Population dynamics of the periwinkle *Littorina littorea* (Linnaeus, 1758) in the East Frisian Wadden Sea

Diplomarbeit

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Animal Biodiversity and Evolutionary Biology
Carl von Ossietzky University Oldenburg

Supervisors: Prof. Dr. Gabriele Gerlach, Dr. Thomas Friedl

March 19, 2010

Outline

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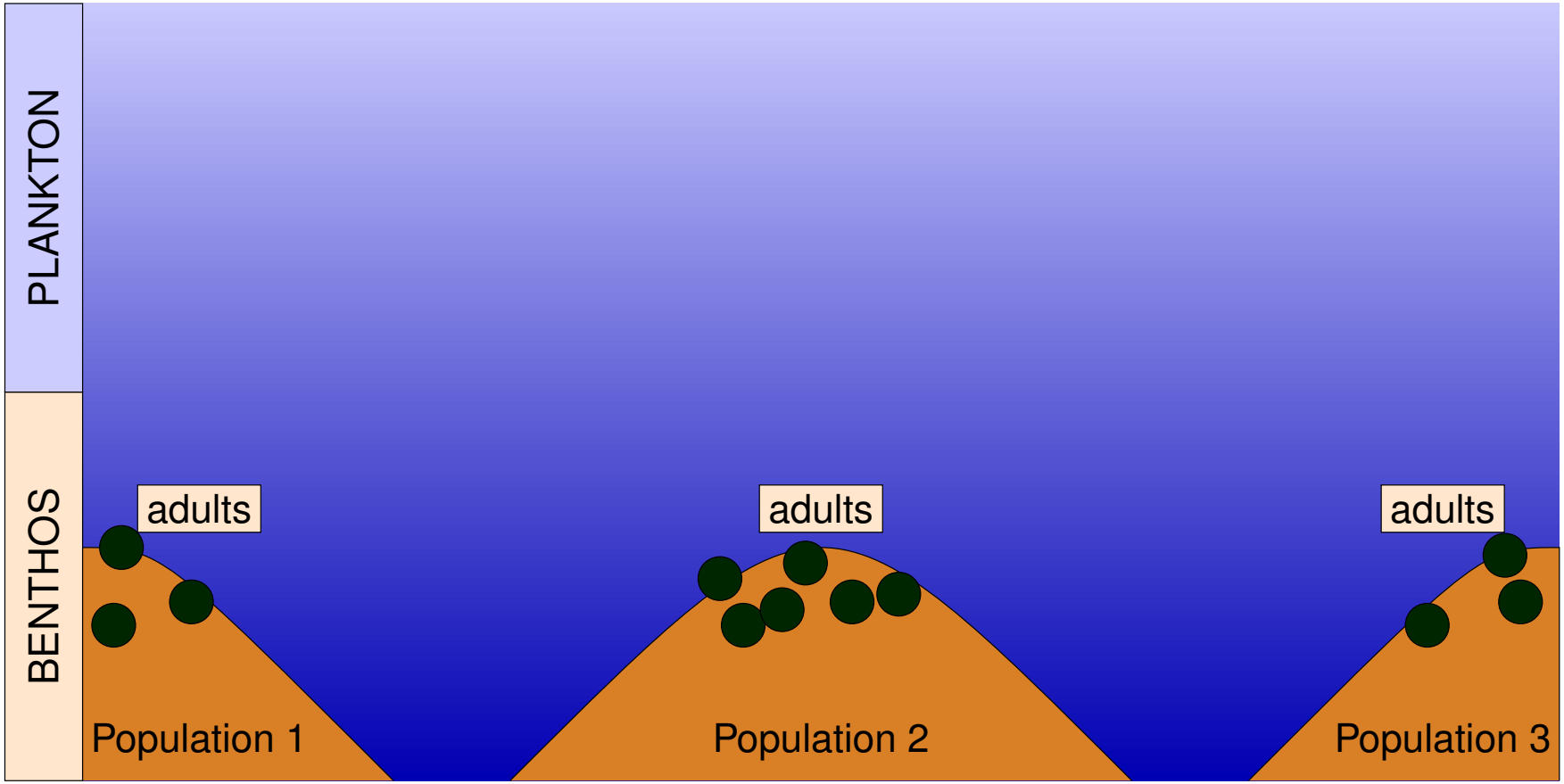
Populations get Connected by Dispersing Larvae



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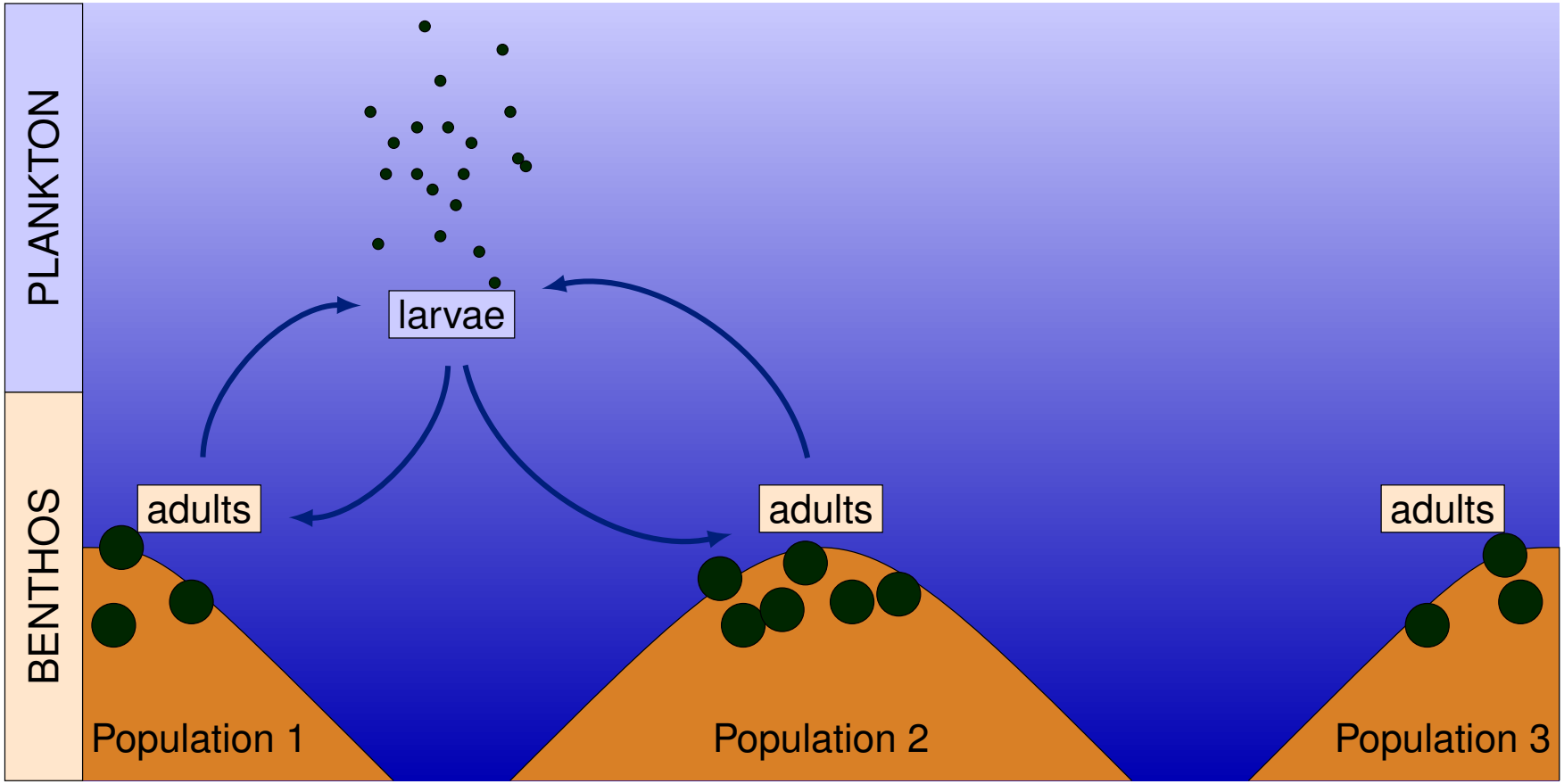

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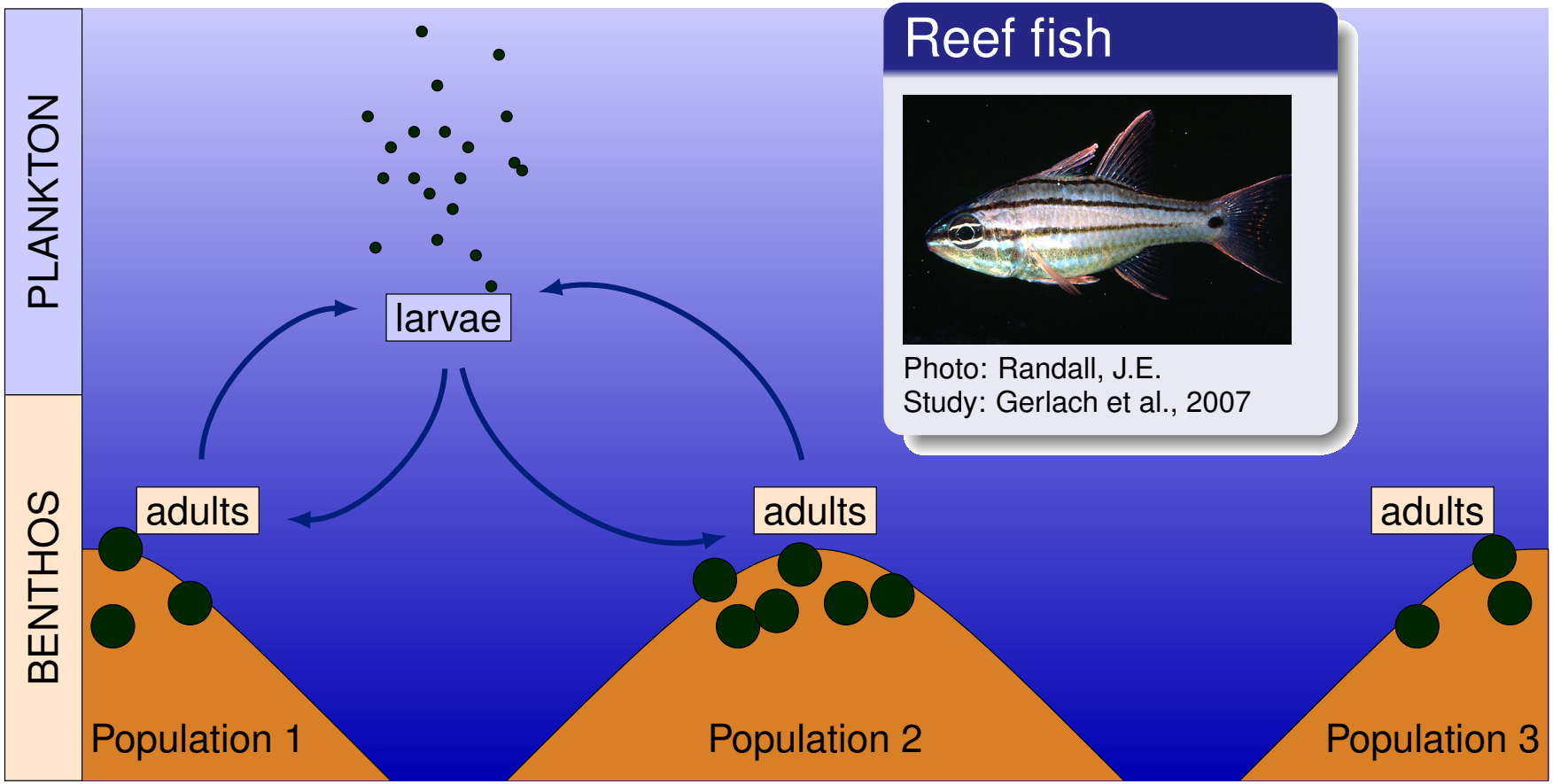

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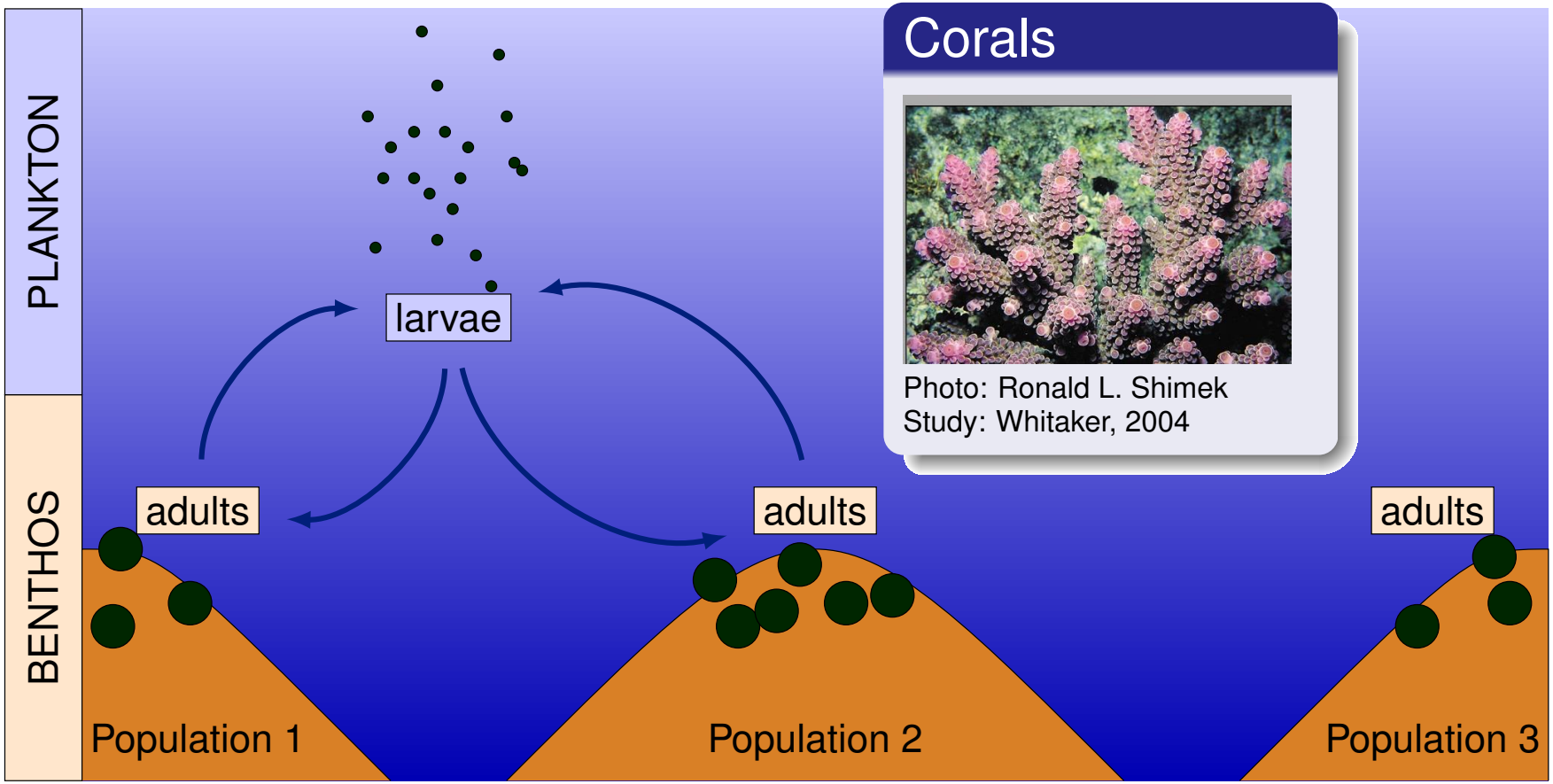

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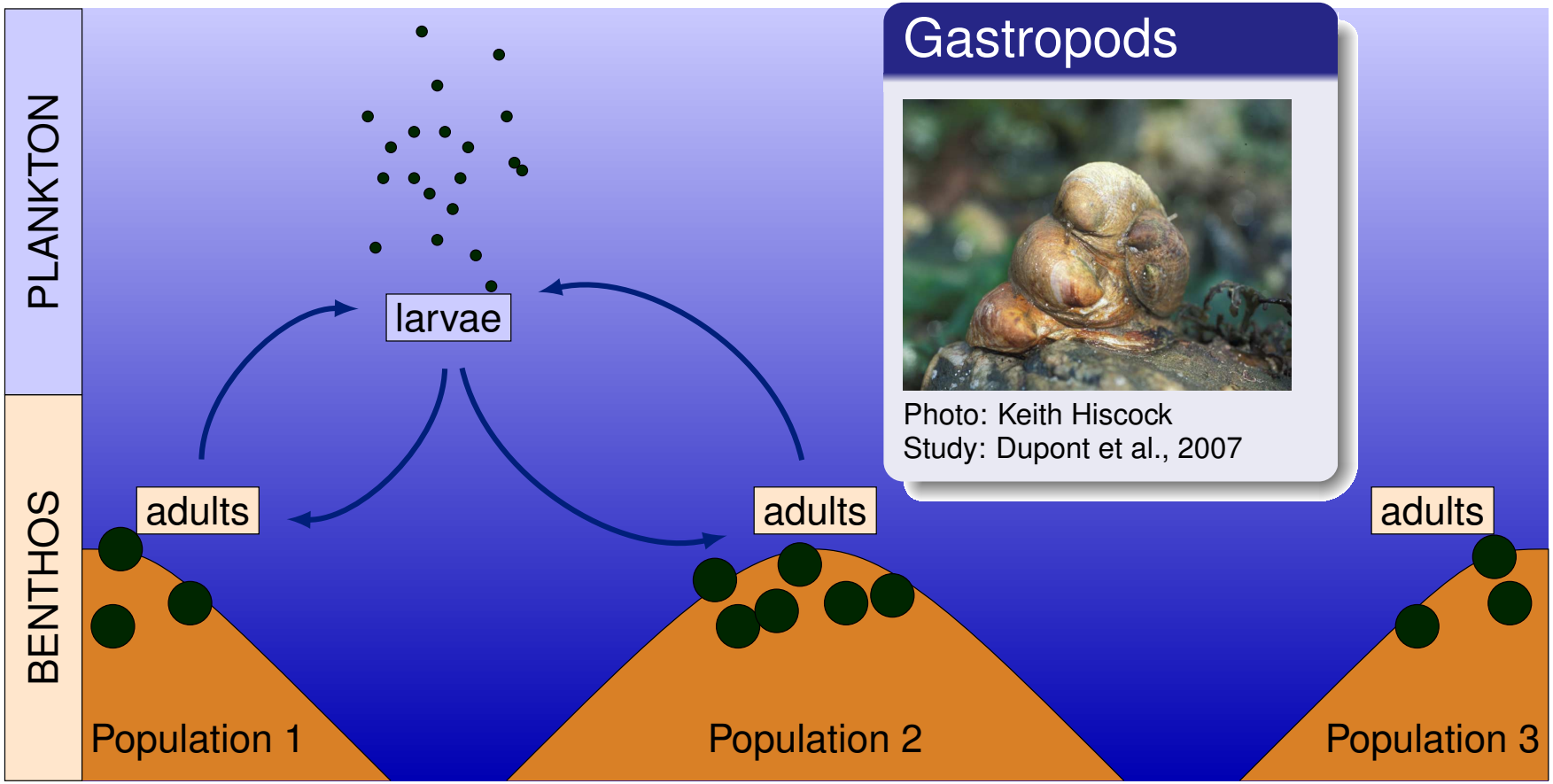

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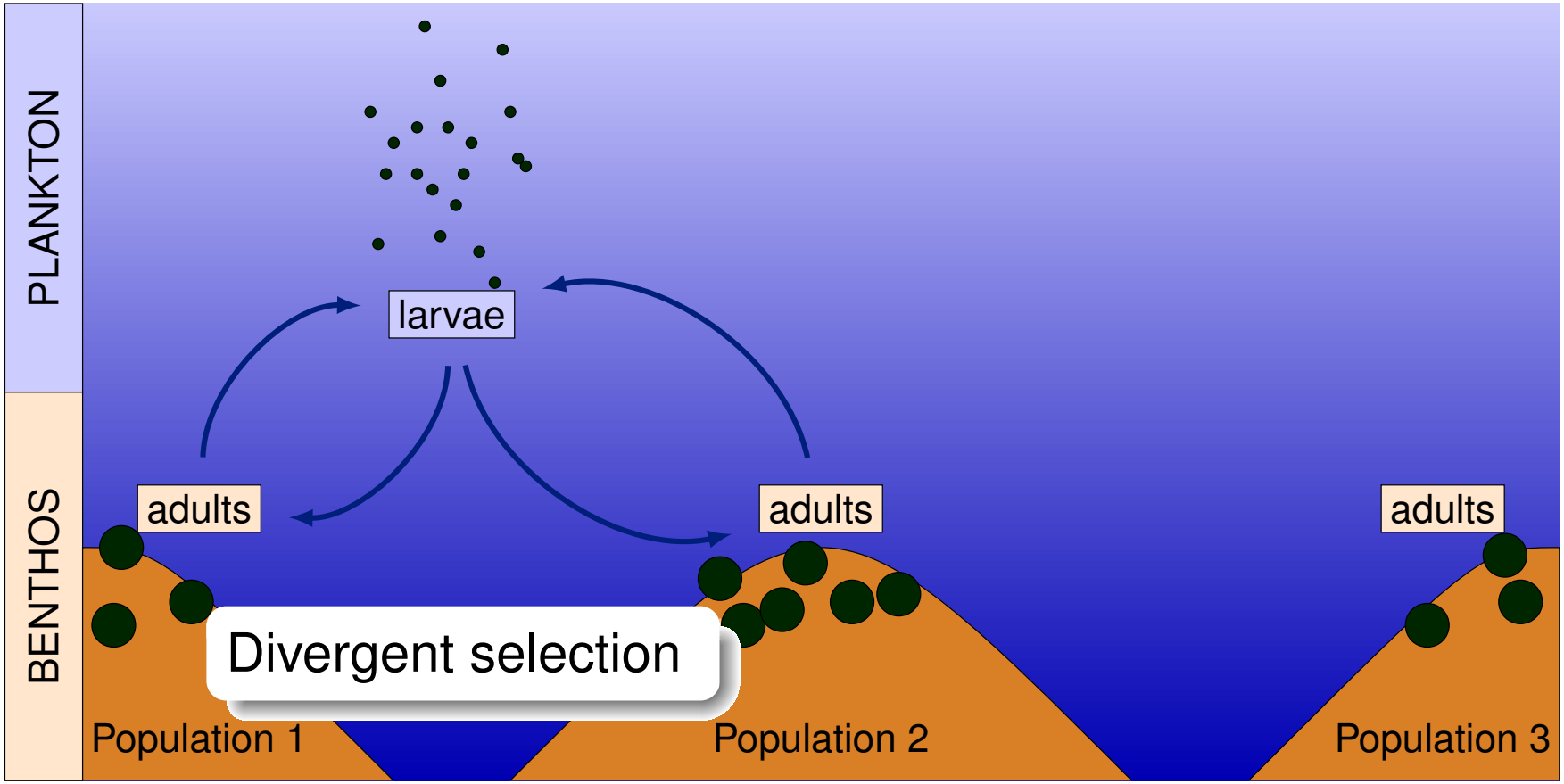

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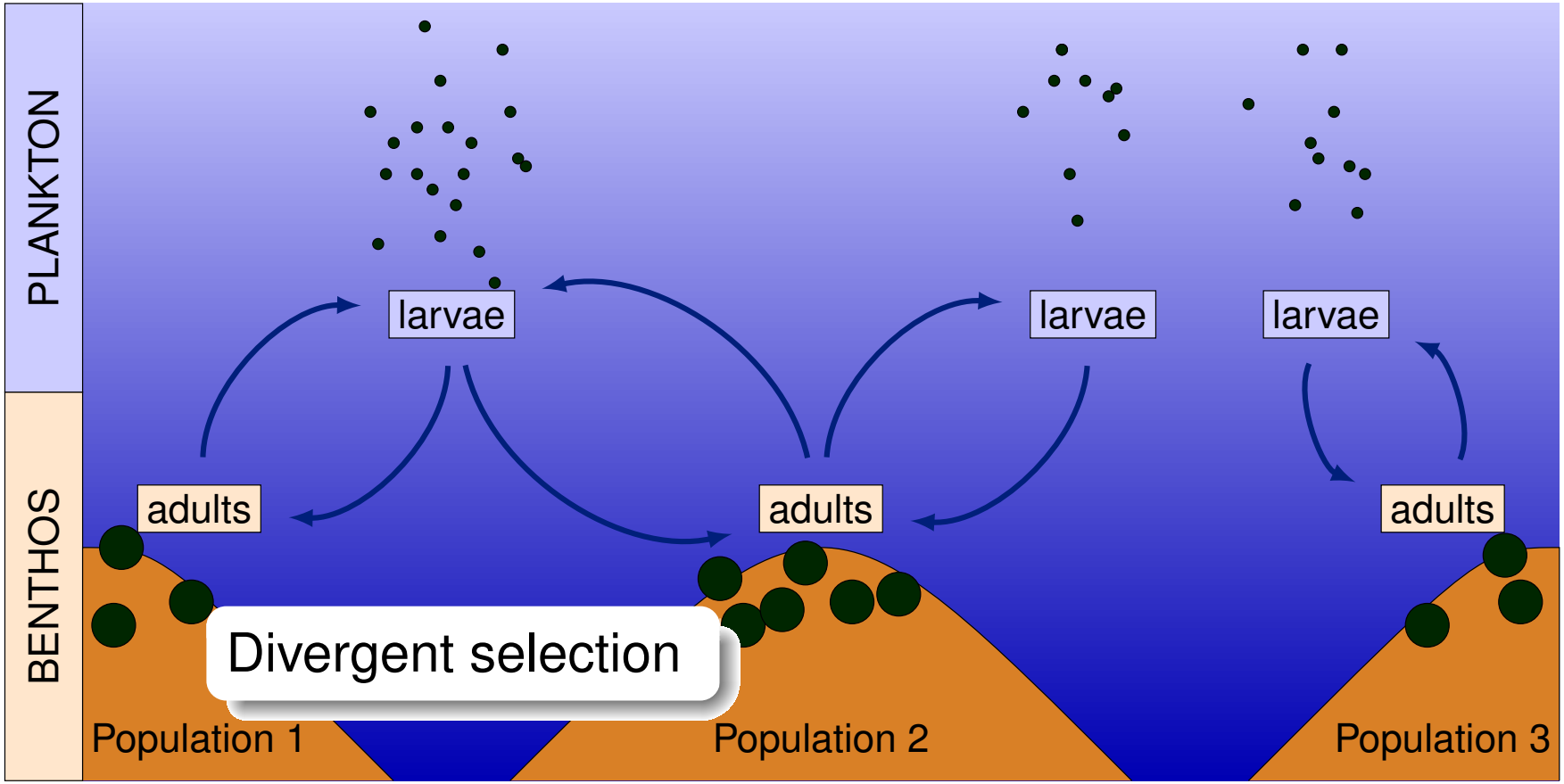

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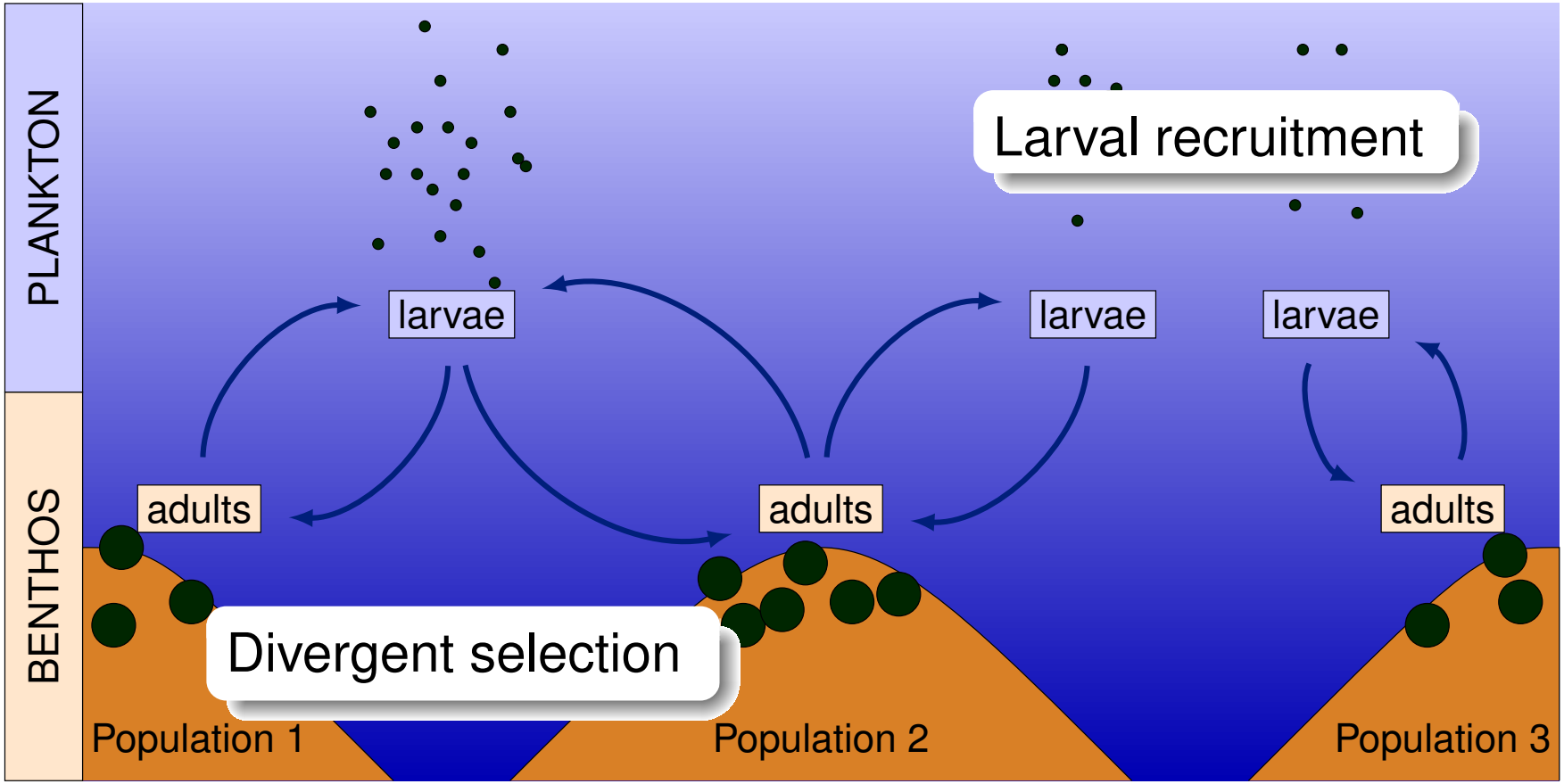

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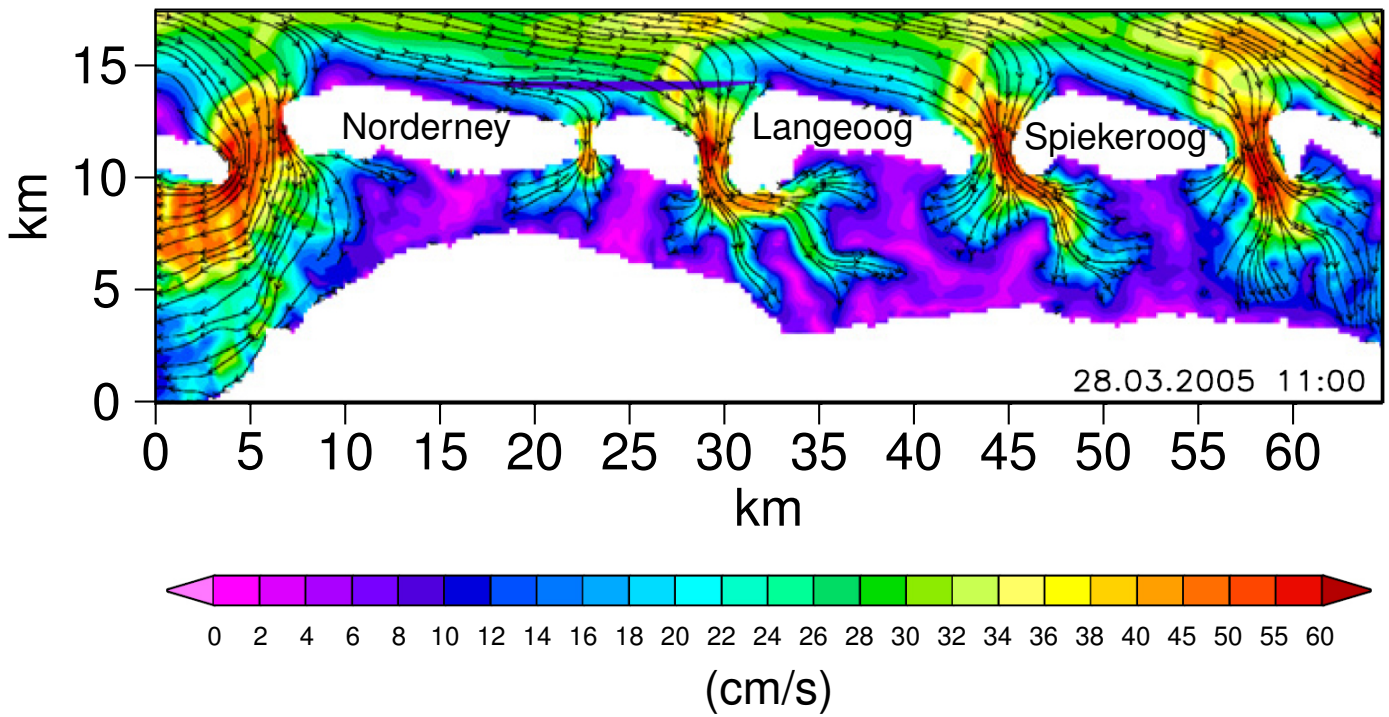

(Staneva et al., 2009)

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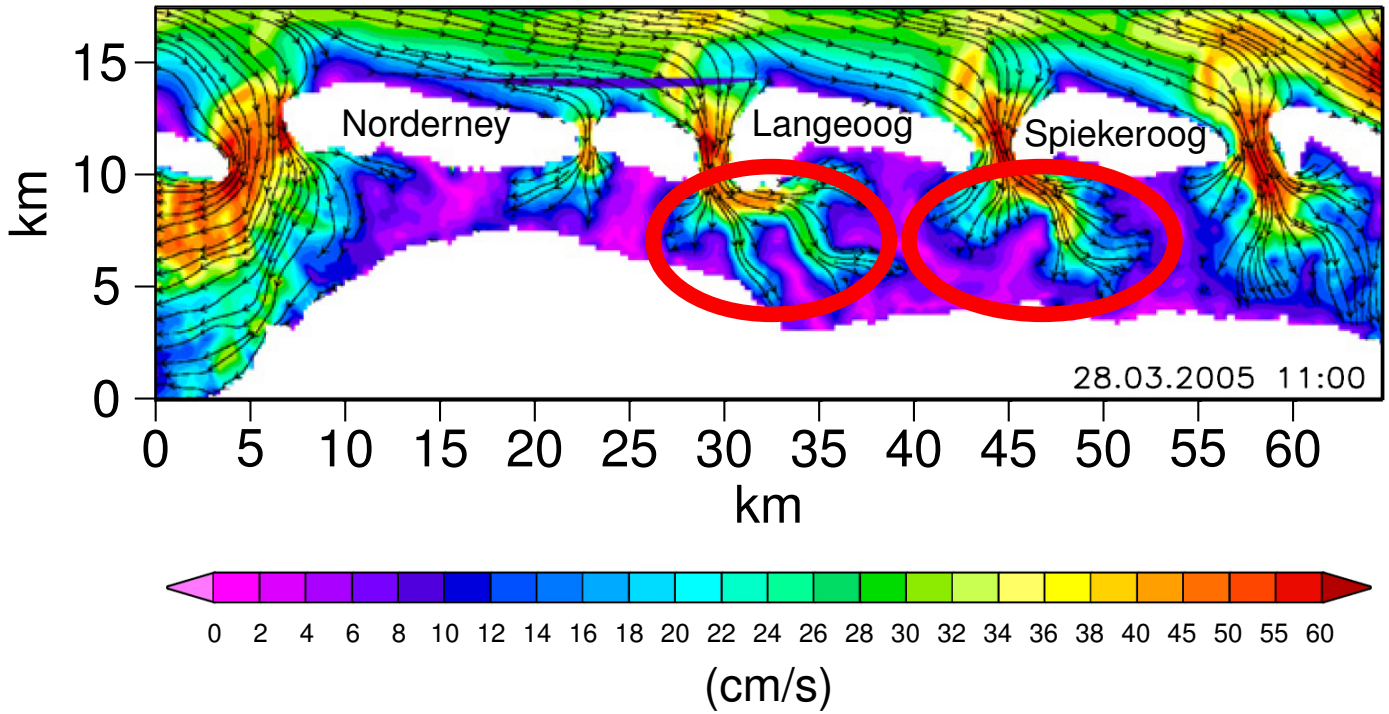

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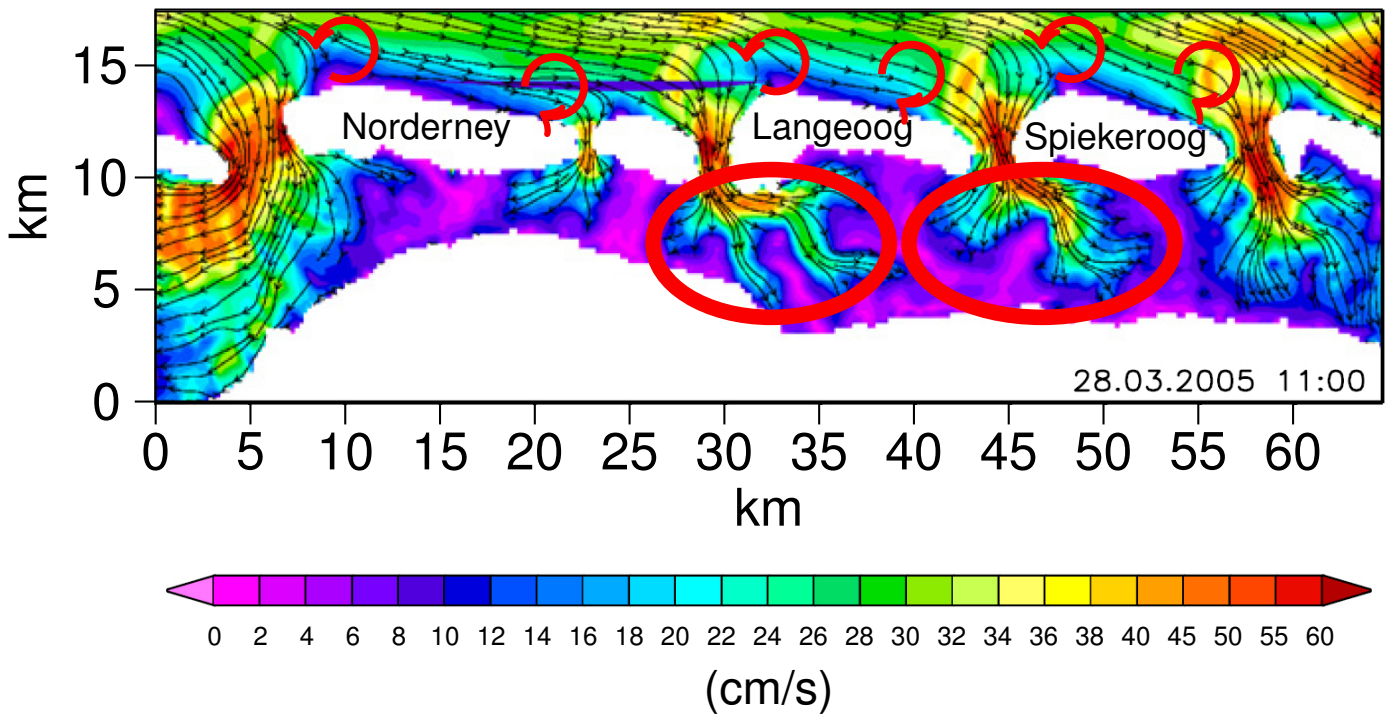

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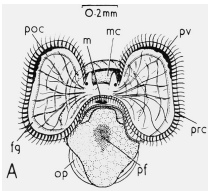

(Fretter and Graham, 1962)

4–7 weeks

(Reid, 1996)

Outline

Main Objectives of the Study

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- Larval recruitment?
- Population preference?
- Morphological differentiation?
- Genetic differentiation?

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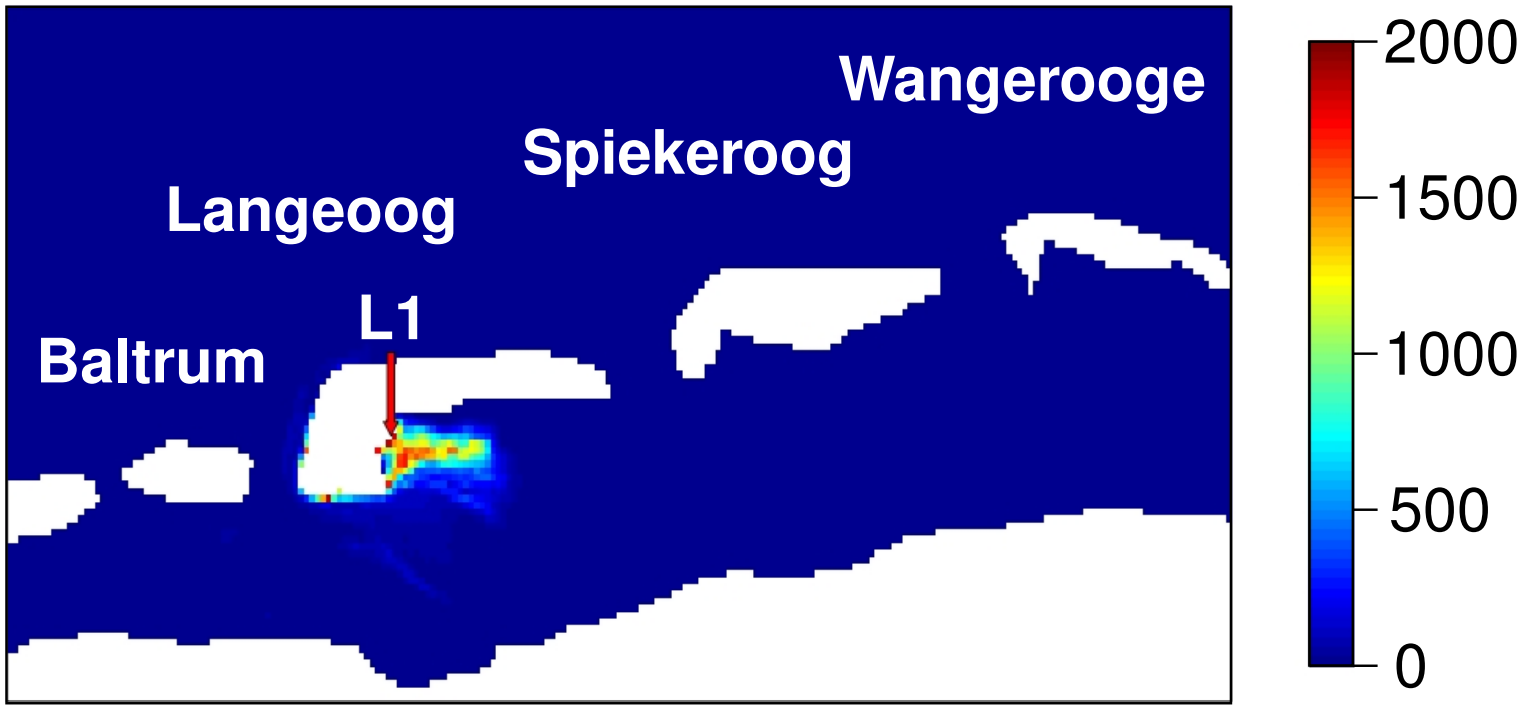
Larval Dispersal in the Wadden Sea was Simulated



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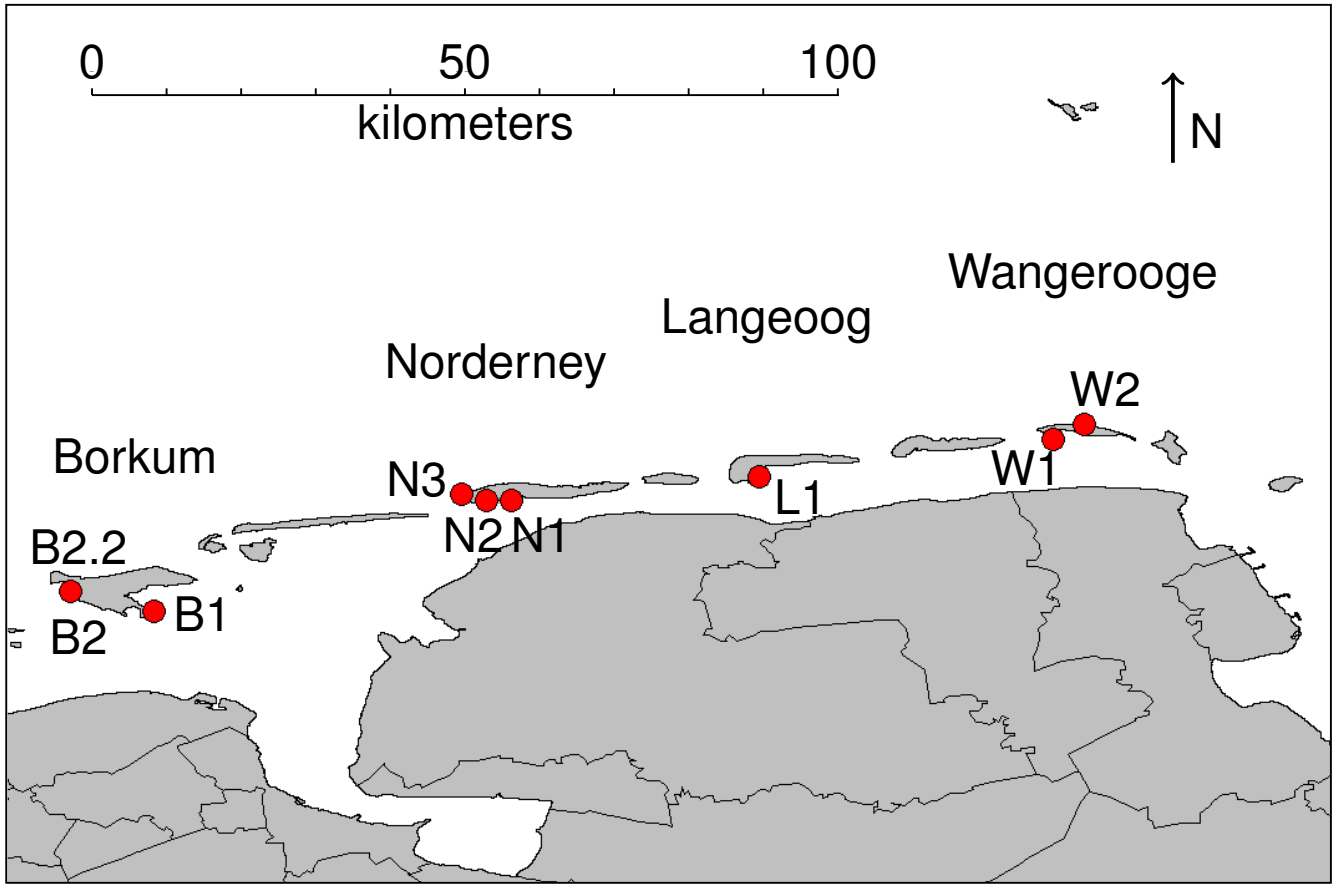
Sampling Sites



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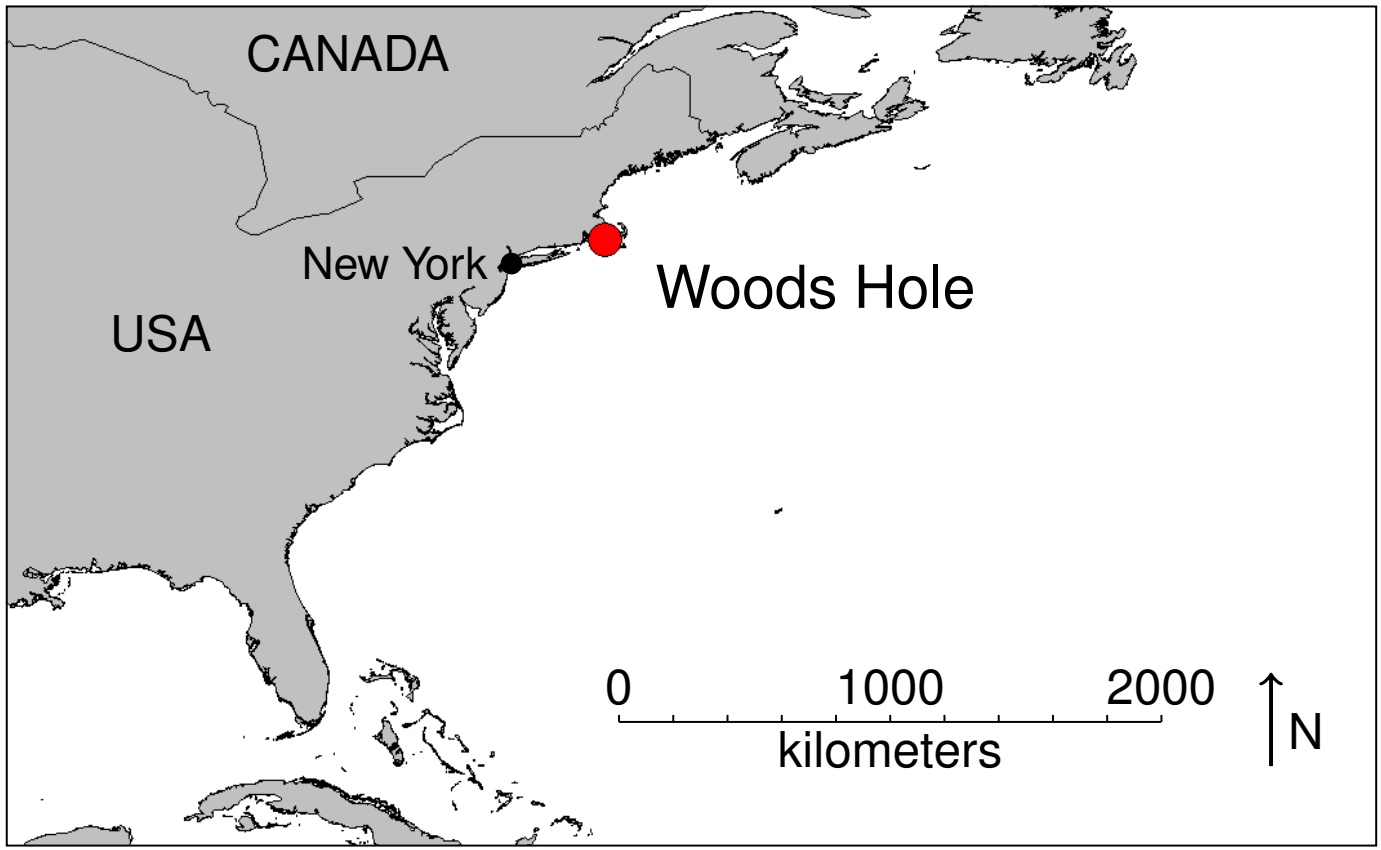
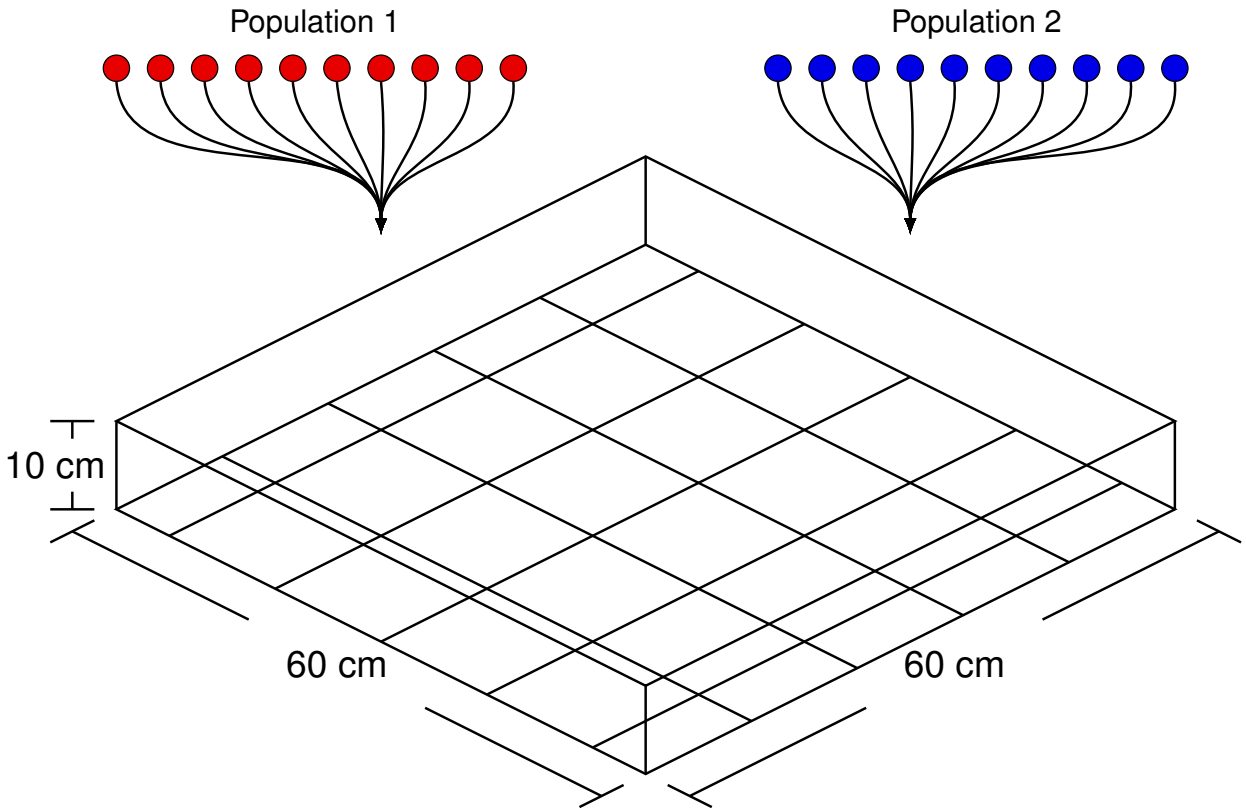


Outline

Conspecifics Aggregate on Hard Bottom Substrate

(Geller–Grimm, 2000)

Snails of 2 Populations Aggregated in Basins



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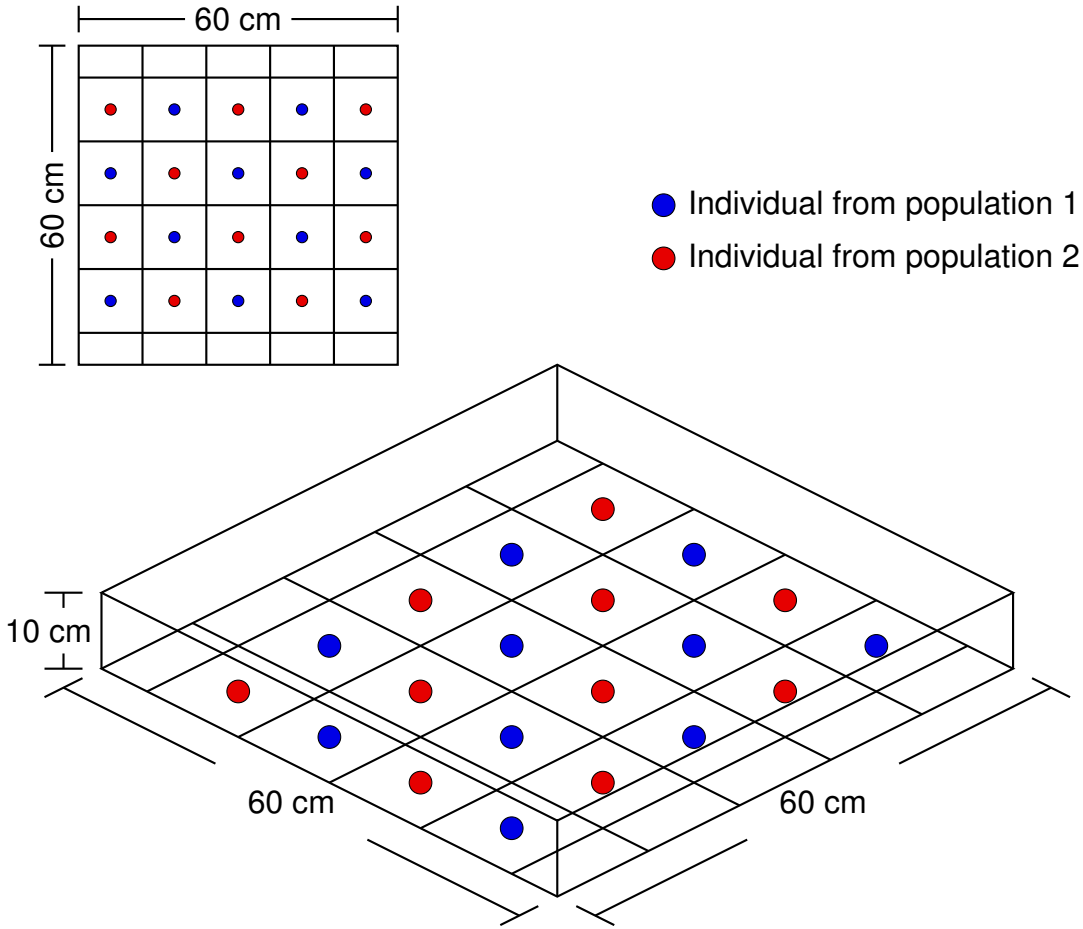

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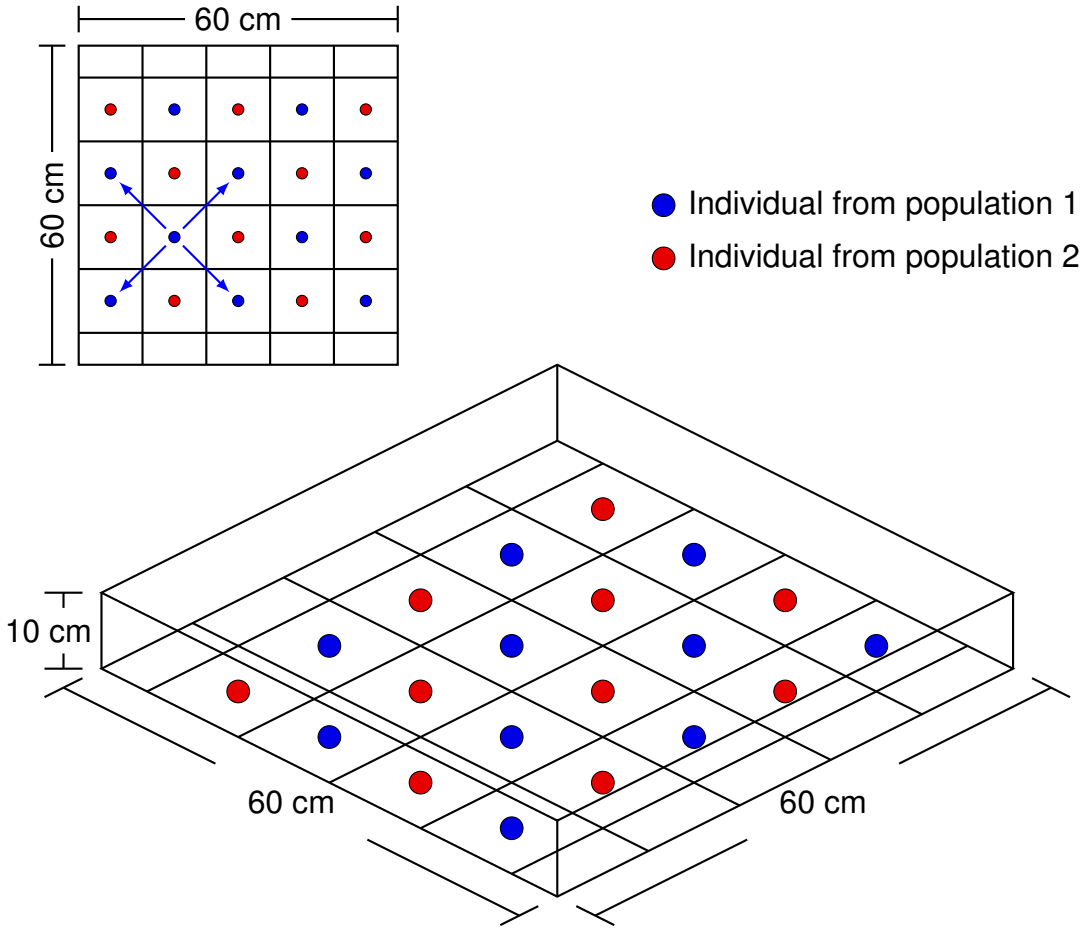

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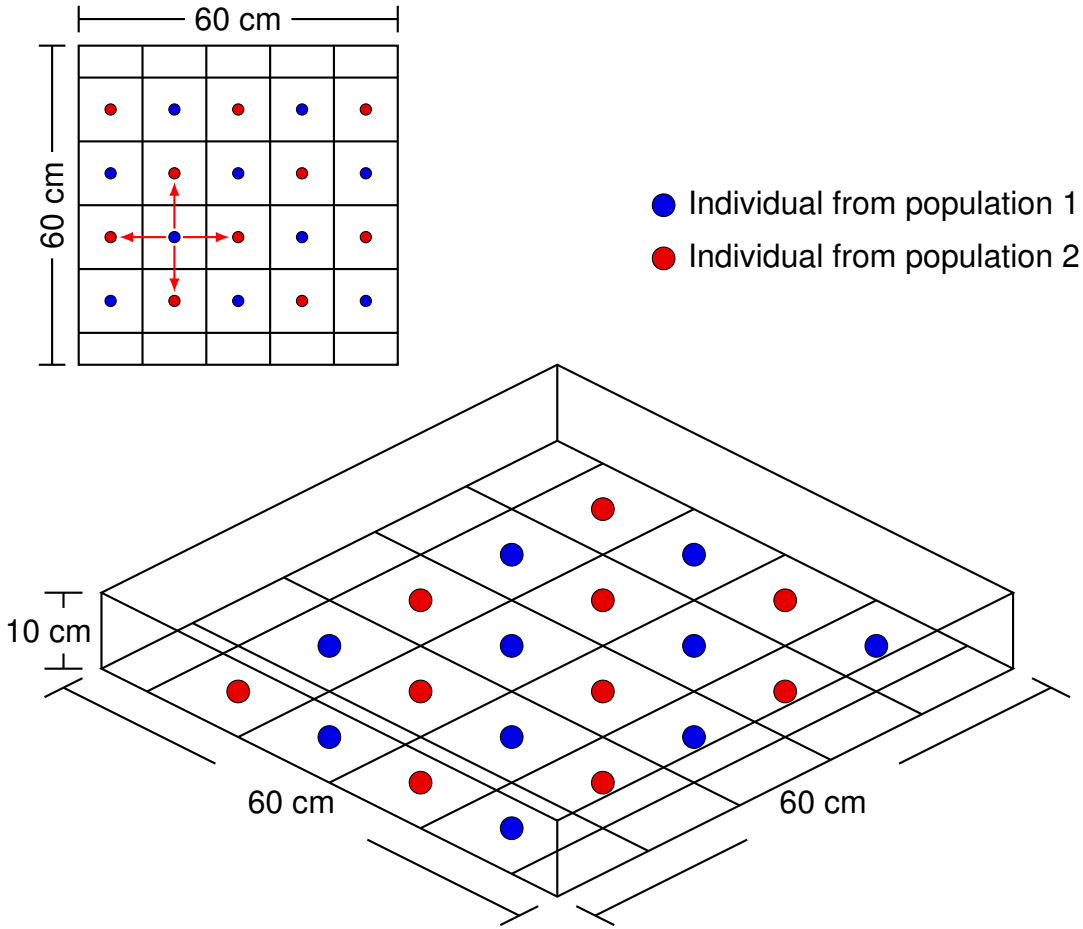
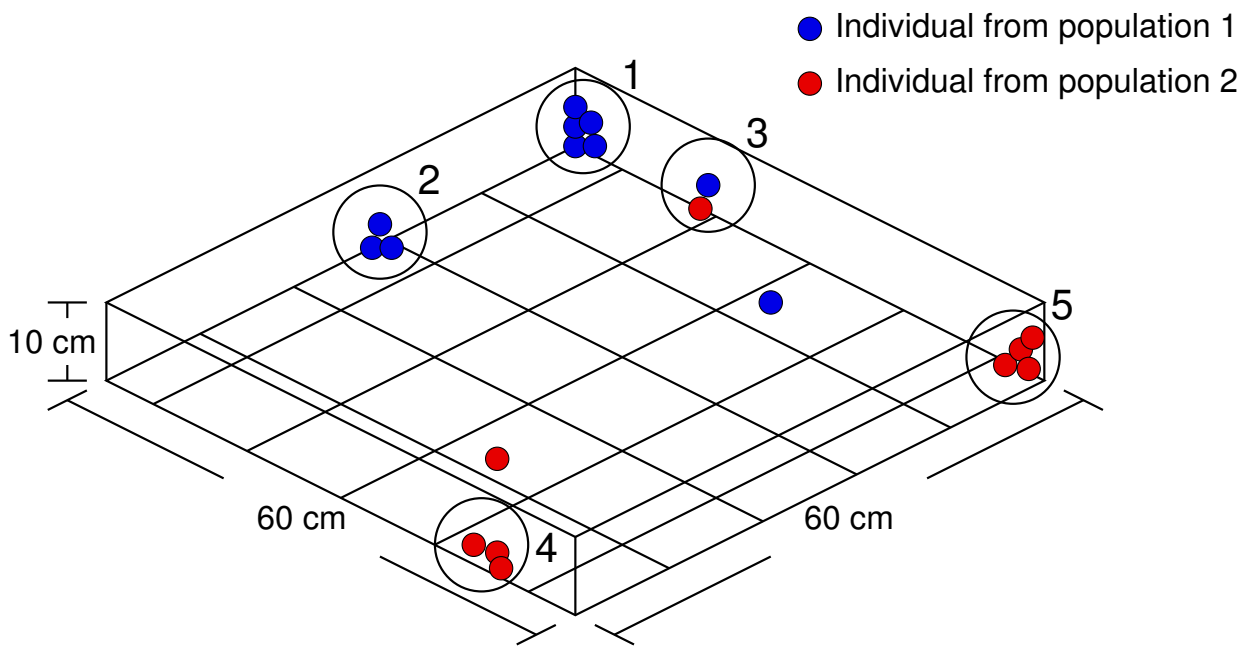


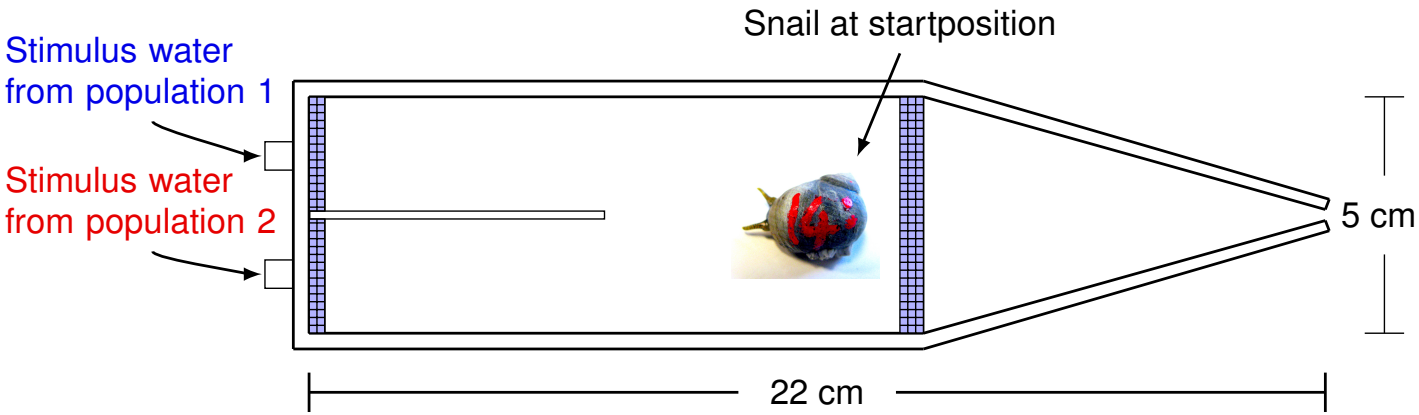
Analysis of Aggregation Experiments

. . . one hour later



- Population Preference Index PPI -

Testing Snails in Olfactory Choice Flumes



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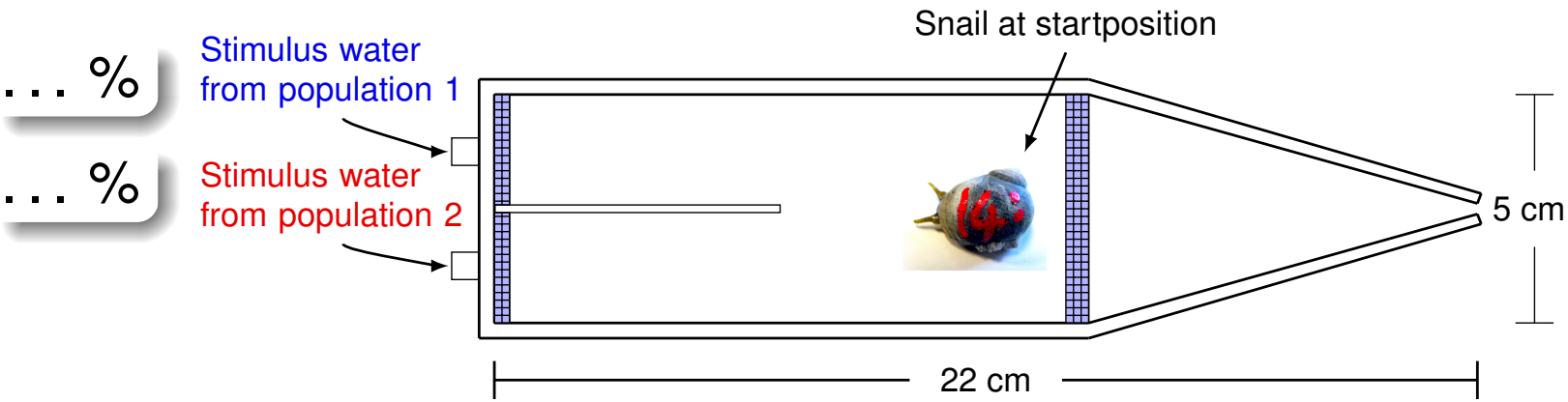

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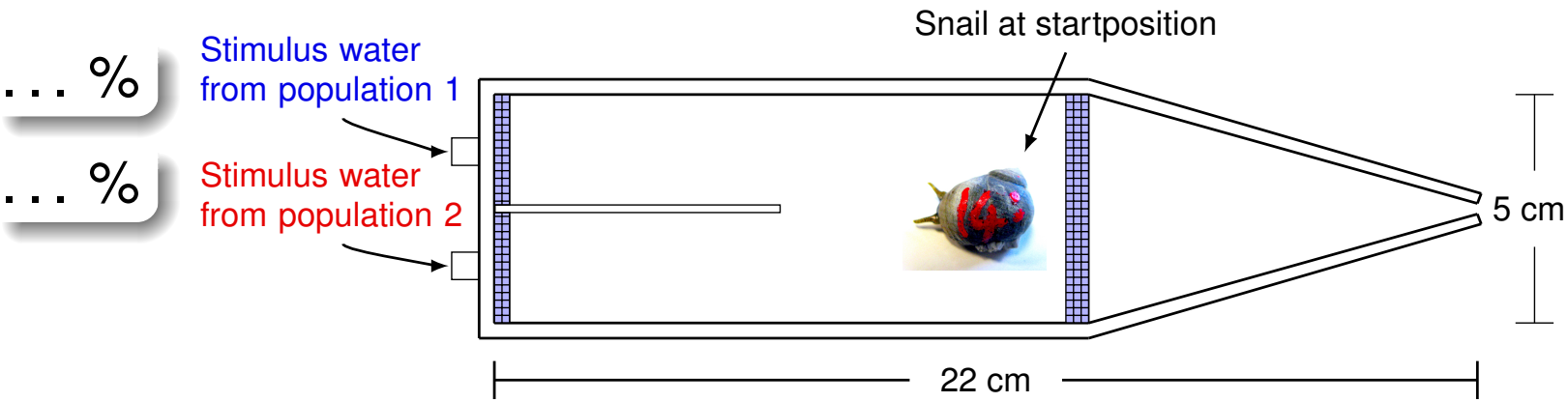
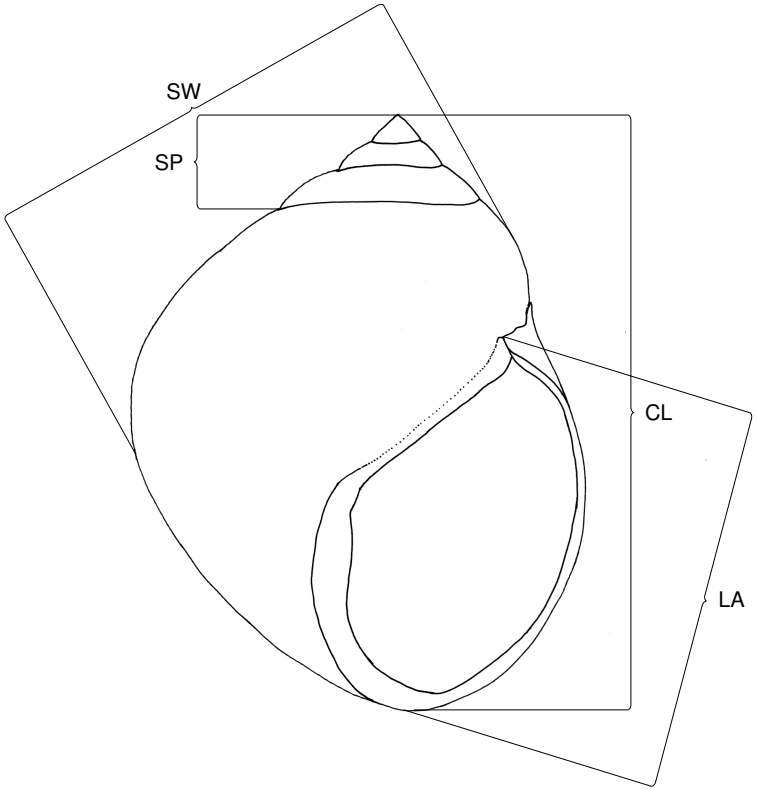


Wilcoxon signed-rank test

Outline

Measurements of the Shell



Linear discriminant analysis

Outline

Genetic Differentiation at Microsatellite Markers

- 48–55 individuals/population
- 5 microsatellite loci
- Differentiation index D_{est} (Jost, 2008)

Outline

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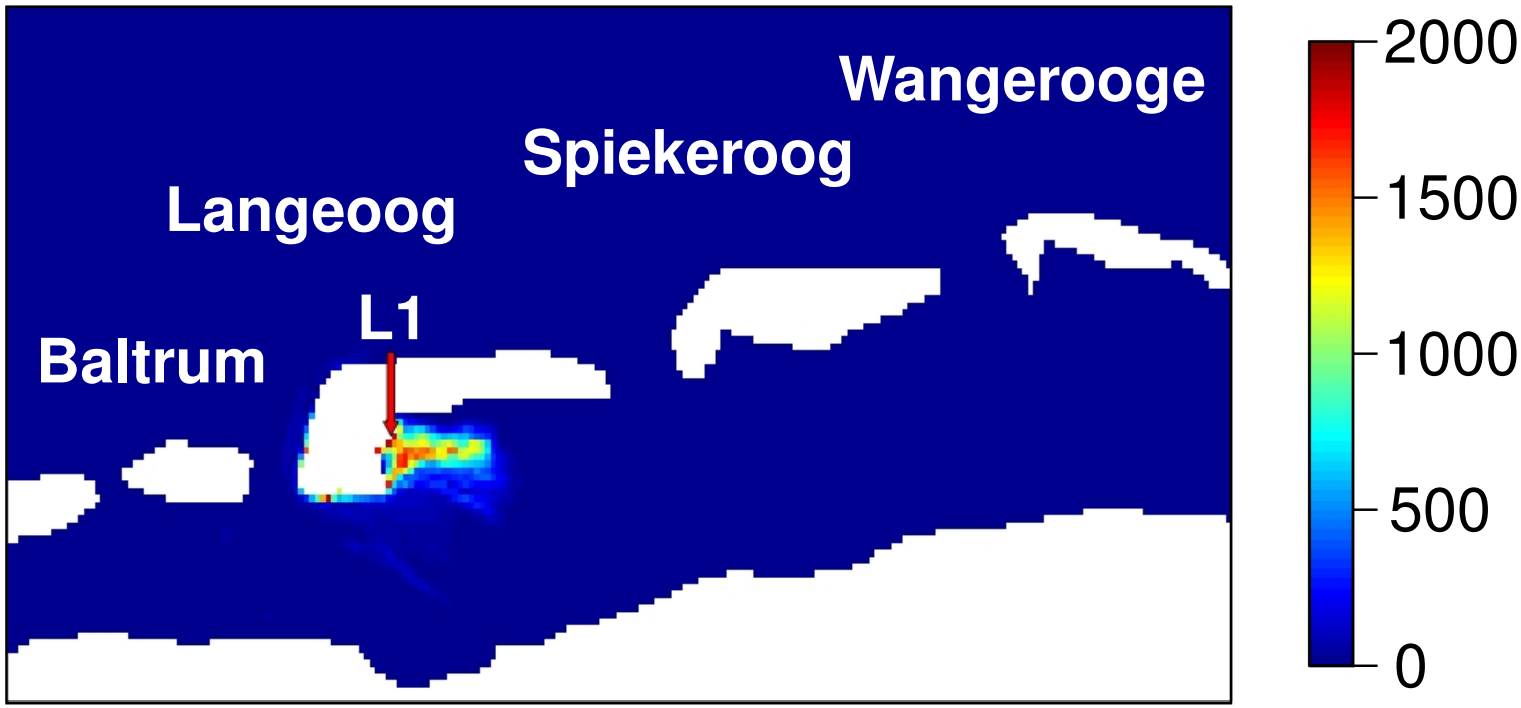
No Local Recruitment by Passive Drift in the EFWS



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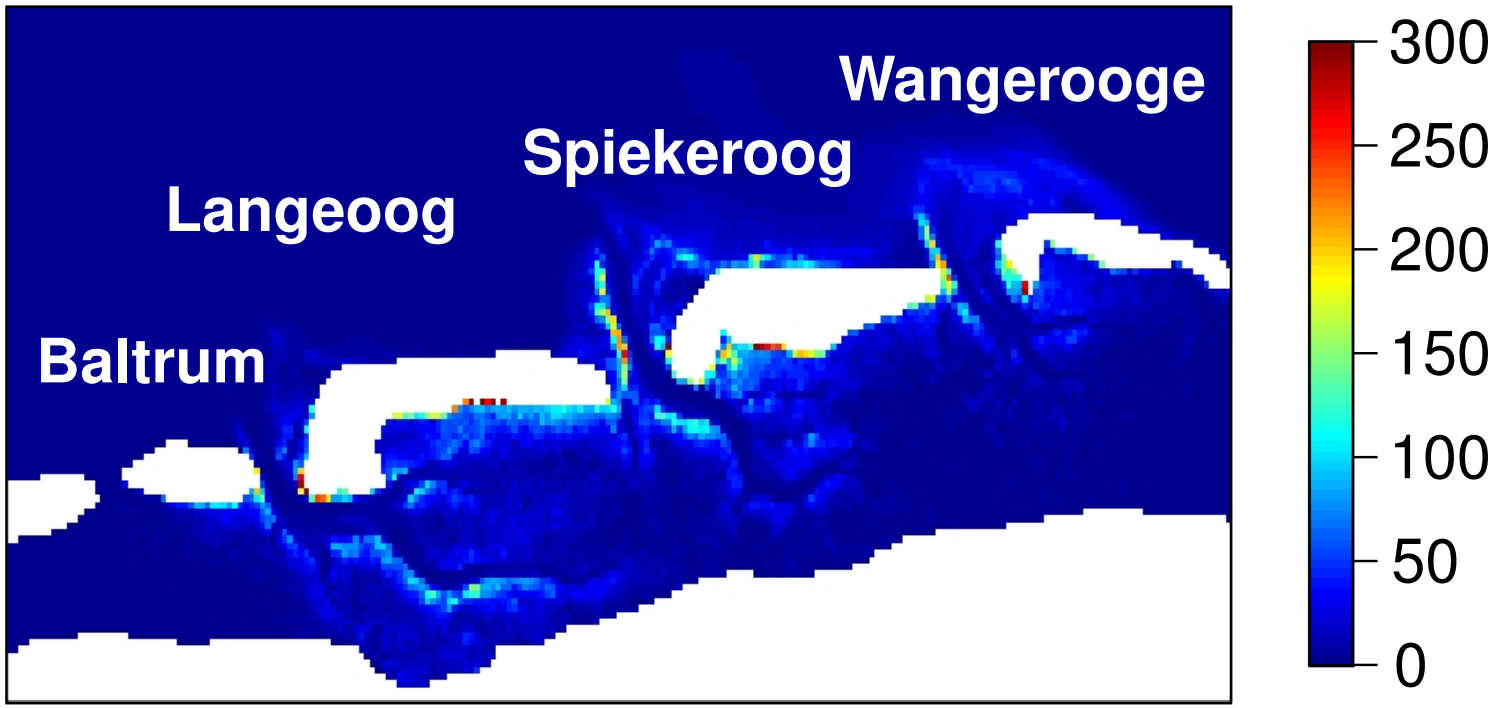
No Local Recruitment by Passive Drift in the EFWS

. . . one week later



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Outline

Snails Prefer Conspecifics of the Own Population

Population-wise aggregation


PPI significant ($p \leq 0.1$) in 6 of 17 tests

Attraction to volatile chemicals

No significant preference in any of 18 tests

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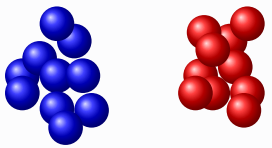

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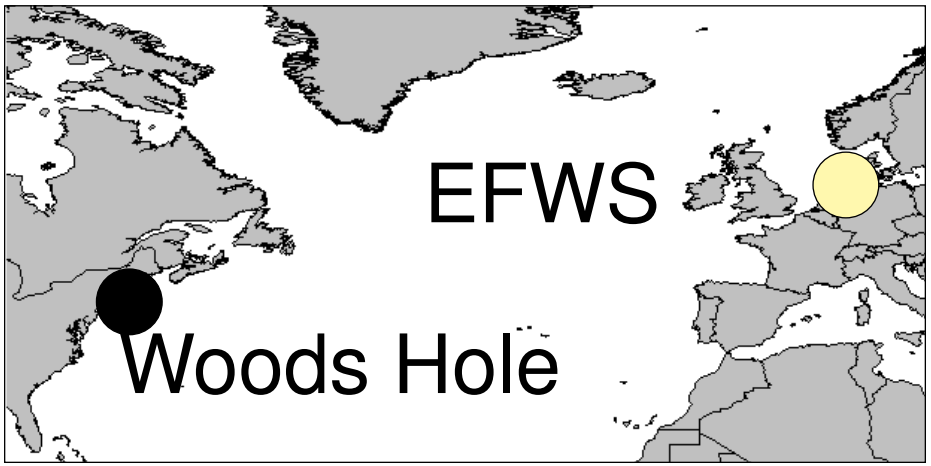
Populations Differ Morphologically

Shell morphology differs between . . .

- Woods Hole – EFWS
- North coasts – South coasts
- North coasts
- South coasts



Wilks' Lambda = 0.867, $p < 0.001$ ***

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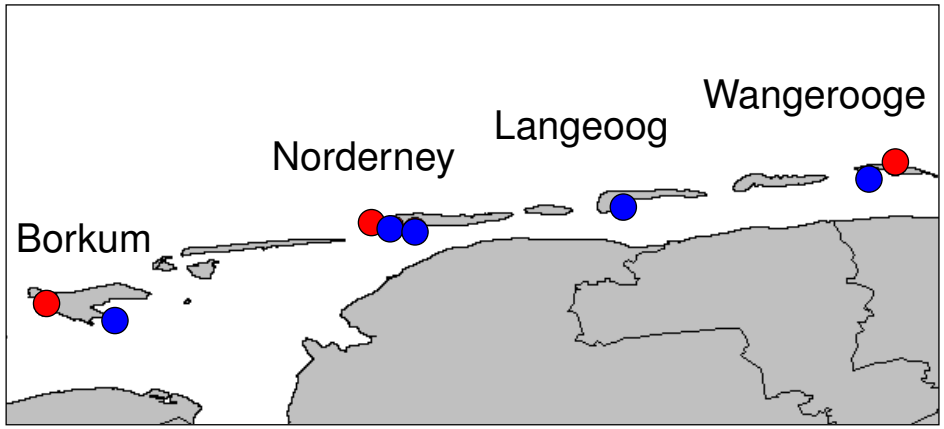

Wilks' Lambda = 0.802, $p < 0.001$ ***

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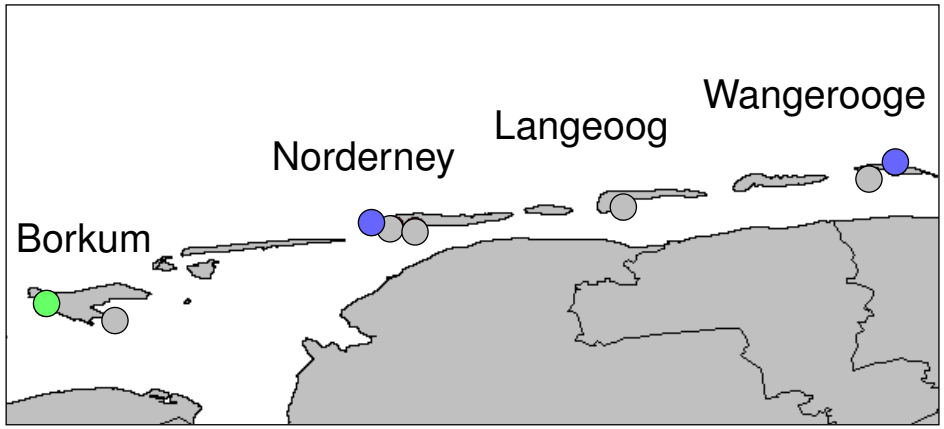

Wilks' Lambda = 0.135, $p < 0.001$ ***

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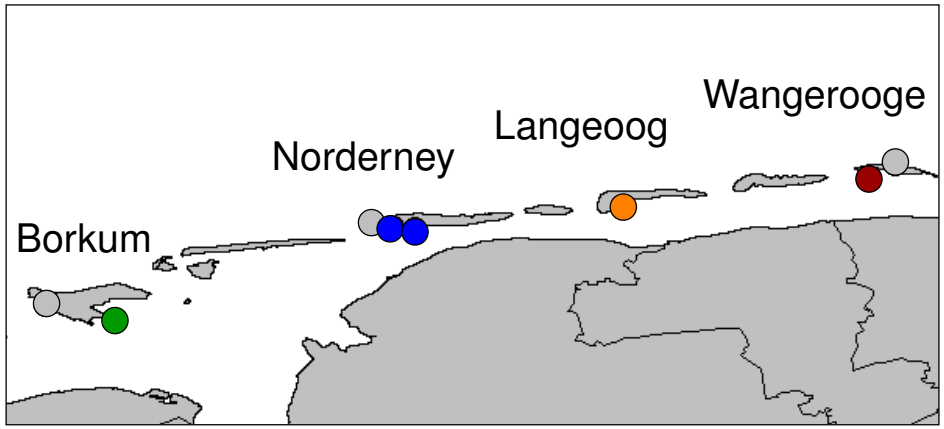


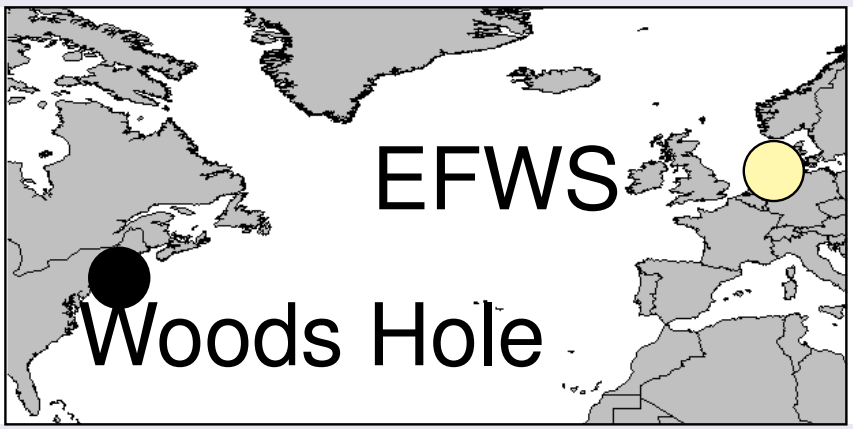
Wilks' Lambda = 0.731, $p < 0.001$ ***

Outline

Genetic Distance . . .

. . . between Woods Hole and East Frisian populations

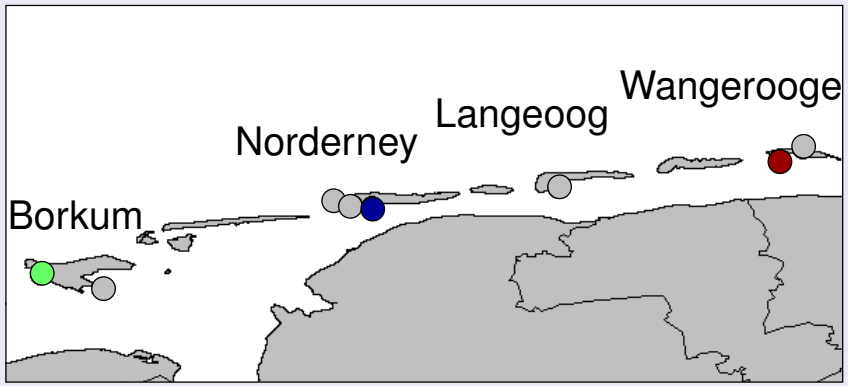
$D_{\text{est}} = 0.033\text{–}0.057$ ***
$p \leq 0.05$



Genetic Distance . . .

. . . between islands

$D_{\text{est}} =$ -0.007–0.001
$p > 0.05$



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Do the Results Indicate Reproductive Isolation?

Objectives

- Larval recruitment?
- Population preference?
- Morphological differentiation?
- Genetic differentiation?

Unanswered questions

- Larval behavior?
- Intrinsic differences
- Recognition cues?
- Assortative mating?
- Expressed loci?
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Overall conclusion

Acknowledgements

Gabriele Gerlach

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Thomas Friedl

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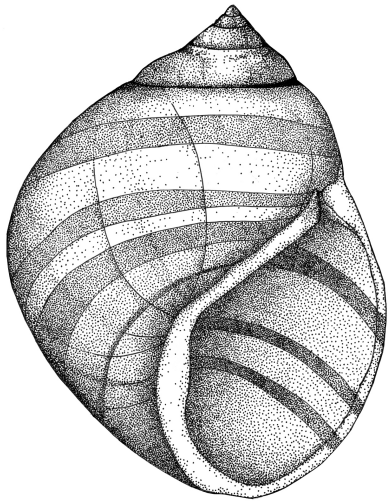
Achim Wehrmann

Anke Müller

Andreas Sommer



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For Further Reading I


Reid, D.G. (1996)
Systematics and Evolution of Littorina.
The Ray Society, London.

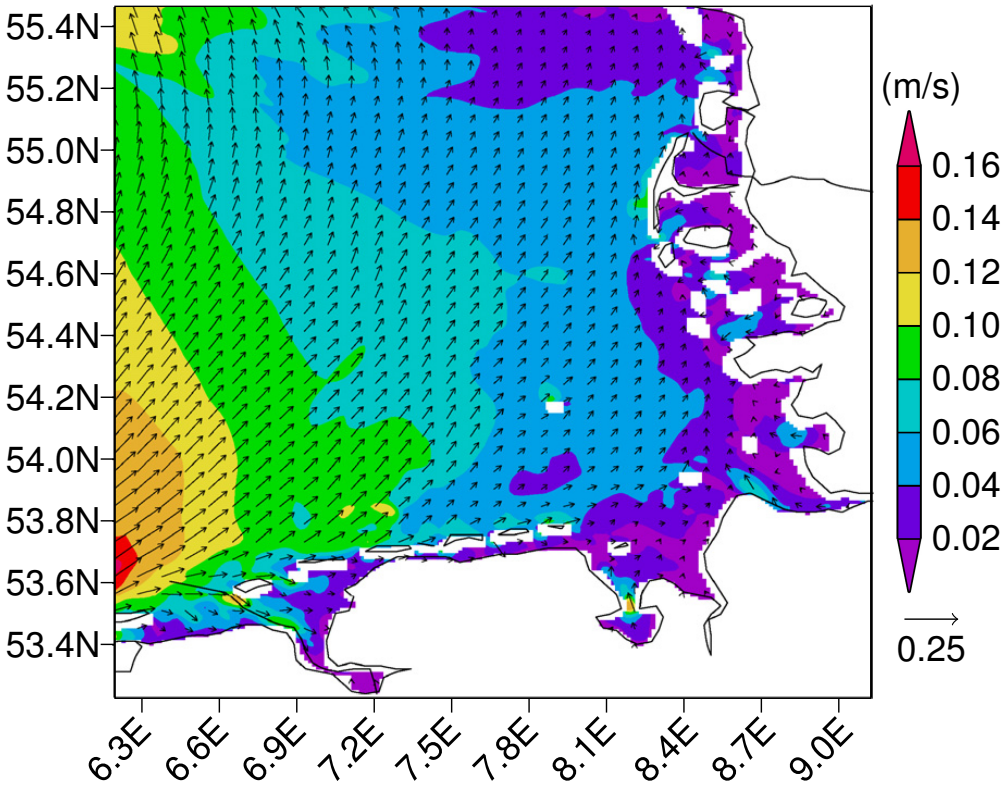

Cowen, R.K. & Sponaugle, S. (2009)
Larval dispersal and marine population connectivity
Annual Review of Marine Science 1:443–466.

For Further Reading II


Staneva, J.; Stanev, E.V.; Wolff, J.-O.; Badewien, T.H.; Reuter, R.; Flemming, B.; Bartholomä, A. & Bolding, K. (2009)
Hydrodynamics and sediment dynamics in the German Bight. A focus on observations and numerical modelling in the East Frisian Wadden Sea.
Continental Shelf Research 29(1):302–319.

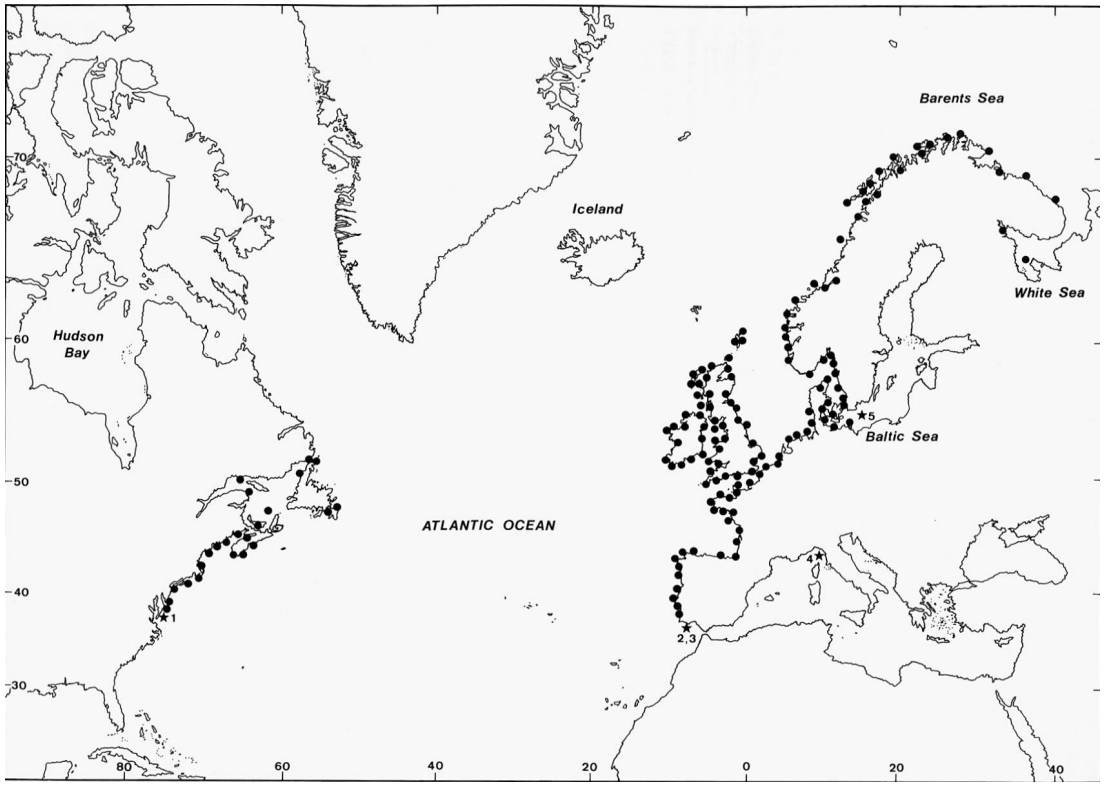

Jost, L. (2008)
Gst and its relatives do not measure differentiation.
Molecular Ecology 17(18):4015–4026.

Residual Current in the German Bight



(Staneva et al., 2009)

L. littorea Occurs on Both Sides of the Atlantic



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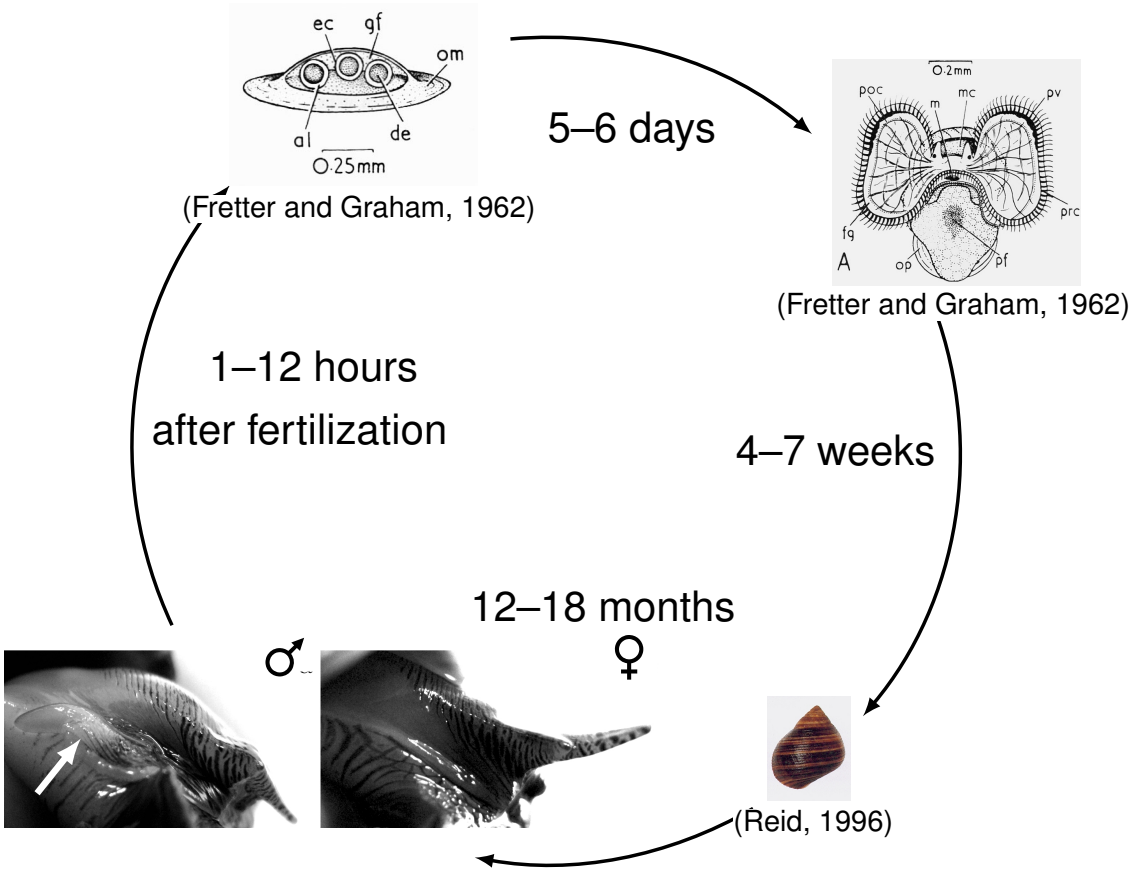

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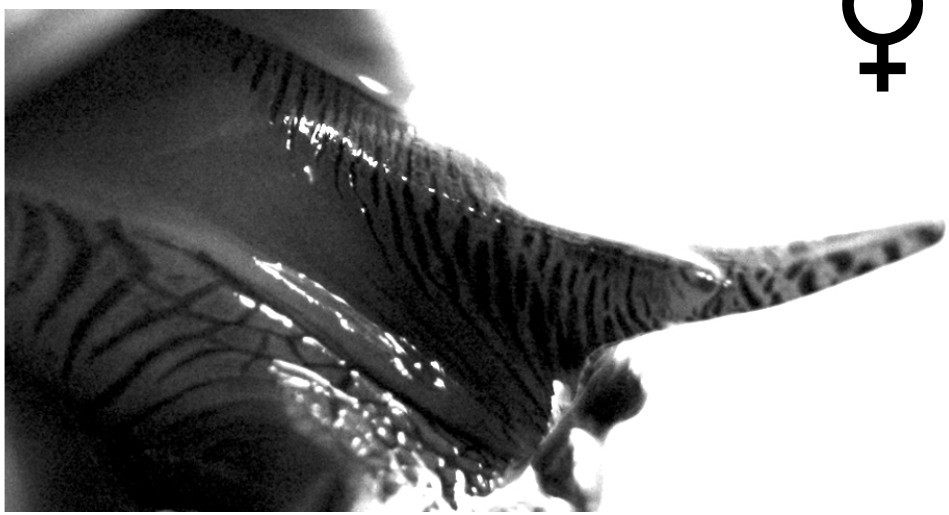

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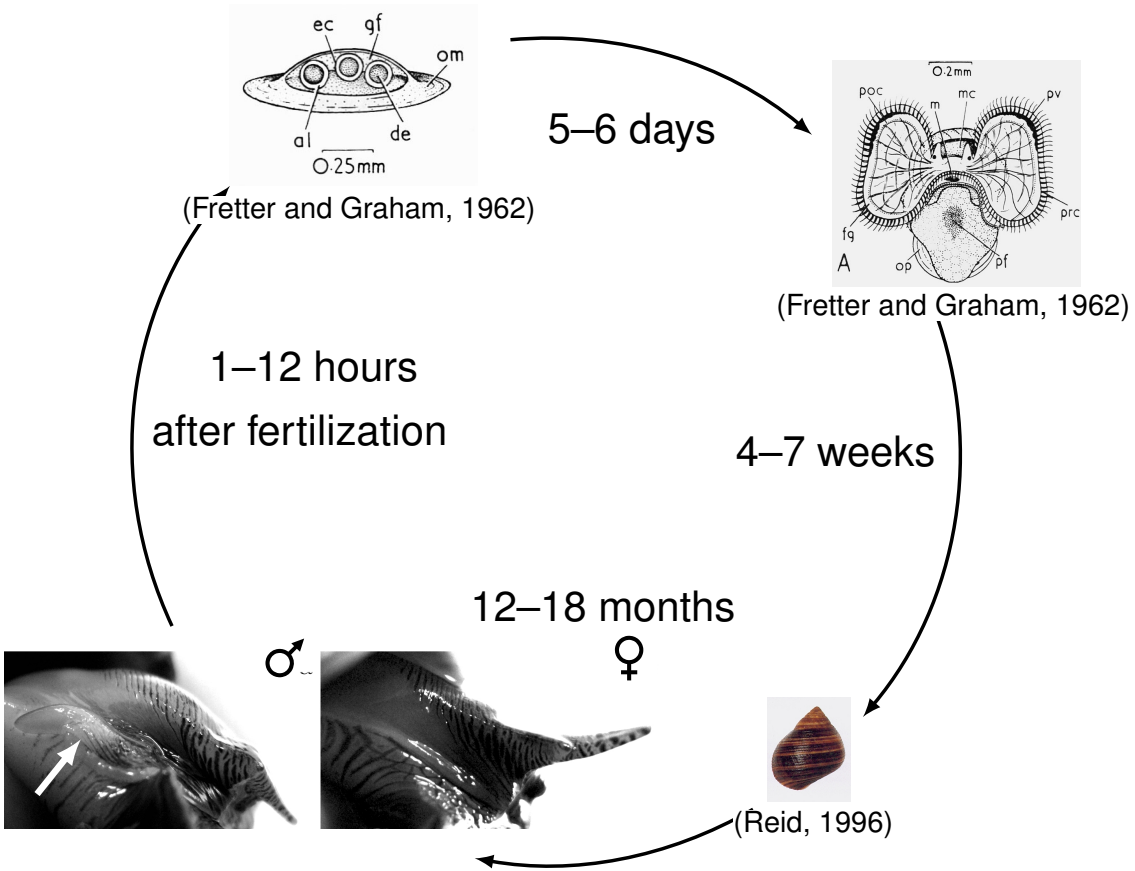
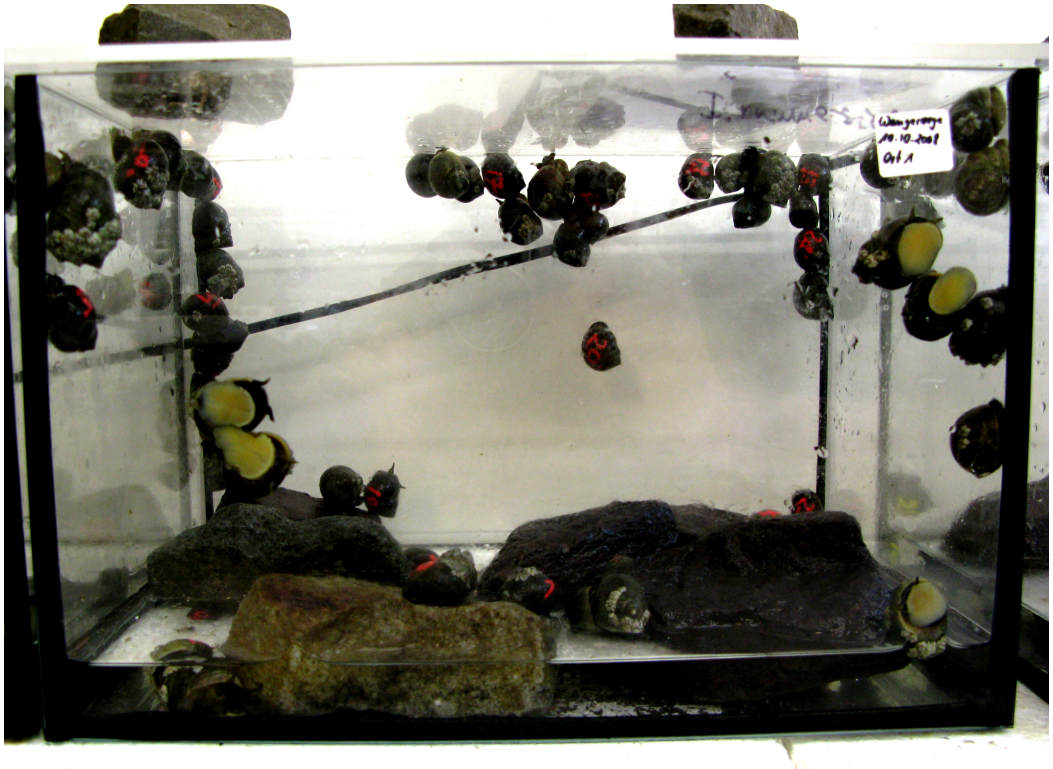
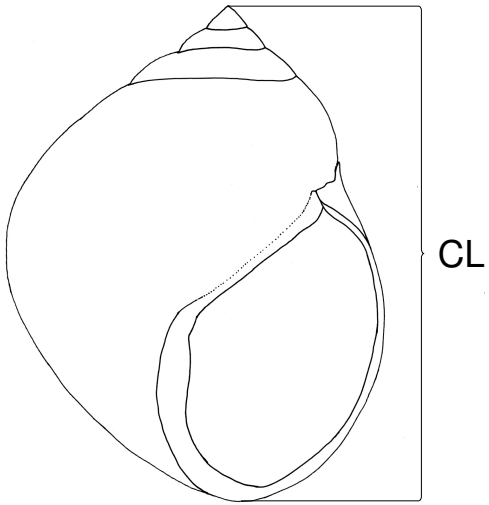


Sampled Snails Were Kept in Aquaria



Snails Were Individually Characterized

Shell height Barnacle fouling Sex



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Shell height | Barnacle fouling | Sex

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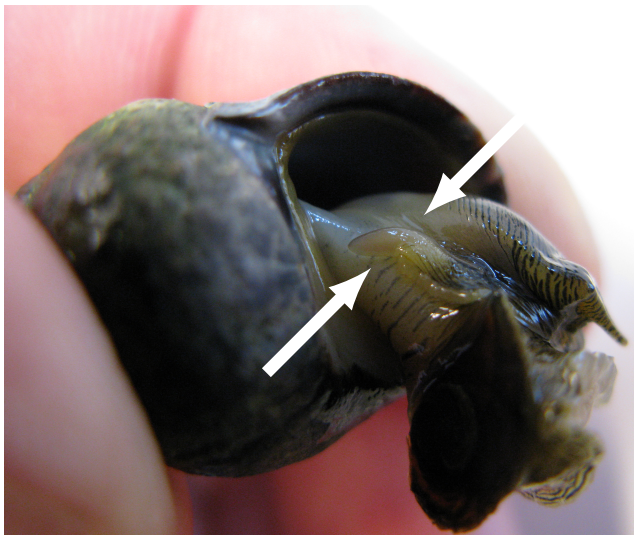
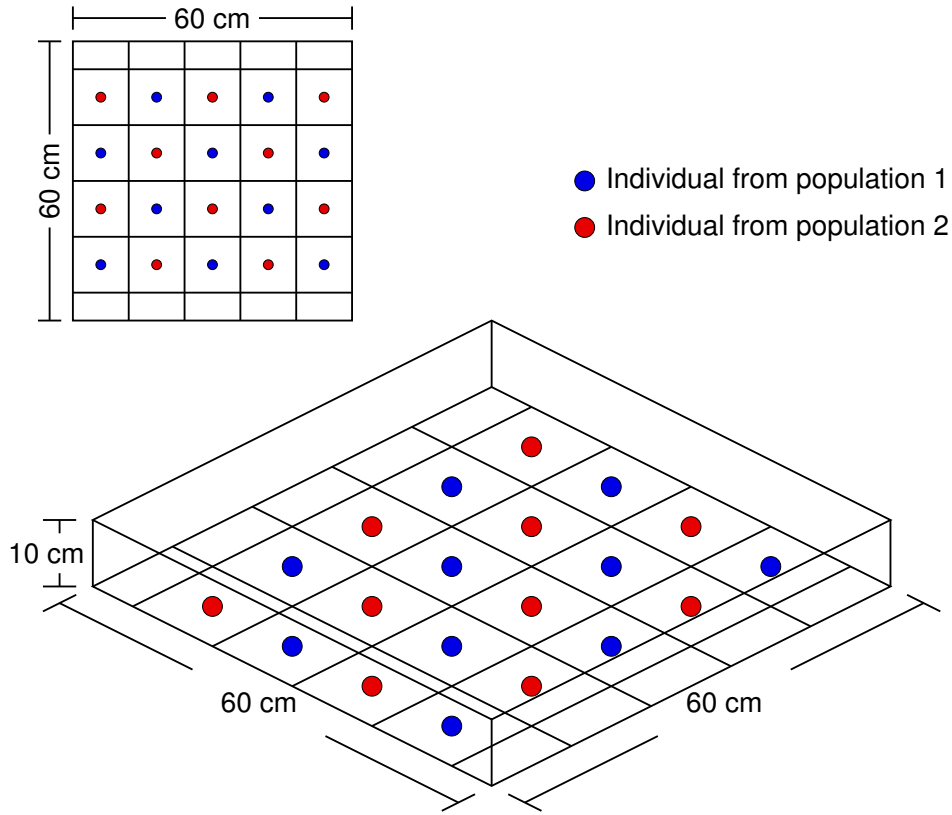
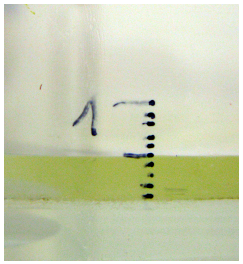
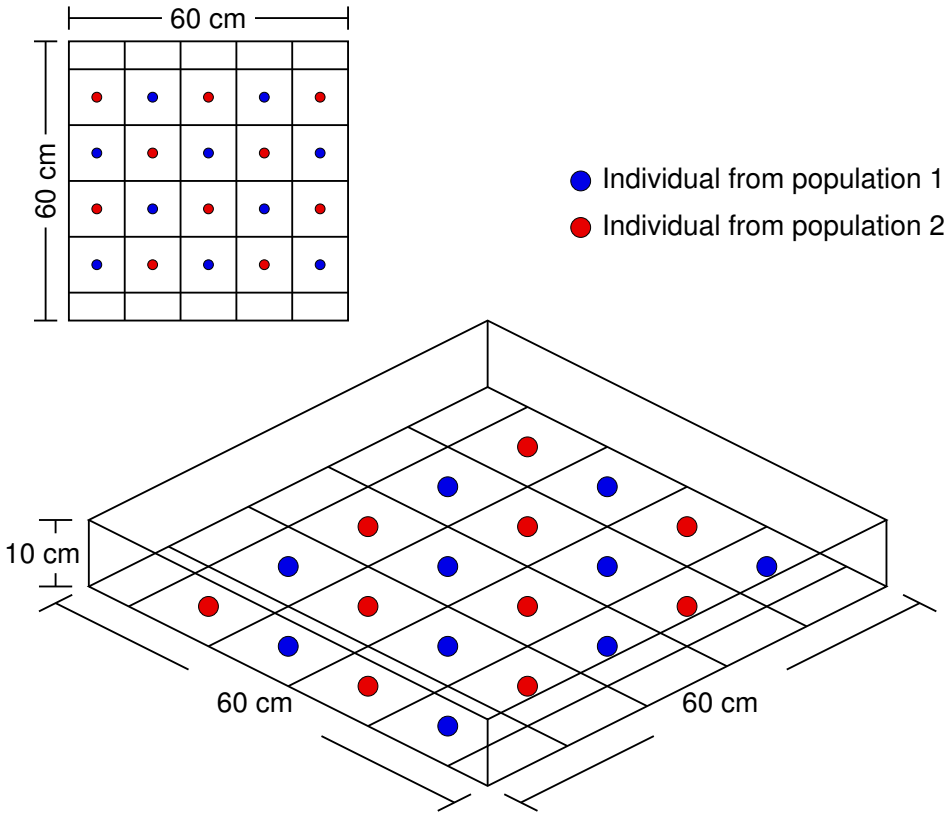


Aggregation Experiments Were Performed in Special Basins

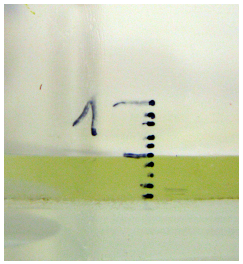


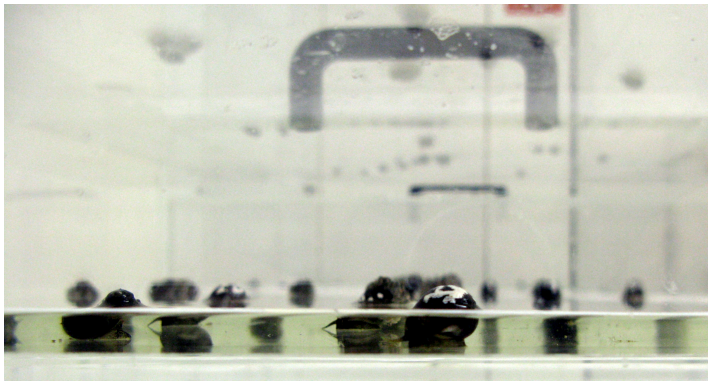
Aggregation Experiments Were Performed in Special Basins

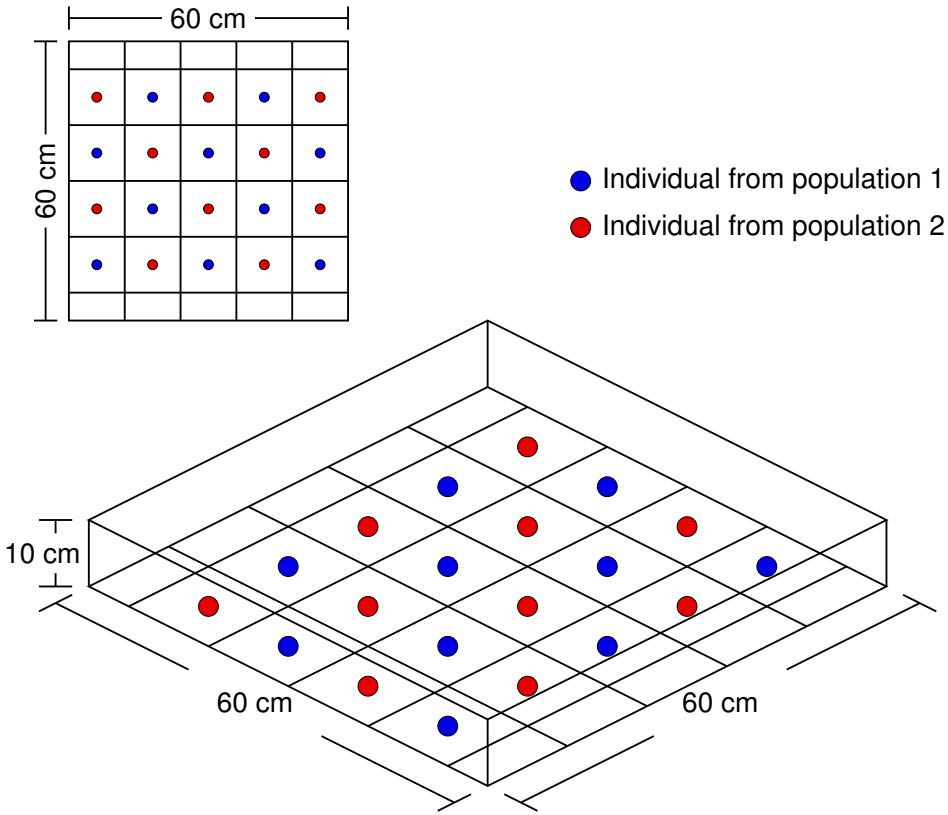




Aggregation Experiments Were Performed in Special Basins

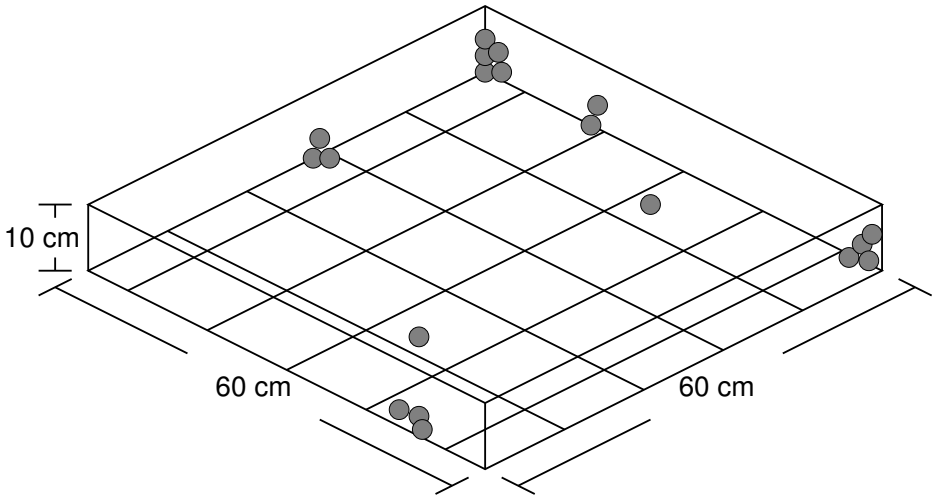






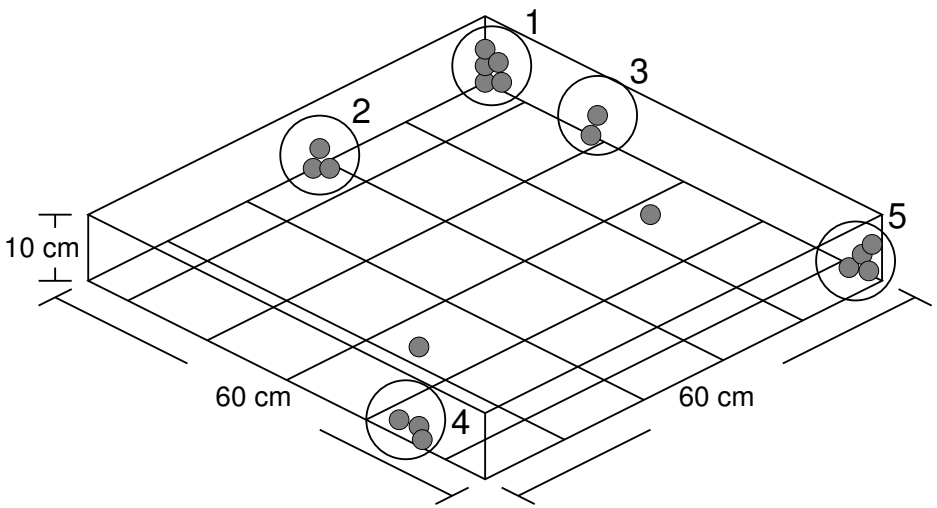
Detailed Analysis of Aggregation experiments

. . . one hour later



. . . 15 tests at least

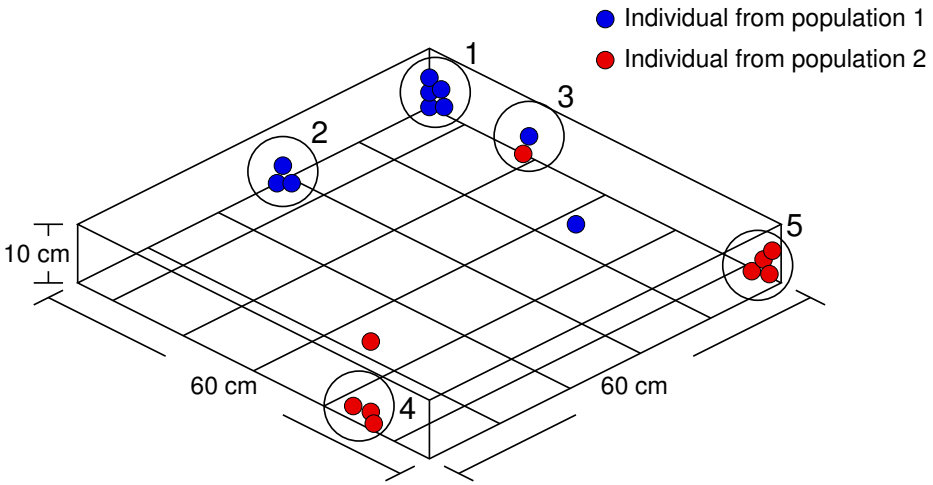
Detailed Analysis of Aggregation experiments



Are certain types of conspecifics preferred?

- Snails of the same population
- Snails of the same sex
- Snails of the same size

Detailed Analysis of Aggregation experiments

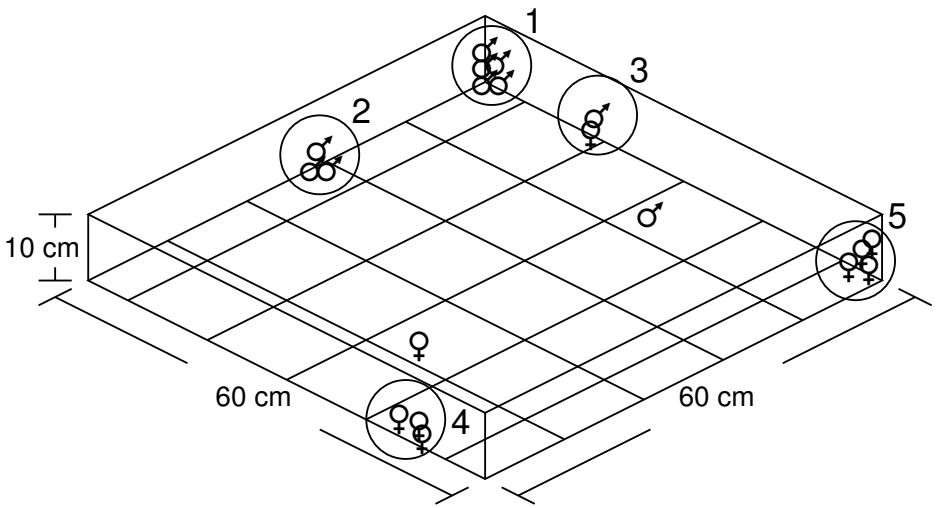


- PPI -

Are certain types of conspecifics preferred?

- Snails of the same population
- Snails of the same sex
- Snails of the same size

Detailed Analysis of Aggregation experiments

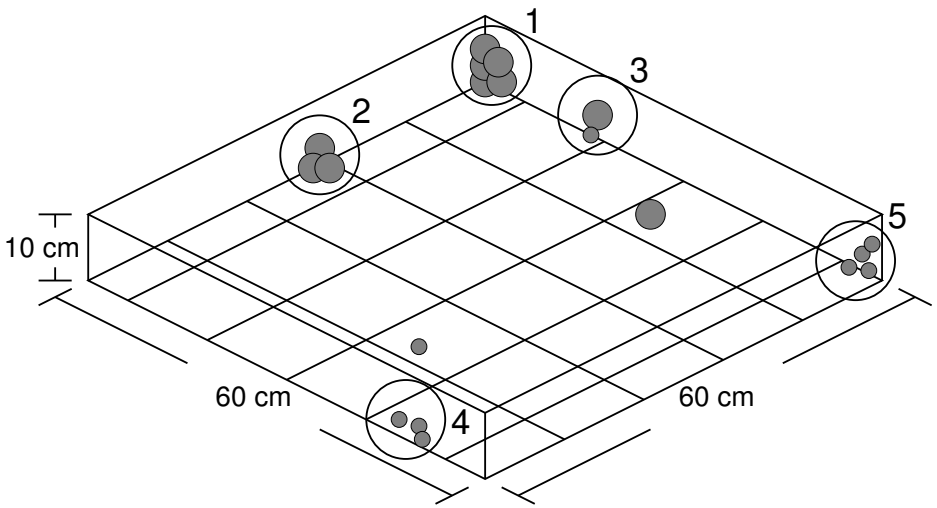


- Sex-PI -

Are certain types of conspecifics preferred?

- Snails of the same population
- Snails of the same sex
- Snails of the same size

Detailed Analysis of Aggregation experiments

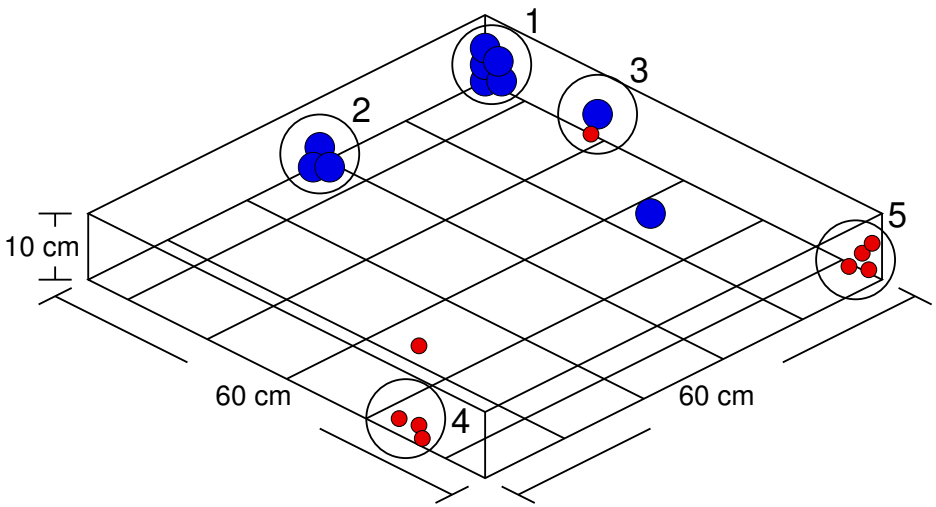


- Size-PI -

Are certain types of conspecifics preferred?

- Snails of the same population
- Snails of the same sex
- Snails of the same size

Detailed Analysis of Aggregation experiments



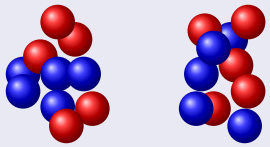
PPI and Size-PI, both high

Are certain types of conspecifics preferred?

- Snails of the same population
- Snails of the same sex
- Snails of the same size

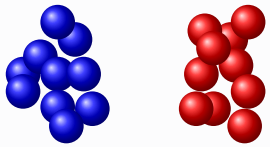
Defining the Population Preference Index

Population mixture



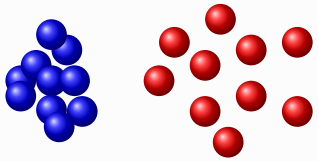
$\bar{p} =$ $var =$

Real population preference



$\bar{p} =$ $var =$

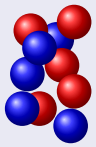
Ambiguous



$\bar{p} =$ $var =$

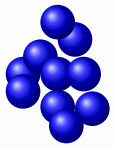
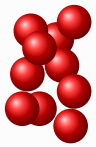
Defining the Population Preference Index

Population mixture

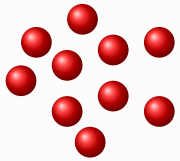
$\overline{p} =$ $var =$

Real population preference

$\overline{p} =$ $var =$

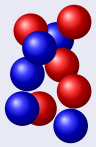
Ambiguous

$\overline{p} =$ $var =$

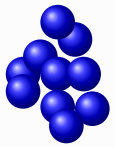
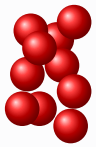
Defining the Population Preference Index

Population mixture

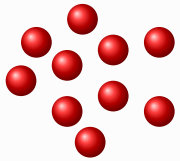
$\overline{p}$ =0.5 var =

Real population preference

$\overline{p}$ = var =

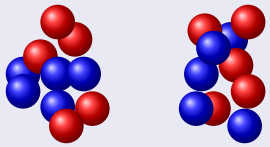
Ambiguous

$\overline{p}$ = var =

Defining the Population Preference Index

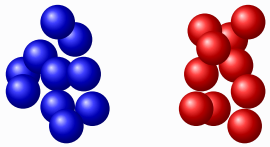
Population mixture



$\overline{p}$ =0.5

var =0.000

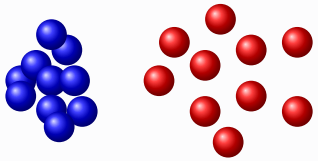
Real population preference



$\overline{p}$ =

var =

Ambiguous

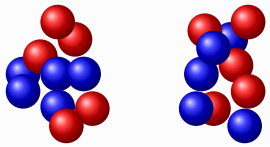


$\overline{p}$ =

var =

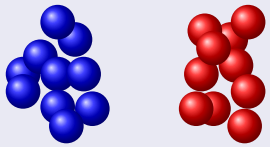
Defining the Population Preference Index

Population mixture



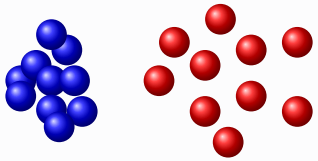
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ = var =

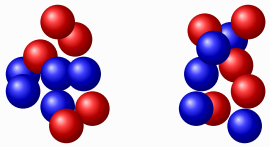
Ambiguous



$\overline{p}$ = var =

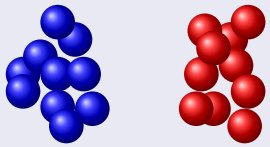
Defining the Population Preference Index

Population mixture



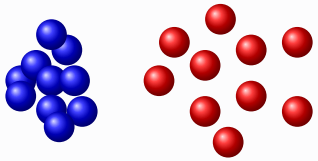
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ =0.5 var =

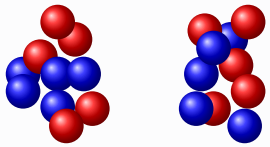
Ambiguous



$\overline{p}$ = var =

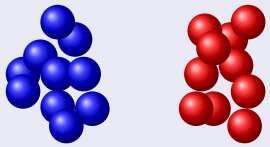
Defining the Population Preference Index

Population mixture



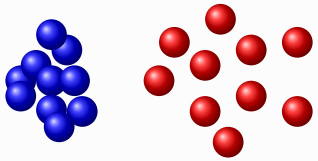
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ =0.5 var =0.263

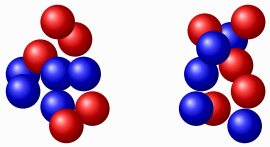
Ambiguous



$\overline{p}$ = var =

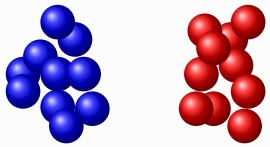
Defining the Population Preference Index

Population mixture



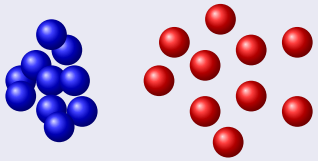
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ =0.5 var =0.263

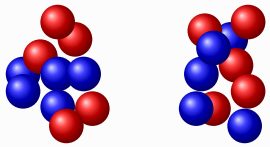
Ambiguous



$\overline{p}$ = var =

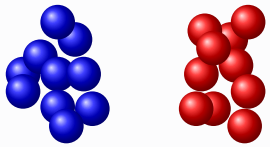
Defining the Population Preference Index

Population mixture



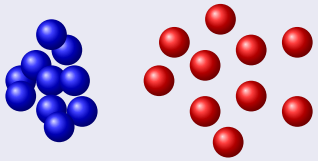
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ =0.5 var =0.263

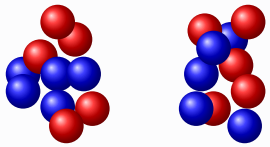
Ambiguous



$\overline{p}$ =1.0 var =

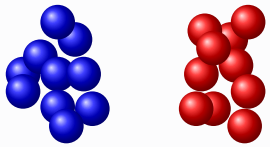
Defining the Population Preference Index

Population mixture



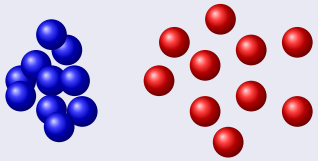
$\overline{p}$ =0.5 *var* =0.000

Real population preference



$\overline{p}$ =0.5 *var* =0.263

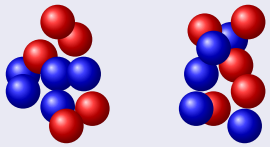
Ambiguous



$\overline{p}$ =1.0 *var* =0.000

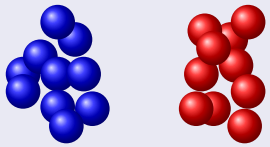
Defining the Population Preference Index

Population mixture



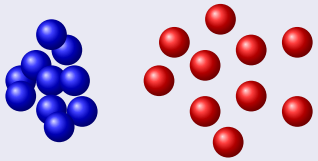
$\overline{p}$ =0.5 *var* =0.000

Real population preference



$\overline{p}$ =0.5 *var* =0.263

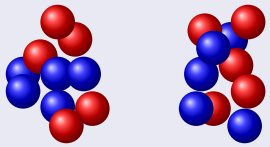
Ambiguous



$\overline{p}$ =1.0 *var* =0.000

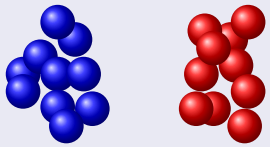
Defining the Population Preference Index

Population mixture



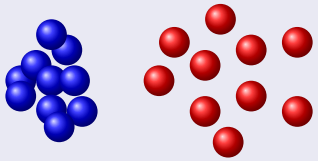
$\overline{p} = 0.5$ $PPI = 0.000$

Real population preference



$\overline{p} = 0.5$ $PPI = 0.263$

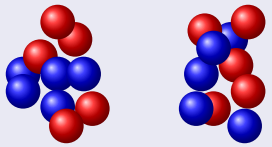
Ambiguous



$\overline{p} = 1.0$ $PPI = 0.000$

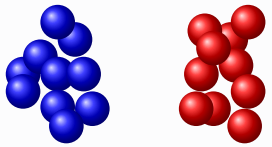
Defining the Population Preference Index in Detail

Population mixture



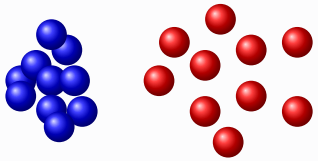
$\bar{p} =$ $var =$

Real population preference



$\bar{p} =$ $var =$

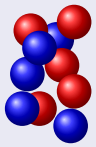
Ambiguous



$\bar{p} =$ $var =$

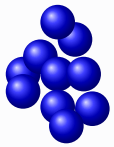
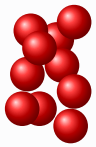
Defining the Population Preference Index in Detail

Population mixture

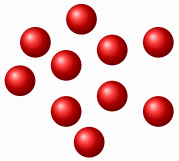
$$\overline{p} = \frac{\frac{5}{10} * 10 + \frac{5}{10} * 10}{20} \qquad var =$$

Real population preference

$$\overline{p} = \qquad var =$$

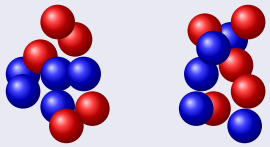
Ambiguous

$$\overline{p} = \qquad var =$$

Defining the Population Preference Index in Detail

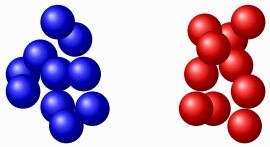
Population mixture



$\overline{p} = 0.5$

$$var = \frac{(\frac{5}{10} - 0.5)^2 * 10 + (\frac{5}{10} - 0.5)^2 * 10}{19}$$

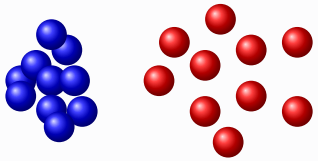
Real population preference



$\overline{p} =$

$var =$

Ambiguous

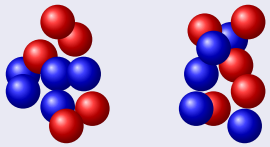


$\overline{p} =$

$var =$

Defining the Population Preference Index in Detail

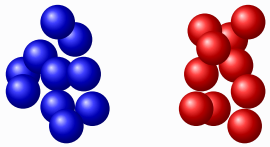
Population mixture



$\overline{p}$ =0.5

var =0.000

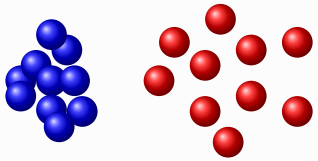
Real population preference



$\overline{p}$ =

var =

Ambiguous

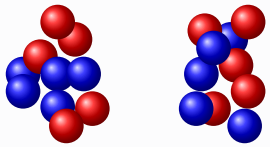


$\overline{p}$ =

var =

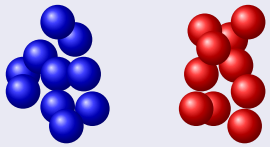
Defining the Population Preference Index in Detail

Population mixture



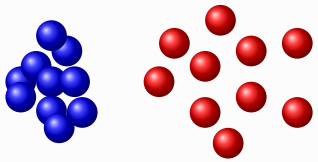
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$$\overline{p} = \frac{\frac{10}{10} * 10 + \frac{0}{10} * 10}{20} \quad var =$$

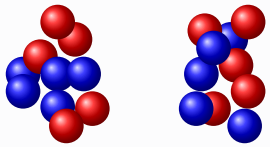
Ambiguous



$\overline{p} =$ $var =$

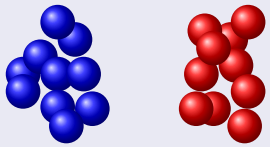
Defining the Population Preference Index in Detail

Population mixture



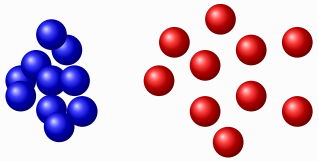
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$\overline{p} = 0.5$ $var = \frac{(\frac{10}{10} - 0.5)^2 * 10 + (\frac{0}{10} - 0.5)^2 * 10}{19}$

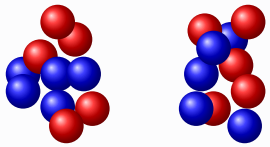
Ambiguous



$\overline{p} =$ $var =$

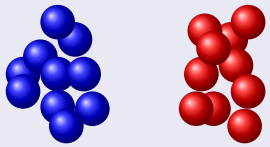
Defining the Population Preference Index in Detail

Population mixture



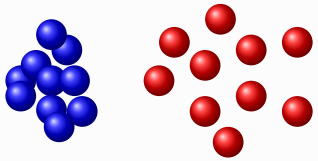
$\overline{p}$ =0.5 var =0.000

Real population preference



$\overline{p}$ =0.5 var =0.263

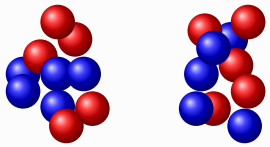
Ambiguous



$\overline{p}$ = var =

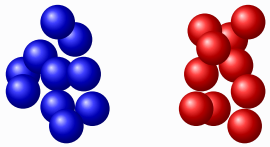
Defining the Population Preference Index in Detail

Population mixture



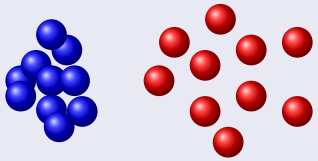
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$\overline{p} = 0.5$ $var = 0.263$

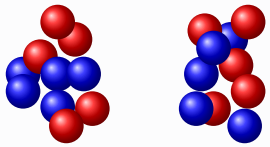
Ambiguous



$\overline{p} = \frac{\frac{10}{10} * 10}{10}$ $var =$

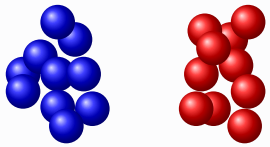
Defining the Population Preference Index in Detail

Population mixture



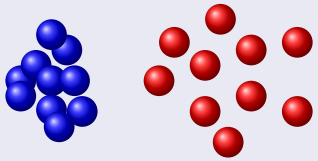
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$\overline{p} = 0.5$ $var = 0.263$

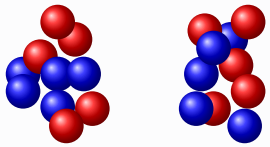
Ambiguous



$\overline{p} = 1.0$ $var = \frac{(\frac{10}{10}-1)^2 * 10}{9}$

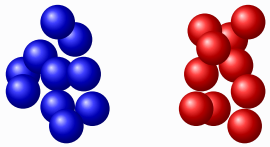
Defining the Population Preference Index in Detail

Population mixture



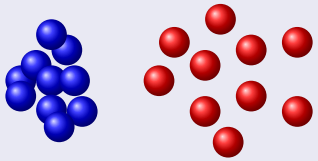
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$\overline{p} = 0.5$ $var = 0.263$

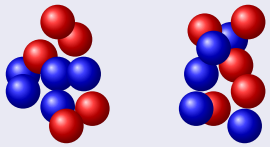
Ambiguous



$\overline{p} = 1.0$ $var = 0.000$

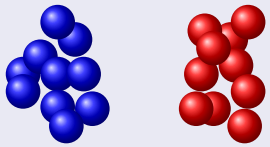
Defining the Population Preference Index in Detail

Population mixture



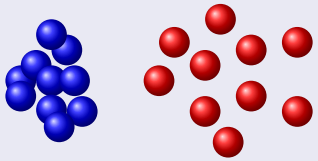
$\overline{p} = 0.5$ $var = 0.000$

Real population preference



$\overline{p} = 0.5$ $var = 0.263$

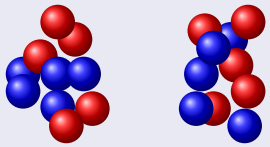
Ambiguous



$\overline{p} = 1.0$ $var = 0.000$

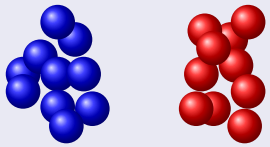
Defining the Population Preference Index in Detail

Population mixture



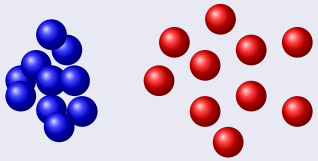
$\overline{p} = 0.5$ $PPI = 0.000$

Real population preference



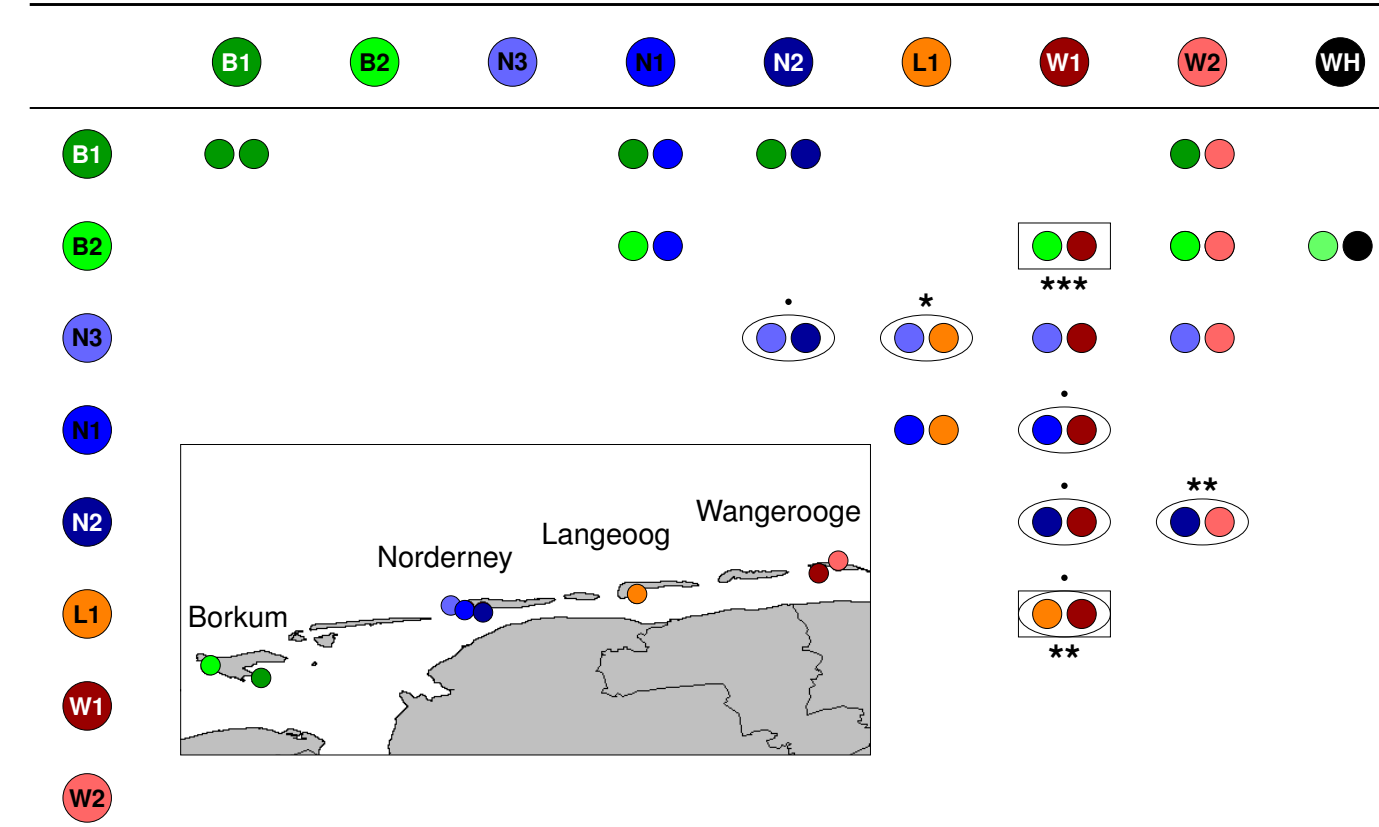
$\overline{p} = 0.5$ $PPI = 0.263$

Ambiguous

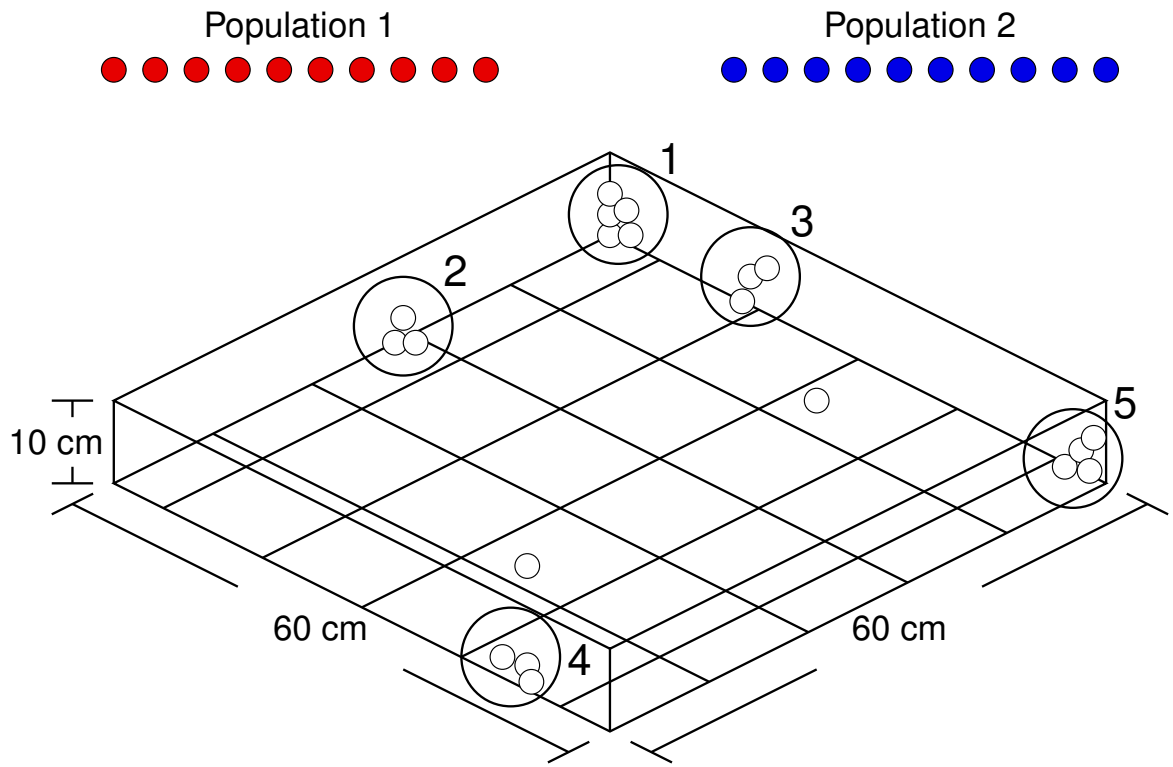


$\overline{p} = 1.0$ $PPI = 0.000$

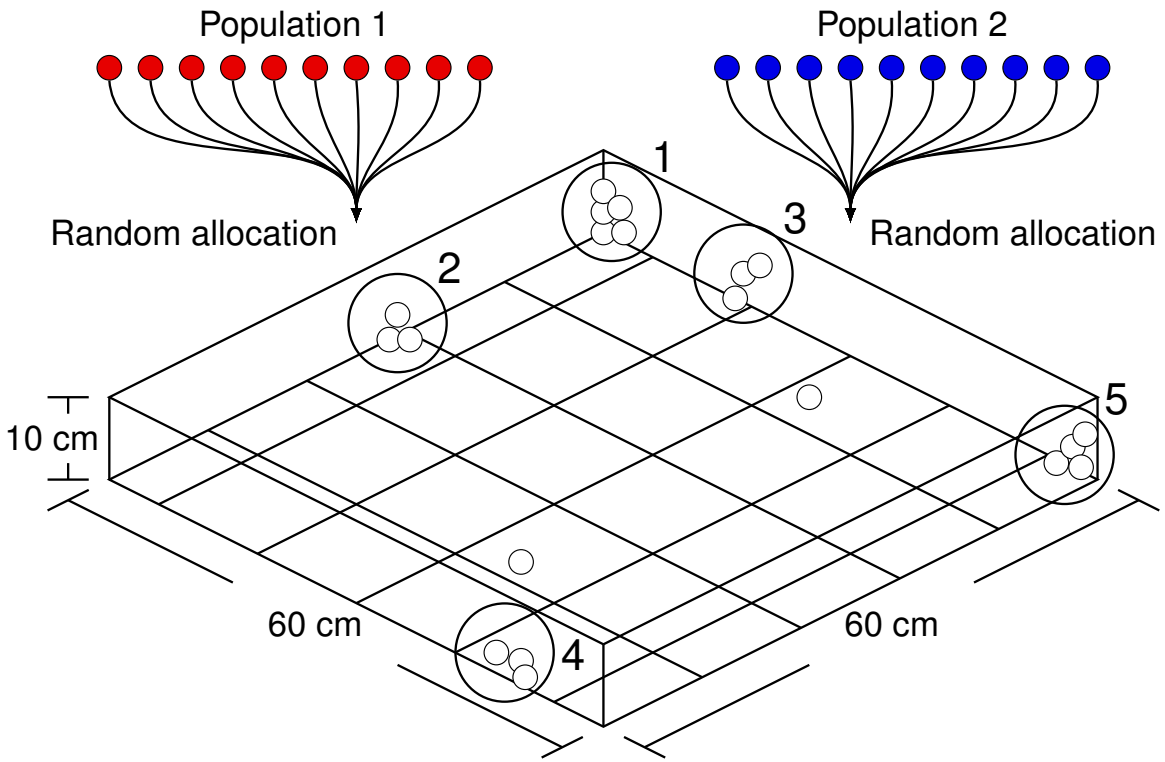
Snails Aggregate Assortatively



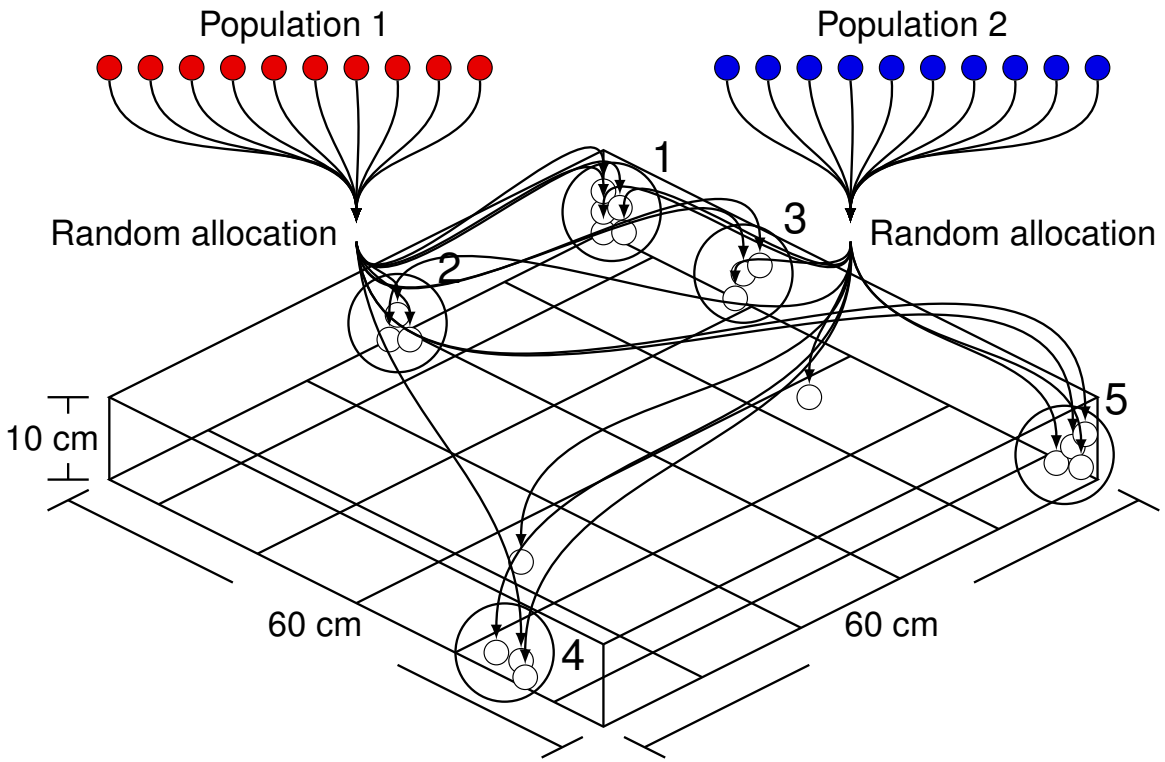
Simplified Monte Carlo Simulation



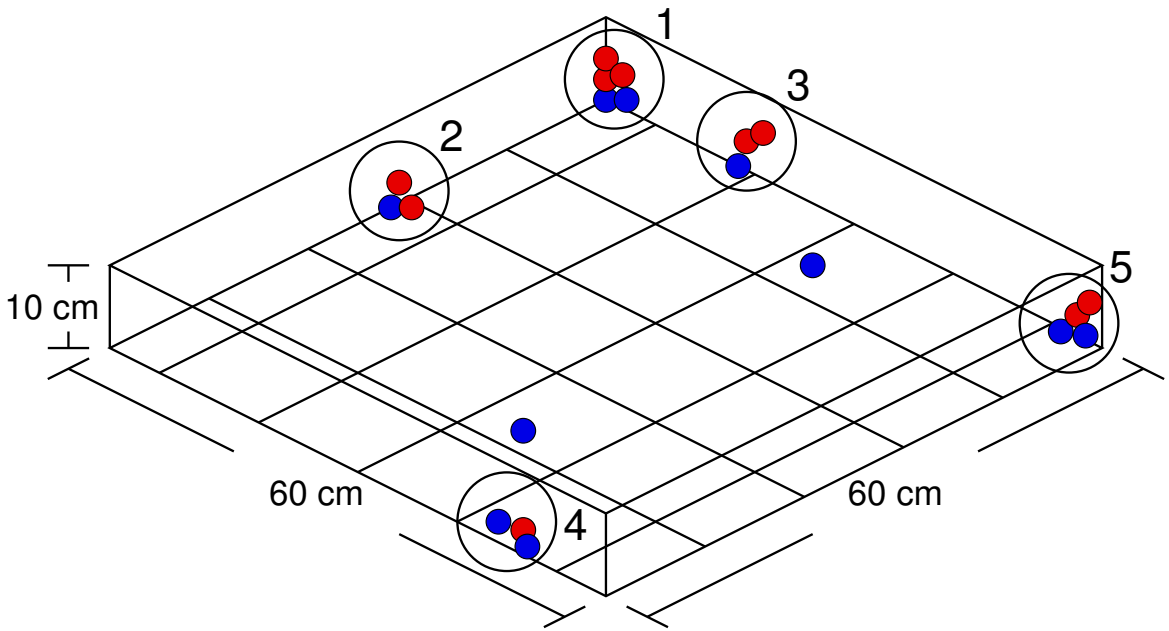
Simplified Monte Carlo Simulation



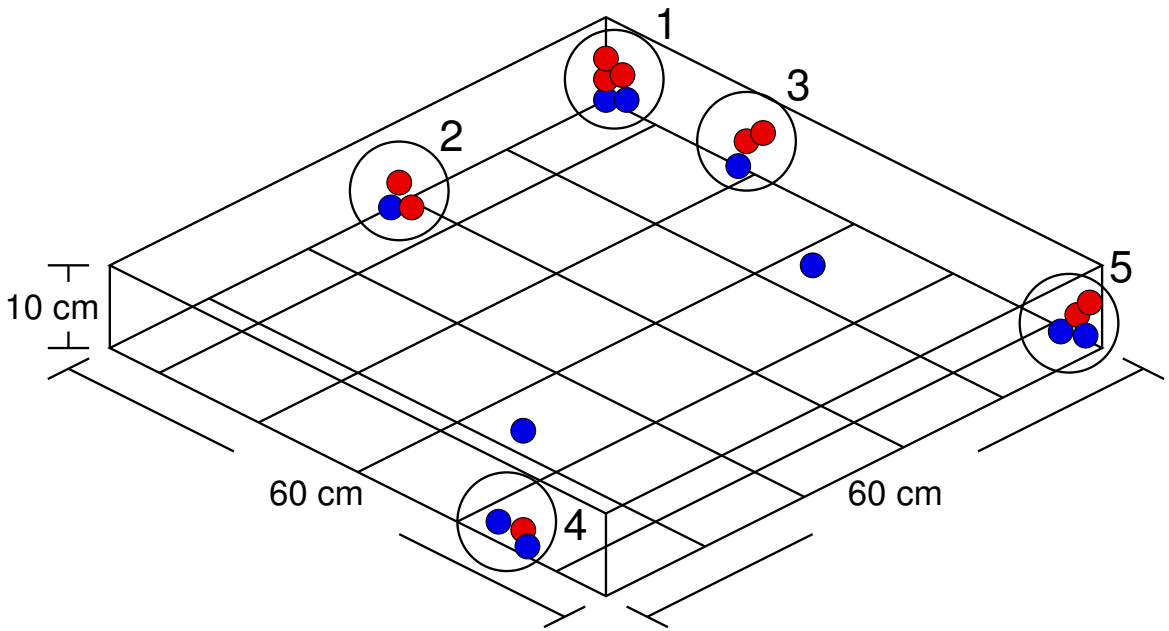
Simplified Monte Carlo Simulation



Simplified Monte Carlo Simulation

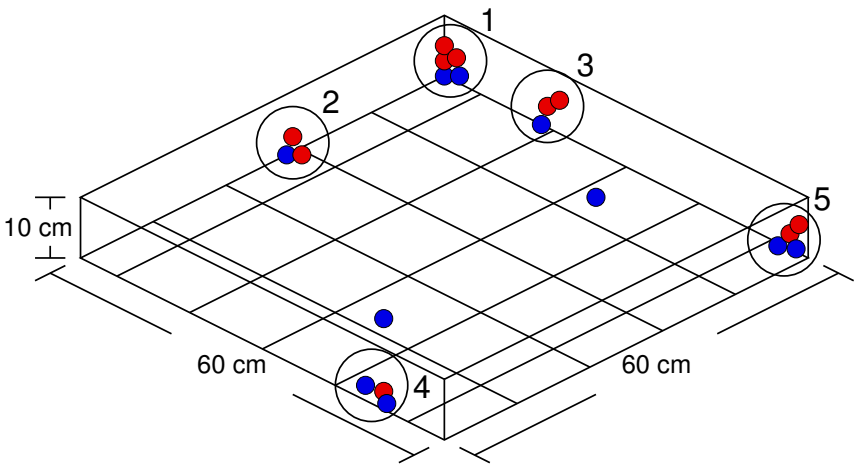


Simplified Monte Carlo Simulation

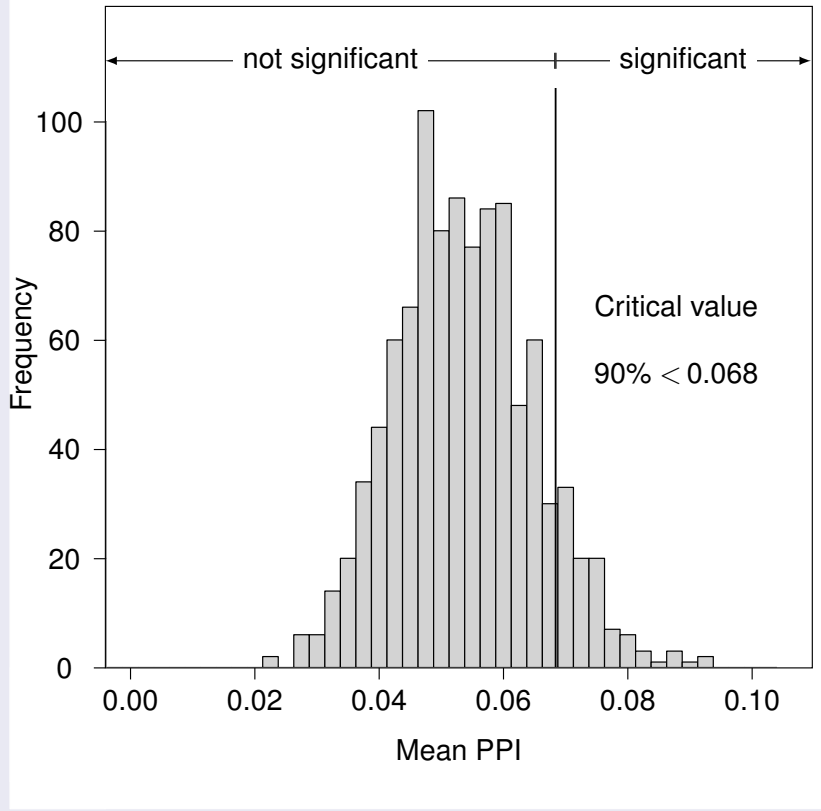


Calculation of PPI

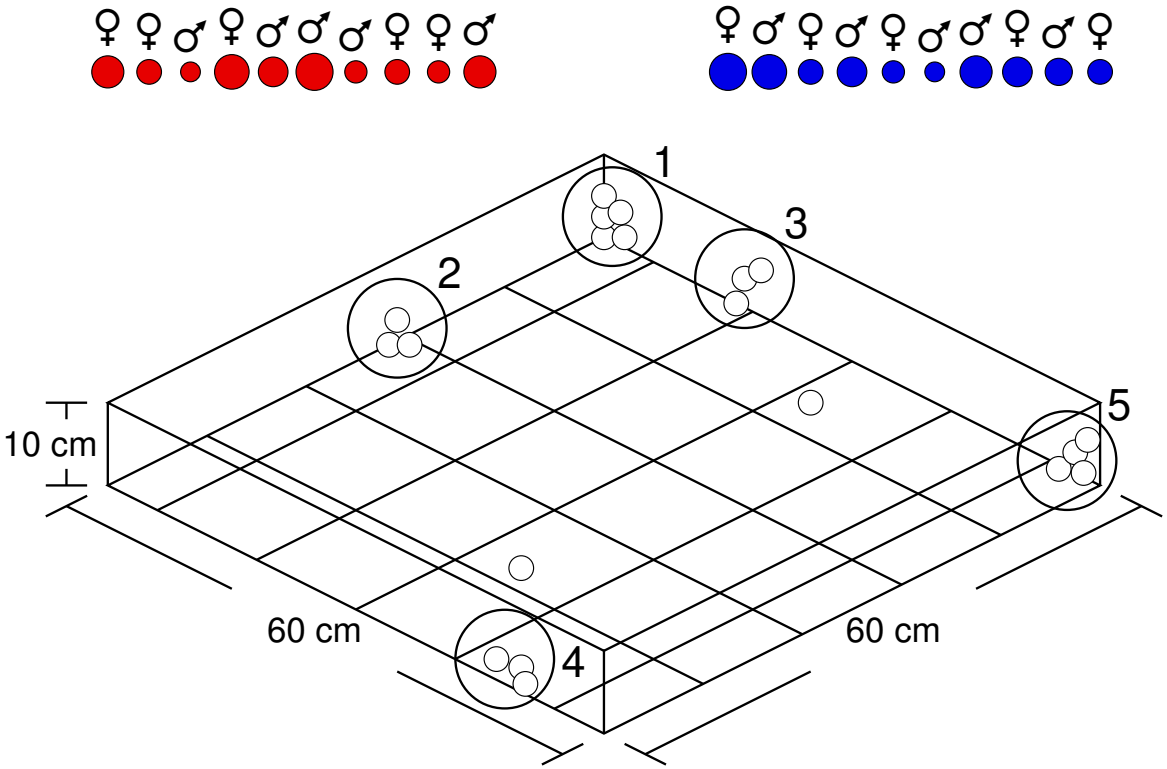
Simplified Monte Carlo Simulation



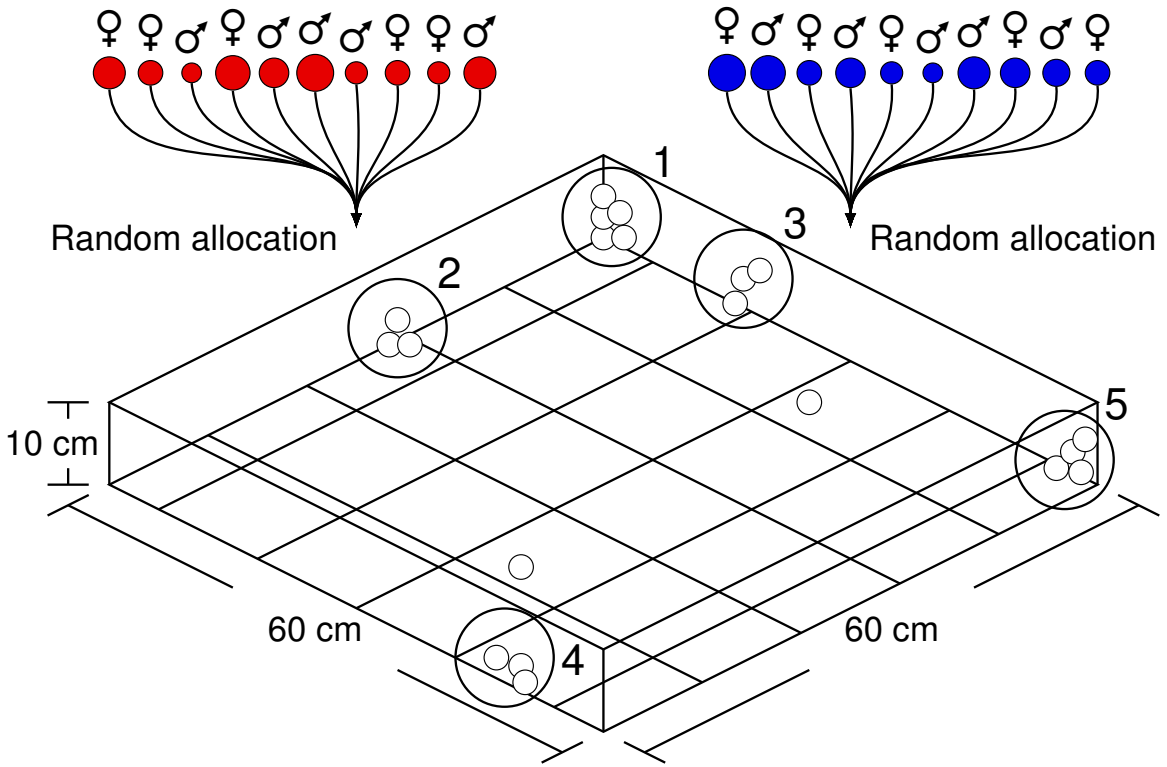
A histogram of PPI values



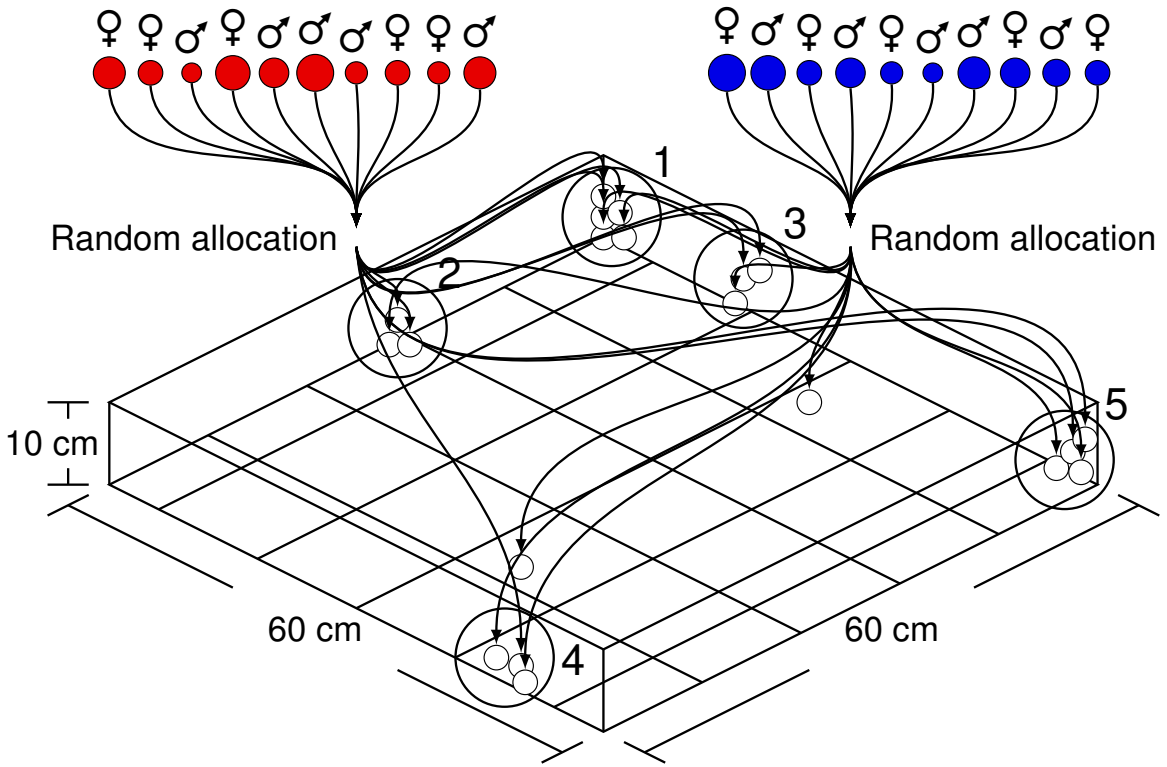
Detailed Monte Carlo Simulation



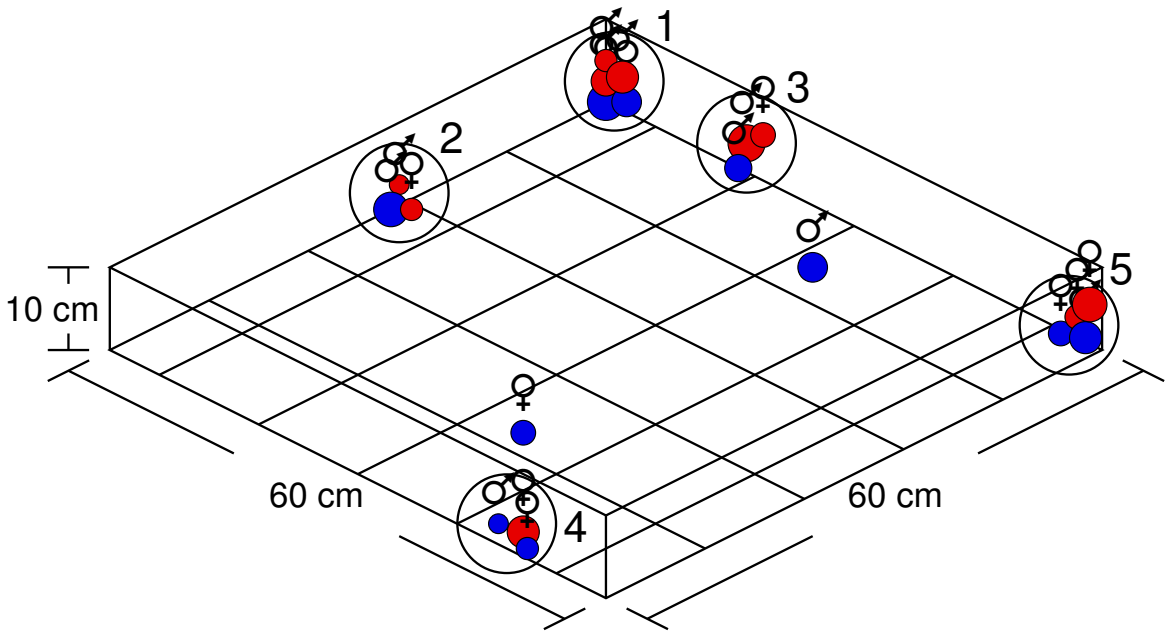
Detailed Monte Carlo Simulation



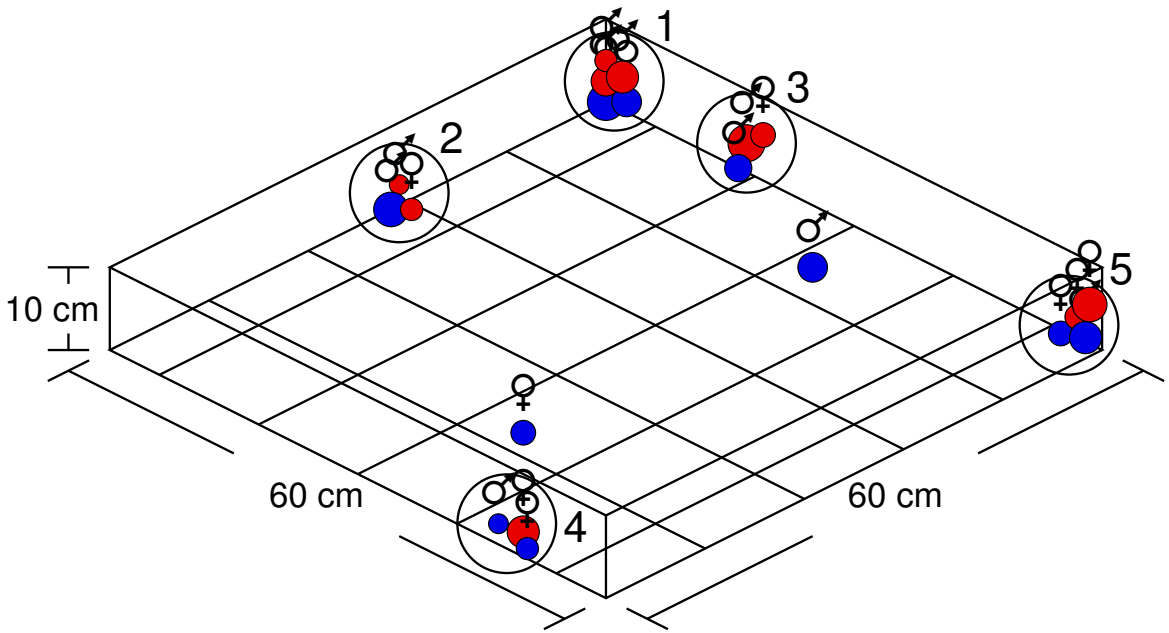
Detailed Monte Carlo Simulation



Detailed Monte Carlo Simulation



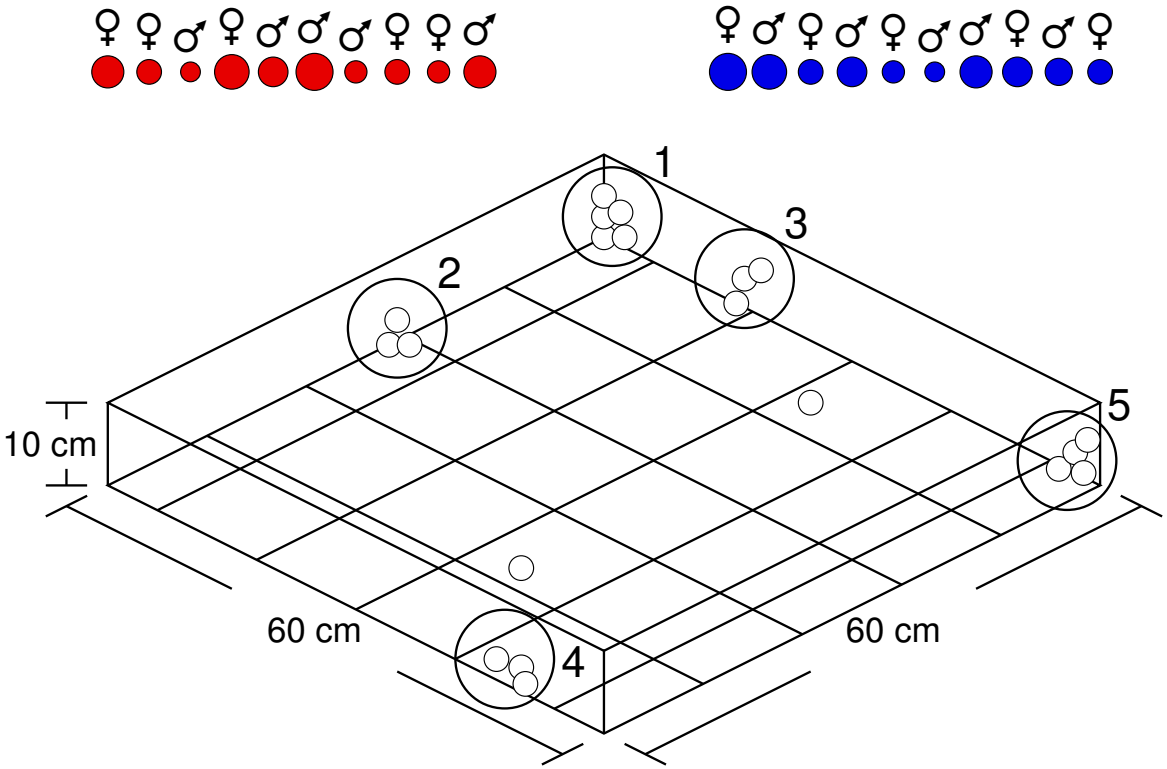
Detailed Monte Carlo Simulation



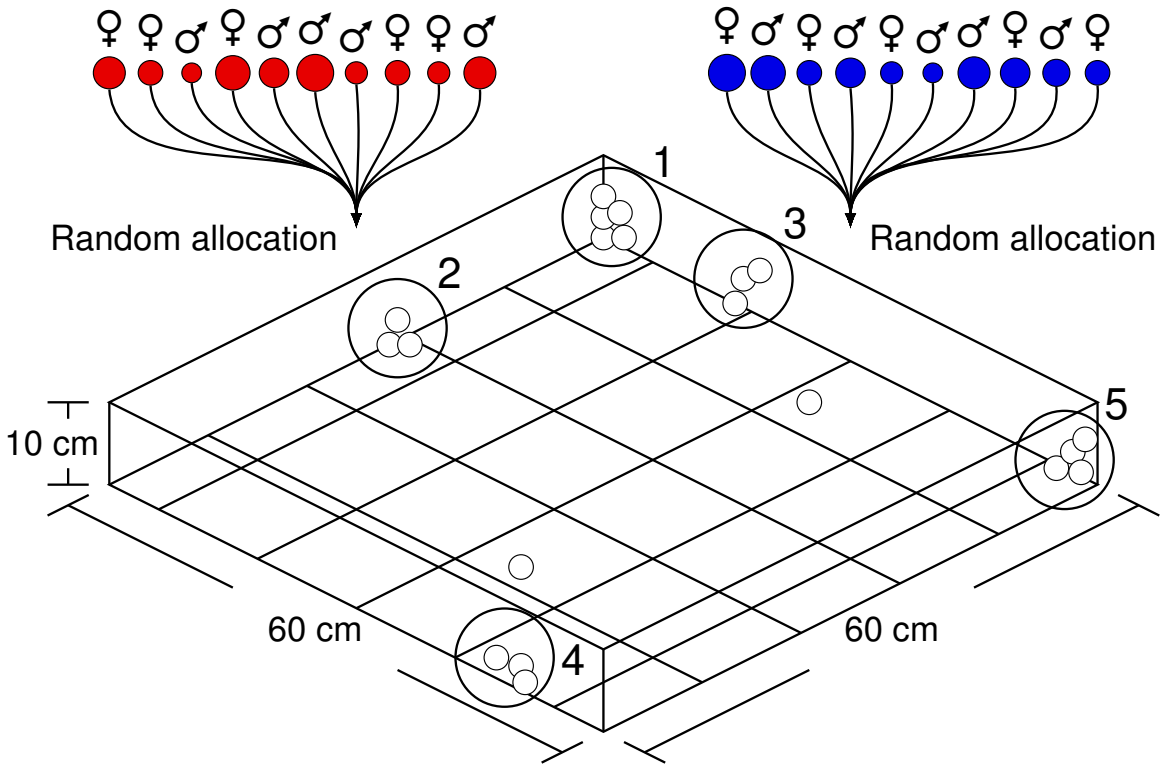
Calculation of PPI, Sex-PI and Size-PI

Detailed Monte Carlo Simulation

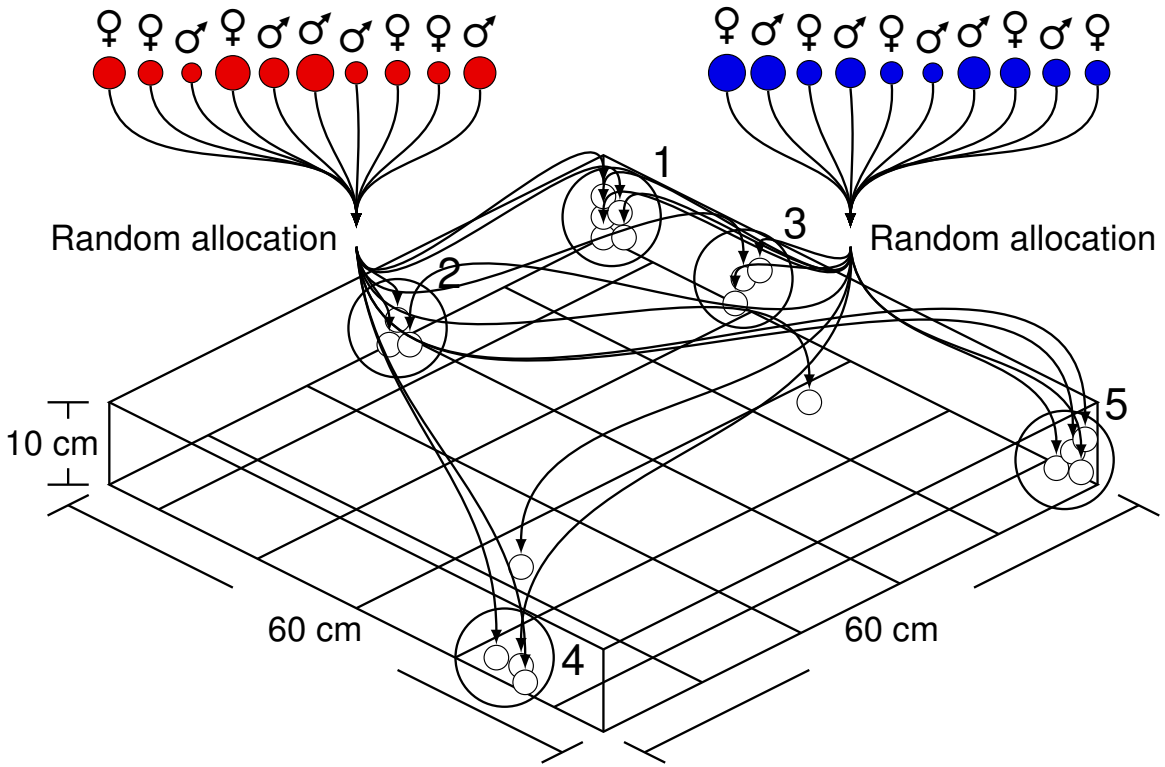
1000-fold repetition



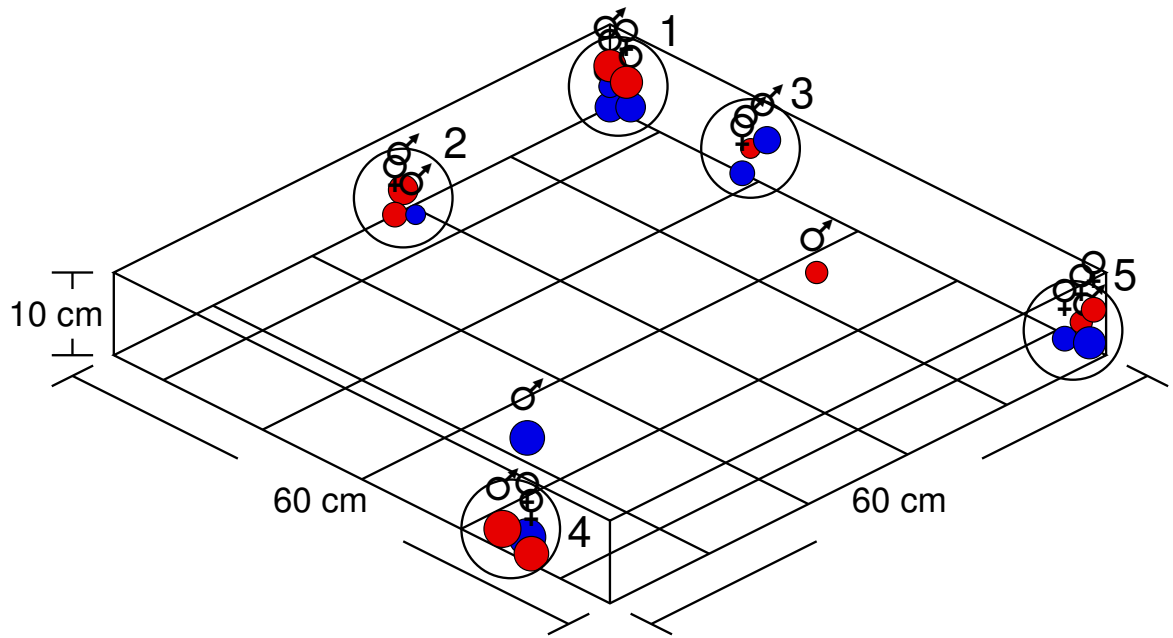
Detailed Monte Carlo Simulation



Detailed Monte Carlo Simulation

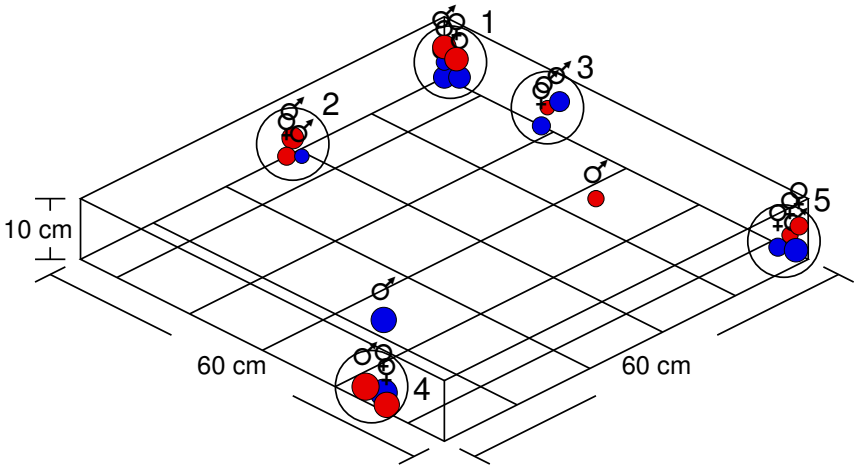


Detailed Monte Carlo Simulation

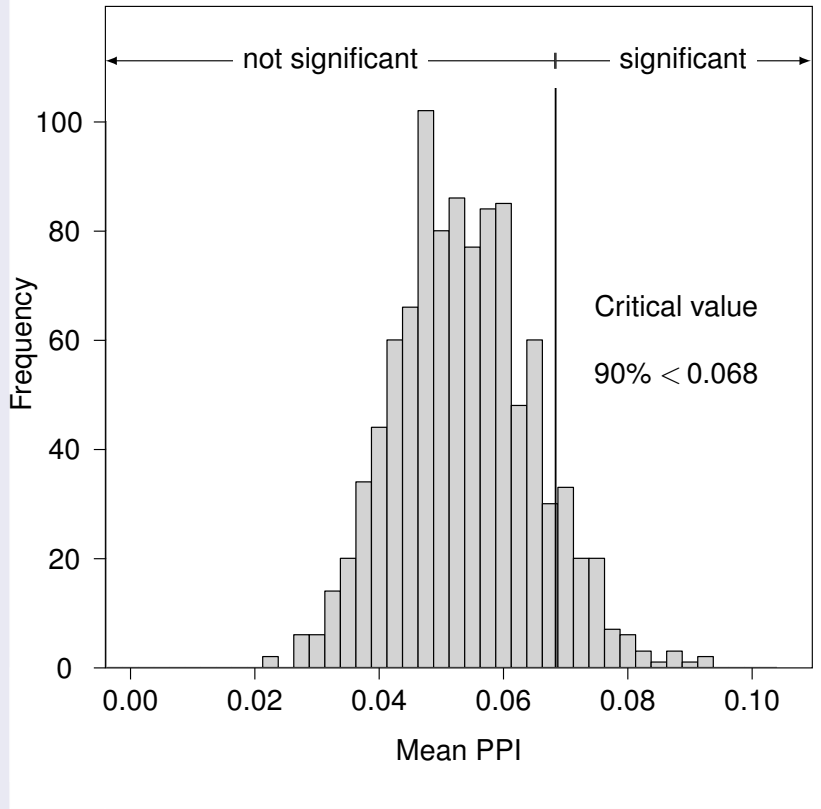


1000-fold calculation of PPI, Sex-PI and Size-PI

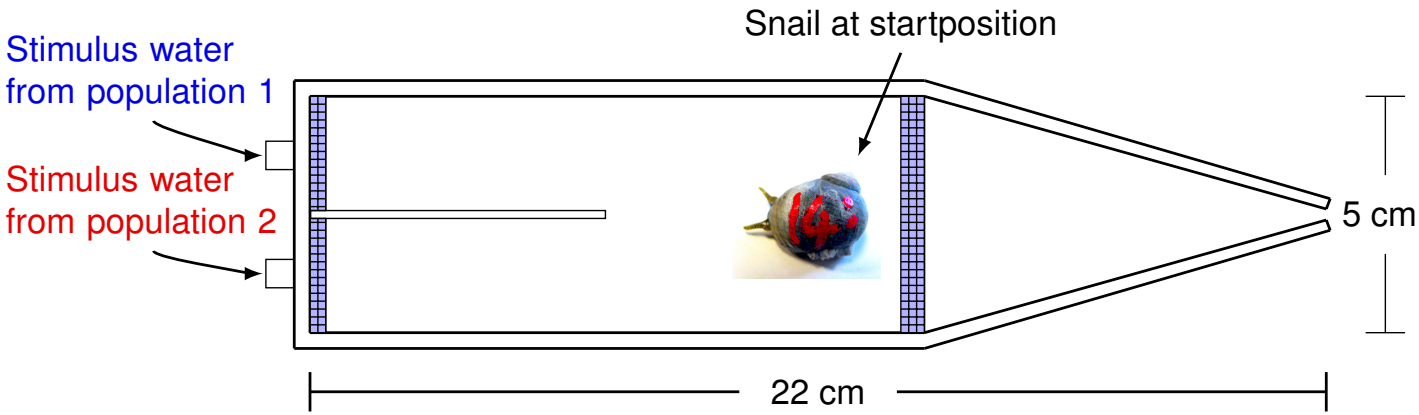
Detailed Monte Carlo Simulation

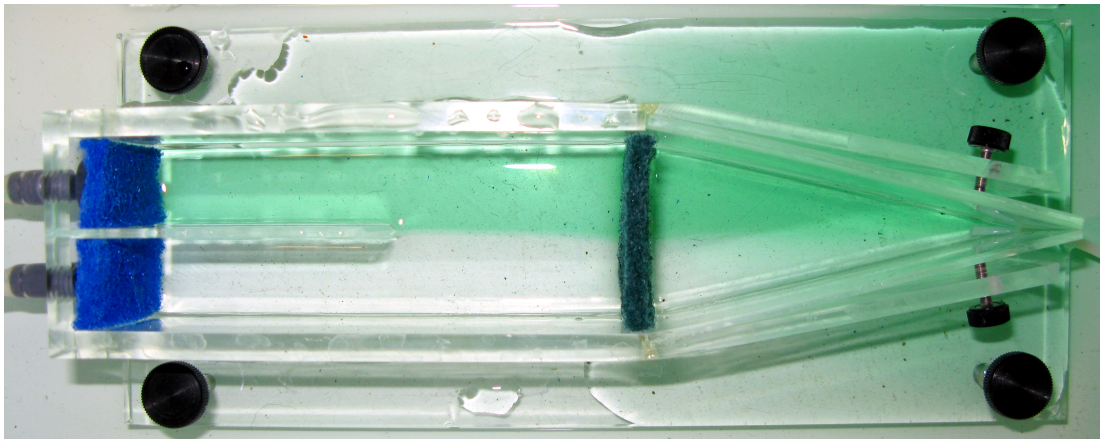


A histogram of PPI values

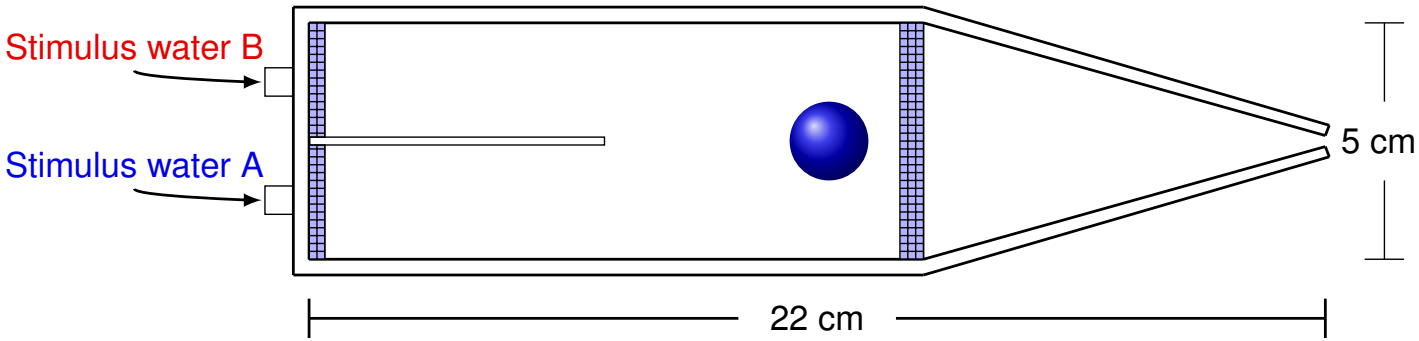


Testing Snails in Olfactory Flumes



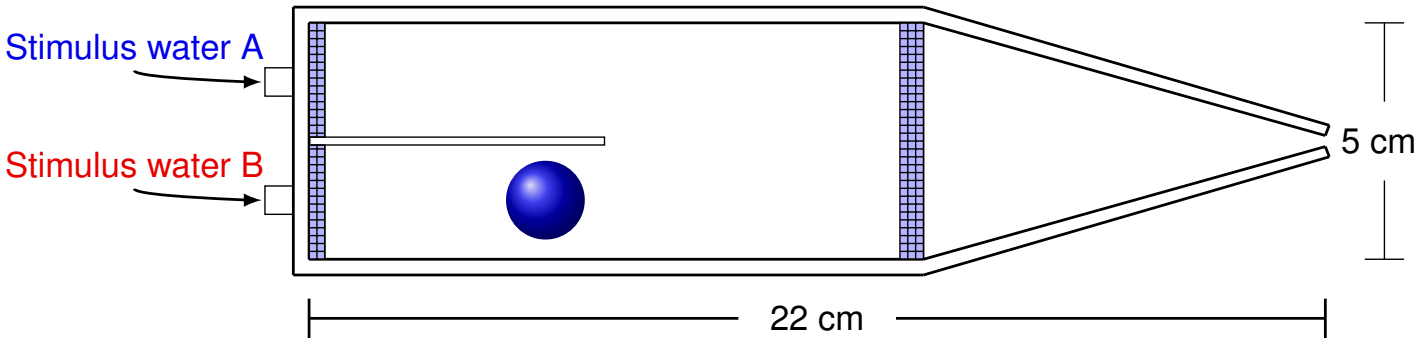


Testing Snails in Olfactory Flumes in Detail



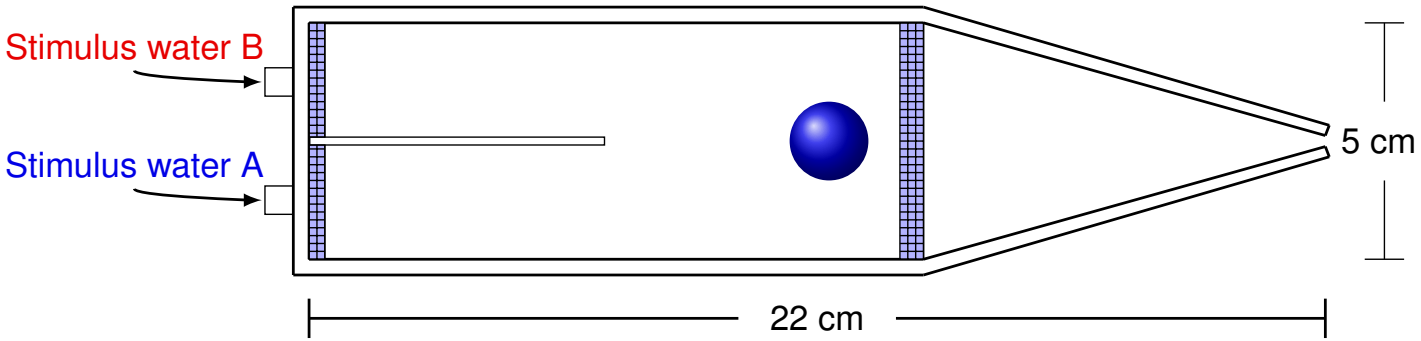
Testing Snails in Olfactory Flumes in Detail

1

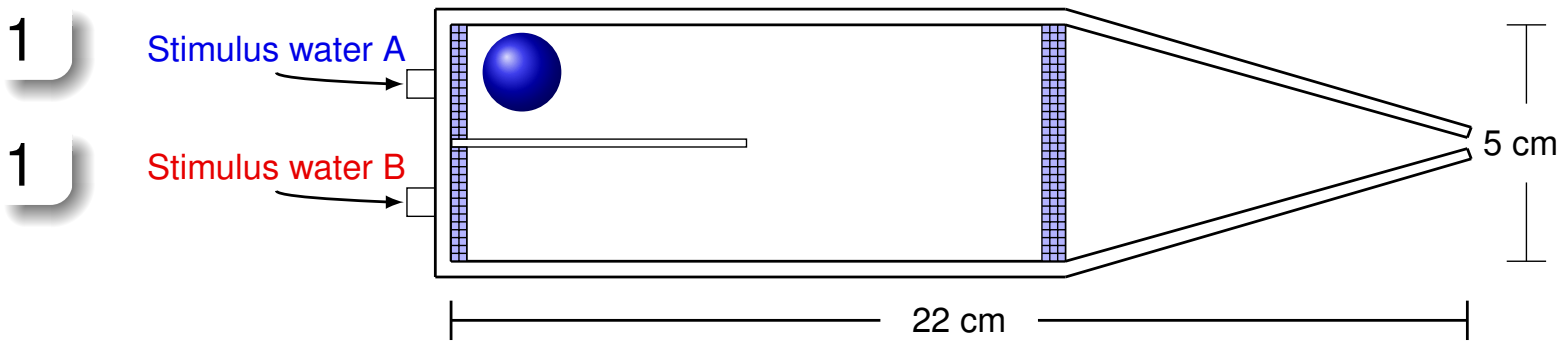


Testing Snails in Olfactory Flumes in Detail

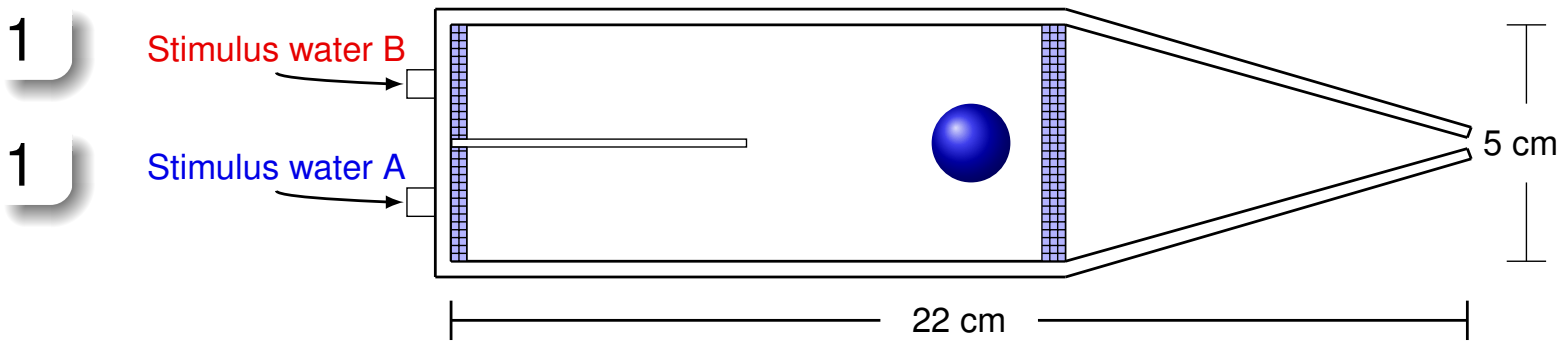
1



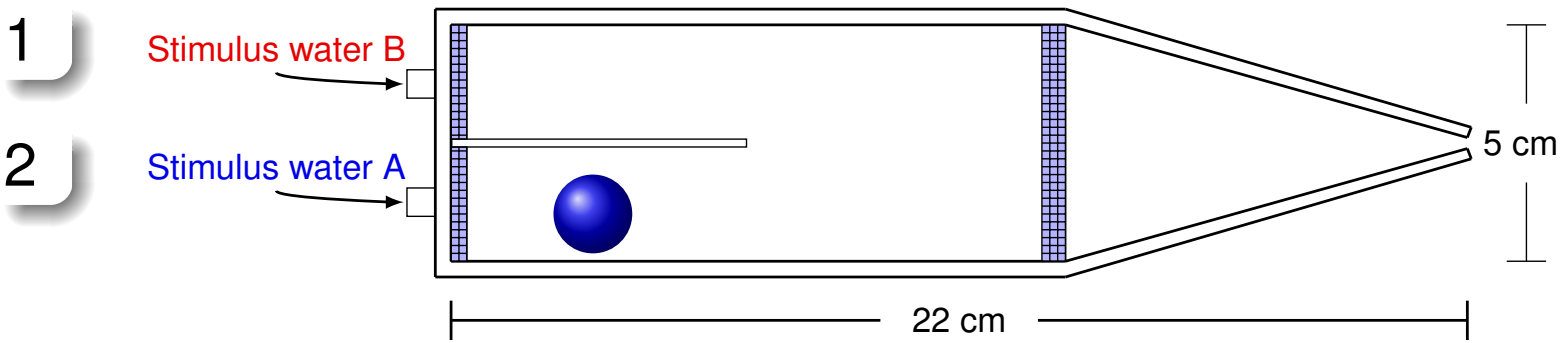
Testing Snails in Olfactory Flumes in Detail



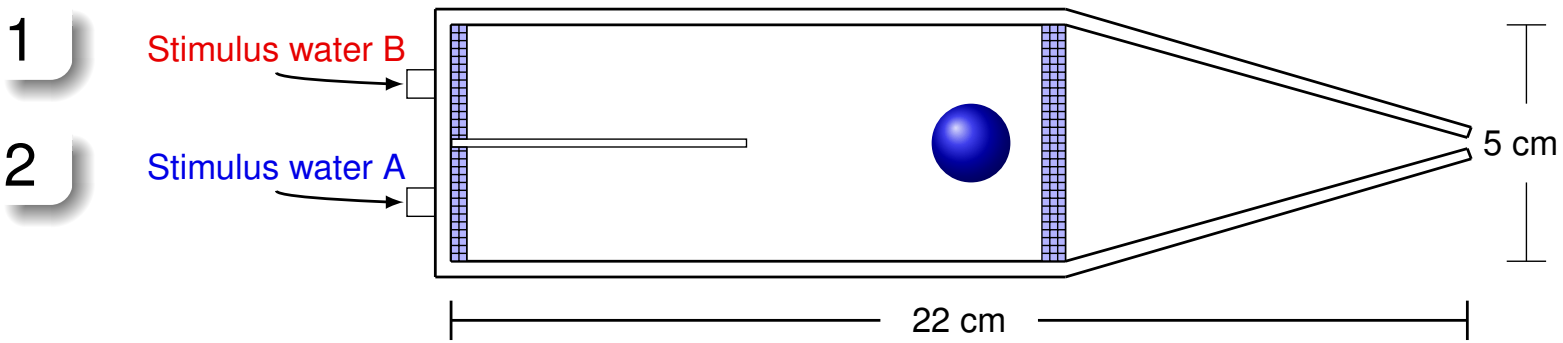
Testing Snails in Olfactory Flumes in Detail



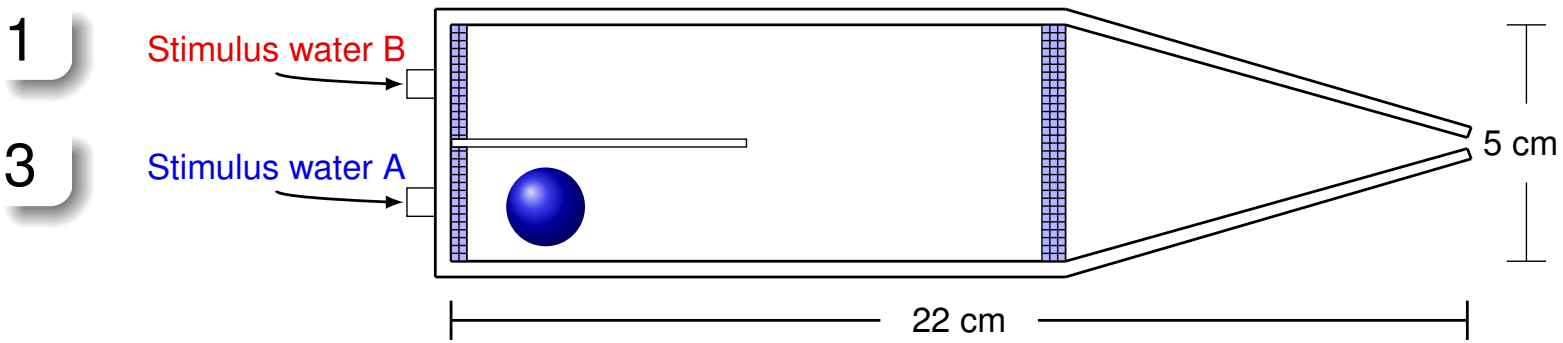
Testing Snails in Olfactory Flumes in Detail



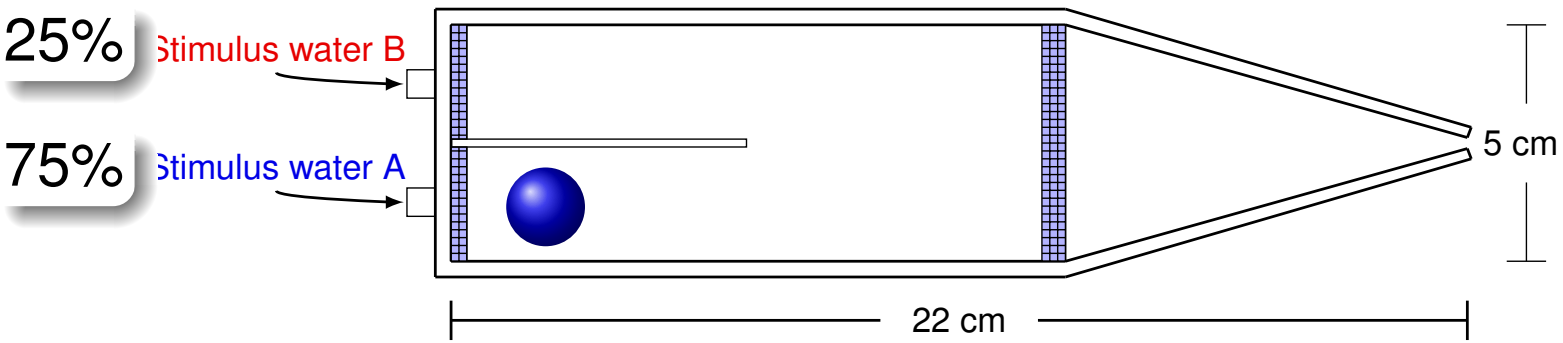
Testing Snails in Olfactory Flumes in Detail



Testing Snails in Olfactory Flumes in Detail



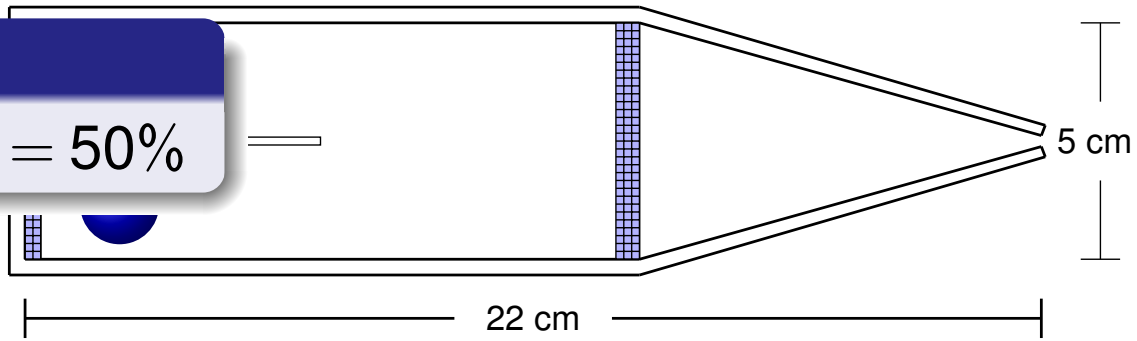
Testing Snails in Olfactory Flumes in Detail



Testing Snails in Olfactory Flumes in Detail

Difference

- $75\% - 25\% = 50\%$



Testing Snails in Olfactory Flumes in Detail

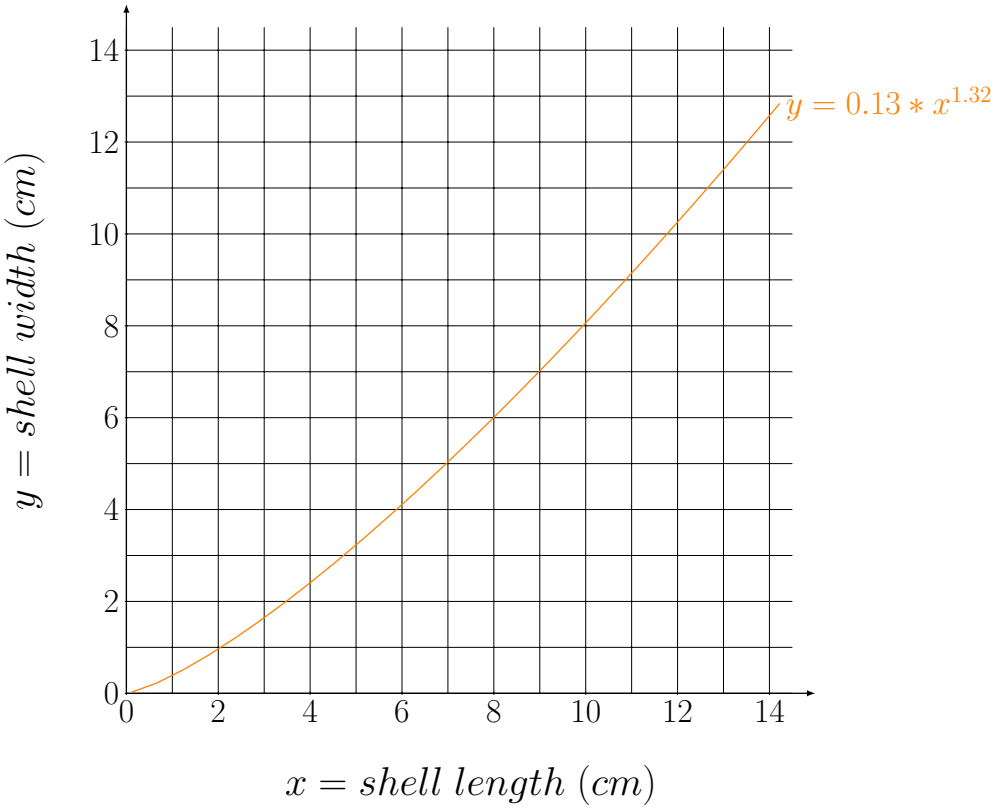
15 Differences

50%
25%
.
.
.
0%

Wilcoxon signed-rank test

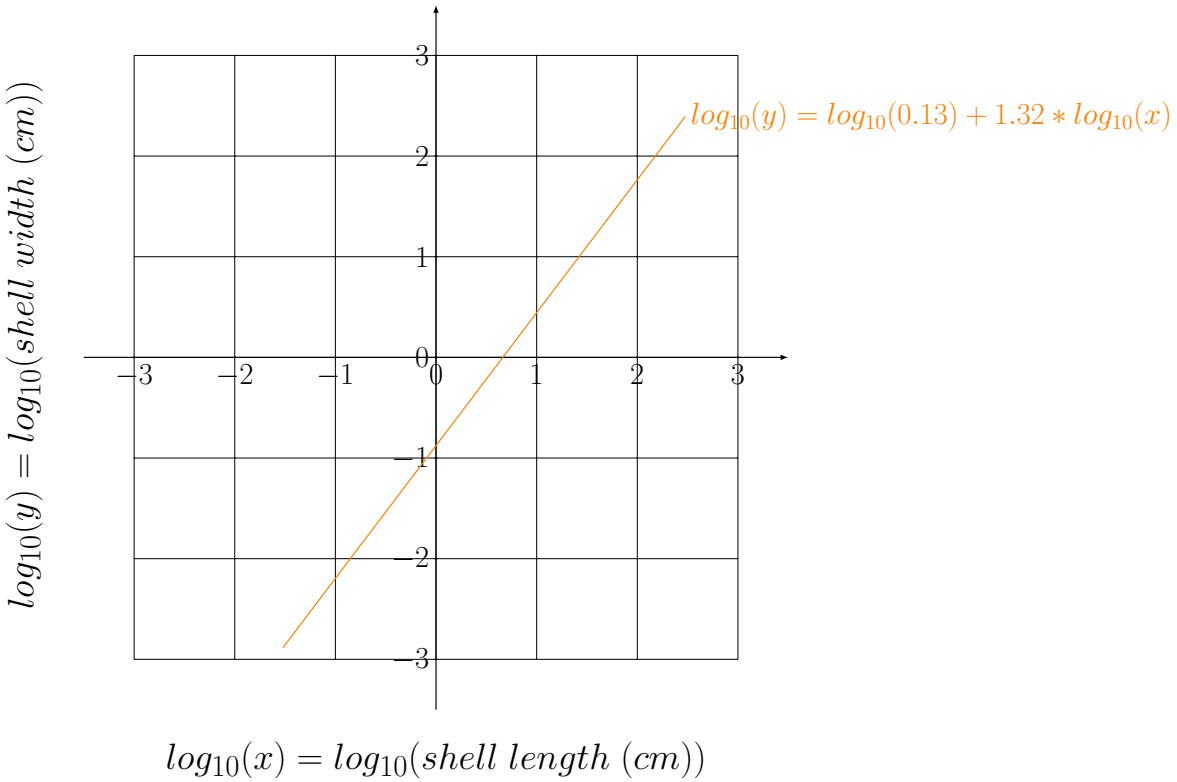
Allometric correction

Arithmetic plot

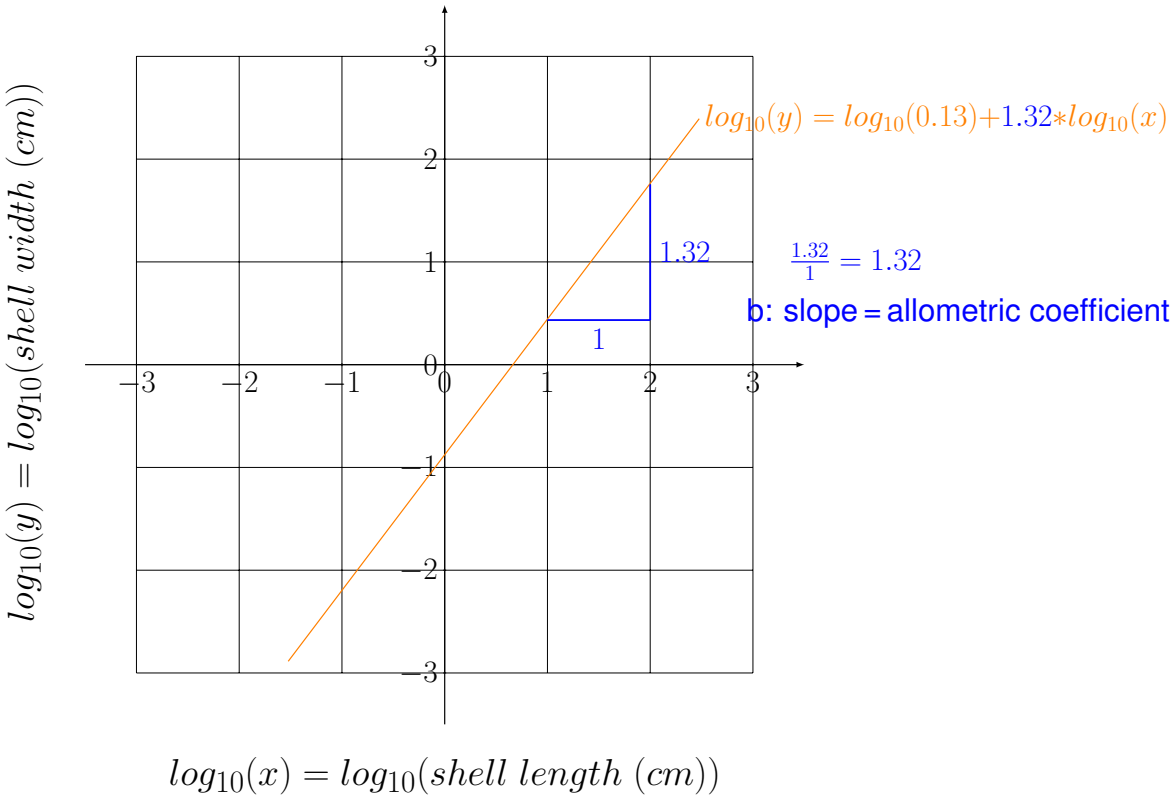


Allometric correction

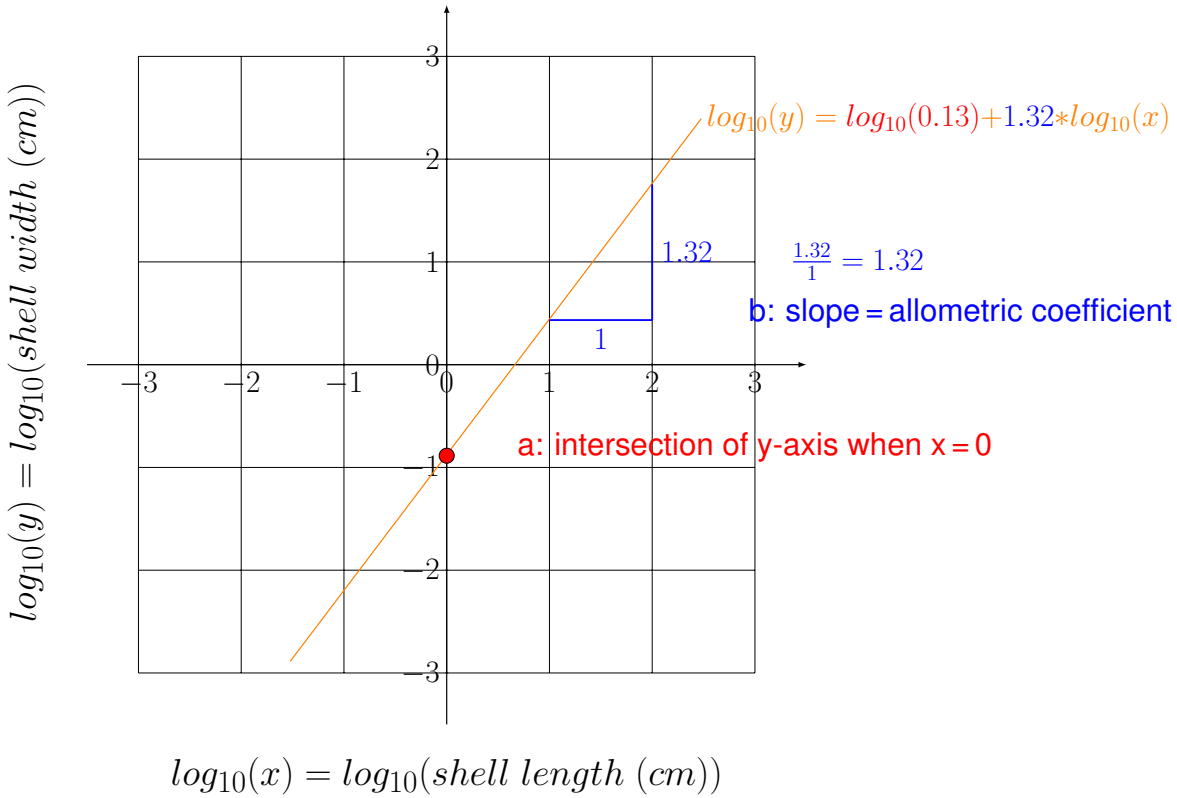
Logarithmic plot



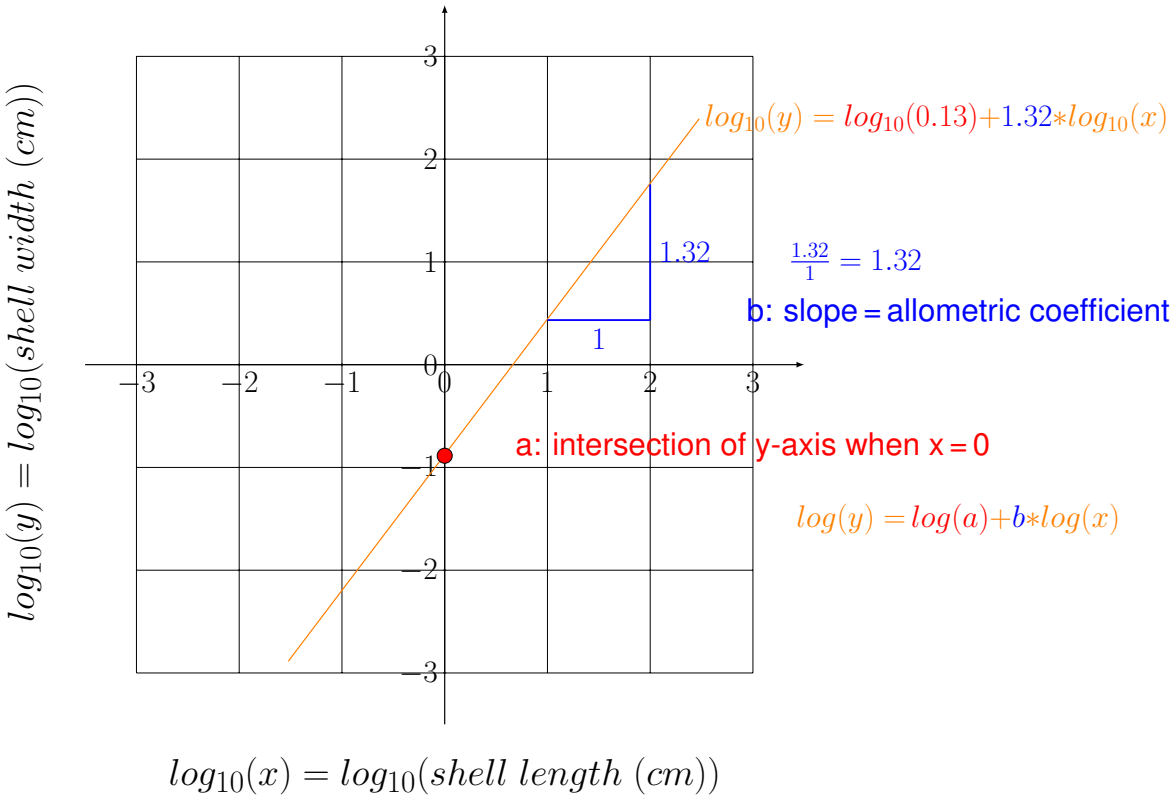
Allometric correction



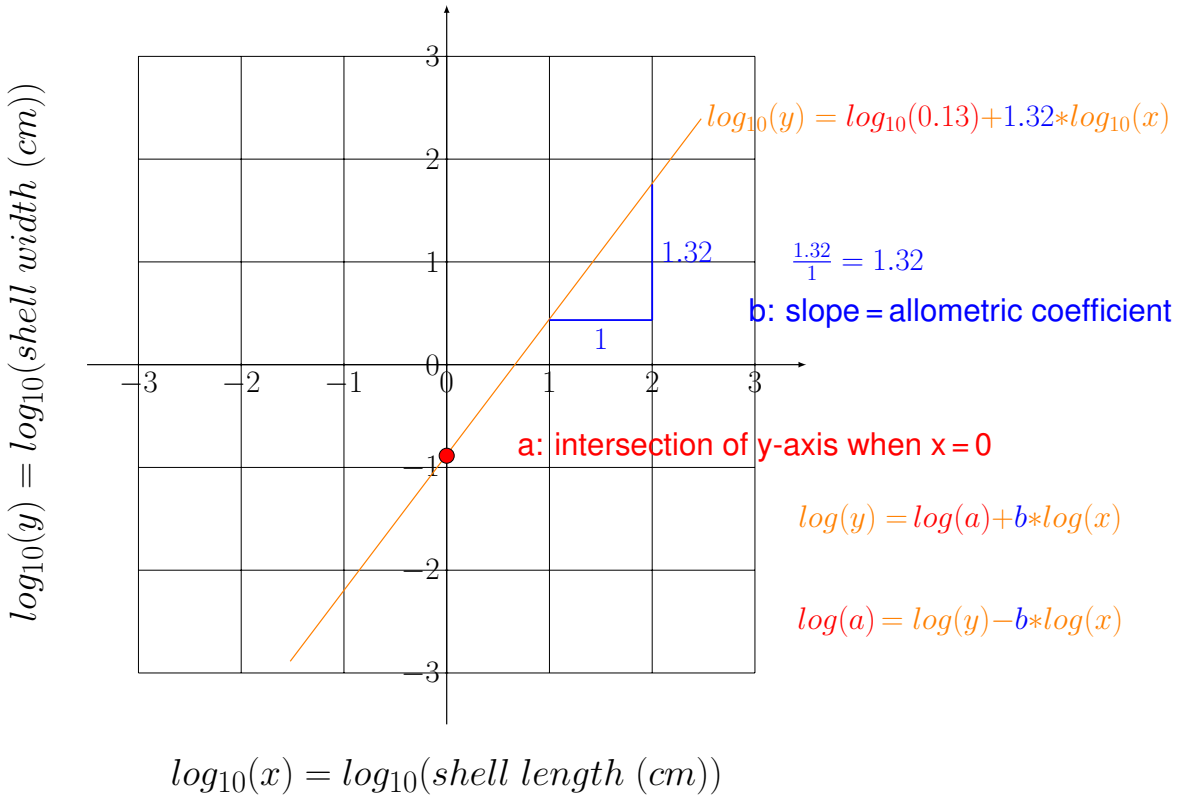
Allometric correction



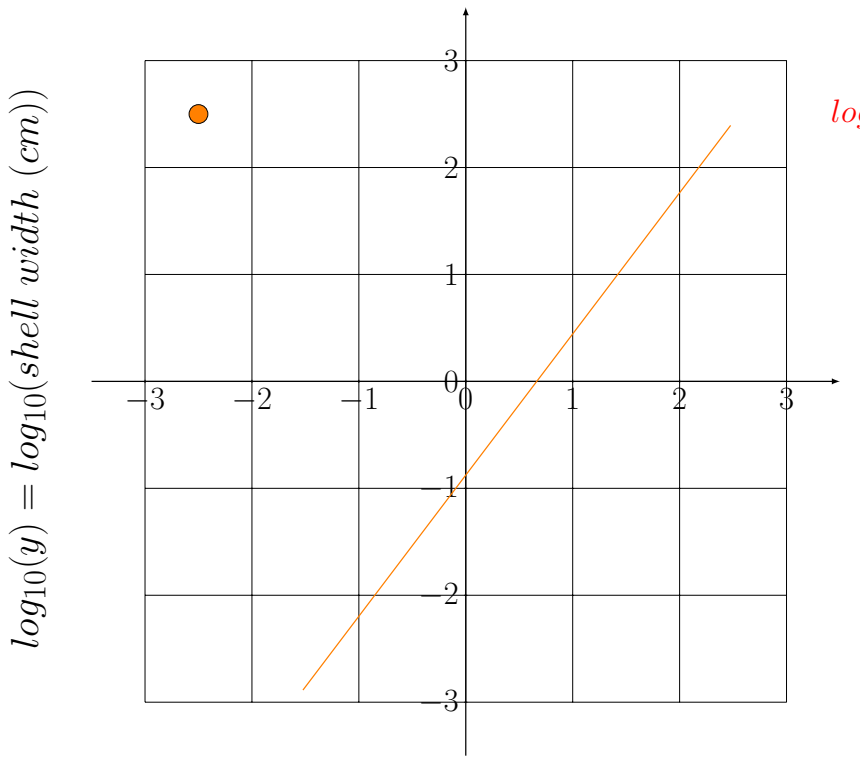
Allometric correction



Allometric correction

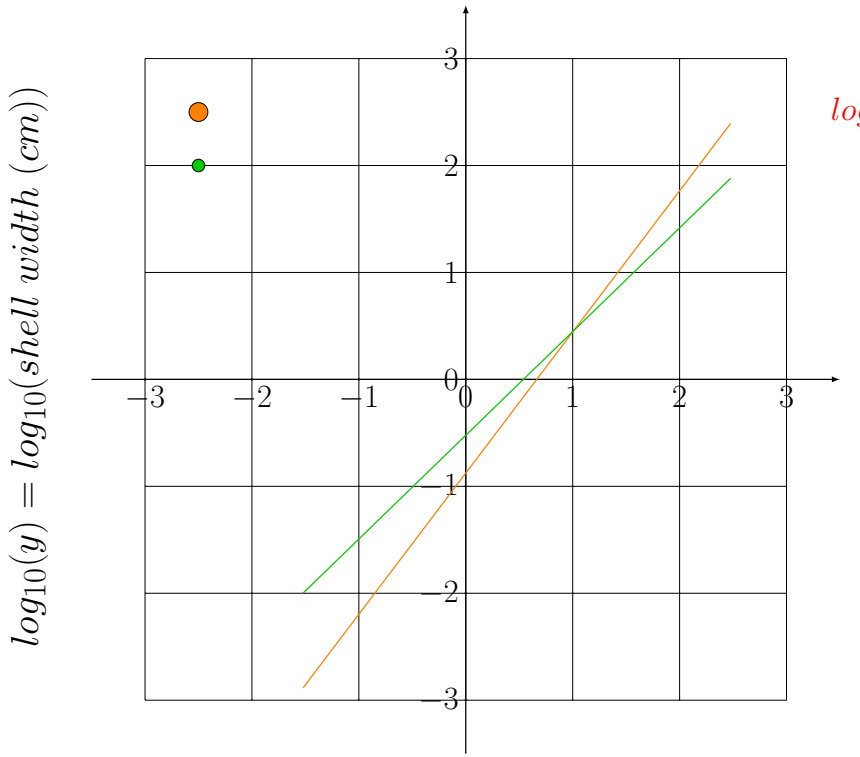


Allometric correction



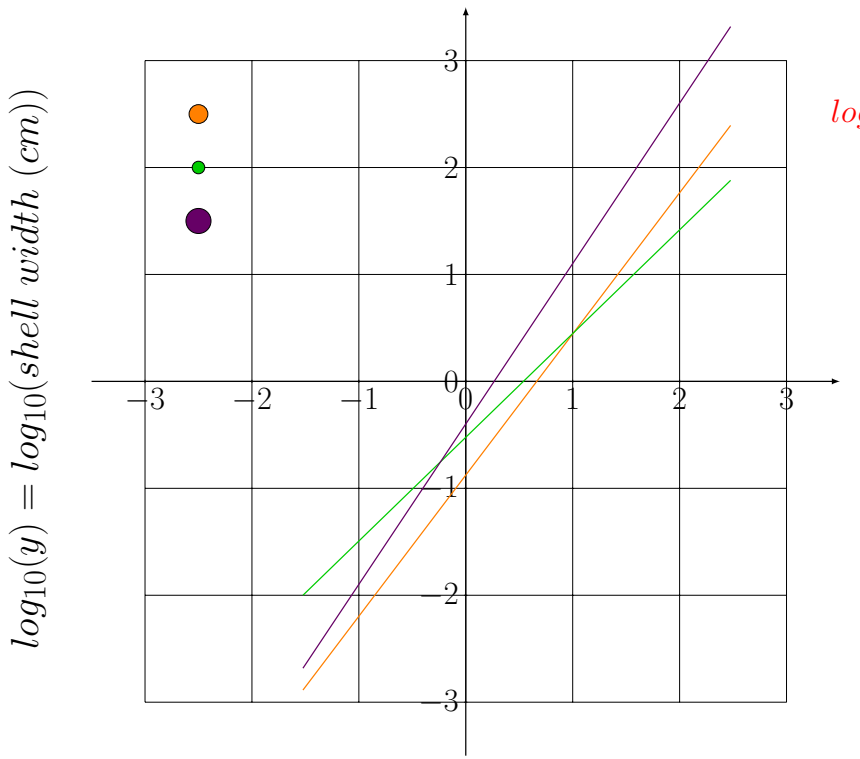
$log(a) = log(y) - b * log(x)$

Allometric correction



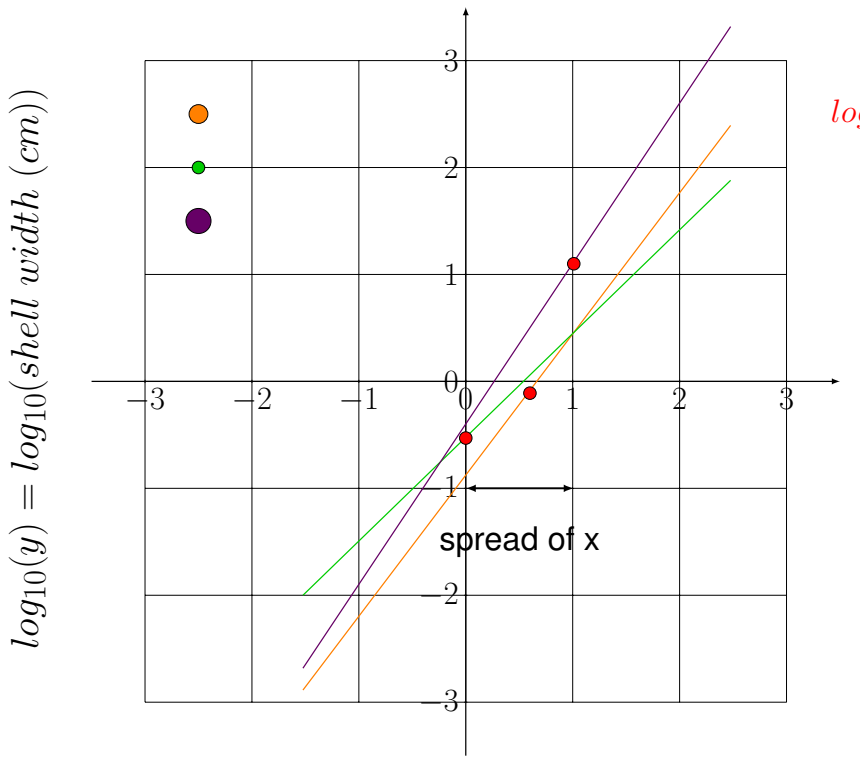
$log(a) = log(y) - b * log(x)$

Allometric correction



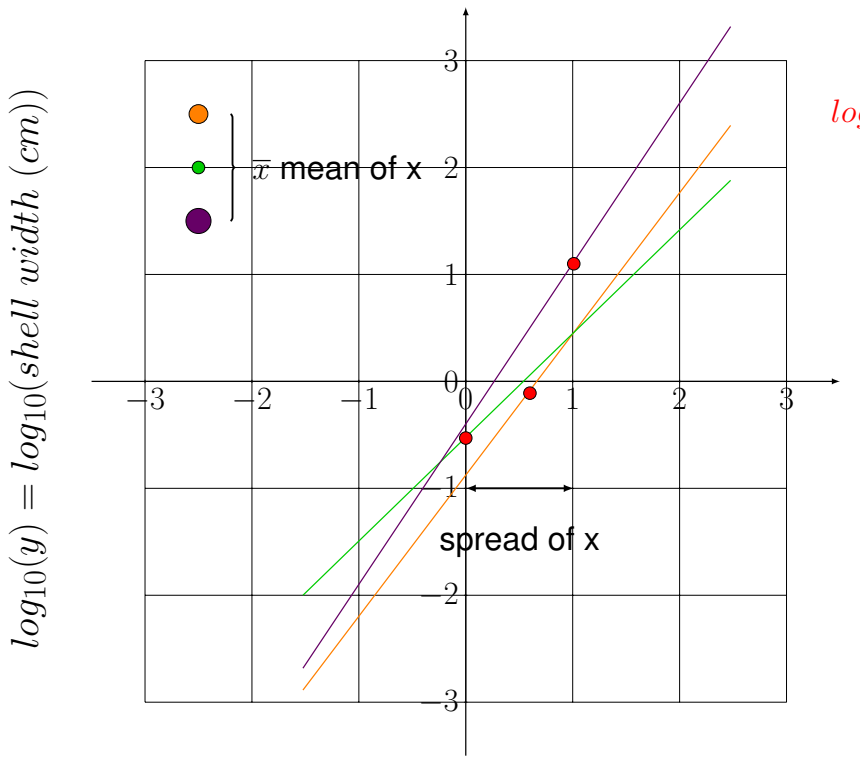
$log(a) = log(y) - b * log(x)$

Allometric correction



$log(a) = log(y) - b * log(x)$

Allometric correction

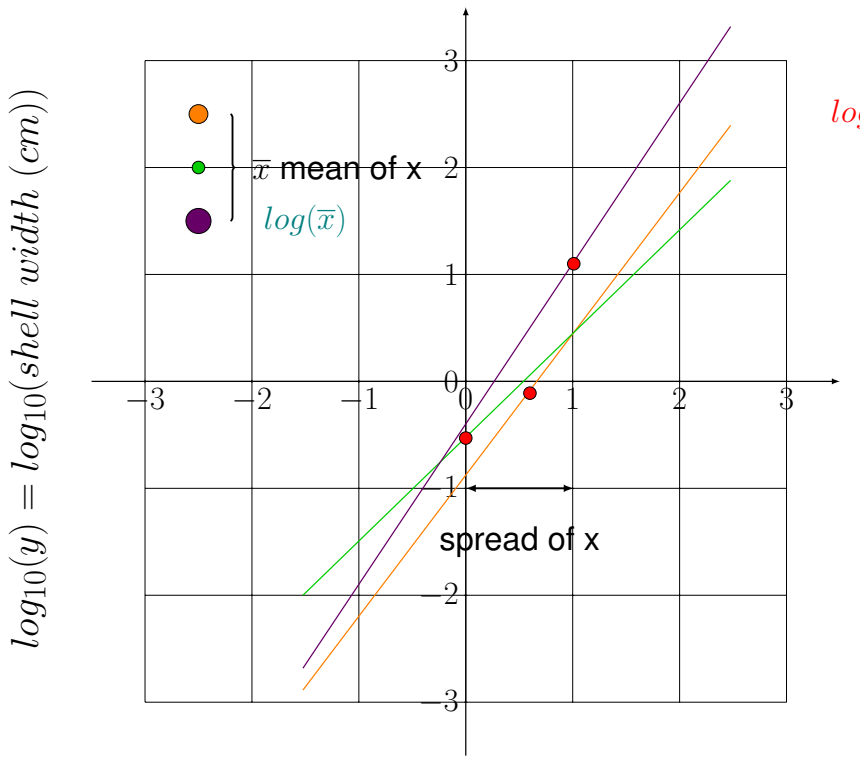


$log_{10}(y) = log_{10}(shell\ width\ (cm))$

$log(a) = log(y) - b * log(x)$

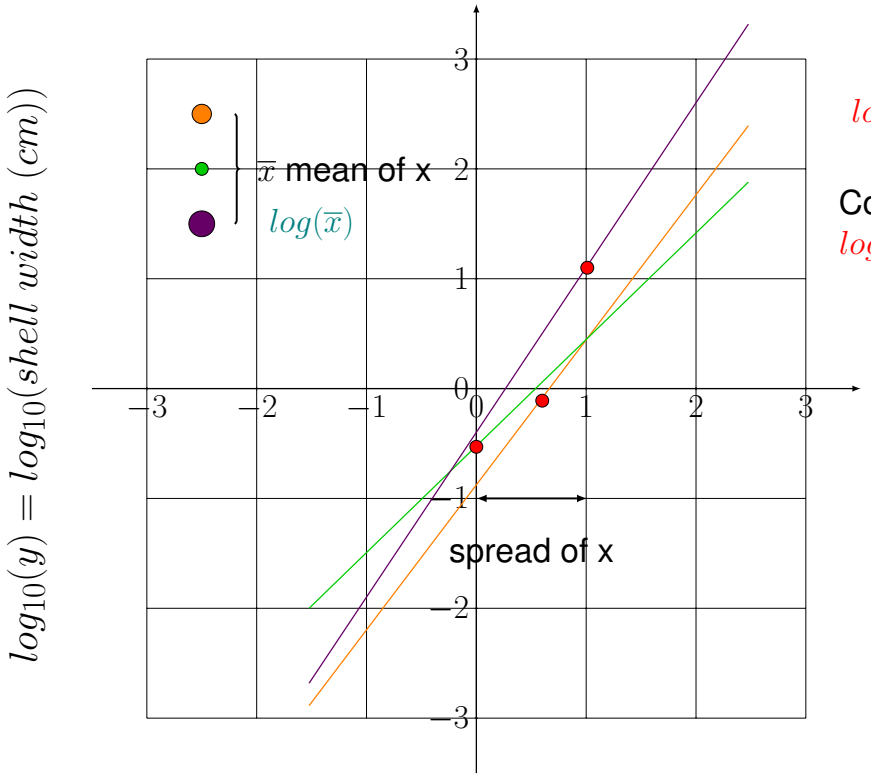
$log_{10}(x) = log_{10}(shell\ length\ (cm))$

Allometric correction



$$log(a) = log(y) - b * log(x)$$

Allometric correction

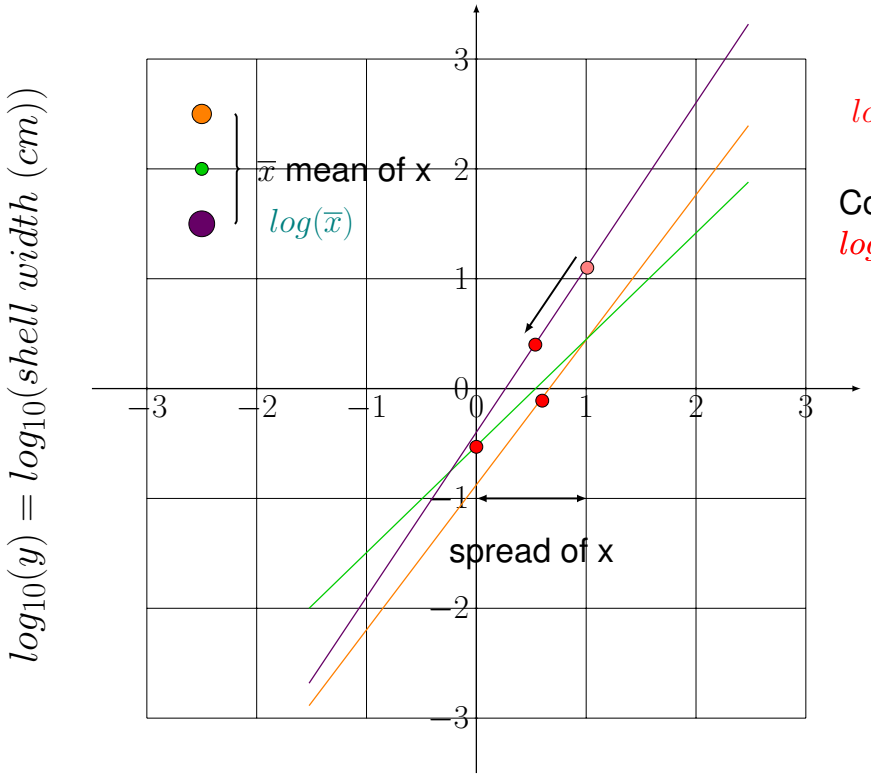


$log(a) = log(y) - b * log(x)$

Correction

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

Allometric correction

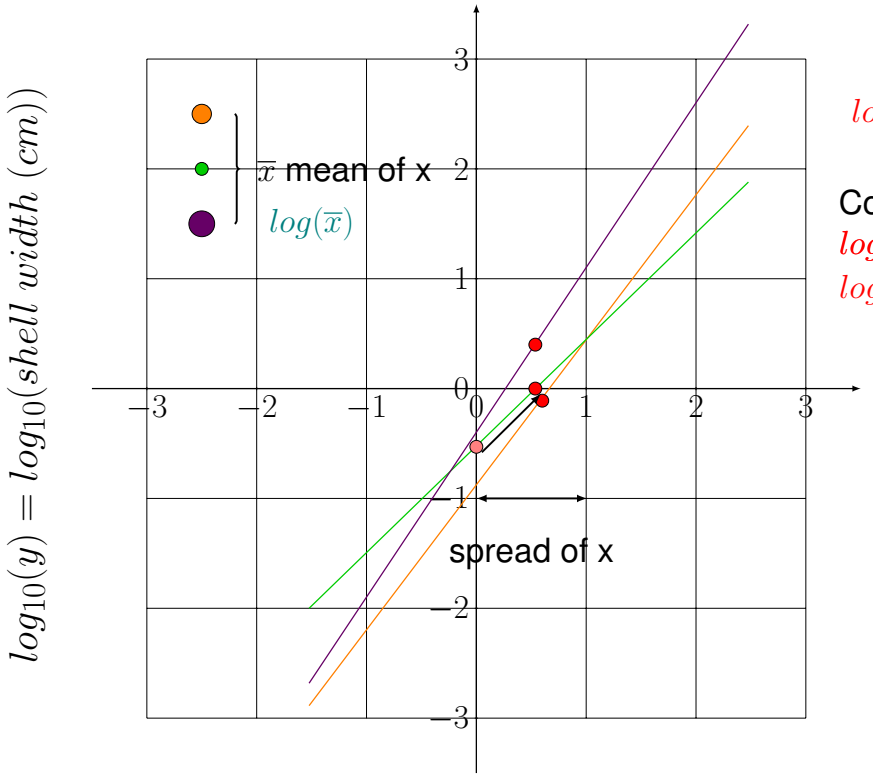


$log(a) = log(y) - b * log(x)$

Correction

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

Allometric correction



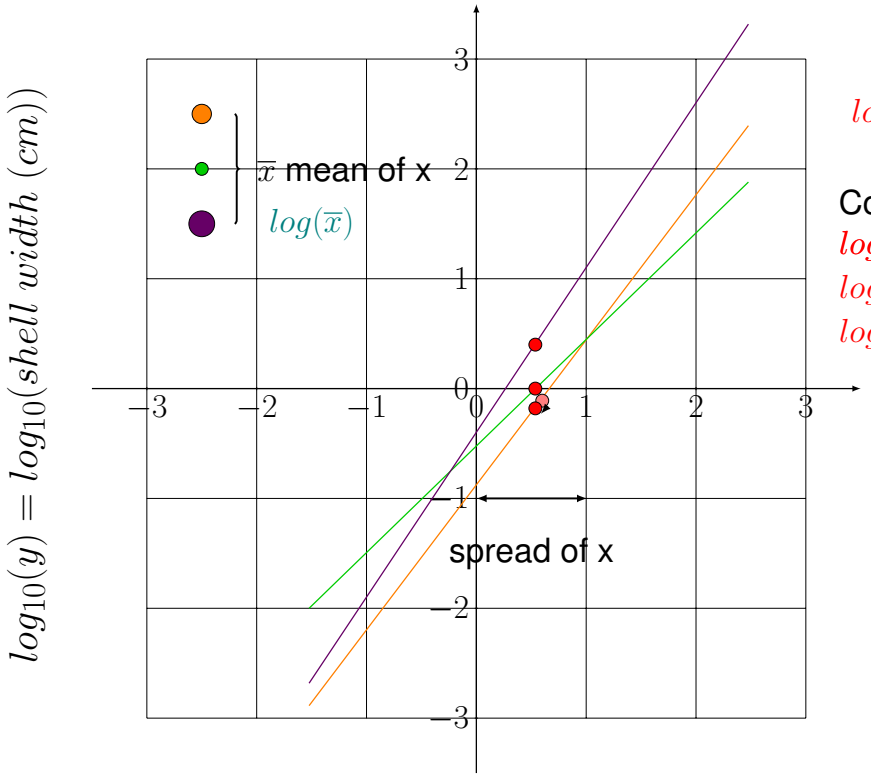
$log(a) = log(y) - b * log(x)$

Correction

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

Allometric correction



$log(a) = log(y) - b * log(x)$

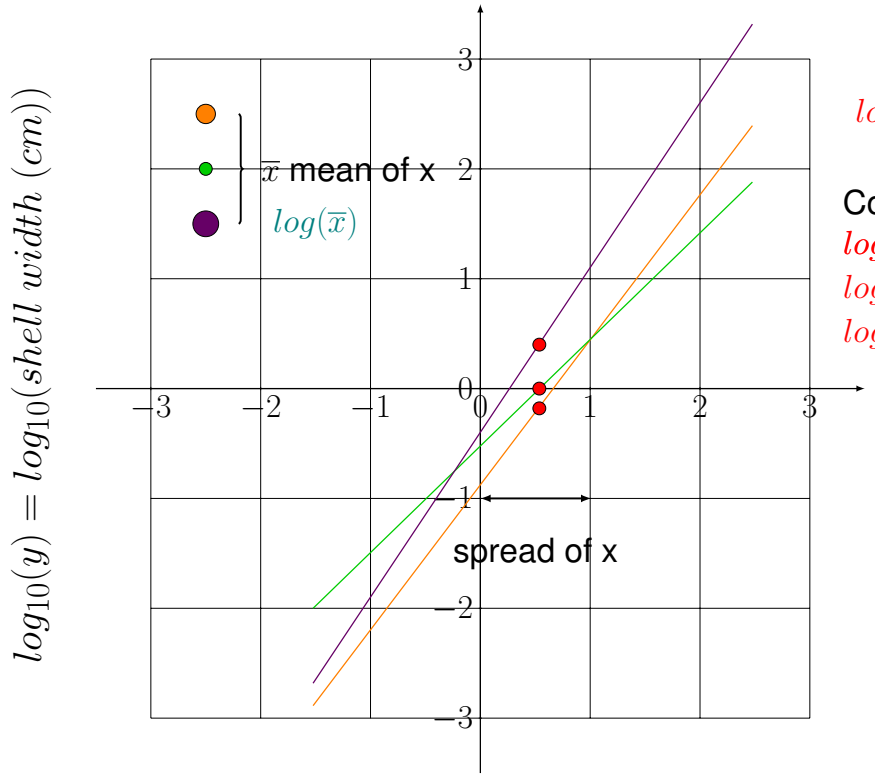
Correction

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

Allometric correction



$log(a) = log(y) - b * log(x)$

Correction

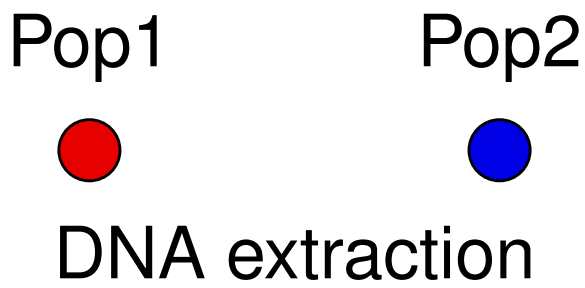
$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

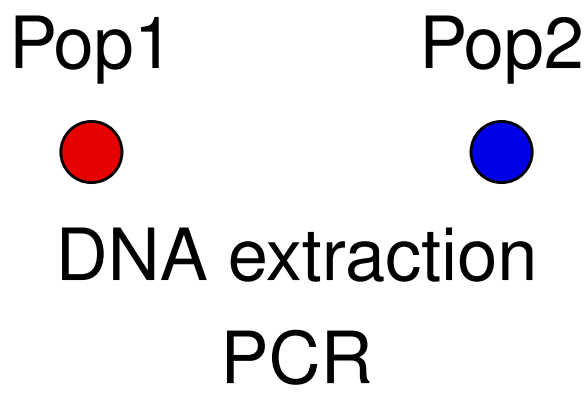
$log(a) = log(y) - b * (log(x) - log(\overline{x}))$

Genetic Differentiation at Microsatellite Markers 1

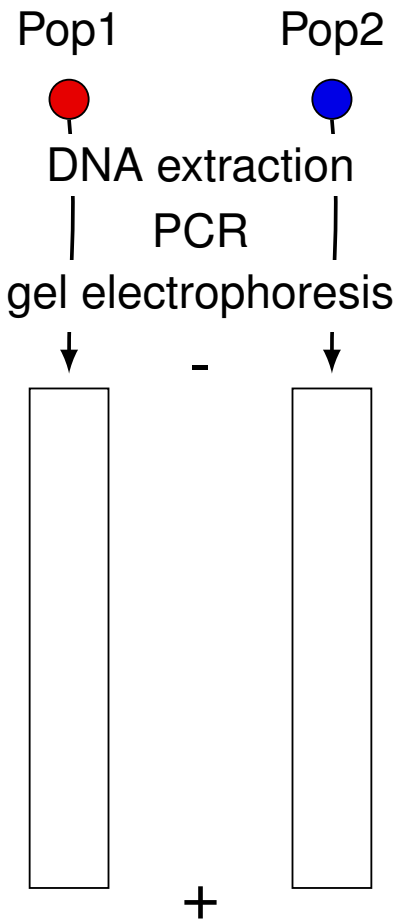
Genetic Differentiation at Microsatellite Markers 1



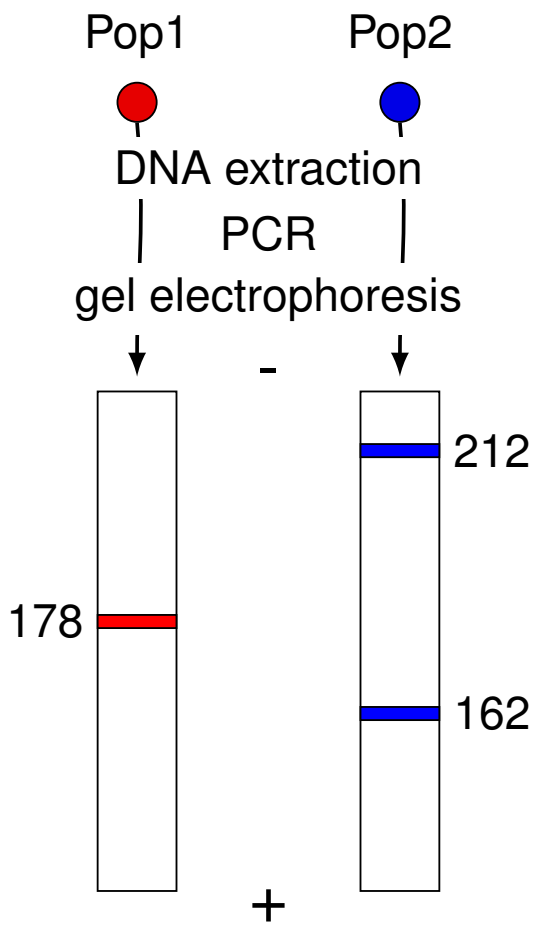
Genetic Differentiation at Microsatellite Markers 1



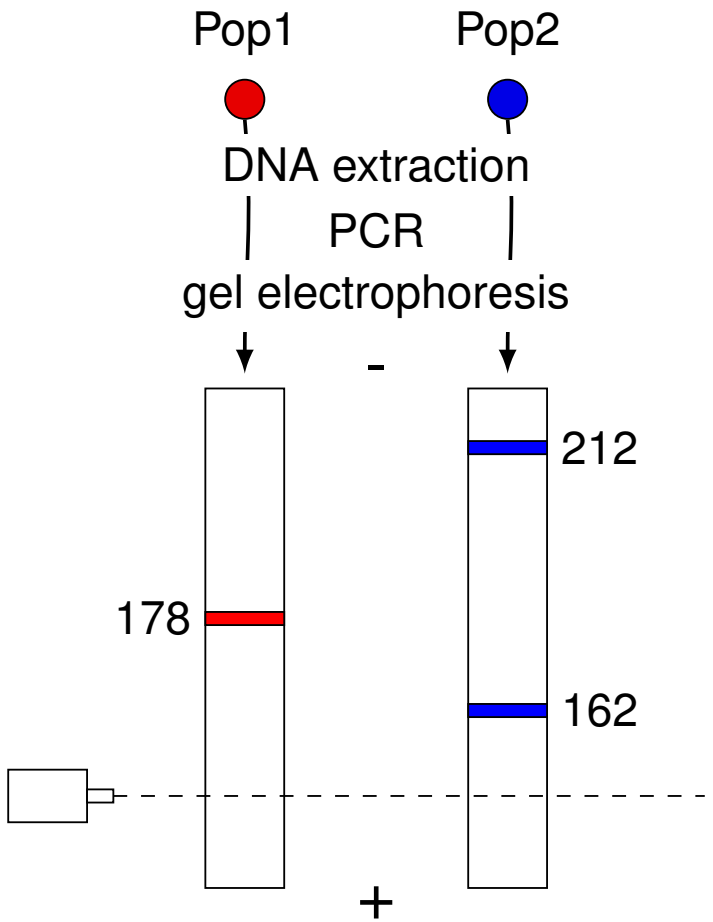
Genetic Differentiation at Microsatellite Markers 1



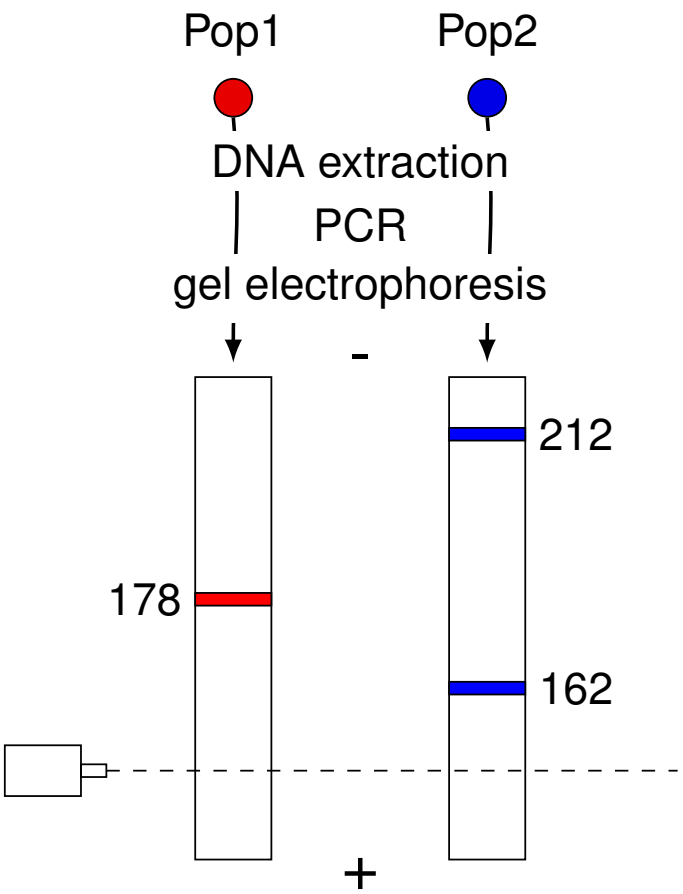
Genetic Differentiation at Microsatellite Markers 1



Genetic Differentiation at Microsatellite Markers 1

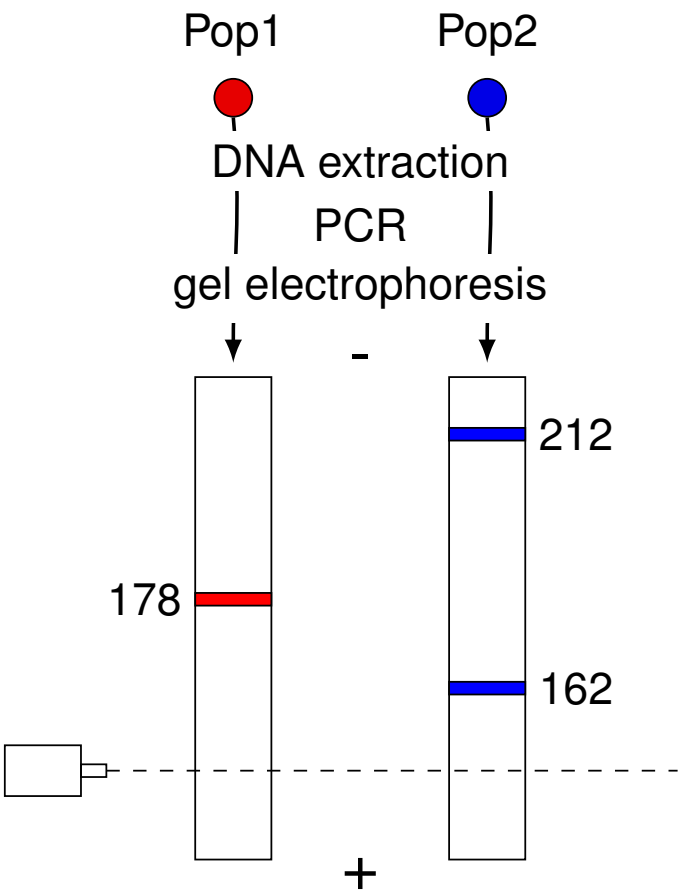


Genetic Differentiation at Microsatellite Markers 1



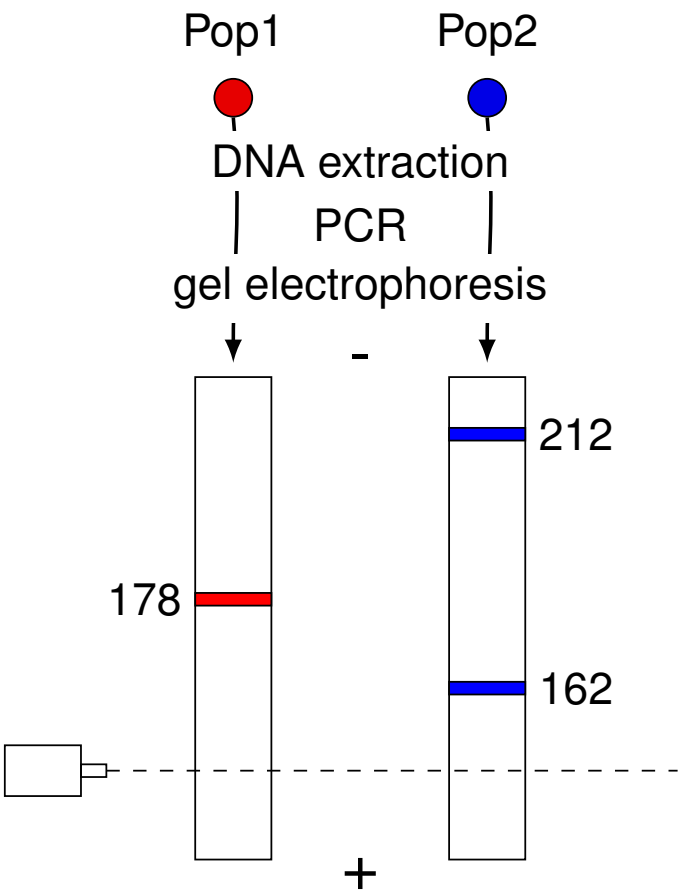
Pop1		Pop2	
allele1	allele2	allele1	allele2
178	178	212	162

Genetic Differentiation at Microsatellite Markers 1



Pop1		Pop2	
allele1	allele2	allele1	allele2
178	178	212	162
178	234	162	162
234	234	212	212
234	178	212	162
...	...	...	...
...	...	...	...
...	...	...	...

Genetic Differentiation at Microsatellite Markers 1



Pop1		Pop2	
allele1	allele2	allele1	allele2
178	178	212	162
178	234	162	162
234	234	212	212
234	178	212	162
...	...	...	...
...	...	...	...
...	...	...	...

Differentiation index D_{est}

Genetic Differentiation at Microsatellite Markers 2

GTA

CAT

Genetic Differentiation at Microsatellite Markers 2

GTAGTAGTAGTAGTAGTA
CATCATCATCATCATCATCAT

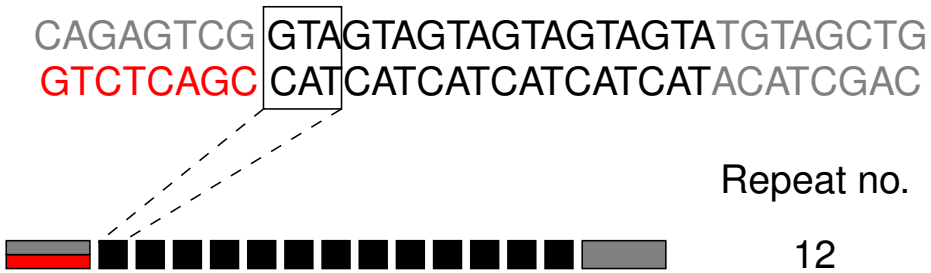
Genetic Differentiation at Microsatellite Markers 2

GTAGTAGTAGTAGTAGTA
CATCATCATCATCATCAT

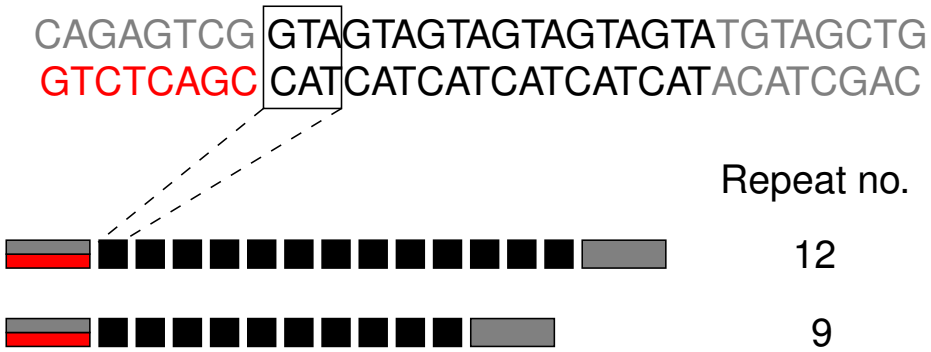
Genetic Differentiation at Microsatellite Markers 2

CAGAGTCG GTAGTAGTAGTAGTAGTATGTAGCTG
GTCTCAGC CATCATCATCATCATCATACATCGAC

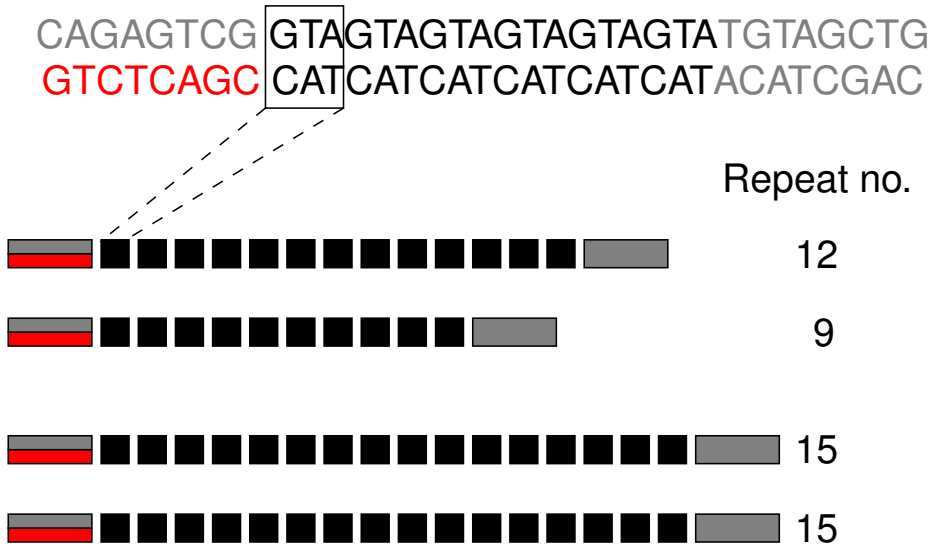
Genetic Differentiation at Microsatellite Markers 2



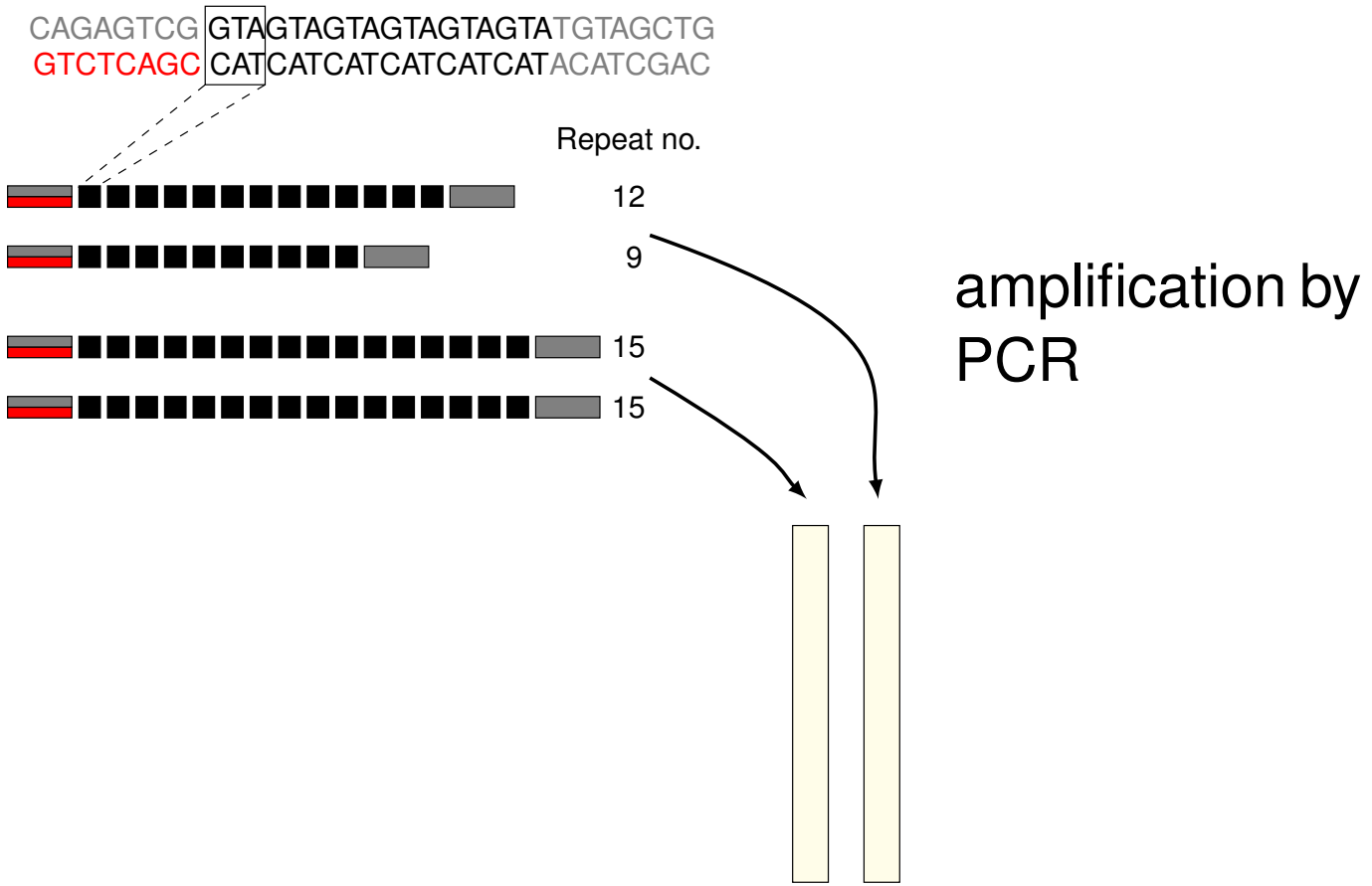
Genetic Differentiation at Microsatellite Markers 2



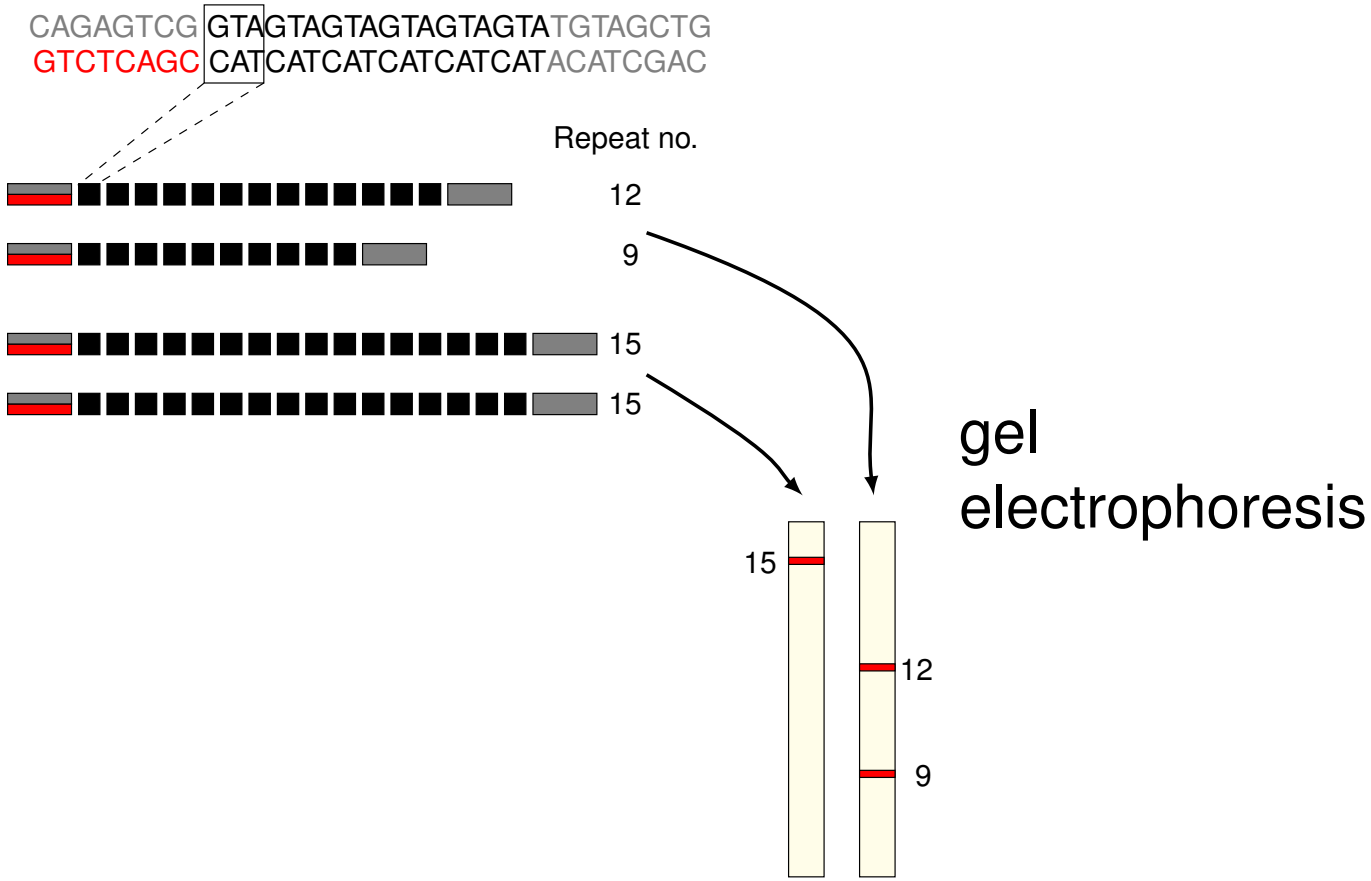
Genetic Differentiation at Microsatellite Markers 2



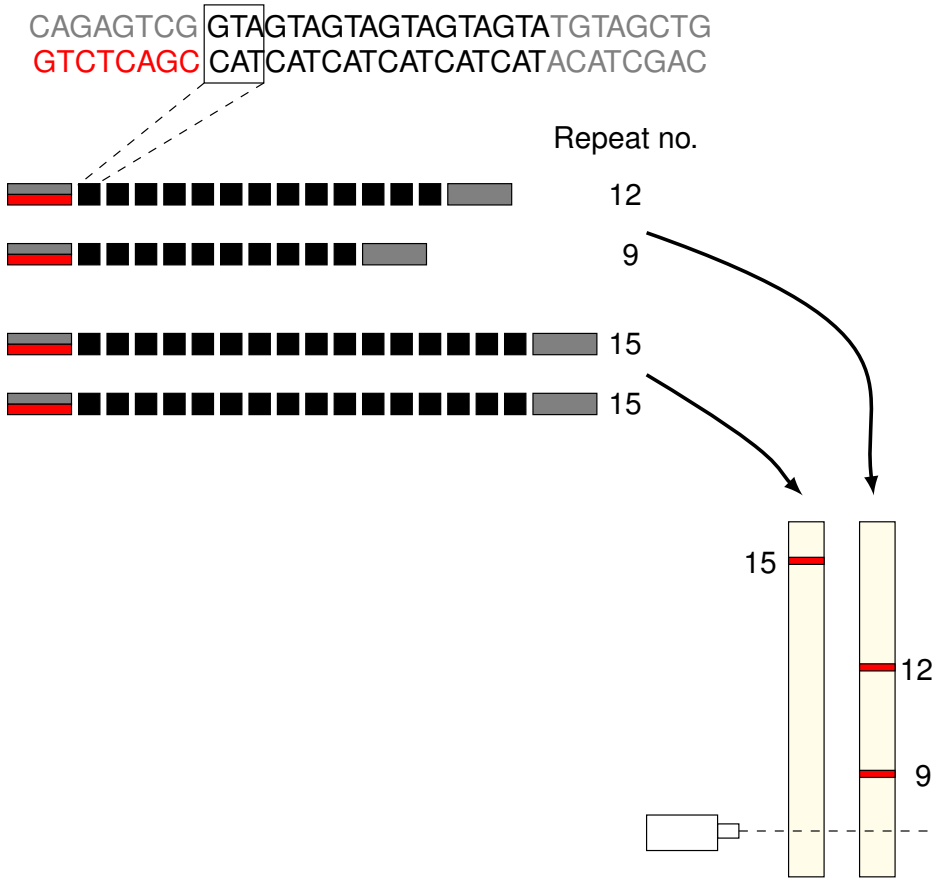
Genetic Differentiation at Microsatellite Markers 2



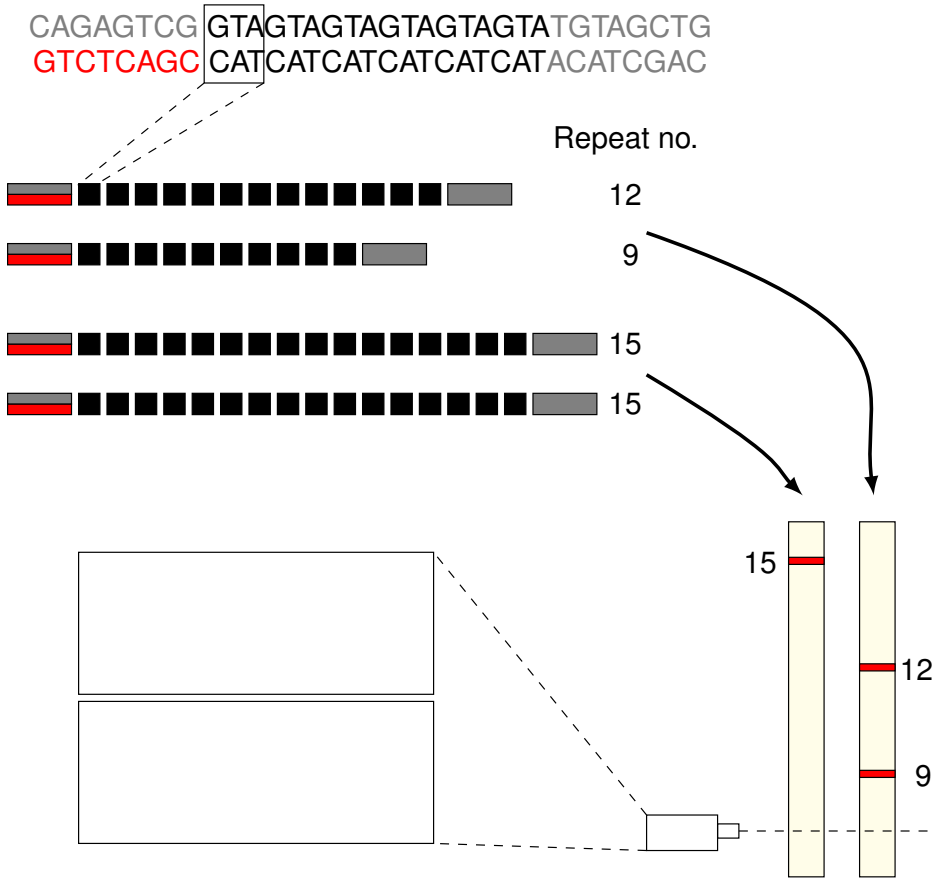
Genetic Differentiation at Microsatellite Markers 2



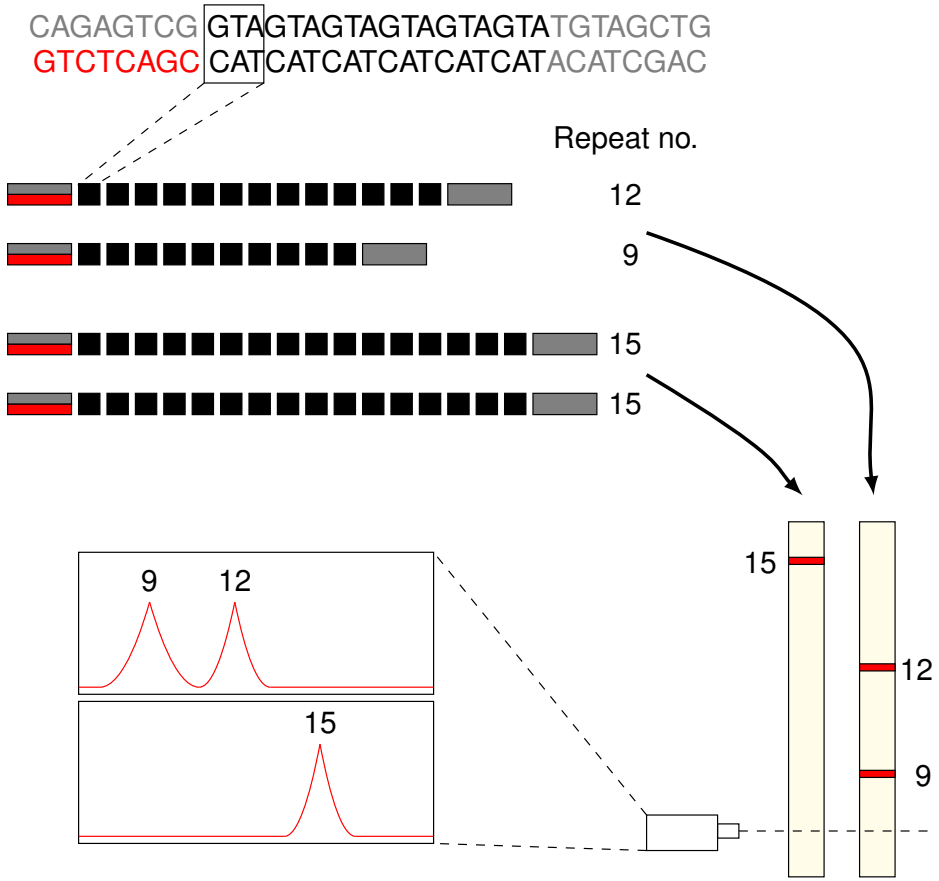
Genetic Differentiation at Microsatellite Markers 2



Genetic Differentiation at Microsatellite Markers 2

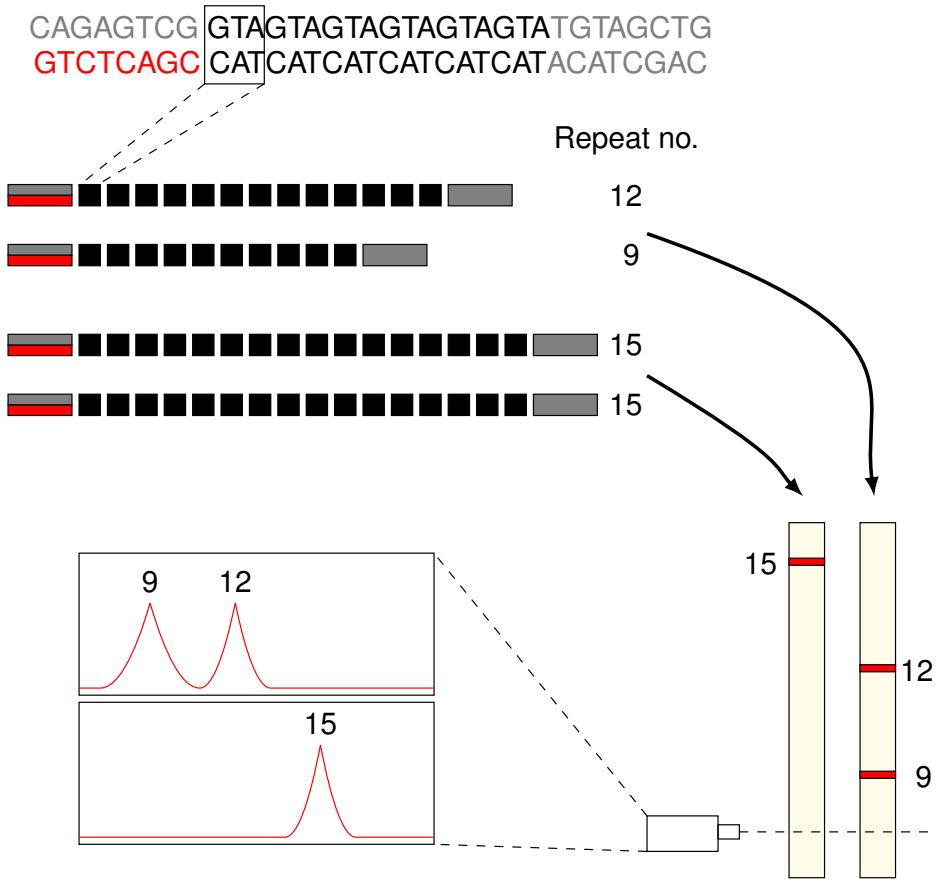


Genetic Differentiation at Microsatellite Markers 2



Genetic Differentiation at Microsatellite Markers 2

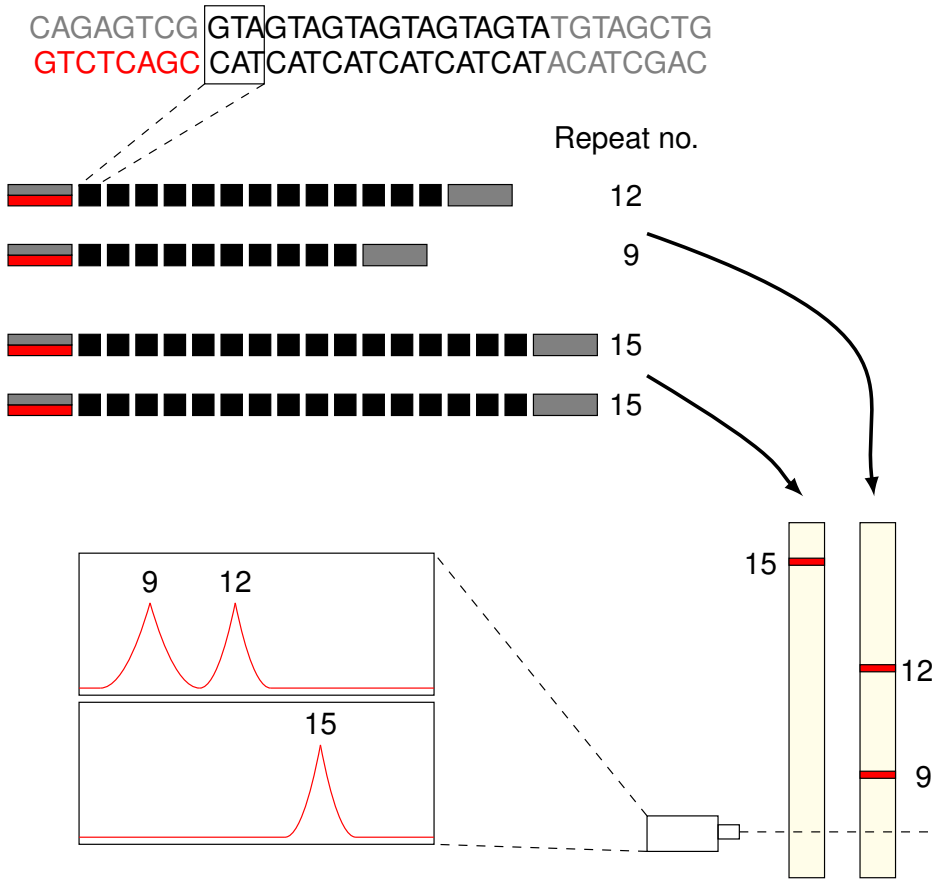
Pop1	Pop2
165 165	170 170
230 165	198 170
230 230	198 198
165 230	170 198
230 230	198 198
165 165	170 170
165 165	170 170
230 165	198 170



Genetic Differentiation at Microsatellite Markers 2

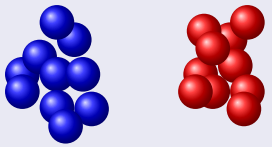
Pop1	Pop2
165 165	170 170
230 165	198 170
230 230	198 198
165 230	170 198
230 230	198 198
165 165	170 170
165 165	170 170
230 165	198 170

Difference D_{est}



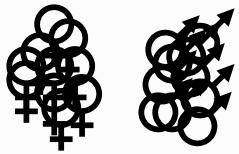
Snails Prefer Conspecifics of the own Population

Population-wise aggregation



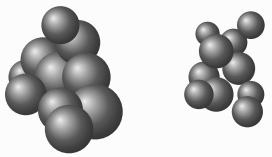
PPI significant ($p \leq 0.1$) in 6 of 17 tests

Sex-bias aggregation



Sex-PI significant ($p \leq 0.1$) in 0 of 17 tests

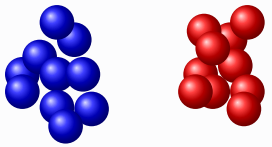
Size-wise aggregation



Size-PI significant ($p \leq 0.1$) in 2 of 17 tests

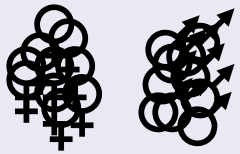
Snails Prefer Conspecifics of the own Population

Population-wise aggregation



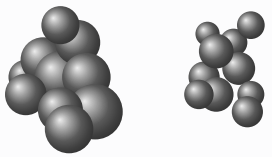
PPI significant ($p \leq 0.1$) in 6 of 17 tests

Sex-bias aggregation



Sex-PI significant ($p \leq 0.1$) in 0 of 17 tests

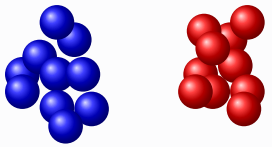
Size-wise aggregation



Size-PI significant ($p \leq 0.1$) in 2 of 17 tests

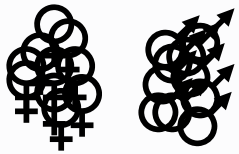
Snails Prefer Conspecifics of the own Population

Population-wise aggregation



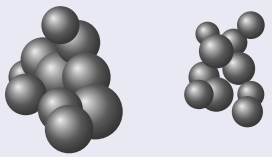
PPI significant ($p \leq 0.1$) in 6 of 17 tests

Sex-bias aggregation



Sex-PI significant ($p \leq 0.1$) in 0 of 17 tests

Size-wise aggregation



Size-PI significant ($p \leq 0.1$) in 2 of 17 tests

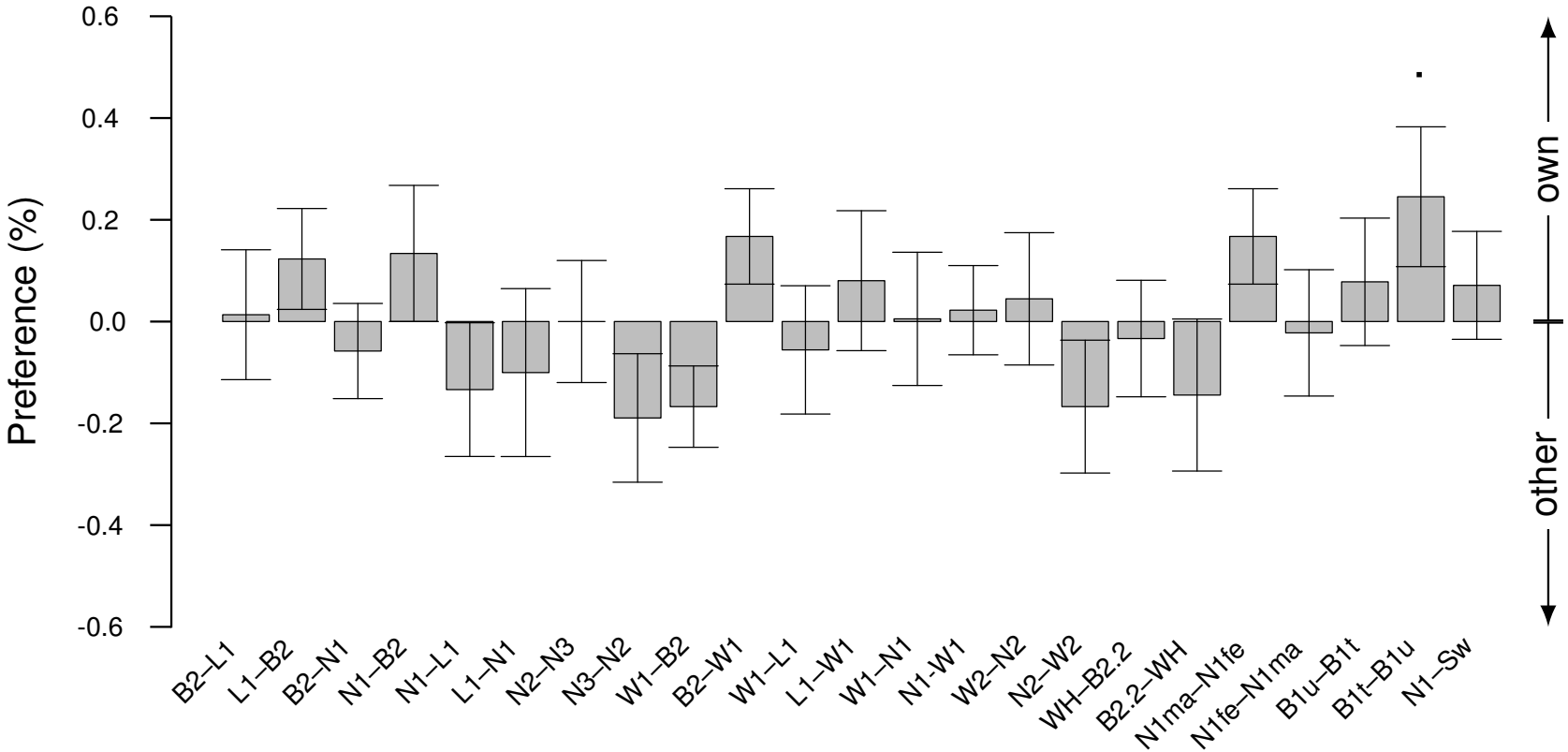
Snails Prefer Conspecifics of the own Population

Populations
differ
intrinsically

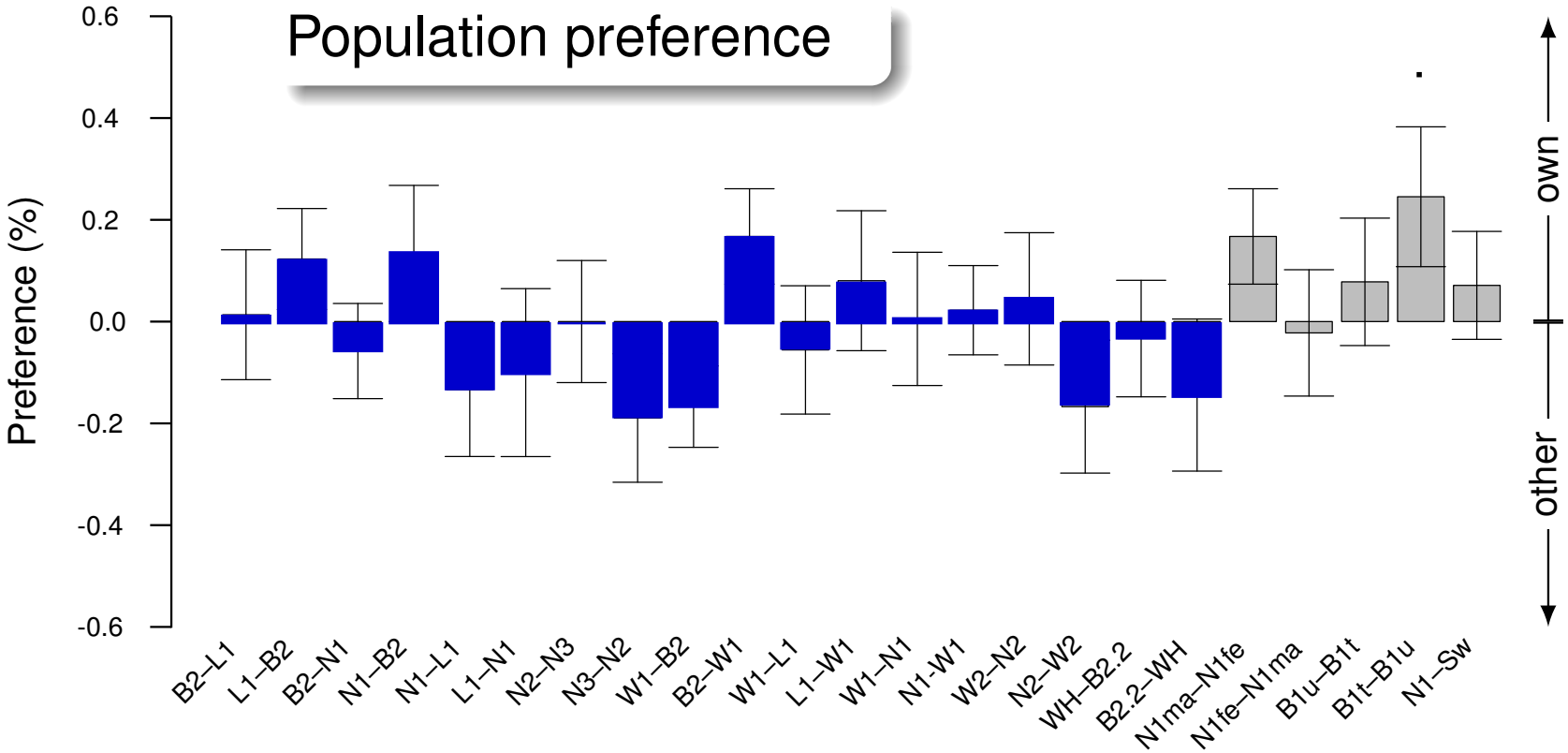
Snails Prefer Conspecifics of the own Population

. . . aggregation frequency
increases
during the
mating season

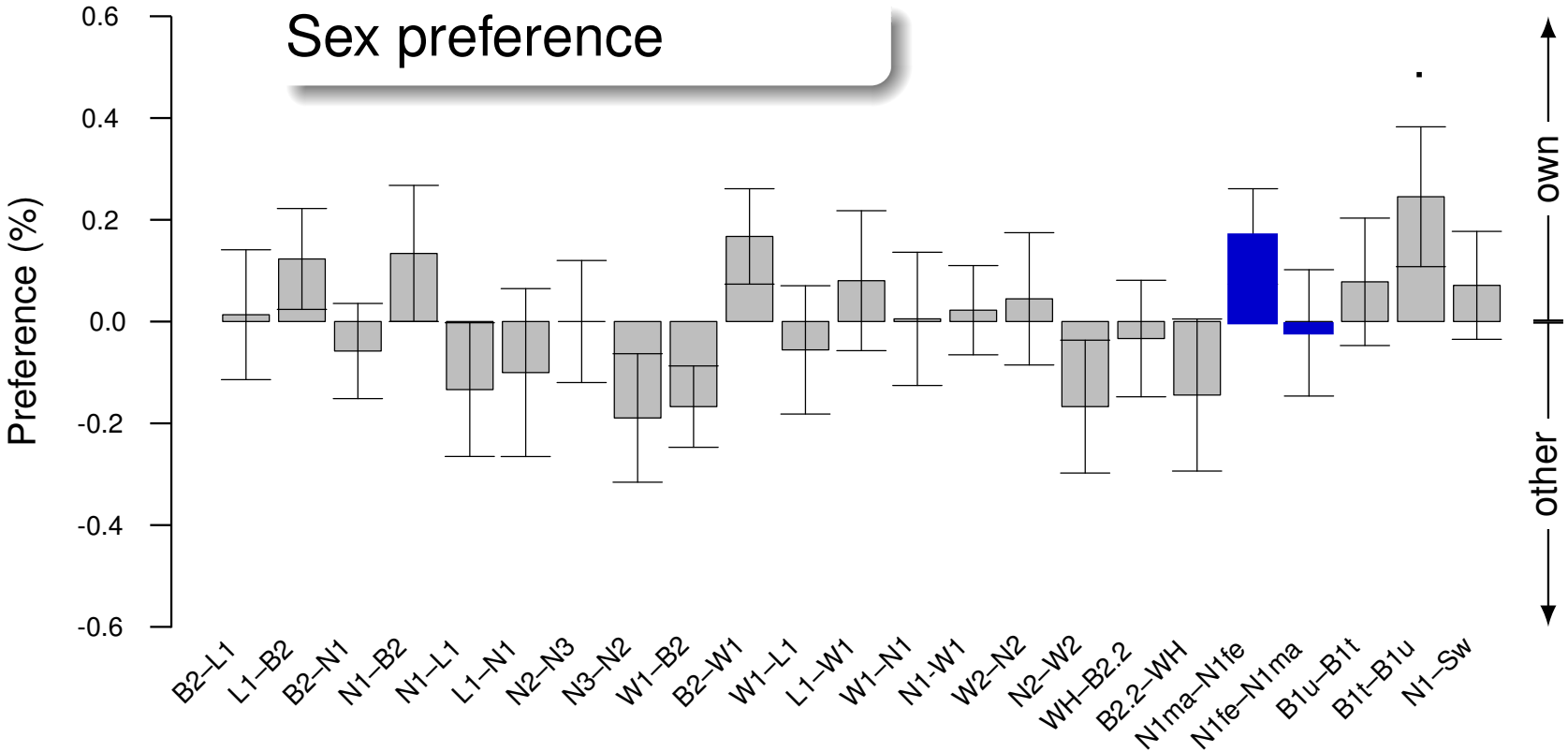
Snails do not Prefer any Volatile Chemicals



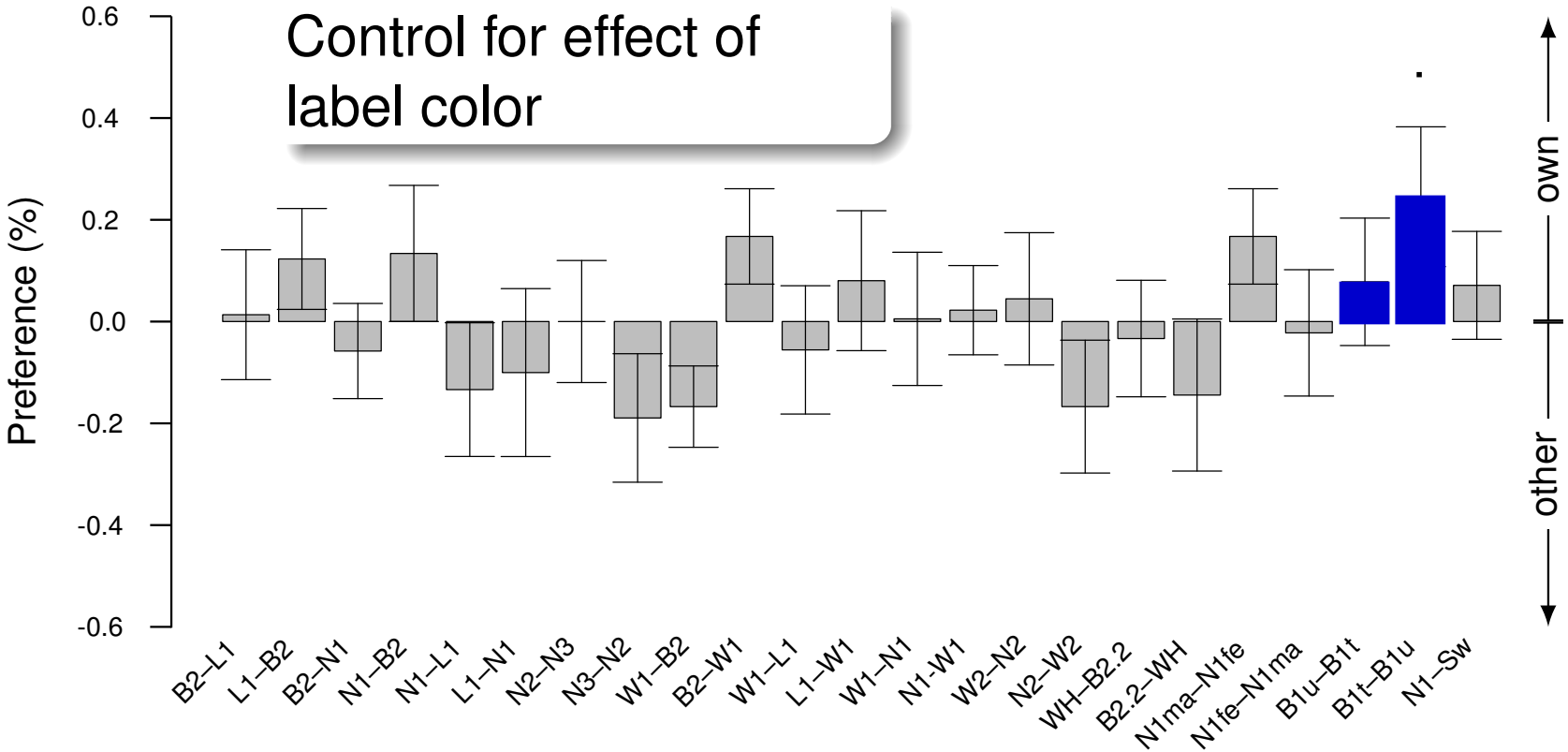
Snails do not Prefer any Volatile Chemicals



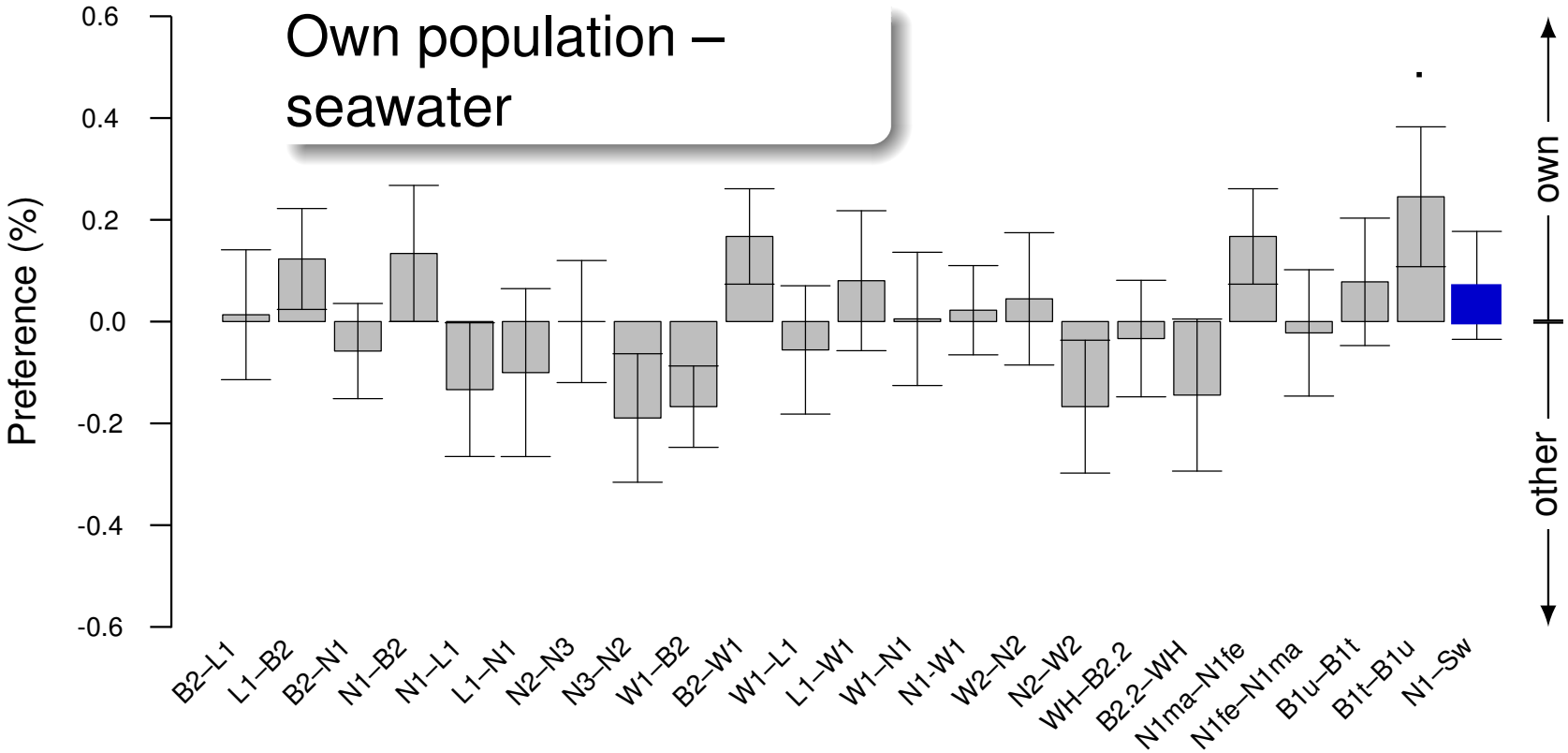
Snails do not Prefer any Volatile Chemicals



Snails do not Prefer any Volatile Chemicals



Snails do not Prefer any Volatile Chemicals

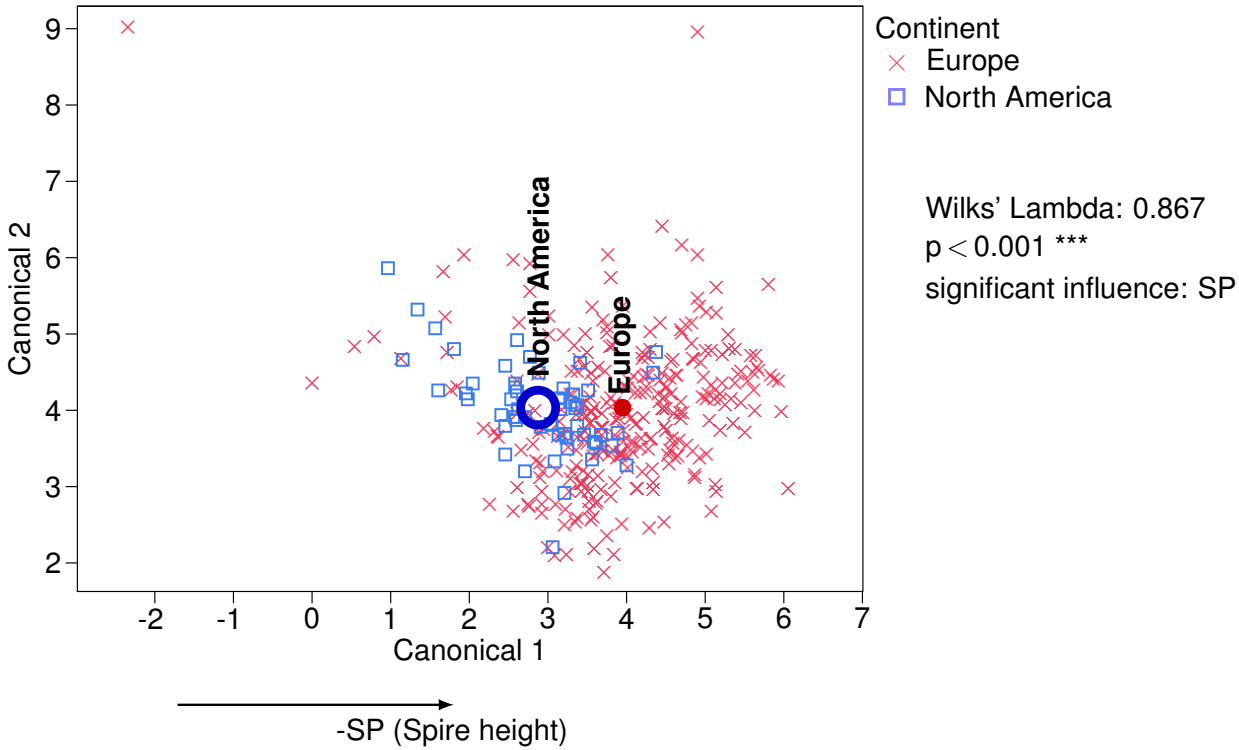


Snails do not Prefer any Volatile Chemicals

Populations
are
not discriminated
by
volatile chemicals

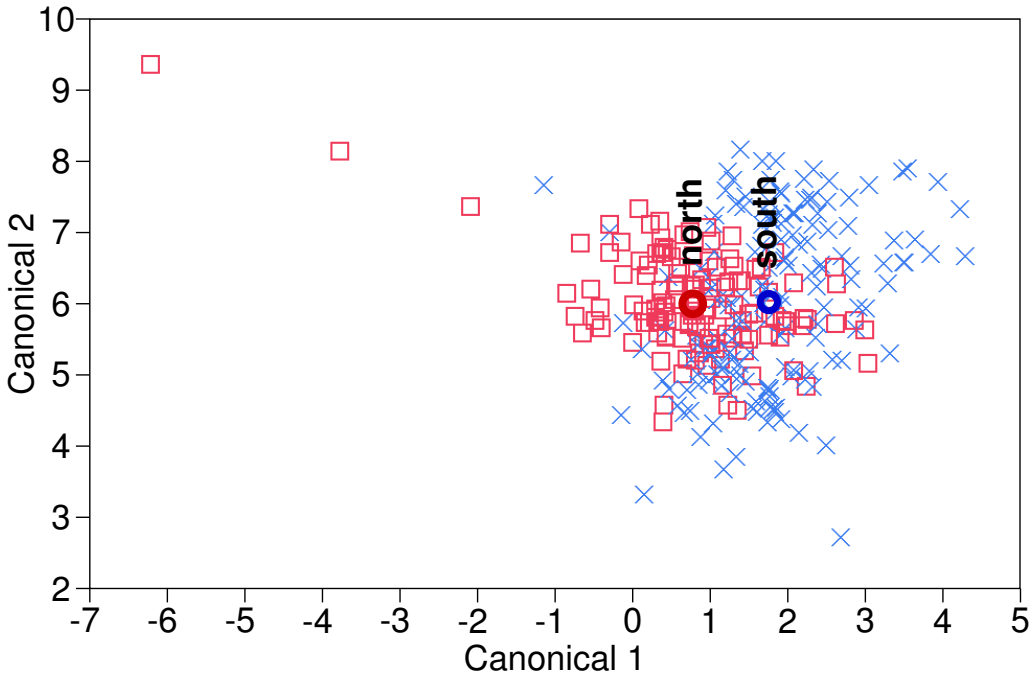
Results of Discriminant analyzes

EFWS – Woods Hole



Results of Discriminant analyzes

North coasts – South coasts



Side
- north
- south

Wilks' Lambda: 0.802

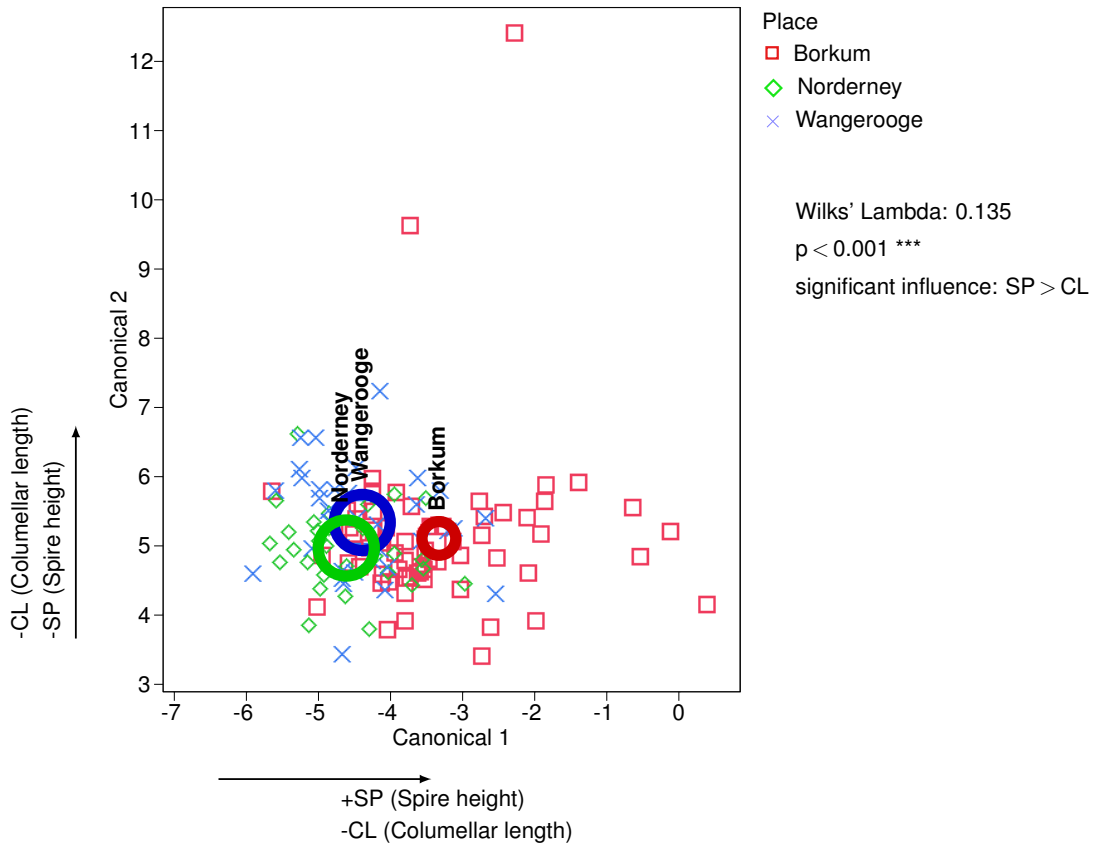
$p < 0.001$ ***

significant influence: CL > LA

+CL (Columellar length)
-LA (Length of aperture

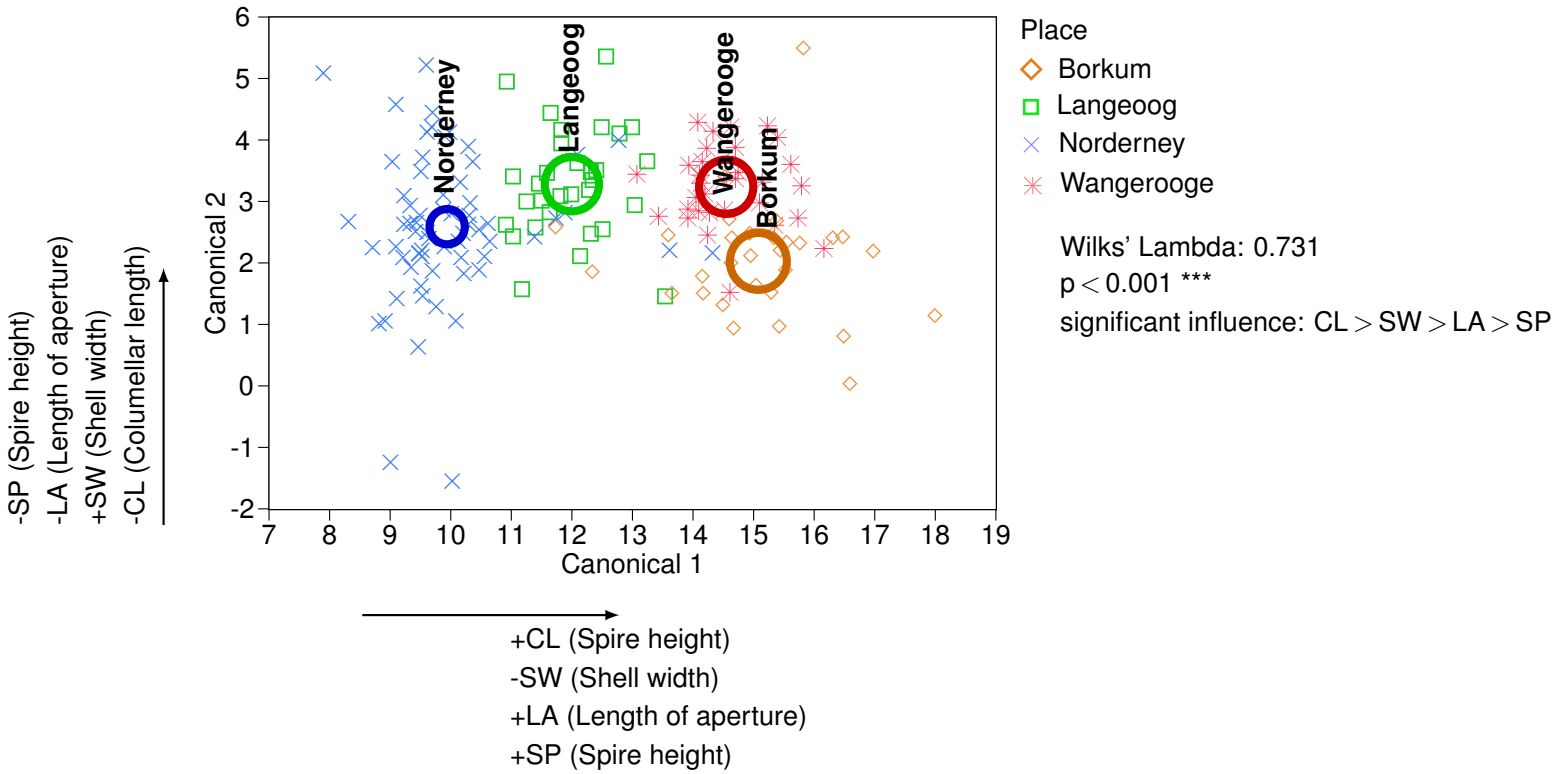
Results of Discriminant analyzes

Within north coasts



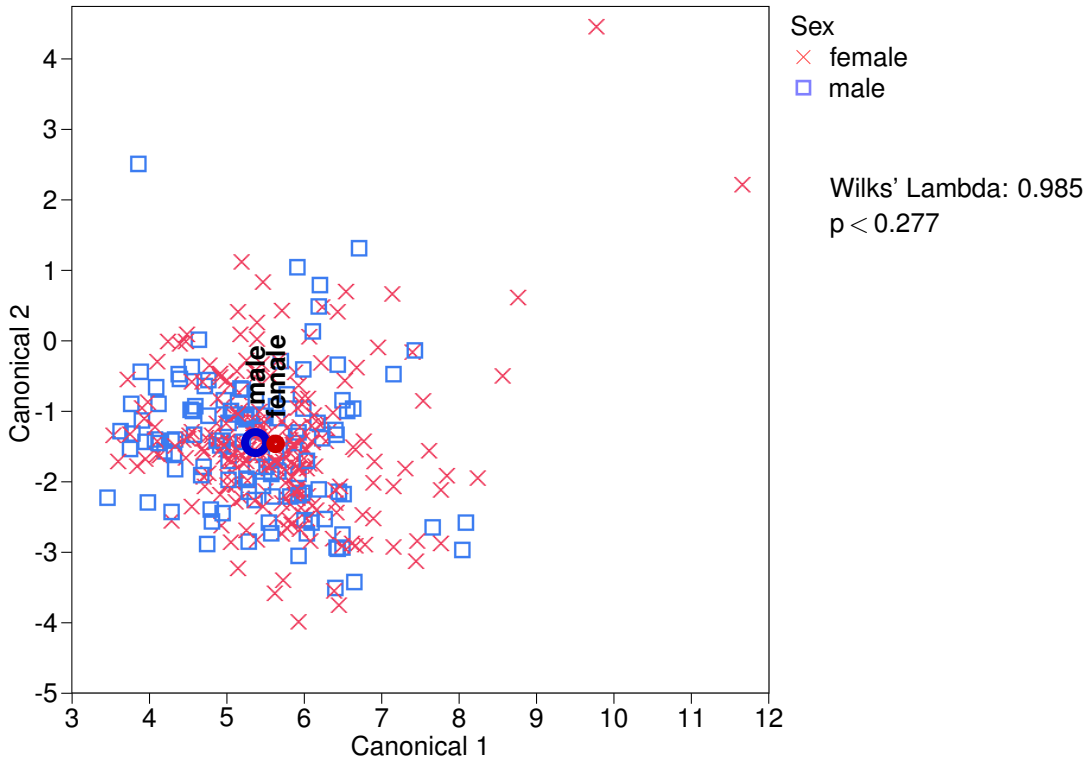
Results of Discriminant analyzes

Within south coasts



Results of Discriminant analyzes

Sexes



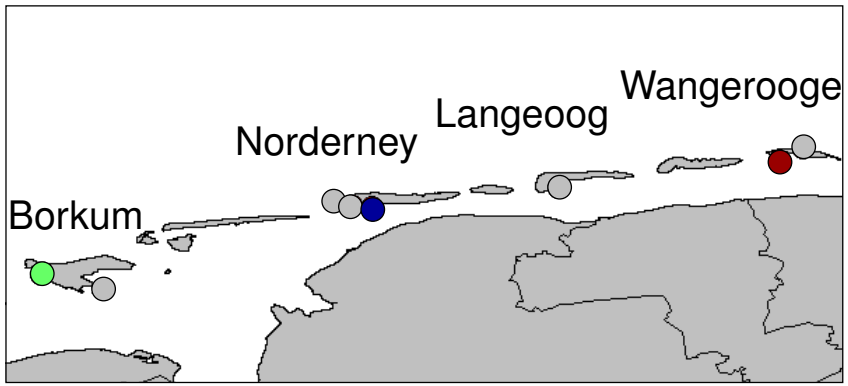
Genetic (D_{est}) and Geographic (km) Distance

	B2●	W1●	N2●	WH●	
B2●	···	0.011	-0.007	**0.033**	*
W1●	82.5	···	0.006	**0.056**	**
N2●	38.0	39.9	···	**0.057**	*
WH●	5662.8	5730.7	5692.3	···	

Genetic (D_{est}) and Geographic (km) Distance

Within the EFWS

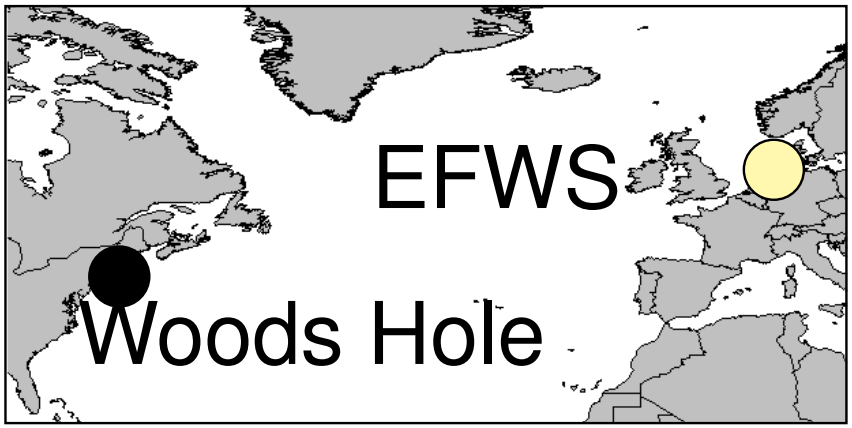
	B2●	W1●	N2●	WH●	
B2●	···	0.011	-0.007	**0.033**	*
W1●	82.5	···	0.006	**0.056**	**
N2●	38.0	39.9	···	**0.057**	*
WH●	5662.8	5730.7	5692.3	···	



Genetic (D_{est}) and Geographic (km) Distance

Between the EFWS and Woods Hole

	B2●	W1●	N2●	WH●	
B2●	···	0.011	-0.007	**0.033**	*
W1●	82.5	···	0.006	**0.056**	**
N2●	38.0	39.9	···	**0.057**	*
WH●	5662.8	5730.7	5692.3	···	



Genetic (D_{est}) and Geographic (km) Distance

Wadden Sea
Populations
are
not differentiated
at
neutral loci