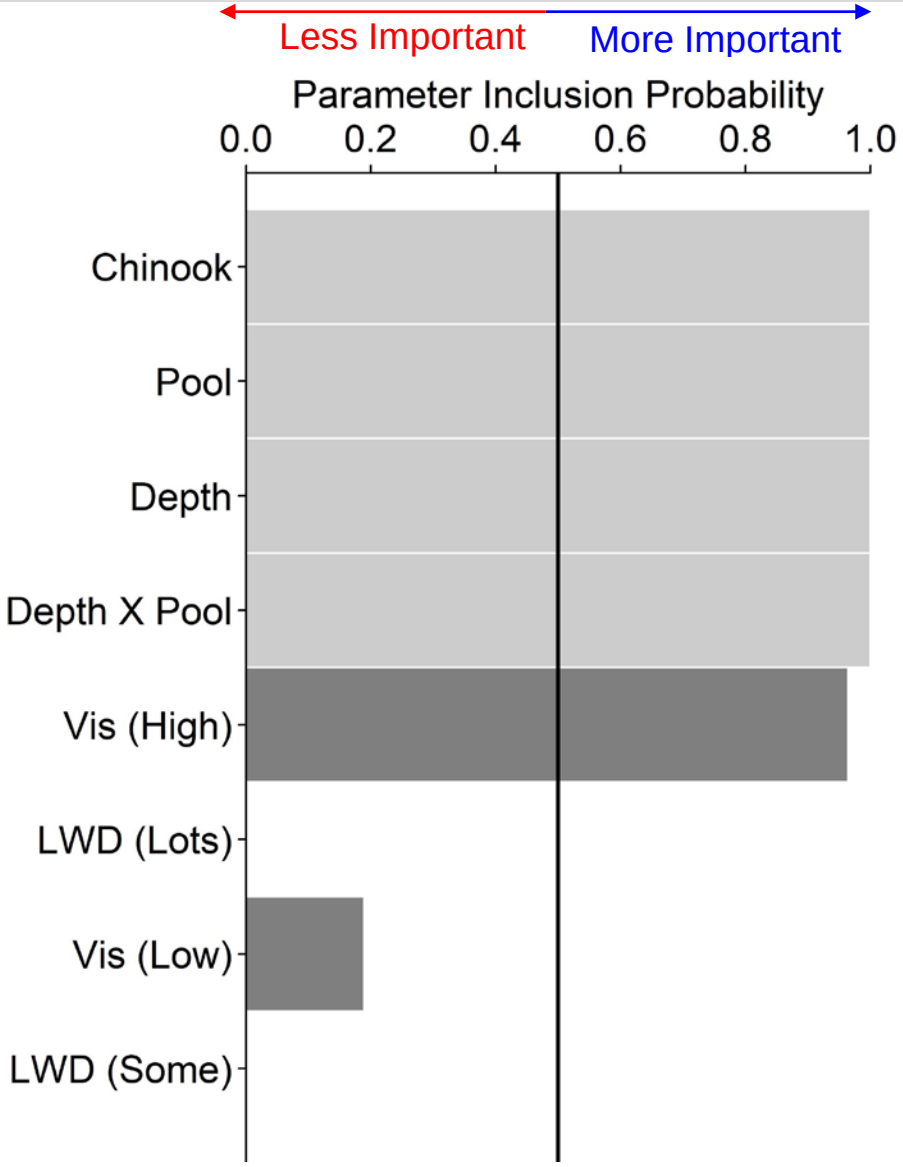

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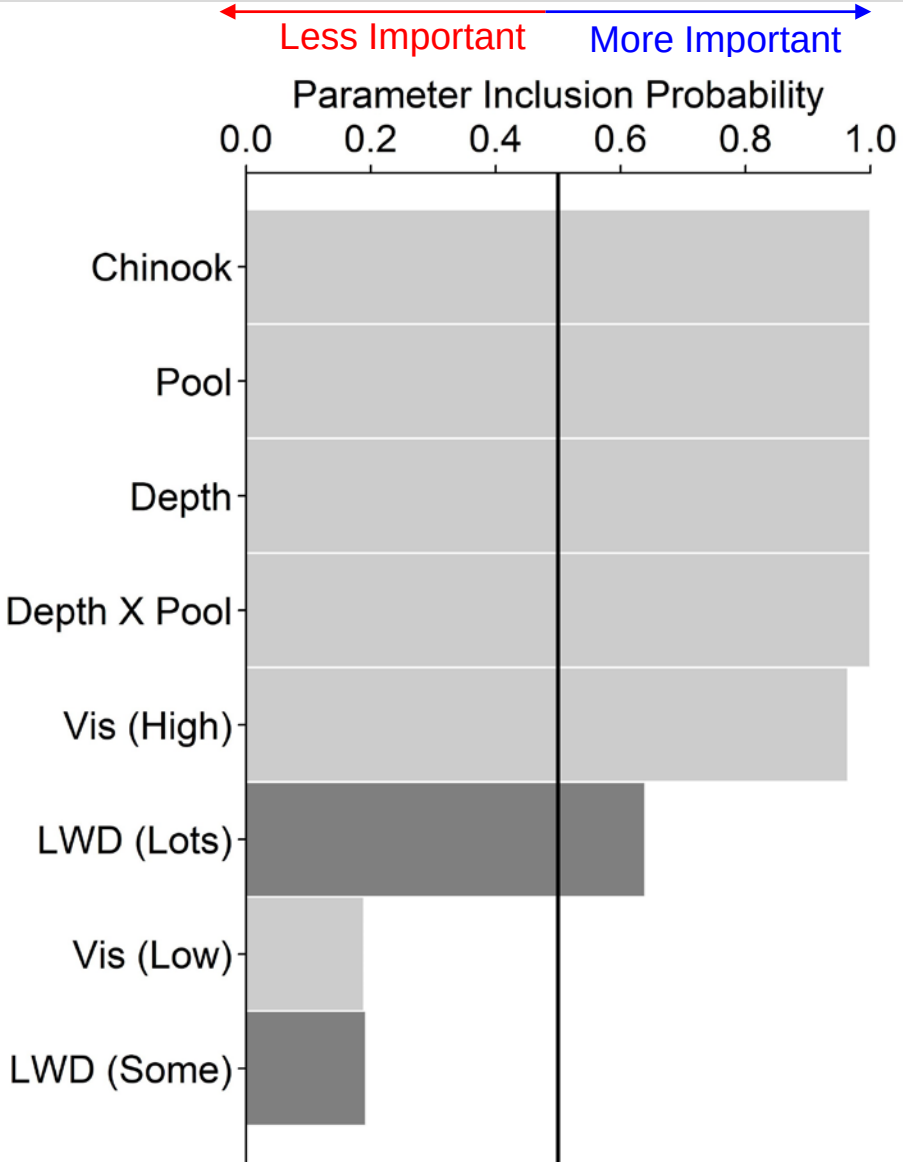

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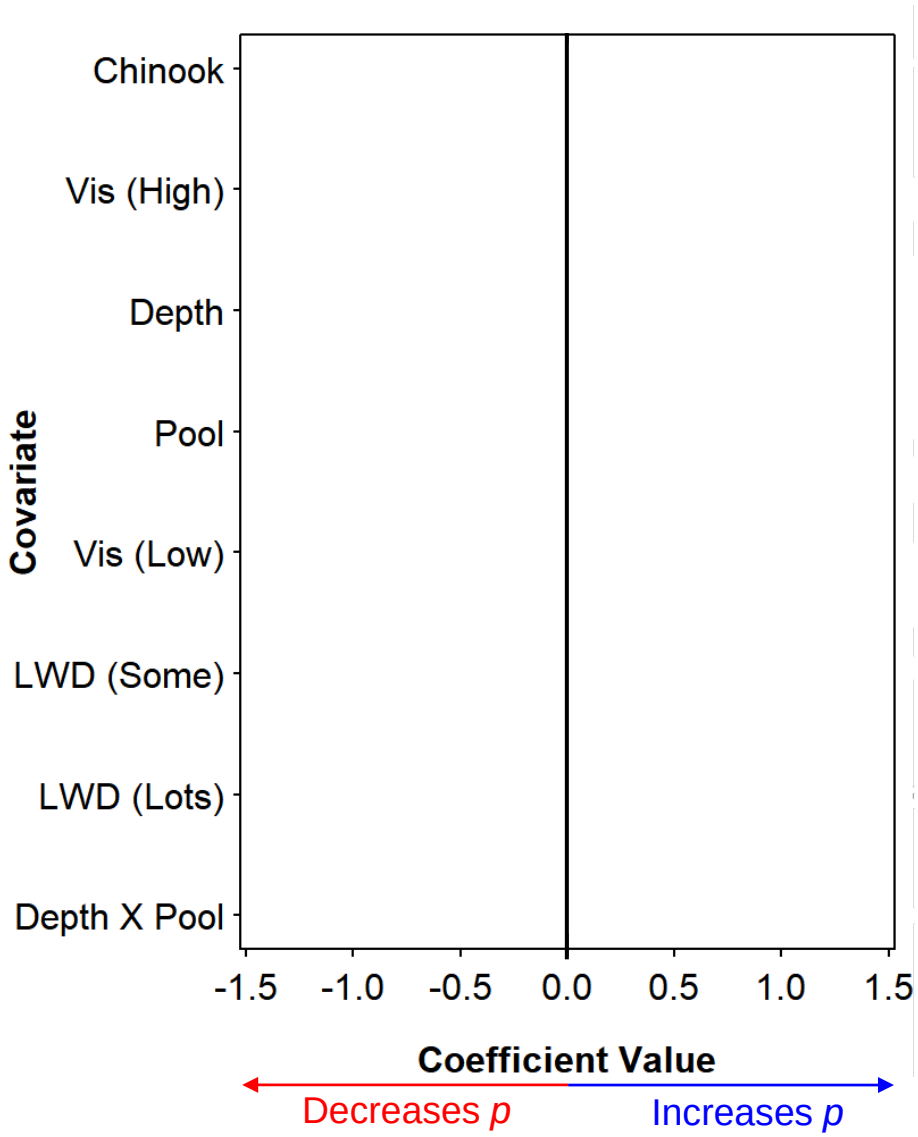
Effect sizes and direction: model-averaged



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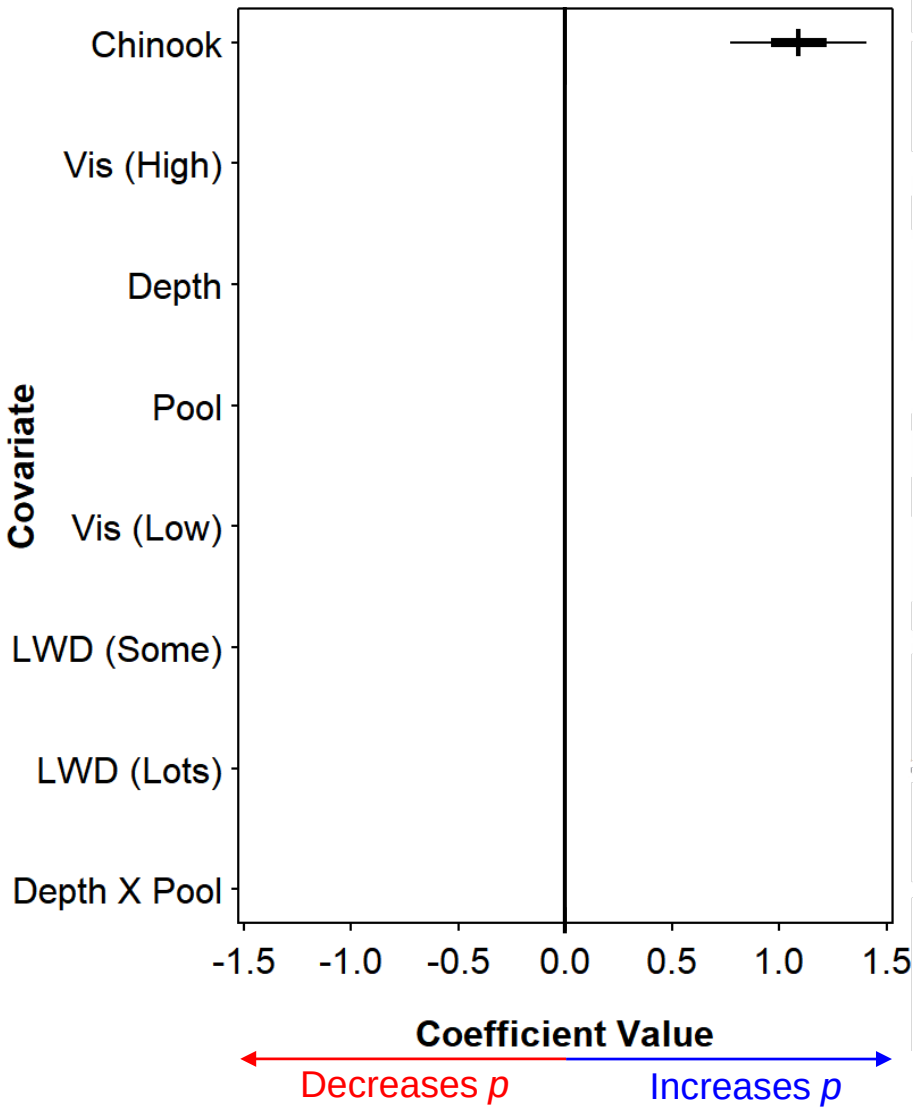

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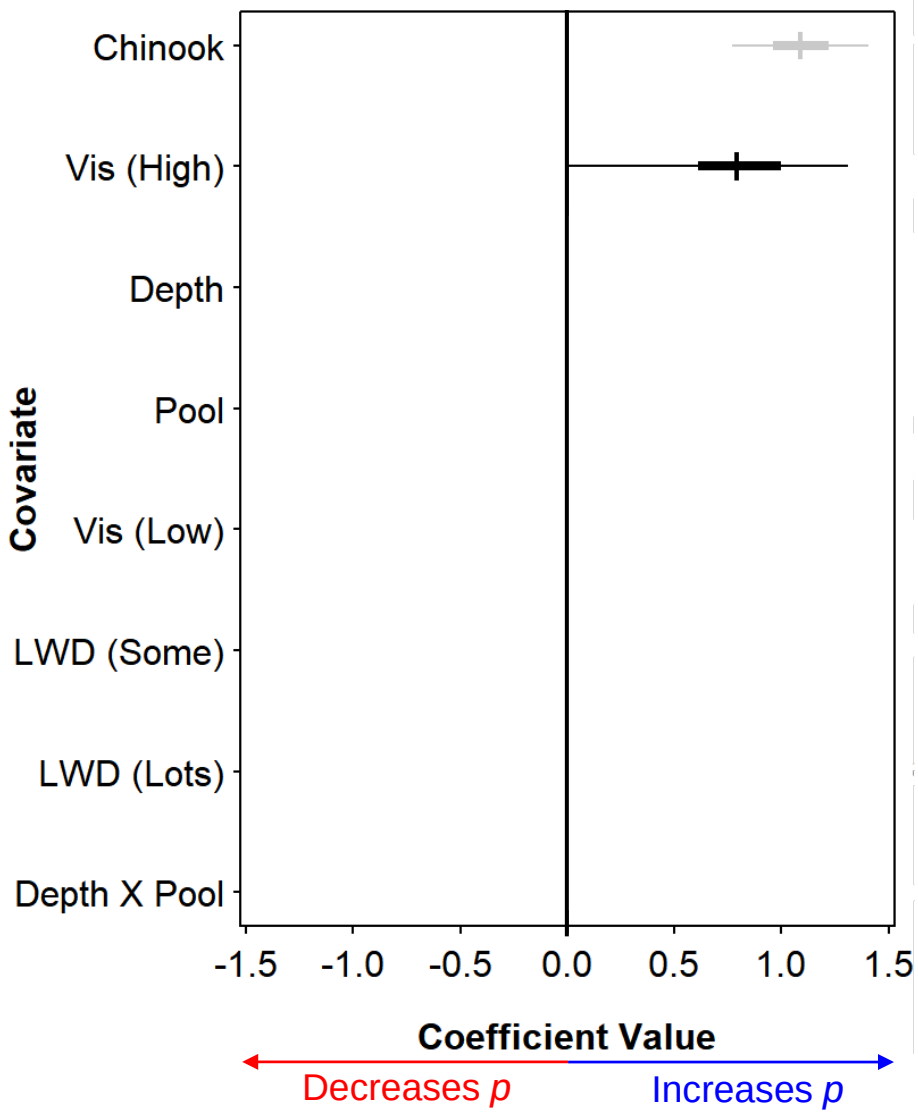

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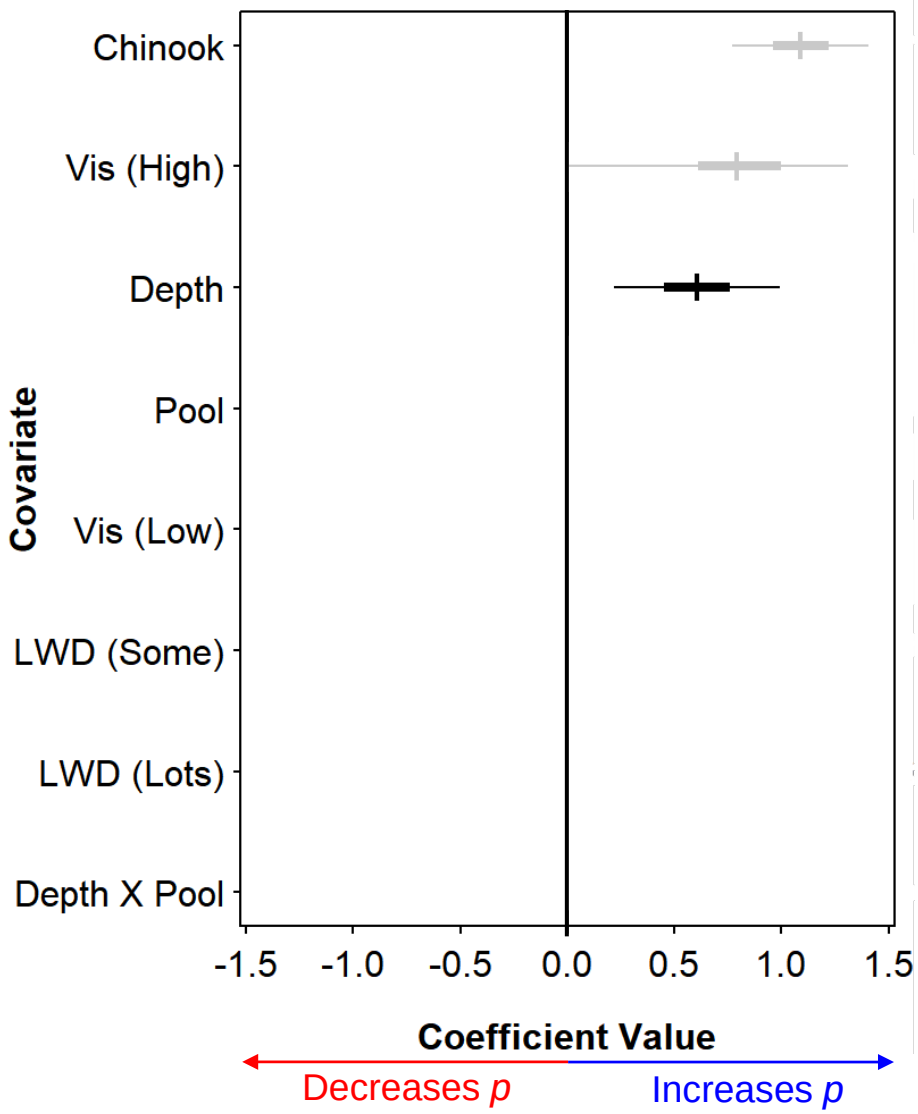

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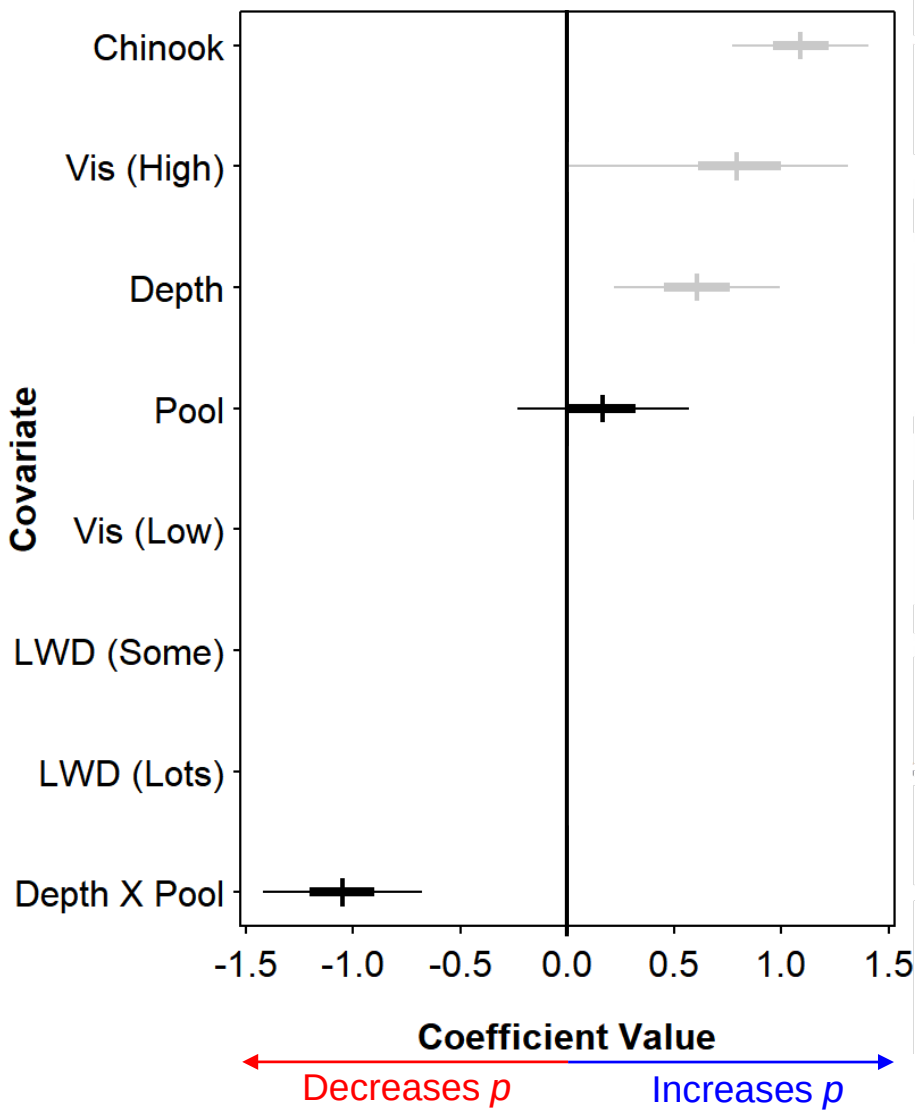

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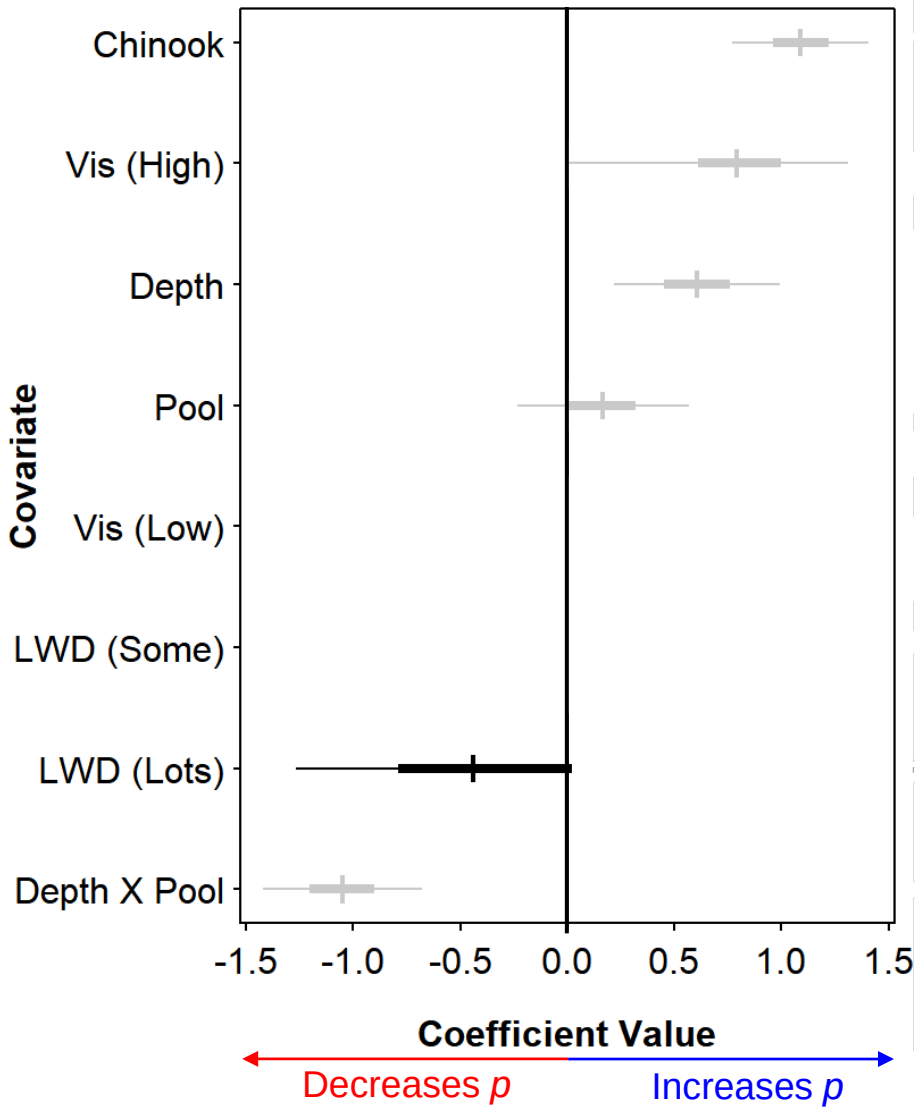

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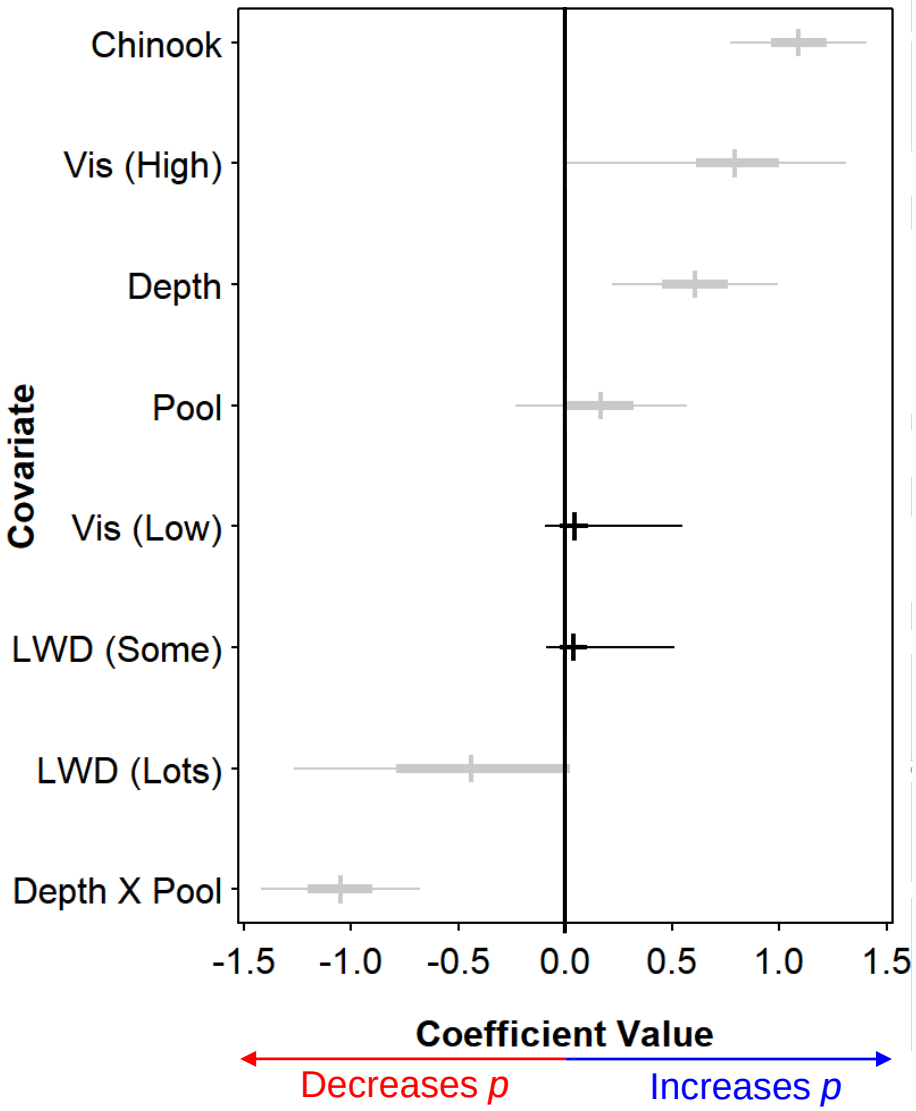

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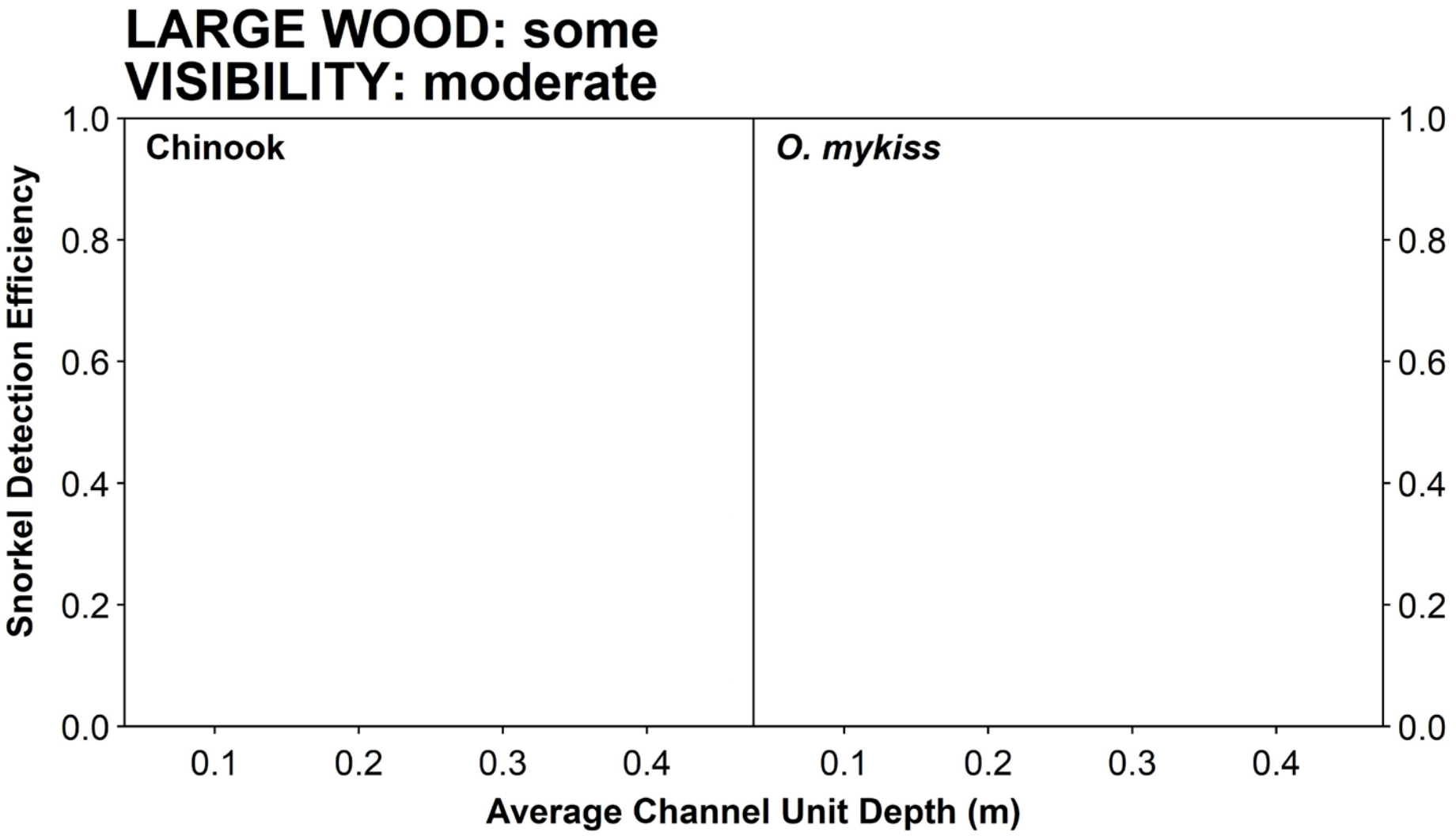

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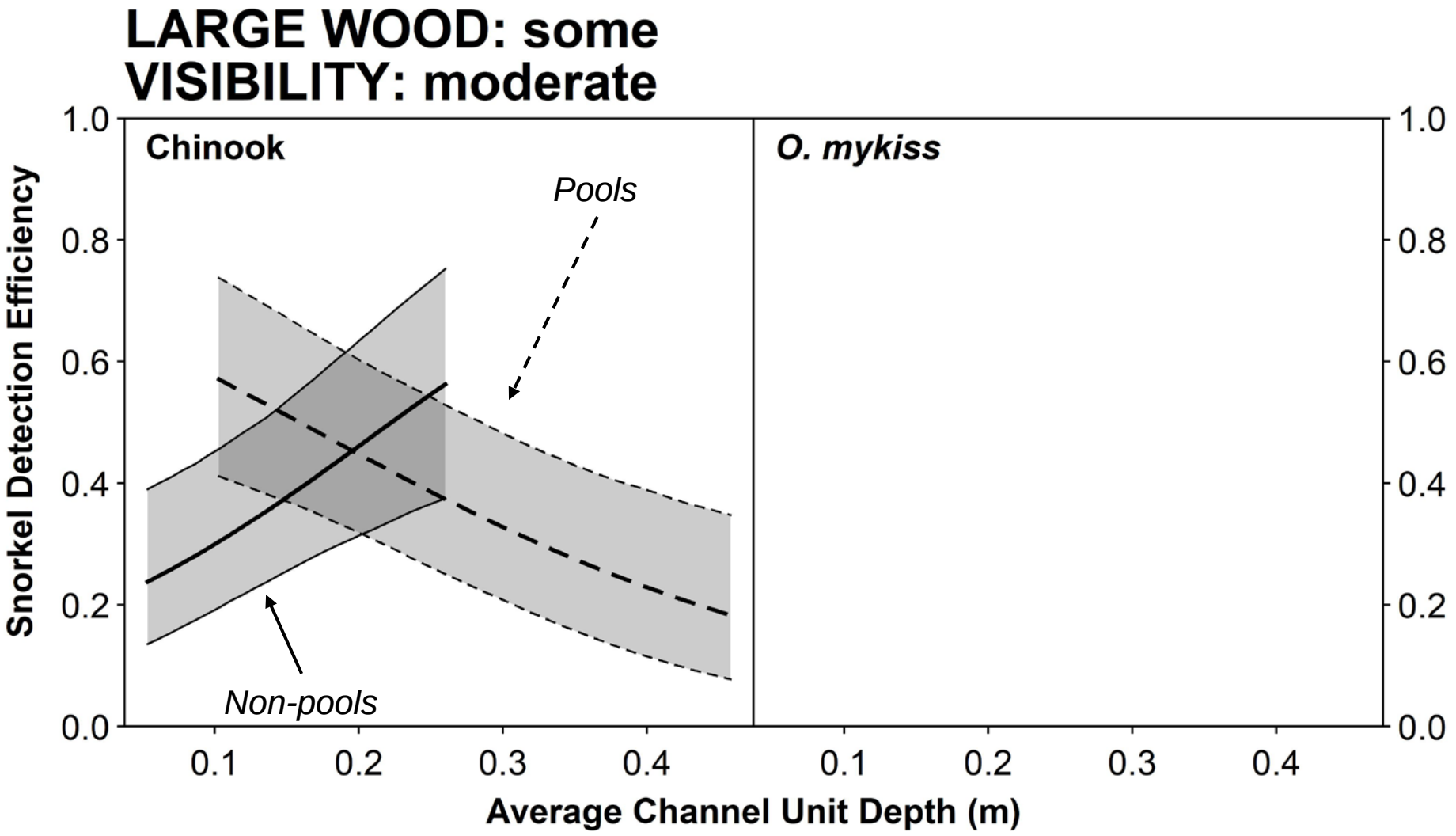

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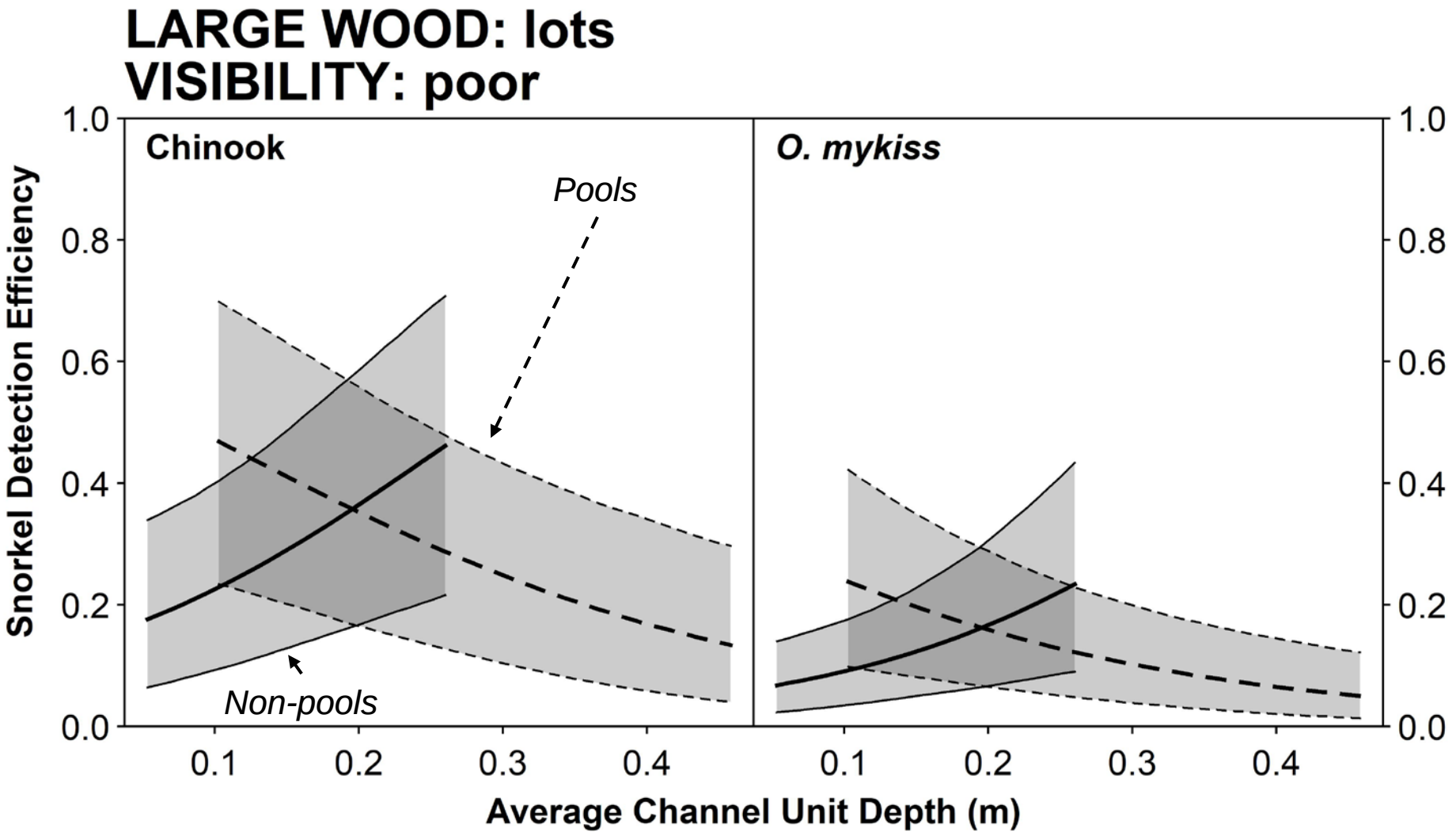

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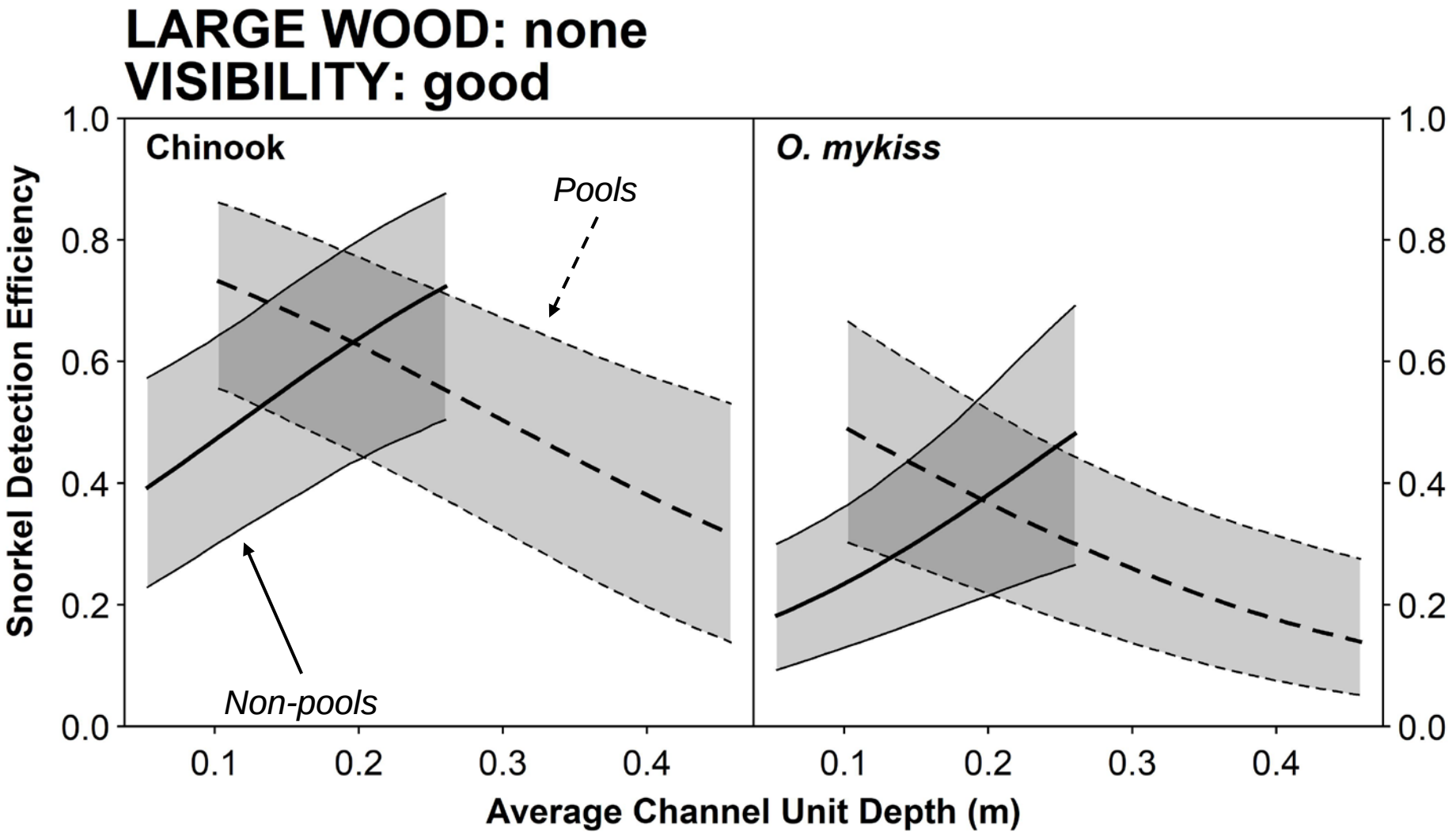
*Effect sizes and direction: **good** snorkel conditions*



Summary

Strengths and Weaknesses

WEAKNESSES

- Lots of random site variability
- Observer-specific effects? Year effects?
- Inference limited to channel units with similar characteristics
- Is count process truly binomial? (*independent, homogenous p*)

STRENGTHS

- Direct estimates of detection probability
- How it changes with local conditions
- Acknowledges uncertainty in mark-recapture sampling
- Output is automatically model-averaged (usage of ω_i terms)

NEXT STEPS: SIMULATION TRIALS

- Sensitive to violated assumptions?
- Necessary sample size?
- Incredibly uninformative mark-recapture data?

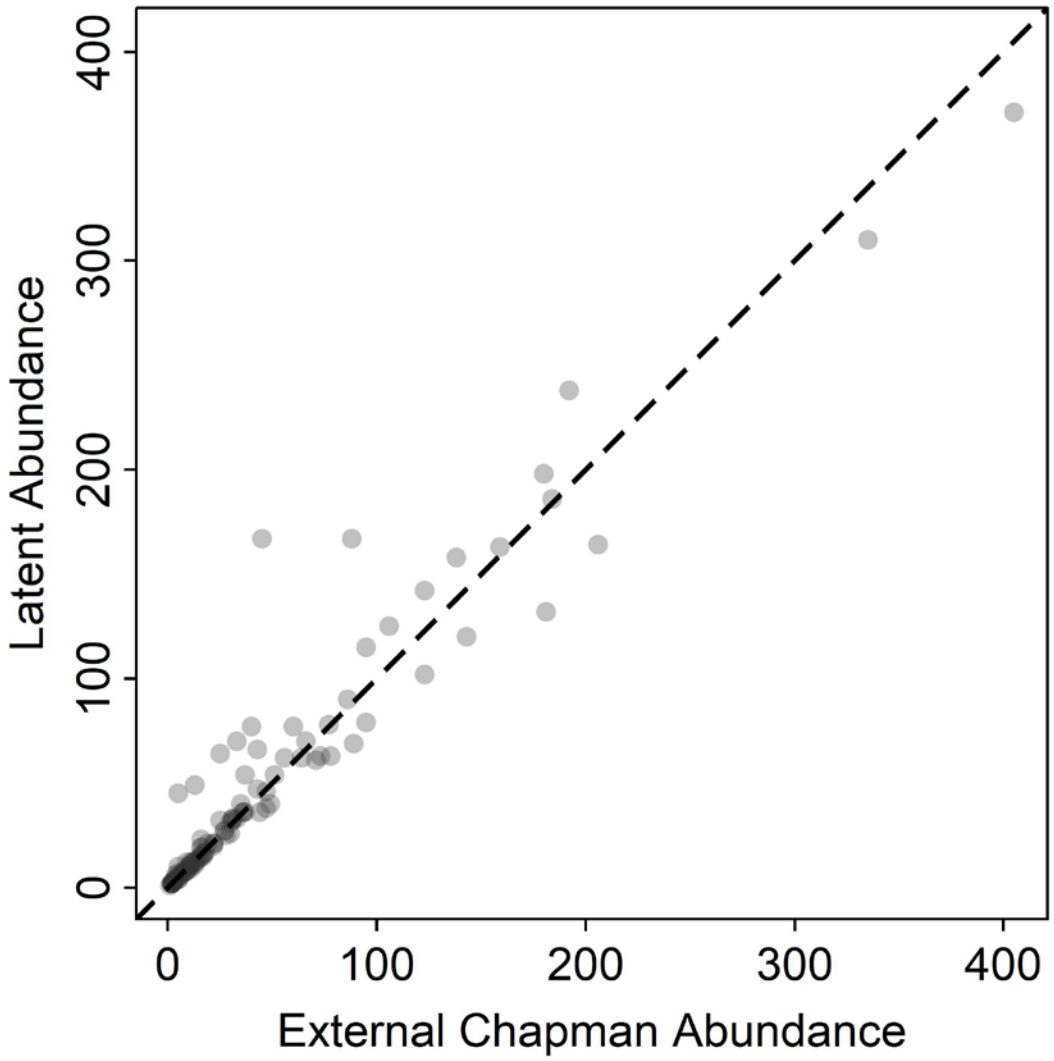
Questions?

Ben Staton
bstaton@critfc.org

BONUS SLIDES

Abundance Estimates

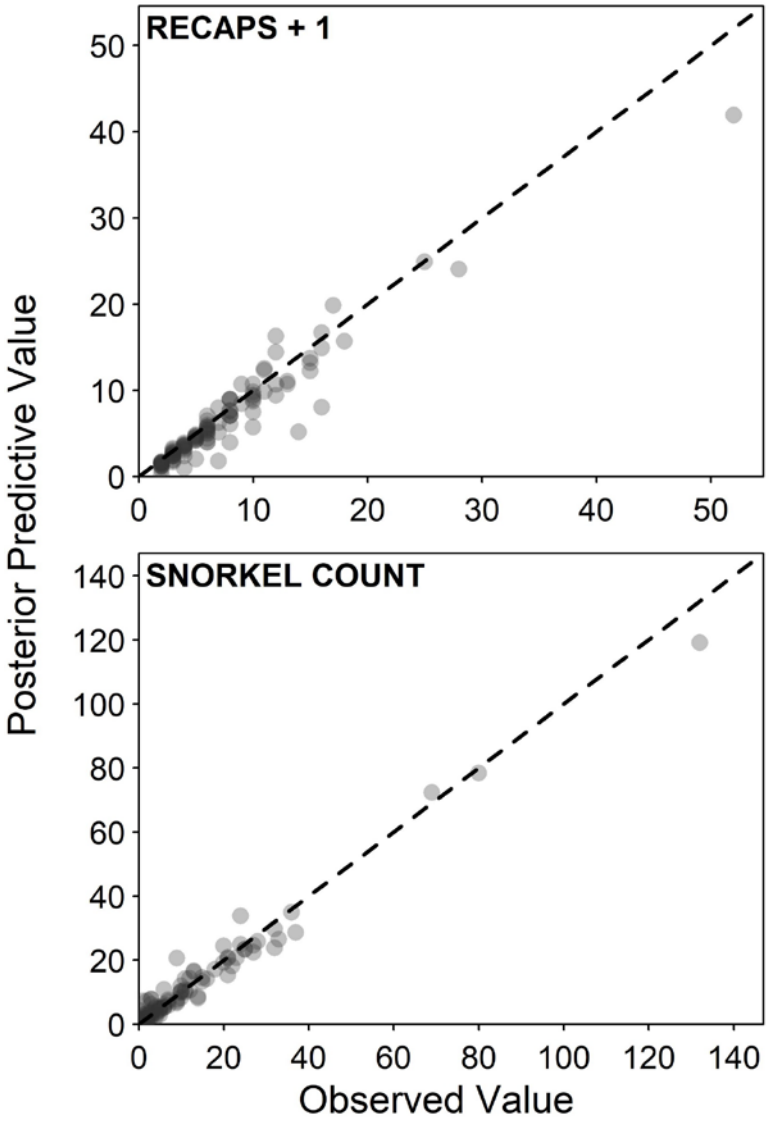
Hierarchical vs. external Chapman estimates

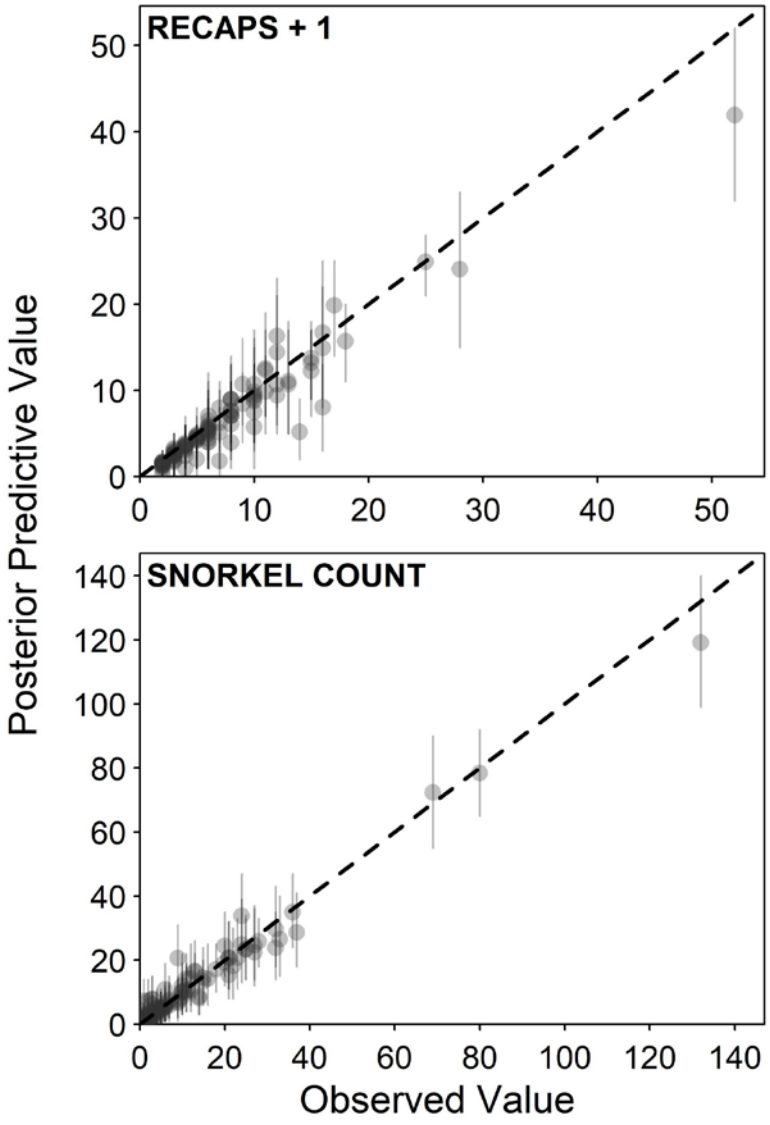


Hierarchical (latent) abundance estimate does not always equal the Chapman estimate

Model must satisfy **both** snorkel and mark-recap data

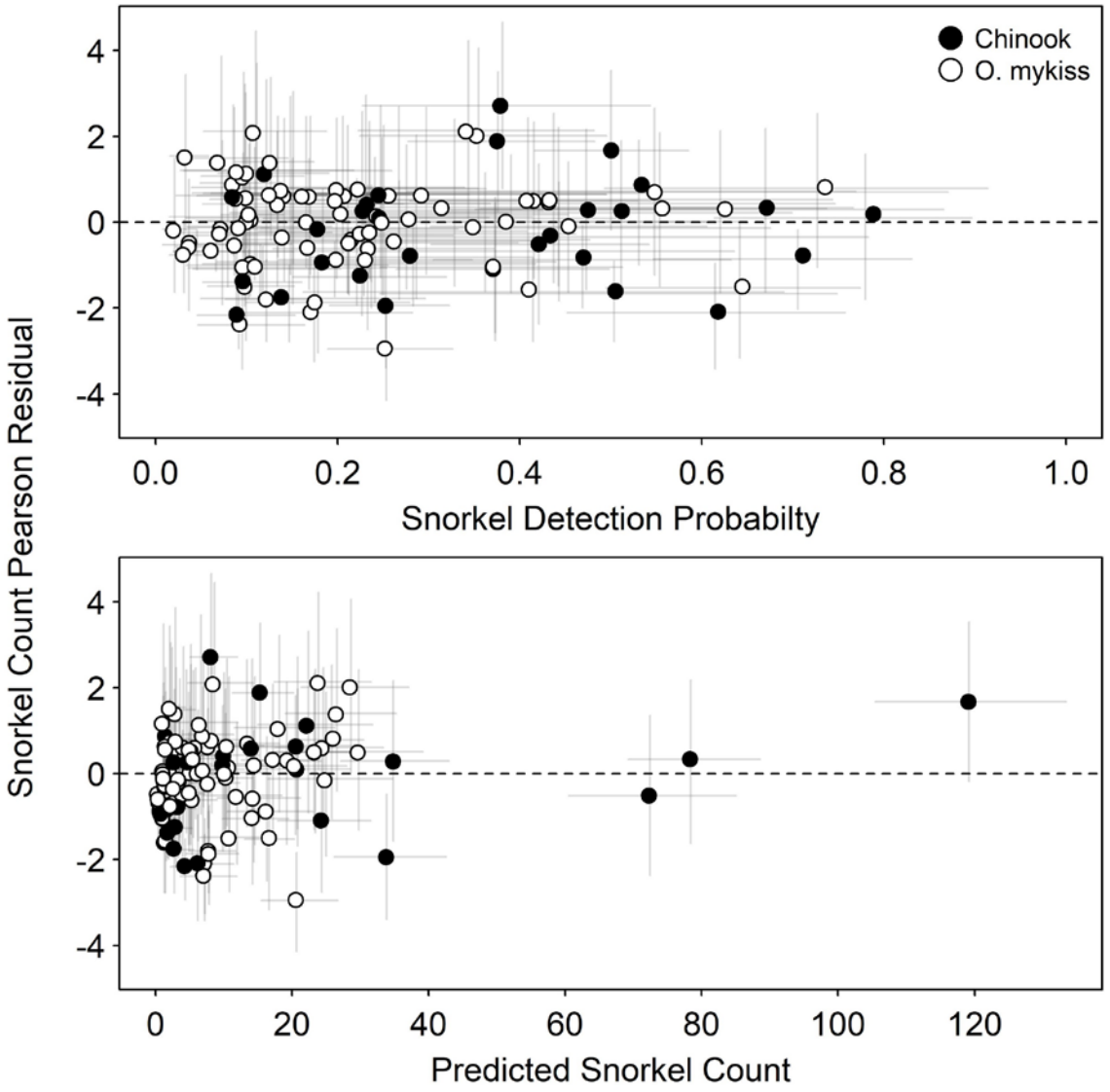
Fit to Data


RECAPS + 1
SNORKEL COUNT
Posterior Predictive Value
Observed Value
0
10
20
30
40
50
0
20
40
60
80
100
120
140


RECAPS + 1
SNORKEL COUNT
Posterior Predictive Value
Observed Value
0
10
20
30
40
50
0
20
40
60
80
100
120
140

Residual Inspection

No residual patterns in snorkel data



Pseudo JAGS Code

```
model {
  # PRIORS: ABUNDANCE
  for (i in 1:nobs) {
    Nu[i] ~ dunif(minN[i], maxN)
    N[i] <- round(Nu[i])
  }

  # PRIORS: LOGIT MODEL COEFFICIENTS
  a ~ dnorm(0, 0.001)
  b ~ dnorm(0, 0.001)
  w ~ dbern(0.5)

  # LIKELIHOOD
  for (i in 1:nobs) {
    # mark-recap data
    recaps1[i] ~ dhyper(marked[i]+1, N[i]-marked[i], K[i]+1, 1)

    # snorkel data
    snorkel[i] ~ dbin(p[i], N[i])
    logit(p[i]) <- a + b * w * cvt[i]
  }
}
```