

Quantitative thinking

Modes	Mantras (10) - habits of mind
Graphical thinking	Are the data portrayed clearly?
Error thinking	What are the errors in the data? (measurement, sample, systematic, random)
Statistical thinking	What are the components of the claim? (population, sample, parameter, statistic) How big and uncertain is the estimate? How strong is the evidence? What is the scope of inference? Can we infer cause?
Computational thinking	What are the steps to solve this problem?
Mathematical thinking	What can be proven or implied?
Common sense thinking	Does this make sense?

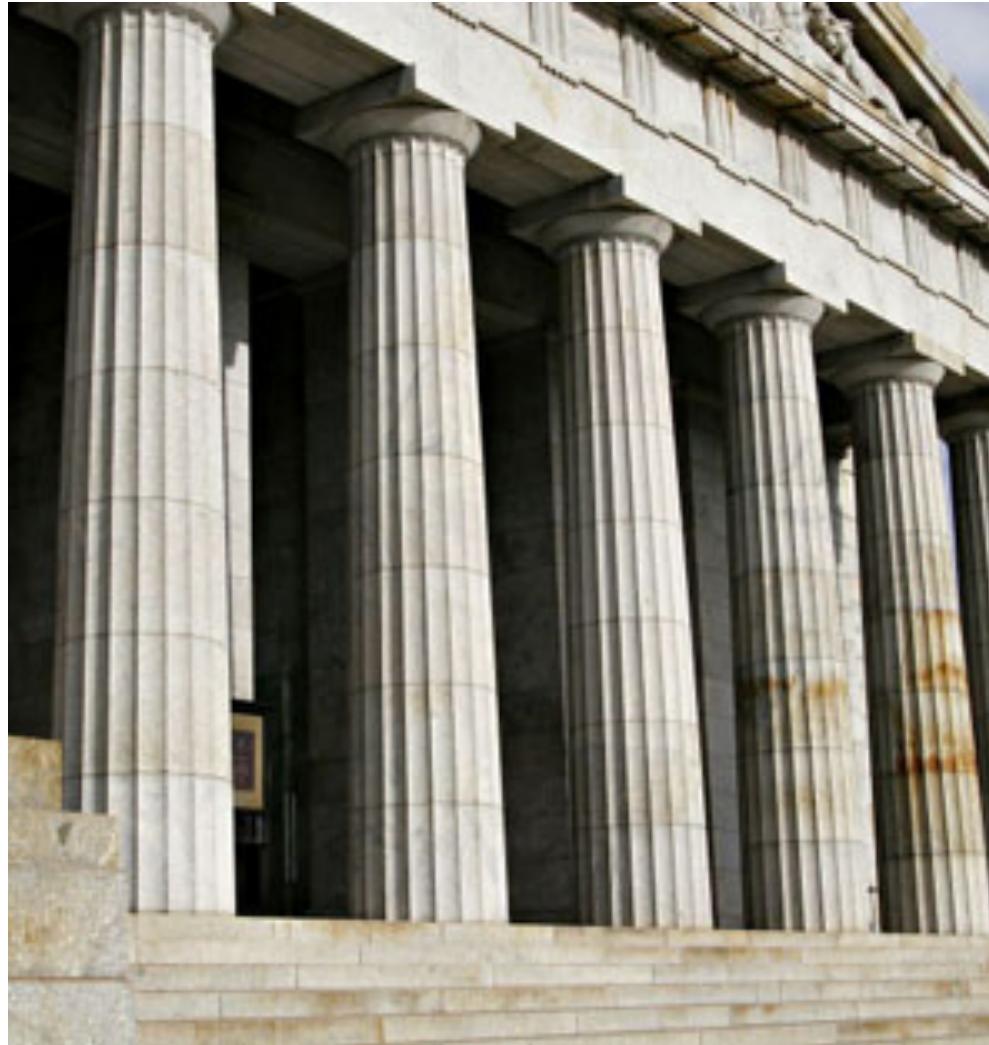
Claims about the world

Inference:

Making a claim about a population
using data from a sample

Statistics: reliable claims despite
error in data

5 pillars of inference



size
uncertainty
strength
scope
cause

Statistical thinking

Pillars

size, uncertainty

strength

scope

cause

Mantras

What are the components of the claim?
(population, sample, parameter, statistic)

How big and uncertain is the estimate?

How strong is the evidence?

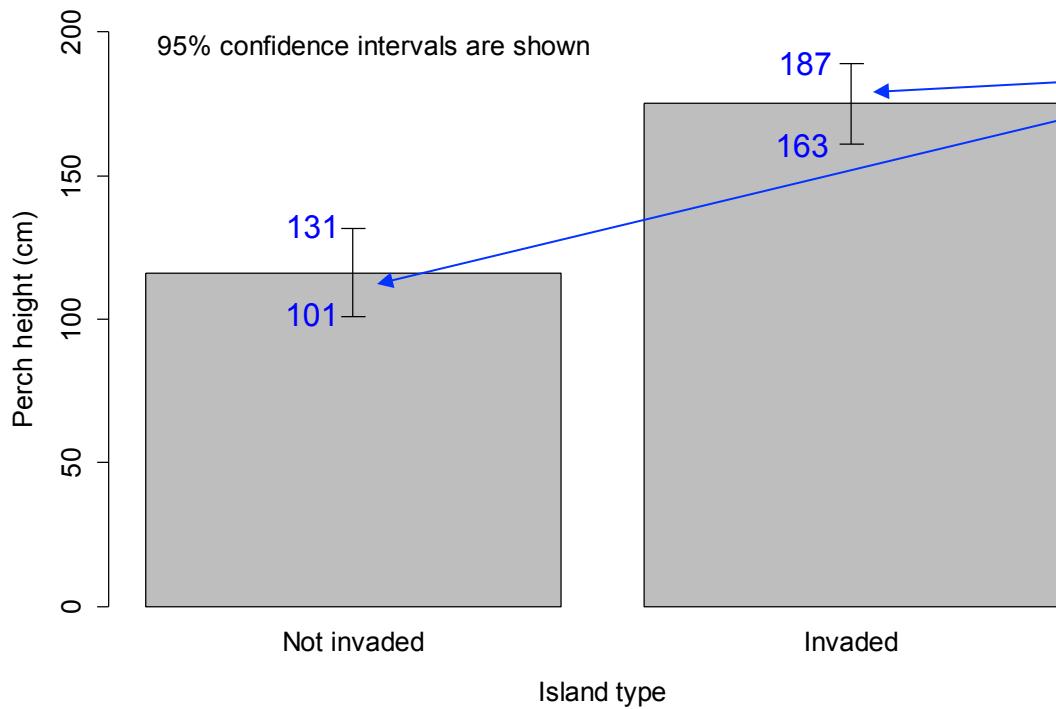
What is the scope of inference?

Can we infer cause?

Claims should include all of these pillars



Example (*Anolis* lizards)



1) Size & uncertainty

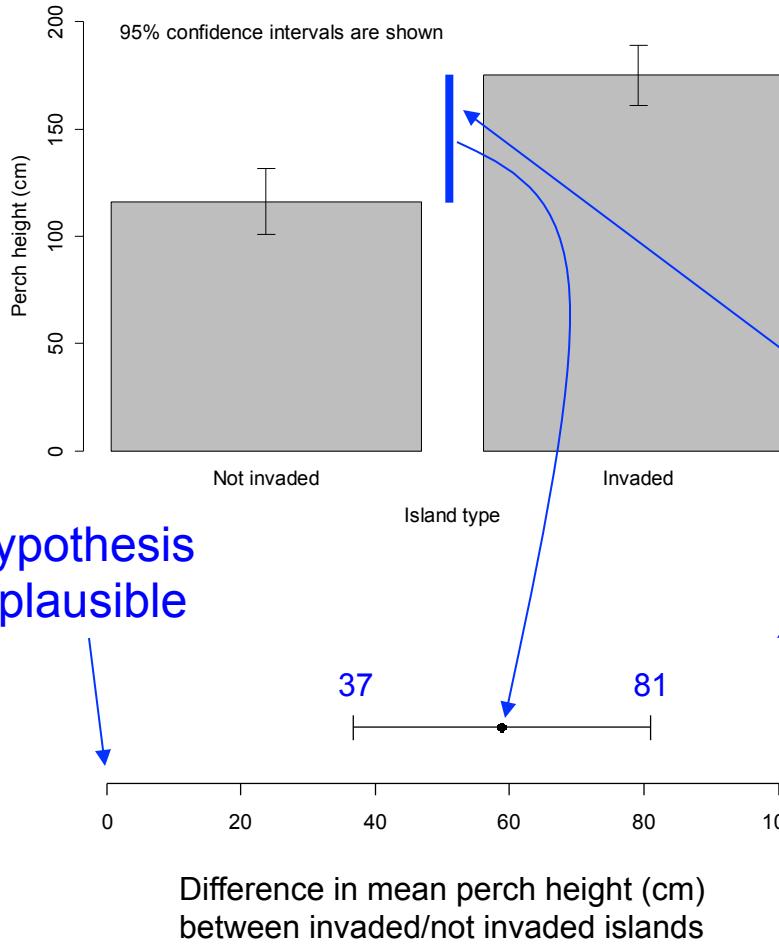
CI: plausible range of the parameter (true mean of the population)

Claim:

"I am at least 95% confident that perch height is higher on invaded islands"



Example (*Anolis* lizards)



1) Size & uncertainty

Null hypothesis
is not plausible

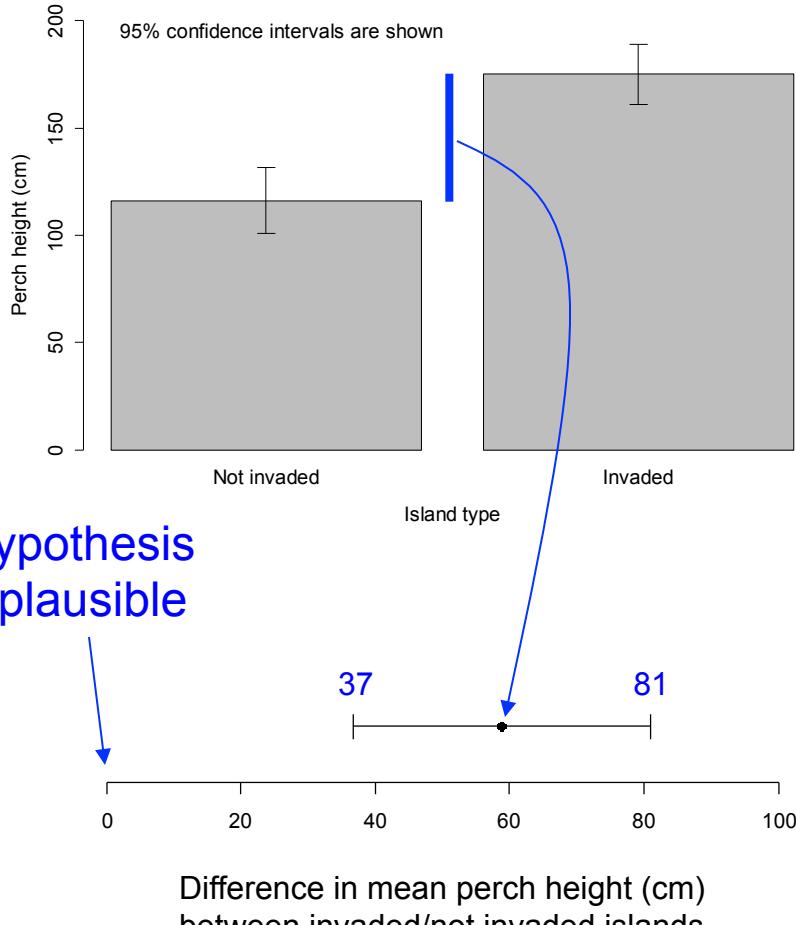
Effect size
difference between means
(size of "island type" effect)

Plausible range of the true difference



Example (*Anolis* lizards)

1) Size & uncertainty



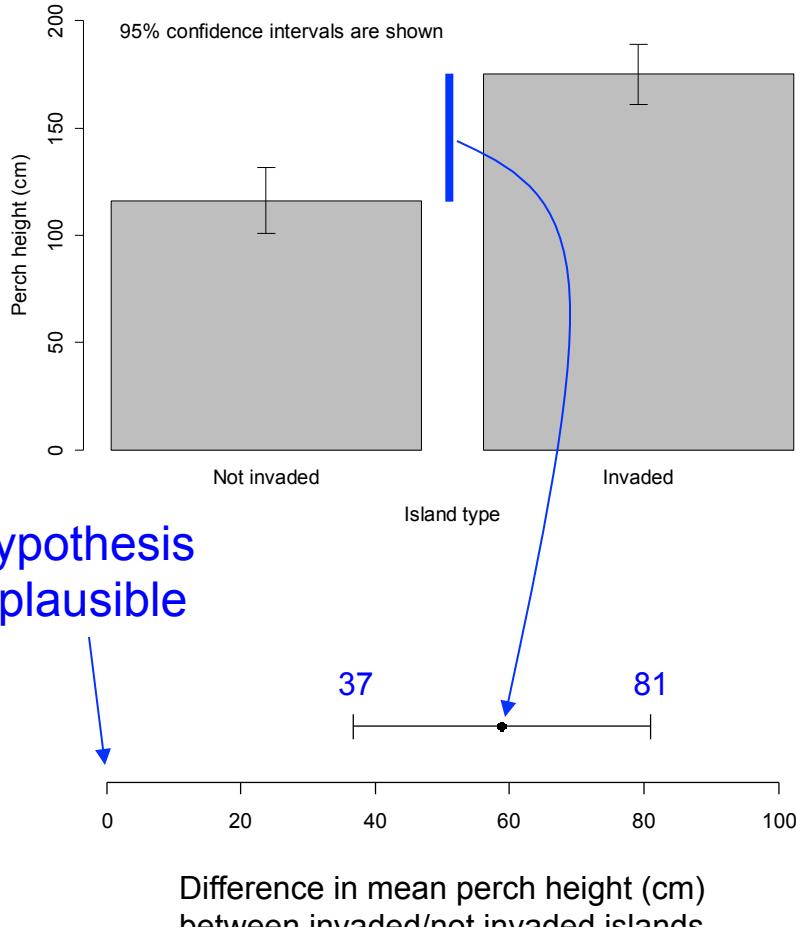
CQ Which claim includes size and uncertainty?

- A) Lizards perch higher on invaded islands
- B) There is an effect of island type on the size of perch height
- C) Perch height is significantly higher on invaded islands
- D) I am 95% confident that perch height is 37 to 81 cm higher on invaded islands
- E) There is a large difference in mean perch height between island types

Plausible range of the true difference



Example (*Anolis* lizards)



Null hypothesis
is not plausible



Plausible range of the true difference

1) Size & uncertainty

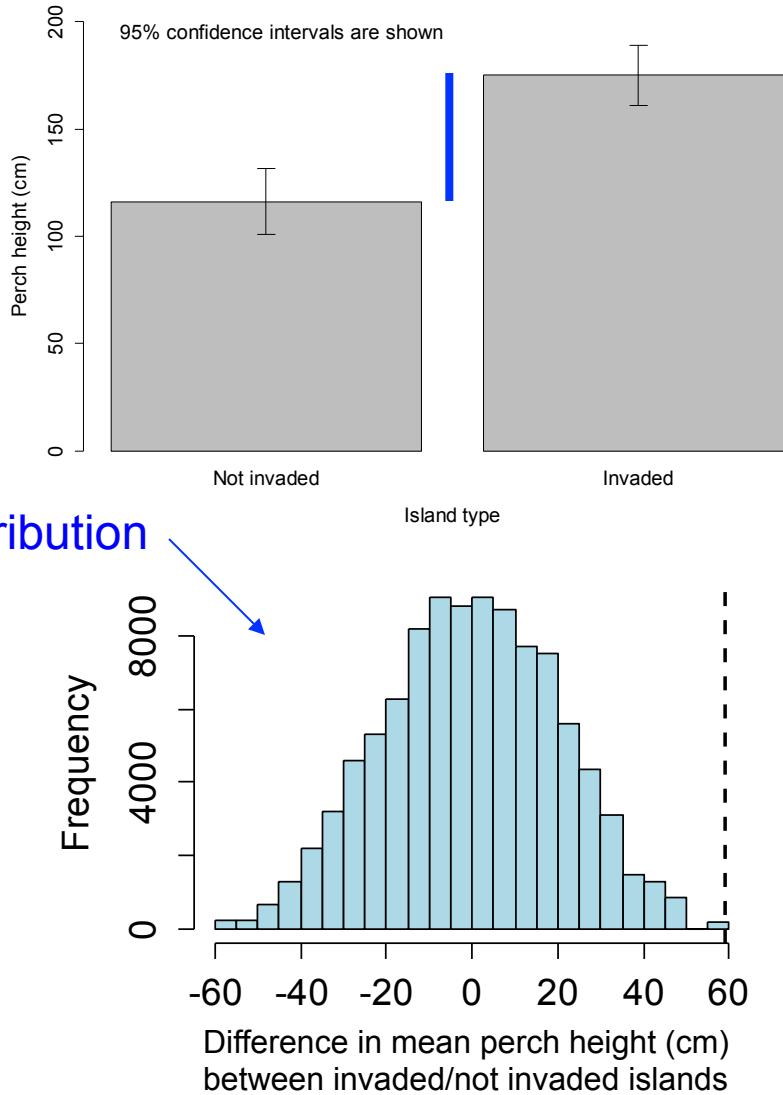
Effect size
difference between means
(size of "island type" effect)

Claim:

"I am 95% confident
that perch height is 37
to 81 cm higher on
invaded islands"



Example (*Anolis* lizards)



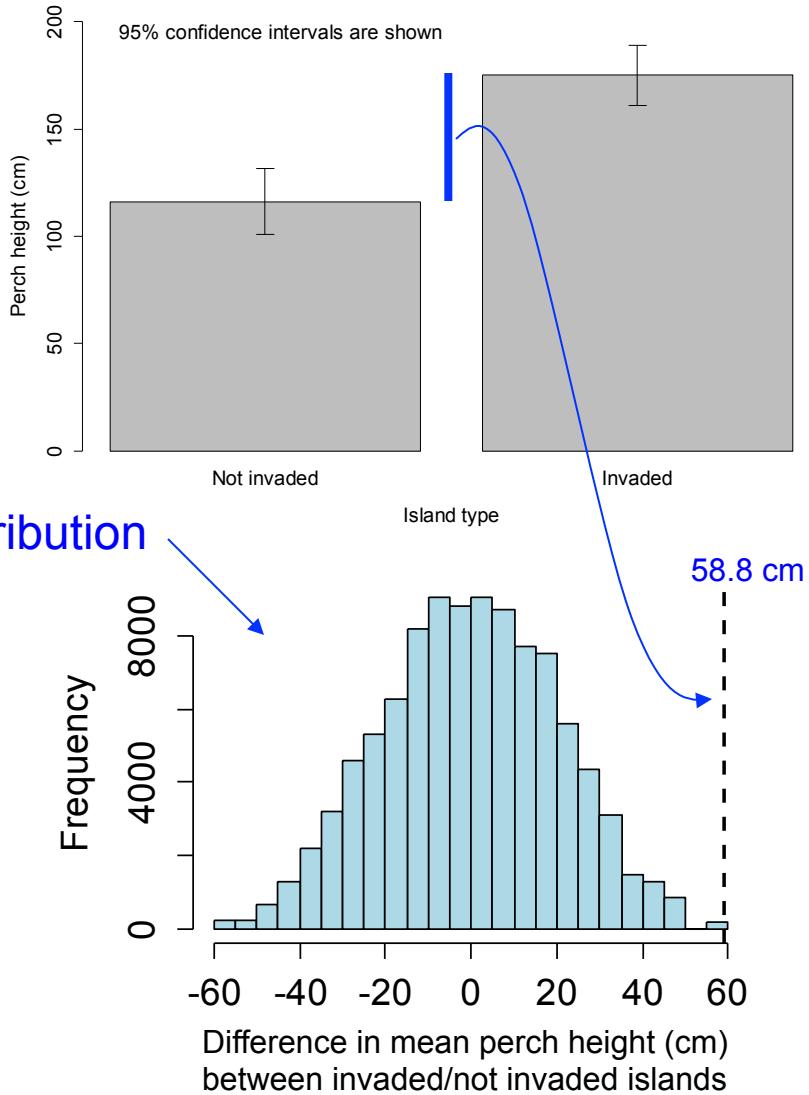
2) Strength

CQ Why is the null distribution centered at zero?

- A) Because there is no difference between islands
- B) Because there is too much error to tell a difference between islands
- C) Because the null hypothesis assumes difference is zero
- D) Because the true difference is zero



Example (*Anolis* lizards)



Null distribution

2) Strength

Effect size
difference between means
(size of "island type" effect)

p = 0

How extreme is the
observed difference
compared to the null
hypothesis?

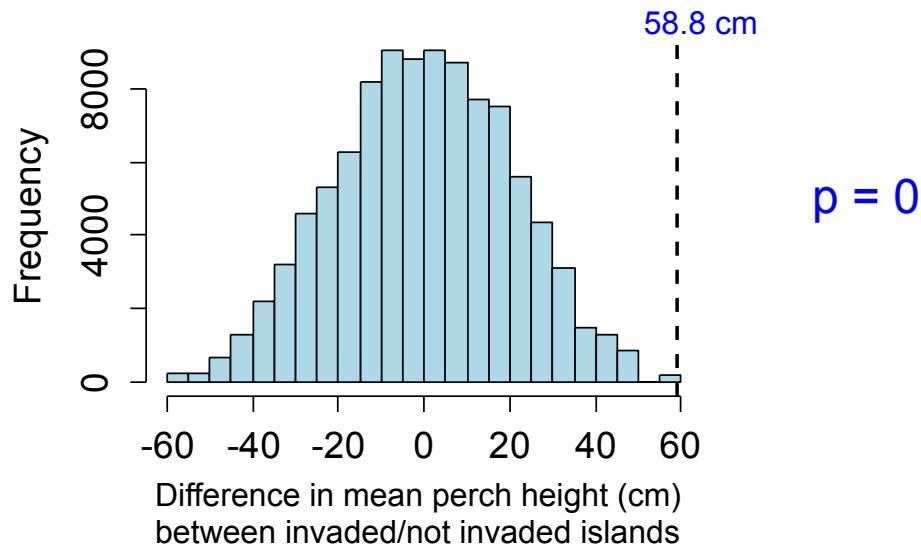
p is a measure of
strength of evidence
against H_0



Example (*Anolis* lizards)

CQ Which is correct?

- A) The p-value of 0 is the probability of observing a difference between sample means at least as extreme as 58.8 cm assuming the true difference is equal to zero
- B) The p-value of 0 is the probability that the null hypothesis is true assuming a difference in sample means of 58.8 cm
- C) The p-value of 0 is the probability that the alternative hypothesis is false assuming a difference in sample means of 58.8 cm
- D) The p-value of zero indicates that we cannot trust the data



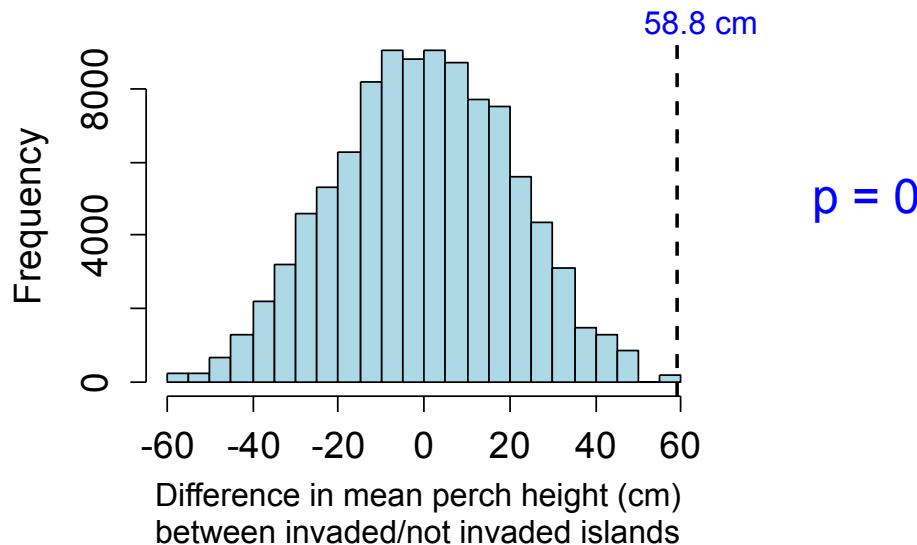


Example (*Anolis* lizards)

CQ Based on the p-value, what **claim** can we make about strength of evidence provided by the data against the null hypothesis?

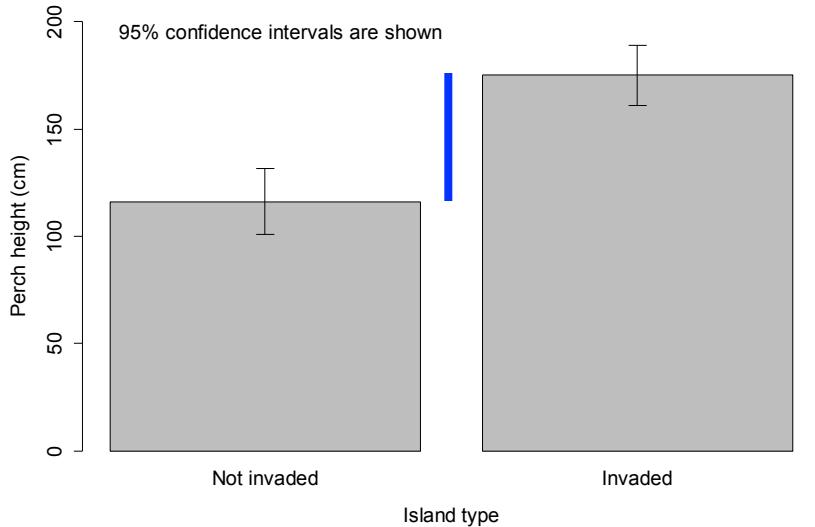
There is _____ against the null hypothesis that invasion status is not associated with perch height.

- A) not much evidence
- B) moderate evidence
- C) strong evidence
- D) very strong evidence



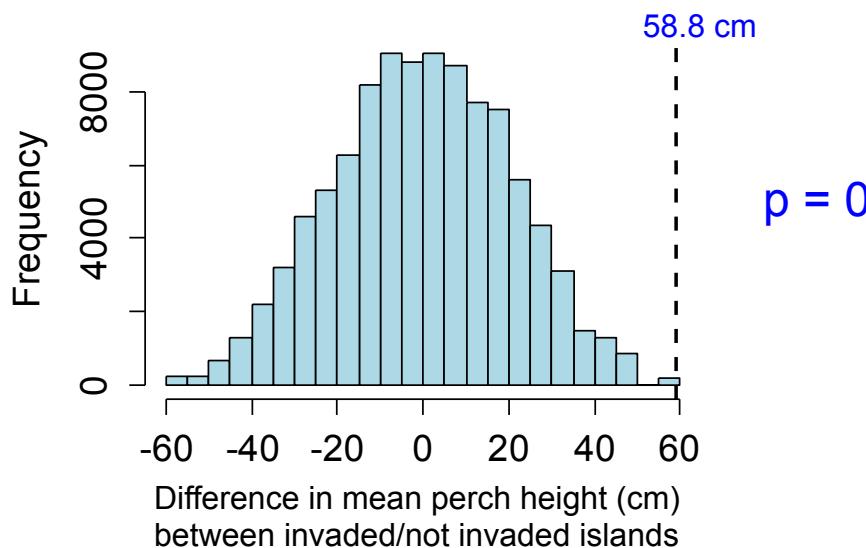


Example (*Anolis* lizards)



2) Strength

Effect size
difference between means
(size of "island type" effect)

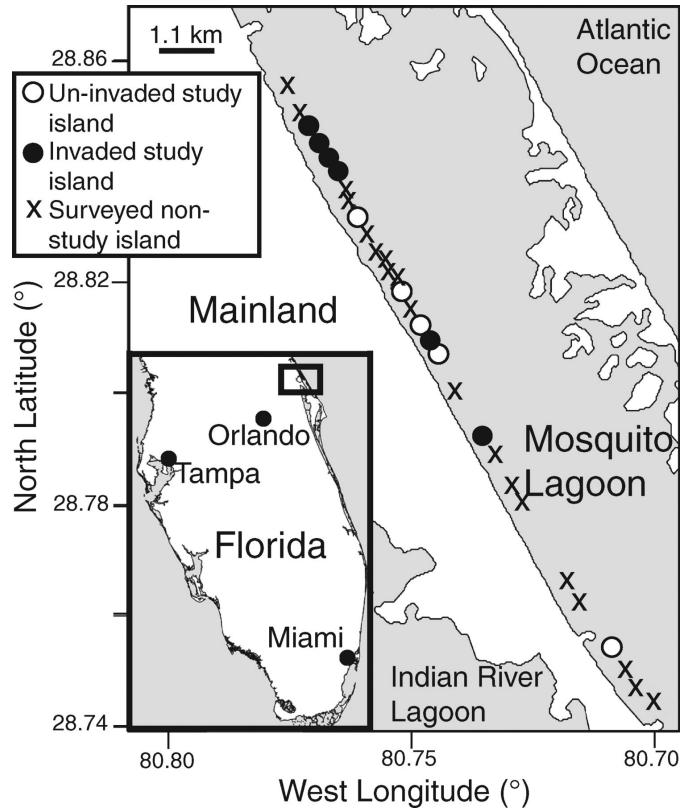


Claim:

"There is very strong evidence against the null hypothesis that invasion status is not associated with perch height"



Example (*Anolis* lizards)



3) Scope

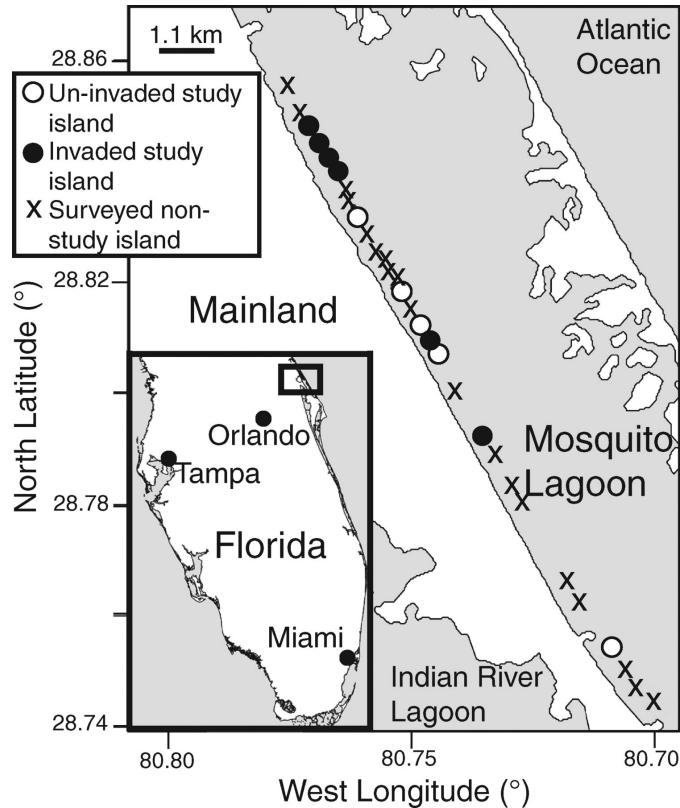
To what population can we generalize?

Random sampling?

Was the sample of 11 islands **representative** of the 30 islands?
How are you deciding?



Example (*Anolis* lizards)



3) Scope

To what population can we generalize?

Claim qualifier:

"... for islands with matching characteristics in Mosquito lagoon"



Example (*Anolis* lizards)

Can we say that invasion by *Anolis sagrei* caused a shift in perch height of the native lizard?
How are you deciding?

- A) Yes, because invasion type was randomly assigned to islands
- B) Yes because we examined islands of both types
- C) No because there was too much error
- D) Yes because the p-value was less than 0.05
- E) No because this was an observational study

4) Cause

Claim qualifier:

"Since this was an observational study, an experiment where invaders are introduced to islands will be required to show that invasion causes the perch height shift"



Example (*Anolis* lizards)

Final claim

I am 95% confident that perch height is 37 to 81 cm higher on invaded islands for islands with matching characteristics in Mosquito lagoon. There is very strong evidence against the null hypothesis that invasion status is not associated with perch height. Since this was an observational study, an experiment where invaders are introduced to islands will be required to show that invasion causes the perch height shift.