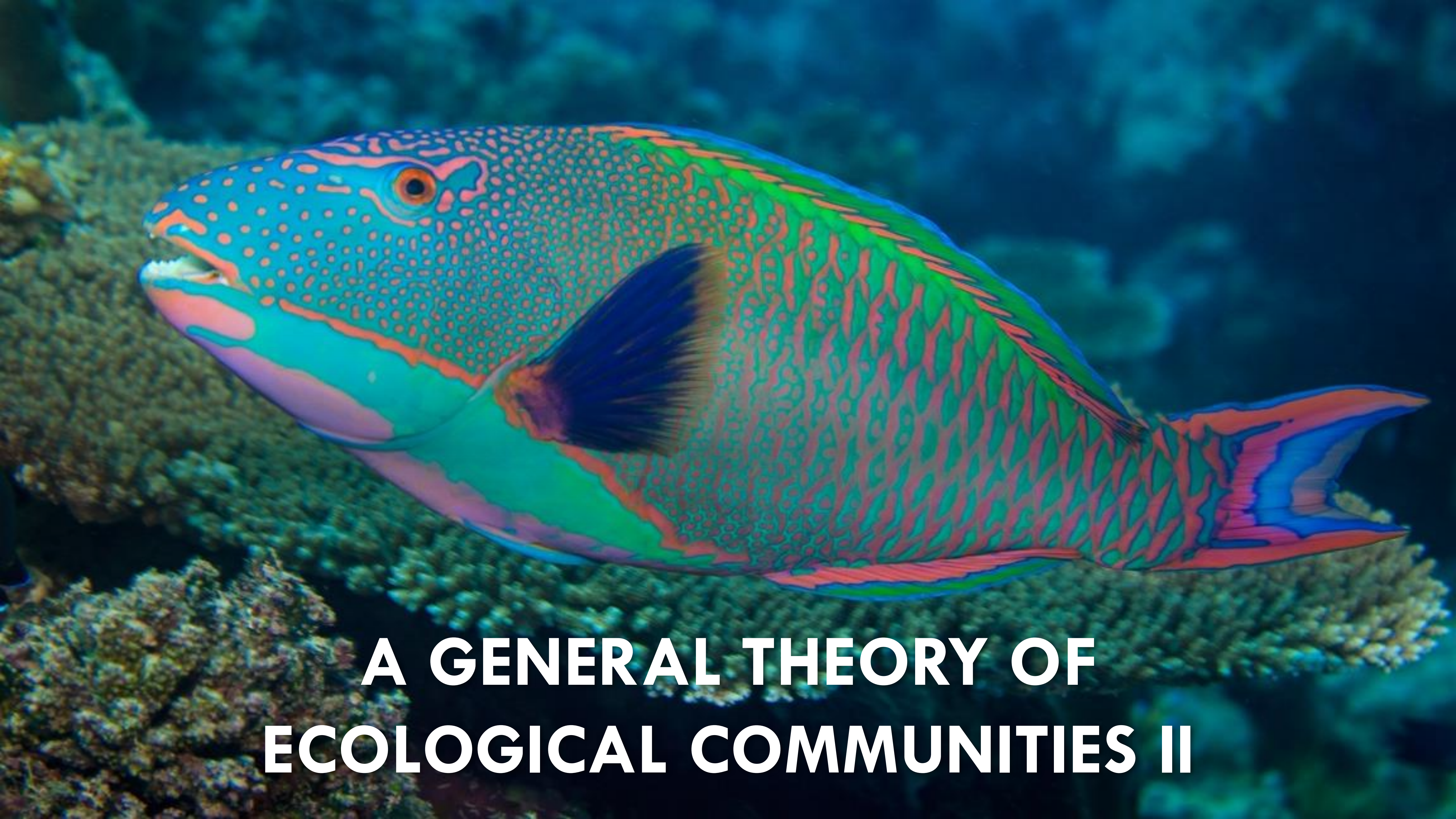


A GENERAL THEORY OF ECOLOGICAL COMMUNITIES II

Housekeeping

Project 1: due on Friday

Thursday: coding and trivia 🥳


DRIFT


SELECTION


DISPERSAL

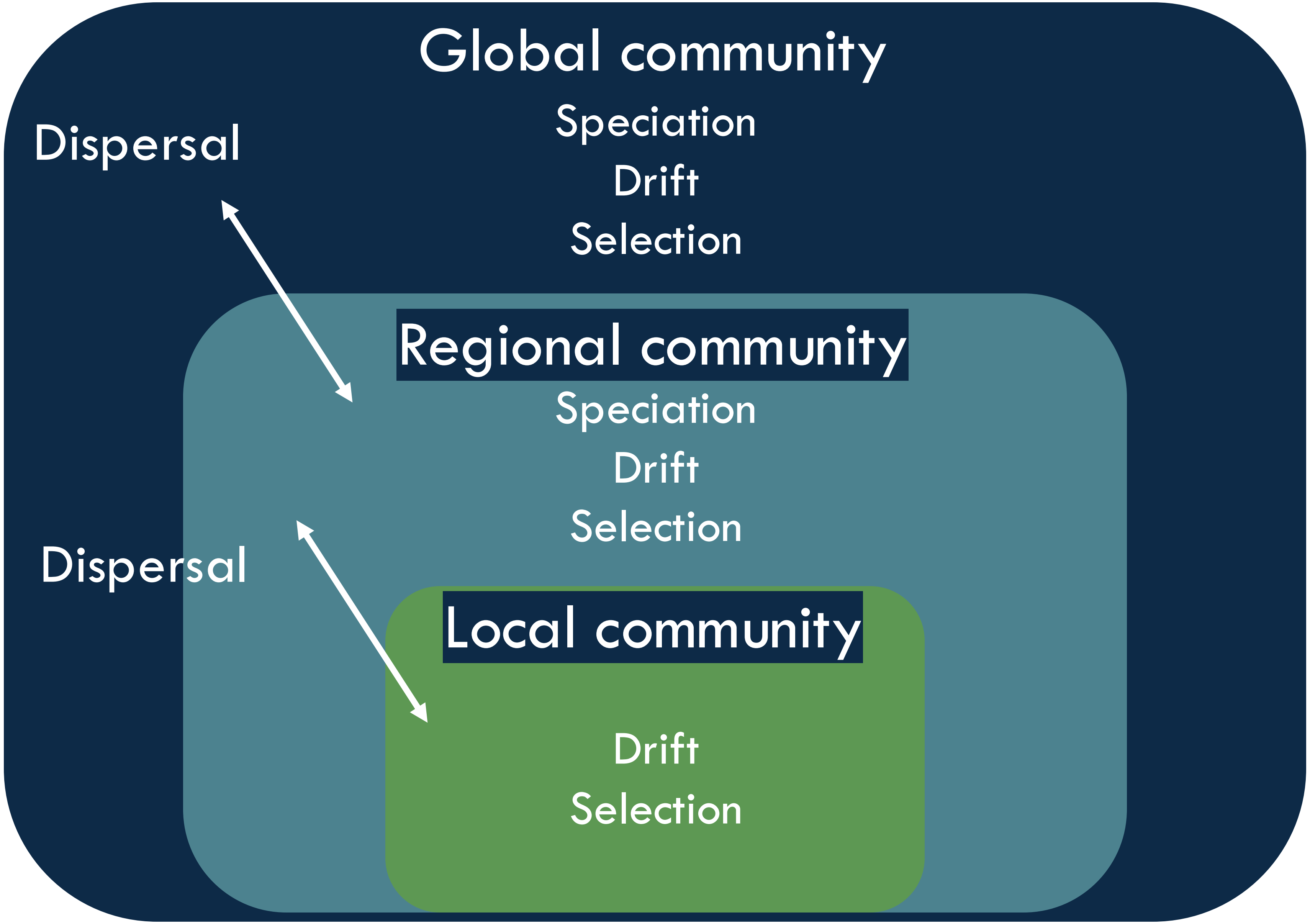

SPECIATION

Four main processes

- Drift
- Selection
- Dispersal
- Speciation

Five lower-level processes of selection

- Constant selection
- Negative frequency-dependent selection
- Positive frequency-dependent selection
- Spatially-variable selection
- Temporally-variable selection


Global community
Speciation
Drift
Selection
Dispersal
Regional community
Speciation
Drift
Selection
Dispersal
Local community
Drift
Selection


TRUST ME, I'M A
PROFESSIONAL
gifs.com


DRIFT
SELECTION
PROOF
DISPERSAL
SPECIATION

All models are wrong, but some are useful.

George Box

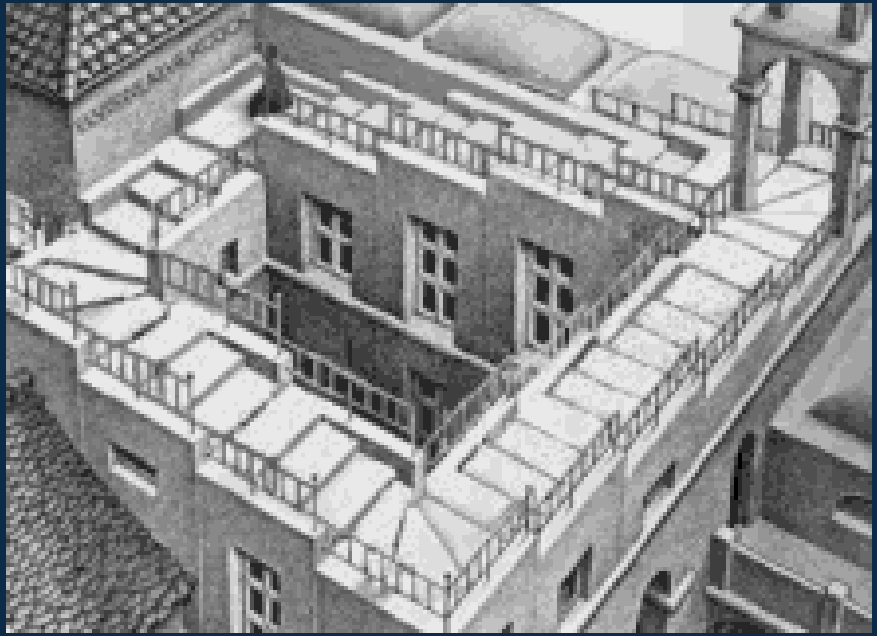
Different types of models

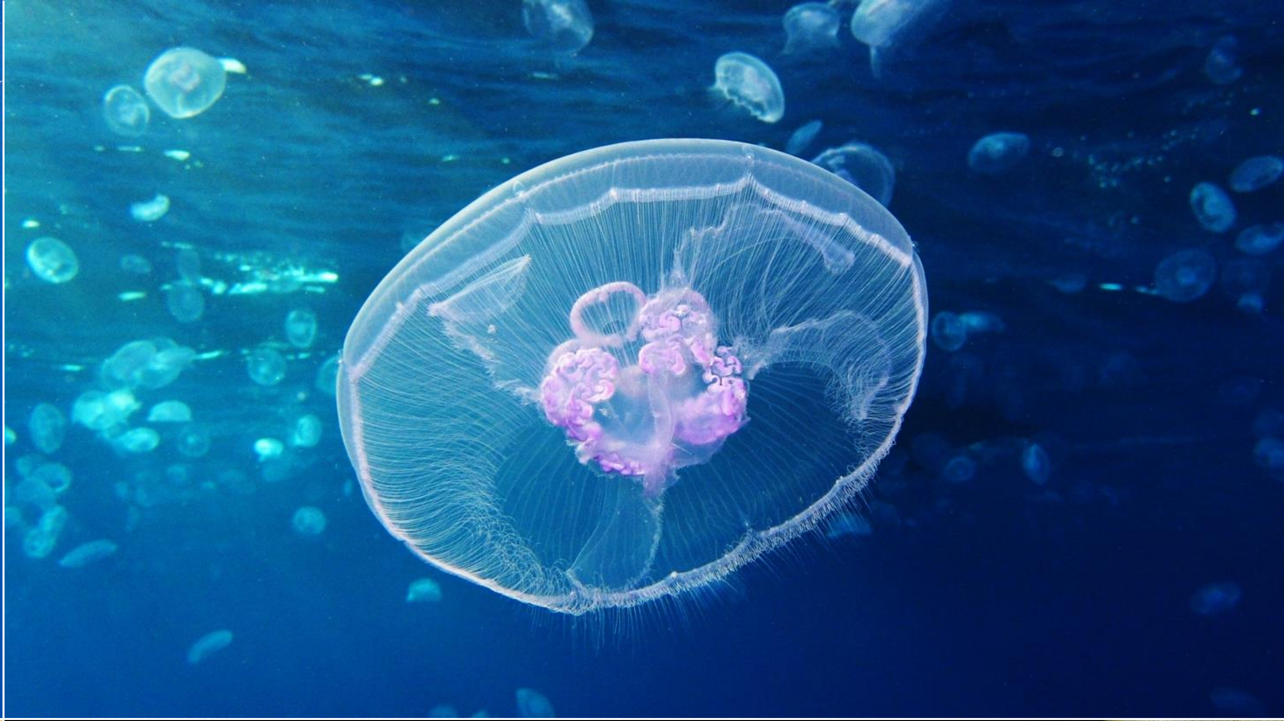
1) Statistical models: physical understanding, closed-form equations

2) Theoretical models: time-stepping simulations to explore dynamics

Loops:

for (i in 1:length(this.slide) {
“roll down the stairs”
}




Drift

The Moran Model

A neutral, closed community with no evolutionary forces

1) Initial community of J individuals divided among S species

2) Select one individual at random to die ☹

3) Select one individual at random to reproduce, replacing the casualty

4) Rinse and repeat

Variables

J = number of individuals in the populations

S = number of species (2)

Y = number of years (50)

Pr = probability of reproduction

The Moran Model: initial conditions

```
J = 10
```

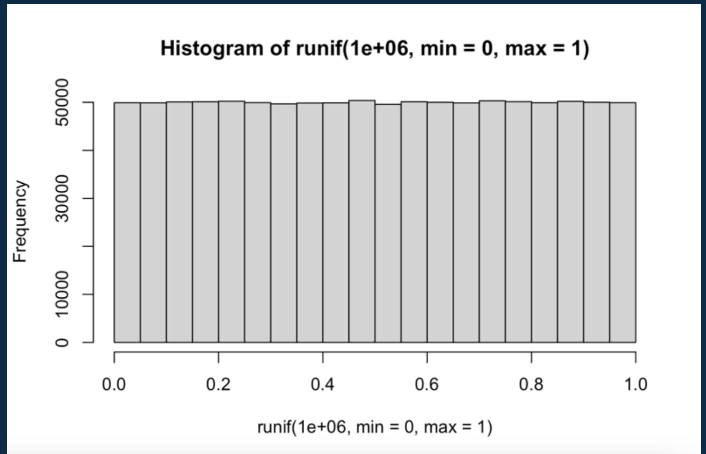
```
t0.sp1 <- J/2

community <- vector(length = J)

community[1:t0.sp1] <- 1

community[(t0.sp1+1):J] <- 2
```

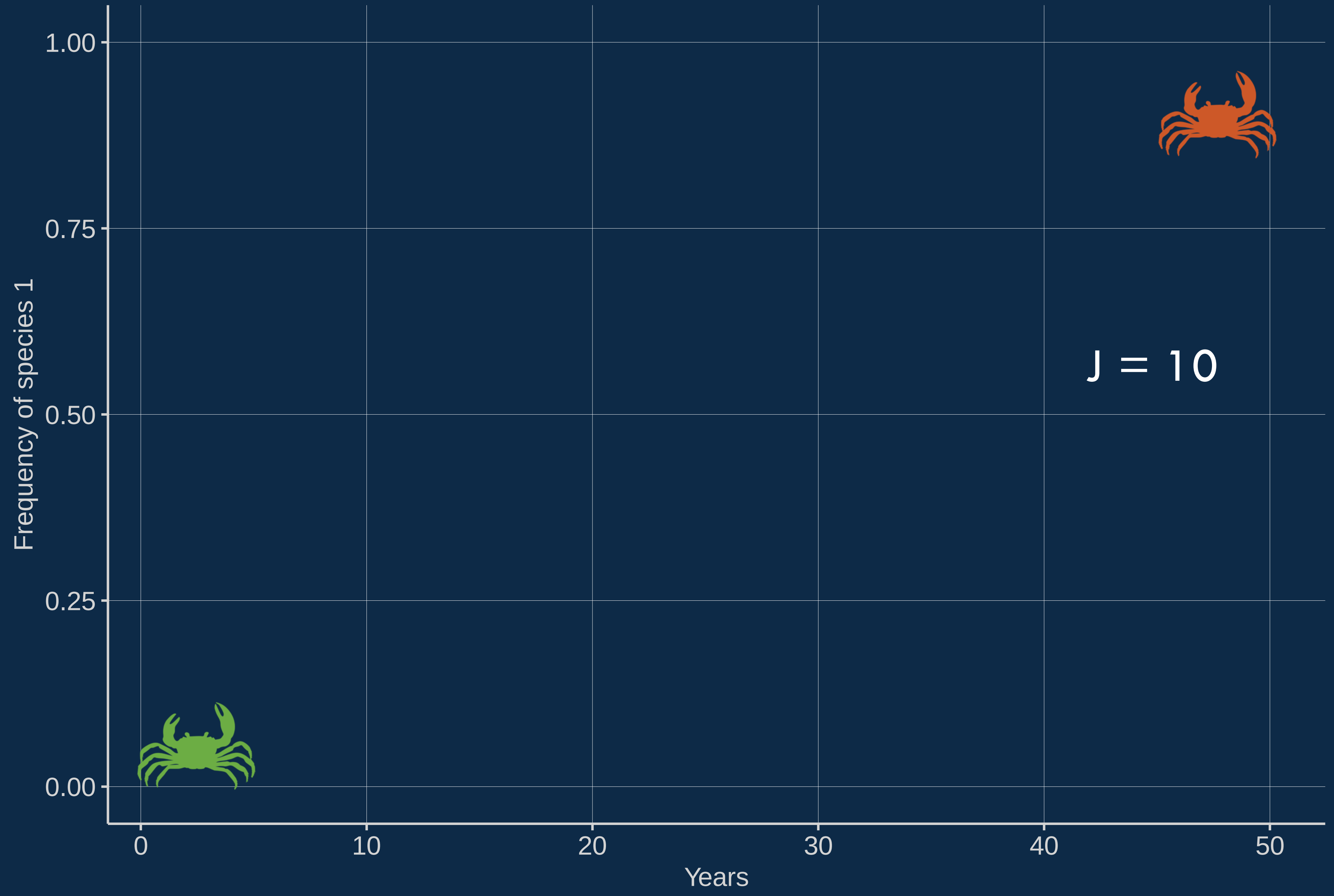
The Moran Model: length and output

```
n.years <- 50

year <- 2

freq.sp1.output <- vector(length = n.years)

freq.sp1.output[1] <- t0.sp1/J
```

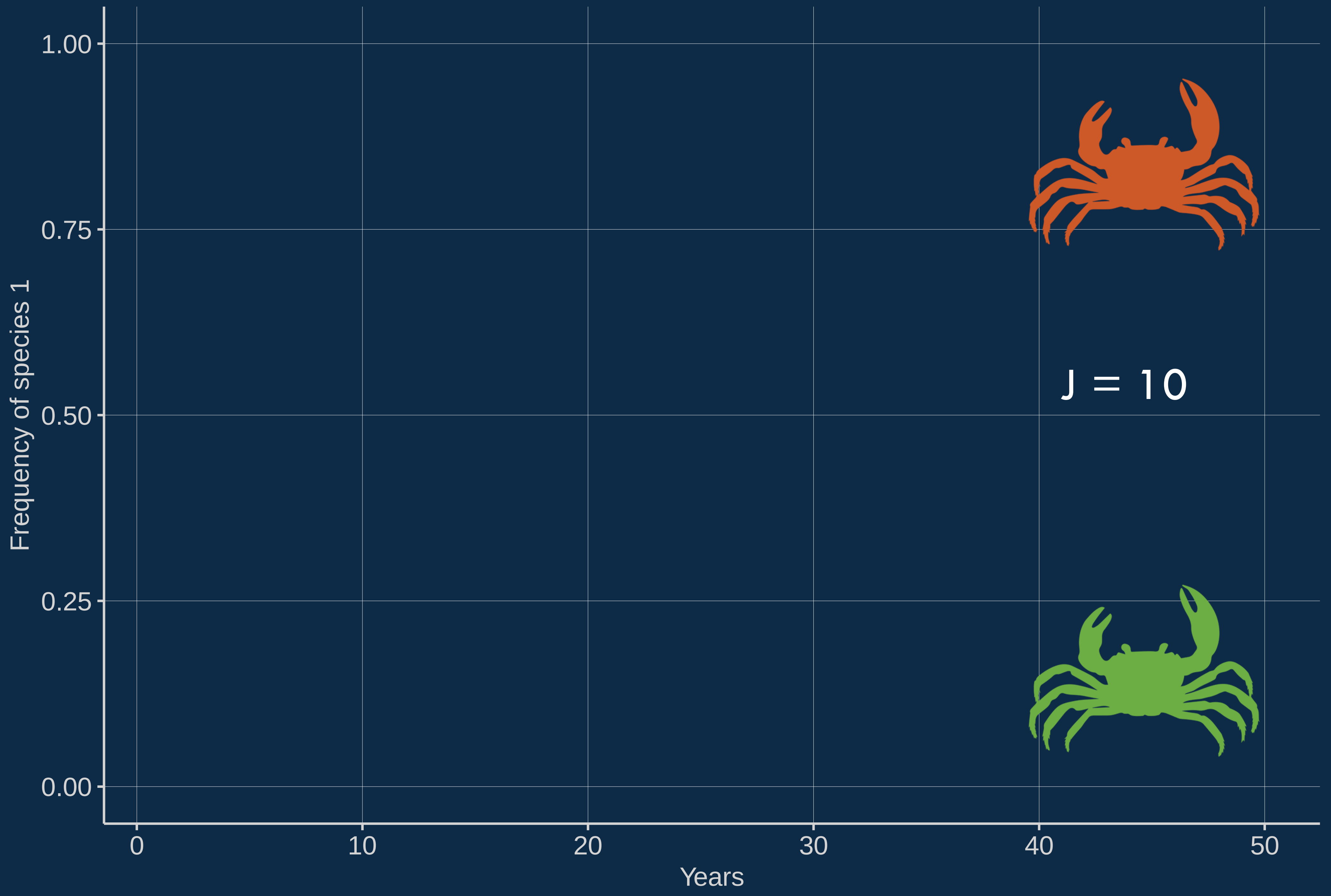
The Moran Model: the loop

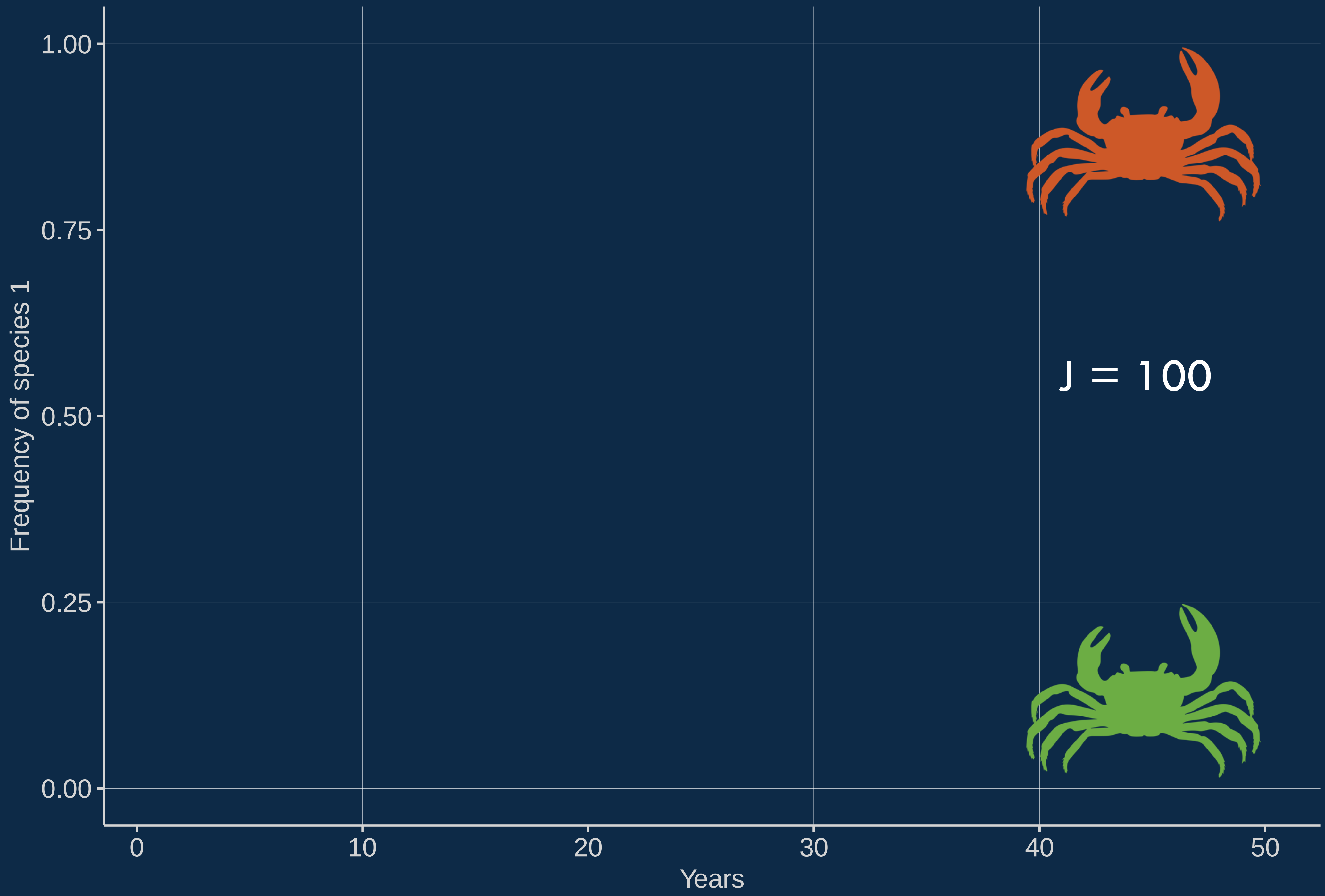
```
for(i in 1:(J*(n.years - 1))) {

  freq.1 <- sum(community == 1)/J
  pr.1 <- freq.1
  community[ceiling(J*runif(1))] <- sample(c(1,2), 1,
                                     prob = c(pr.1, 1-pr.1))

    if (i %% J == 0) {
      freq.sp1.output[year] <- sum(community == 1)/J
      year <- year + 1
    }
}
```





J = 10
Frequency of species 1
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
Years


1.00
0.75
0.50
0.25
0.00
Frequency of species 1
0
10
20
30
40
50
Years
J = 10

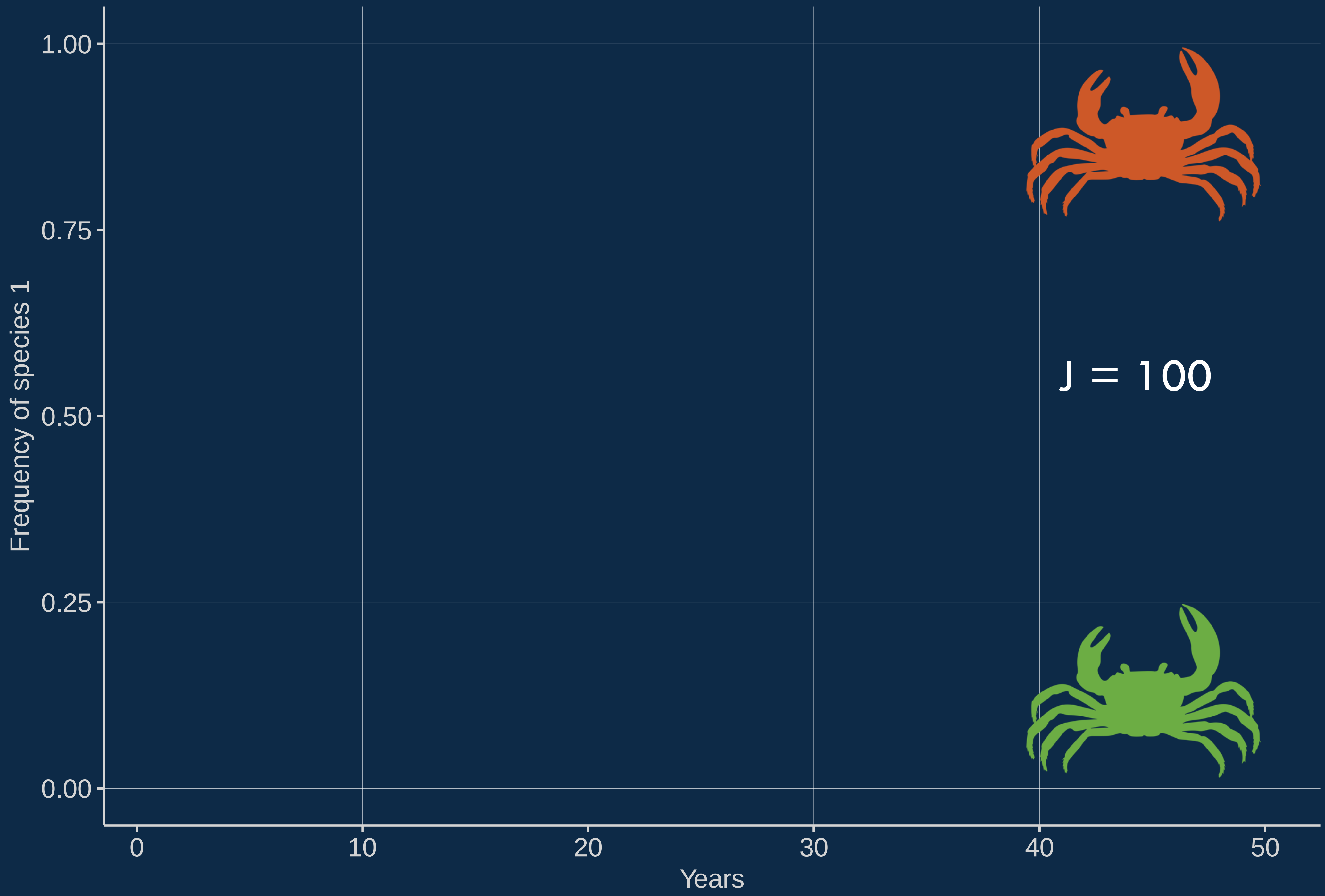


1.00
0.75
0.50
0.25
0.00
Frequency of species 1
0
10
20
30
40
50
Years
J = 100


THAT FEELING WHEN THE INSTRUCTOR LOST YOU AT “GOOD MORNING”

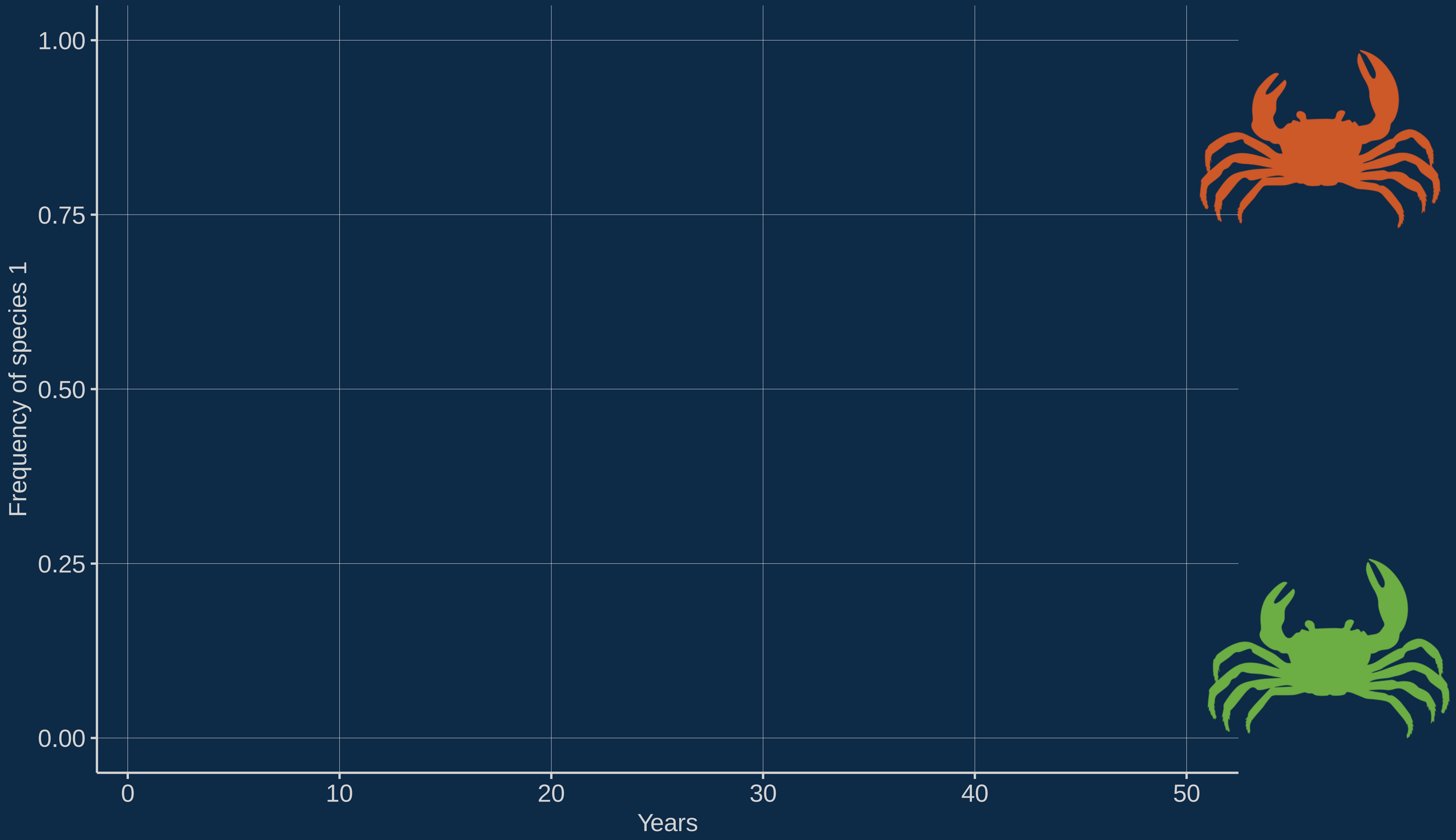
Outcomes

1) Coexistence
2) Stochastic extinctions
3) Sp1 dominance
4) Sp2 dominance


1.00
0.75
0.50
0.25
0.00
Frequency of species 1
0
10
20
30
40
50
Years
J = 100

$J = 1000$

Ecological drift



Selection

Ecological selection

How do we introduce fitness differences?

Probability of reproduction: pr.1 ≠ freq.1

```
for(i in 1:(J*(n.years - 1))) {

  freq.1 <- sum(community == 1)/J
  pr.1 <- freq.1
  community[ceiling(J*runif(1))] <- sample(c(1,2), 1,
                                prob = c(pr.1, 1-pr.1))

    if (i %% J == 0) {
      freq.sp1.output[year] <- sum(community == 1)/J
      year <- year + 1
    }
}
```

Ecological selection

J = 40

N = 10 | reproductive output (fitness) = 20 = 200

N = 30 | reproductive output (fitness) = 10 = 300

frequency of sp1 = 0.25 | probability of reproduction = 0.4

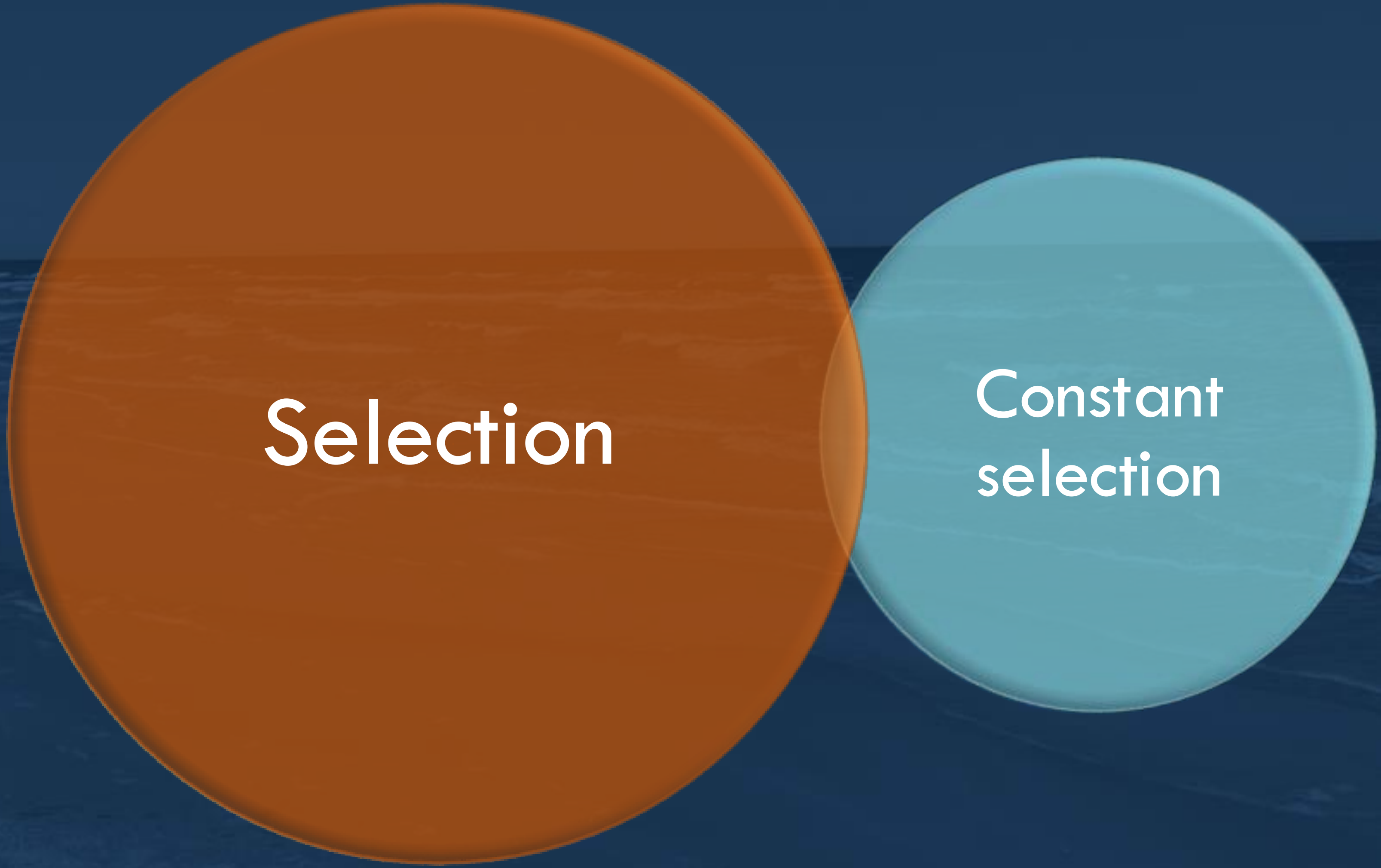
Ecological selection

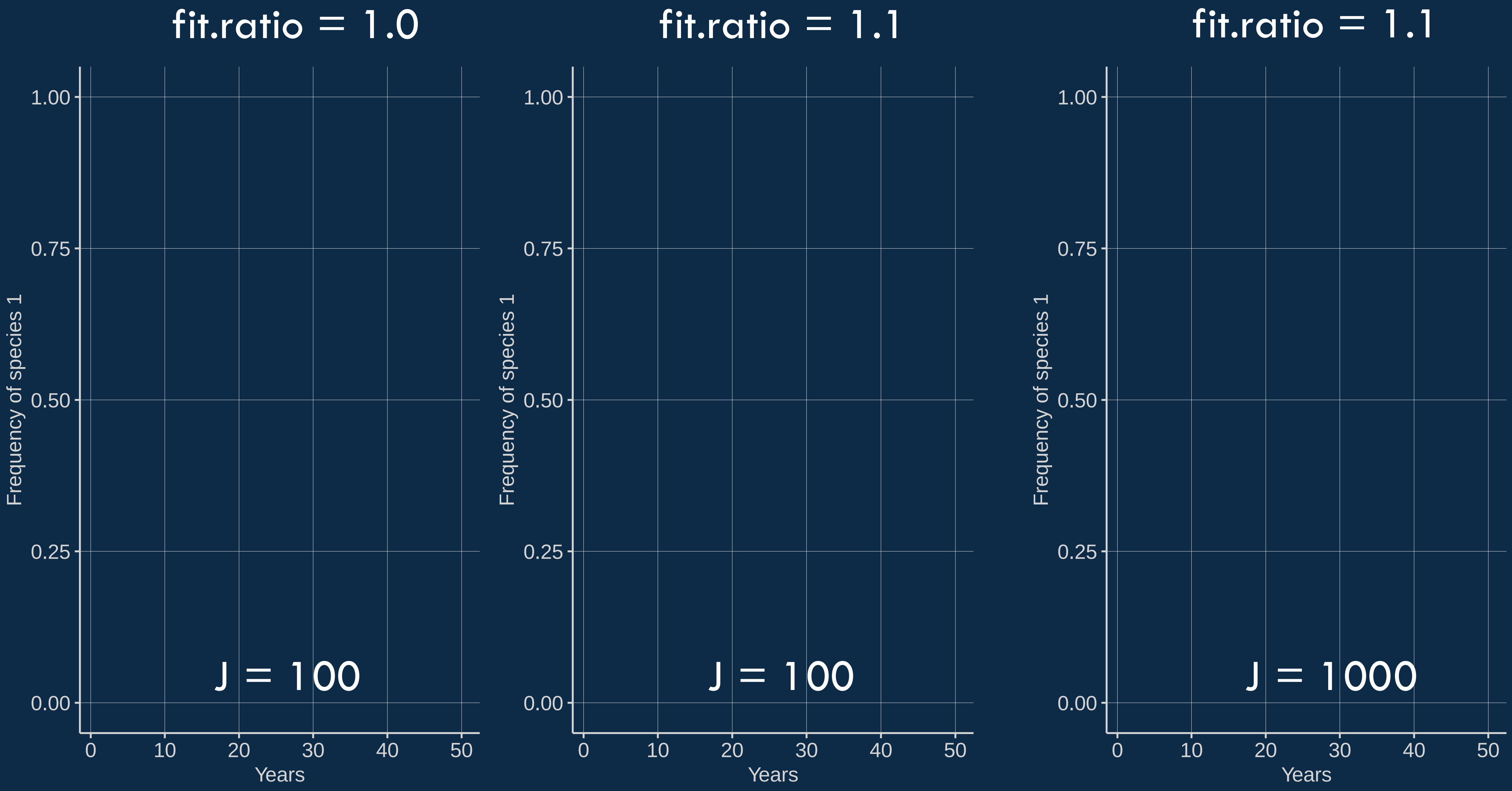
Probability of reproduction = fitness ratio (*fit.ratio*)

fit.ratio = 1 → no selective advantage

fit.ratio > 1 → selective advantage for orange crab

fit.ratio < 1 → selective advantage for green crab

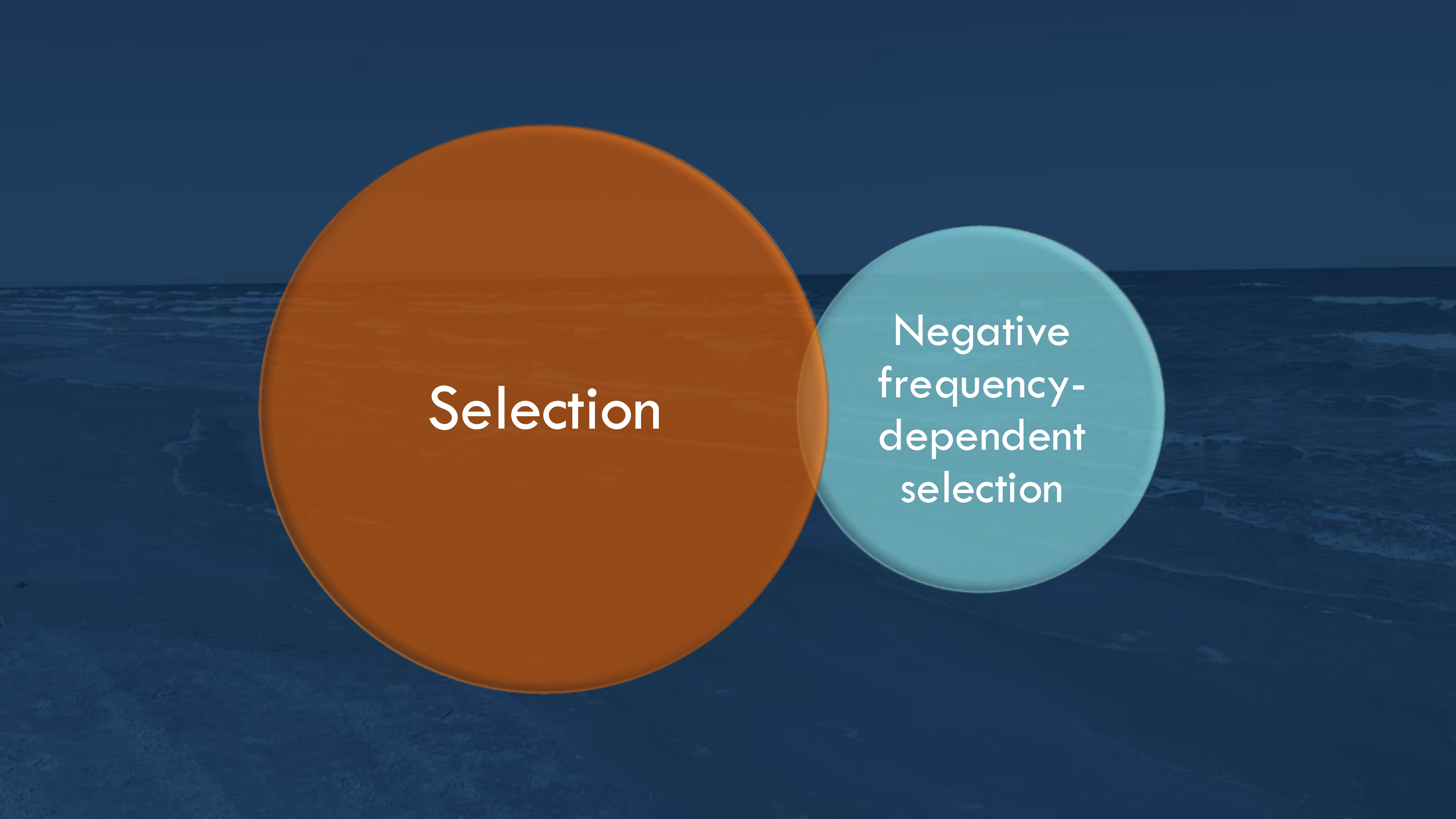

Selection
Constant selection

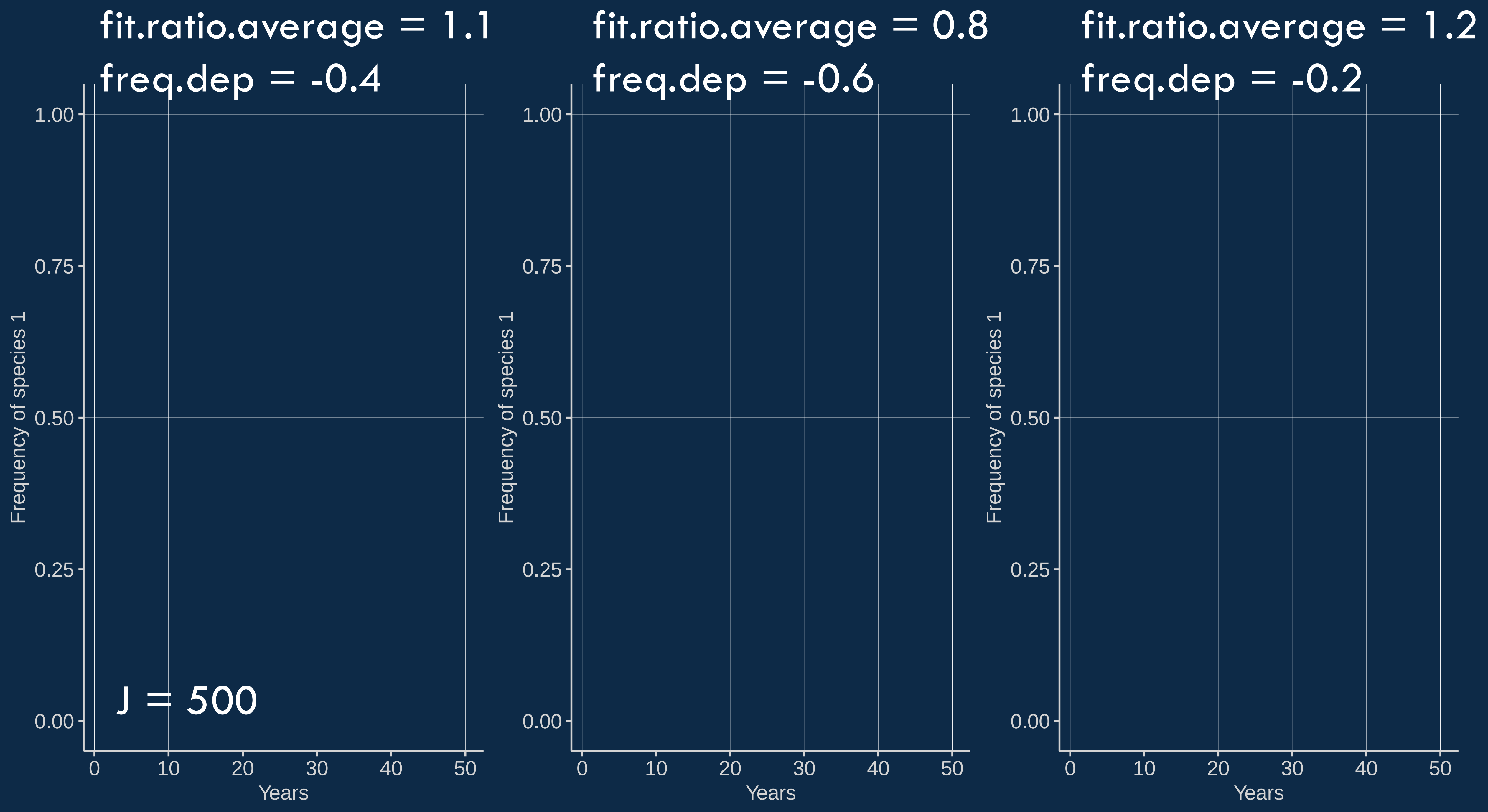


fit.ratio = 1.0
fit.ratio = 1.1
fit.ratio = 1.1
Frequency of species 1
1.00
0.75
0.50
0.25
0.00
J = 100
J = 100
J = 1000
0
10
20
30
40
50
Years

fit.ratio = 0.7

J = 100

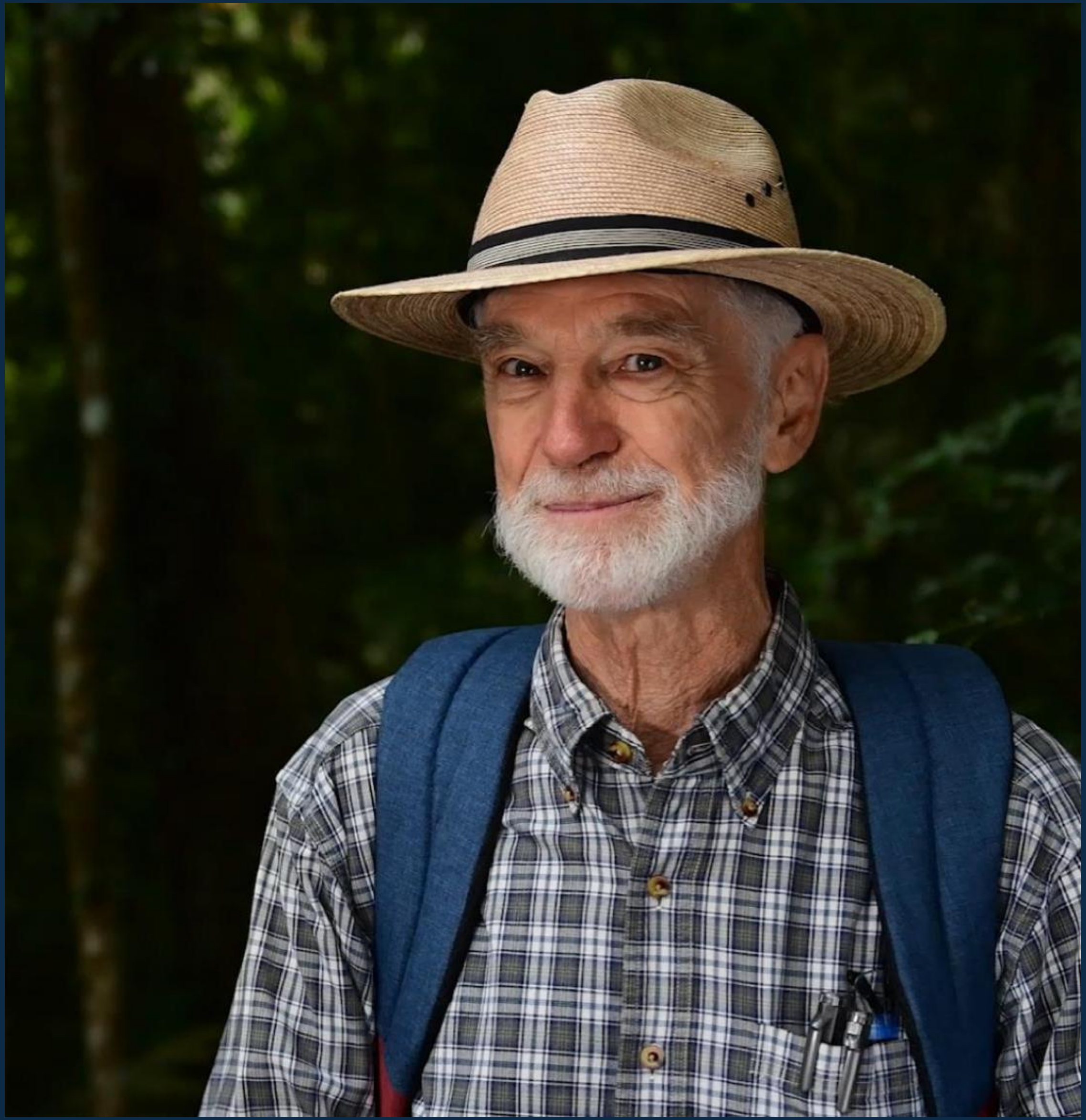

Selection
Negative frequency-dependent selection



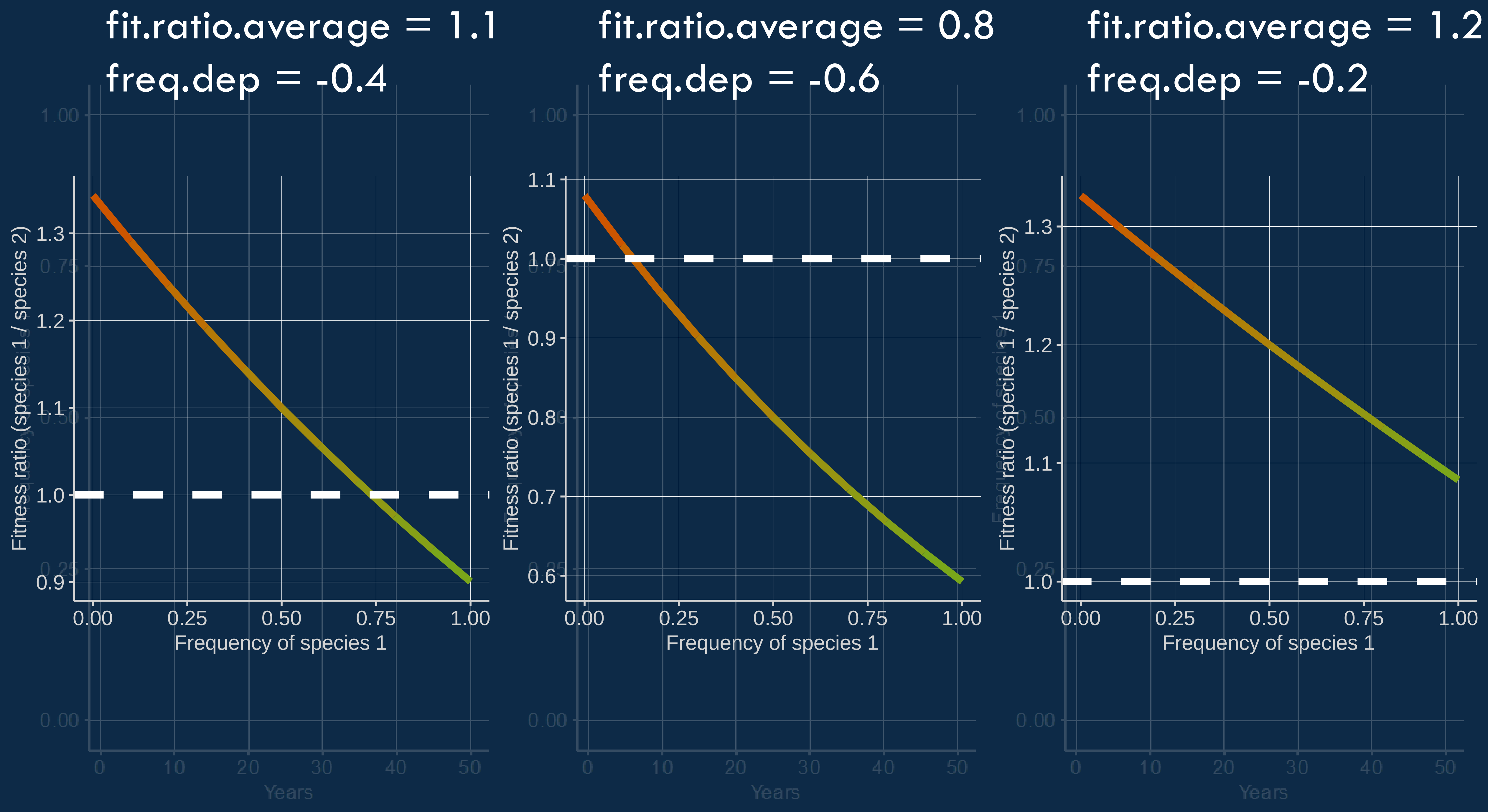
fit.ratio.average = 1.1
freq.dep = -0.4
J = 500
fit.ratio.average = 0.8
freq.dep = -0.6
fit.ratio.average = 1.2
freq.dep = -0.2
Frequency of species 1
Years

Peter Chesson

Janneke HilleRisLambers

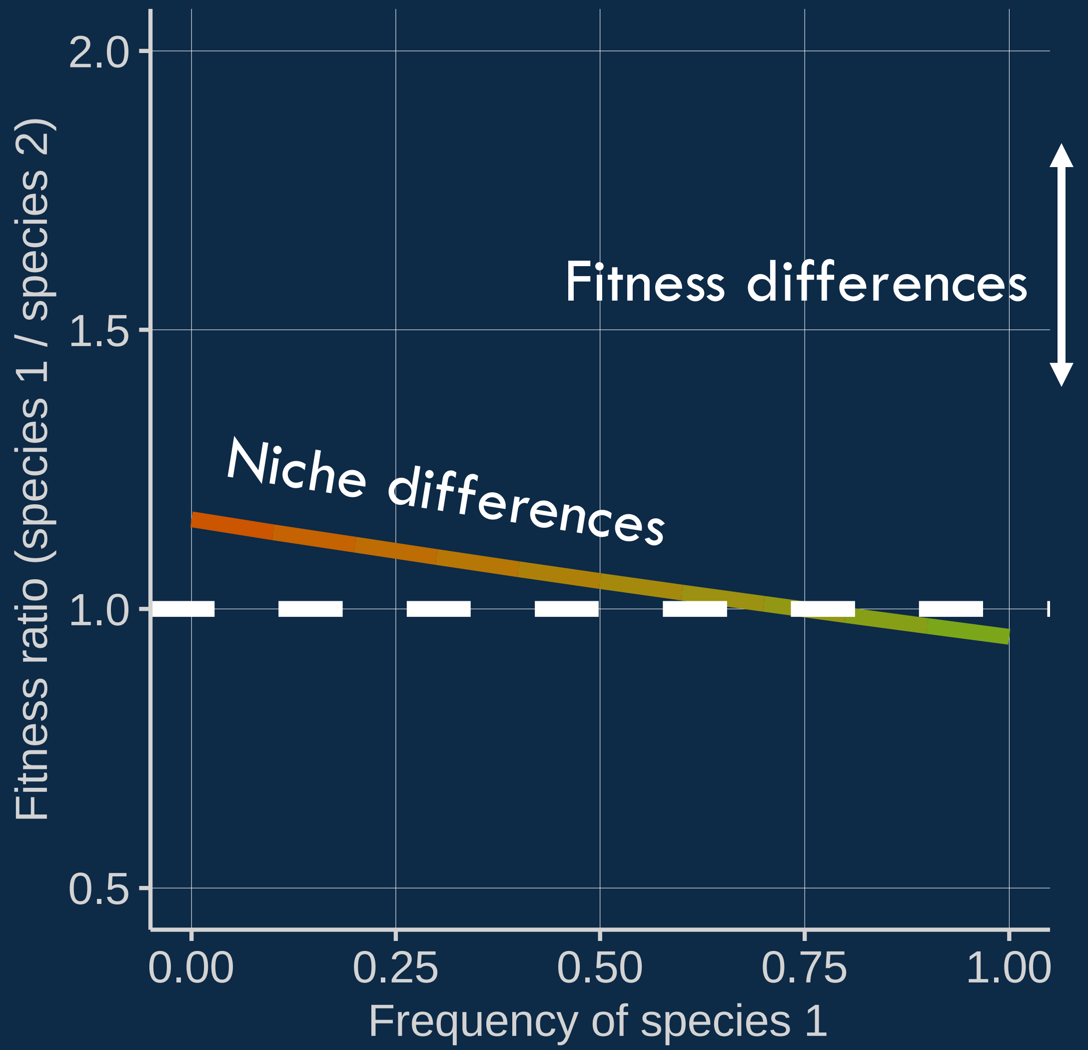


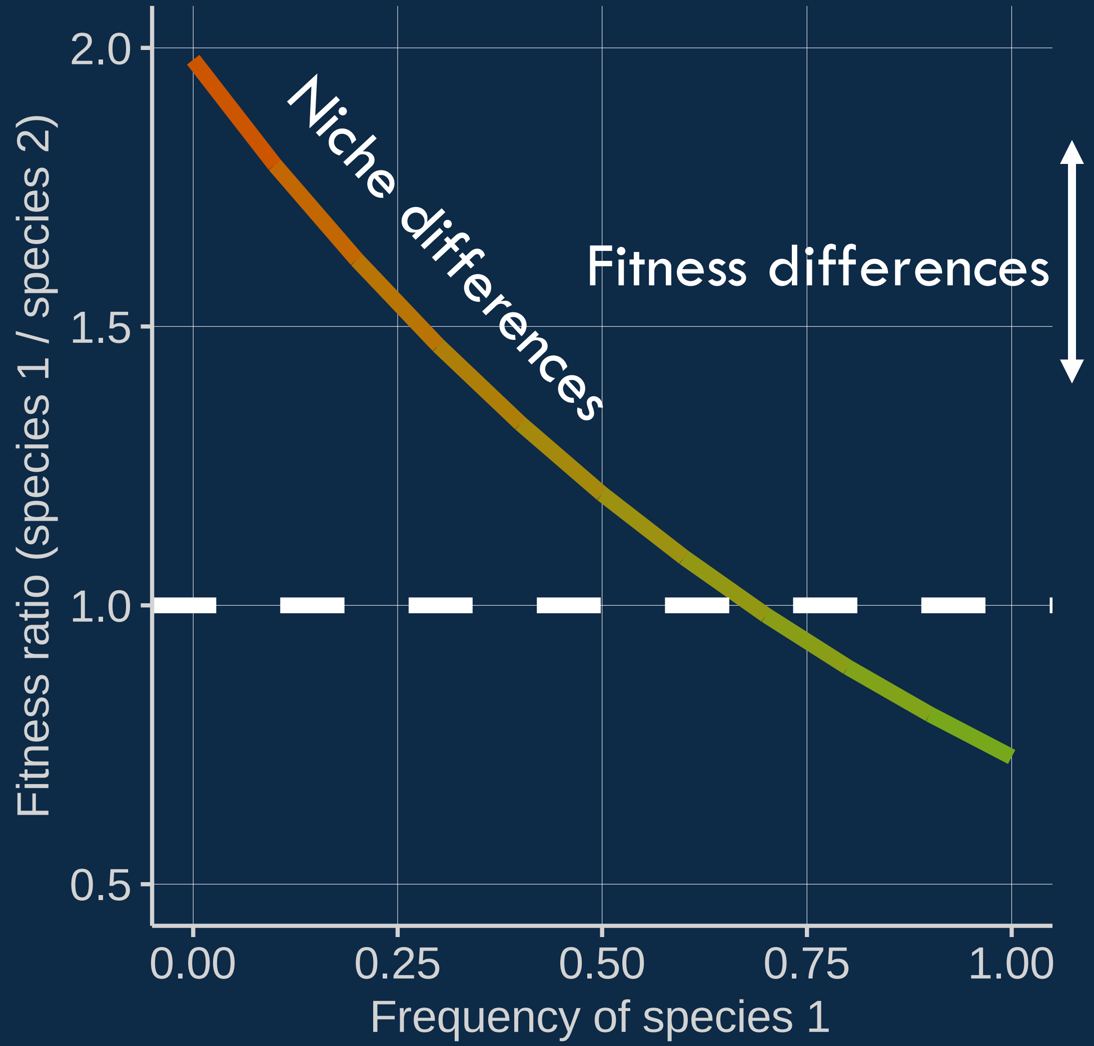
Modern coexistence theory



fit.ratio.average = 1.1
freq.dep = -0.4
fit.ratio.average = 0.8
freq.dep = -0.6
fit.ratio.average = 1.2
freq.dep = -0.2
Fitness ratio (species 1 / species 2)
Frequency of species 1
0.00
0.25
0.50
0.75
1.00
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
Years
0
10
20
30
40
50

Ecological selection: modern coexistence theory

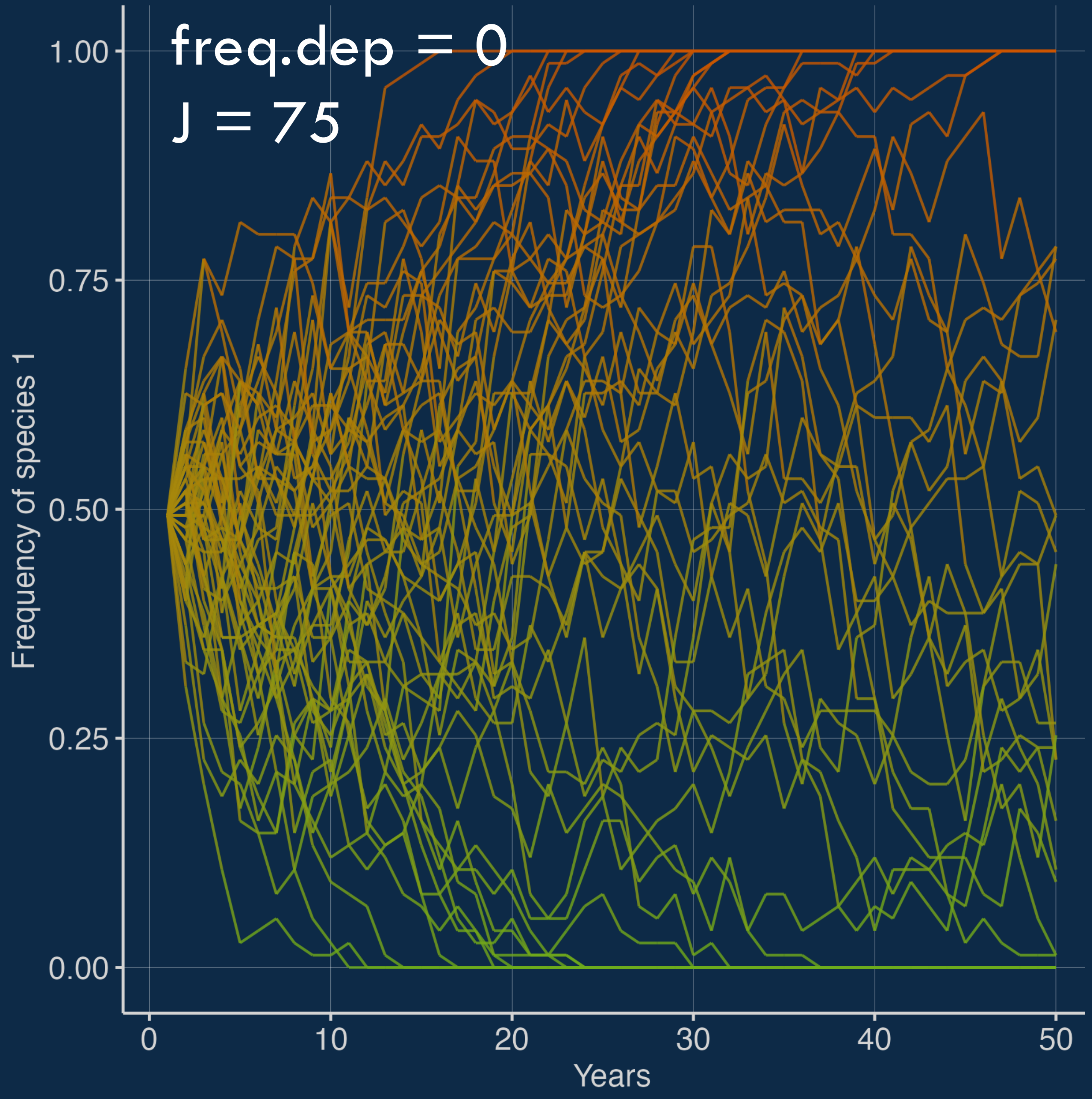




fit.ratio.average = 1.0

freq.dep = 0

J = 75



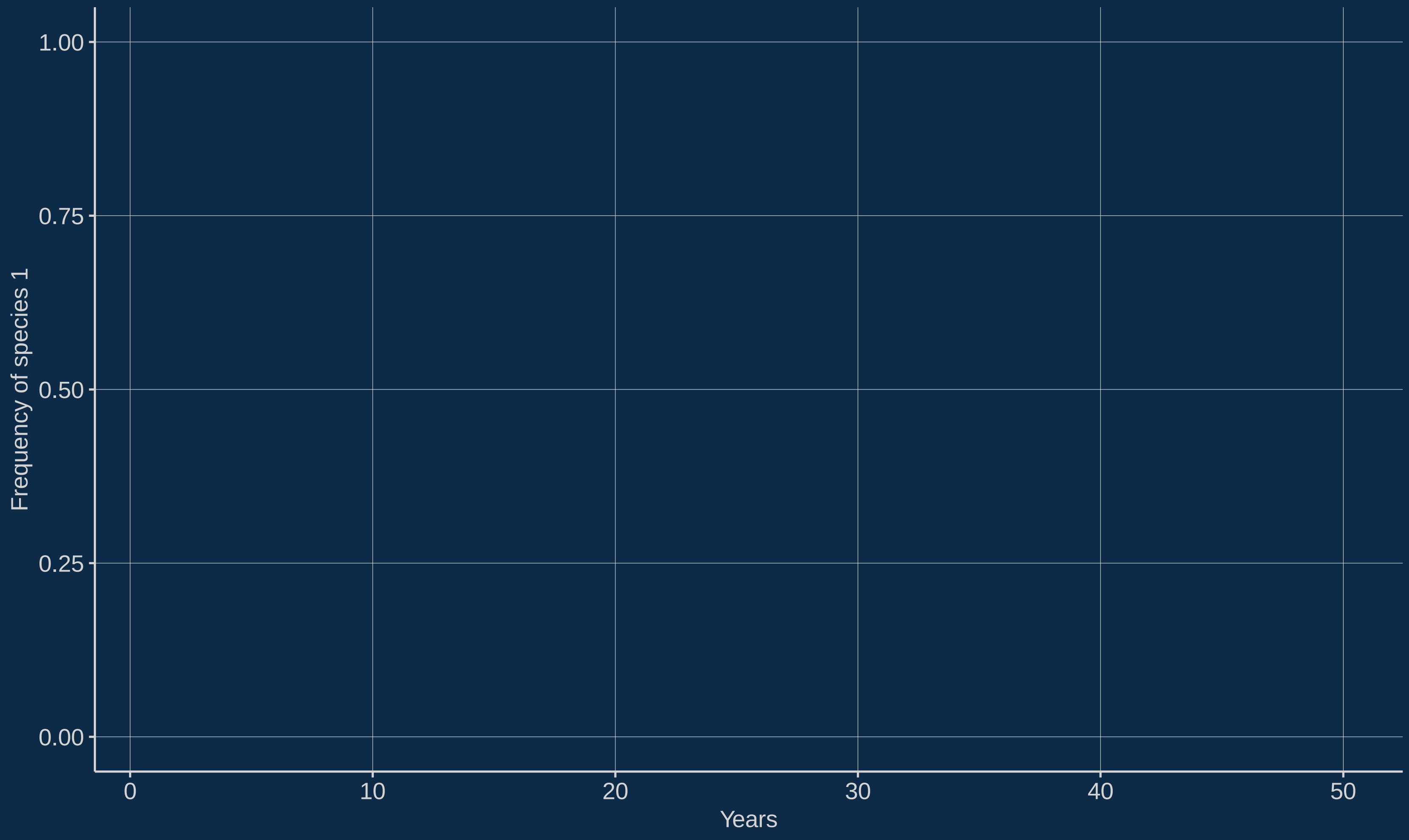
fit.ratio.average = 1.0

freq.dep = -0.9

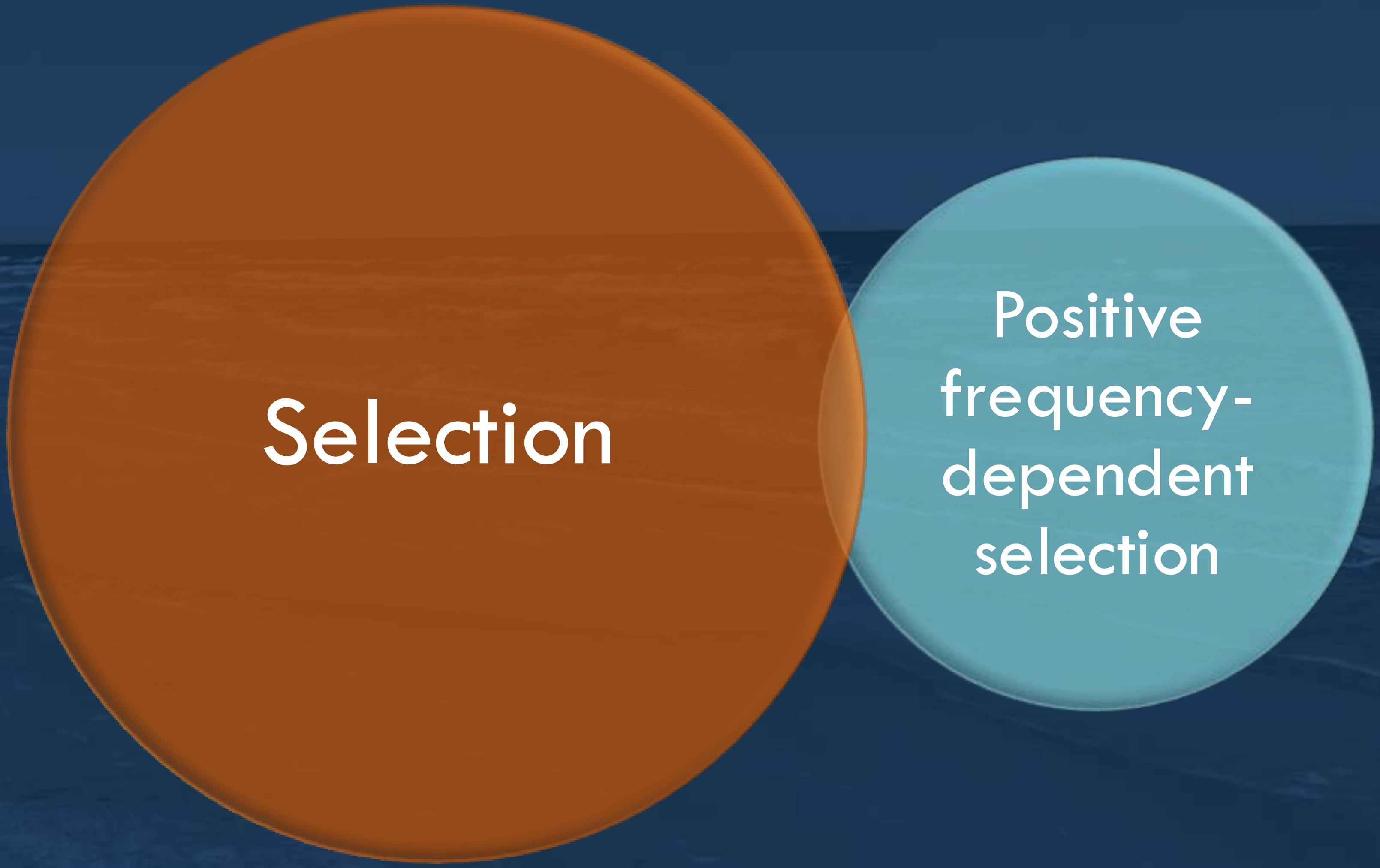
J = 75

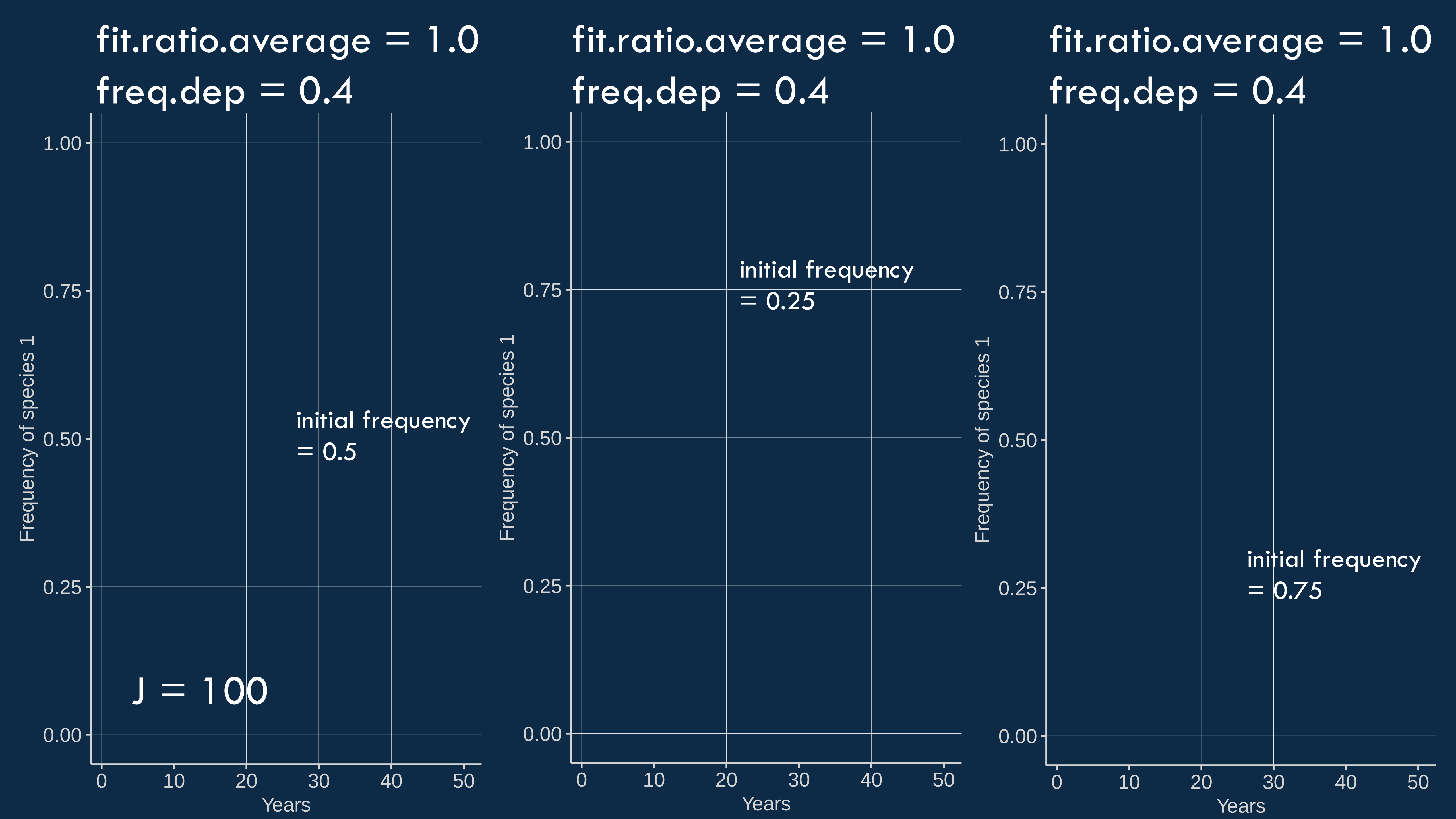
Cyclical dynamics

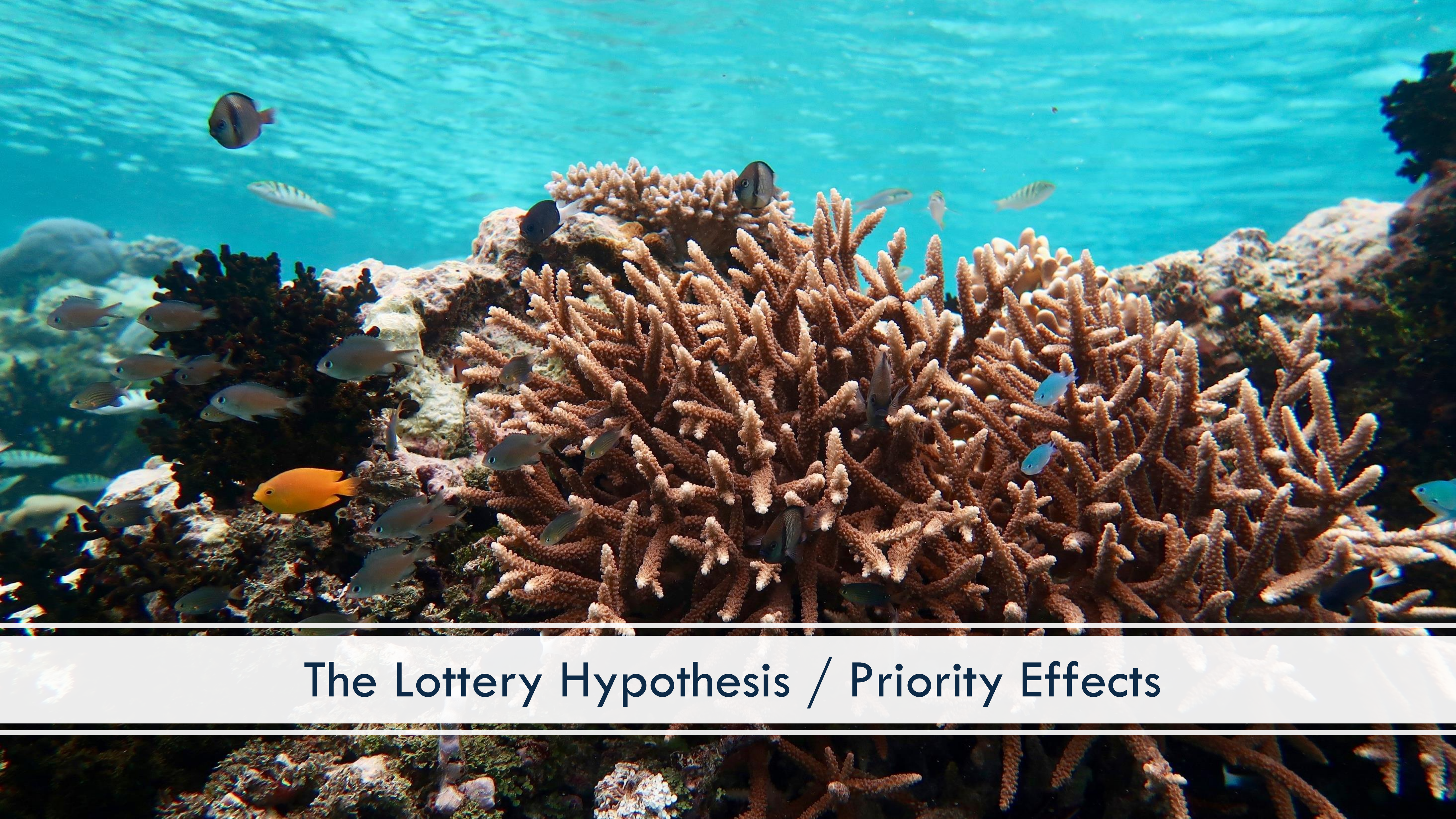
- Species overshoot equilibrium point
- Usually driven by biotic drivers (e.g. predators, competitors)



Intransitive competition theory


Selection
Positive frequency-dependent selection


fit.ratio.average = 1.0
freq.dep = 0.4
initial frequency = 0.5
J = 100
fit.ratio.average = 1.0
freq.dep = 0.4
initial frequency = 0.25
fit.ratio.average = 1.0
freq.dep = 0.4
initial frequency = 0.75
Frequency of species 1
Years
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50



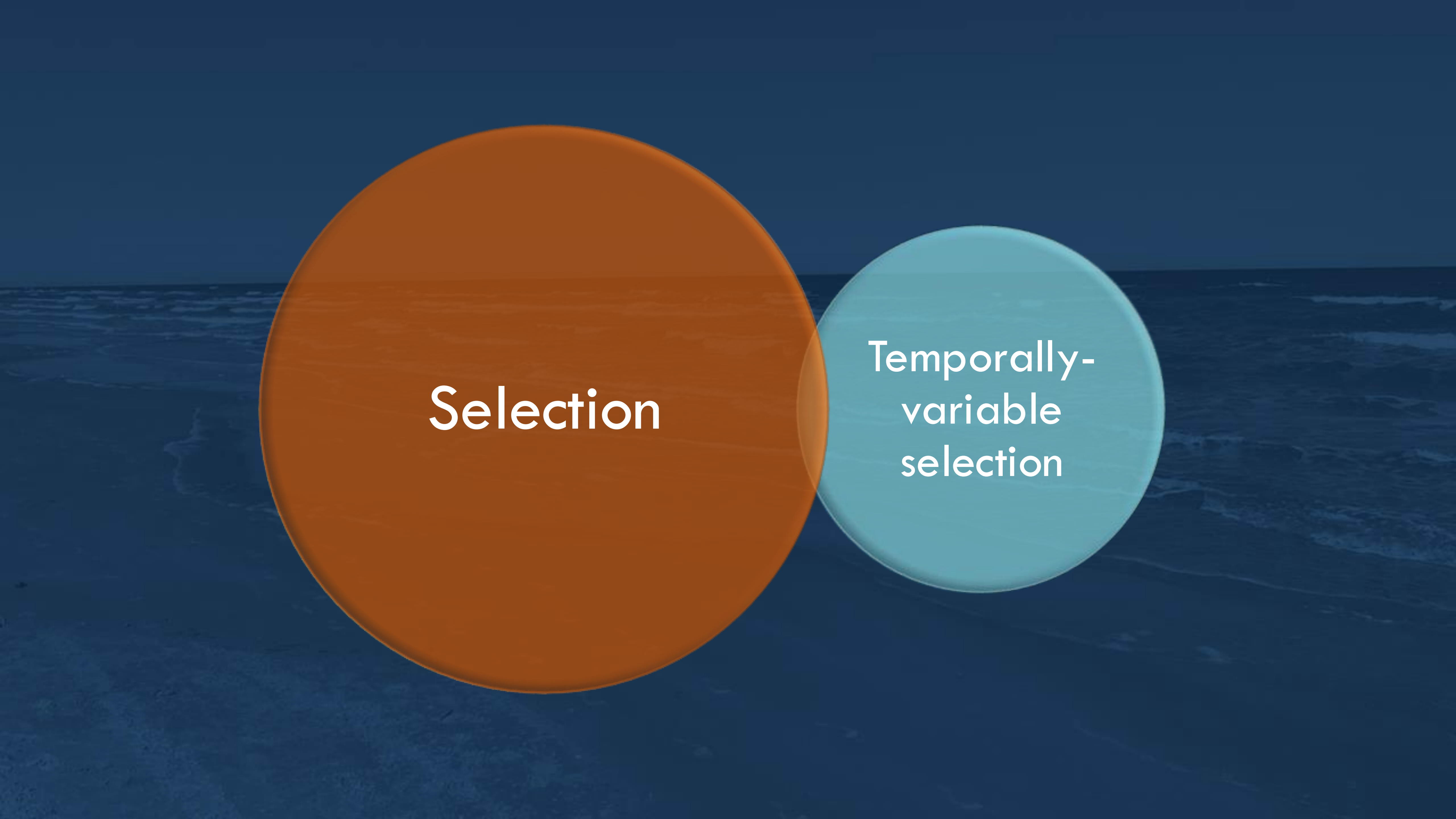
The Lottery Hypothesis / Priority Effects

fit.ratio.average = 1.0

freq.dep = 0.4

initial frequency = 0.5

J = 3000

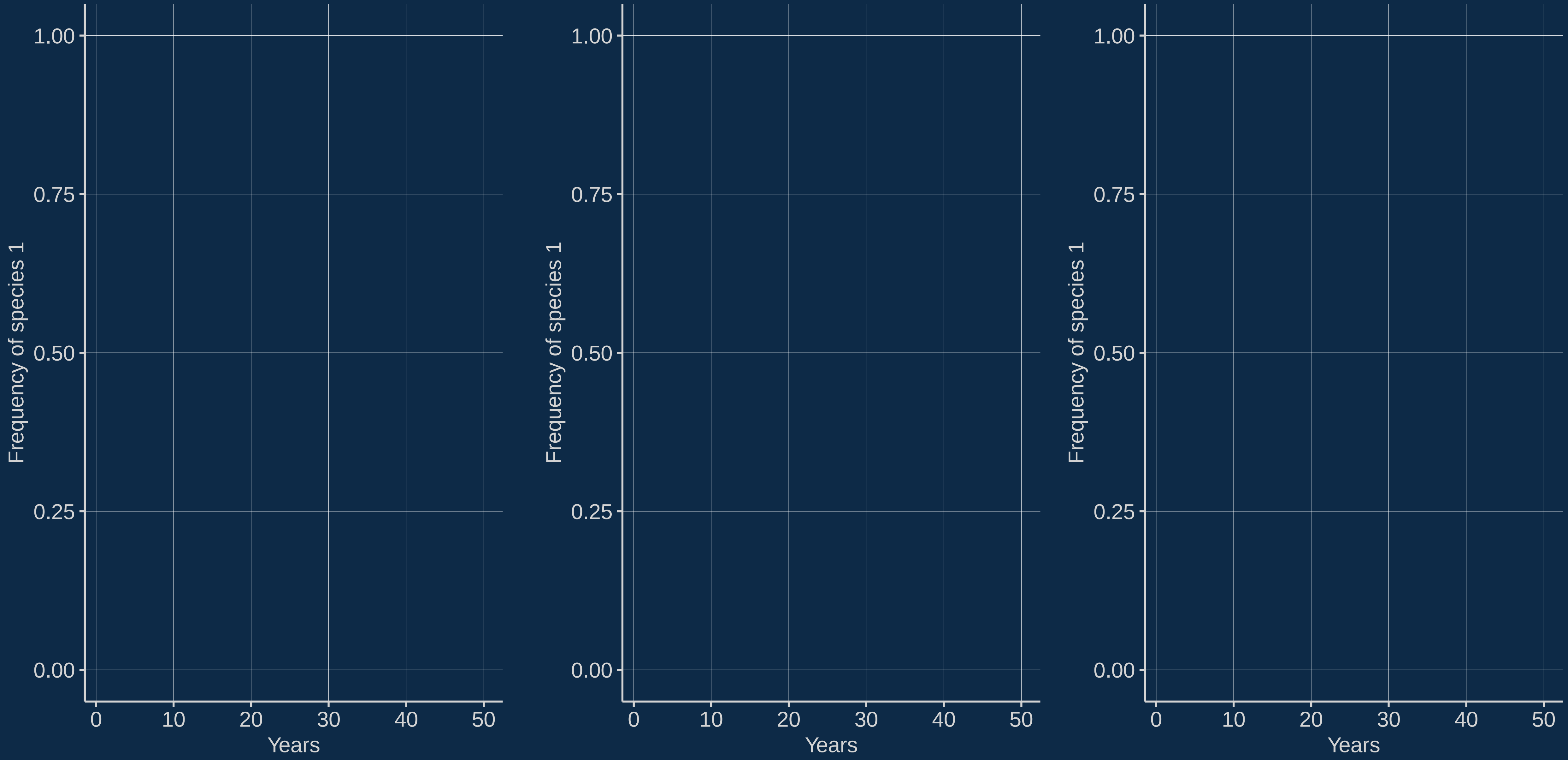

Selection
Temporally-variable selection

Temporally-variable selection

fit.ratios = 1.1and 0.9
J = 1000

fit.ratios = 1.1and 0.9
J = 5000

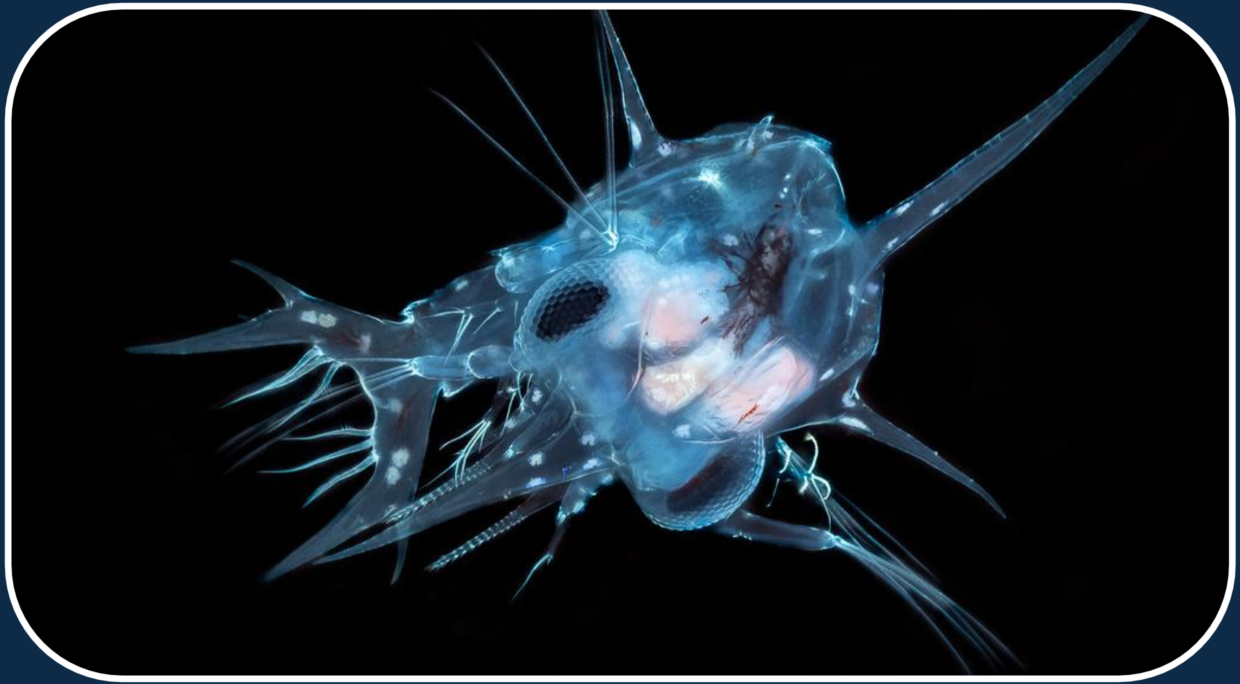
fit.ratios = 1.5 and 0.6
J = 1000




Temporal storage effect


ADDS DISPERSAL
TO COMMUNITIES
RUINS EVERYTHING
imgflip.com

Dispersal

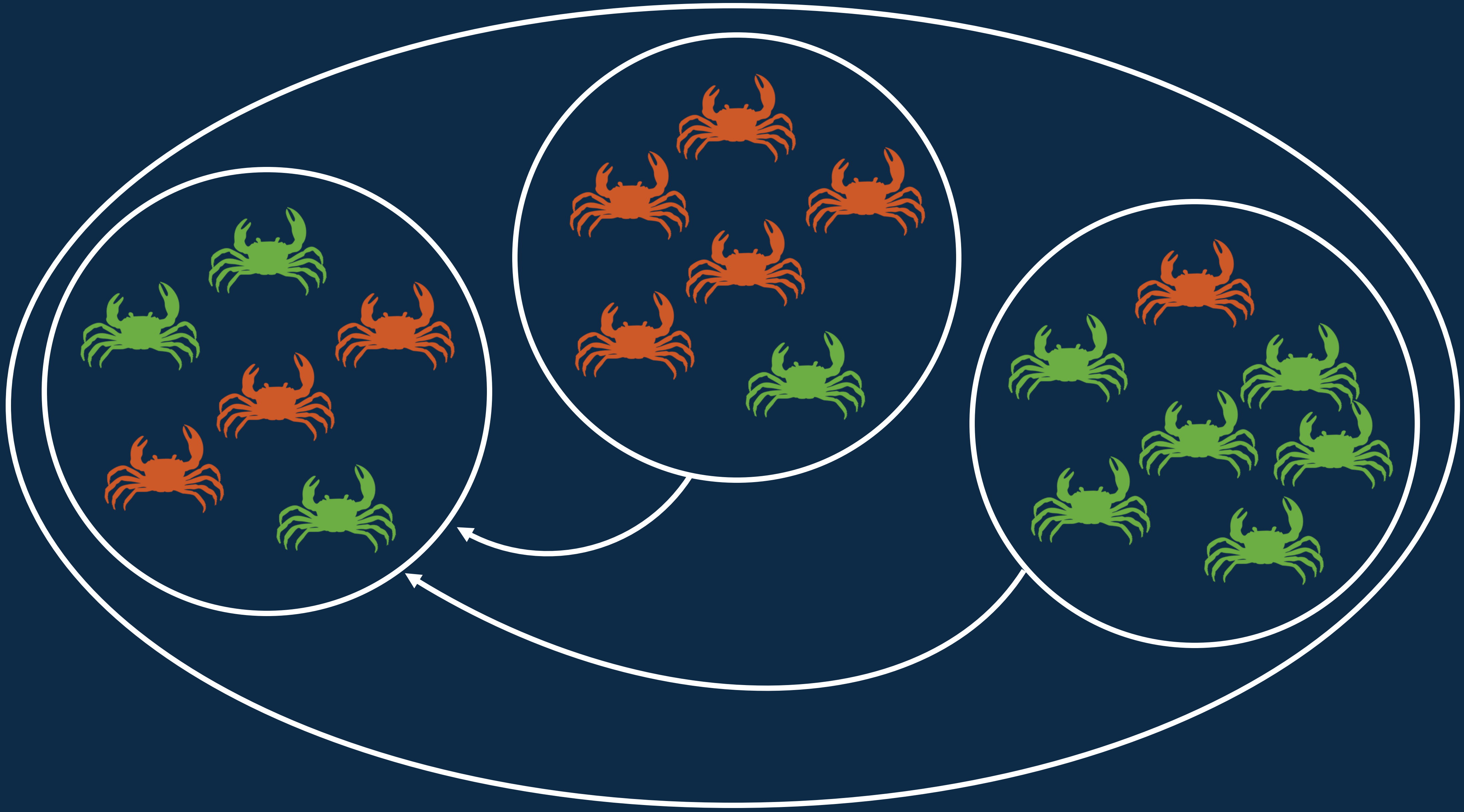


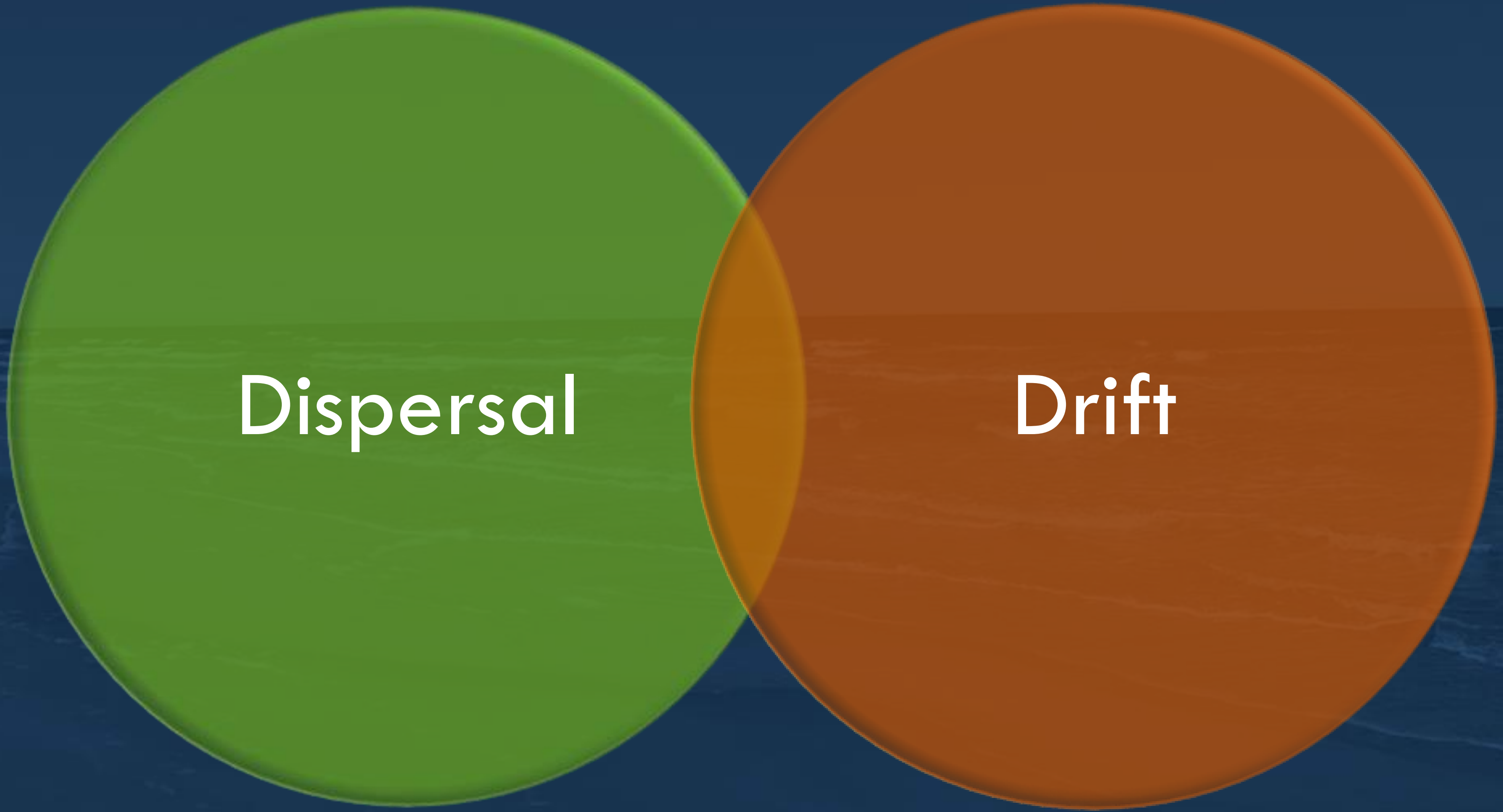

COMMUNITY

META-COMMUNITY

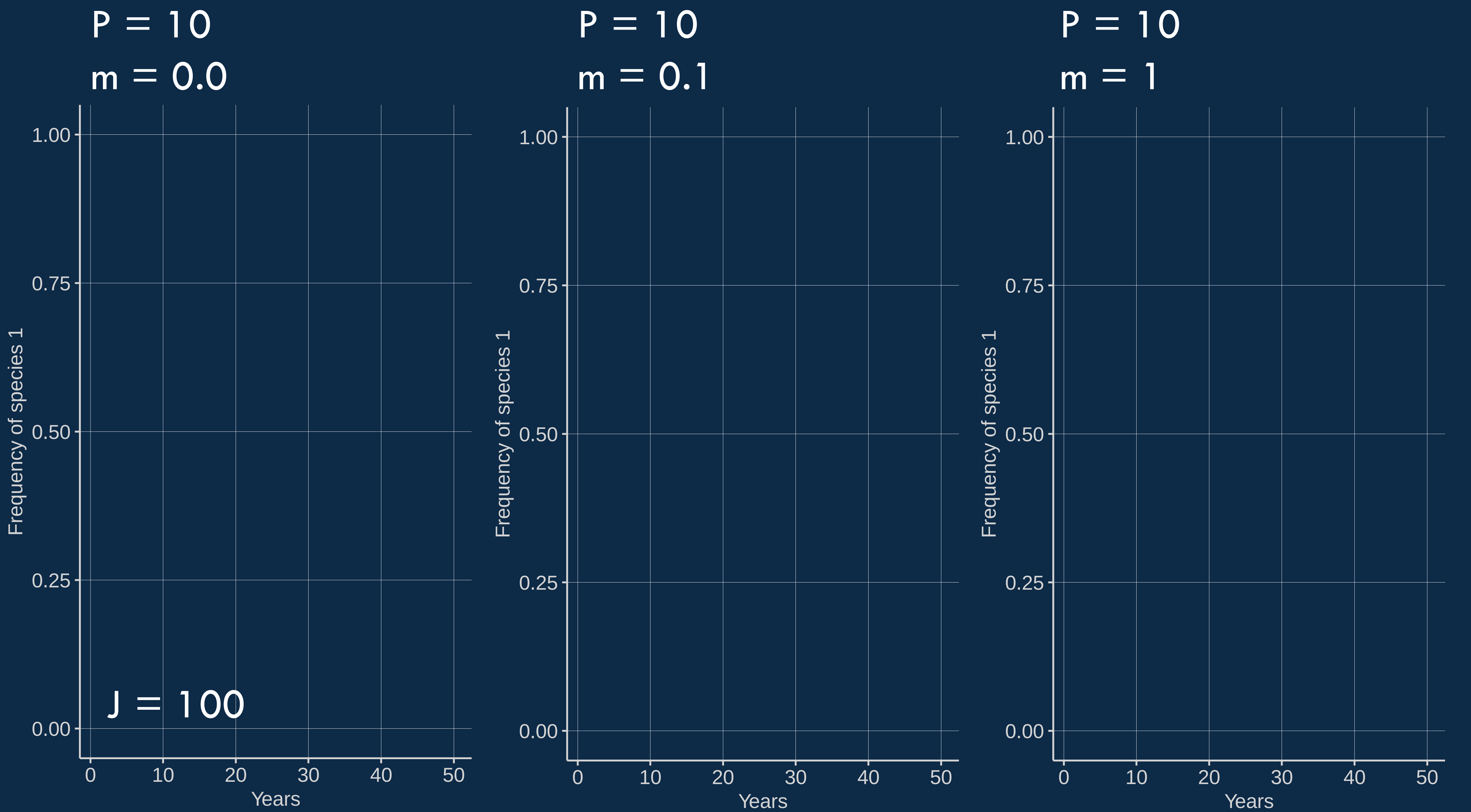
Dispersal parameter *m*

Dispersal parameter *m*





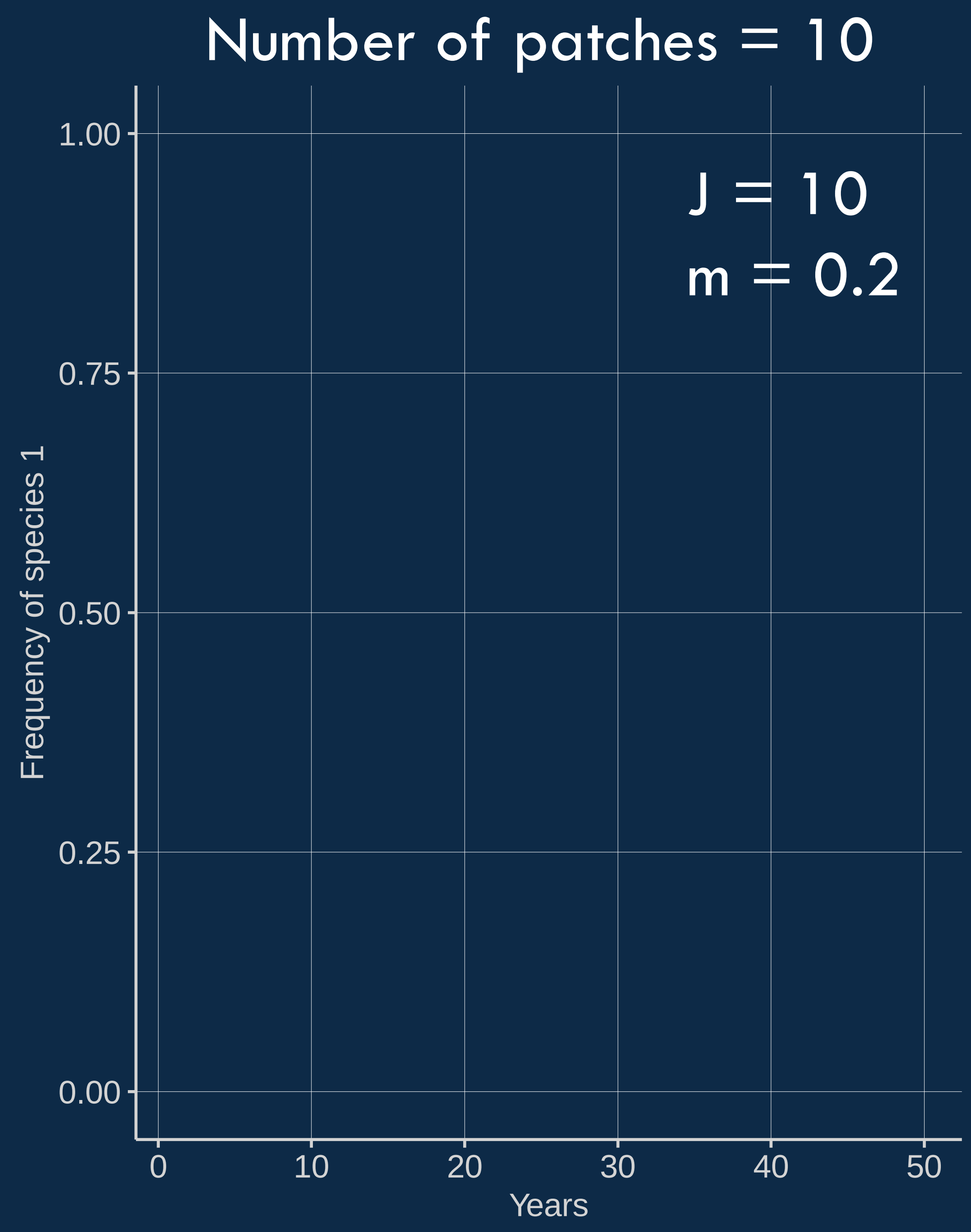
Dispersal parameter *m*
Number of patches *P*

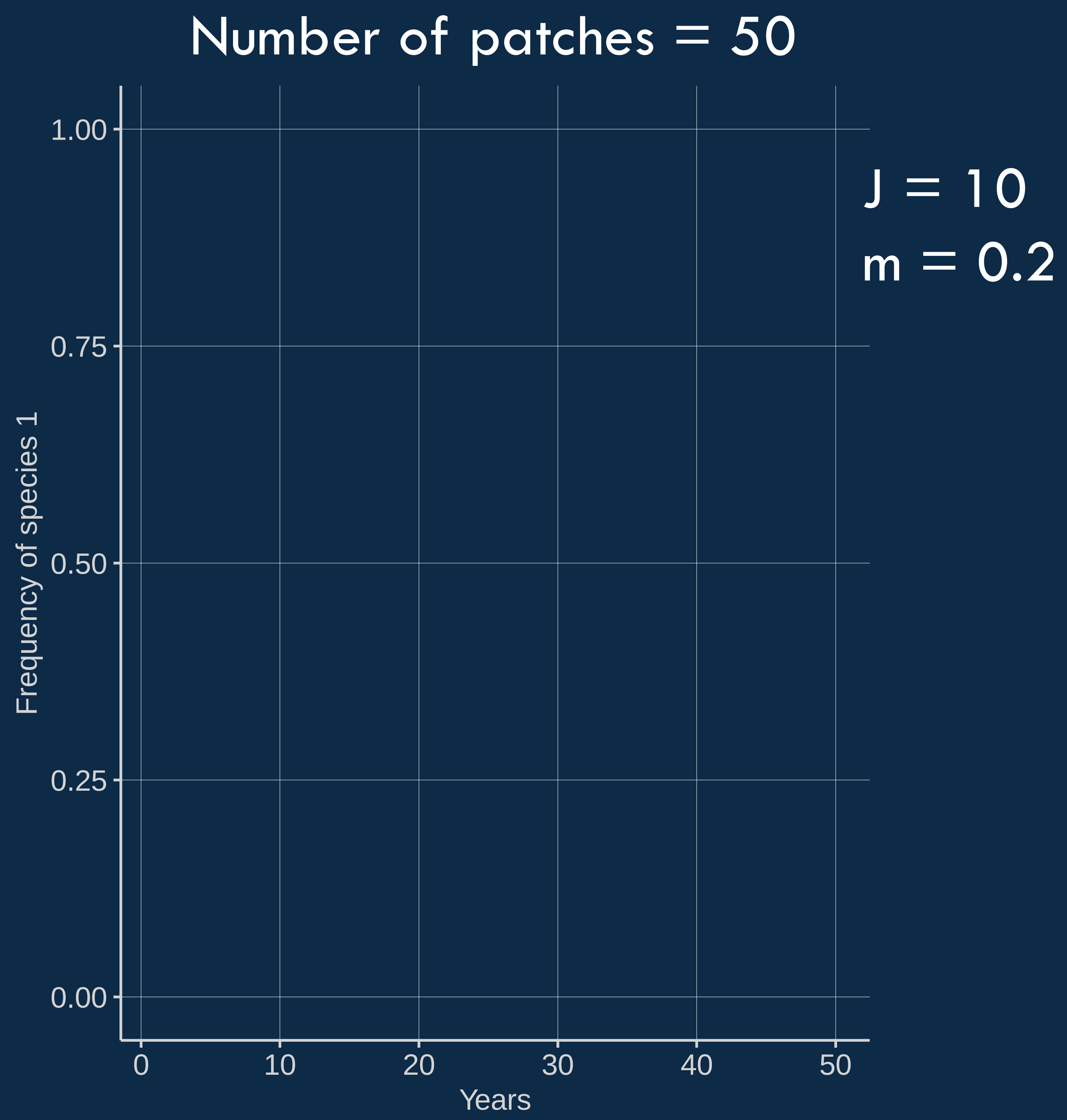

P = 10
m = 0.0
P = 10
m = 0.1
P = 10
m = 1
J = 100
Frequency of species 1
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
Years

$P = 10$

$J = 1000$

$m = 1$


Number of patches = 10
J = 10
m = 0.2
1.00
0.75
0.50
0.25
0.00
Frequency of species 1
0
10
20
30
40
50
Years


Number of patches = 50
J = 10
m = 0.2
1.00
0.75
0.50
0.25
0.00
Frequency of species 1
0
10
20
30
40
50
Years

$P = 100$

$J = 10$

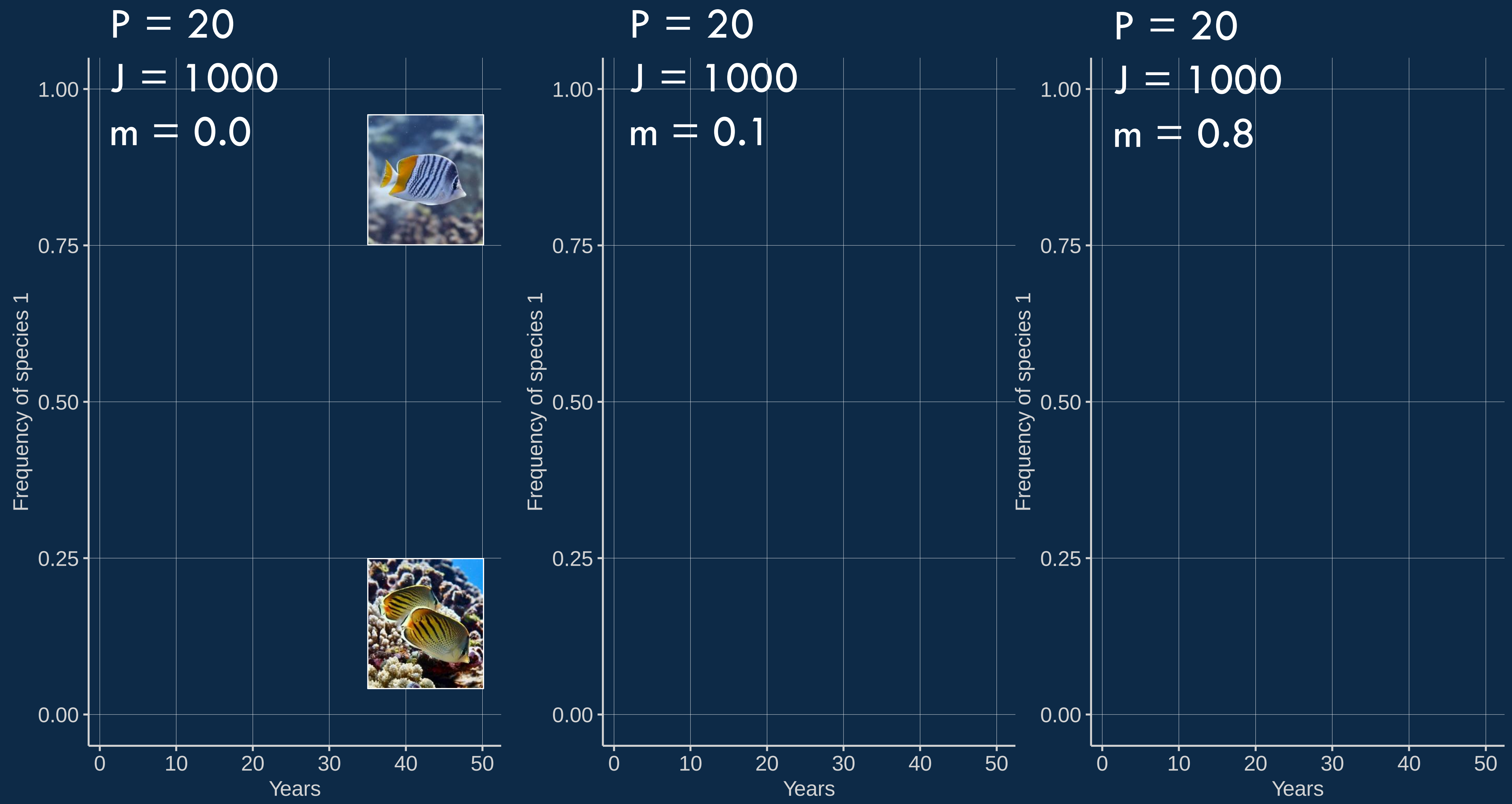
$m = 1$

Not all patches are created equal…


Dispersal
Selection
Spatially-
variable
selection


fitness ratio sp1: 1.2


fitness ratio sp2: 1.2


P = 20
J = 1000
m = 0.0
P = 20
J = 1000
m = 0.1
P = 20
J = 1000
m = 0.8
Frequency of species 1
1.00
0.75
0.50
0.25
0.00
Years
0
10
20
30
40
50

$P = 10$

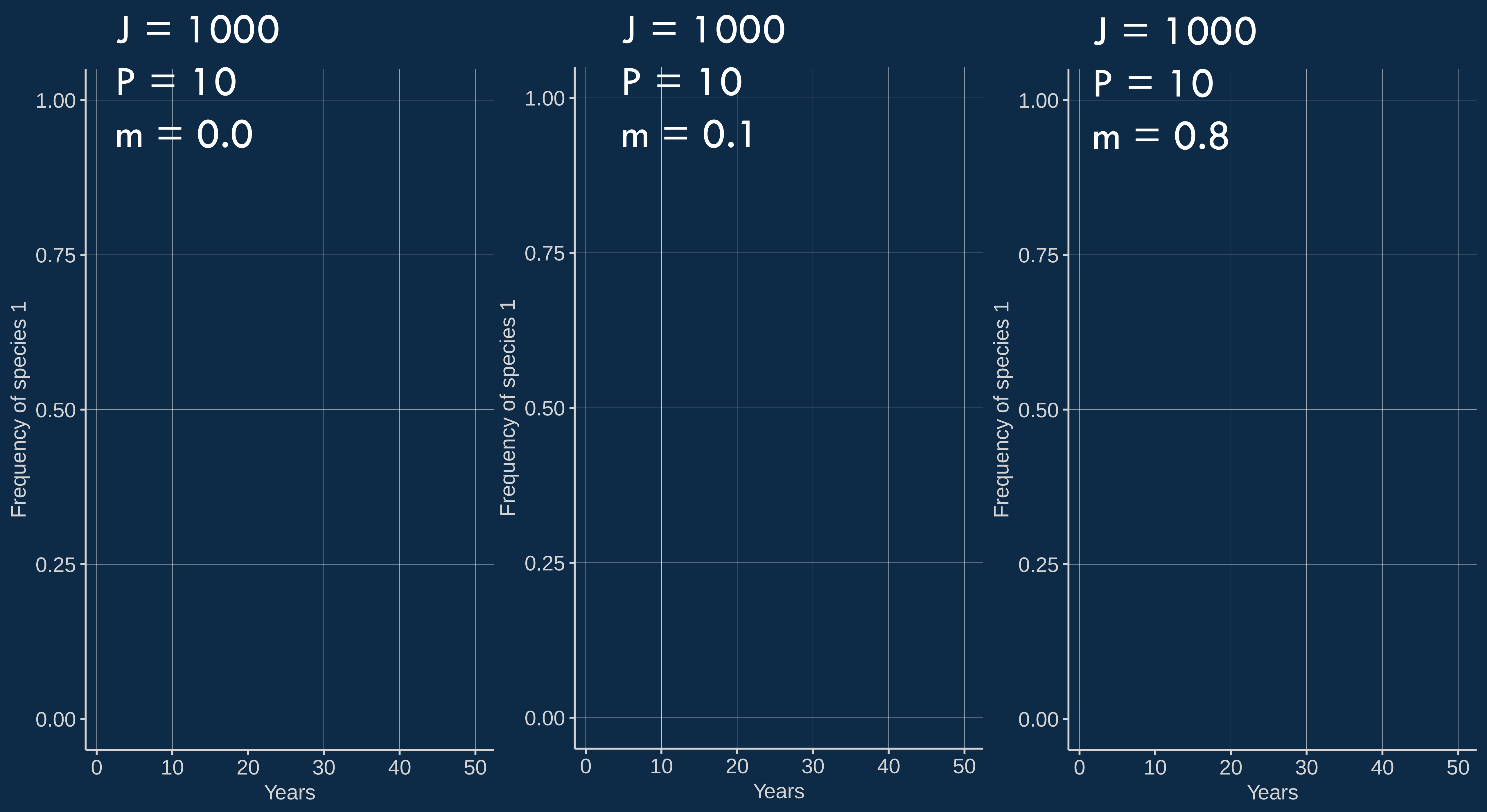
$J = 100$

$m = 0.1$

Spatially-variable selection and high dispersal decreases the likelihood of species dominance and extinction


fitness ratio sp1: 1.5

fitness ratio sp2: 1.1


J = 1000
P = 10
m = 0.0
J = 1000
P = 10
m = 0.1
J = 1000
P = 10
m = 0.8
Frequency of species 1
Years
0.00
0.25
0.50
0.75
1.00
0
10
20
30
40
50

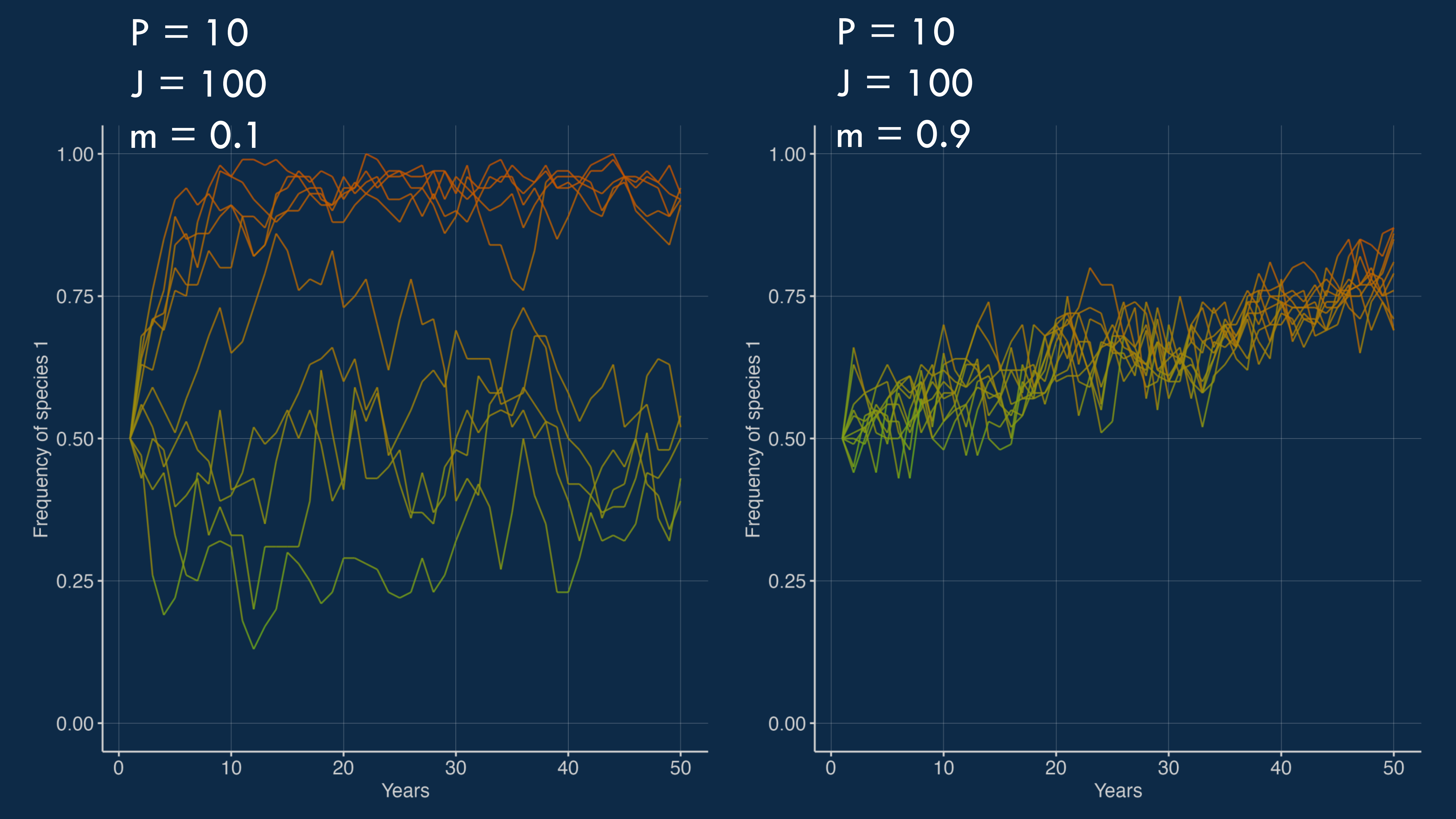
P = 10

J = 100

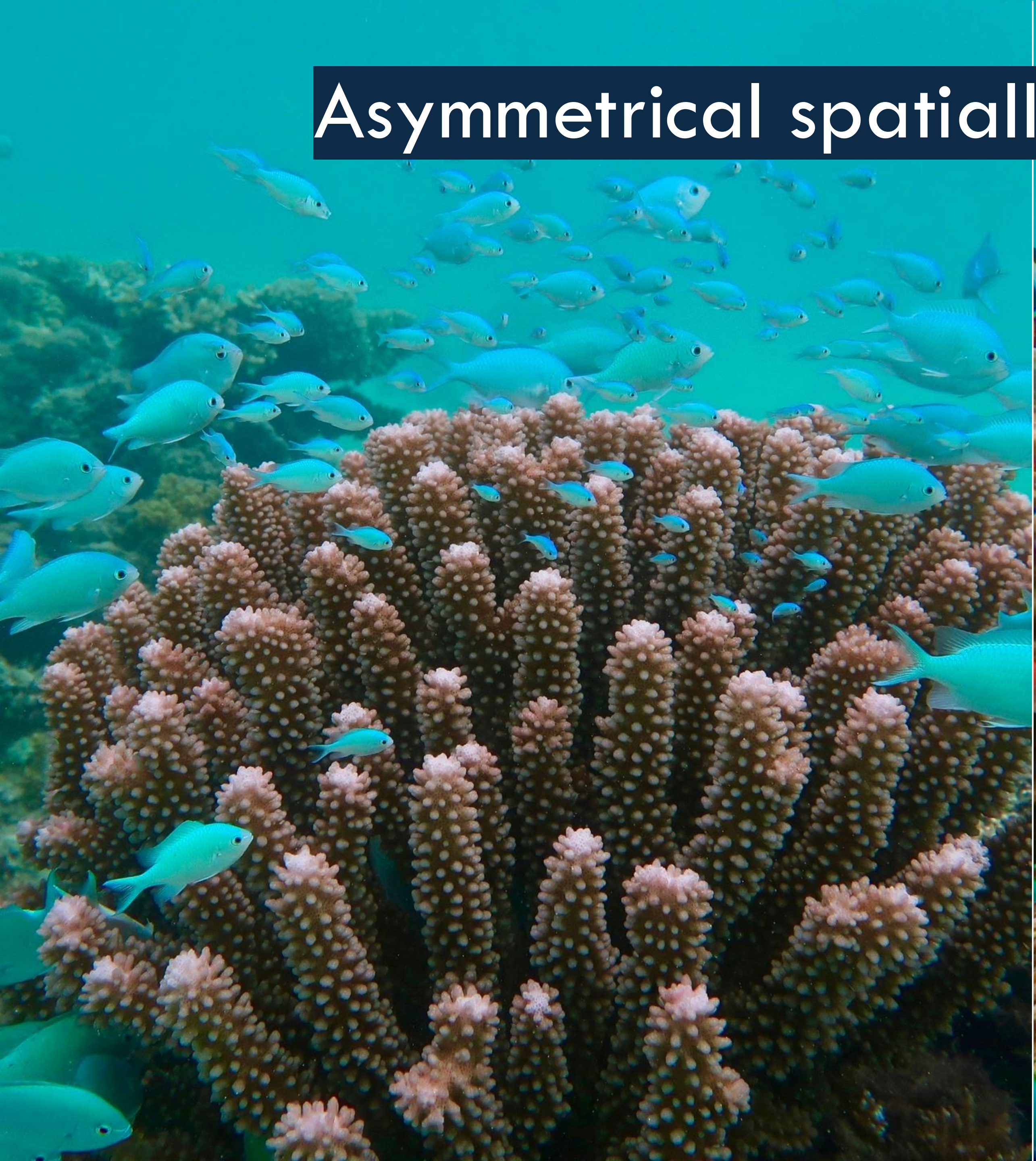
m = 0.5

fit.ratio sp1 = 1.8

fit.ratio sp2 = 1.1


P = 10
J = 100
m = 0.1
P = 10
J = 100
m = 0.9
Frequency of species 1
Years
0.00
0.25
0.50
0.75
1.00
0
10
20
30
40
50

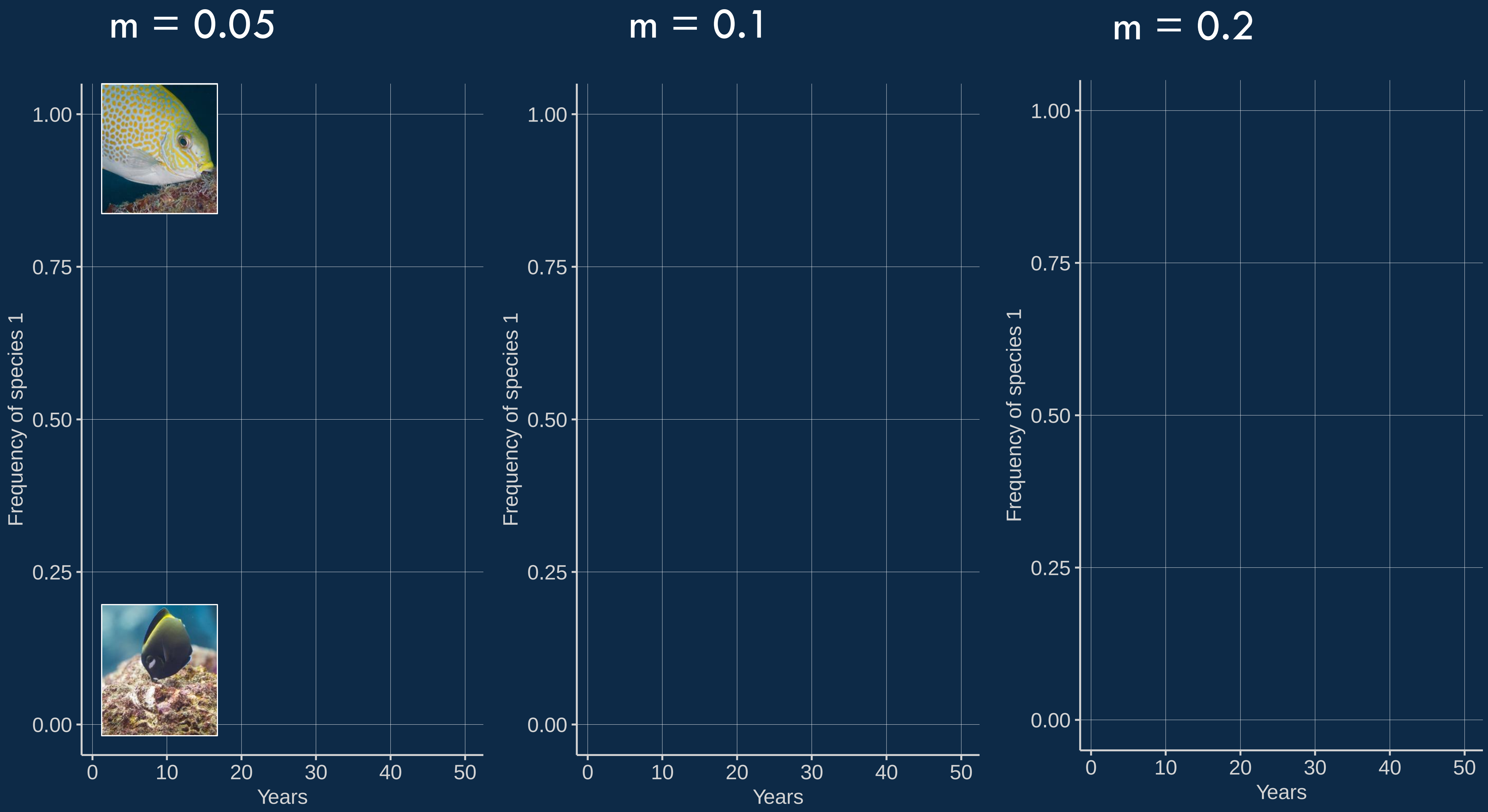
Asymmetrical spatially-variable selection



Effects of dispersal depend on symmetrical vs asymmetrical fitness differences


Poor disperser
Good competitor
Egg scattering


Good disperser
Poor competitor
Broadcast spawning



m = 0.05
m = 0.1
m = 0.2
Frequency of species 1
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
Years

$P = 10$

$J = 1000$

$m = 0.5$

Competition-colonization trade-offs

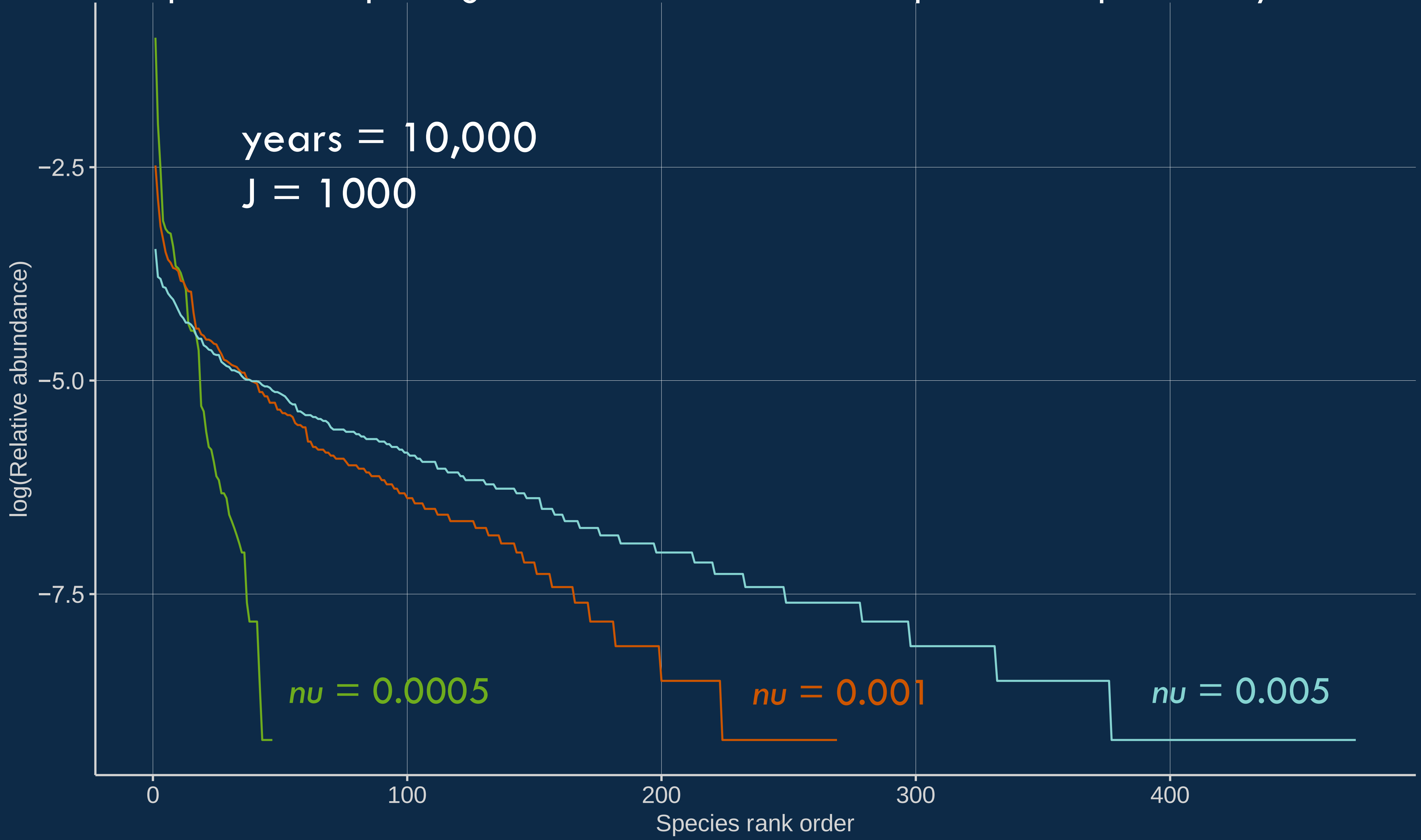
Intermediate disturbance hypothesis

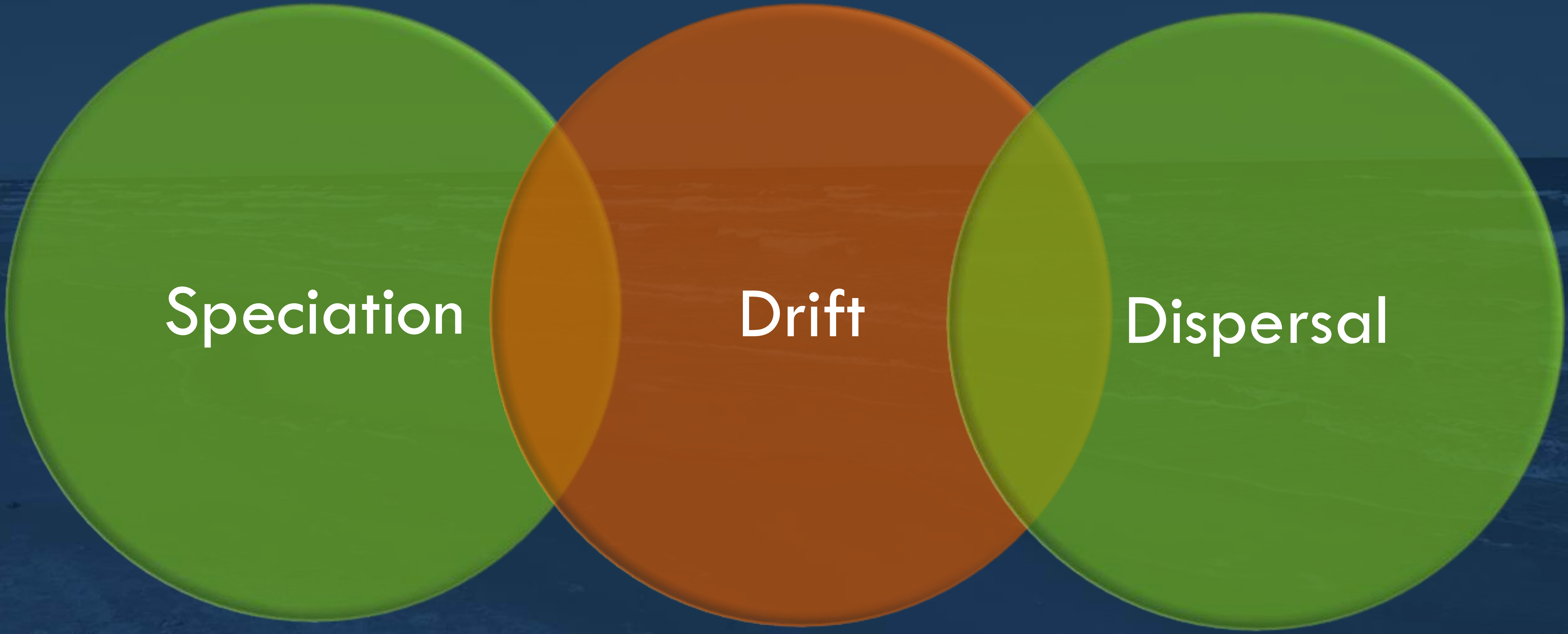
The ugly face of dispersal…

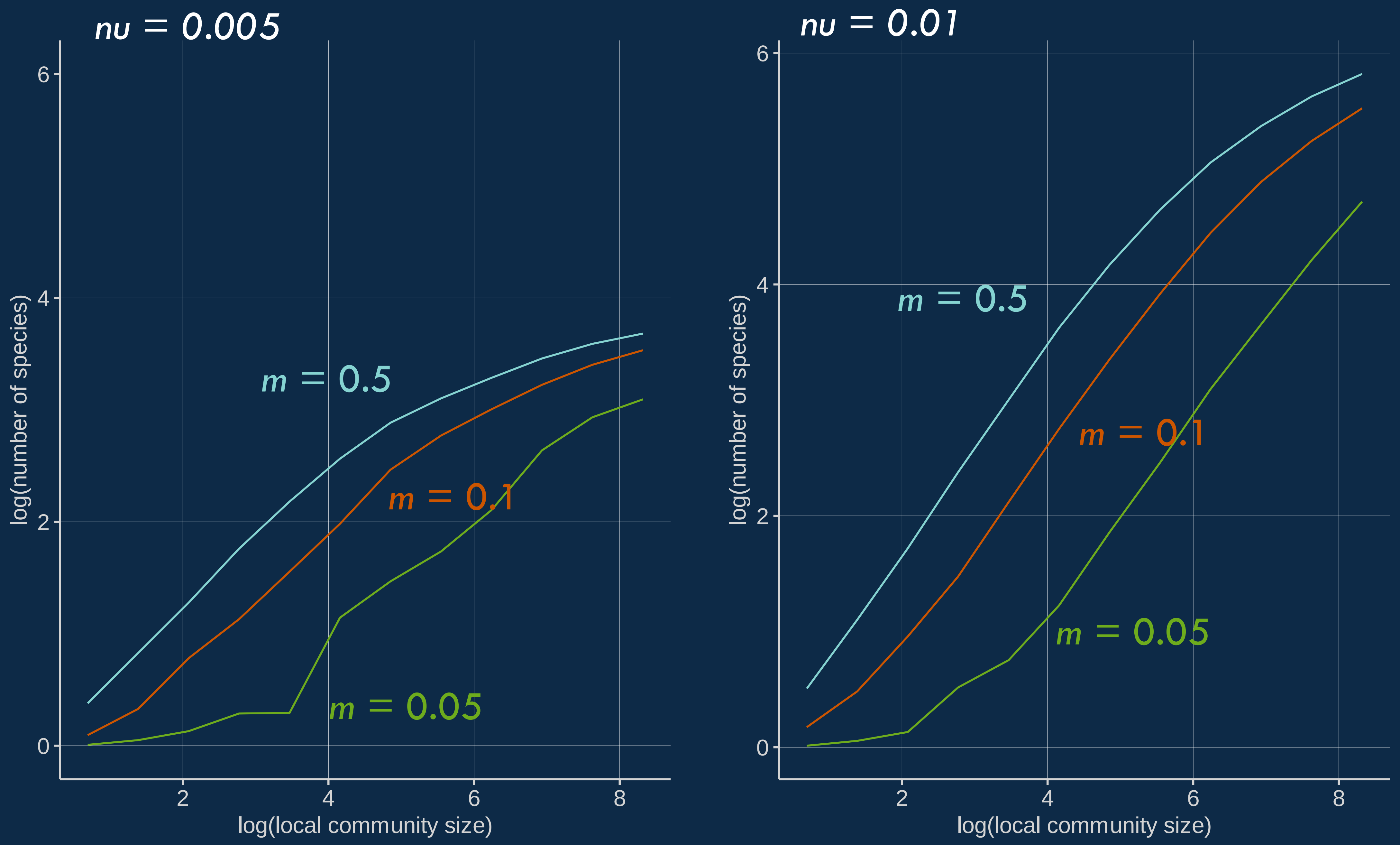
Speciation

Speciation

Speciation: replacing dead individual with new species with probability *nu*




Speciation
Drift
Dispersal



nu = 0.005
nu = 0.01
m = 0.5
m = 0.1
m = 0.05
log(number of species)
log(local community size)
0
2
4
6
8

The Unified Neutral Theory of
BIODIVERSITY AND BIOGEOGRAPHY

STEPHEN P. HUBBELL

MONOGRAPHS IN POPULATION BIOLOGY • 32


DRIFT, DISPERSAL, AND SELECTION
imgflip.com
SPECIATION


DRIFT
SELECTION
PROOF
DISPERSAL
SPECIATION

Thursday: bird trivia & coding loops

Homework:

- watch simulation tutorial
- draw three bird species ☺

MATHEMATICAL MODELS TO SIMULATE THE FOUR PROCESSES

- illustrate expected community dynamics under the four general processes
- emphasize that the most models in community ecology use these four ingredients
- give you an opportunity to play with these simulations