Archaeo-riddle RQ1

What was the relationship between the two groups?

Was it peaceful or hostile?

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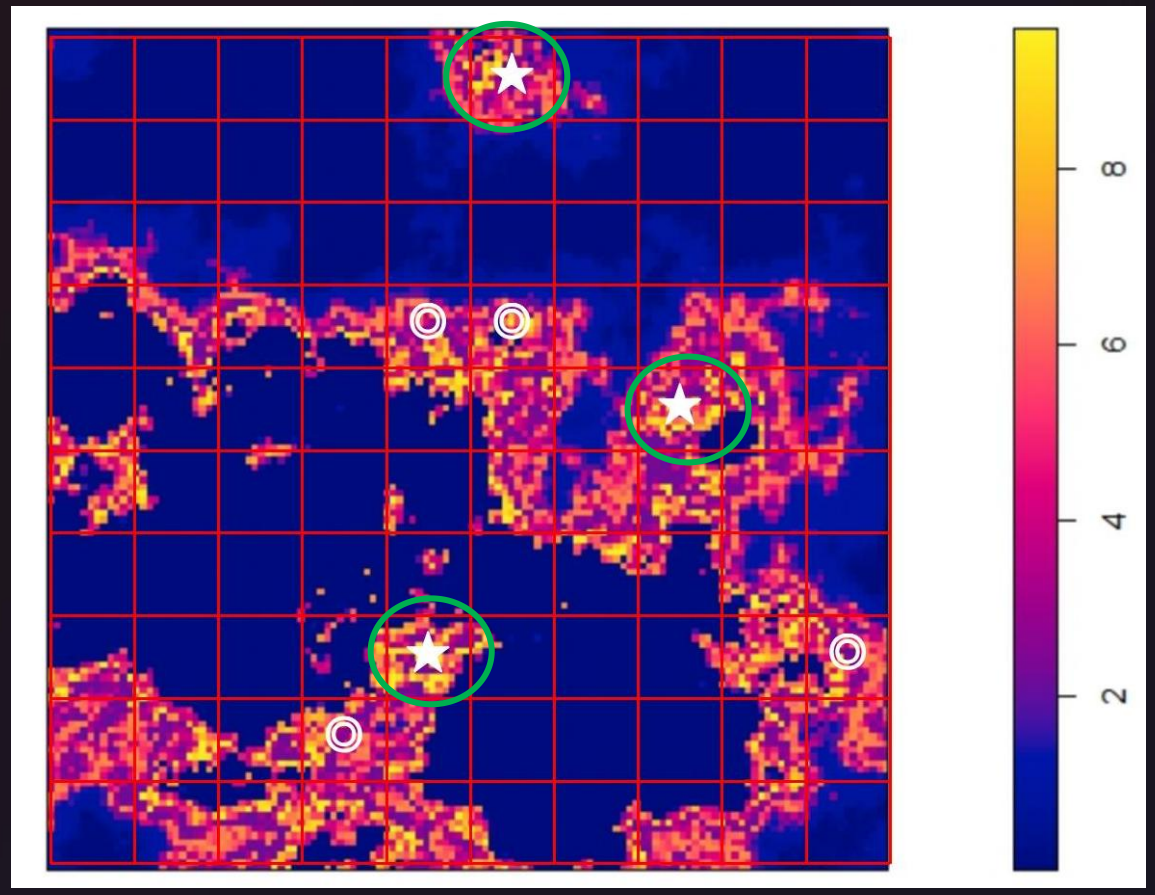
PART 01

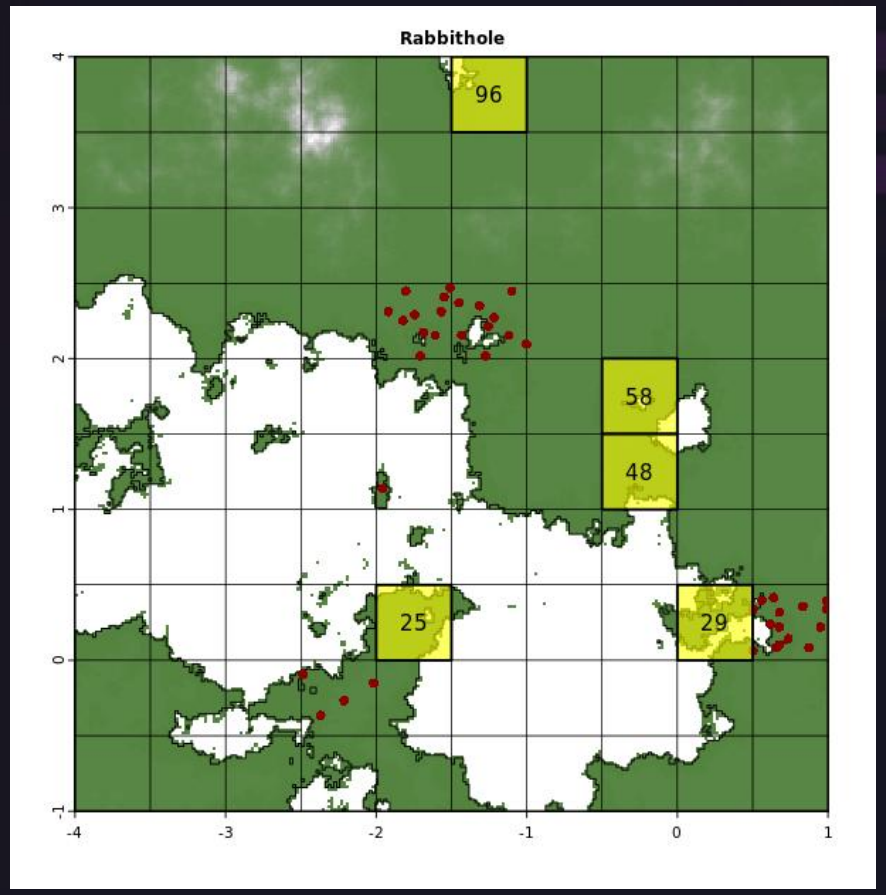
Data

- 5 more squares
- 3 periods

Part 1 Data: 5 more squares

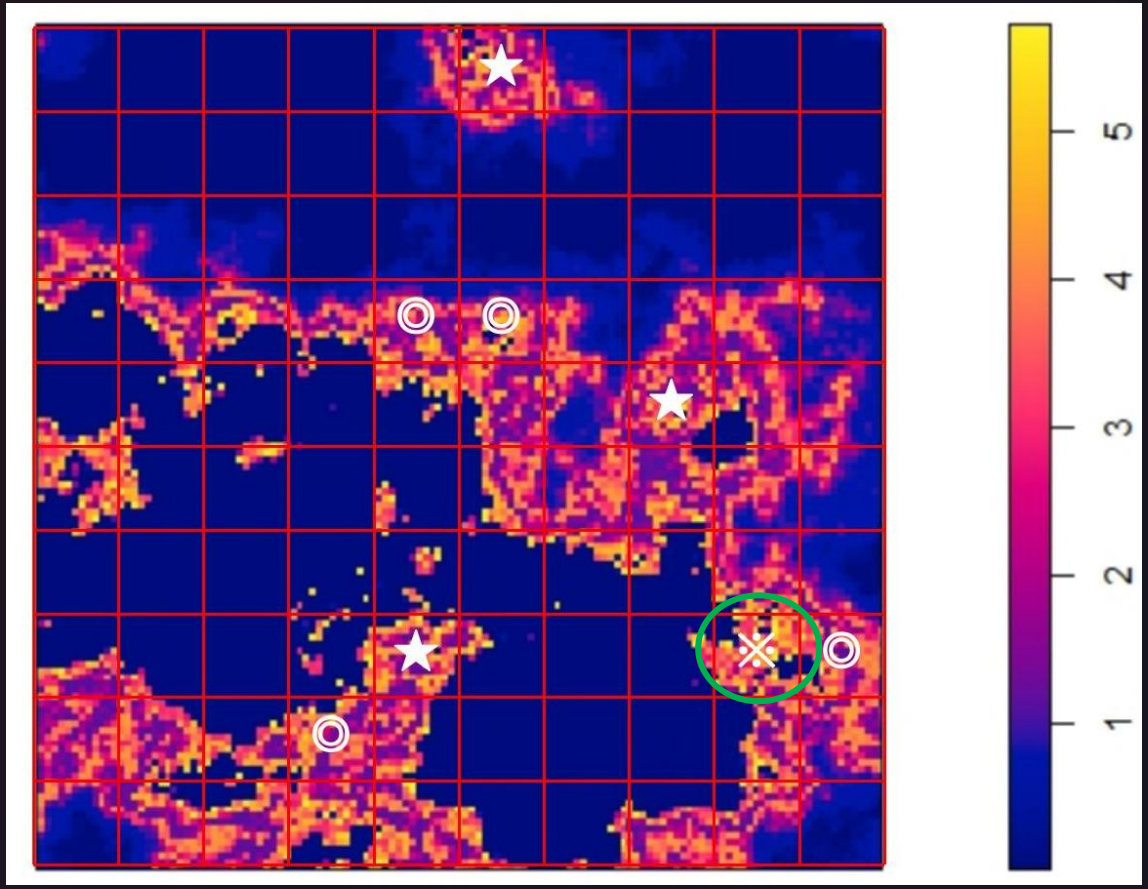
★
3
squares
for all
sites

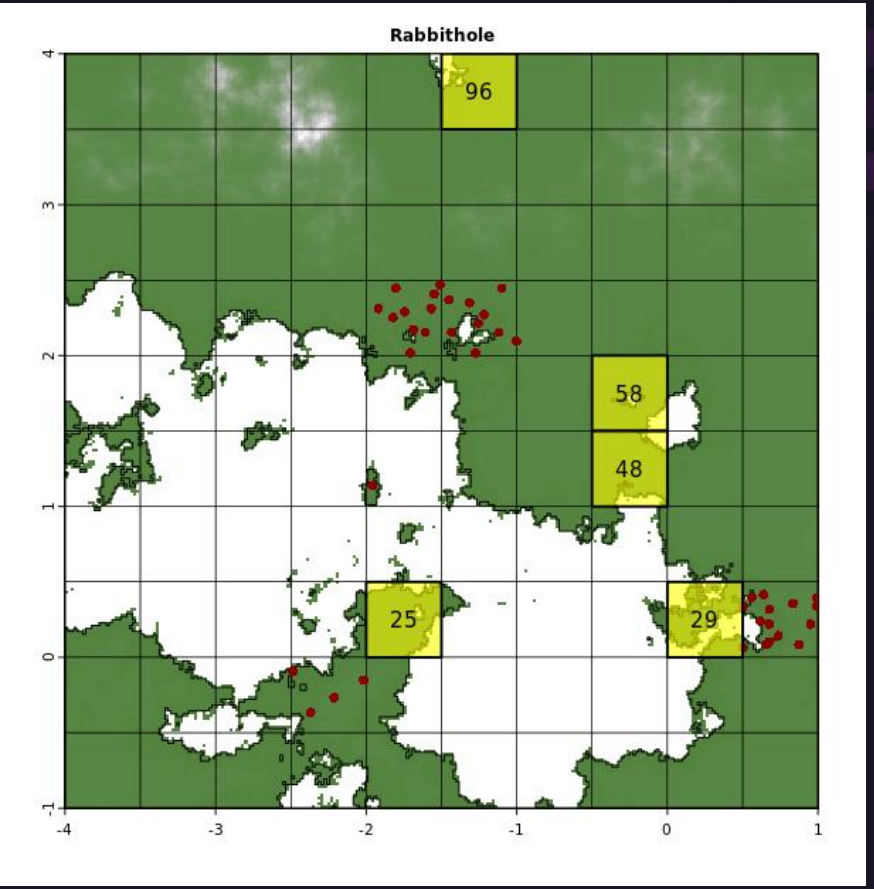




Part 1 Data: 5 more squares

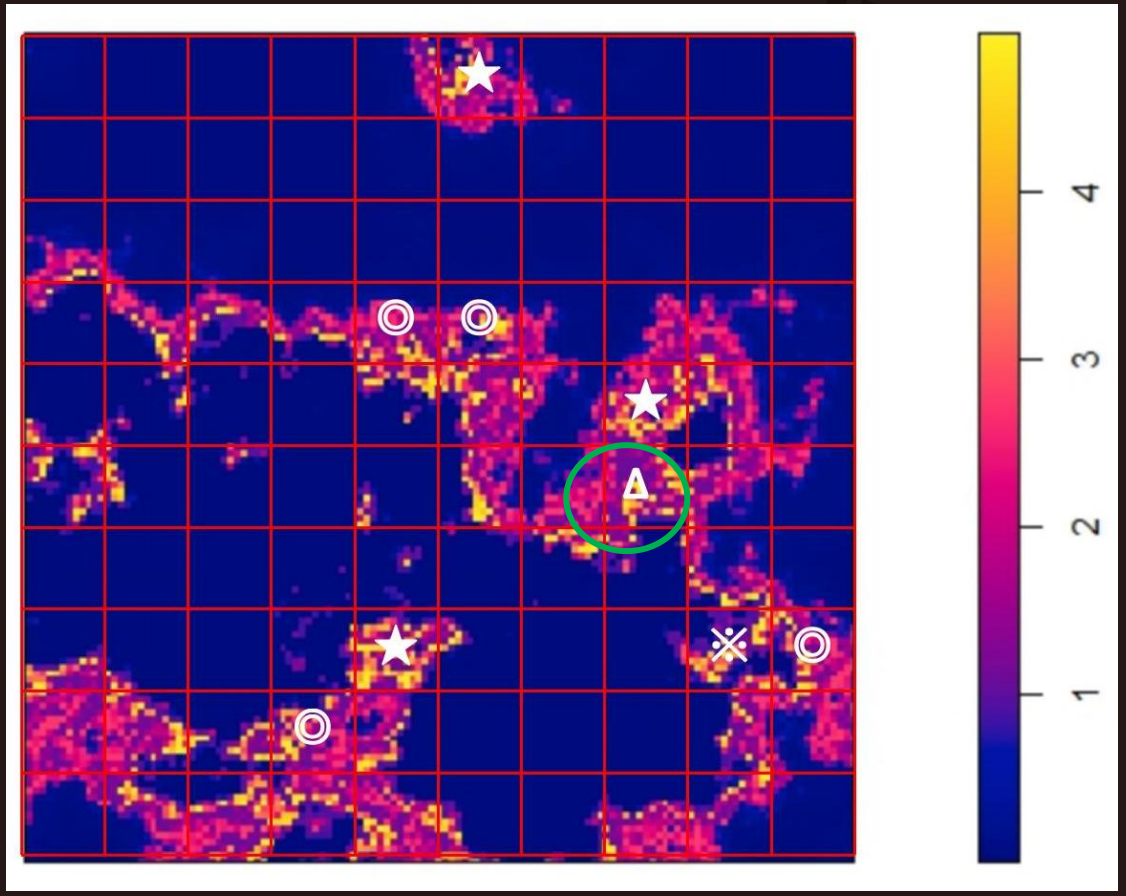
※
1 square
for
Farmers

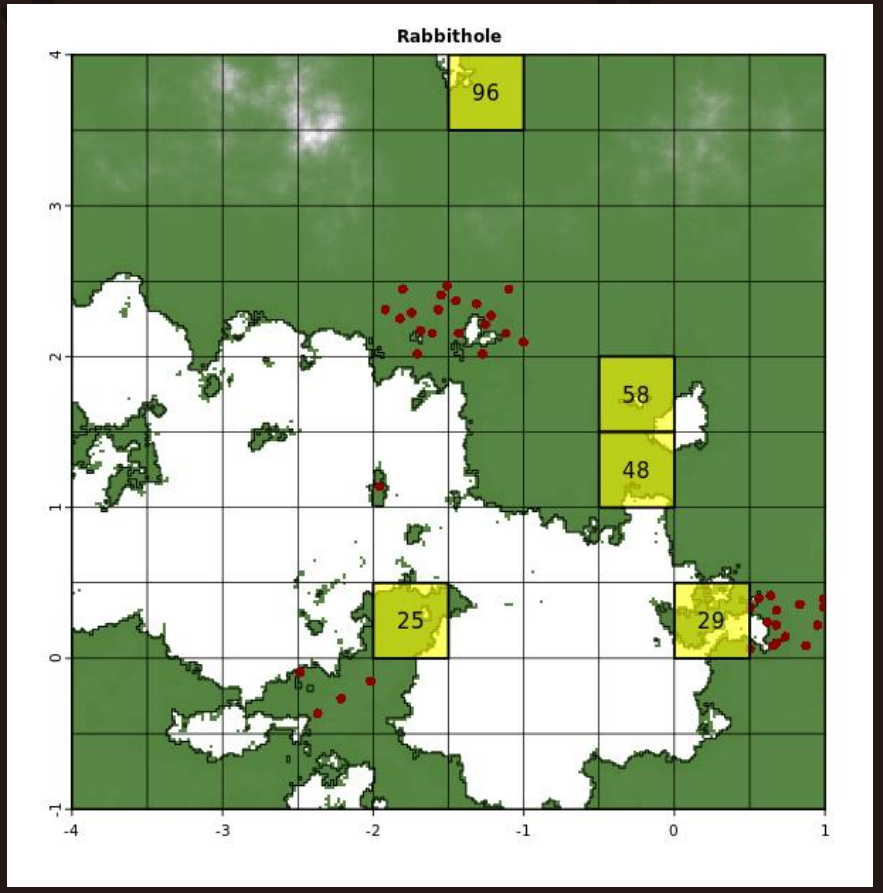




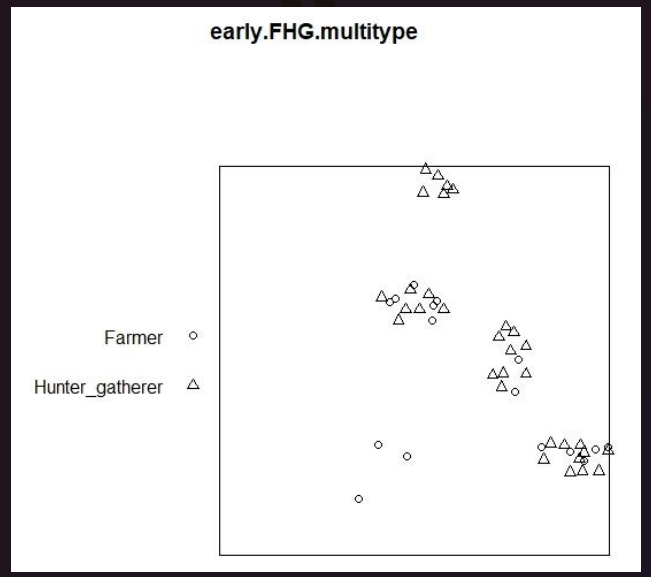
Part 1 Data: 5 more squares

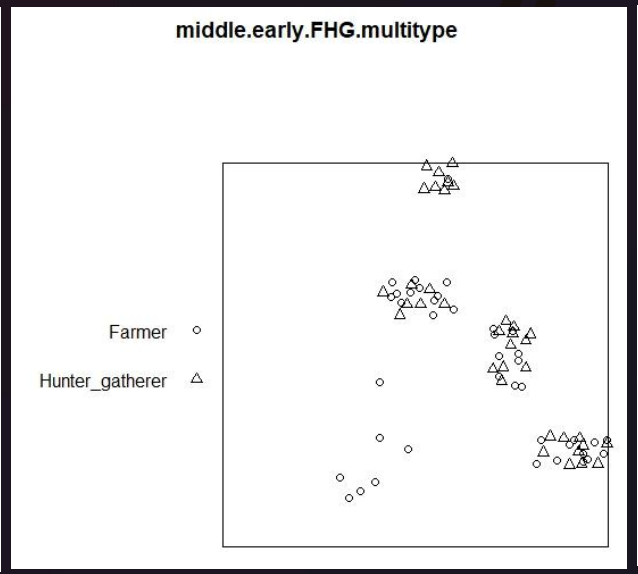
Δ
1 square for hunter-gatherers

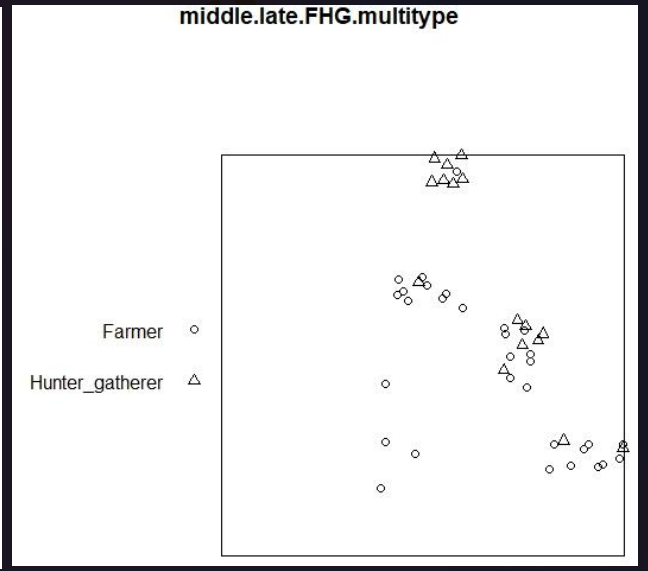


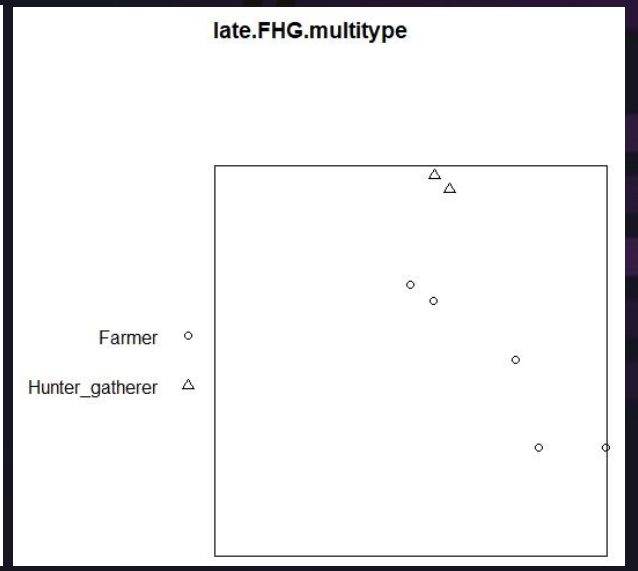


Part 1 Data: 3 periods









early period

before 6000 BC
48 sites

middle period

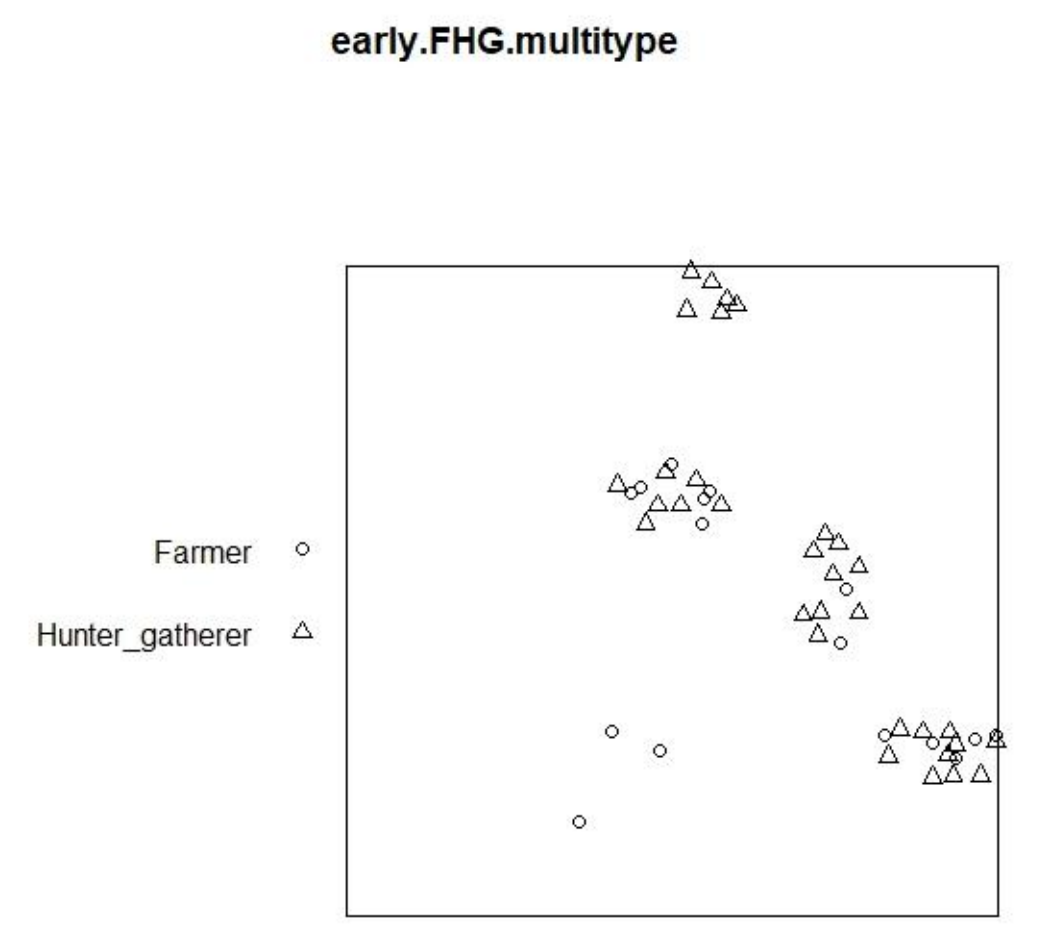
from 6000 BC to 5000 BC
middle-early period: from 6000 BC to 5500 BC (77 sites)
middle-late period: from 5500 BC to 5000 BC (47 sites)

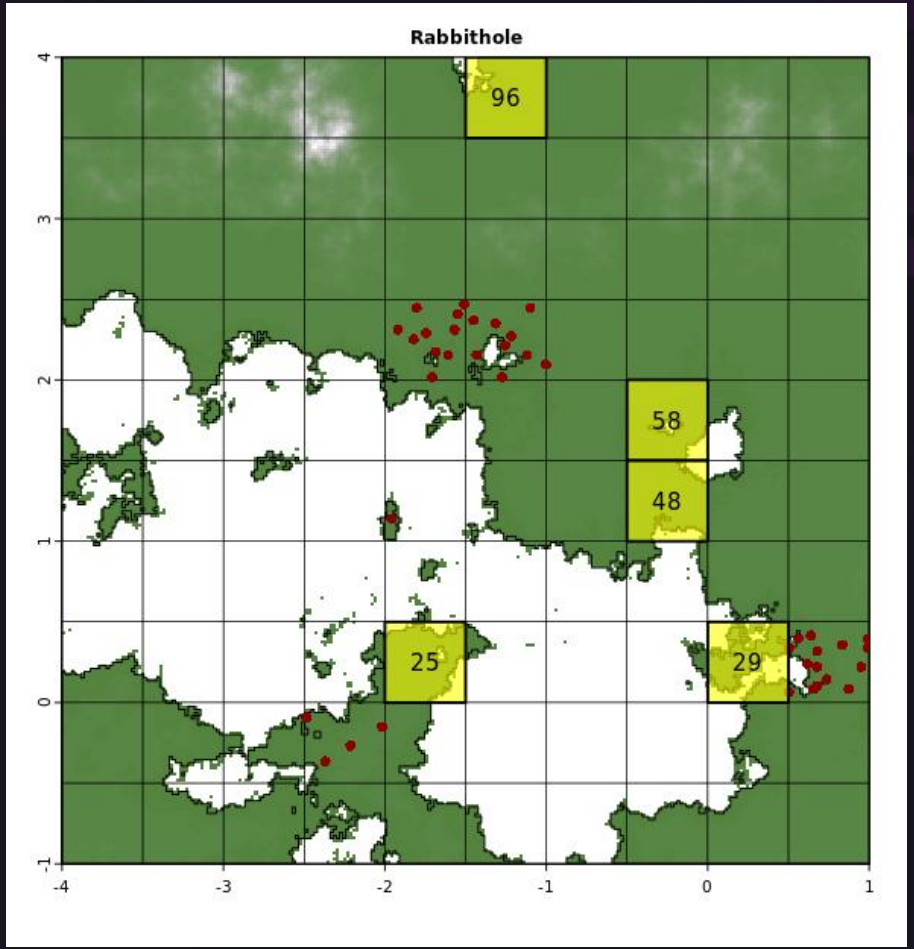
late period

after 5000 BC
7 sites

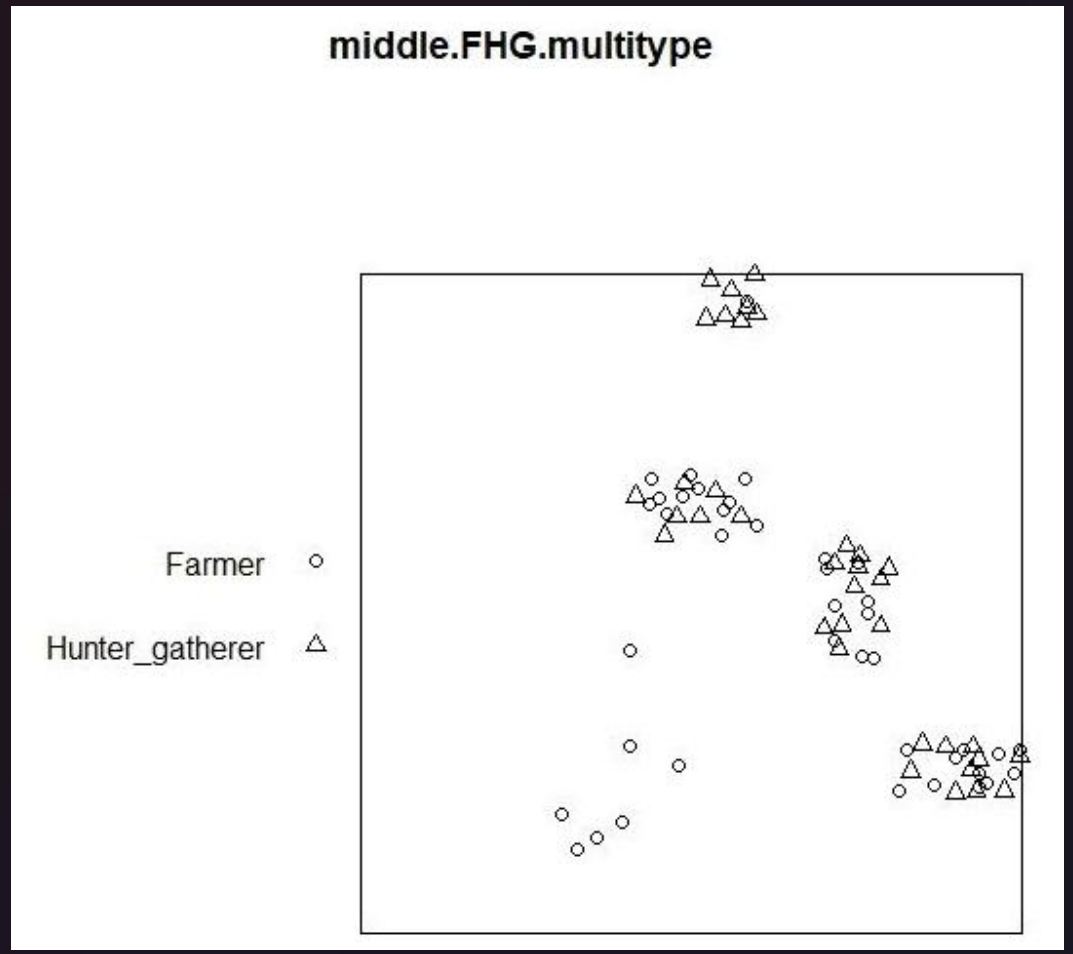
OxCal online

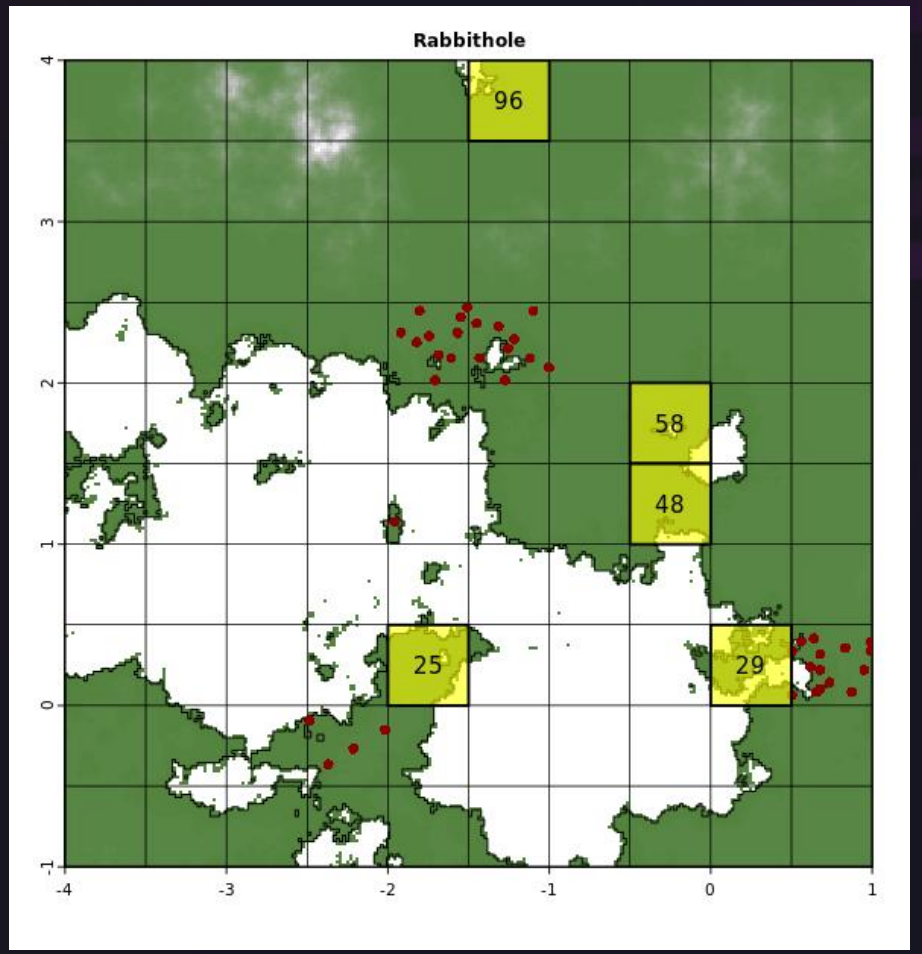
Part 1 Data: 3 periods



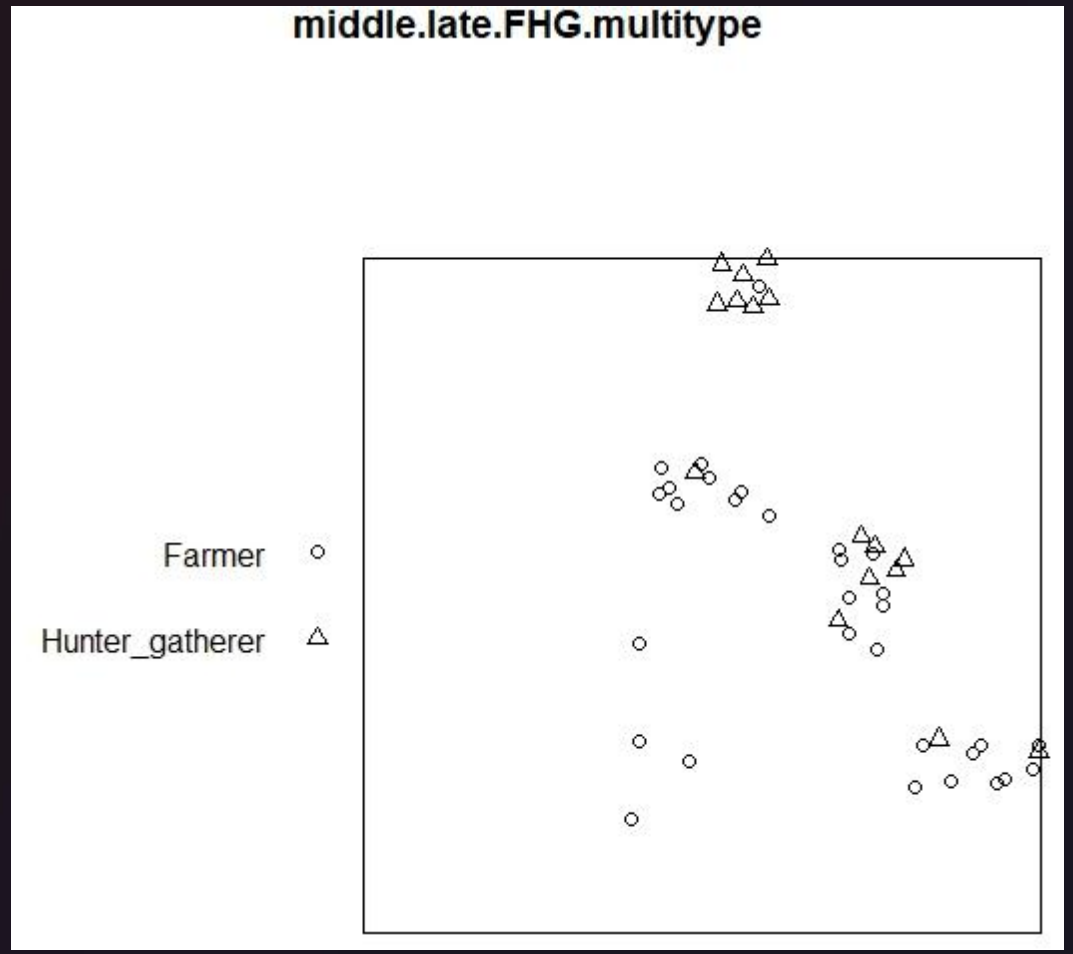


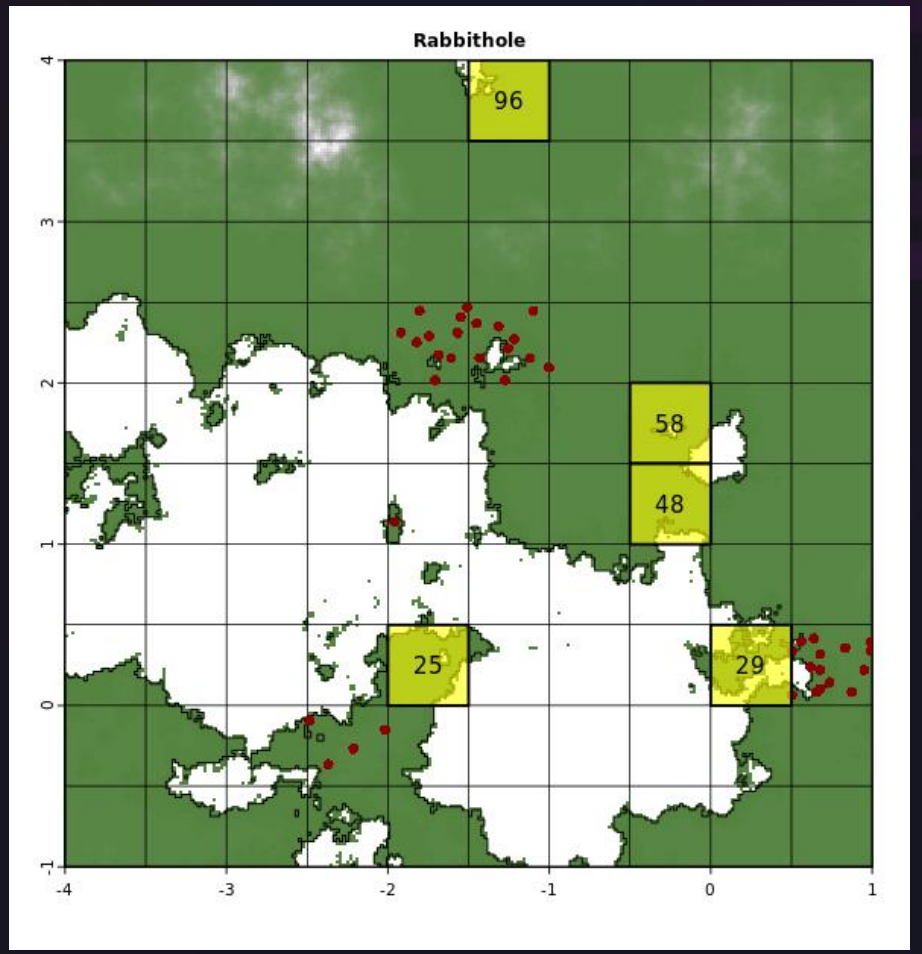
Part 1 Data: 3 periods



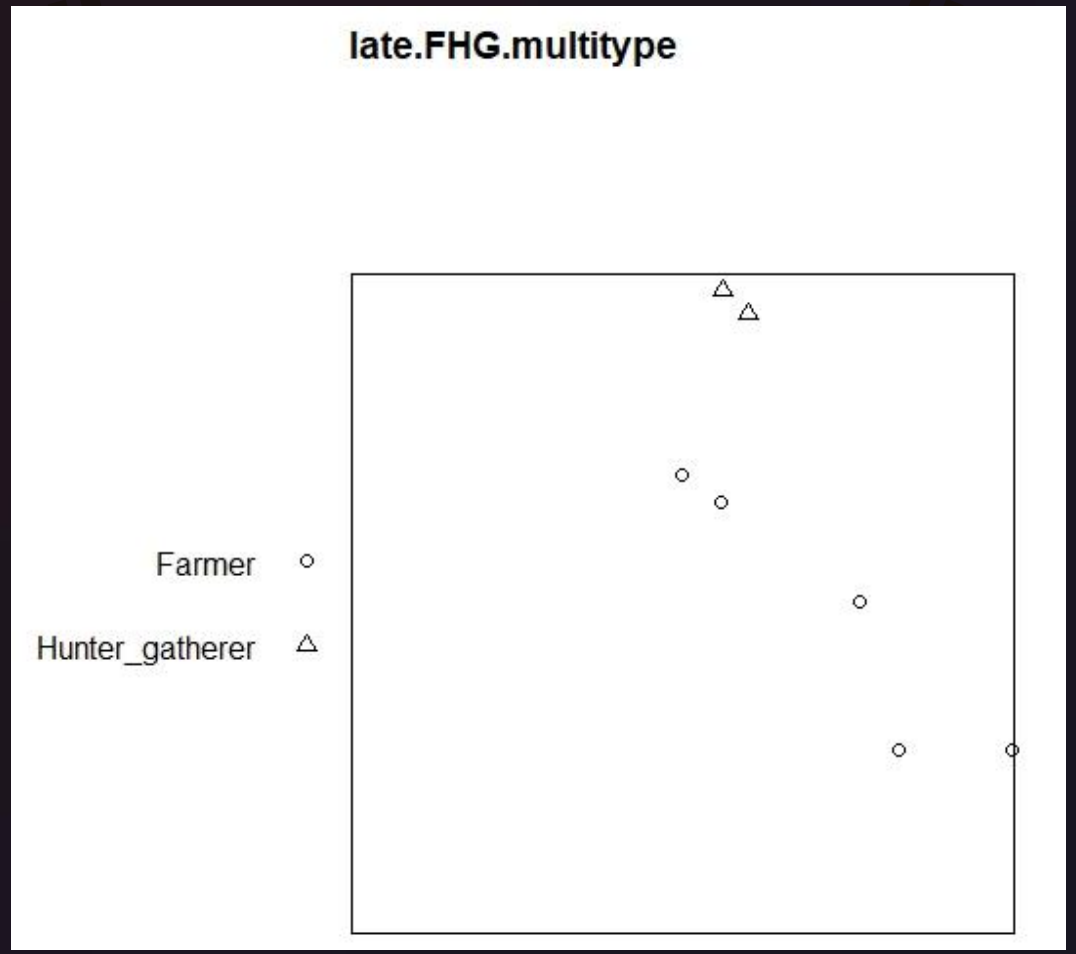


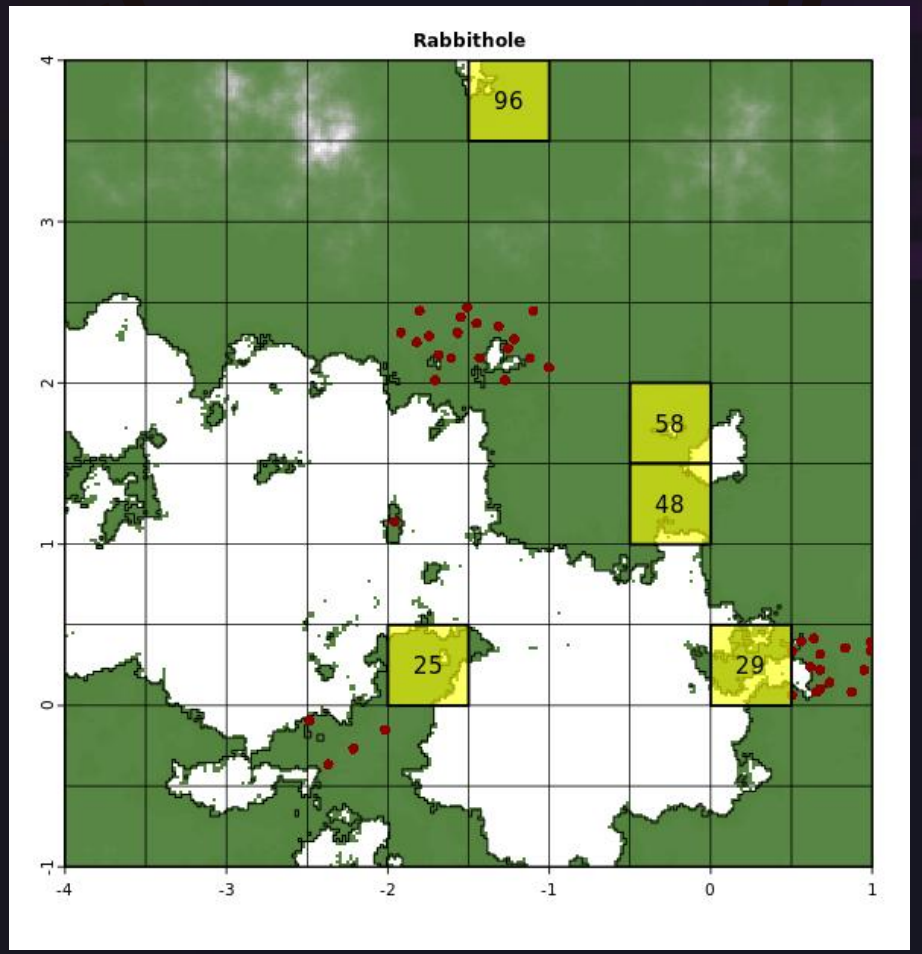
Part 1 Data: 3 periods





Part 1 Data: 3 periods





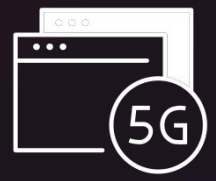
PART 02

Methods

-from distance to relationship

-point process modeling

Part 2 Methods



- from distance to relationship

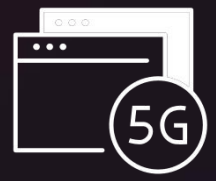
Hi, HG! Can the distance between us tell something about our relationship?

Hi, F! Yes it can, according to evolutionary ecology studies (Field 2003).

If resources were dense and predictable, we would compete to maintain exclusive access to resources, being crowded with each other (hostile).

If resources were scattered and unpredictable, we would cooperate to share or exchange resources, keeping reasonable distances from each other (peaceful).

Part 2 Methods



- from distance to relationship
- point process modeling

I see. How to analyze it?

Xuan asked me to say we could try to do this through **point process modeling (PPM)**.

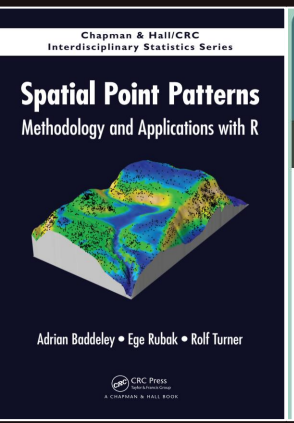
Is PPM able to answer this question?

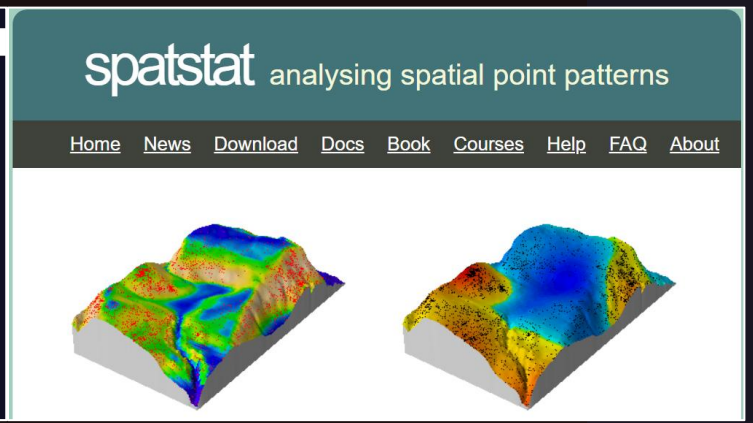
Remain to be seen.

Part 2 Methods

- point process modeling
- first-order
- second-order

  Gibbs models





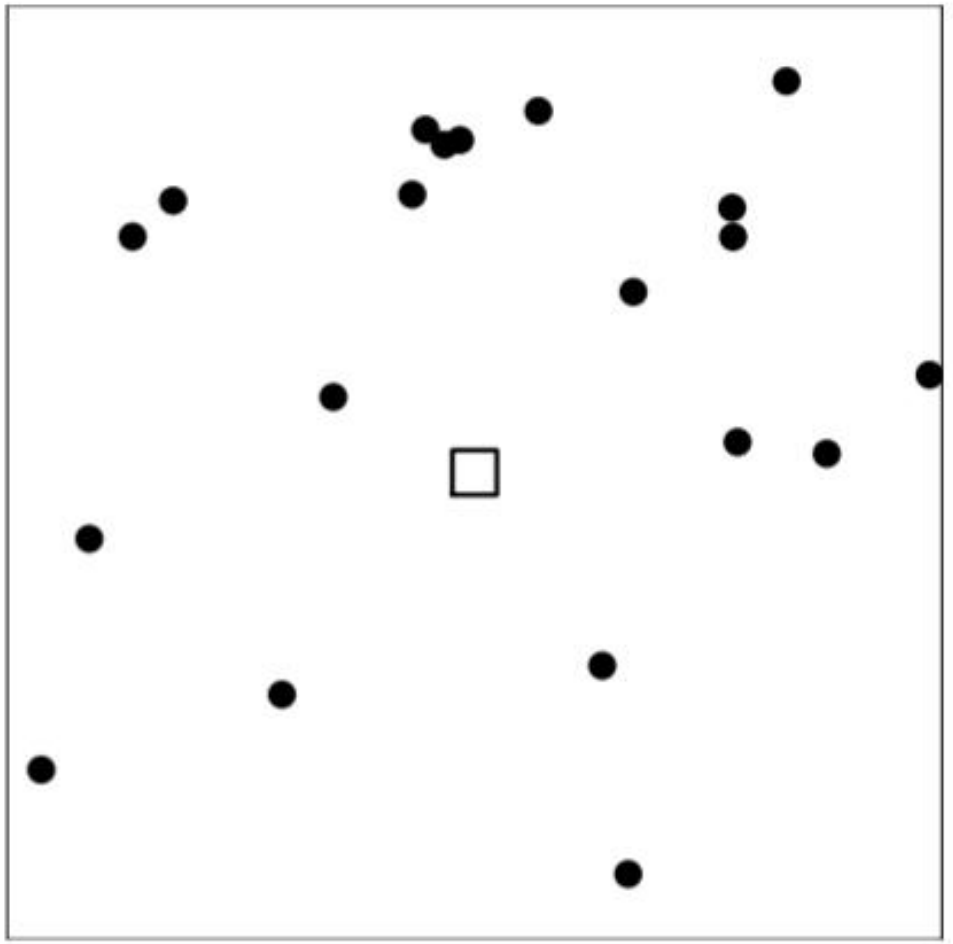


Figure 13.2. *Heuristic definition of conditional intensity* $\lambda(u \mid \mathbf{x})$ *as the intensity of points inside a pixel ('□') at location u given the point pattern* **x** *outside the pixel.*

Part 2 Methods

- point process modeling
- first-order
- second-order

  Gibbs models
- higher-order

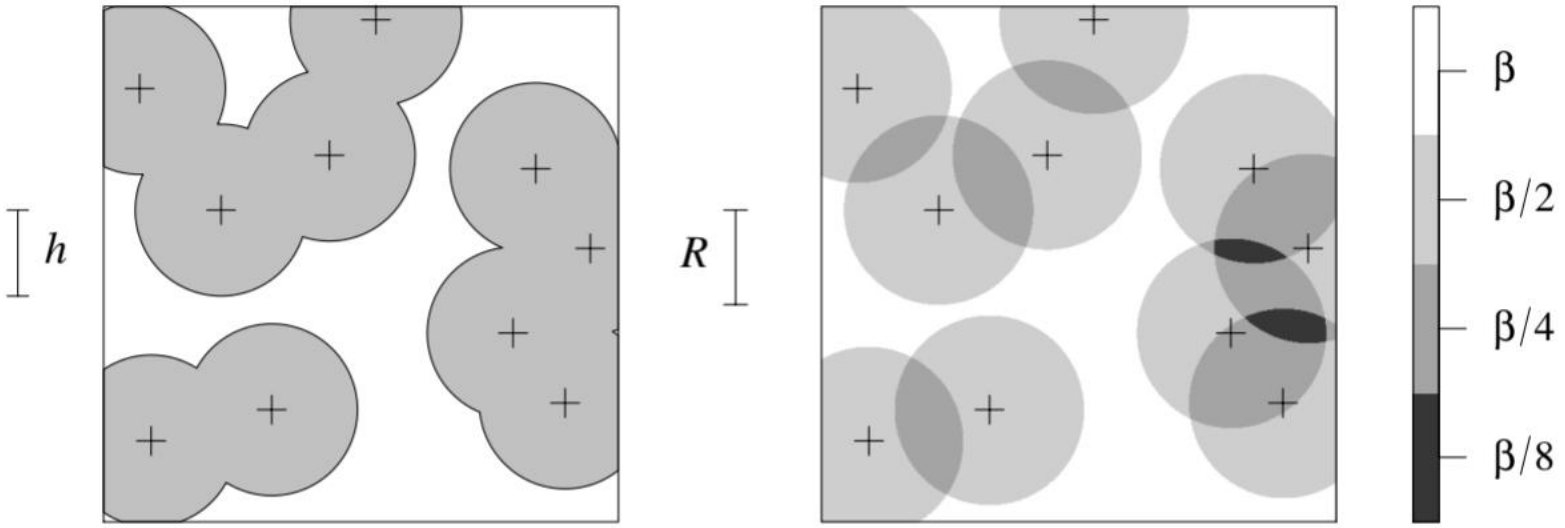


Figure 13.3. *Conditional intensity* $\lambda(u \mid \mathbf{x})$ *as a function of spatial location u given a point pattern* **x** *(marked by '+'). Left: hard core with distance h: new points are forbidden in the shaded region. Right: Strauss model with interaction distance R: new points are less likely in the darker regions.*

Part 2 Methods

- point process modeling
- first-order
- second-order

  Gibbs models

    multitype points
- higher-order

Multitype Strauss model

"Suppose that there are only two types,1 and 2.

If γ1,2 is equal to 1,then the sub-processes X(1)and X(2),consisting of points of types 1 and 2,respectively,are independent Strauss processes.

The resulting process is the same as if two independent Strauss processes were generated,marked "1"and "2",respectively,and then superimposed.

Thus,a test of independence of components could be performed by testing the null hypothesis H0 : γ12 =1."

Part 2 Methods

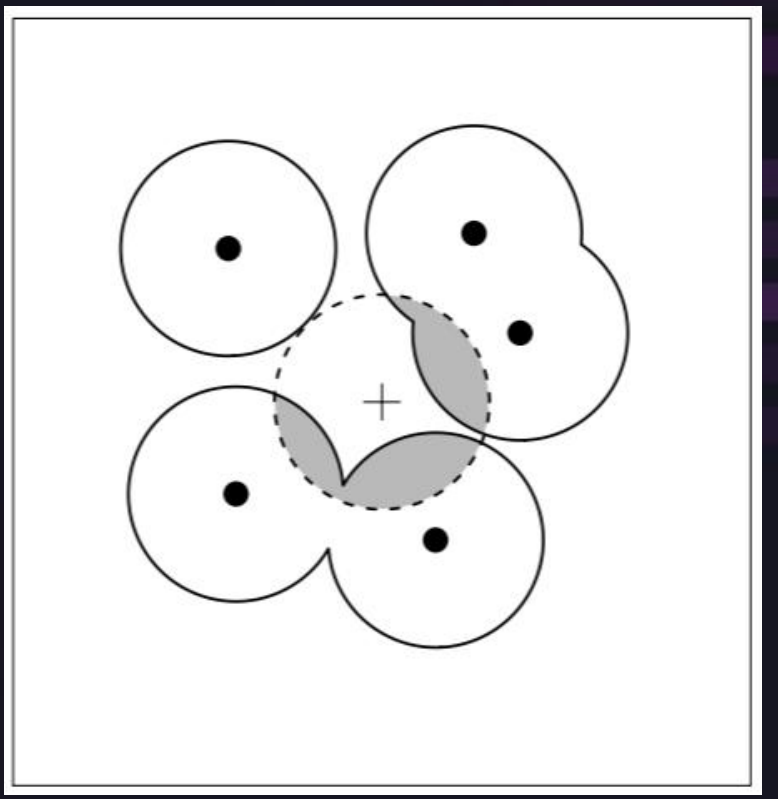
- point process modeling
- first-order
- second-order
- higher-order

  Gibbs models

    Area-interaction

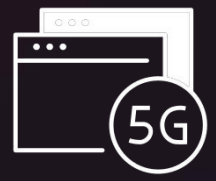
Area-interaction model

"In the canonical scale-free form, the parameter η can take any nonnegative value. The value $\eta = 1$ again corresponds to a Poisson process, with intensity β. If $\eta < 1$ then the process is regular, while if $\eta > 1$ the process is clustered. The value $\eta = 0$ corresponds to a hard core process with hard core distance $h = 2r$, so that circles of radius r centred at the data points do not overlap."

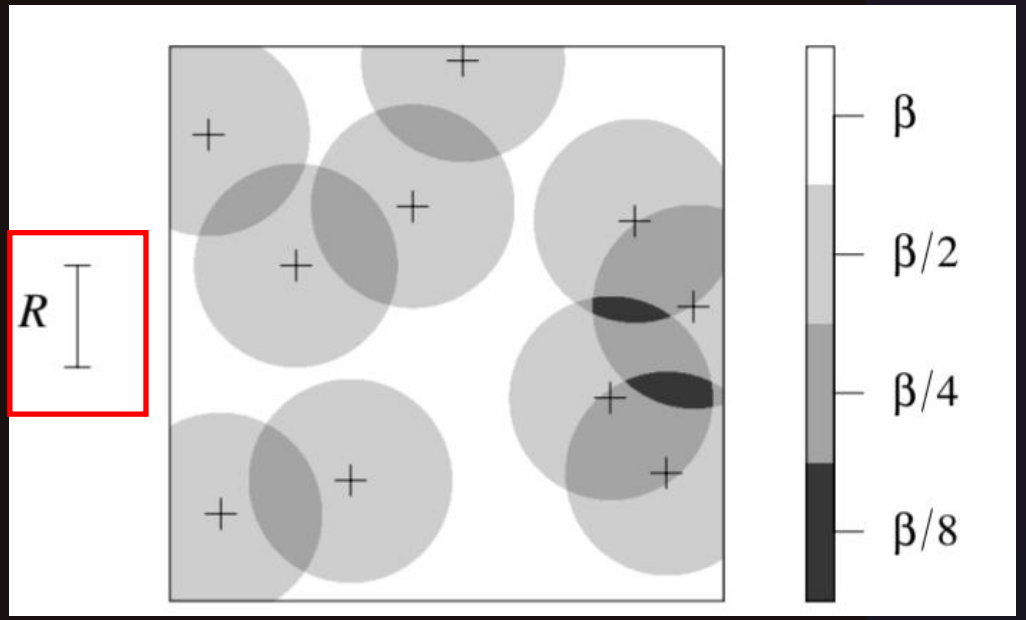


Area-interaction model. Sketch of the 'contested zone' (dark grey) associated with the location u (+) given the point pattern x (•).

Part 2 Methods



- from distance to relationship
- point process modeling



What are the specific steps?

1.Data preparation:
build ppms and select 5 more squares; divide the sites into 3 periods.

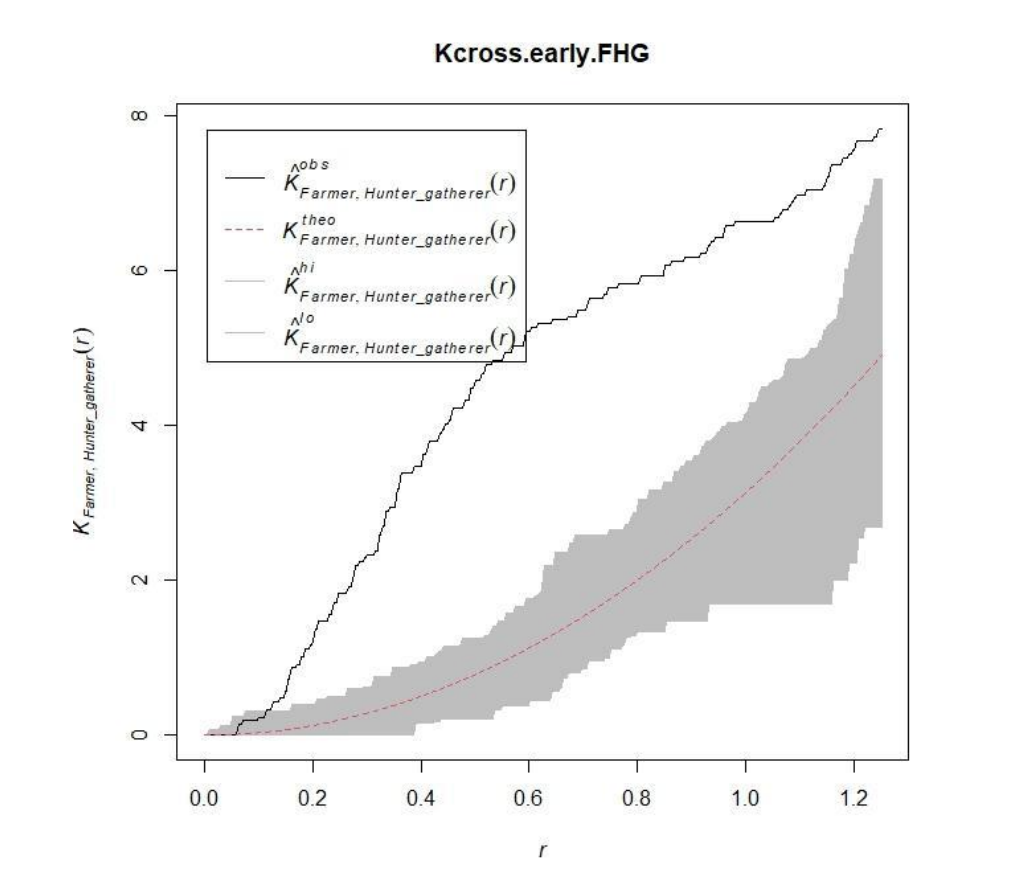
2. Data analysis:
1) exploratory analysis like cross type K-function;
2) multitype struass models (profile maximum pseudolikelihood);
3) significance test like anova.ppm.

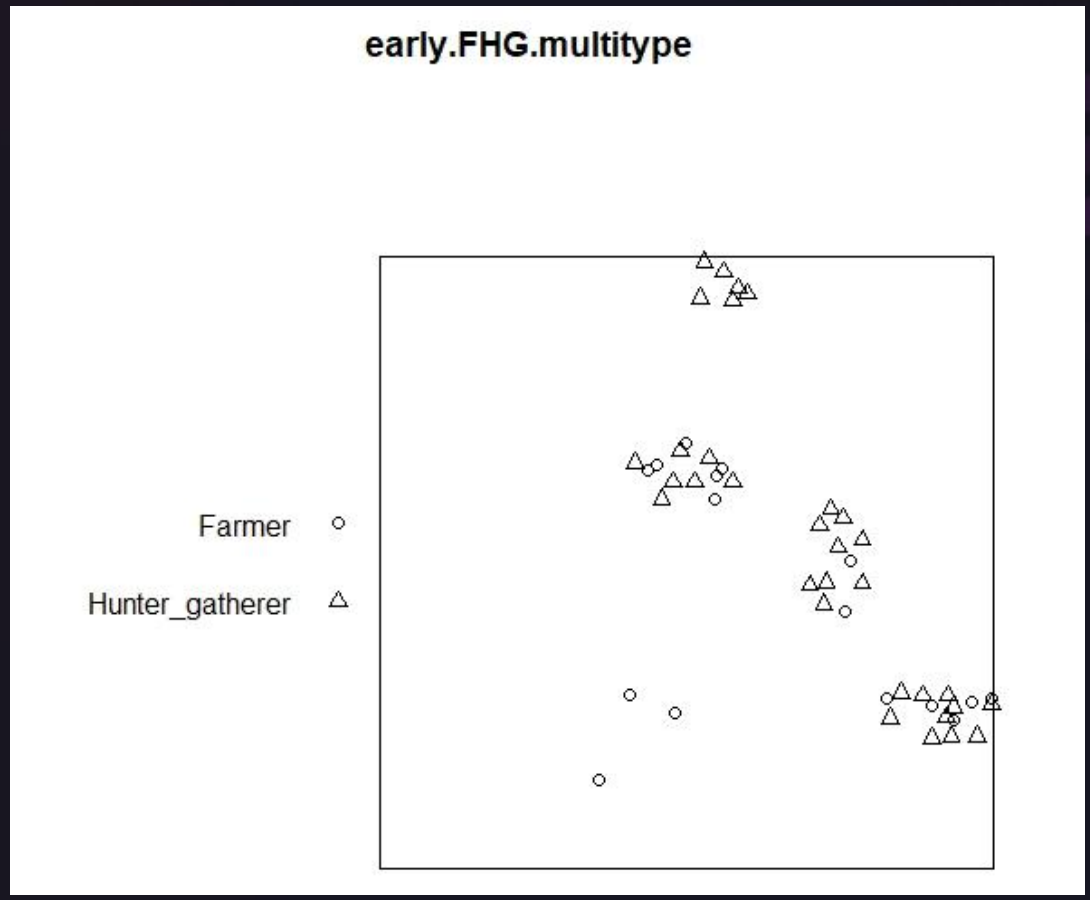
PART 03

Results and discussion

- early period
- middle period
- late period

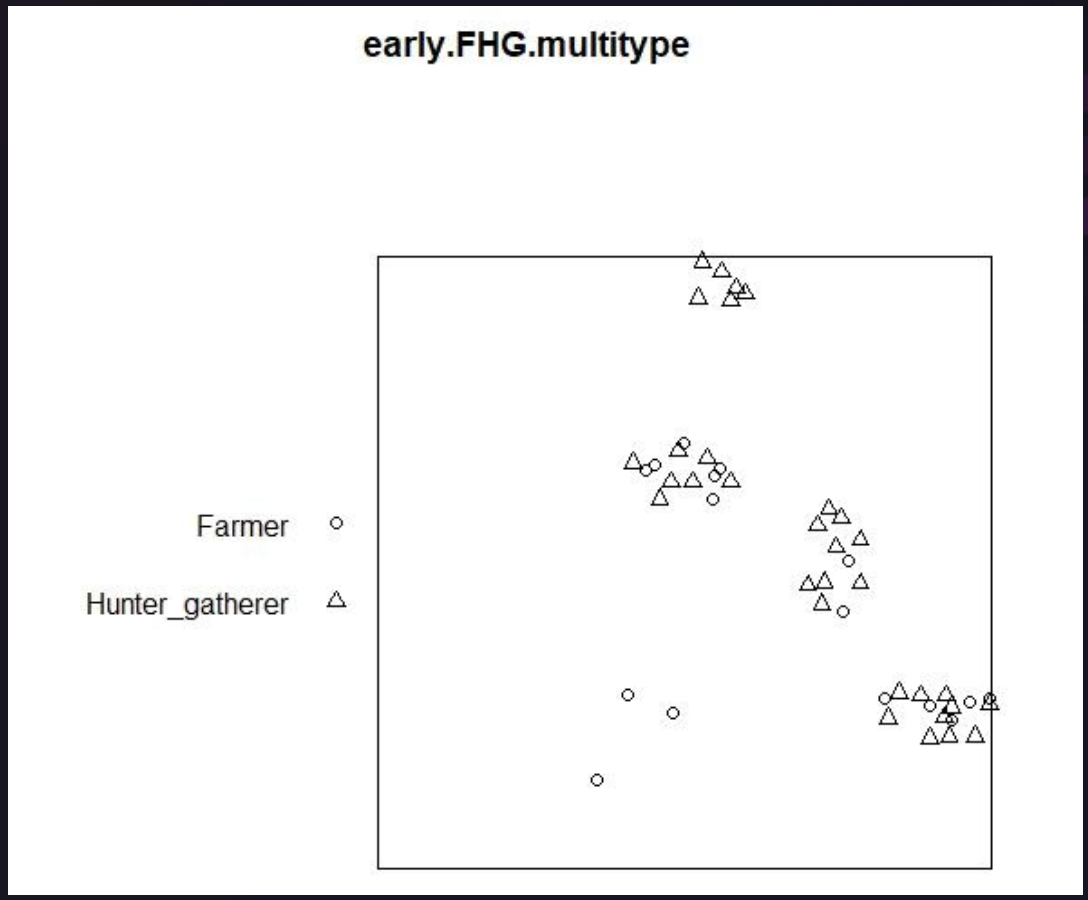
Part 3 Results: early period



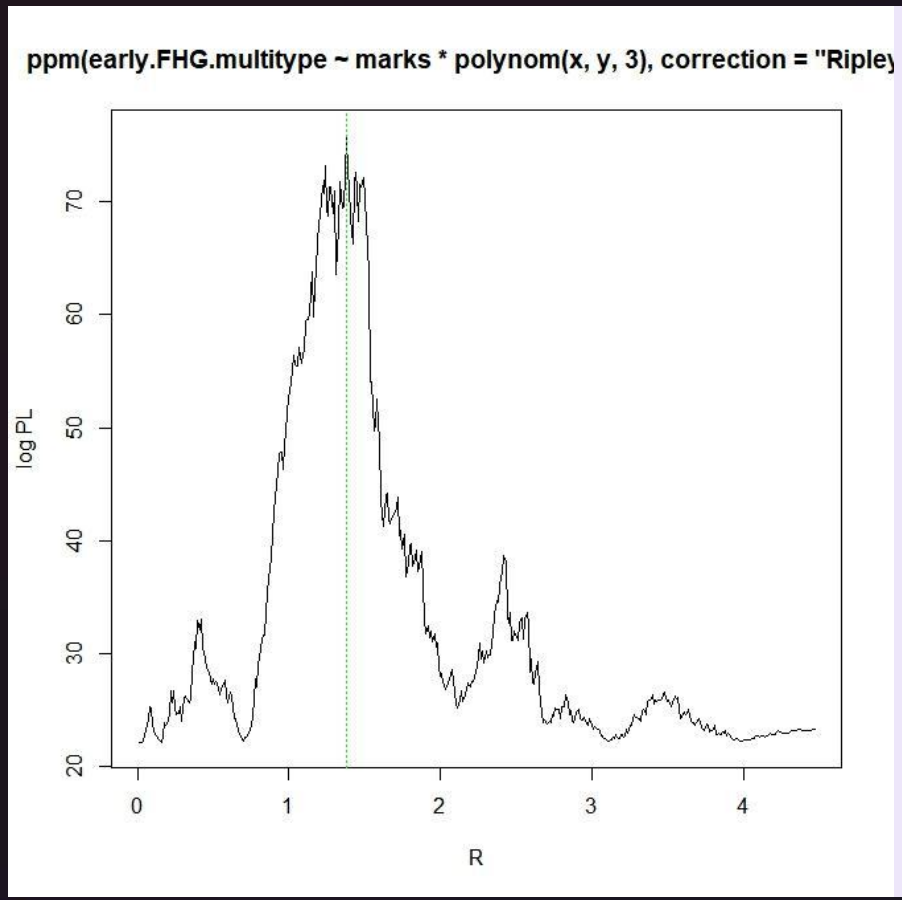


Part 3 Results: early period

- early.dist.2 <- pairdist(early.FHG.multitype)
- max(early.dist.2)
- # [1] 4.462367
- mean(early.dist2)
- # [1] 1.814042



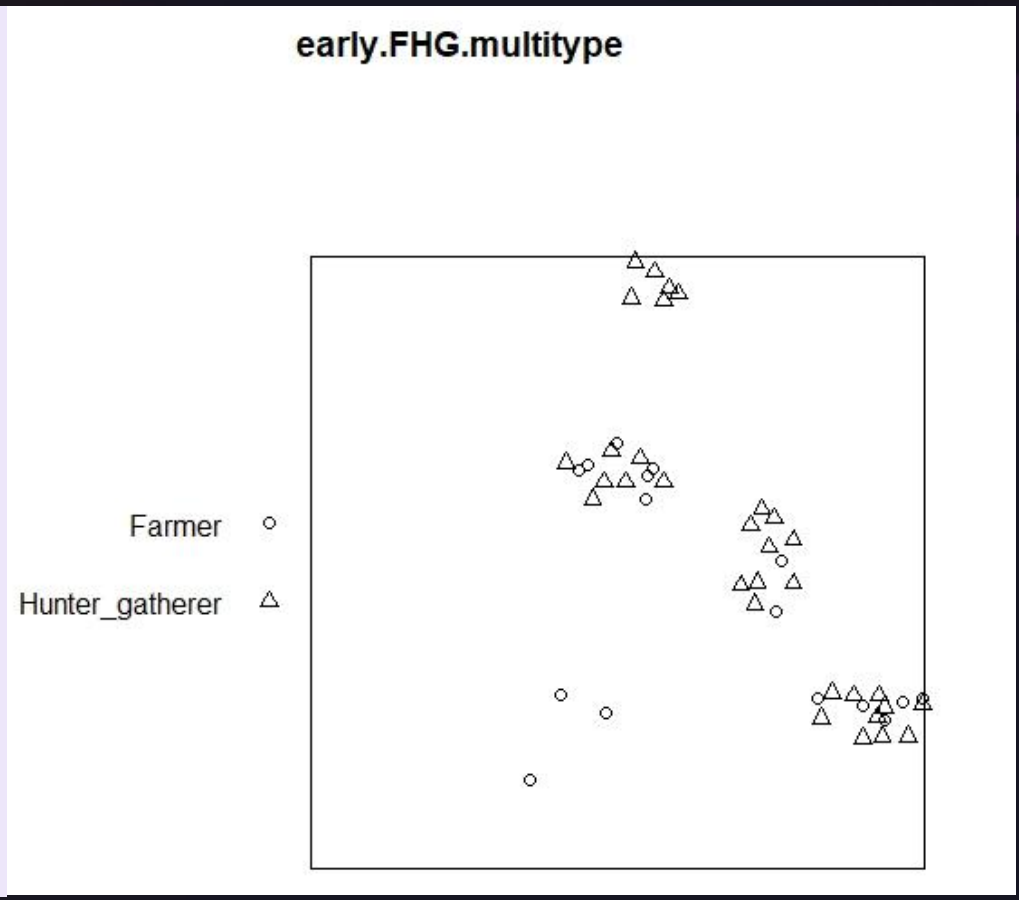
Part 3 Results: early period



interaction: Multitype Strauss process

irregular parameter: R in [0.01, 4.47]

optimum value of irregular parameter: R = 1.38

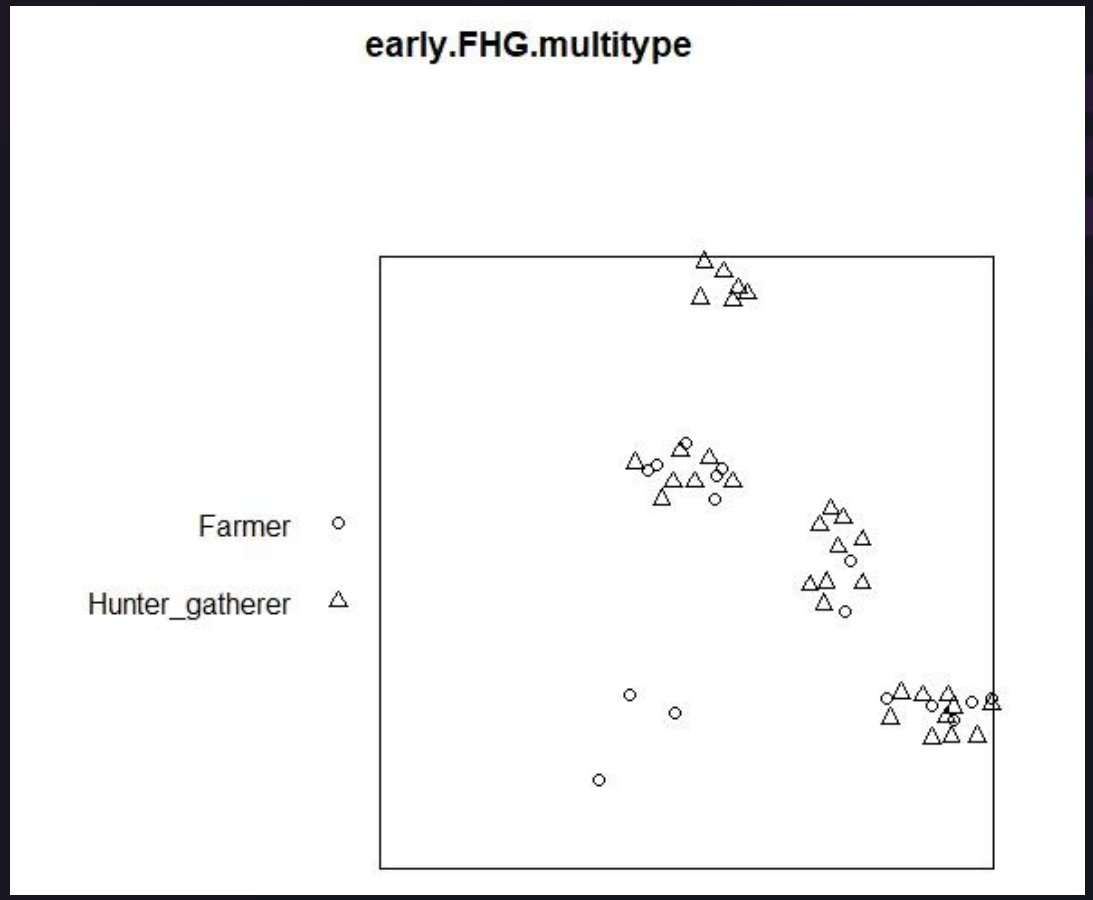


Part 3 Results: early period

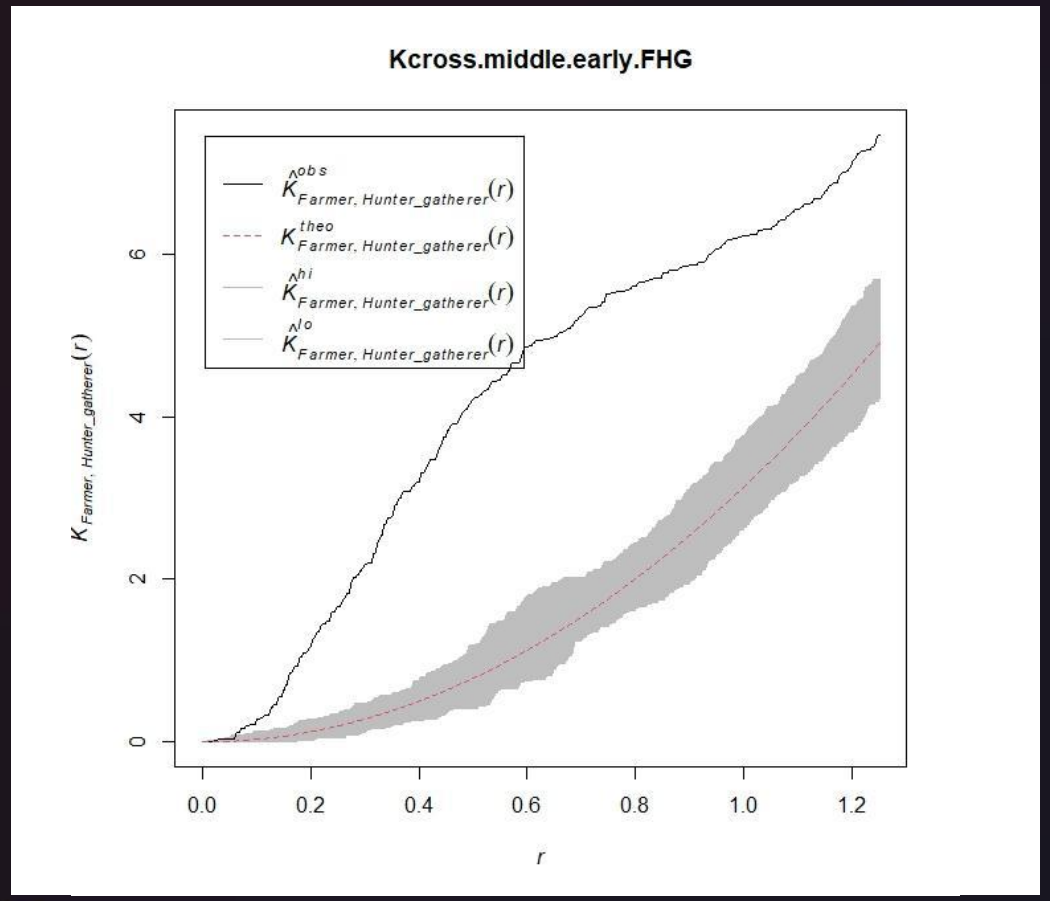
```
# Fitted interaction parameters gamma_ij
#                    Farmer Hunter_gatherer
# Farmer          0.1136299              NA
# Hunter_gatherer        NA       0.5183687
```

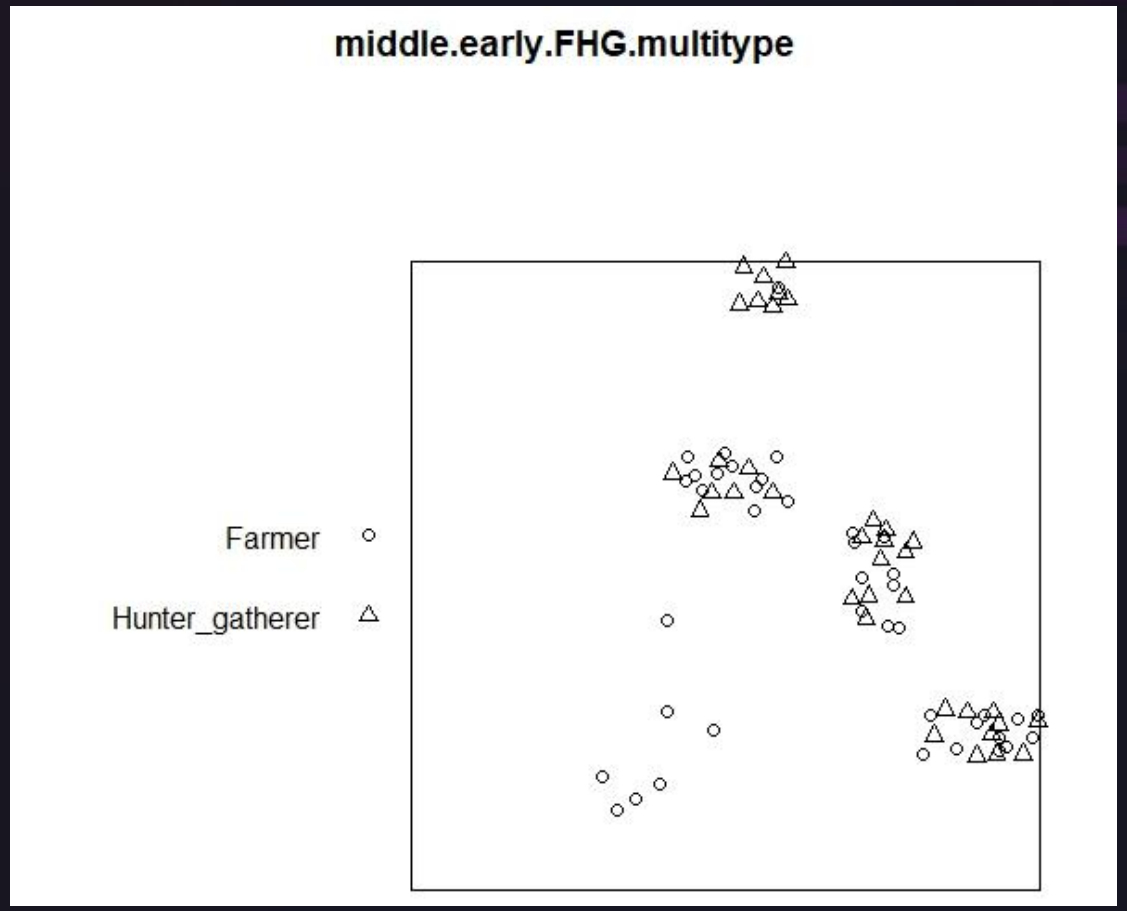
	Npar	Df	AdjDeviance	Pr(>Chi)	
1	13				
2	14	1	8.17	0.004263	**
3	15	1	362.09	< 2.2e-16	***
4	16	1	41.07	1.466e-10	***
5	17	1	23.50	1.248e-06	***
6	18	1	4.46	0.034696	*
7	19	1	16.68	4.414e-05	***
8	20	1	1.26	0.261180	
9	21	1	1.16	0.282233	
10	22	1	131.67	< 2.2e-16	***

```
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



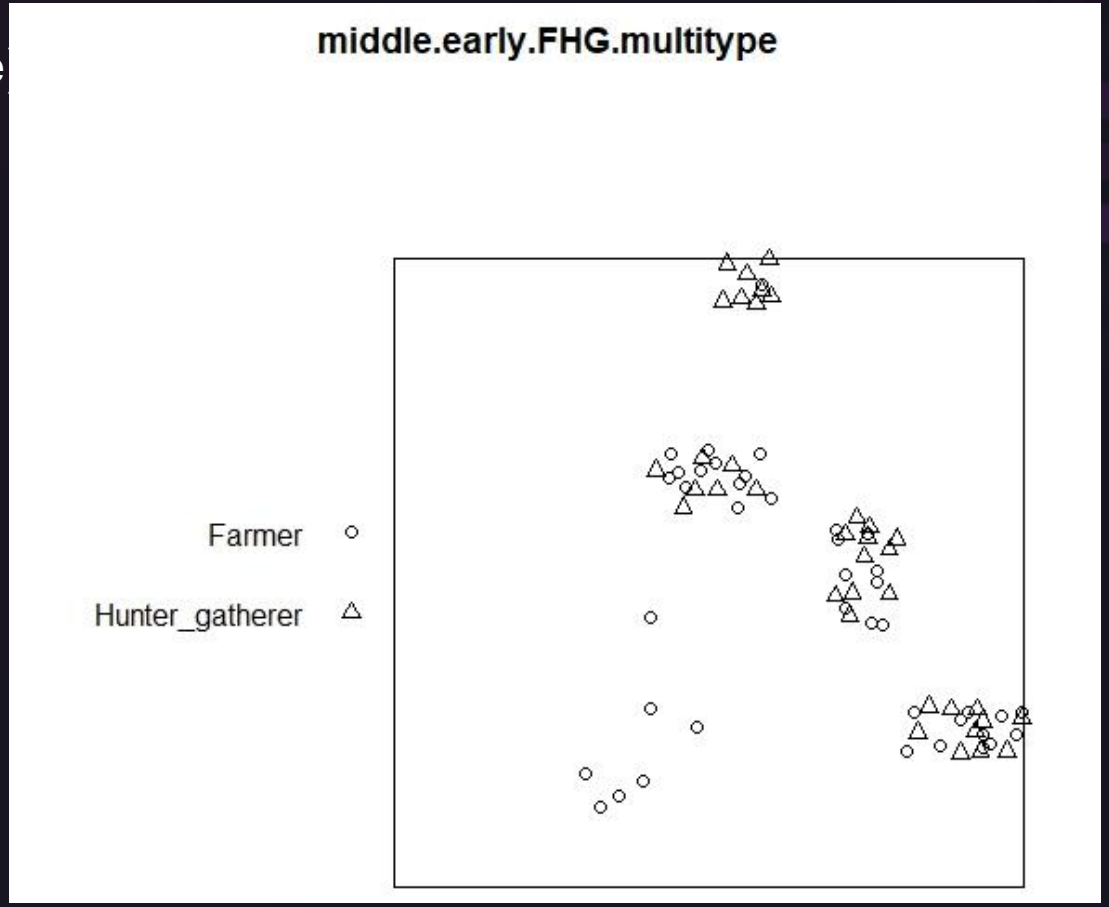
Part 3 Results: middle-early period



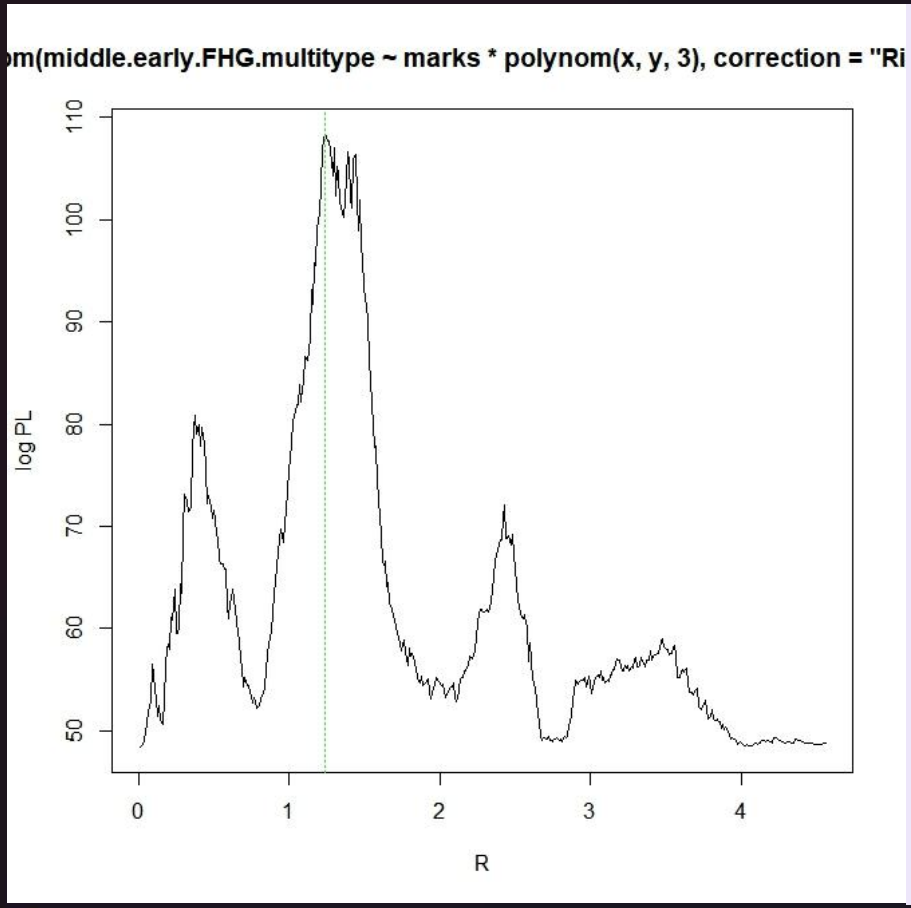


Part 3 Results: middle-early period

```
middle.early.dist2 <- pairdist(middle.early.FHG.multitype)
max(middle.early.dist2)
# [1] 4.559198
mean(middle.early.dist2)
# [1] 1.840964
ks.test(early.dist.2,middle.early.dist2)
# Asymptotic two-sample Kolmogorov-Smirnov test
# data:  early.dist.2 and middle.early.dist2
# D = 0.021377, p-value = 0.4391
# alternative hypothesis: two-sided
```



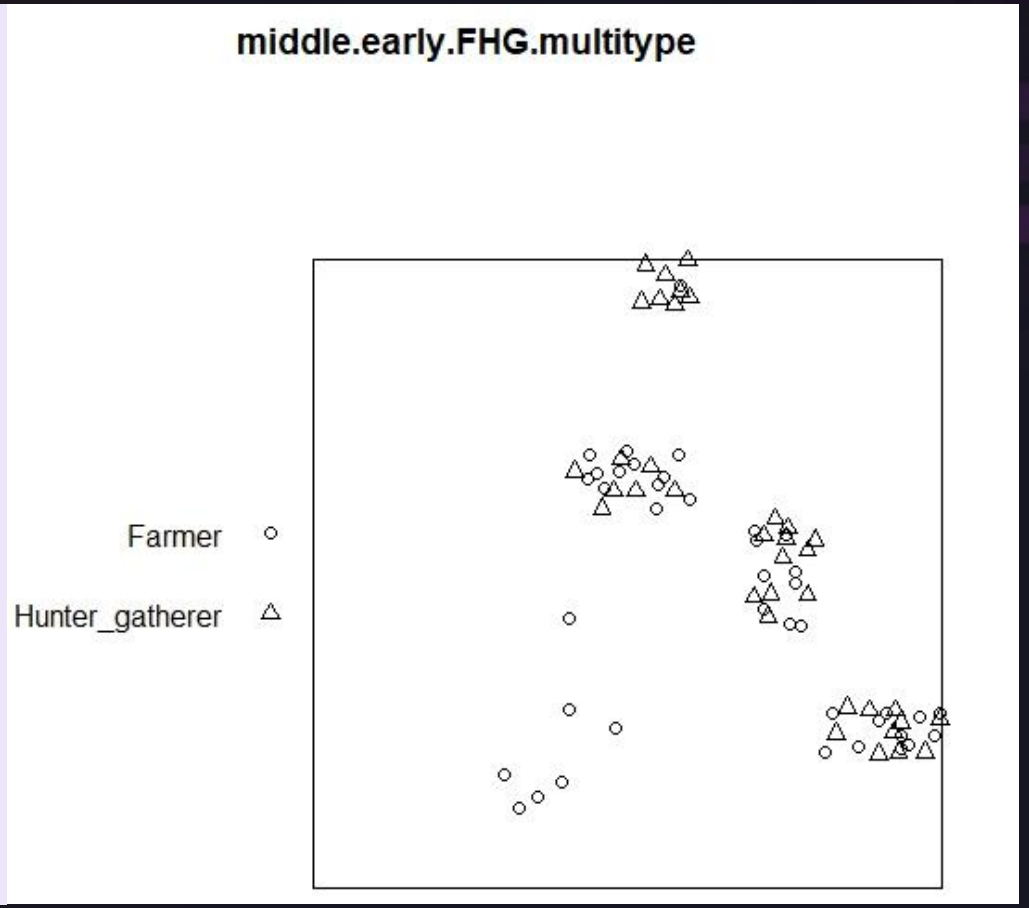
Part 3 Results: middle-early period



interaction: Multitype Strauss process

irregular parameter: R in [0.01, 4.56]

optimum value of irregular parameter: R = 1.24

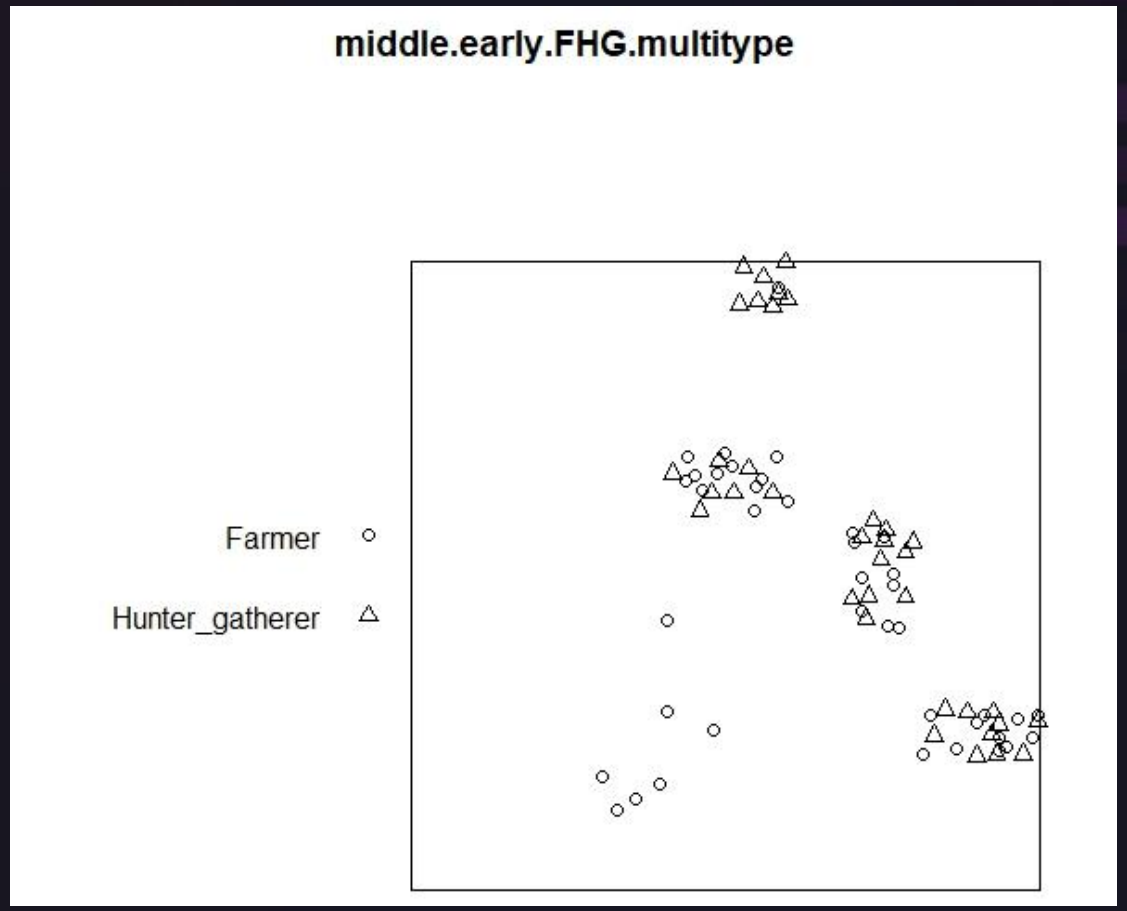


Part 3 Results: middle–early period

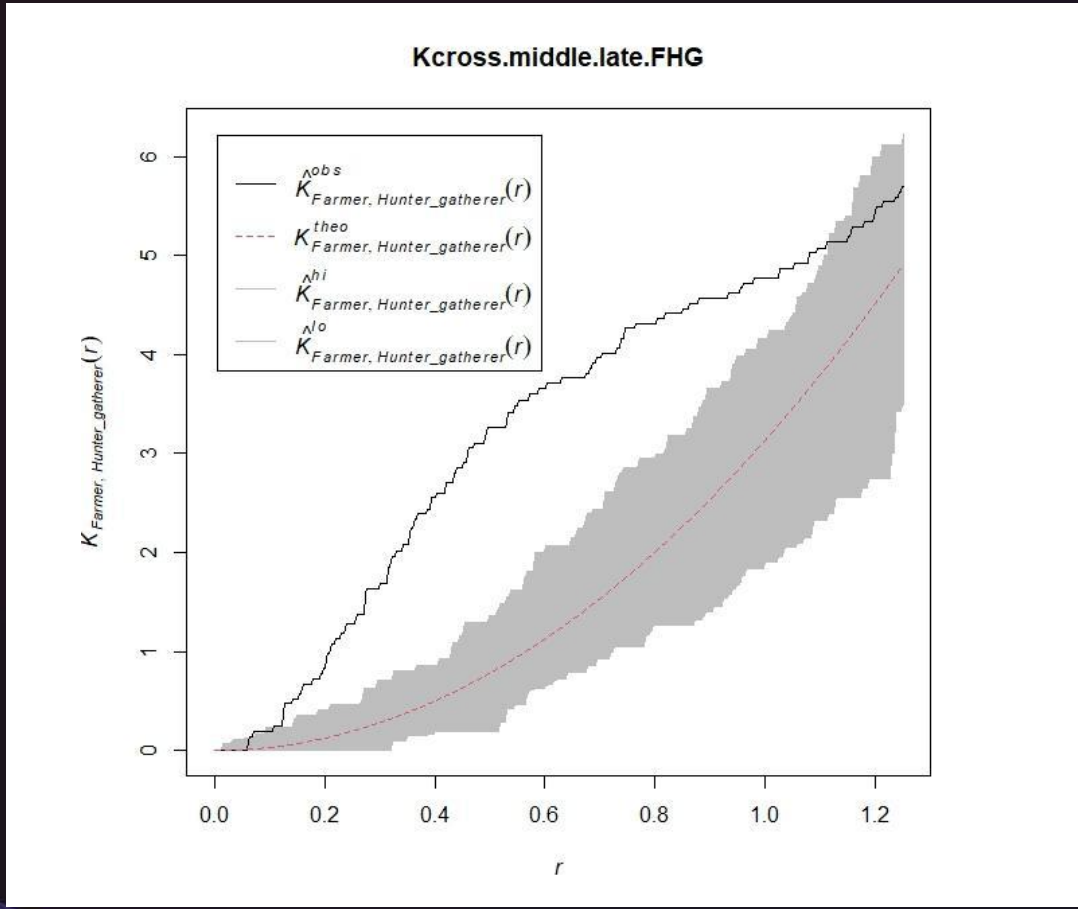
```
# Fitted interaction parameters gamma_ij
#                   Farmer Hunter_gatherer
# Farmer         0.6852975              NA
# Hunter_gatherer       NA       0.5347298
```

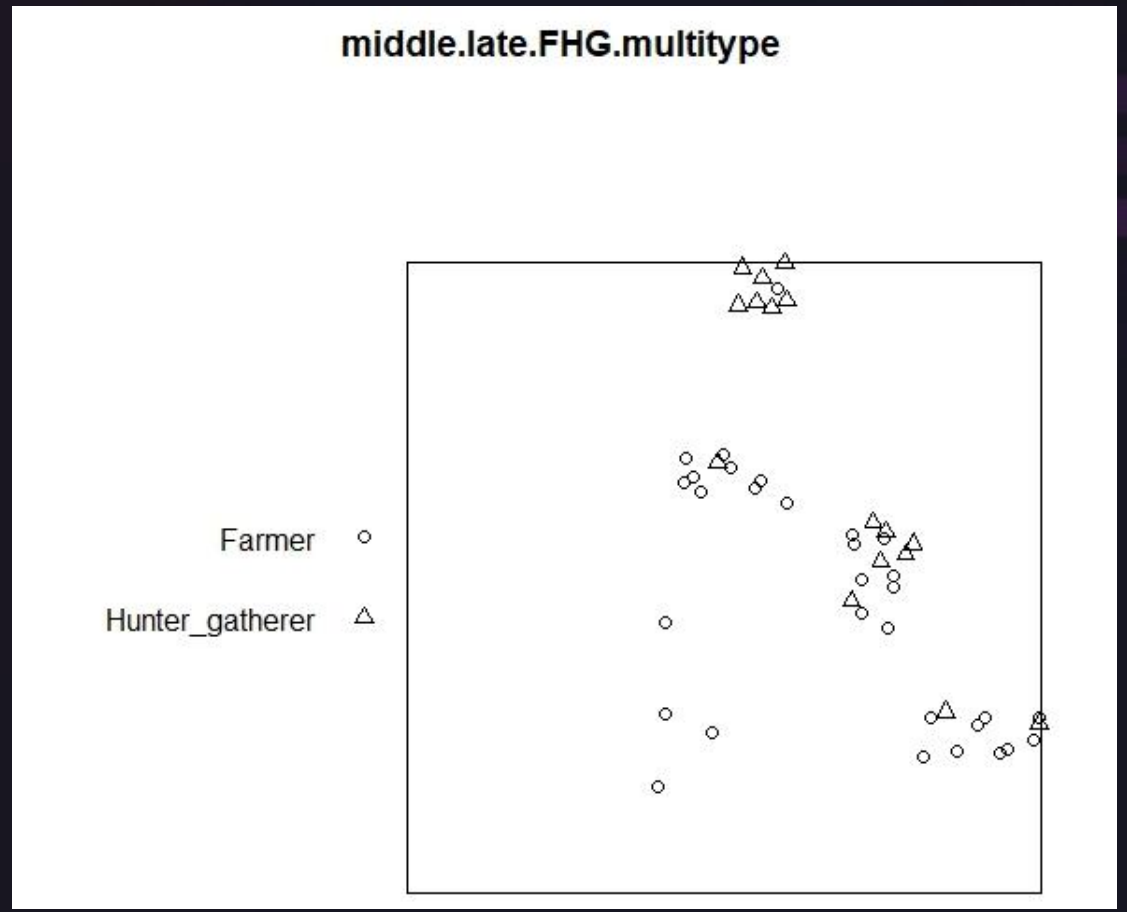
```
#    Npar Df AdjDeviance  Pr(>Chi)
# 1    13
# 2    14  1      12.938 0.0003220 ***
# 3    15  1     245.386 < 2.2e-16 ***
# 4    16  1      17.187 3.388e-05 ***
# 5    17  1      35.628 2.388e-09 ***
# 6    18  1       4.413 0.0356669 *
# 7    19  1      -2.912 0.0879171 .
# 8    20  1       0.661 0.4161415
# 9    21  1      11.528 0.0006854 ***
# 10   22  1    -206.515 < 2.2e-16 ***
```

```
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



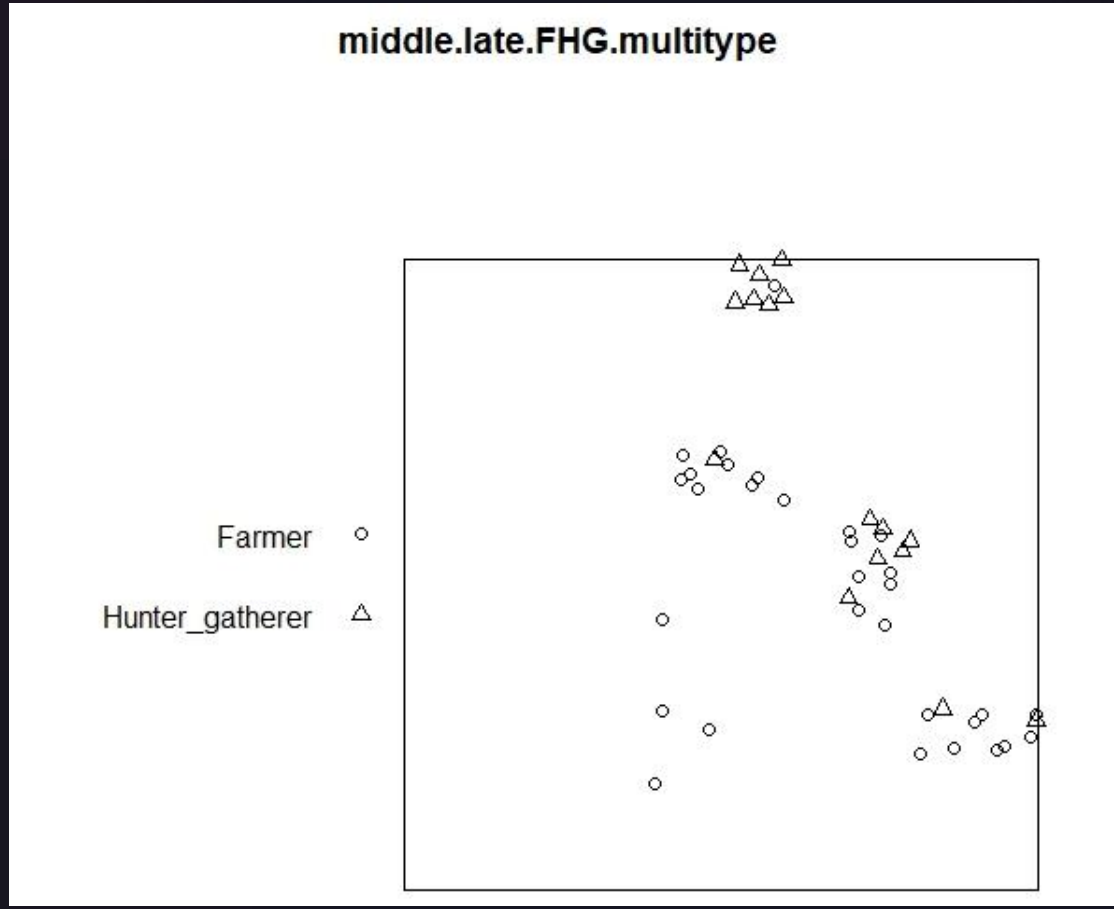
Part 3 Results: middle-late period



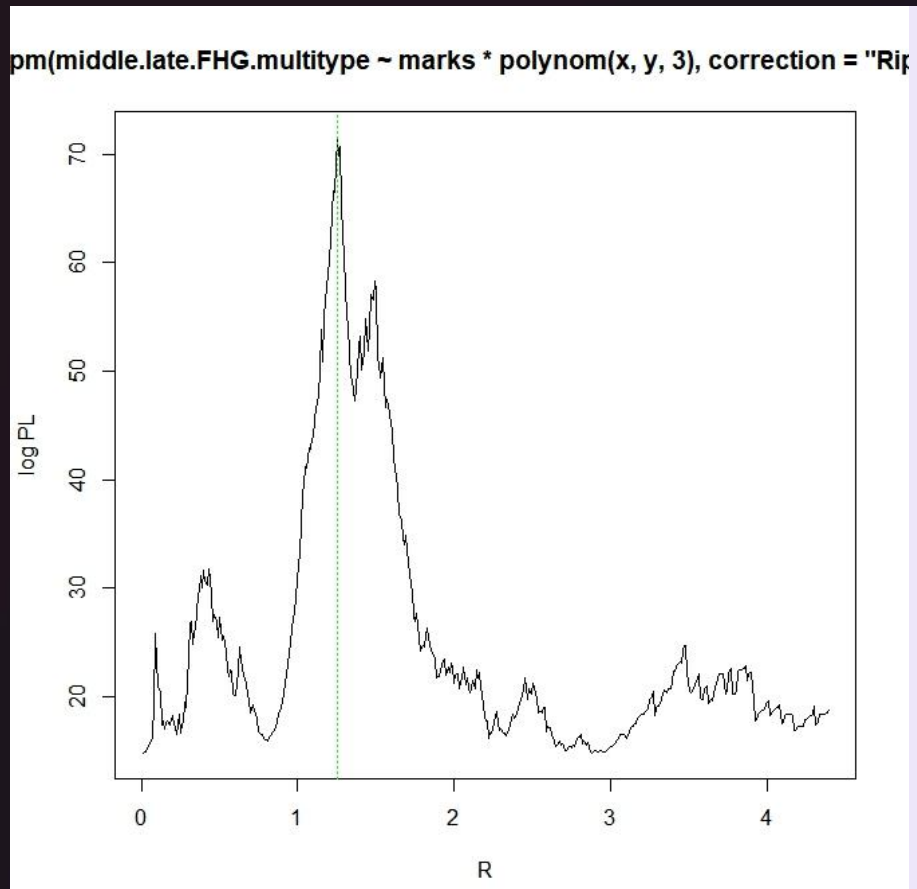


Part 3 Results: middle-late period

```
middle.late.dist2 <- pairdist(middle.late.FHG.multitype)
max(middle.late.dist2) # [1] 4.384972
mean(middle.late.dist2) # [1] 1.817461
ks.test(middle.early.dist2,middle.late.dist2)
# Asymptotic two-sample Kolmogorov-Smirnov test
# D = 0.053897, p-value = 0.0001859
# alternative hypothesis: two-sided
ks.test(early.dist.2,middle.late.dist2)
# Asymptotic two-sample Kolmogorov-Smirnov test
# D = 0.049088, p-value = 0.008723
# alternative hypothesis: two-sided
```



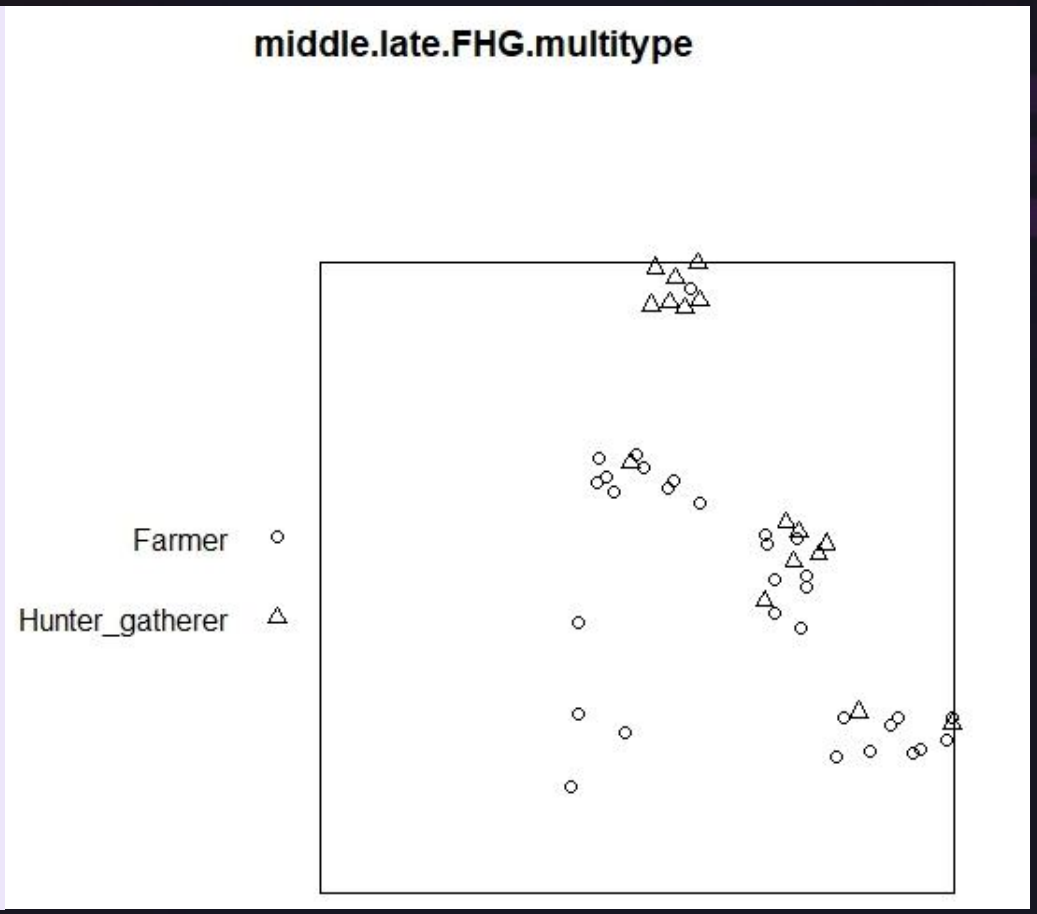
Part 3 Results: middle-late period



interaction: Multitype Strauss process

irregular parameter: R in [0.01, 4.39]

optimum value of irregular parameter: R = 1.25

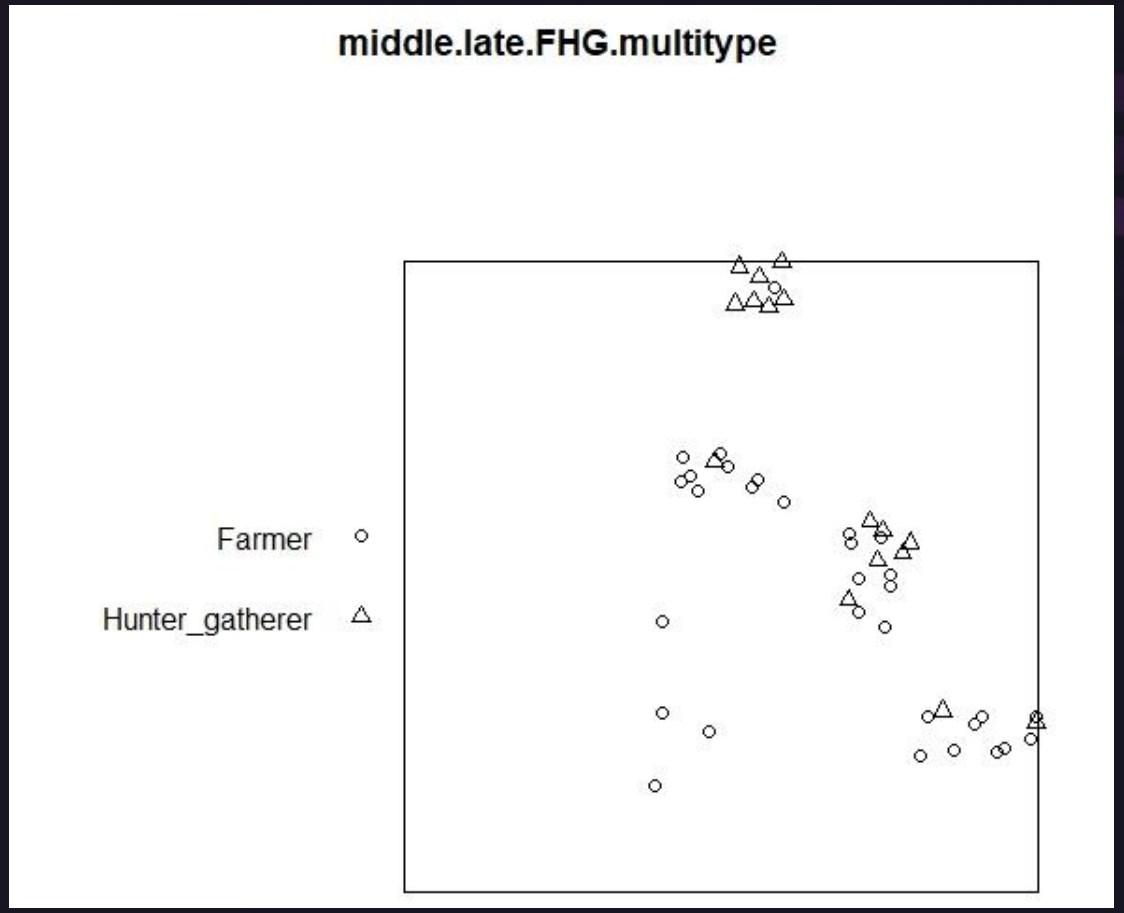


Part 3 Results: middle-late period

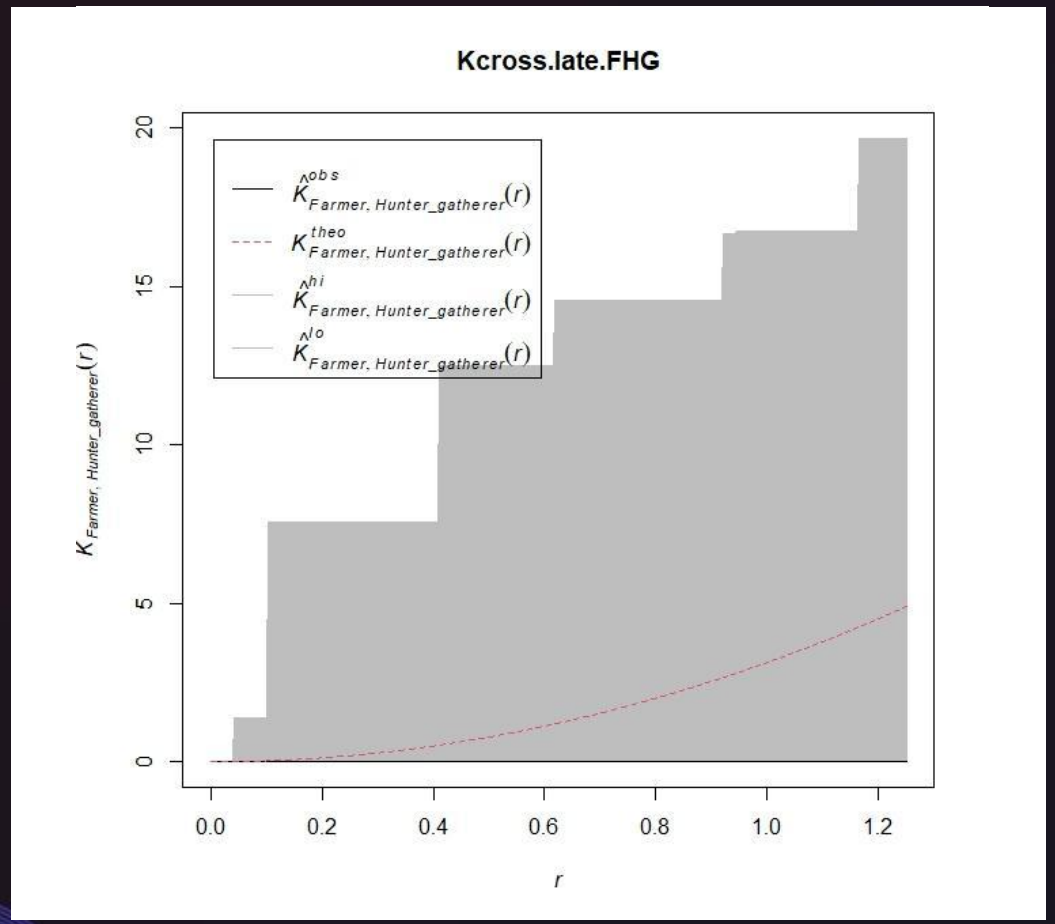
```
# Fitted interaction parameters gamma_ij
#                  Farmer Hunter_gatherer
# Farmer          0.4715164              NA
# Hunter_gatherer        NA       0.1740358
```

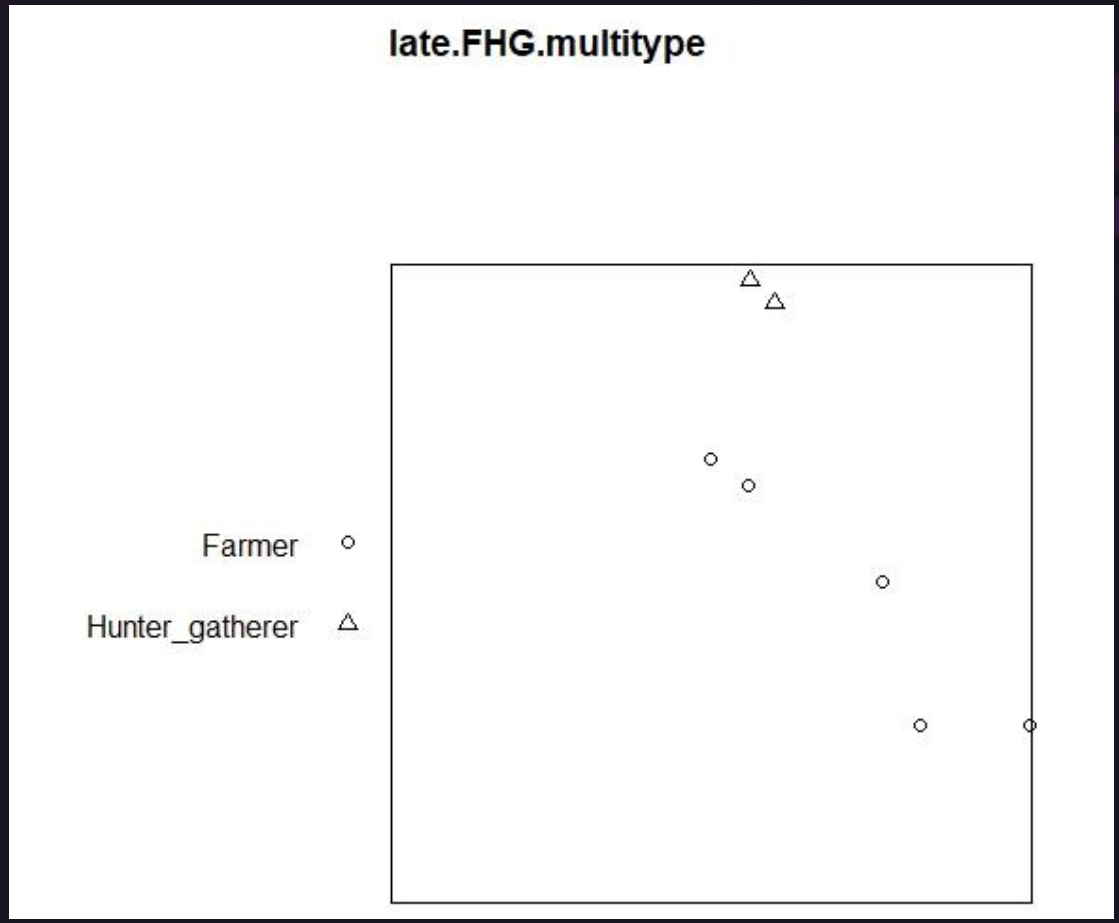
	Npar	Df	AdjDeviance	Pr(>Chi)	
1	13				
2	14	1	2.609	0.106256	
3	15	1	76.083	< 2.2e-16	***
4	16	1	-2.379	0.122986	
5	17	1	18.187	2.003e-05	***
6	18	1	35.328	2.786e-09	***
7	19	1	6.796	0.009137	**
8	20	1	15.250	9.419e-05	***
9	21	1	36.968	1.201e-09	***
10	22	1	117.126	< 2.2e-16	***

```
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



Part 3 Results: late period





Part 3 Results: late period

late.dist2 <- pairdist(late.FHG.multitype)

max(late.dist2) # [1] 4.107511

mean(late.dist2) # [1] 1.803547

ks.test(middle.late.dist2,late.dist2)

Asymptotic two-sample Kolmogorov-Smirnov test

D = 0.13416, p-value = 0.3541

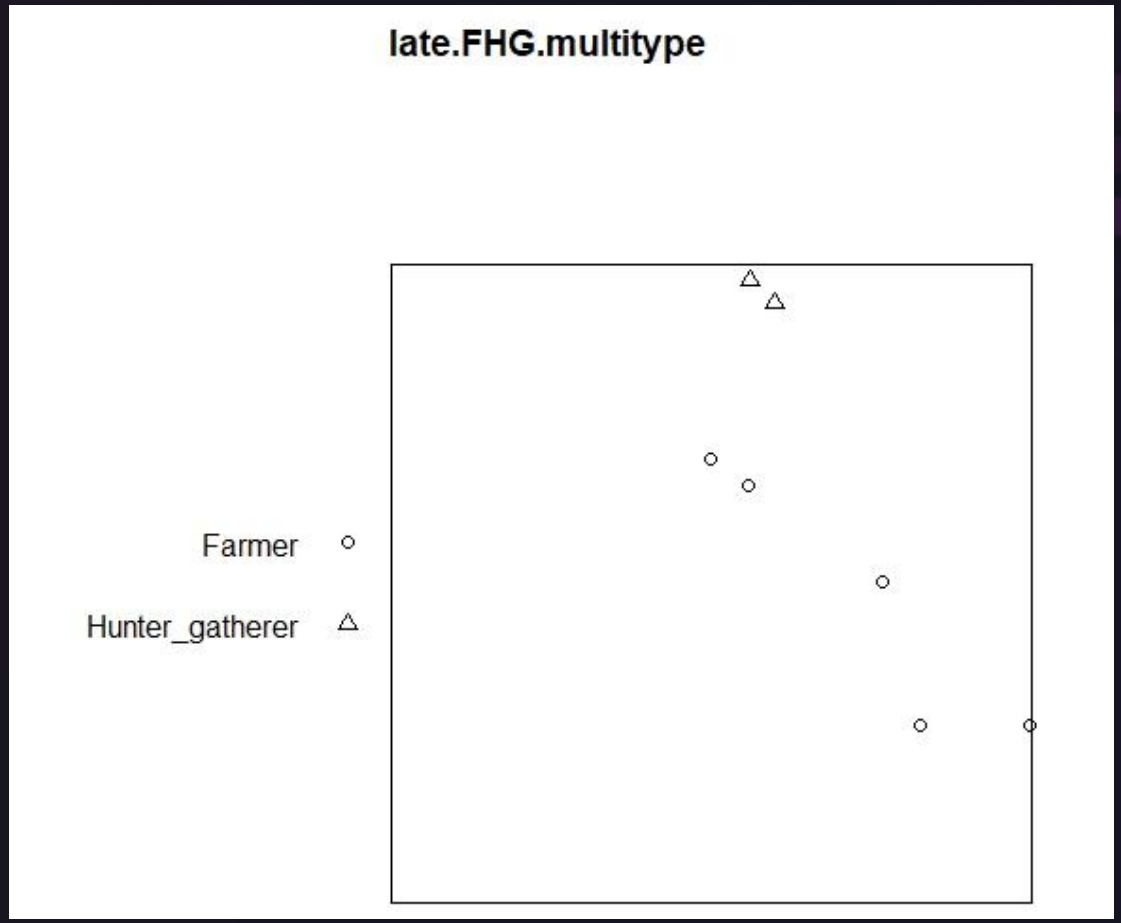
alternative hypothesis: two-sided

ks.test(early.dist.2,late.dist2)

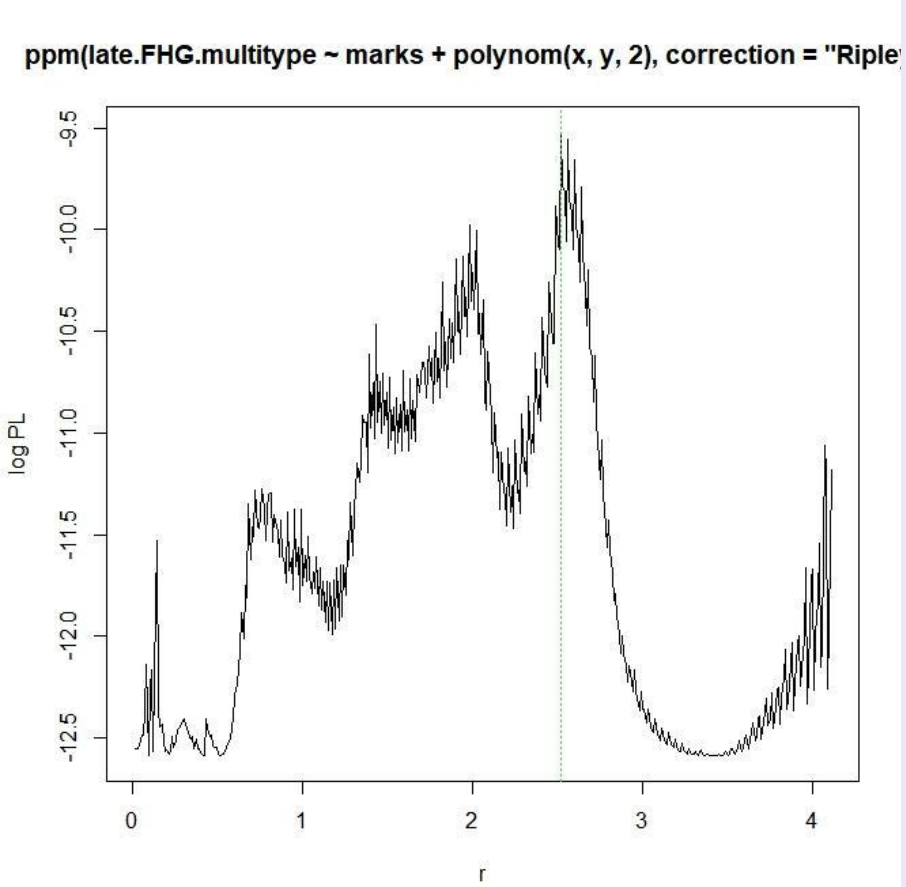
Asymptotic two-sample Kolmogorov-Smirnov test

D = 0.12202, p-value = 0.4726

alternative hypothesis: two-sided



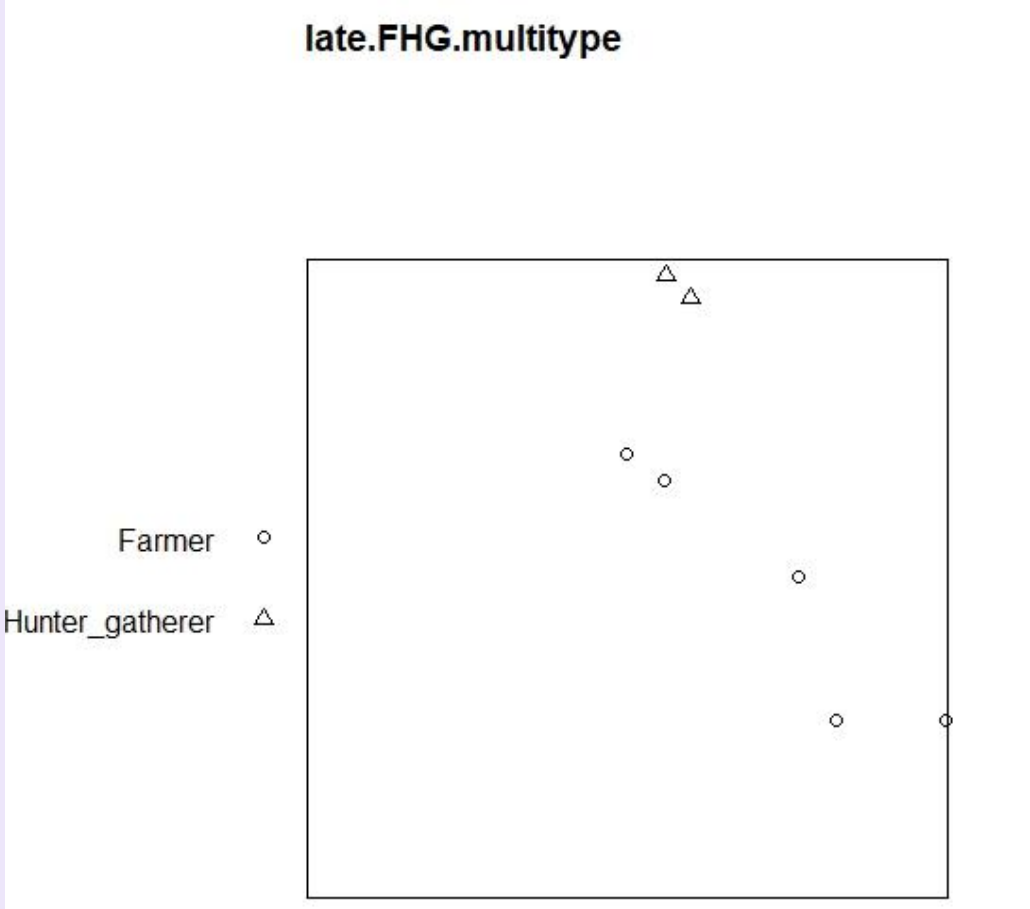
Part 3 Results: late period



\# Nonstationary Area-interaction process

\# Disc radius: 2.52

\# Fitted interaction parameter eta: 1.38197e-70



PART 04

Summary

- relationship
- PPM?

Part 4 Summary

- relationship between F and HG
- point process modeling

What are our relationship?

Seen from Xuan's analysis:

Something happened in the middle period.

We were hostile to each other.

You were not nice to me.

You won the fight... You made me sad.

Part 4 Summary

- relationship between F and HG
- point process modeling

How's PPM's performance in answering the question?

Advantages:

1) dealing with different-order interactions;
2) analyzing multitype second-oder interactions;

Disadvantages:
Are the differences among periods, especially the interaction radius significant enough?

Thank you!

https://theia.arch.cam.ac.uk/archaeoriddle/

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