

# TEMPERATURE'S EFFECT ON FROG POPULATIONS INFECTED WITH CHYTRID FUNGUS

# CHYTRID FUNGUS

- *Batrachochytrium dendrobatidis* (Bd) is the most prominent species[1]
- Is a water-born fungal pathogen[2]
- Prefers colder temperatures[3]
- Causes chytridiomycosis[4]
  - Is a skin disease affecting the outer keratin layer[5]
  - Has a ~100% mortality rate[5]
  - Is causing the extinction of amphibians[4]

Bd has caused:

> ***"the greatest recorded loss of biodiversity attributable to a disease"***

(Scheele et al., 2019)

# RESEARCH QUESTION

How will changes in temperature due to climate change affect populations of susceptible frog species infected with Bd?

# PREDICTIONS

Since Bd favours cooler temperatures, at higher temperatures there will be a lower probability that a frog population infected with Bd will go extinct.

# METHODS

1. Data collection

2. Thermal performance curve (TPC) creation

3. Mathematical modeling

4. Frog population simulations

# METHODS: DATA COLLECTION

| Authors, Published Year | Study Type | Location | Data Used |
|---|---|---|---|
| Kriger & Hero, 2007[6] | Field study | Queensland, Australia | Zoospore count and associated temperature |
| Kriger et al., 2007[7] | Field study | East coast, Australia | |
| Sheets et al., 2021[8] | Lab study | United States | |

# METHODS: TPC

**Negative binomial distribution**

**Parameter combinations**

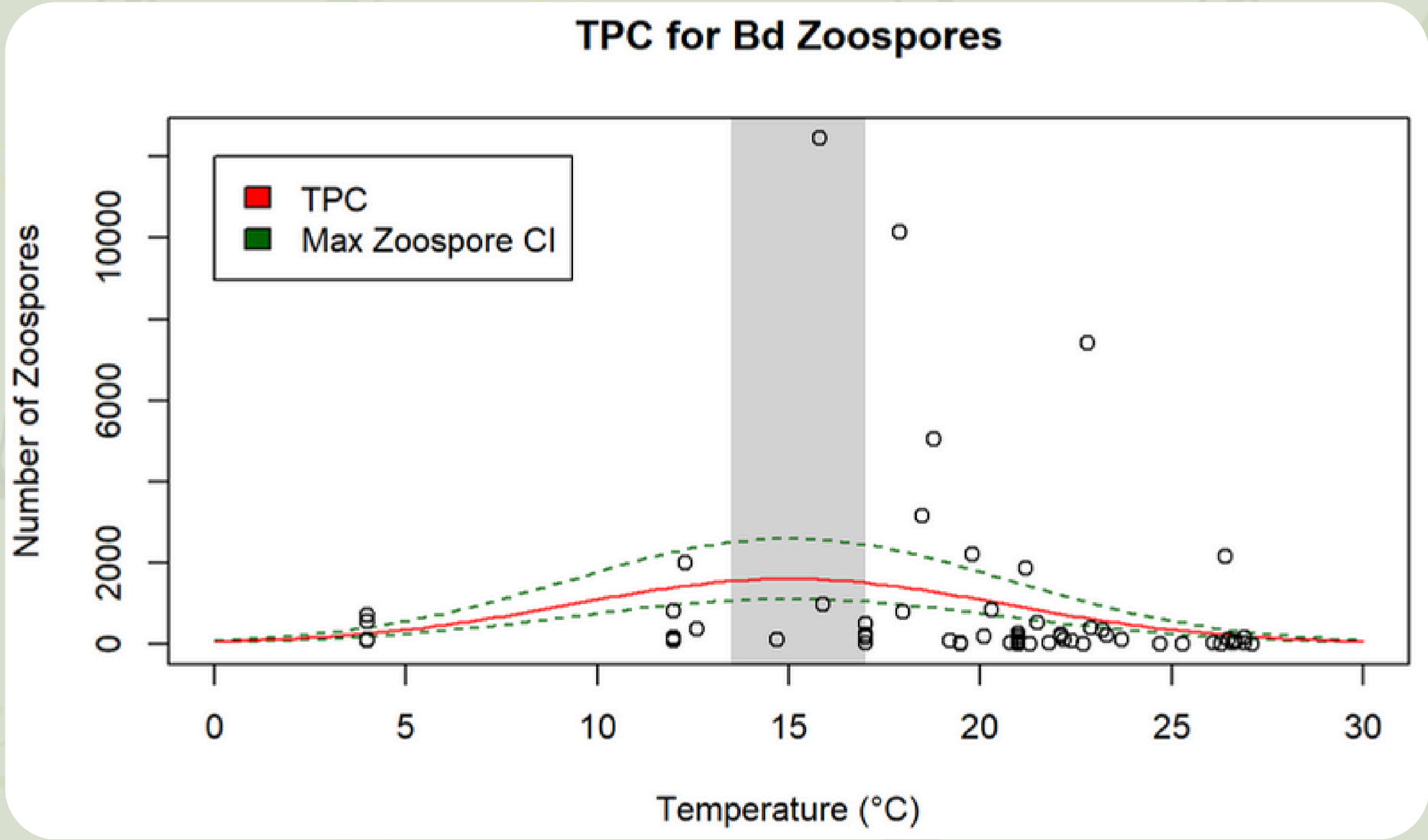
- **Topt**
- **A**
- **w**
- **size**

**Maximum Likelihood Estimator (MLE)**

# METHODS: TPC FORMULA

$$Ae^{\frac{-(temperature - Topt)^2}{(2w^2)}}$$

# METHODS: TPC




- Topt: 15°C
- Literature Topt: 17-25°C
- TPC is symmetric

# METHODS: MATHEMATICAL MODEL

**Zoospores**

$$\frac{dZ}{dt} = -d_z Z + p_f I_f Z + p_t I_t Z$$

**Tadpoles**

$$\frac{dS_t}{dt} = b(S_f + I_f) - \beta_t S_t I_t - \beta_f S_t I_f - \beta_z S_t Z - m_S S_t - d_{St} S_t + r_t I_t$$

$$\frac{dI_t}{dt} = \beta_t S_t I_t + \beta_f S_t I_f + \beta_z S_t Z - d_{It} I_t - v_t I_t - m_I I_t - r_t I_t$$

**Frogs**

$$\frac{dS_f}{dt} = m_S S_t - \beta_t S_f I_t - \beta_f S_f I_f - \beta_z S_f Z - d_{Sf} S_f + r_f I_f$$

$$\frac{dI_f}{dt} = m_I I_t + \beta_t S_f I_t + \beta_f S_f I_f + \beta_z S_f Z - d_{If} I_f - v_f I_f - r_f I_f$$

# MODEL VARIABLES

Z : # of zoospores

St : # of susceptible tadpoles

It : # of infected tadpoles

Sf : # of susceptible frogs

If : # of infected frogs

pt : production rate of zoospores from infected tadpole

pf : production rate of zoospores from infected frog

mS : maturation rate of susceptible tadpole

mI : maturation rate of infected tadpole

b : birth rate of tadpoles

dz : death rate of zoospores

rt: recovery rate of tadpoles

rf : recovery rate of frogs

vt : virulence in tadpoles

vf : virulence in frogs

beta f : rate of infection from frogs

beta t : rate of infection from tadpoles

beta z : rate of infection from environmental zoospores

d St : death rate of susceptible tadpoles

d It : death rate of infected tadpoles

d Sf : death rate of susceptible frogs

d If : death rate of infected frogs

# ZOOSPORE EQUATION

$$\frac{dZ}{dt} = \overbrace{-d_z Z}^{\textbf{Zoospore Death Rate}} + \underbrace{p_f I_f Z + p_t I_t Z}_{\textbf{Zoospore Production Rate}}$$

# TADPOLE EQUATIONS

## Susceptible Tadpoles

$$\frac{dS_t}{dt} = \underbrace{b(S_f + I_f)}_{\textbf{Birth Rate}} - \beta_t S_t I_t - \beta_f S_t I_f - \beta_z S_t Z - m_S S_t - \overbrace{d_{St} S_t}^{\textbf{Death Rate}} + r_t I_t$$

## Infected Tadpoles

$$\frac{dI_t}{dt} = \underbrace{\beta_t S_t I_t + \beta_f S_t I_f + \beta_z S_t Z}_{\textbf{Infection Rate}} - d_{It} I_t - \underbrace{v_t I_t}_{\textbf{Virulence}} - \overbrace{m_I I_t}^{\textbf{Maturation Rate}} - \underbrace{r_t I_t}_{\textbf{Recovery Rate}}$$

# FROG EQUATIONS

## Susceptible Frogs

$$\frac{dS_f}{dt} = m_S S_t - \beta_t S_f I_t - \beta_f S_f I_f - \beta_z S_f Z - d_{Sf} S_f + r_f I_f$$

## Infected Frogs

$$\frac{dI_f}{dt} = m_I I_t + \beta_t S_f I_t + \beta_f S_f I_f + \beta_z S_f Z - d_{If} I_f - v_f I_f - r_f I_f$$

# MODEL ASSUMPTIONS

- Homogenous mixing of the population [9]
- The chance of zoospore infection is equal for all zoospores
- No vertical inheritance of the disease
- No immigration or emigration of the population
- Recovery from disease does not mean immunity
- Our parameters are estimates

# MODEL LIMITATIONS

- Our model does not reflect other factors that affect Bd survival in the real world (e.g. moisture)[10,11]
- The initial zoospore count is solely based on data from *Litoria wilcoxii* and *Litoria lesueuri*
- The epidemic spread of Bd across different communities and countries is not accounted for in our model

# METHODS: POPULATION SIMULATION

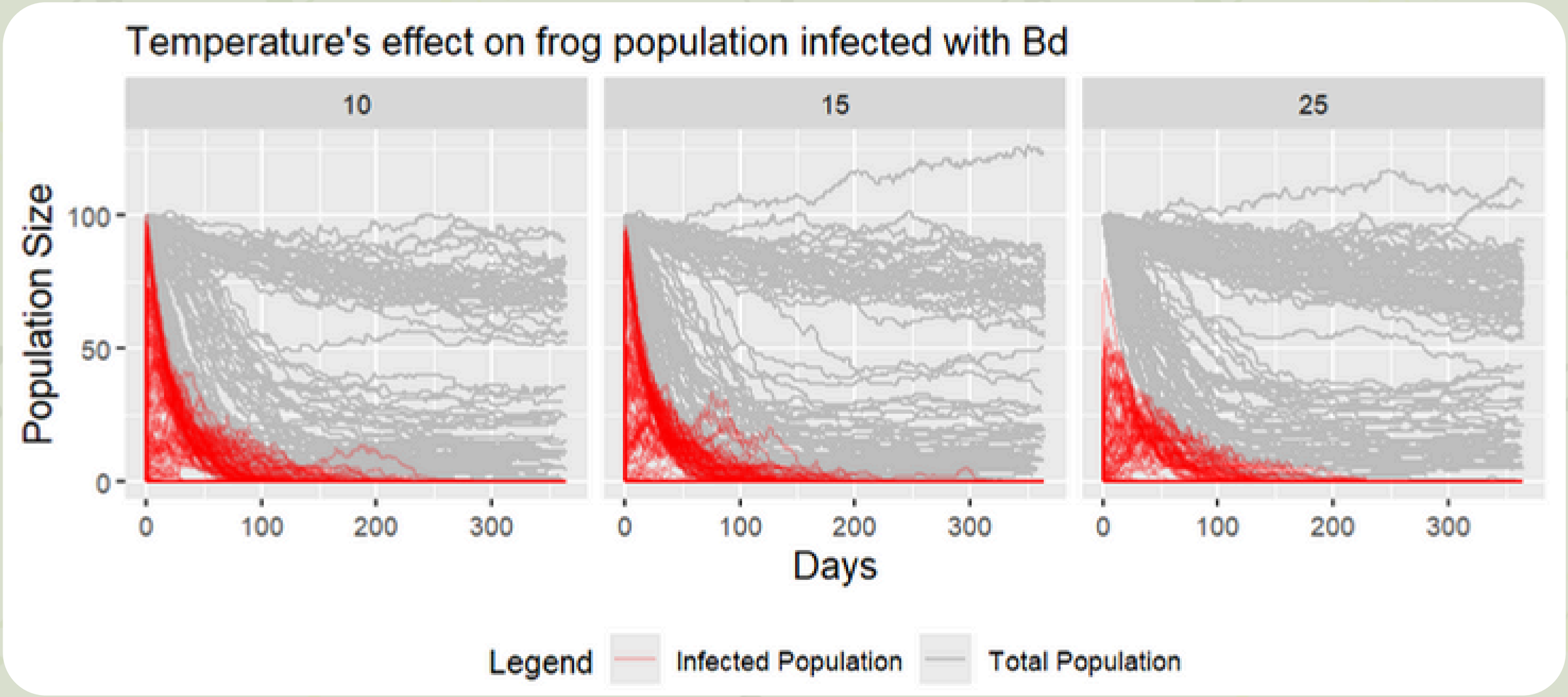
**Simulation Framework:**

- **Chosen temperature points (°C): 10,15, 25**
- **Number of simulations: 100**
- **Time per simulation: 365 days**

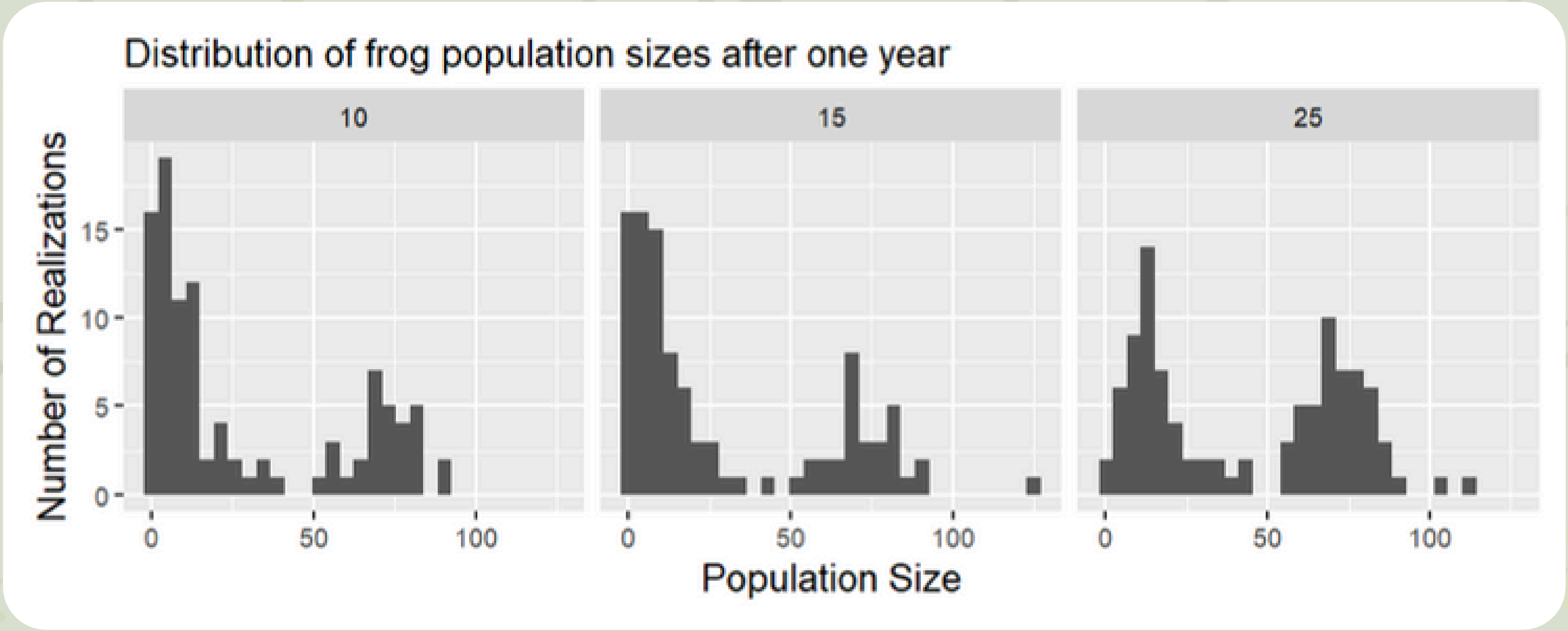
**Starting Conditions:**

- **Initial zoospore count determined by TPC**
- **Start with 100 susceptible tadpoles**

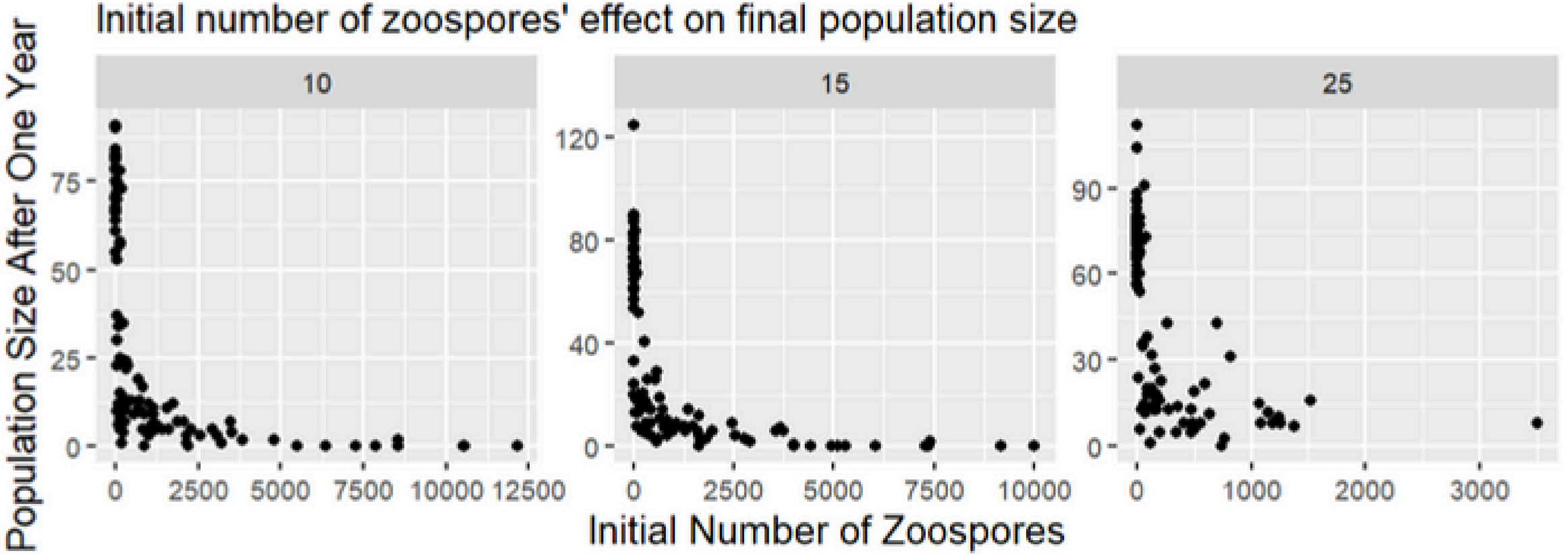
# RESULTS


Temperature's effect on frog population infected with Bd
10
15
25
Population Size
100
50
0
0
100
200
300
Days
Legend
Infected Population
Total Population

# RESULTS


Distribution of frog population sizes after one year
10
15
25
Number of Realizations
0
5
10
15
0
50
100
Population Size

# RESULTS


Initial number of zoospores' effect on final population size
10
15
25
Population Size After One Year
0
25
50
75
0
40
80
120
0
30
60
90
0
2500
5000
7500
10000
12500
0
1000
2000
3000
Initial Number of Zoospores

# RESULTS

| Temperature (°C) | Fraction of Extict Populations | Fraction of Populations Reduced Below 50% |
|---|---|---|
| 10 | 0.10 | 0.71 |
| 15 | 0.11 | 0.71 |
| 25 | 0.01 | 0.51 |

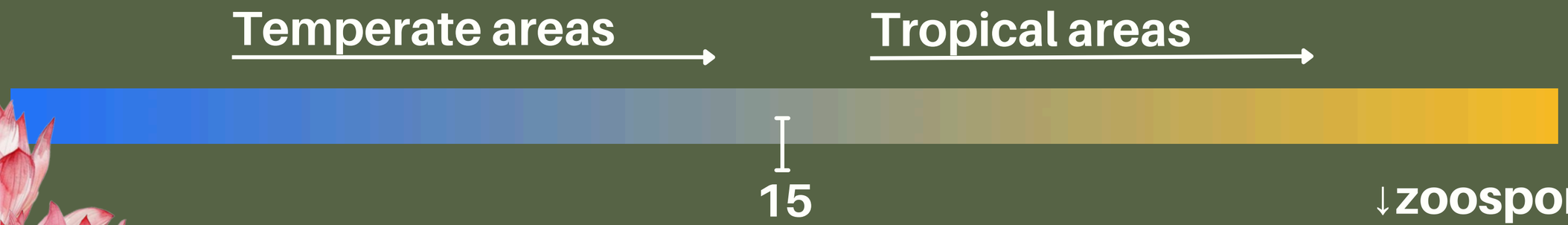
# DISCUSSION

**Temperature** → **Zoospore count** → **Frog persistence**

## Prediction:

- Frog populations are more likely to persist in higher temperatures

## Effect of climate change:



# Thank you!


Questions?

# REFERENCES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