Main Points

1) Occupancy modeling wrap-up
   -- naïve and informed occupancy, continued
   -- odds ratios, continued
   -- Bui et al
   -- a bunch of questions to answer about occupancy modeling

Pre-reading: Tues 31 Oct = Wright et al; Thurs 2 Nov = NA

Extra Credit/Homework #3 will be available today at 5pm in WyoCourses. It is due Tues 7 Nov by 5pm.

Quiz #5 will be assigned today by 5pm in WyoCourses, covers Thurs 19 Oct, Tues 24 Oct, and today. It is due Thurs 2 Nov by 5pm, along with Quizzes #3-4.

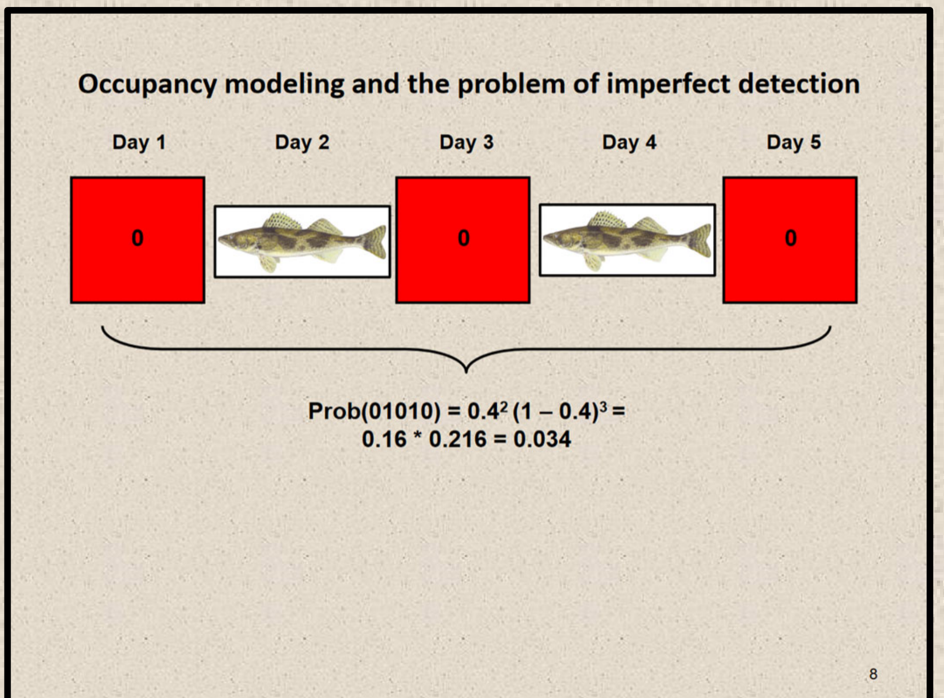
No lecture Thurs 2 Nov. Use this time to finish Quizzes #3-5.

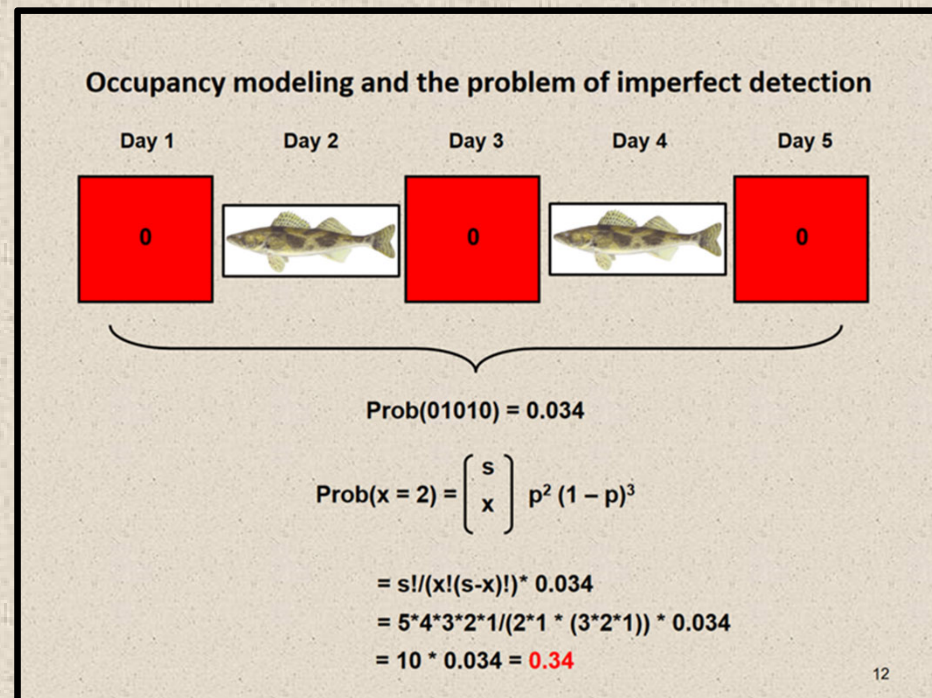
No office hours Thurs 2 Nov.

Terms: Akaike's Information Criterion (AIC), ΔAIC, Akaike weights, animosymous

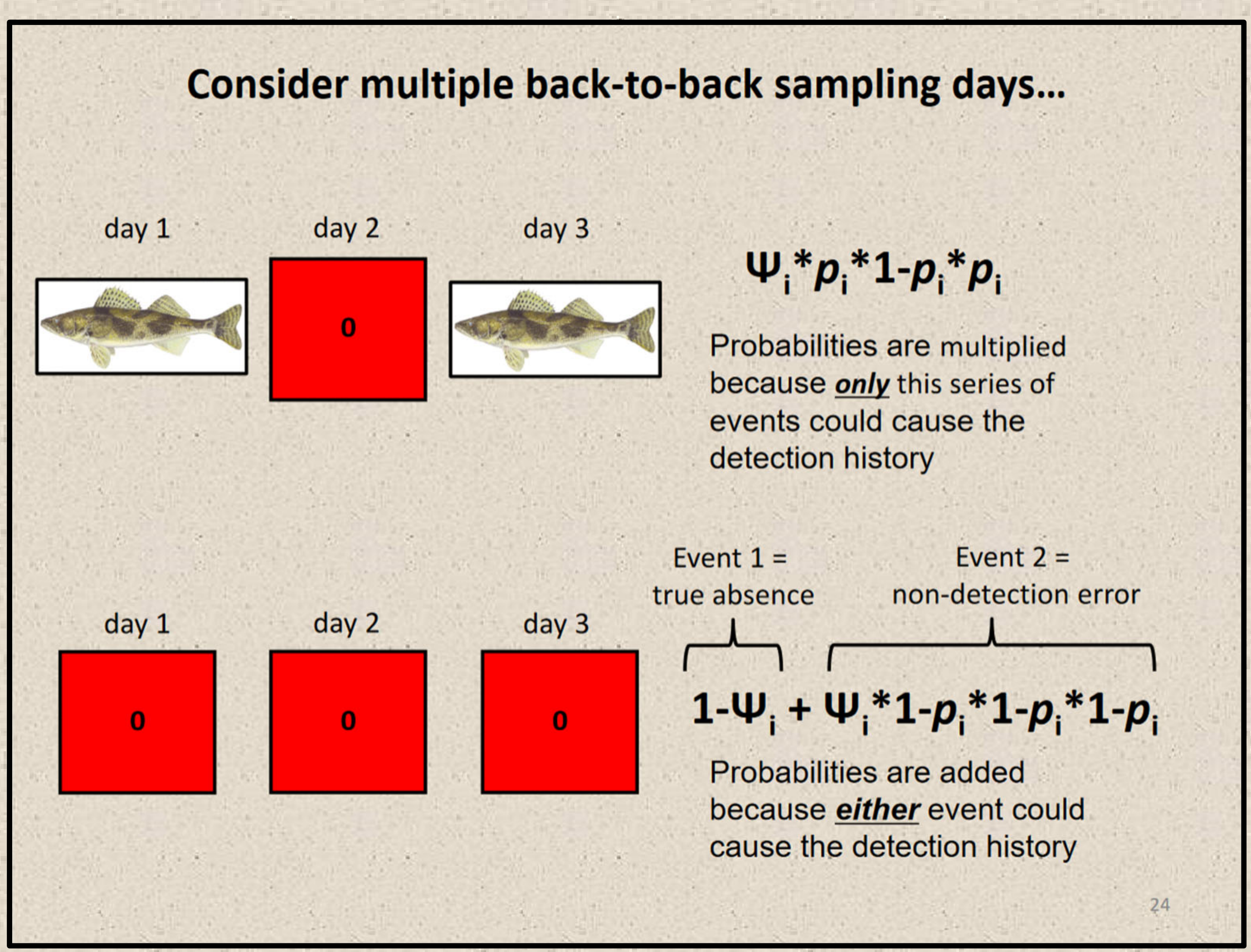
Extra credit: Bui et al described a study to model occupancy of a "predator" in western Wyoming. What was the predator?

Punchline #1: given a detection probability, we learned how to calculate the probability of getting an *exact* detection history, and also *any* detection history with x detections in s trials.



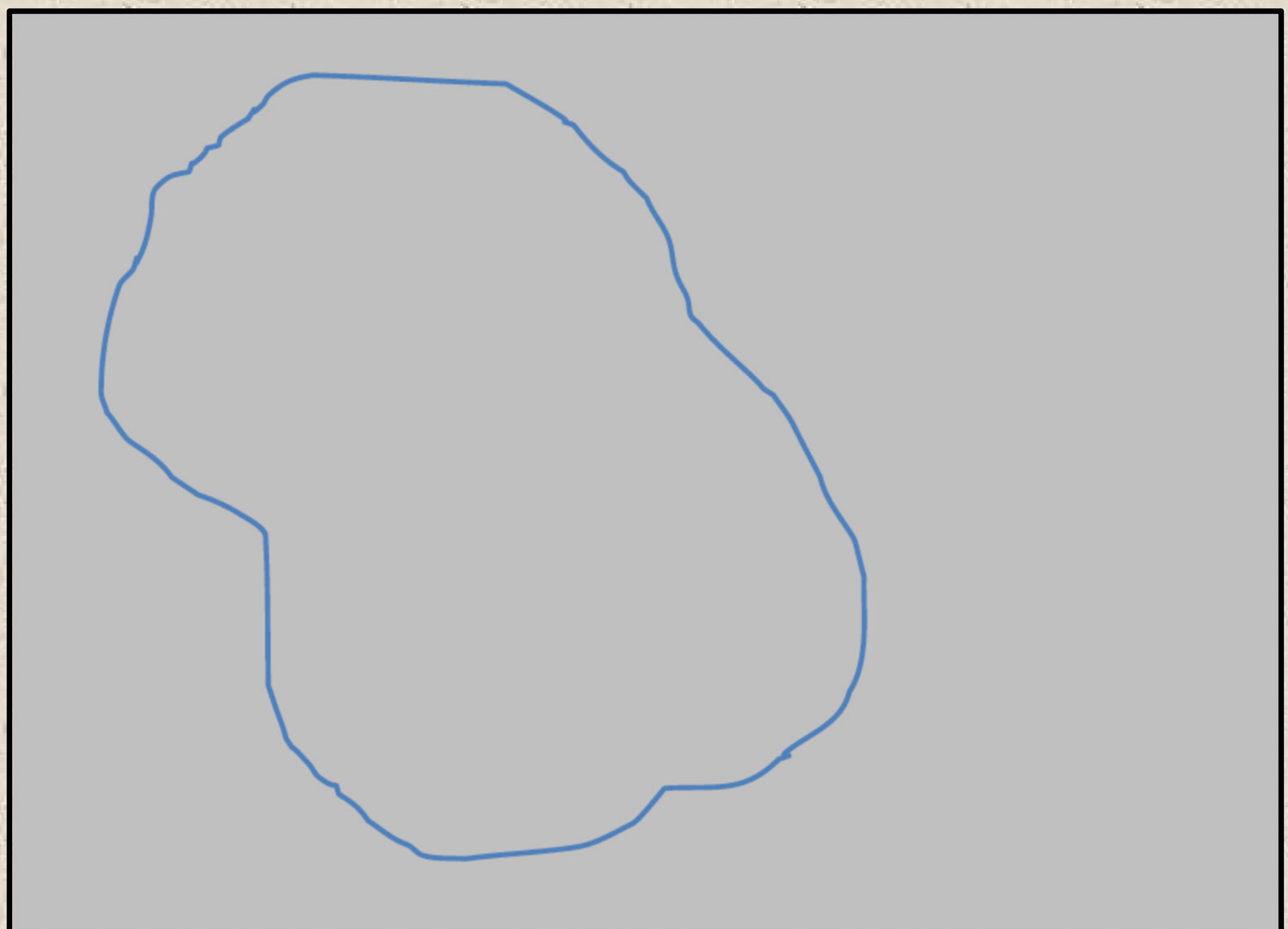


Punchline #2: we learned about the parameters Ψ and p, occupancy probability and detection probability. We learned how to calculate the probability of true absence vs the probability of a non-detection error.



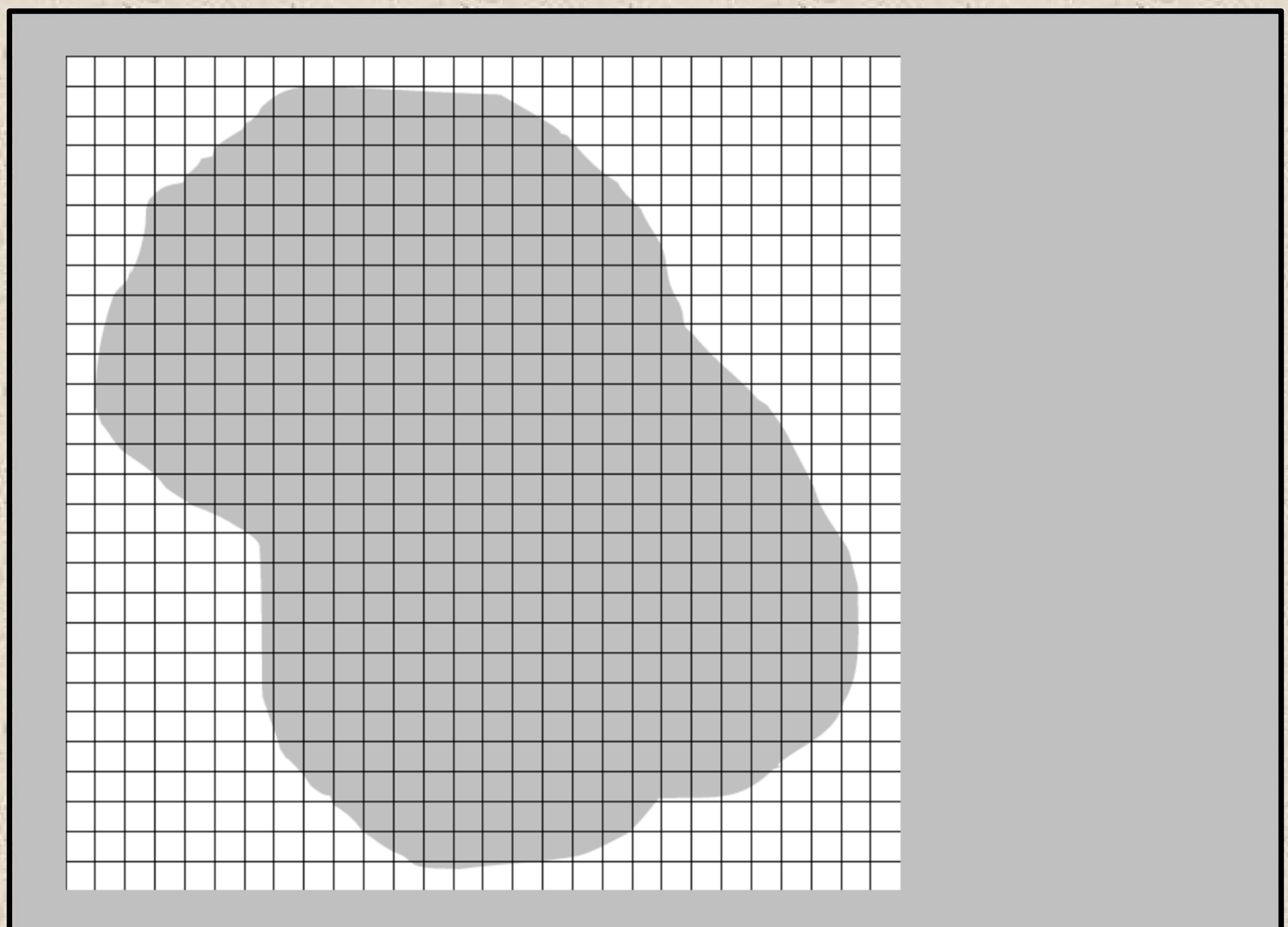
Steps for occupancy modeling

#1: define your study area.



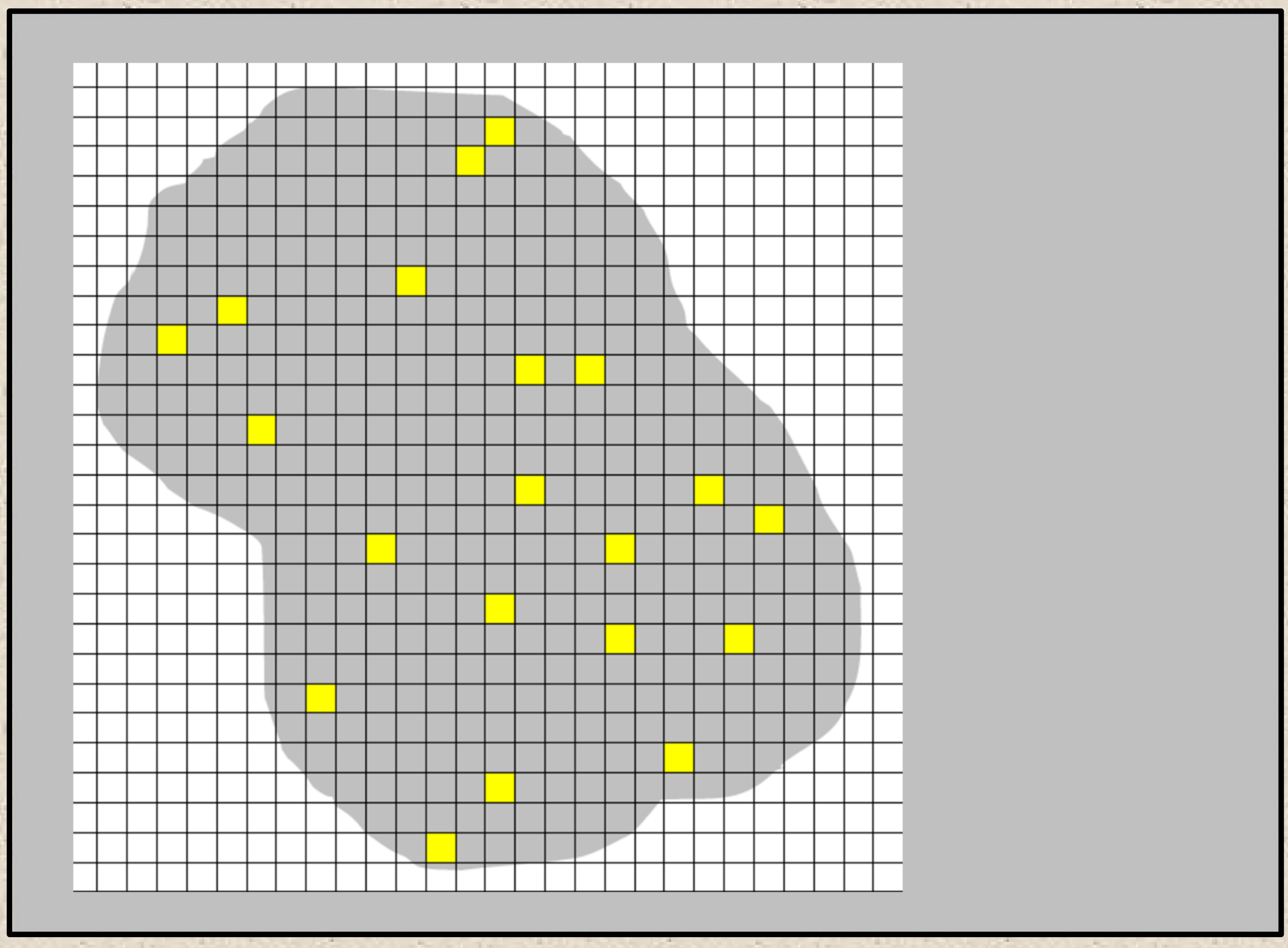
Steps for occupancy modeling

#2: define your sites.



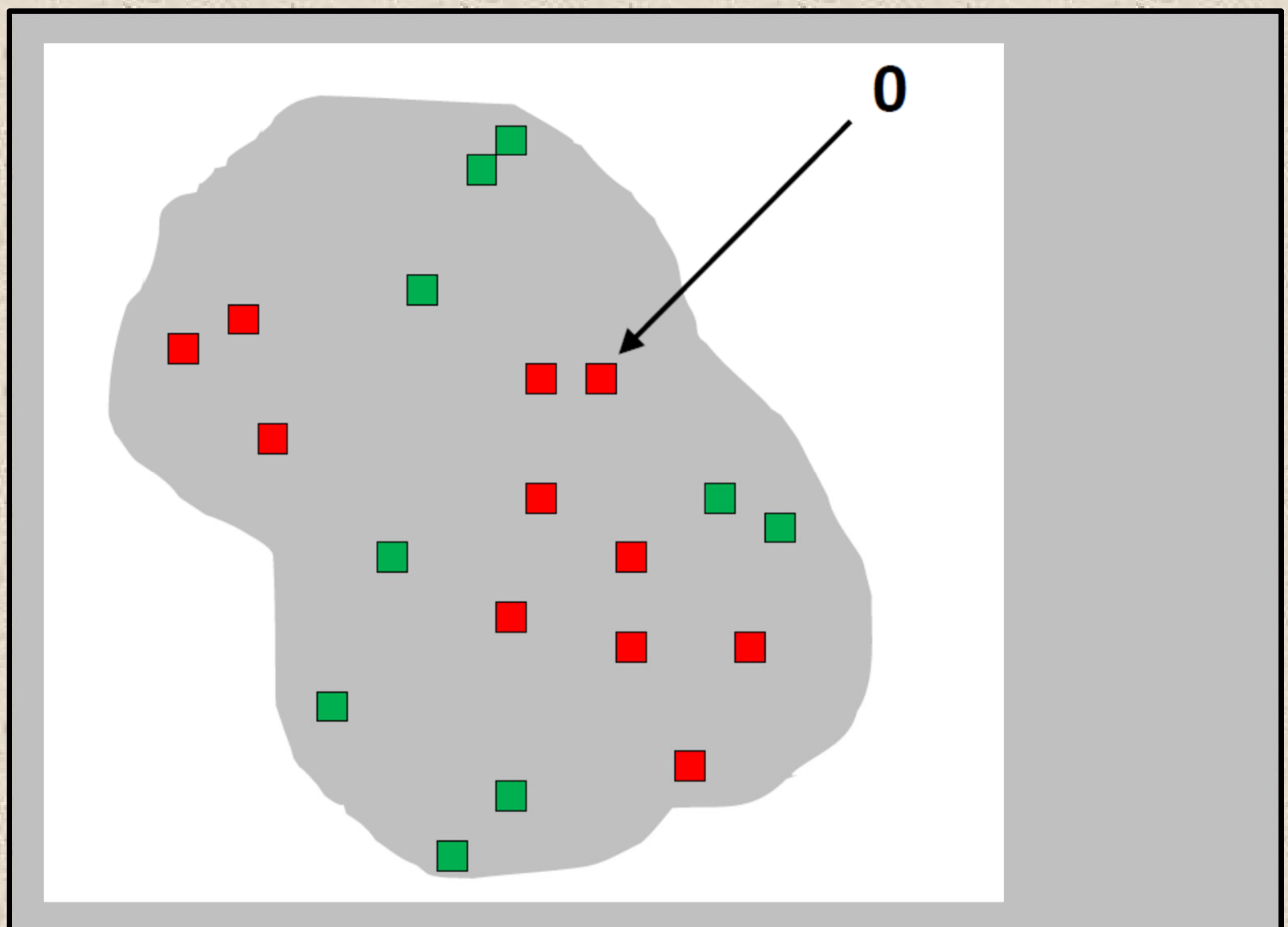
Steps for occupancy modeling

#3: select a sample of sites.



Steps for occupancy modeling

#4: survey sites repeatedly to build detection histories.



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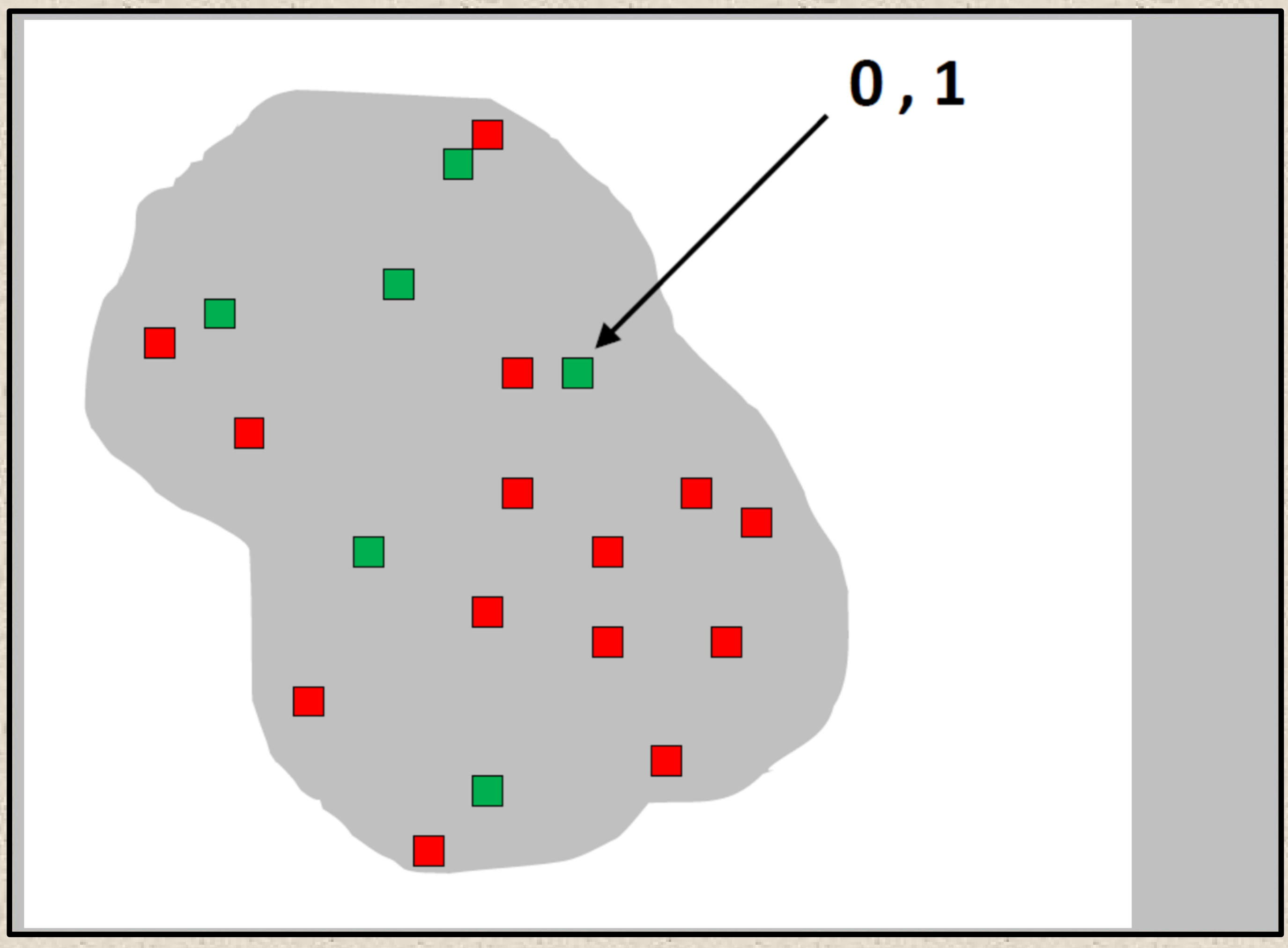

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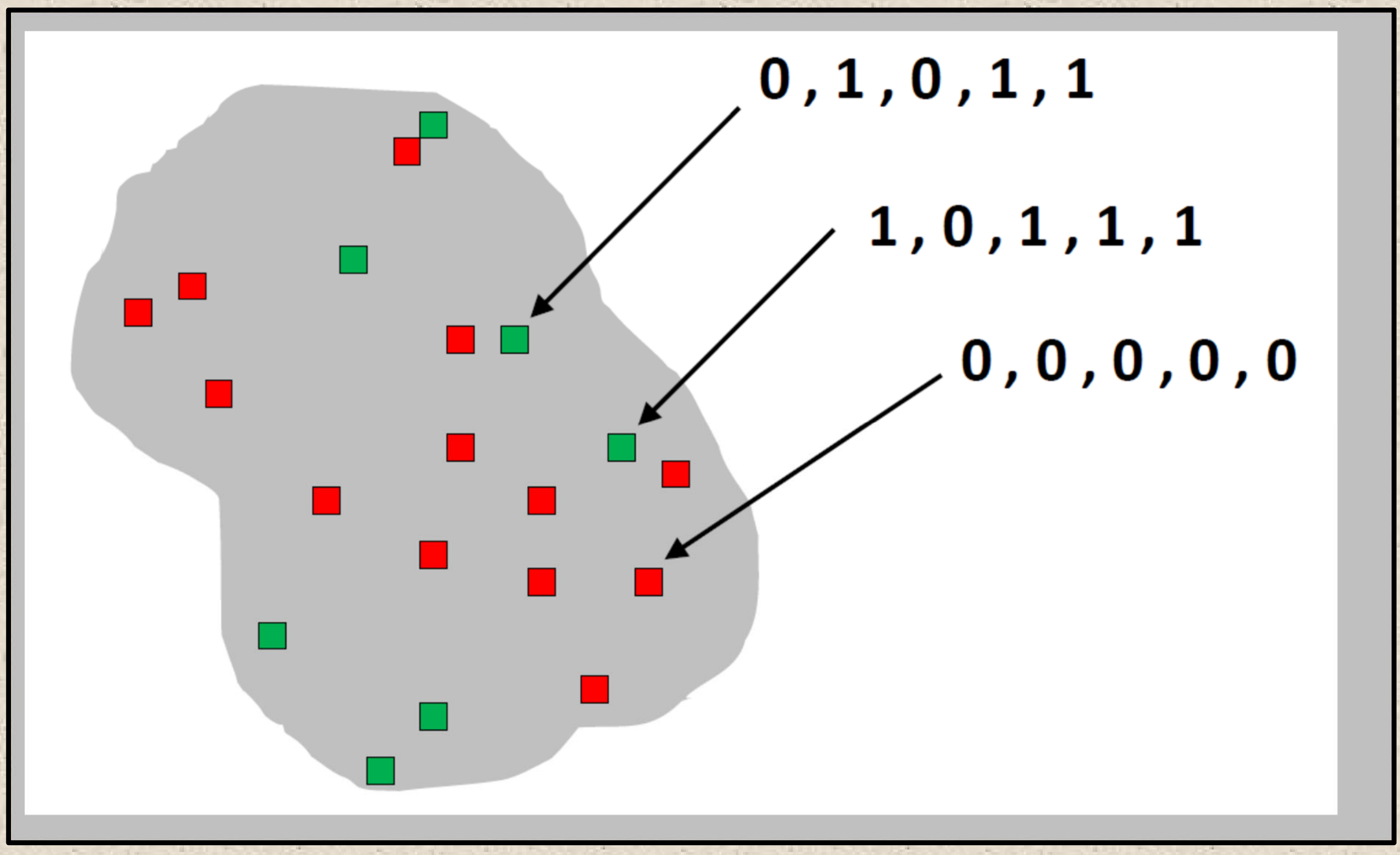
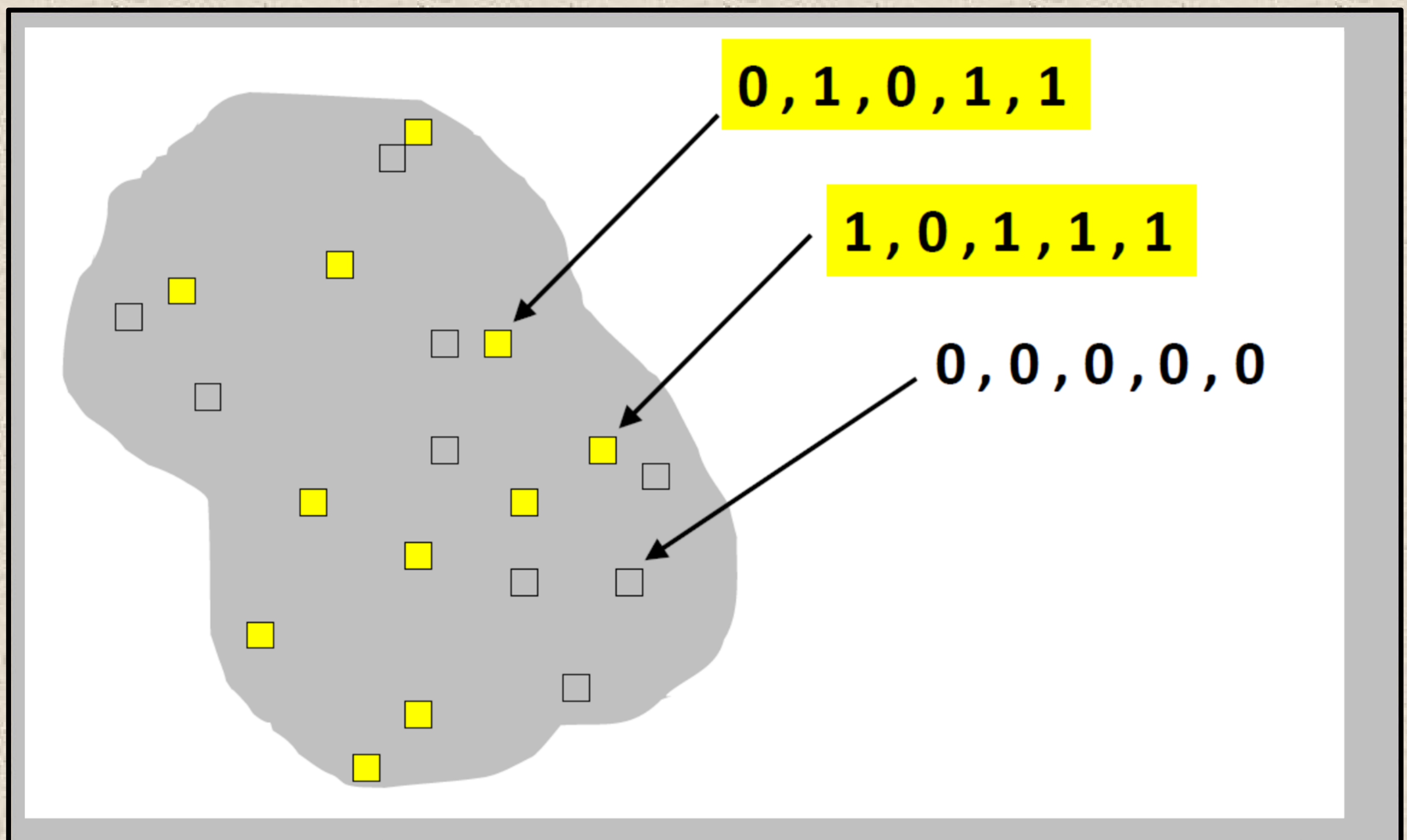


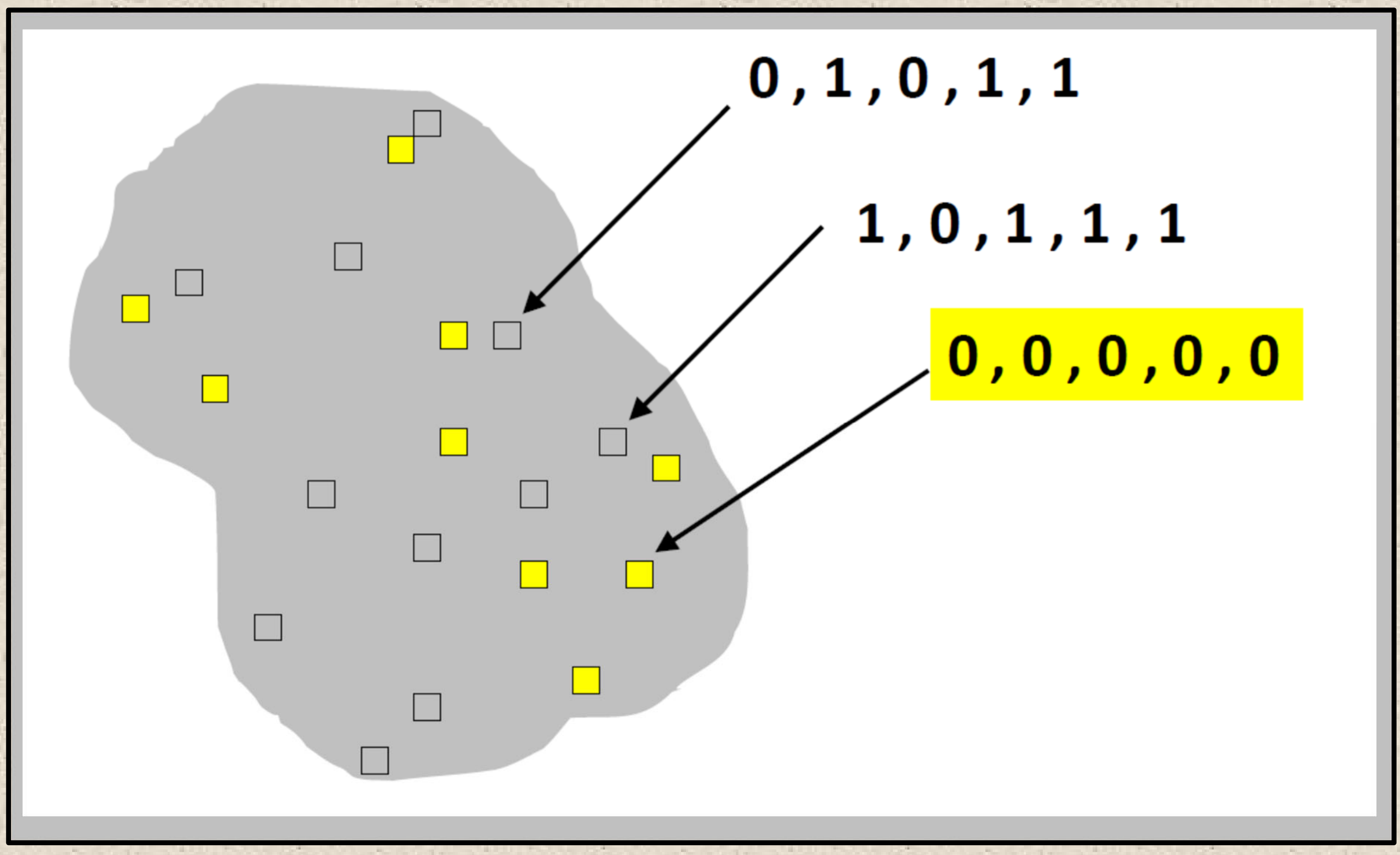
Steps for occupancy modeling

#5: estimate naïve occupancy.
(Ψ_{naive} = # sites with detections / # sites)



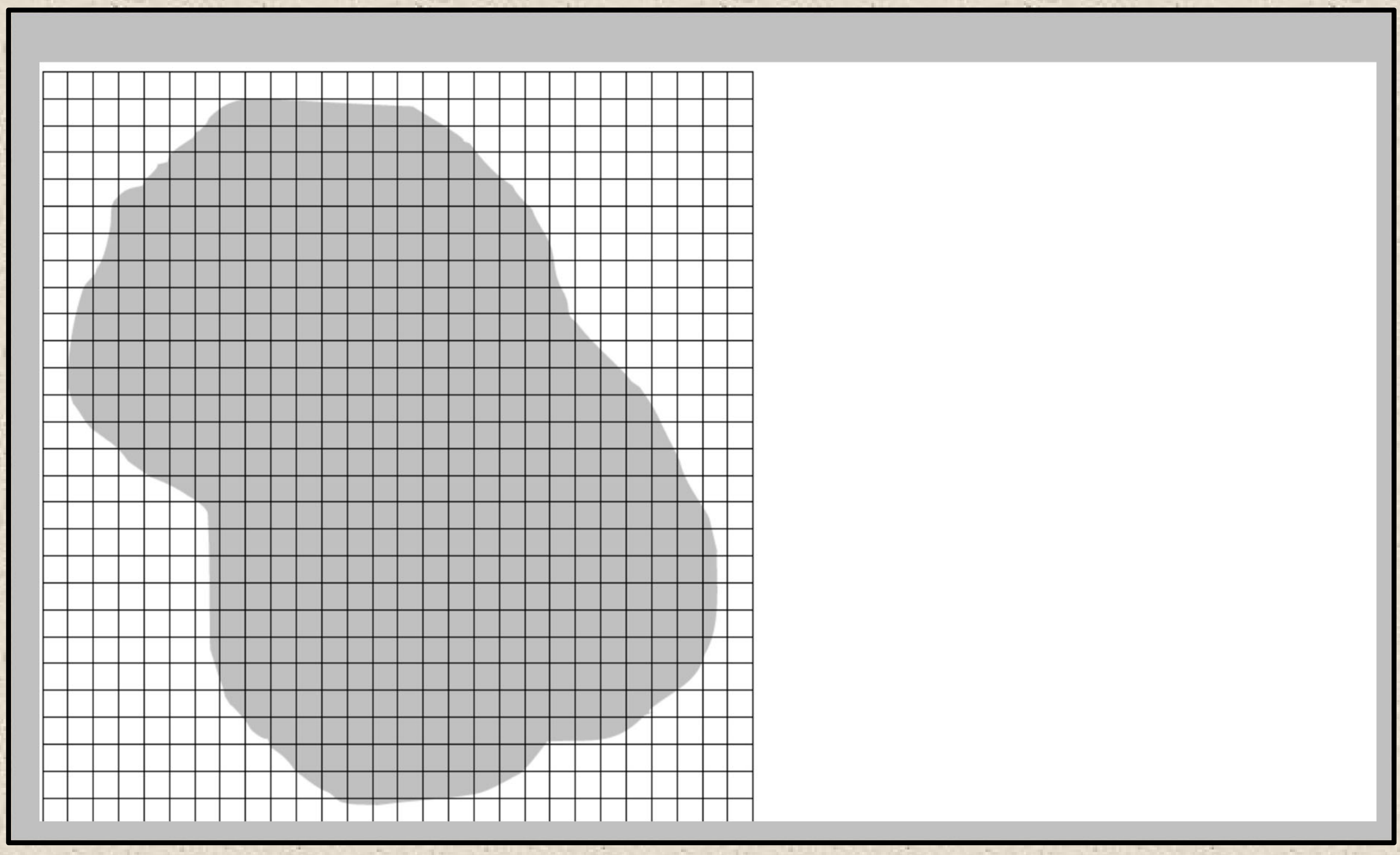
Steps for occupancy modeling

#6: estimate proportion of sites with all 0's in detection histories.

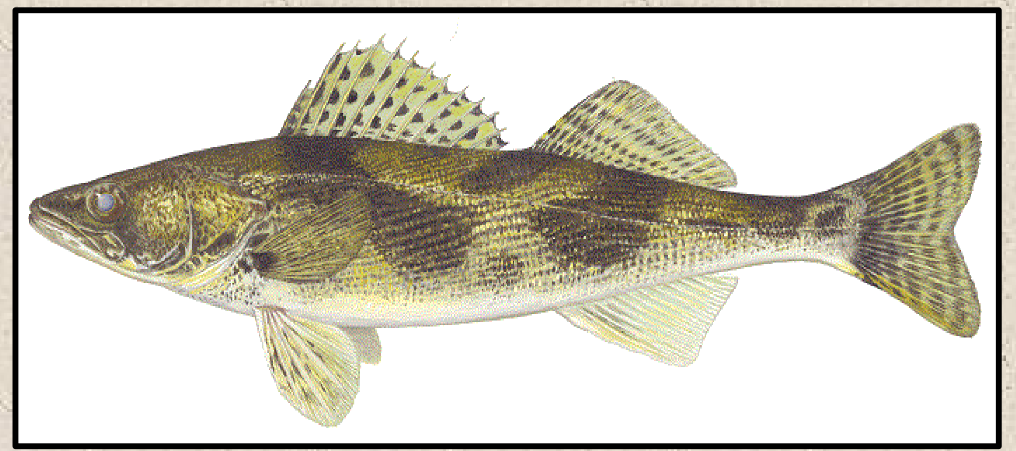


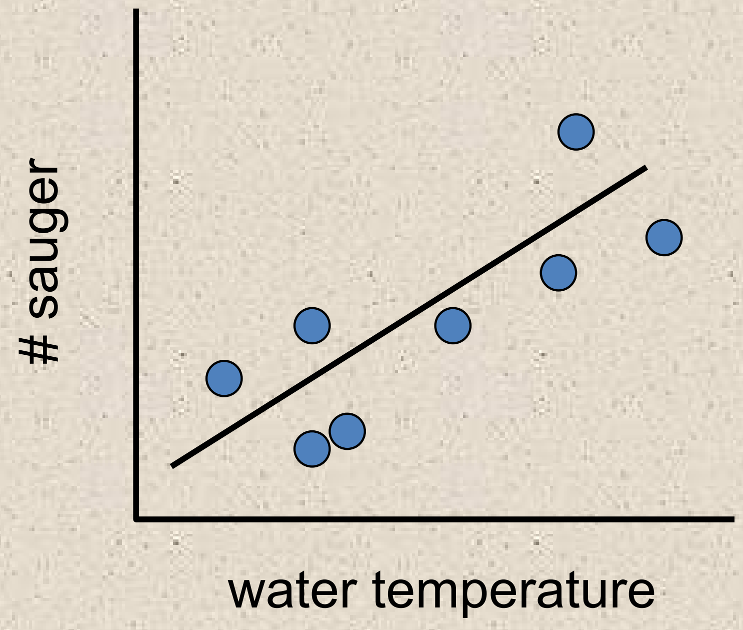
Steps for occupancy modeling

#7: estimate detection probability (p), and calculate informed occupancy. $\Psi_{informed} = \Psi_{naive} / p$



Site-specific variation in covariates

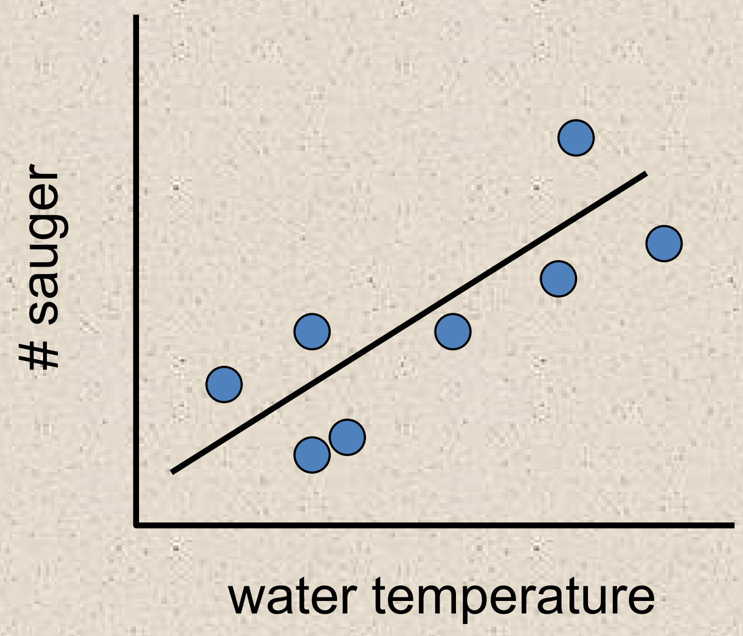


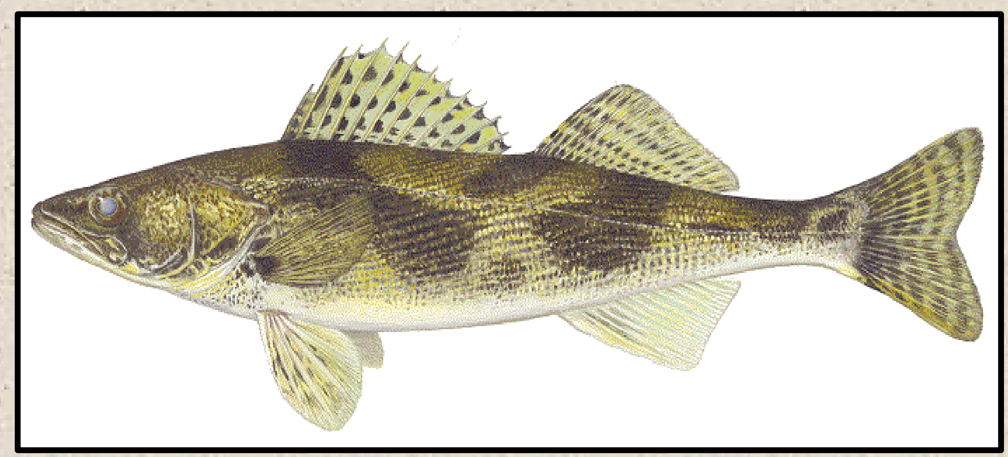


Site-specific variation in covariates

- **linear regression =**

  $y = b_0 + b_1x$, where b_1 is the coefficient of independent variable x, and y is a continuous dependent variable





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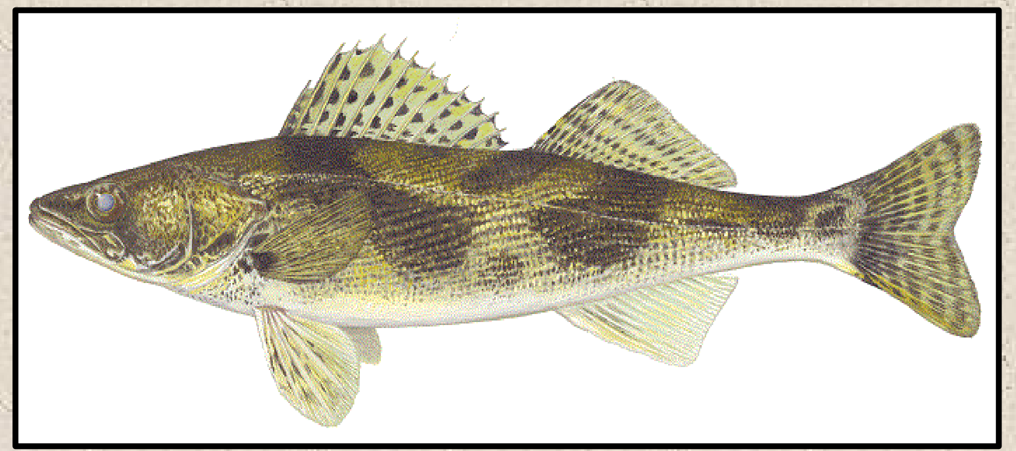
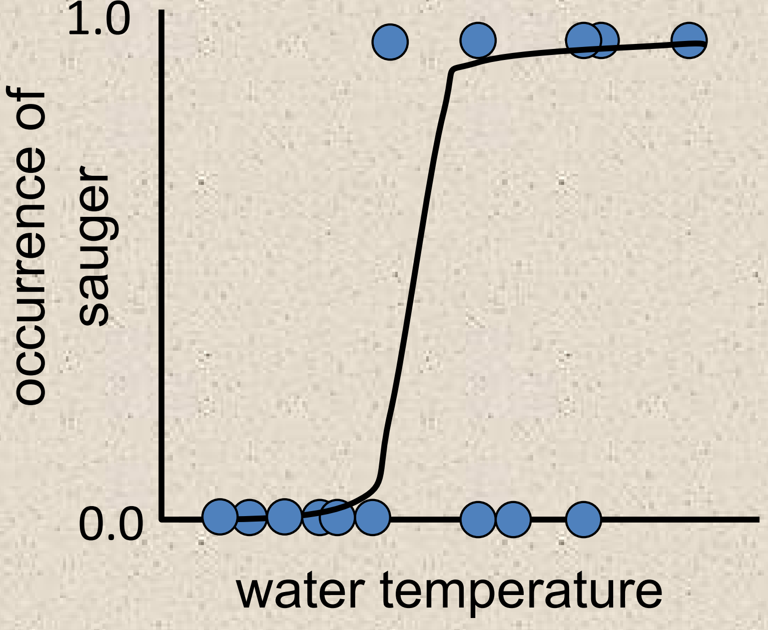
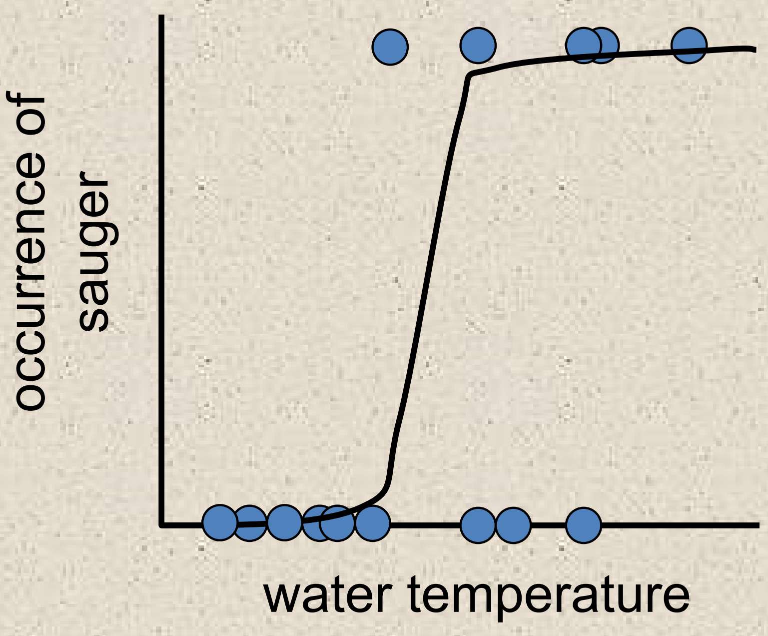
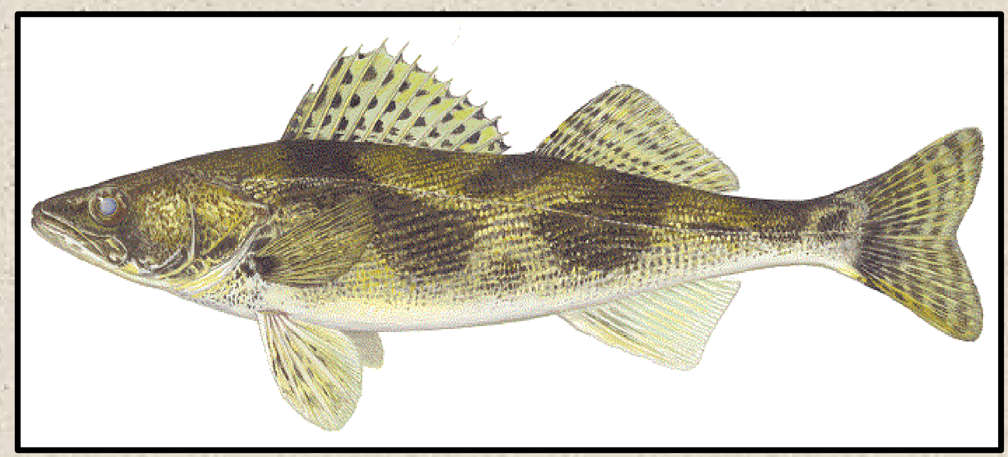




Site-specific variation in covariates

- **coefficients of predictors in logistic regression are <u>odds</u> = when exponentiated to the inverse of the natural log (e.g., 2.71^b_1) and multiplied by 100, these give the percent change in the probability of an event occurring (e.g., the occurrence probability)**





Consider multiple surveys…

Now consider the following "**detection histories**" ($\mathbf{h_i}$) for s sites:

site1 1 0 1 1 0 0 1 1 0 1, p = 0.60

site2 0 0 0 0 0 0 0 0 0 0, p = 0.00, or NA

site3 1 0 1 1 0 0 0 1 1 1, p = 0.80

site4 1 0 1 0 0 0 0 1 0 0, p = 0.30

site5 0 0 0 0 0 0 0 0 0 0, p = 0.00, or NA

…

site 50 1 0 0 1 0 0 0 1 0 1

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$\mathbf{\Psi_{naive}}$ **= 35 detections/50 sites = 0.70**

$\mathbf{\Psi_{informed} = (\Psi_{naive}/p) = 0.70/0.80 = 0.875}$

This is usually the average p across all the sites in a study

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0.875 * 50 ~ 44 sites actually occupied—35 detections, 9 non-detections

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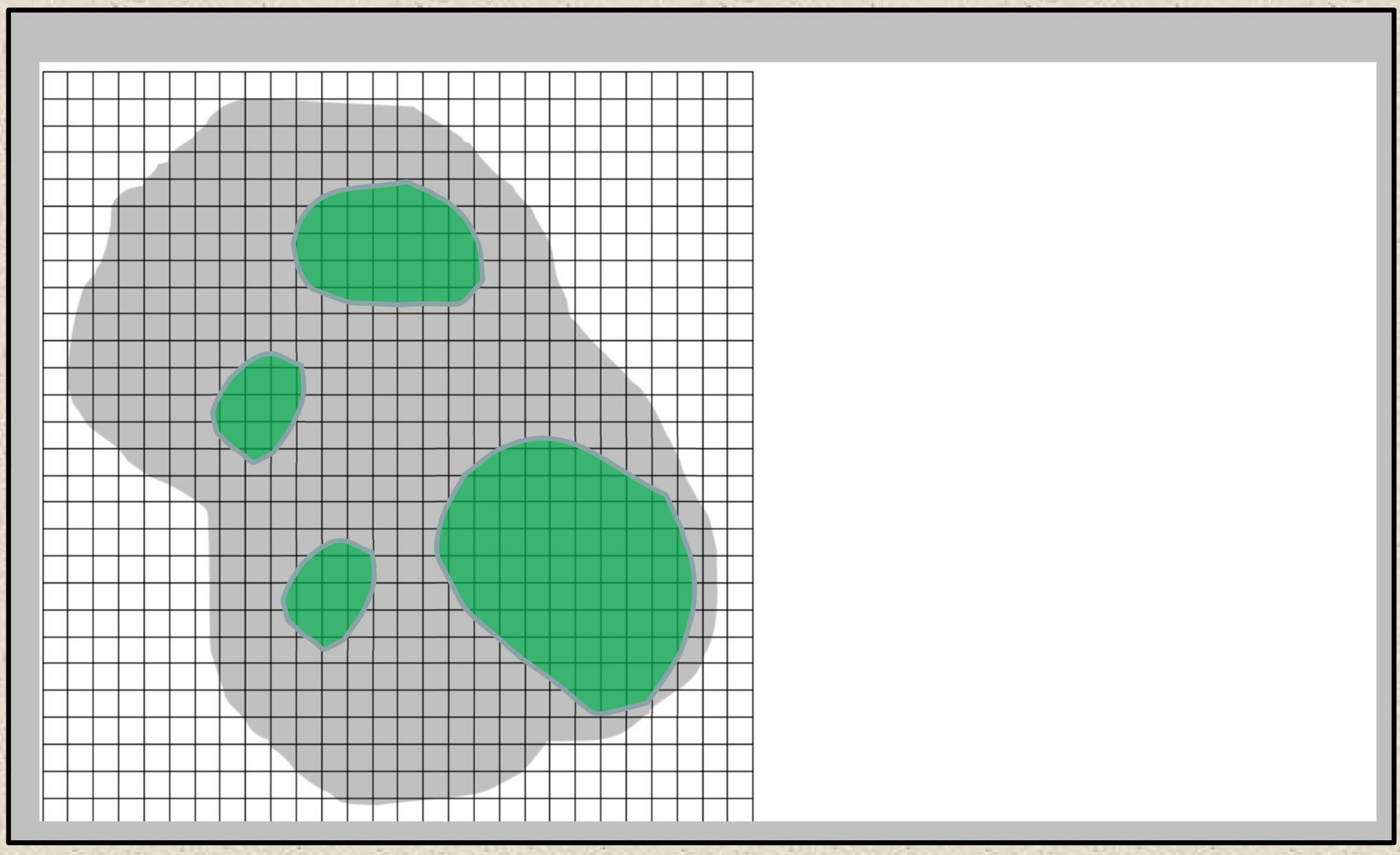
$$\Psi_{informed} = (\Psi_{naive}/p) = 0.70/0.80 = 0.875$$

0.875 * 50 ~ 44 sites actually occupied—35 detections, 9 non-detections

50 – 44 = 6 sites are true absences

Steps for occupancy modeling

#8: calculate odds for predictor variables of interest, like forest v non-forest, or distance to forest.



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Incorporate predictors for Ψ and p…

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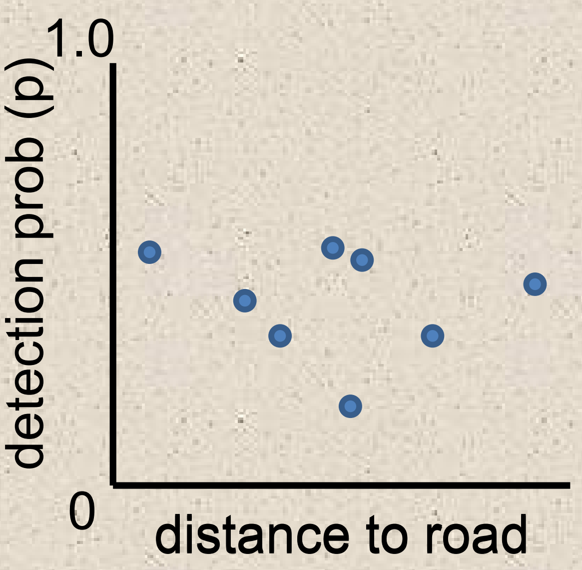

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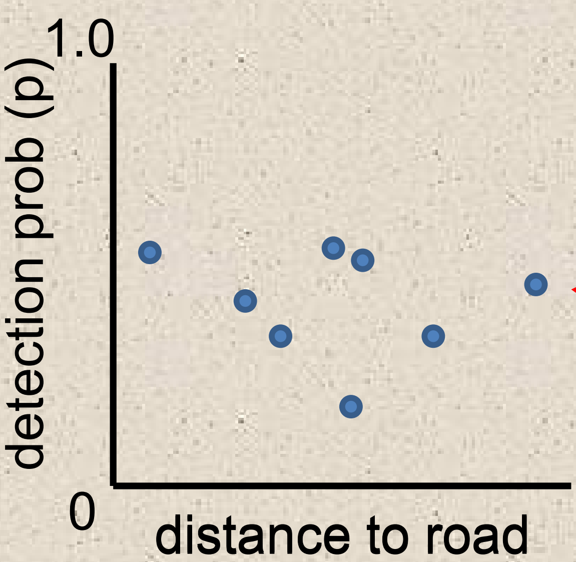

But here, we're using the detection erobability associated with each site—each site's p is a datapoint

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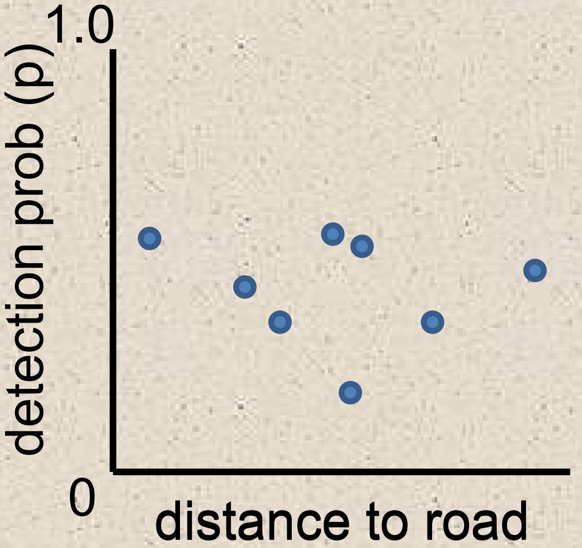

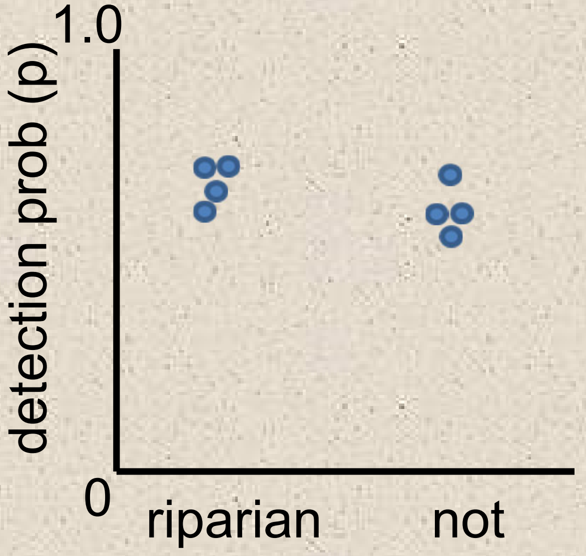

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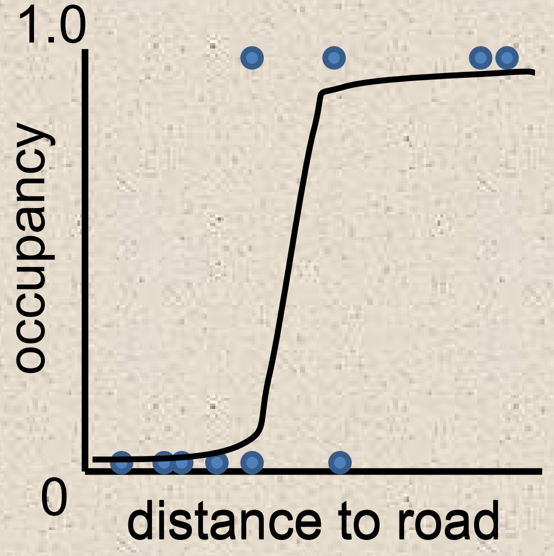

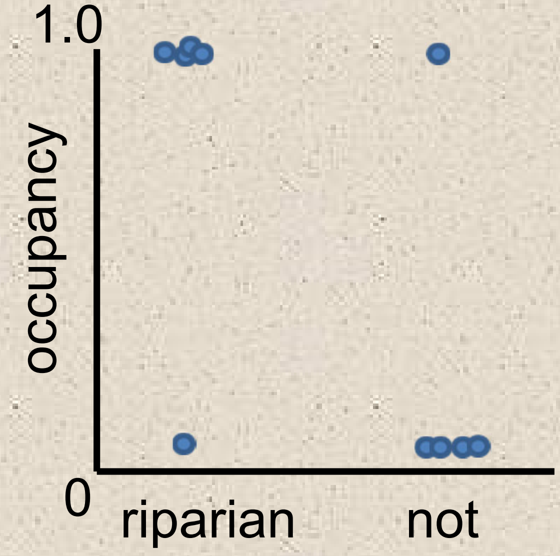

Modeling occupancy of generalist predators

<u>Akaike's Information Criterion</u> (AIC) = an estimator of predictive ability of a model, typically used to compare among multiple models

Bui et al
2010.

Modeling occupancy of generalist predators

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Rules-of-thumb for interpreting AIC

- **lower AIC = better predictive ability**

- **ΔAIC = AIC often is scaled such that the lowest AIC is set to 0.**

Bui et al 2010.

Modeling occupancy of generalist predators

TABLE 2. Top-ranked models (out of 10 considered) of raven occupancy in relation to land cover, study site, and study year.

Occupancy model	ΔAIC
Detectability constant; occupancy varies by land cover and study site[a]	0.0
Detectability varies by land cover; occupancy varies by land cover and study site	1.2
Detectability varies by city/noncity and study site; occupancy varies by land cover and study site	1.5
Detectability varies by land cover; occupancy varies by study site	2.1
Detectability varies by study site; occupancy varies by land cover and study site	2.2

[a] AIC = 403.3.

Bui et al 2010.

Modeling occupancy of generalist predators

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Rules-of-thumb for interpreting AIC

- lower AIC = better predictive ability
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- Akaike weights = relative likelihood of each model; these sum to 1.0.

Bui et al 2010.

Modeling occupancy of generalist predators

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Detectability constant; occupancy varies by land cover and study site[a]	0.0	0.37
Detectability varies by land cover; occupancy varies by land cover and study site	1.2	0.20
Detectability varies by city/noncity and study site; occupancy varies by land cover and study site	1.5	0.17
Detectability varies by land cover; occupancy varies by study site	2.1	0.13
Detectability varies by study site; occupancy varies by land cover and study site	2.2	0.12

[a] AIC = 403.3.

Bui et al 2010.

Modeling occupancy of generalist predators

	Coefficients (SE) from logistic regression on occupancy			
	Pinedale		Jackson	
Variable	Unstandardized	Odds Ratio	Unstandardized	Odds Ratio
Intercept	−0.04	N/A	1.64	N/A
City	1.89 (0.87)	6.6	2.19 (1.09)	8.9
Oil field	2.33 (0.95)	10.3	N/A	N/A
Riparian	0.29 (0.79)	1.3	1.49 (0.98)	4.4
Edge	1.22 (1.41)	3.4	−1.24 (1.45)	0.29
Contrast-weighted edge density	0.03 (0.09)	1.0	−0.11 (0.10)	0.90
Road	0.88 (0.90)	2.4	1.07 (1.06)	2.9
Hayfield	N/A	N/A	0.52 (0.82)	1.7
Contagion	−0.02 (0.01)	0.98	−0.02 (0.01)	0.98
Distance to road	0.000 (0.0)	1.0	0.000 (0.0)	1.0
Distance to landfill	0.000 (0.0)	1.0	N/A	N/A
Distance to city	0.000 (0.0)	1.0	0.000 (0.0)	1.0

Bui et al 2010.

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Modeling occupancy of generalist predators

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Bui et al 2010.

Pinedale = 2.71^0.88 = 2.4

Jackson = 2.71^1.07 = 2.9

<u>Discussion #1:</u> Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of *<u>not</u>* detecting black-backed woodpeckers?

Roger

Discussion #2: **Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.**

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *any* one of the three survey days?

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<u>Discussion #4:</u> after surveying NW Wyoming for black-backed woodpeckers, you generate the following AIC table for Ψ (occupancy probability) and p (detection probability):

Model	AIC	Coefficients from logistic regression
Ψ constant; p constant	150	$\beta\psi = 0.0$; $\beta p = 0.0$
Ψ increases in patches burned within 2 years; p constant	119	$\beta\psi = 1.7$; $\beta p = 0.0$
Ψ constant; p decreases in patches burned within 2 years	112	$\beta\psi = 0.0$; $\beta p = -0.8$
Ψ increases in patches burned within 2 years; p decreases within patches burned within 2 years	96	$\beta\psi = 1.7$; $\beta p = -0.8$

Roger

From your best-supported occupancy model, how much more/less likely are black-backed woodpeckers to occur in patches burned within 2 years?

How much more/less likely are black-backed woodpeckers to be detected in patches burned within 2 years?

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Roger

$$\underbrace{1-\Psi_i}_{\text{Event 1 = true absence}} + \underbrace{\Psi_i * 1-p_i * 1-p_i * 1-p_i}_{\text{Event 2 = non-detection error}}$$

= (1-0.4) + [0.4*(0.7)*(0.7)*(0.7)]

= 0.6 + (0.4*0.34)

= 0.6 + 0.14 = 0.74

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After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *any* one of the three survey days?

Roger

Step 1: pick a single event, for example detection on day 1, and non-detections on days 2 and 3

$$\Psi_i * p_i * 1 - p_i * 1 - p_i$$

$$= 0.4 * [(0.3)*(0.7)*(0.7)]$$
$$= 0.059$$

This is the probability of getting this *exact* event, but we want to know the probability of getting *any* event with a single detection in 3 days of sampling

<u>Discussion #2:</u> Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *<u>any</u>* one of the three survey days?

Roger

Step 2: multiply the probability of an exact event by the number of ways we can get 1 event (detection) out of 3 tries (days of sampling)

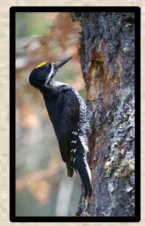
$$\binom{S}{X} = 3! / 1!(2)! = 6/2 = 3 \text{ ways to get 1 event out of 3 trials}$$

<u>Discussion #2:</u> Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *<u>any</u>* one of the three survey days?

Roger

Note: because this is a simple example, we can quickly check to make sure that our calculation makes sense:

1st way  X X detection on day 1, non-detections on days 2 and 3

2nd way X  X detection on day 2, non-detections on days 1 and 3

3rd way X X  detection on day 3, non-detections on days 2 and 3

<u>Discussion #2:</u> Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *<u>any</u>* one of the three survey days?

Roger

Step 2: multiply the probability of an exact event by the number of ways we can get 1 event (detection) out of 3 tries (days of sampling)

$$= 3 * 0.059 = 0.176$$

Discussion #3: Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *any* two of the three survey days?

Roger

So, repeat the steps on the previous slides, but with 2 detections instead of 1.

$$\Psi_i * p_i * p_i * 1 - p_i$$

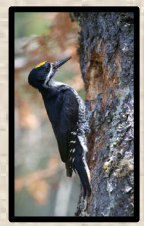
$$= 0.4 * [(0.3)*(0.3)*(0.7)]$$
$$= 0.025$$
$$= 0.025 * 3 = 0.075$$

<u>Discussion #3:</u> Ψ for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.4. p for black-backed woodpecker in beetle-killed stands of northwestern Wyoming is 0.3.

After three days of surveying in a beetle-killed stand of northwestern Wyoming, what is the probability of detecting black-backed woodpeckers on *<u>any</u>* two of the three survey days?

Roger

Note: because this is a simple example, we can quickly check to make sure that our calculation makes sense:

1st way   X — detections on days 1 and 2, non-detection on day 3

2nd way X   — detections on days 2 and 3, non-detection on day 1

3rd way  X  — detection on days 1 and 3, non-detection on day 2

So, we have calculated:

(1) the probability of not detecting black-backed woodpeckers in 3 days.

(2) the probability of detecting black-backed woodpeckers once in 3 days.

(3) the probability of detecting black-backed woodpeckers twice in 3 days.

One final outcome remains: the probability of detecting black-backed woodpeckers 3 times in 3 days:

Roger

$$\Psi_i * p_i * p_i * 1 - p_i$$

$$= 0.4 * [(0.3)*(0.3)*(0.3)]$$
$$= 0.01$$

So, we have calculated:

(1) the probability of not detecting black-backed woodpeckers in 3 days.

(2) the probability of detecting black-backed woodpeckers once in 3 days.

(3) the probability of detecting black-backed woodpeckers twice in 3 days.

One final outcome remains: the probability of detecting black-backed woodpeckers 3 times in 3 days:

Roger

Note: we can quickly check to make sure that our calculations makes sense by adding all the outcomes (everything circled in red on slides 1-7) and ensuring they sum to ~1.0:

$$= 0.74 + 0.176 + 0.075 + 0.01 = 1.0$$

no woodpeckers detected

woodpeckers detected once

woodpeckers detected twice

woodpeckers detected 3 times

<u>Discussion #4:</u> after surveying NW Wyoming for black-backed woodpeckers, you generate the following AIC table for Ψ (occupancy probability) and p (detection probability):

Roger

Model	AIC	Coefficients from logistic regression
Ψ constant; p constant	150	$\beta\psi = 0.0$; $\beta p = 0.0$
Ψ increases in patches burned within 2 years; p constant	119	$\beta\psi = 1.7$; $\beta p = 0.0$
Ψ constant; p decreases in patches burned within 2 years	112	$\beta\psi = 0.0$; $\beta p = -0.8$
Ψ increases in patches burned within 2 years; p decreases within patches burned within 2 years	96	$\beta\psi = 1.7$; $\beta p = -0.8$

Our best-supported model is the last one, with AIC = 96.

Discussion #4: after surveying NW Wyoming for black-backed woodpeckers, you generate the following AIC table for Ψ (occupancy probability) and p (detection probability):

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Ψ increases in patches burned within 2 years; p decreases within patches burned within 2 years	96	$\beta\psi = 1.7$; $\beta p = -0.8$

Our best-supported model is the last one, with AIC = 96.

Black-backed woodpeckers are 2.71^1.7 = 4.6 times more likely (or 460% more likely) to occur in 2-year burns.

<u>Practice Q #4:</u> after surveying NW Wyoming for black-backed woodpeckers, you generate the following AIC table for Ψ (occupancy probability) and p (detection probability):

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Our best-supported model is the last one, with AIC = 96.

Black-backed woodpeckers are 2.71^1.7 = 4.6 times more likely (or 460% more likely) to occur in 2-year burns.

Black-backed woodpeckers are 2.71^-0.8 = 2.2 times *<u>less likely</u>* (or 220% less likely) to be detected in 2-year burns, given that they occur there. So, if p outside 2-year burns is 0.4, p in 2-year burns = 0.4/2.2 = 0.18.

Practice Q #4: after surveying NW Wyoming for black-backed woodpeckers, you generate the following AIC table for Ψ (occupancy probability) and p (detection probability):

Model	AIC	Coefficients from logistic regression
Ψ constant; p constant	150	$\beta\psi = 0.0$; $\beta p = 0.0$
Ψ increases in patches burned within 2 years; p constant	119	$\beta\psi = 1.7$; $\beta p = 0.0$
Ψ constant; p decreases in patches burned within 2 years	112	$\beta\psi = 0.0$; $\beta p = -0.8$
Ψ increases in patches burned within 2 years; p decreases within patches burned within 2 years	96	$\beta\psi = 1.7$; $\beta p = -0.8$

Roger

Note: it would be weird (but not impossible) for occupancy probability to go up while detection probability goes down with the same predictor.

But this was an example to demonstrate how coefficients <0.0 should be interpreted.

Mid-semester evaluation (anonymous, not <u>animosymous</u>)

1) **What things would you like to learn more about in class?**

2) **If there were one thing you could change about class, what would it be?**