A Conceptual and Practical Introduction to Occupancy Models

Hanna Jackson

Les Ecols

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Occupancy Models

- **Occupancy** is **whether** a species is present at a site or not

Site 1  Occupied

Site 2  Occupied

Site 3  Occupied

Site 4 Not occupied

Occupancy Models

- **Occupancy** is **whether** a species is present at a site or not
- Occupancy models infer **where** a species is found and **why** it is found there

Site 1  Occupied

Site 2  Occupied

Site 3  Occupied

Site 4 Not occupied

Occupancy as a Stochastic Process

We assume that each site has a characteristic **occupancy probability**

0.8	0.8	0.8	0.8	0.3	0.3	0.3	0.3
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0.8	0.8	0.8	0.8	0.3	0.3	0.3	0.3
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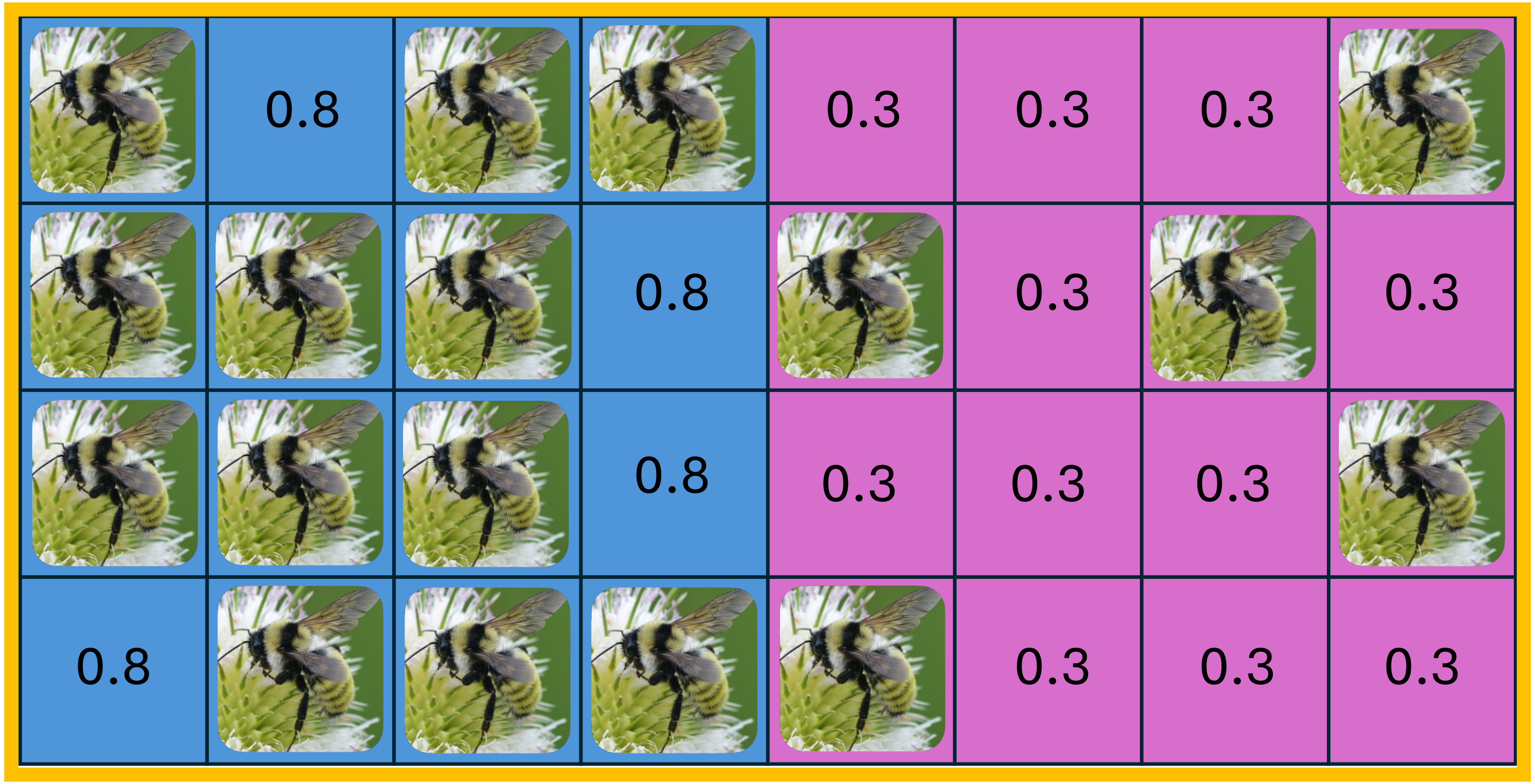
Occupancy as a Stochastic Process

We assume that each site has a characteristic **occupancy probability**

And that the sites are occupied with that probability



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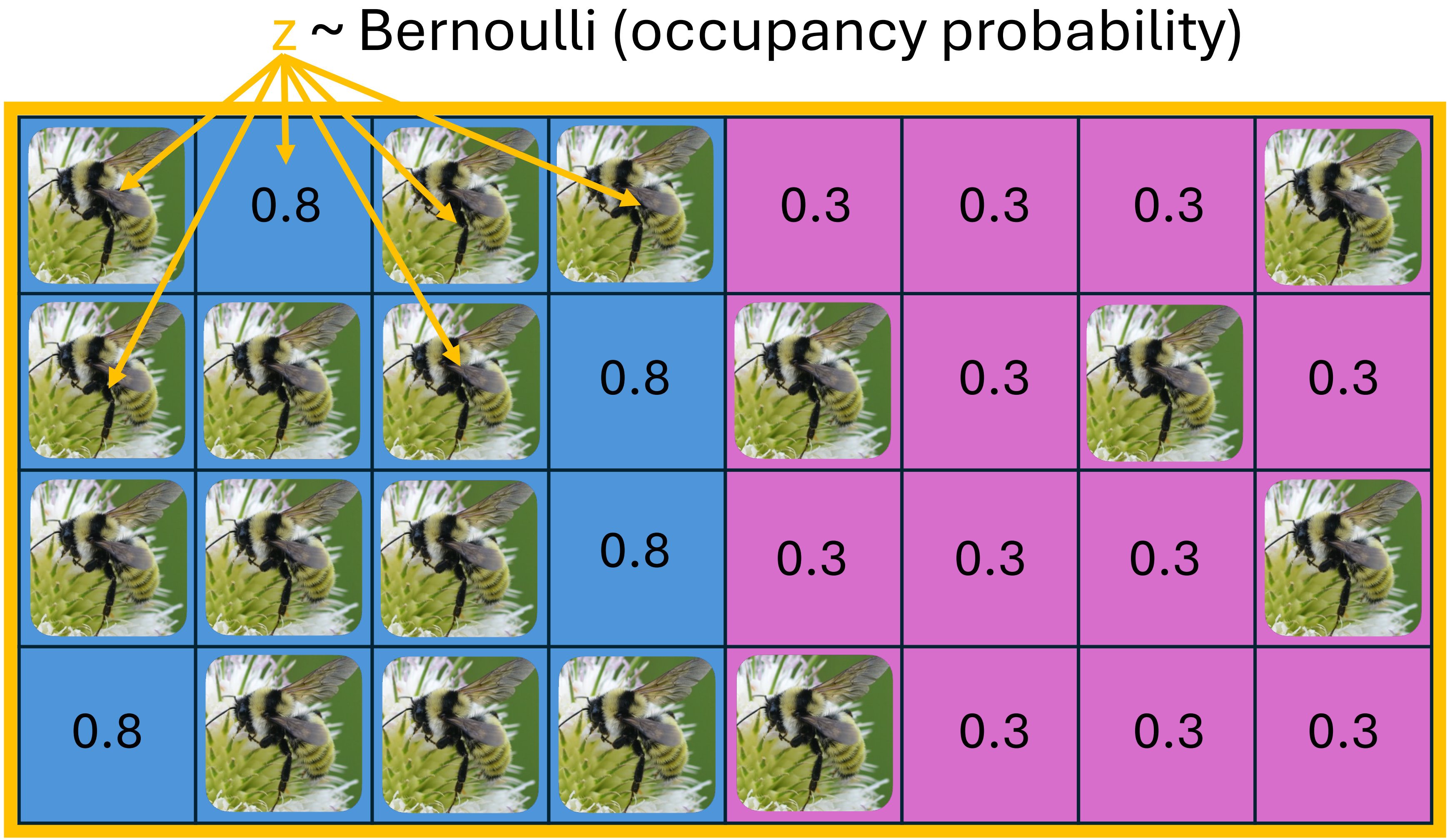

Occupancy as a Stochastic Process

z ~ Coin Flip (occupancy probability)

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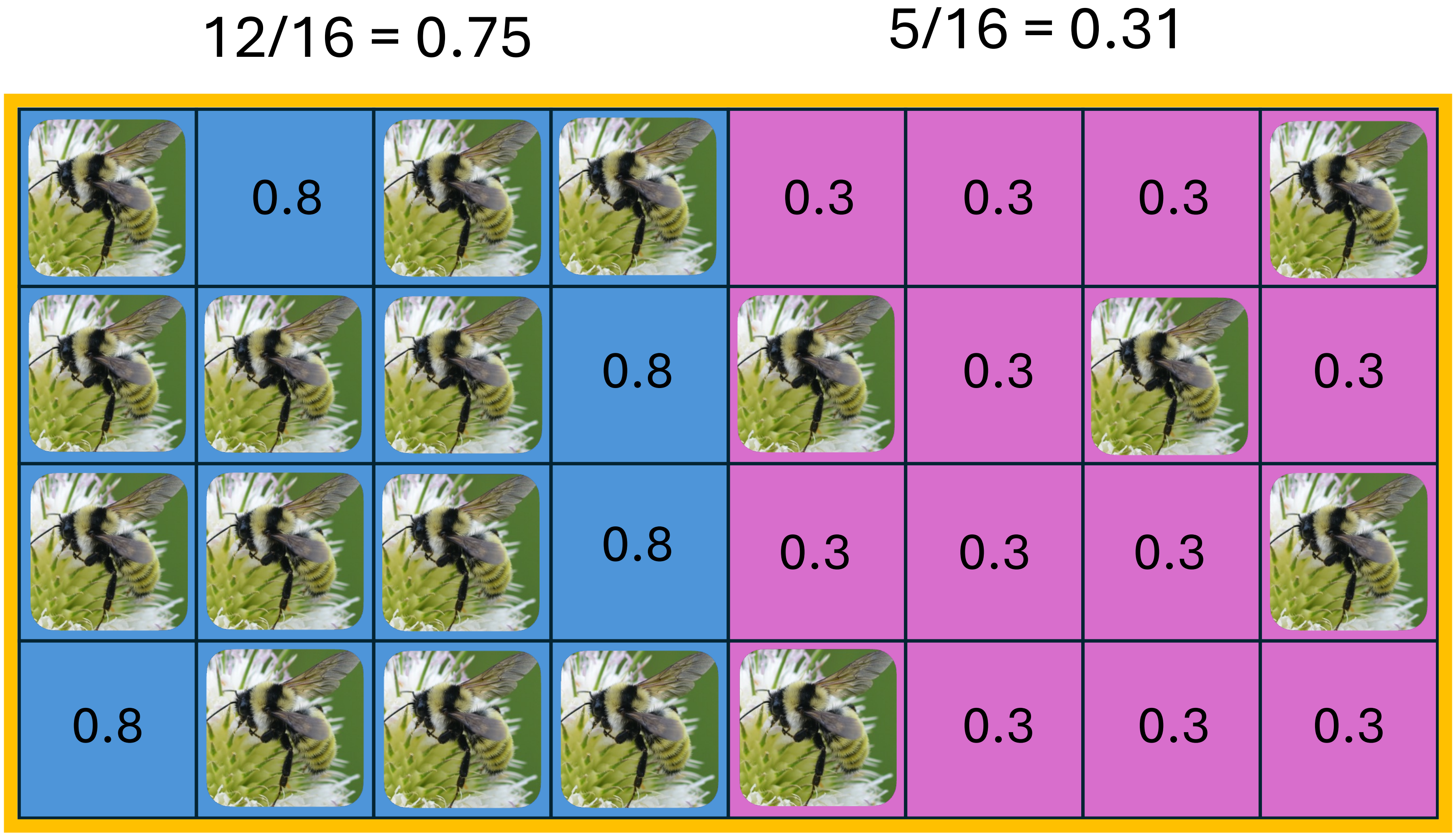
And that the sites are occupied with that probability

Occupancy as a Stochastic Process

So given a set of sites with known **occupancy**, we can get our best estimate of the **occupancy probability**



Occupancy as a Stochastic Process

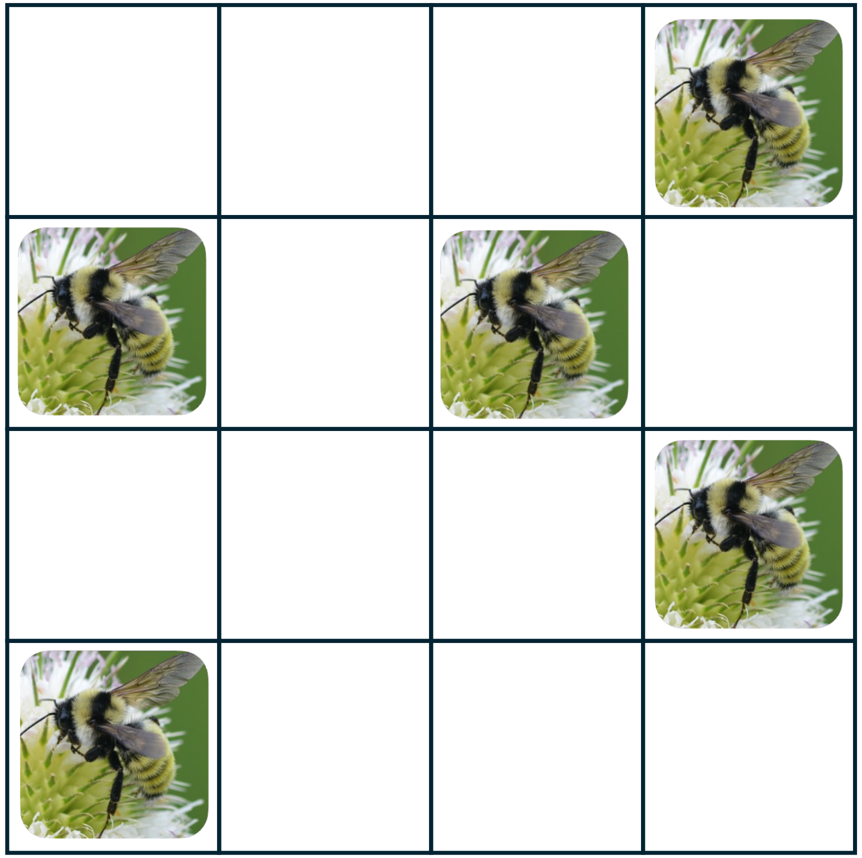
So given a set of sites with known **occupancy**, we can get our best estimate of the **occupancy probability**

But knowing the true occupancy of the site is hard!

12/16 = 0.75

5/16 = 0.31

Finding the true occupancy of the sites is hard!



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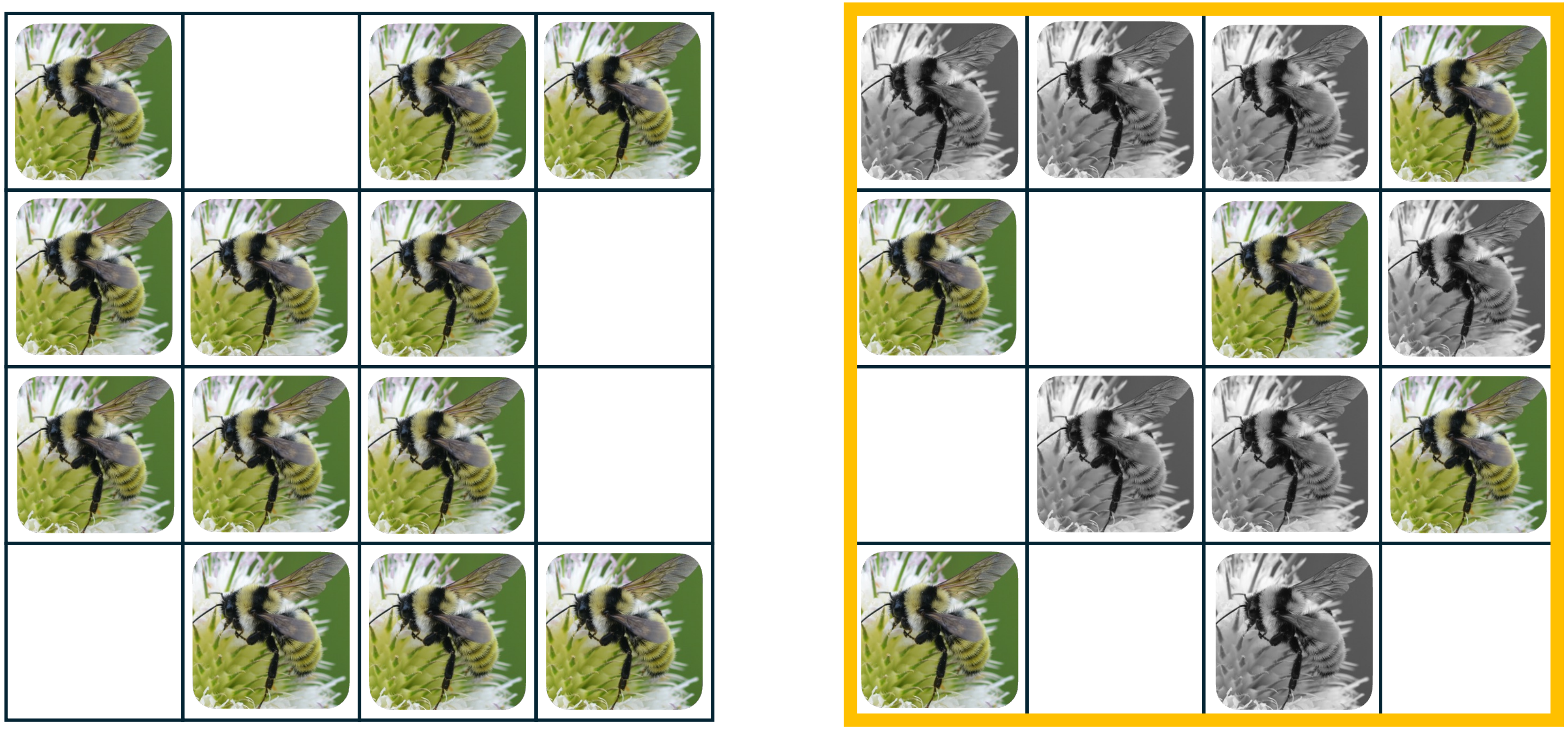
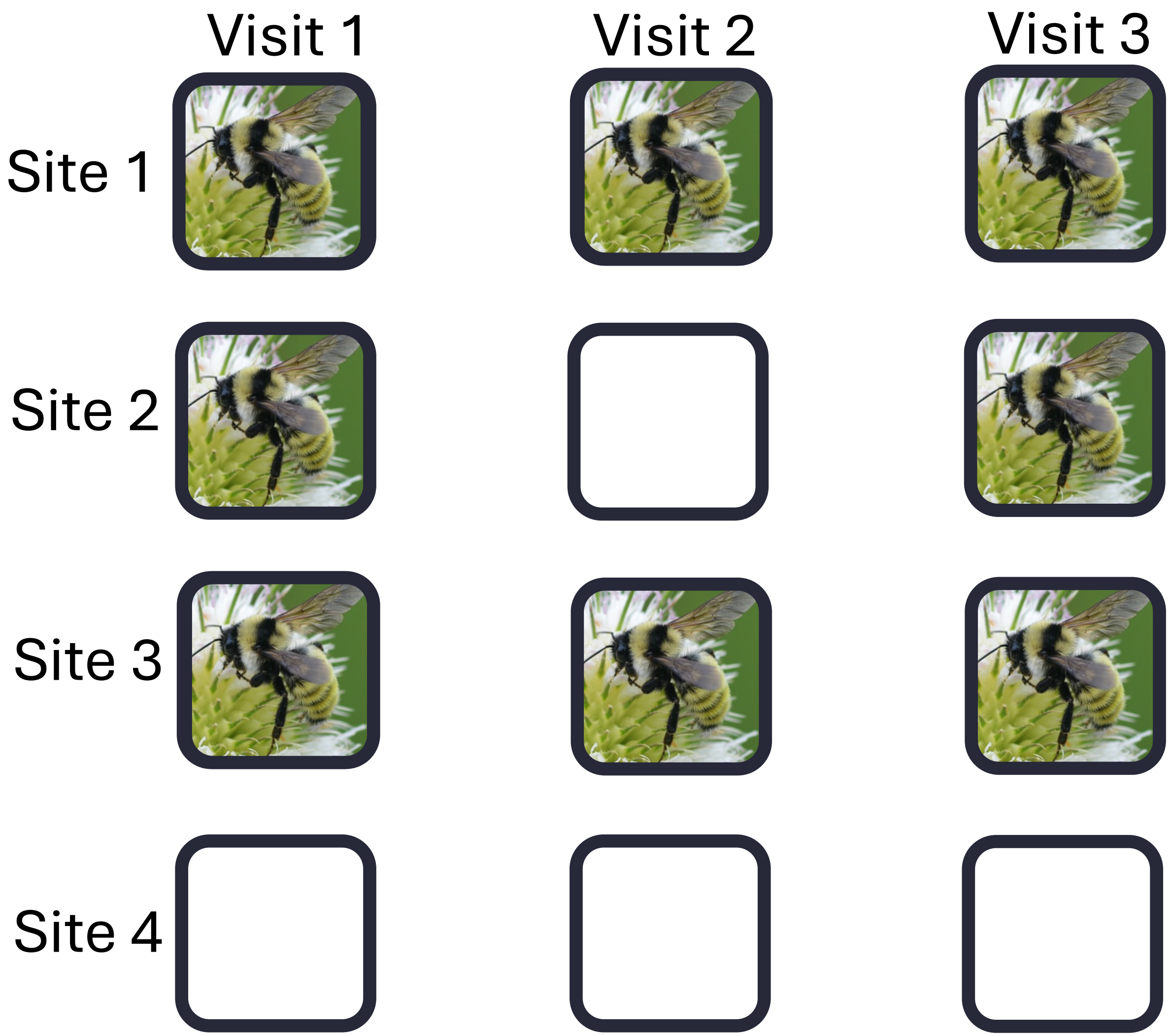


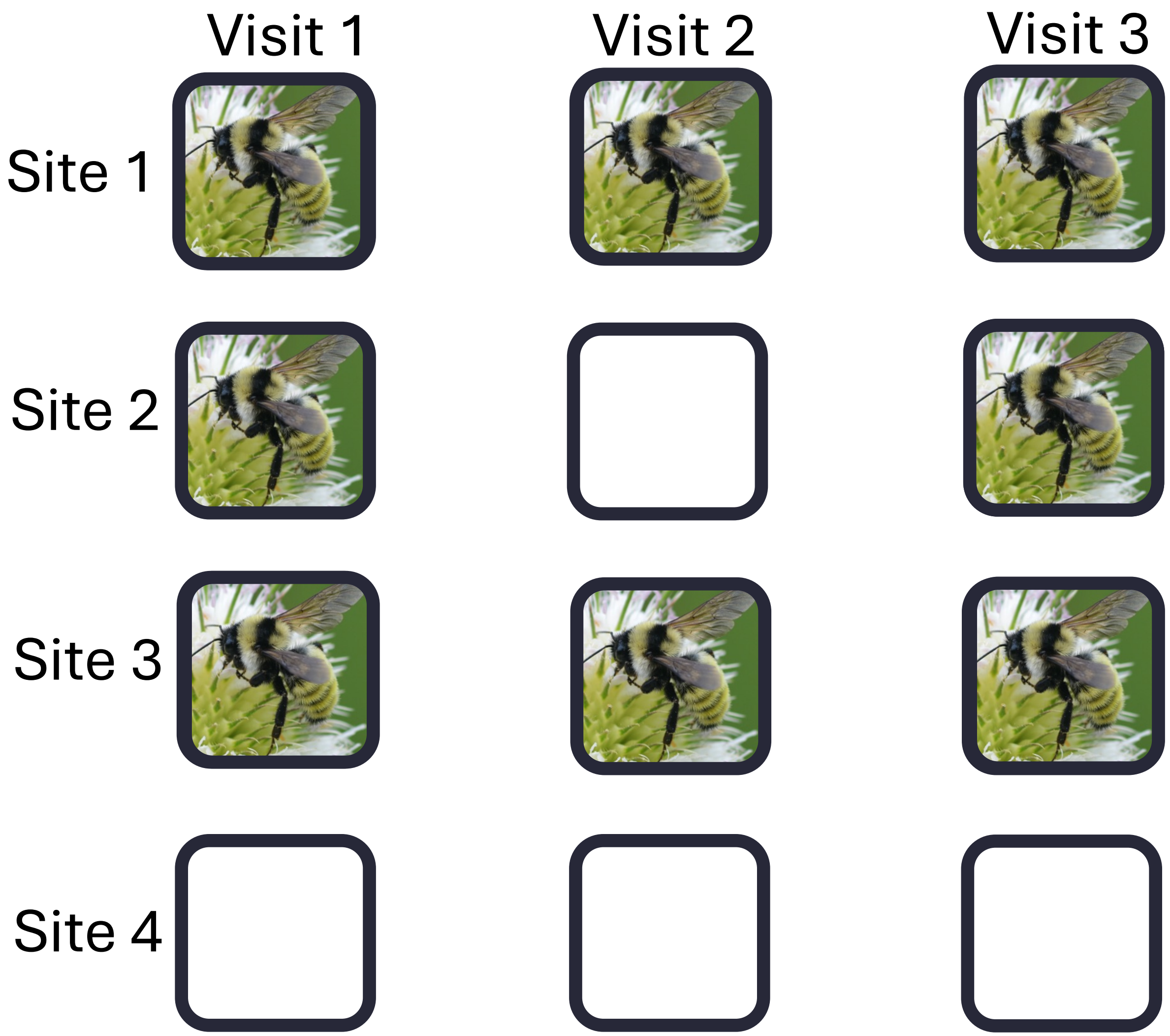
Occupancy Models

Occupancy Models



Occupancy Models

How is this structured data useful?



Occupancy Models

We **know** this species is at these sites

Occupancy Models

We **know** this species is at these sites

Absent from this site
or
did we miss it?

Occupancy Models

We appear to be **GOOD** at **finding bees** when they are present

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Occupancy Models

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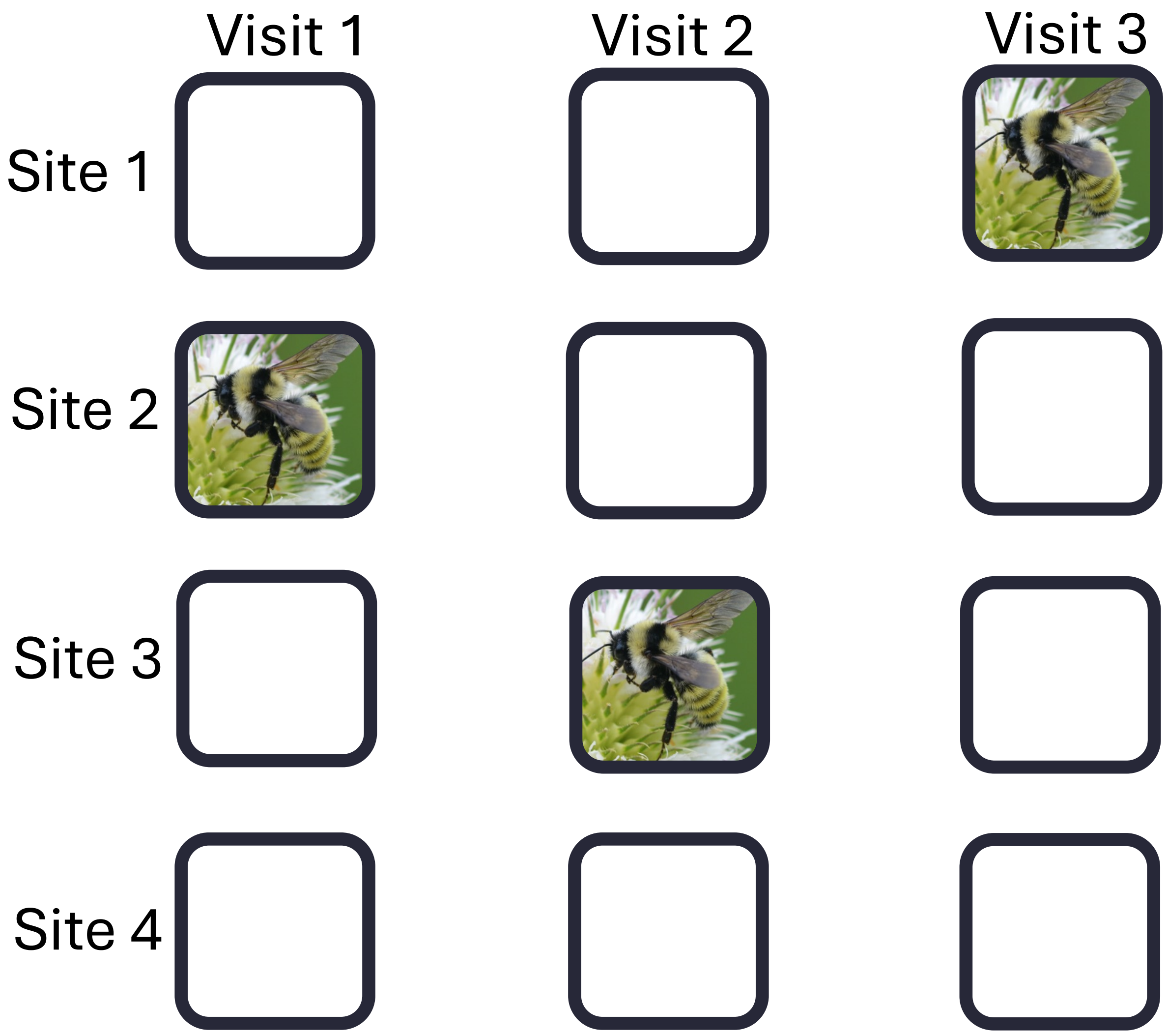
High Detection Probability

Occupancy Models



Absent from this site
or
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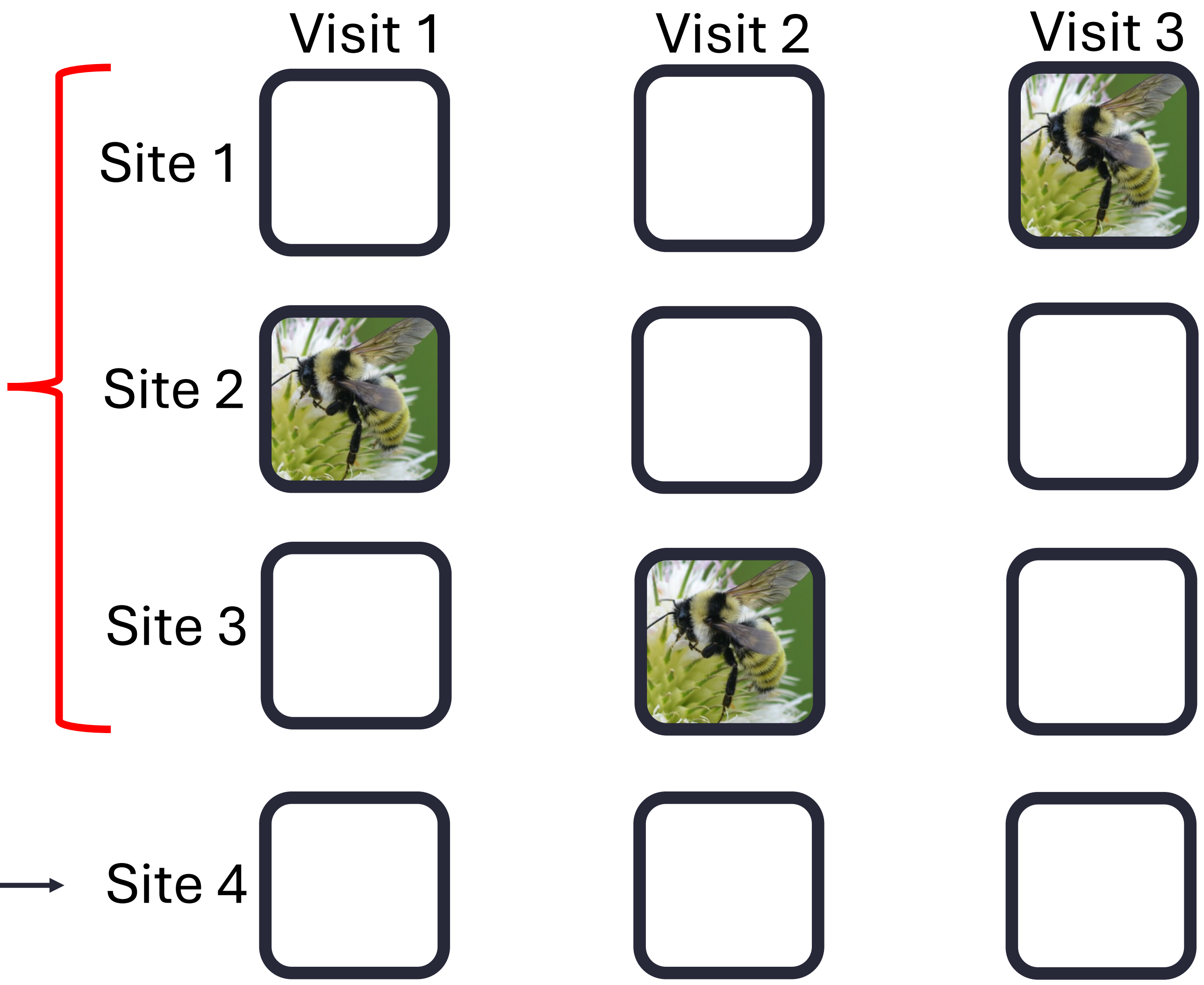
Occupancy Models

We appear to be **BAD at finding bees** when they are present



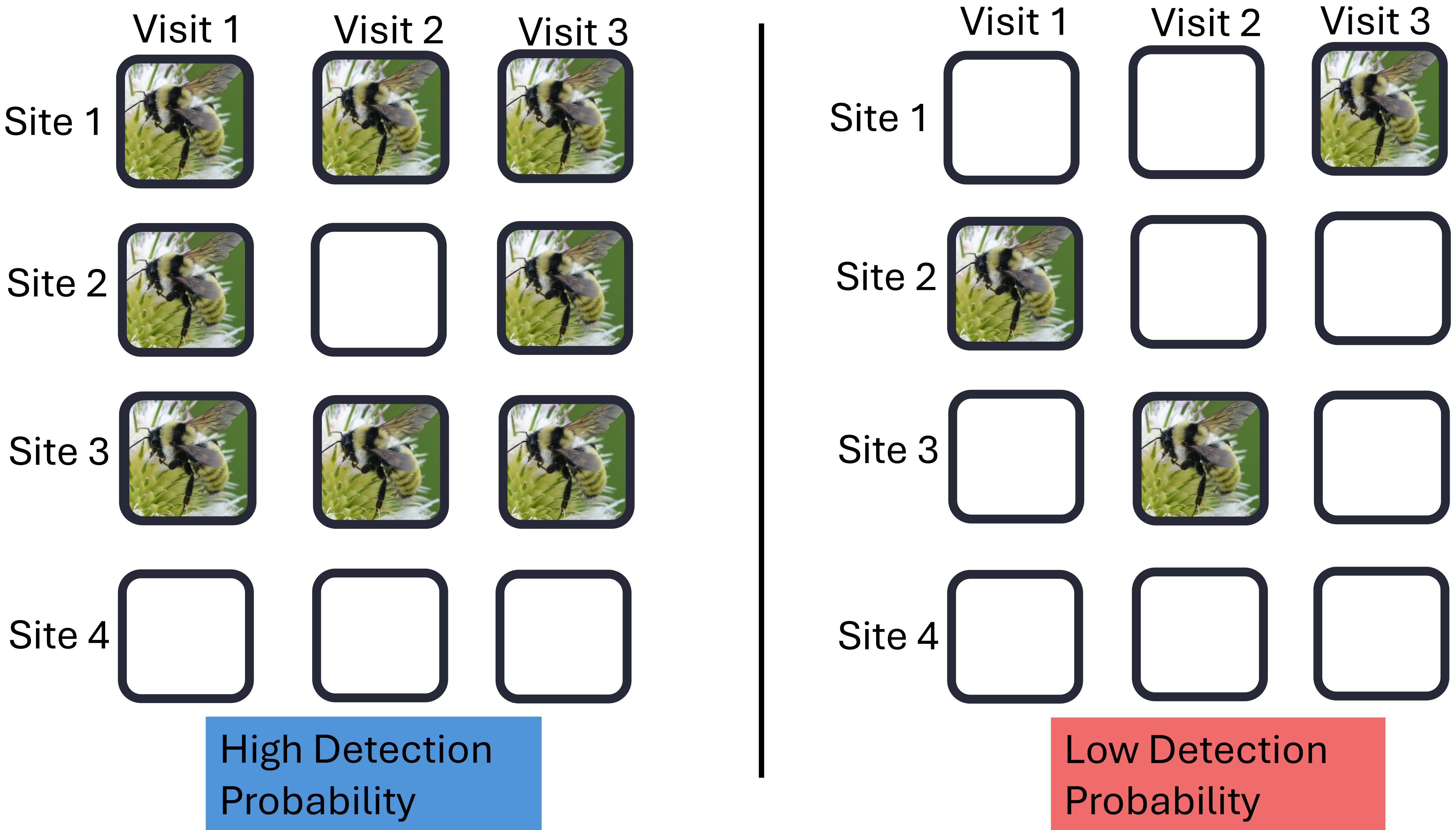
Absent from this site
or
did we miss it?

Occupancy Models

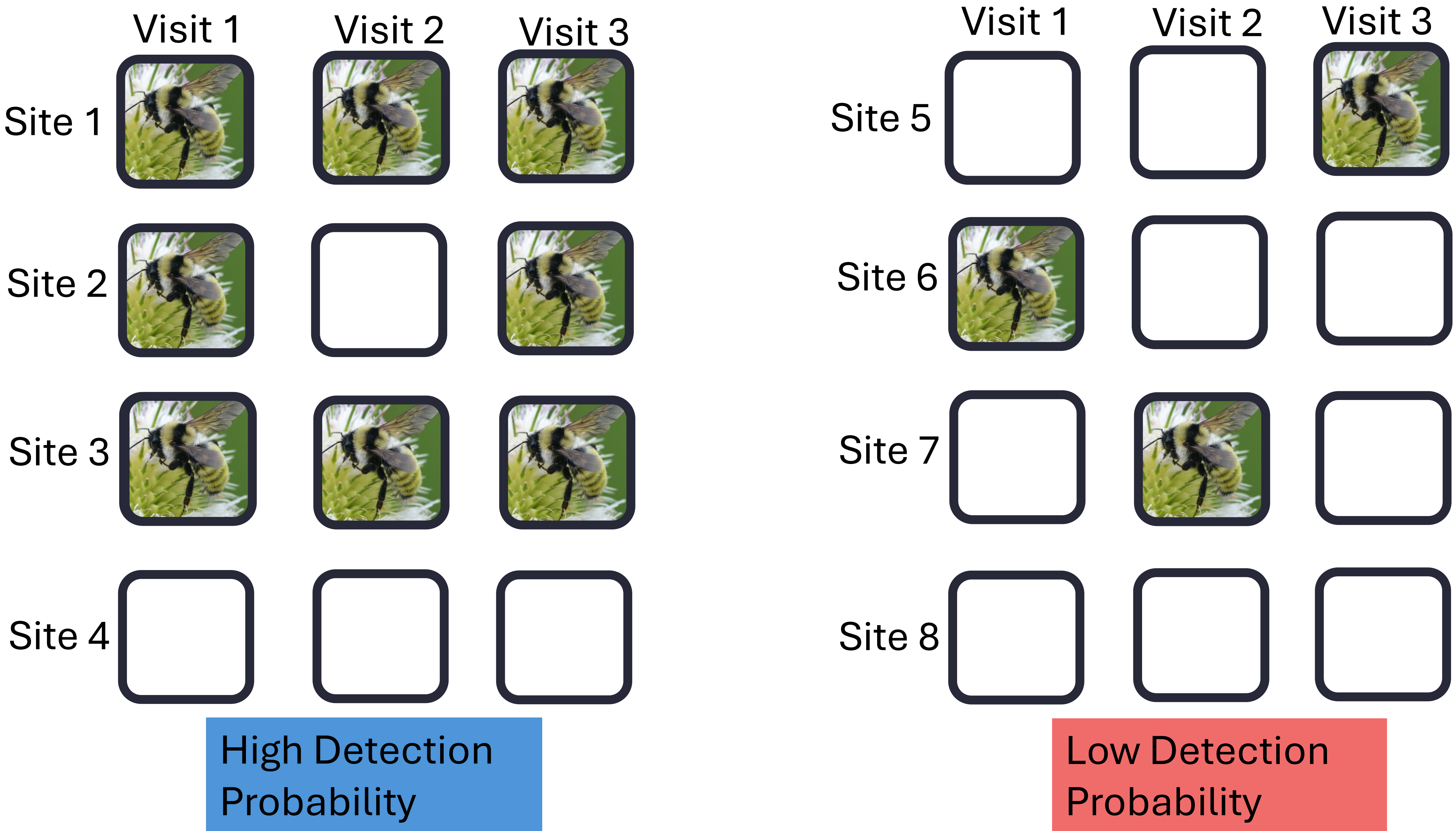
We appear to be **BAD at finding bees** when they are present

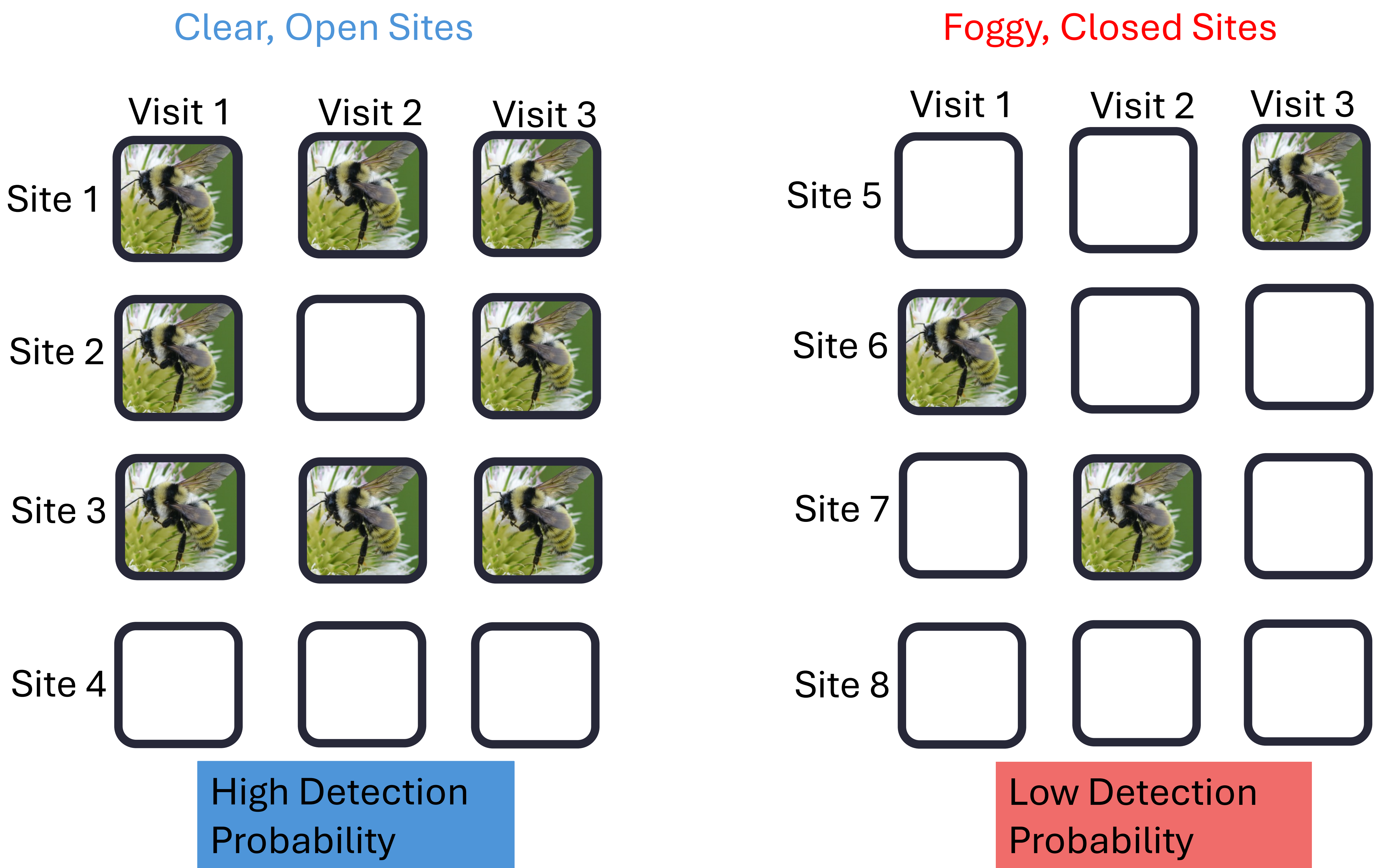
Low Detection Probability

But what if instead of two separate scenarios...



… It was one study, with two kinds of sites




Clear, Open Sites
Foggy, Closed Sites
Visit 1
Visit 2
Visit 3
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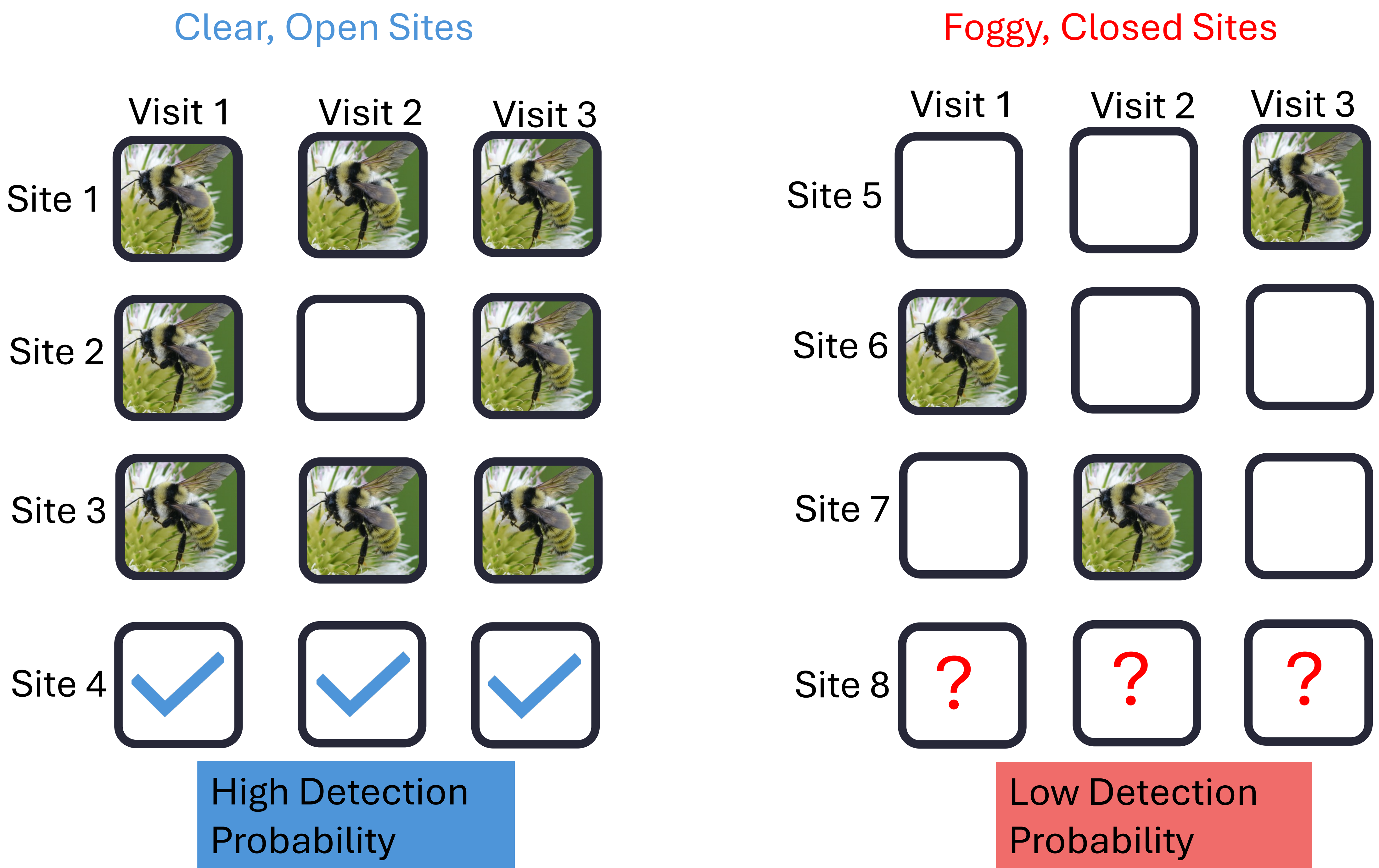
Visit 3
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site 8
High Detection Probability
Low Detection Probability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?
?
?
High Detection Probability
Low Detection Probability

Takeaway:

Occupancy models:

- Use **repeat visits** to sites
- To quantify **detection probability**
- So that when we model **occupancy probability** we are **accounting for this uncertainty** in whether observed absences are true zeros or missed detections

Hierarchical Models

A "Hierarchical Model" is two GLMs that are connected to each other *

$$\text{logit}\left(\boxed{\begin{array}{c}\text{State Process:}\\ \text{Occupancy}\\ \text{Probability}\end{array}}\right) = \alpha 0 + \alpha 1 * X1 + \alpha 2 * X2 + \alpha 3 * X1 * X2$$

$$\text{logit}\left(\boxed{\begin{array}{c}\text{Observation Process:}\\ \text{Detection}\\ \text{Probability}\end{array}}\right) = \beta 0 + \beta 1 * X1 + \beta 2 * X2 + \beta 3 * X1 * X2$$

Hierarchical Models

A "Hierarchical Model" is two GLMs that are connected to each other *

$$\text{logit}\left(\boxed{\begin{array}{c}\text{State Process:}\\ \text{Occupancy}\\ \text{Probability}\end{array}}\right) = \psi0 + \psi1*X1 + \psi2*X2 + \psi3*X1*X2$$

$$\text{logit}\left(\boxed{\begin{array}{c}\text{Observation Process:}\\ \text{Detection}\\ \text{Probability}\end{array}}\right) = p0 + p1*X1 + p2*X2 + p3*X1*X2$$

But how does that work?

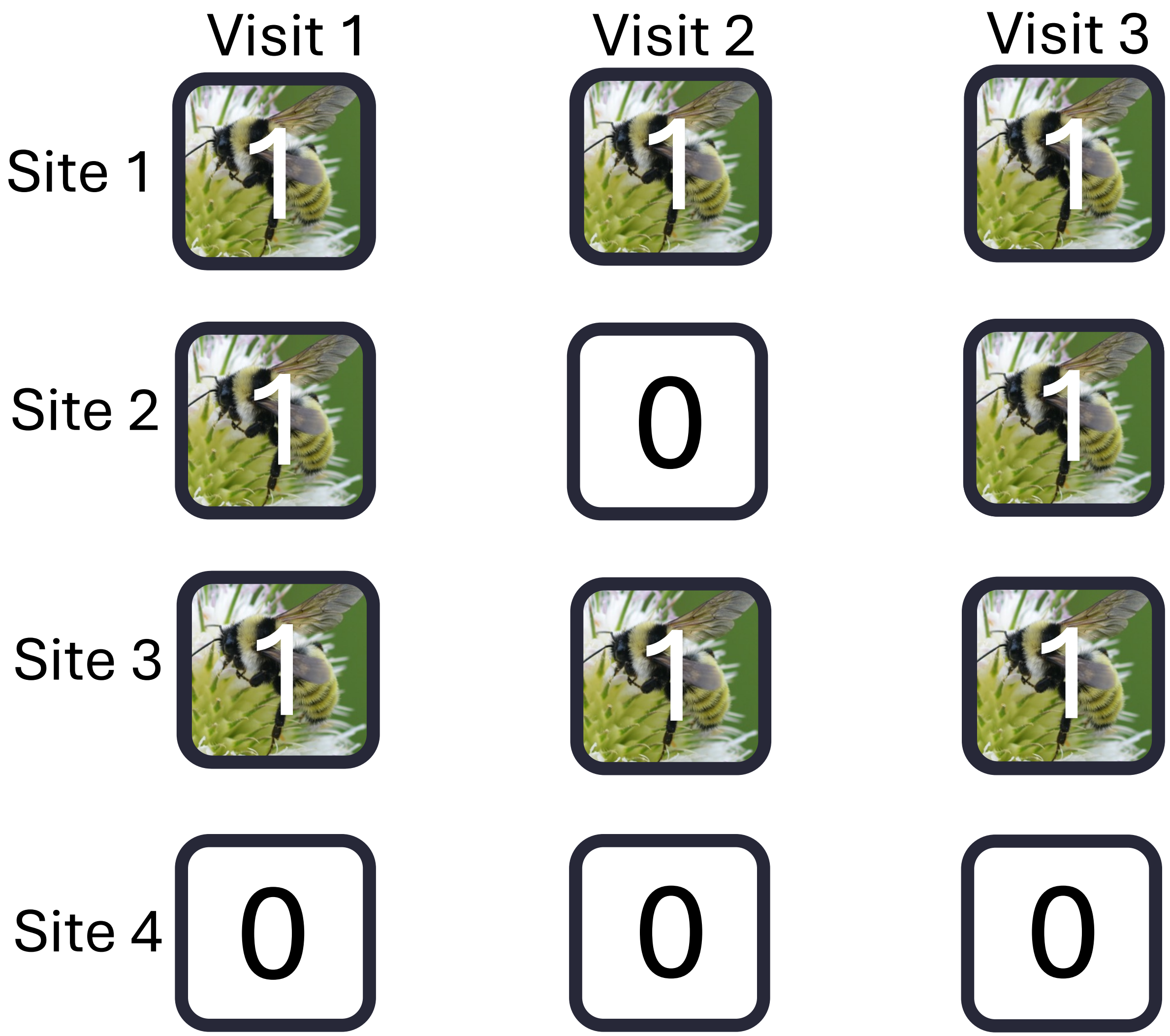
We appear to be **GOOD** at **finding bees** when they are present

High Detection Probability

Occupancy Models - Gears and Cogs

Each of these observations will be denoted X going forward

(I’ve coloured X green because they’re our field observations)



Occupancy Models - Gears and Cogs

$$\text{logit}\left(\boxed{\text{Occupancy Probability}}\right) = \psi.0 + \psi1 * X1 + \psi2 * X2 + \psi3 * X1 * X2$$

$$\text{logit}\left(\boxed{\text{Detection Probability}}\right) = p.0 + p1 * X1 + p2 * X2 + p3 * X1 * X2$$

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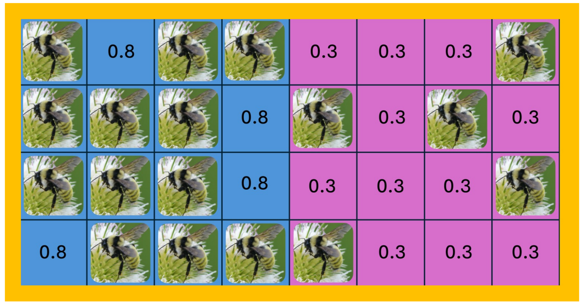

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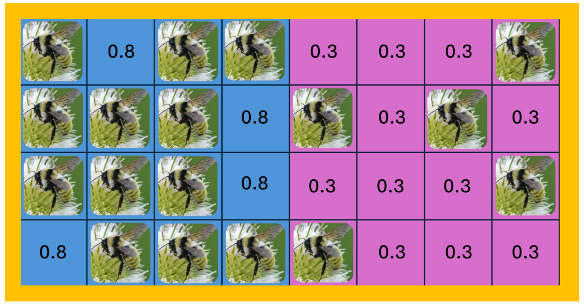
Occupancy Models - Gears and Cogs

Z ~ Coin Flip (Occupancy Probability)



logit (Occupancy Probability) = ψ.0 + ψ1*X1 + ψ2*X2 + ψ3*X1*X2

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Occupancy Models - Gears and Cogs

Observations, X don't <u>just</u> depend on the probability the species is present

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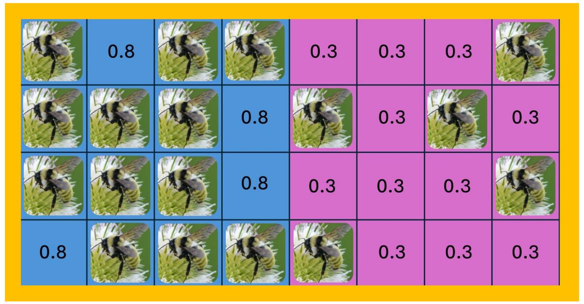

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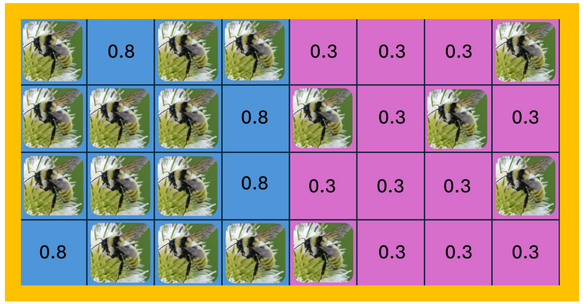
Occupancy Models - Gears and Cogs

Observations, X don’t <u>just</u> depend on the probability the species is present

X ~ Coin Flip (Z * $\boxed{\text{Detection Probability}}$)

Z ~ Coin Flip ($\boxed{\text{Occupancy Probability}}$)



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Occupancy Models - Gears and Cogs

Observations, X don’t just depend on the probability the species is present

X ~ Coin Flip (Z * Detection Probability)

Z ~ Coin Flip (Occupancy Probability)

At all sites where the species was found, Z must be 1

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logit (Detection Probability) = p.0 + p1*X1 + p2*X2 + p3*X1*X2

Occupancy Models - Gears and Cogs

At all sites where the species was found, Z must be 1

For one such site,

1 ~ Coin Flip (Occupancy Probability)

Visit 1

Visit 2

Visit 3

0

Occupancy Models - Gears and Cogs

At all sites where the species was found, Z must be 1

For one such site,

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Visit 1 

~ Coin Flip (1 * Detection Probability)

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Occupancy Models - Gears and Cogs

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Visit 1 

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Visit 3 0 ~ Coin Flip (1 * Detection Probability)

For two successes and one failure, the most likely detection probability is 0.66

Detection Probability = 0.66

Occupancy Models - Gears and Cogs

At all sites where the species was not found, Z could be 1 OR 0

1 ~ Coin Flip (Occupancy Probability)

0 ~ Coin Flip (Occupancy Probability)

Occupancy Models - Gears and Cogs

At all sites where the species was not found, Z could be 1 OR 0

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Occupancy Models - Gears and Cogs

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0 ~ Coin Flip (

Both sides here are consistent with the data (all zeros)

lip (0 * Detection Probability)

0 ~ Coin Flip (1 * Detection Probability)

0 ~ Coin Flip (0 * Detection Probability)

Hierarchical* Models are weird, but cool!

- Normally, your ’y’ is something that you have observed or calculated from your observations of the world
- Here, things are different
  1. We have TWO y’s

     Occupancy Probability

     Detection Probability

  2. AND neither of them are something we’ve directly measured

     Instead, we have observations, **X**, that depend on both of those quantities AND we have Z, the true occupancy state that we are also estimating
- But, their structure allows for us to systematically correct for biases in the data