

589Project

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Libraries

```
#install.packages("mapcan")
#install.packages("bcmaps")
#install.packages("rgbif")

library(rgbif) #allows searching and retrieving data from GBIF
library(ggplot2) #use ggplot2 to add layer for visualization
library(sp) #Standardized Support for Spatial Vector Data
library(sf)
library(spatstat)
library(maptools)
#library(raster)
#library(mapcan)
#library(bcmaps)
#library(tidyverse)
#library(rgdal)
```

Introduction:

```
#occ_count() # occurrence count for all the species in GBIF (Global Biodiversity Information Facility) -
redFox <- name_backbone(name="Vulpes vulpes")
redFoxList <- occ_data(taxonKey = redFox$speciesKey, hasCoordinate=TRUE, stateProvince='British Columbia')
mydata <- redFoxList$data
n_row <- nrow(redFoxList$data)
n_col <- ncol(redFoxList$data)
#n_row
#n_col
```

For our Data 589 project, we have selected Red Fox (Scientific Name - *Vulpes Vulpes*) to do the analysis. In the GBIF database they have approximately, 610,958+ georeferences records for this species around the world, however for this project we have selected to do the analysis of the occurrence of Red Fox in BC only. So with the above function we have fetched the information for British Columbia only in 127 columns and 242 number of entries.

```

load("BC_Covariates.Rda")

# Create a spatial points data frame from the longitude and latitude columns
coordinates <- mydata[,c("decimalLongitude", "decimalLatitude")]
dat.sp <- SpatialPointsDataFrame(c(mydata[,c('decimalLongitude','decimalLatitude')]), data = mydata)

# Set the current CRS
proj4string(dat.sp)<- CRS("+proj=longlat +datum=WGS84")

# Define the new CRS you want to transform to
new_crs <- CRS("+proj=aea +lat_0=45 +lon_0=-126 +lat_1=50 +lat_2=58.5 +x_0=1000000
+y_0=0 +datum=NAD83 +units=m +no_defs")

# Transform the data to the new CRS
data.sp_trans <- spTransform(dat.sp, new_crs)

#data_transformed
#data.sp_trans

#plot(data.sp_trans, main = "Locations in BC", cex = 0.8, col ="blue")

```

```

library(sf)
lapply(DATA, FUN = class)

```

```

## $Window
## [1] "SpatialPolygons"
## attr(),"package"
## [1] "sp"
##
## $Elevation
## [1] "im"
##
## $Forest
## [1] "im"
##
## $HFI
## [1] "im"
##
## $Dist_Water
## [1] "im"

```

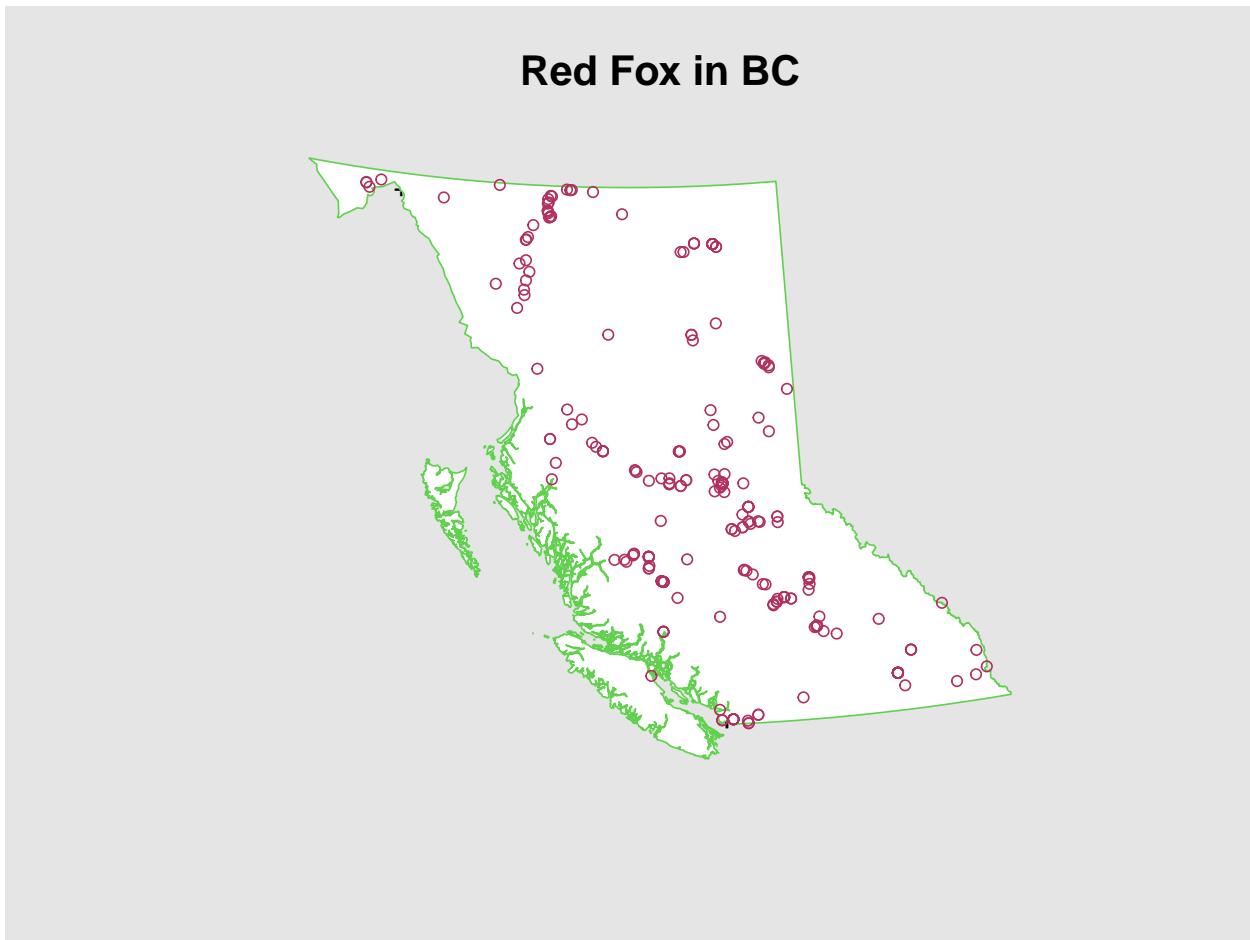
```

parks_ppp <- ppp(x = data.sp_trans@coords[,1], # X coordinates
                    y = data.sp_trans@coords[,2], # Y coordinates
                    window = as.owin( DATA[["Window"]]),# Observation window
                    )

col_pal <- c("maroon")
plot(parks_ppp,
      main = "Red Fox in BC",
      cex = 0.9,
      col ="white",
      border = 3,

```

```
cols = col_pal,  
par(bg = "grey90",cex.main = 1.6))
```



Here we have plotted all the occurrences of Red Fox in the BC region and we can see that the species are scattered in the region specially in the upper and middle part of the province. Now we will be exploring what is contributing to the occurrences of the species in the specific places based on various factors like elevation, close to water bodies, forests, human habitats, etc.

Methods:

Briefly describe the data and what variables are included. Provide a detailed description of the analytical workflow that was applied to the data, citing any relevant literature and statistical packages employed. There should be enough information that anyone can reproduce the workflow if they had access to the data. Length: As long as necessary.

First Moment Analysis

```
#summary(parks_ppp)  
intensity(parks_ppp)
```

```
## [1] 2.509854e-10
```

Per the summary, Average intensity 5.063089e-10 points per square unit which is 0.0000000005063089 per square unit and this does not explain the observance of Vulpes Vulpes in a meaningful way.

Quadratcount: 5 by 5 and 10 by 10 - Both convey different view points on the intensity of the observance. According to plot 1, most of the Vulpes Vulpes are spotted in the South West areas around Vancouver.

The 10X10 figure shows the intensity is high in the coastal areas with higher density in the South West region.

```
#Split into a 5 by 5 quadrat and count points
```

```
Q <- quadratcount(parks_ppp,
                    nx = 5,
                    ny = 5)
```

```
#Plot the output
```

```
par(mfrow=c(1,2))
plot(parks_ppp,
      pch = 12,
      cex = 0.5,
      cols = "#046C9A",
      main = "Vulpes Vulpes locations")
```

```
## Warning in plot.ppp(parks_ppp, pch = 12, cex = 0.5, cols = "#046C9A", main =
## "Vulpes Vulpes locations"): 4 illegal points also plotted
```

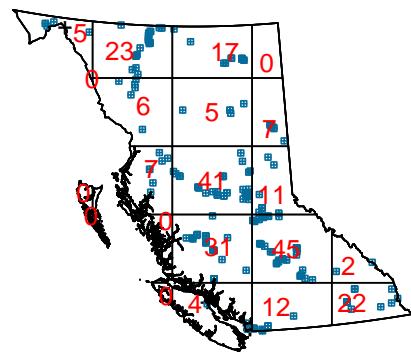
```
plot(Q, cex = 1, col = "red", add = T)
```

```
Q <- quadratcount(parks_ppp,
                    nx = 10,
                    ny = 10)
```

```
#Plot the output
```

```
par(mfrow=c(1,2))
```

Vulpes Vulpes locations

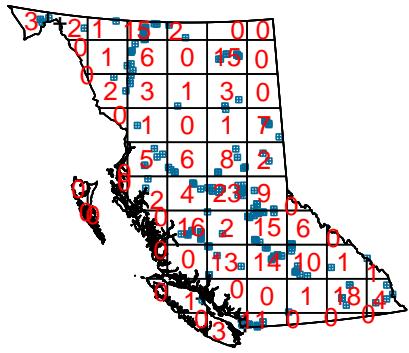


```
plot(parks_ppp,
  pch = 12,
  cex = 0.5,
  cols = "#046C9A",
  main = "Beilschmiedia pendula locations")
```

```
## Warning in plot.ppp(parks_ppp, pch = 12, cex = 0.5, cols = "#046C9A", main =
## "Beilschmiedia pendula locations"): 4 illegal points also plotted
```

```
plot(Q, cex = 1, col = "red", add = T)
```

Beilschmiedia pendula locations



Quadrat counting suggests varying intensity and to confirm that the variation is not due to chance alone, we conduct an objective test for spatial (in)homogeneity. We do a Chi-square test to validate if the deviations are significant.

```
#Quadrat test of homogeneity  
quadrat.test(Q)
```

```
## Warning: Some expected counts are small; chi^2 approximation may be inaccurate  
  
##  
## Chi-squared test of CSR using quadrat counts  
##  
## data:  
## X2 = 352.69, df = 63, p-value < 2.2e-16  
## alternative hypothesis: two.sided  
##  
## Quadrats: 64 tiles (irregular windows)
```

The null hypothesis of the test suggests homogeneity in the process and as the p-value is very small, the null hypothesis is rejected and its confirmed there is significant deviation from homogeneity.

Hot spot analysis: As the next step, we analyze for any hot spots in the south west coastal areas of BC.

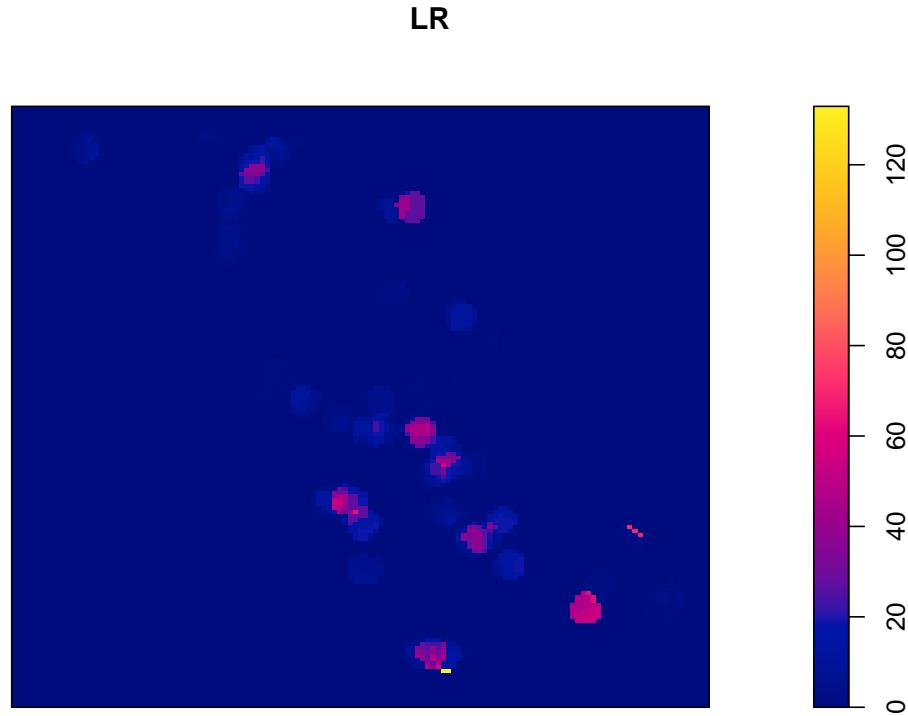
```

# Estimate R
R <- bw.ppl(parks_ppp)

#Calculate test statistic
LR <- scanLRTS(parks_ppp, r = R)

#Plot the output
plot(LR)

```



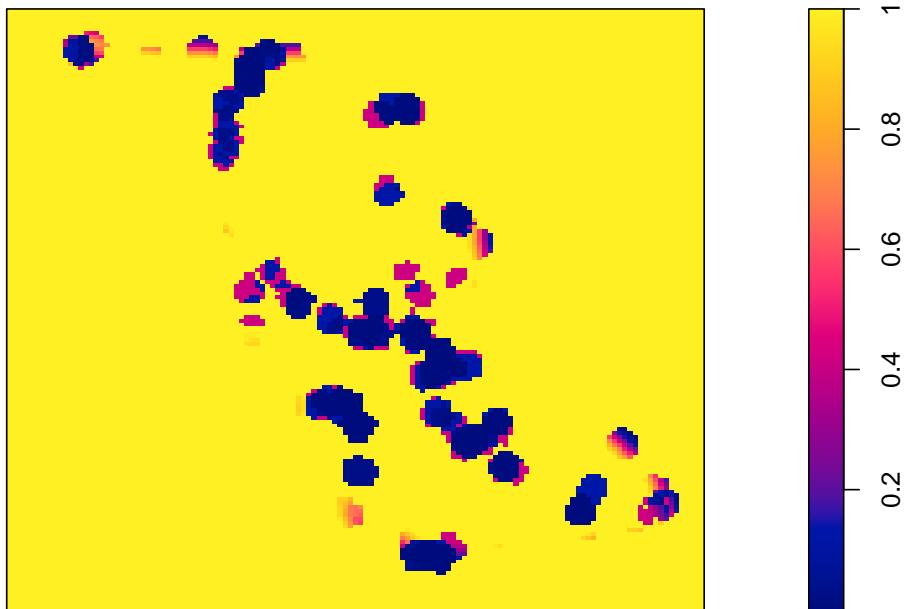
```

#Compute local p-values
pvals <- eval.im(pchisq(LR,
                         df = 1,
                         lower.tail = FALSE))

#Plot the output
plot(pvals, main = "Local p-values")

```

Local p-values



Question: Do we need p -value intensity analysis? Also, is it possible to add the window for better observation window boundary (shape of BC)?

```
#add marks and relationship with one covariate to start with
parks_ppp <- ppp(x = data.sp_trans$decimalLatitude, # X coordinates
                     y = data.sp_trans$decimalLongitude)

#.....
```

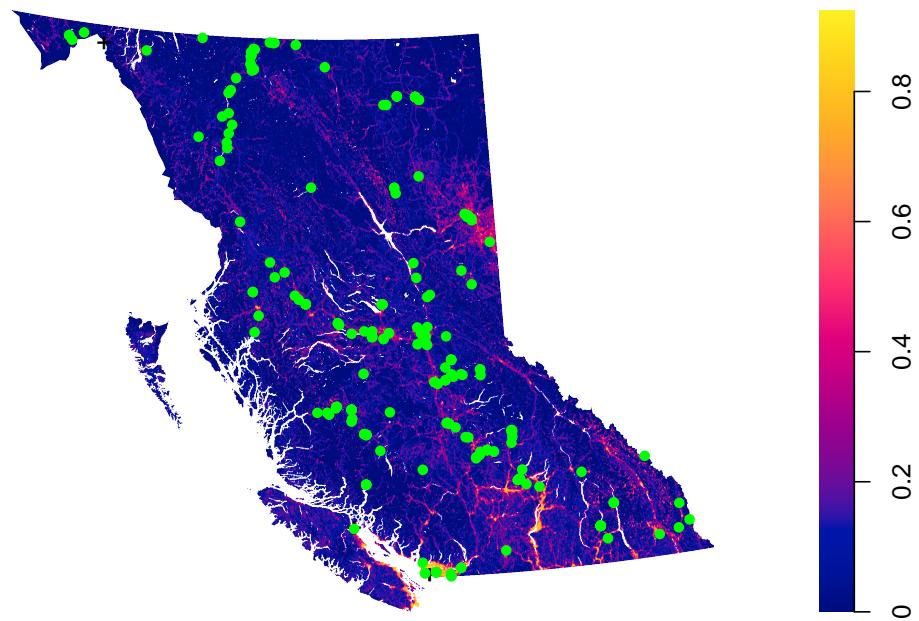
Covariates Analysis

Our data includes 4 covariates we can explore: the elevation, the forest cover, the human footprint inventory (HFI), and the distance to water. Given our research questions, we will start with investigating the HFI and the forest cover.

HFI

```
plot(DATA$HFI, box = F, par(cex.main = 2), main = "HFI")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

HFI

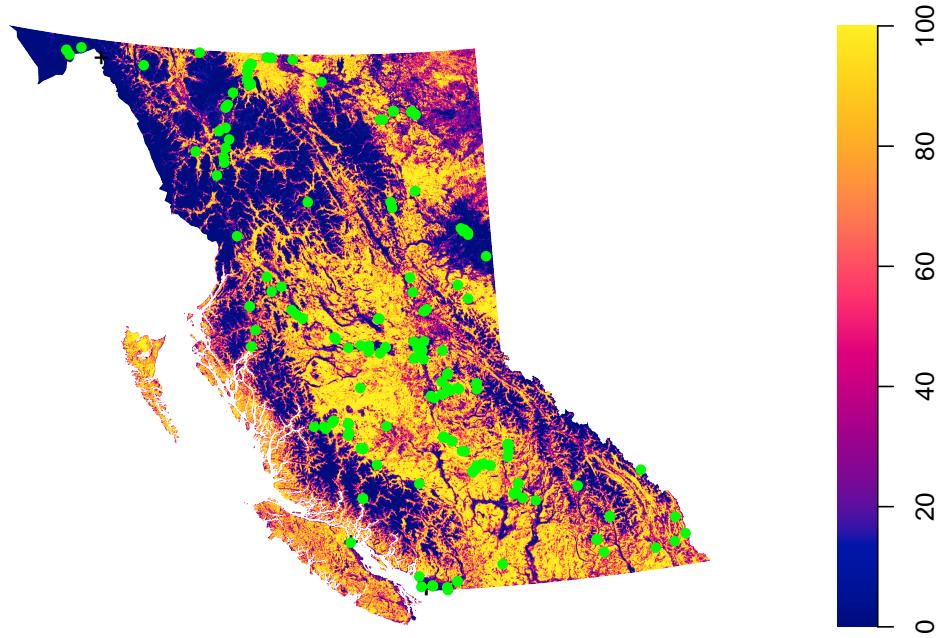


From this plot, it is hard to tell if there is a possible relationship between a red fox occurrence and the HFI.

Forest Cover

```
plot(DATA$Forest, box = F, par(cex.main = 2), main = "Forest")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

Forest

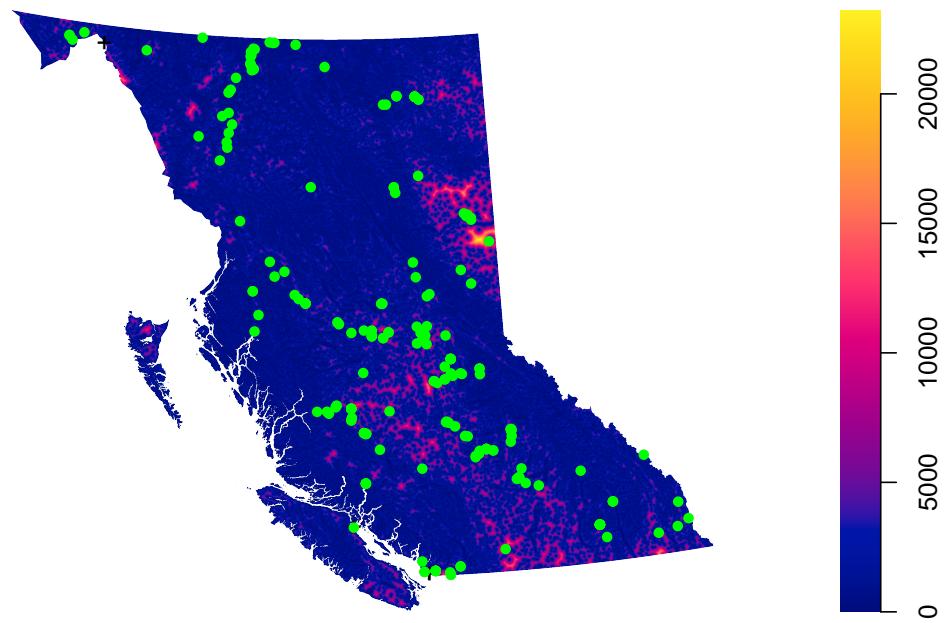


It is also very hard to see if there is a relationship, this time because there are a lot of high values for forest cover all over the province.

Distance to water

```
plot(DATA$Dist_Water, box = F, par(cex.main = 2), main = "Distance to water")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

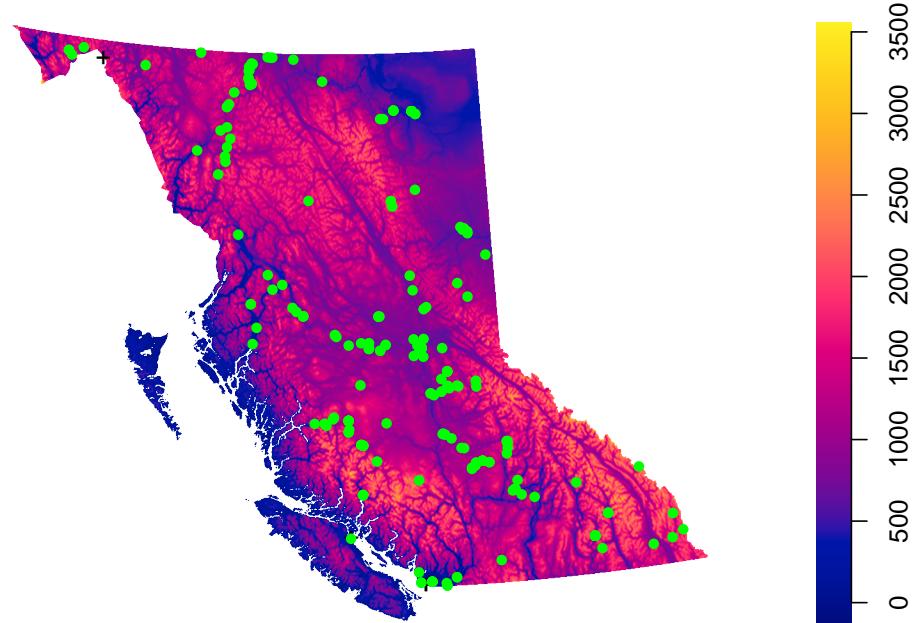
Distance to water



Elevation

```
plot(DATA$Elevation, box = F, par(cex.main = 2), main = "Elevation")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

Elevation



Conclusion: maybe need to segment the continuous values of covariates so that it is easier to see trend, like histogram in lab 1.

2nd Moment Analysis

Morisita's Index plot

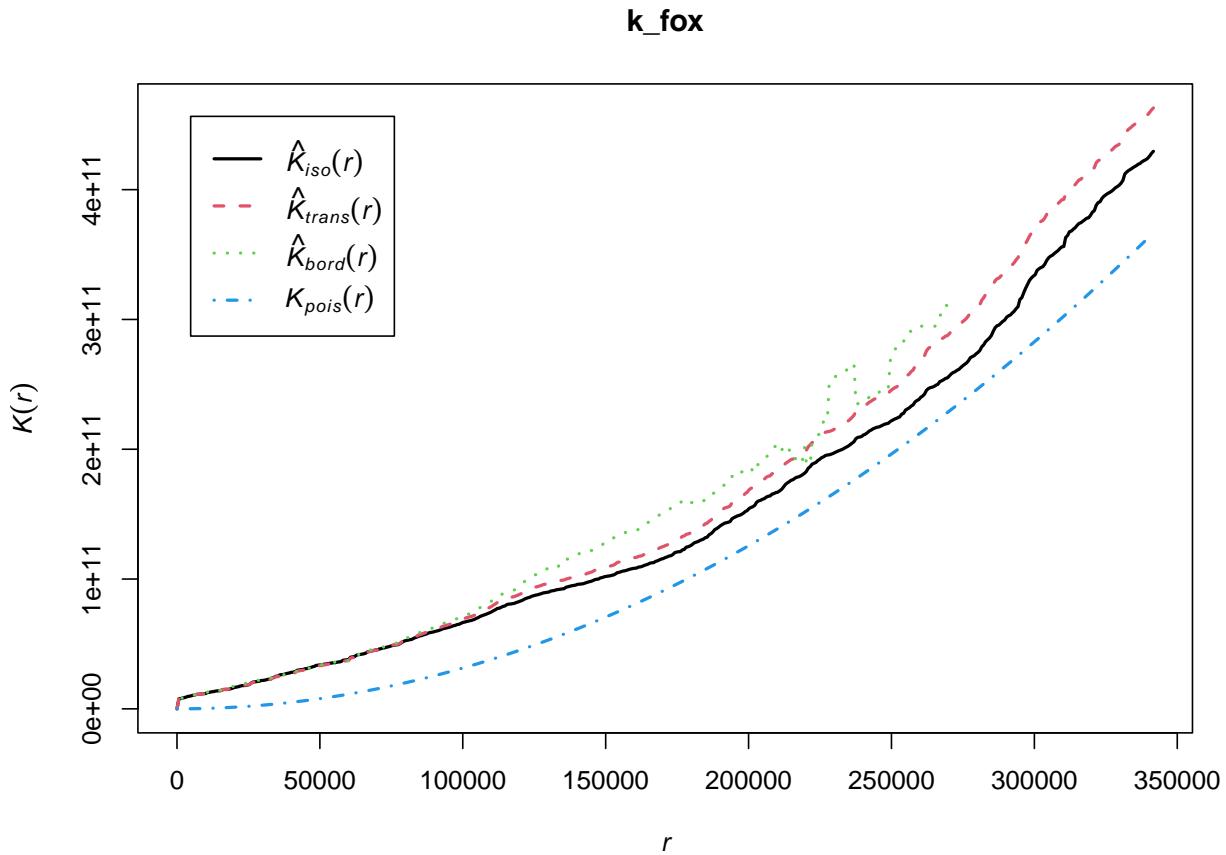
this produces an error, and we don't need to include it

```
miplot(parks_ppp,  
       main = "",  
       pch = 16,  
       col = "maroon")
```

Ripley's K function

Ripley's K-function provides information on whether there are significant deviations from independence between points.

```
k_fox <- Kest(parks_ppp)  
plot(k_fox, lwd=2)
```



The blue line is the theoretical line. (I don't know what the other lines mean)

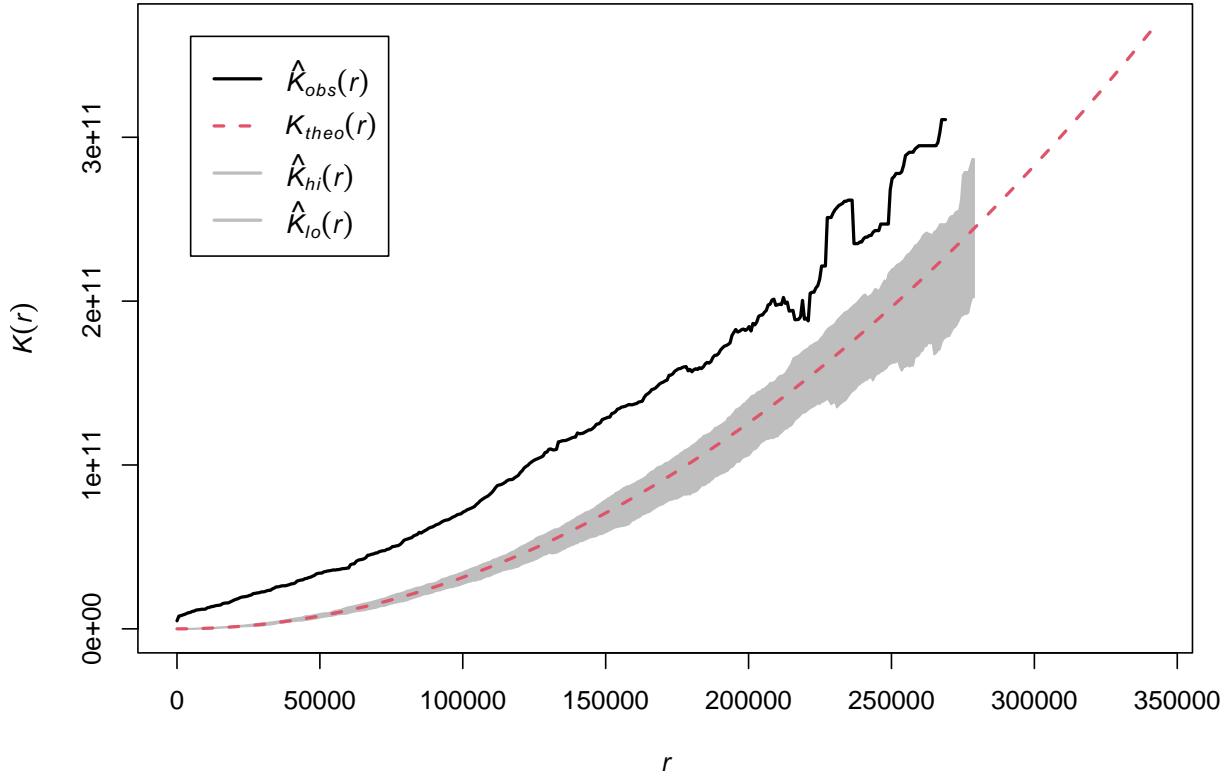
Adding confidence interval at a significance level of 0.05:

```
E_fox_homo <- envelope(parks_ppp,
    Kest,
    correction="border",
    rank = 1,
    nsim = 19, # aka alpha of 0.05
    fix.n = T)

## Generating 19 simulations of CSR with fixed number of points ...
## 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
##
## Done.

plot(E_fox_homo, lwd = 2)
```

E_fox_homo



(I don't know why it only plotted these lines and not the other ones) We see that the effect appears significant. It is suspicious that the confidence bands increase a lot, (what's the explanation for that?)

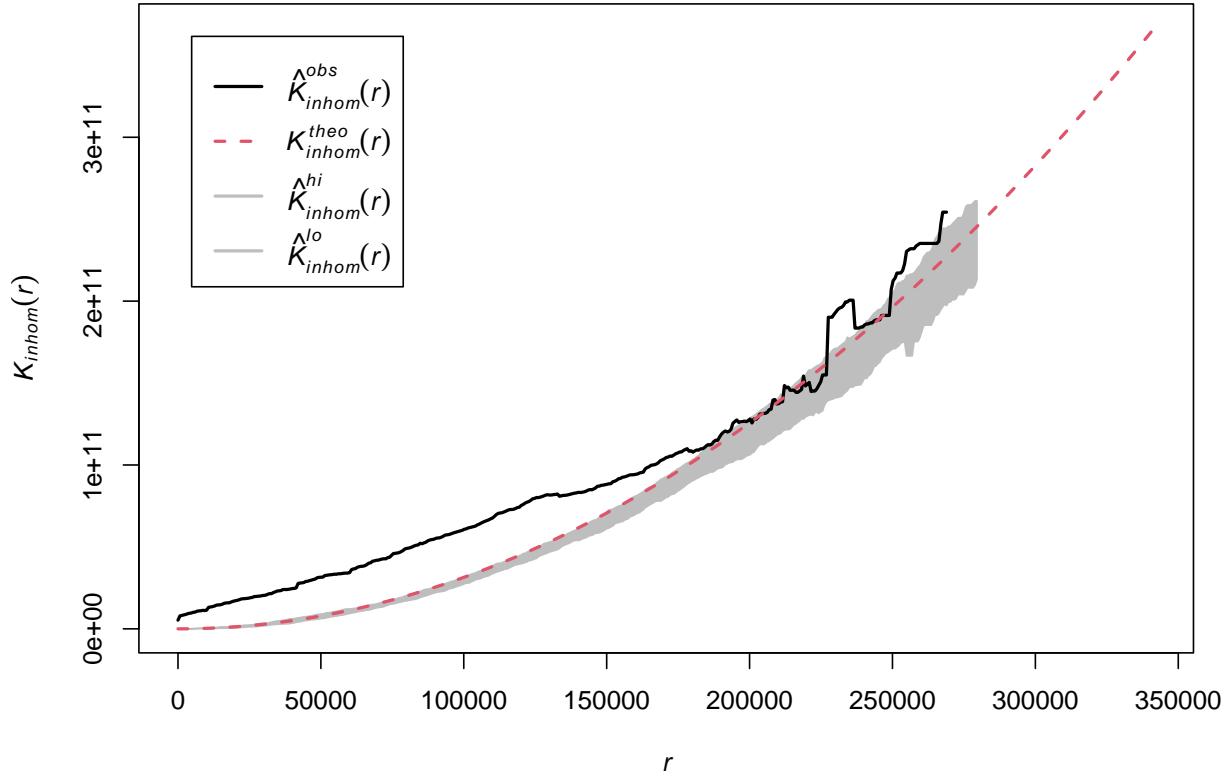
However, we know from first moment analysis that the intensity does not seem homogenous (right? Might need to double check). Trying inhomogenous:

```
E_fox <- envelope(parks_ppp,
                    Kinhom,
                    correction="border",
                    rank = 1,
                    nsim = 19, # aka alpha of 0.05
                    fix.n = T)

## Generating 19 simulations of CSR with fixed number of points ...
## 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
##
## Done.

plot(E_fox, lwd = 2)
```

E_fox



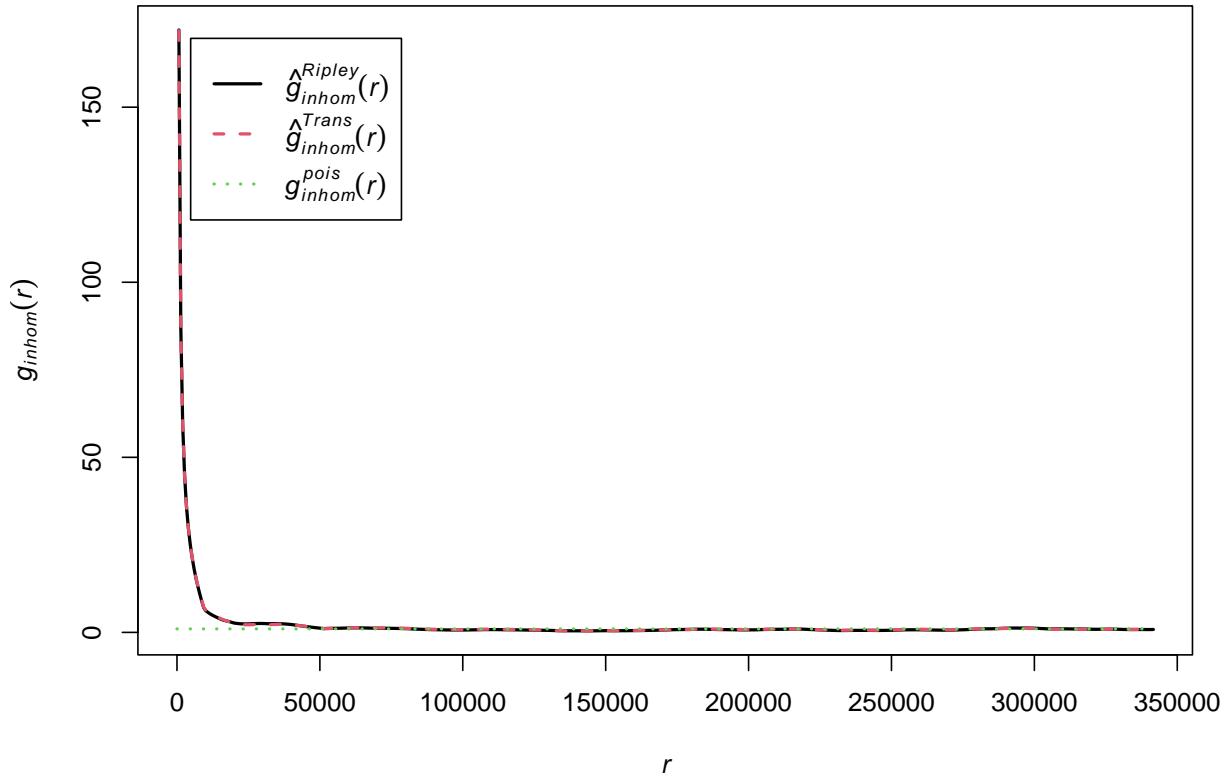
Using the Kinhom function ensures that we are not assuming the intensity is homogenous. It seems like from the smaller numbers, ie smaller distances between points, there is ‘evidence’ of clustering, whereas there are funny things going on as distances increase. The deviations are still meaningful in the ‘smaller’ distances, suggesting that the relationship between points may be due to effects between points rather than relationship with covariates.

Pair correlation function

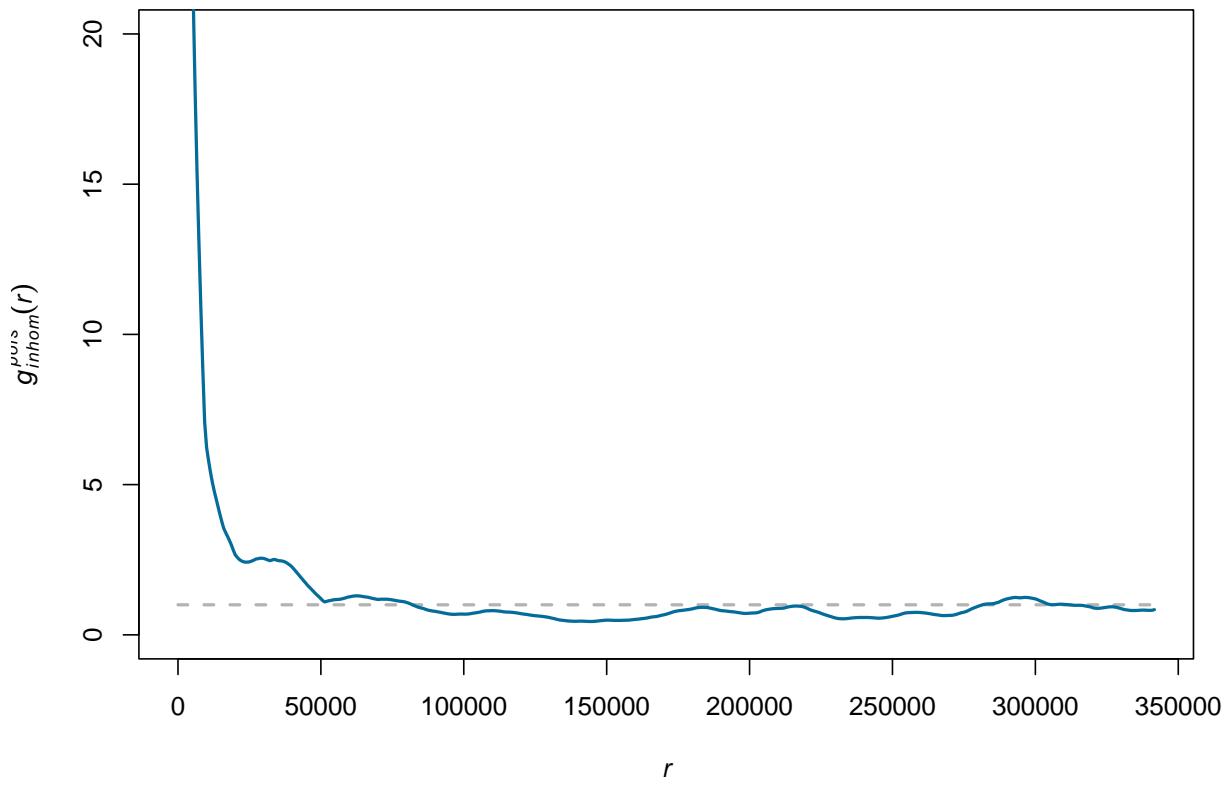
```
# Estimate the g function
pcf_fox <- pcfinhom(parks_ppp) # assumes inhomogeneity

# Default plot method
plot(pcf_fox, lwd = 2)
```

pcf_fox



```
# visualise the results
plot(pcf_fox,
      theo ~ r,
      ylim = c(0,20),
      main = "",
      col = "grey70",
      lwd = 2,
      lty = "dashed")
plot(pcf_fox,
      iso ~ r,
      col = c("#046C9A"),
      lwd = 2,
      add = T)
```



We observe that there seem to be evidence for clustering at smaller than 50 000, but after that it rides the $y = 1$ line slightly under.

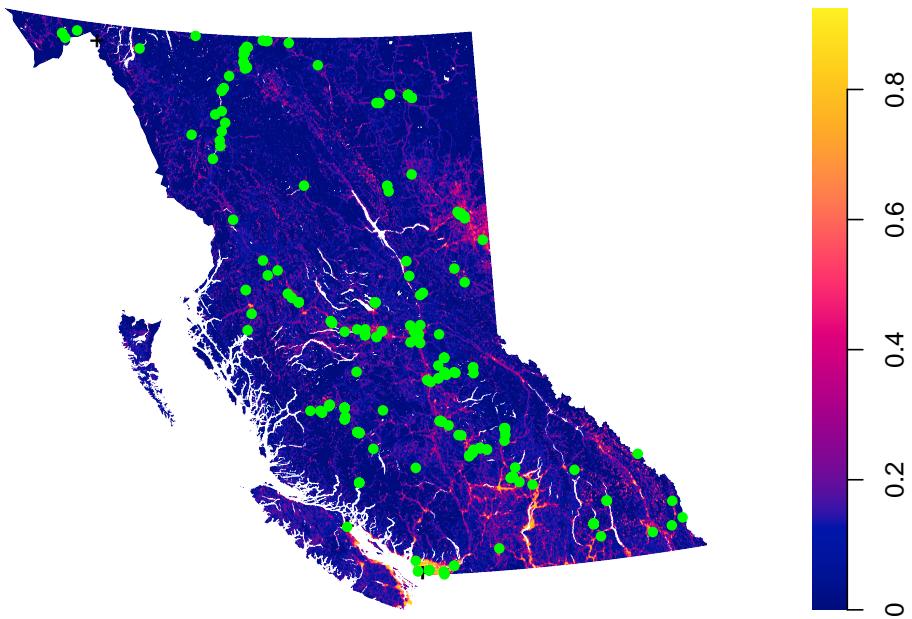
We need to validate clustering effects after modeling the data with covariates.

Relationship with Covariates

HFI

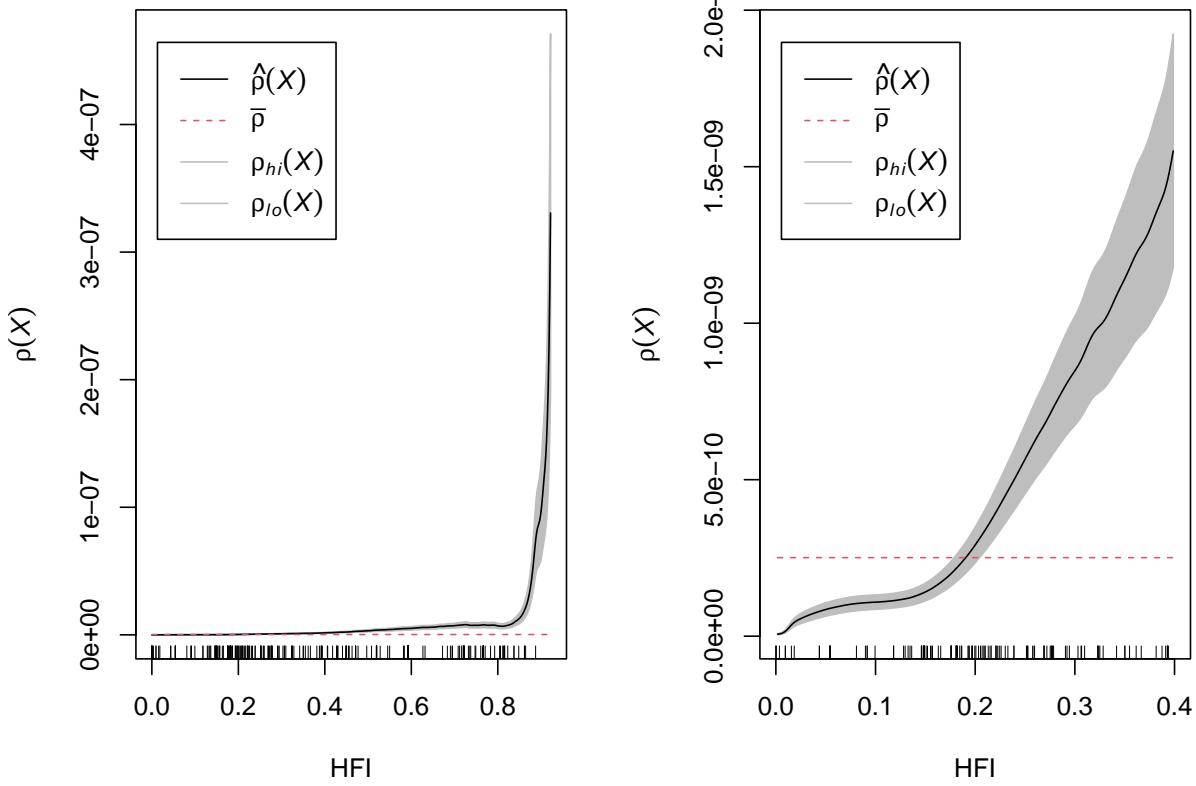
```
plot(DATA$HFI, box = F, par(cex.main = 2), main = "Forest")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

Forest



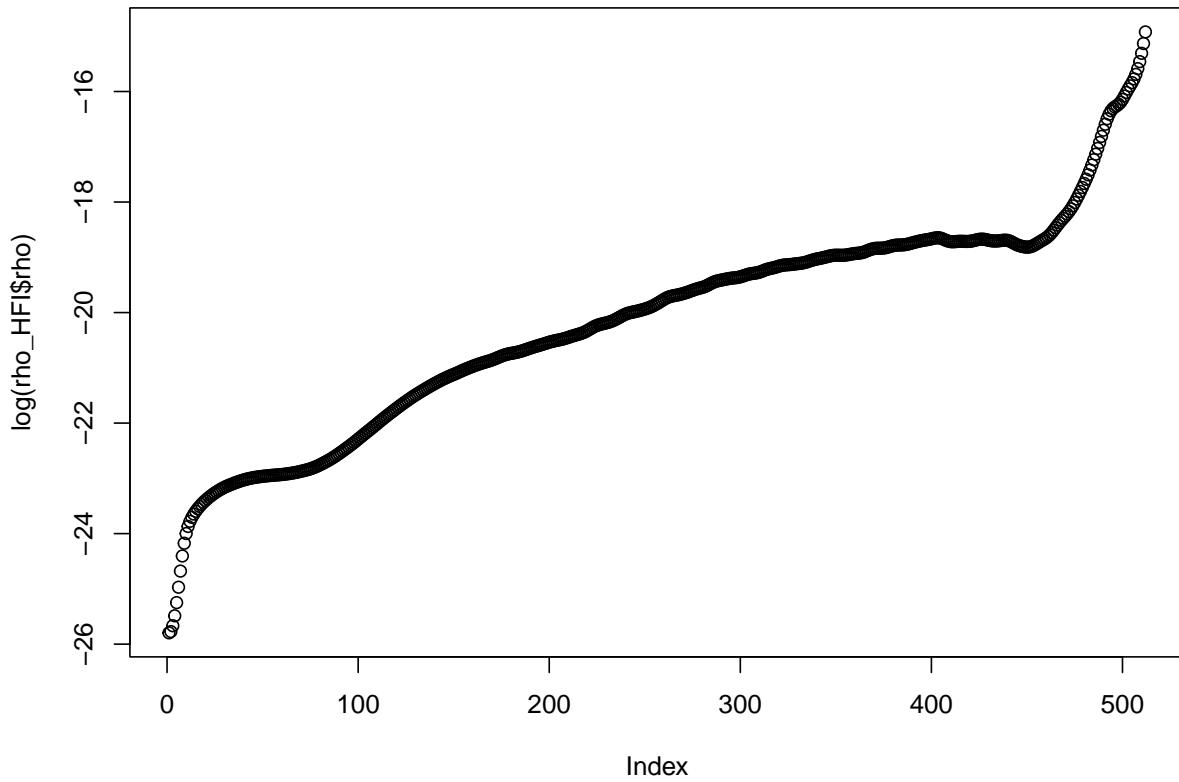
```
rho_HFI <- rhohat(parks_ppp, DATA$HFI)

par(mfrow = c(1,2))
plot(rho_HFI,
      main = "",
      xlab = "HFI")
plot(rho_HFI,
      main = "",
      xlab = "HFI", xlim = c(0,0.4))
```



In the first figure, we could be fooled into thinking that there is no relationship up to around $HFI = 0.4$, until which it seems like an exponential relationship. However, zooming in from $HFI \in [0, 1]$ to $HFI \in [0, 0.4]$, we see that the confidence bands don't intersect at all with the red line, which is the expected value given no relationship. This relationship appears non-linear and possibly exponential, where the greatest intensity of observed red foxes occurs at high HFIs. This relationship was expected, as our dataset is not exhaustive but rather is crowdsourced, and naturally foxes are more likely to be noticed by humans in spaces with higher HFIs.

```
plot(log(rho_HFI$rho))
```



If we plot the log of the rho, we get a line that could be reasonably interpreted as linear.

simple model

```

fitHFI <- ppm(parks_ppp ~ HFI, data=DATA)
summary(fitHFI)

## Point process model
## Fitted to data: parks_ppp
## Fitting method: maximum likelihood (Berman-Turner approximation)
## Model was fitted using glm()
## Algorithm converged
## Call:
## ppm.formula(Q = parks_ppp ~ HFI, data = DATA)
## Edge correction: "border"
## [border correction distance r = 0 ]
##
## Quadrature scheme (Berman-Turner) = data + dummy + weights
##
## Data pattern:
## Planar point pattern: 238 points
## Average intensity 2.51e-10 points per square unit

```

```

## Window: polygonal boundary
## 379 separate polygons (2 holes)
##           vertices      area relative.area
## polygon 1          5454 889865000000  9.38e-01
## polygon 2          2129 319023000000  3.36e-02
## polygon 3 (hole)    55   -49871200 -5.26e-05
## polygon 4 (hole)    21   -15073400 -1.59e-05
## polygon 5          751   6476610000  6.83e-03
## polygon 6          764   2633530000  2.78e-03
## polygon 7          379   2286840000  2.41e-03
## polygon 8          281   1397560000  1.47e-03
## polygon 9          155   1020880000  1.08e-03
## polygon 10         178   822976000  8.68e-04
## polygon 11         189   531172000  5.60e-04
## polygon 12         135   523600000  5.52e-04
## polygon 13         93    429077000  4.52e-04
## polygon 14         59    375017000  3.95e-04
## polygon 15         80    366555000  3.87e-04
## polygon 16         130   389457000  4.11e-04
## polygon 17         129   361761000  3.81e-04
## polygon 18         73    325642000  3.43e-04
## polygon 19         72    284295000  3.00e-04
## polygon 20         98    291606000  3.08e-04
## polygon 21         87    301693000  3.18e-04
## polygon 22         60    271131000  2.86e-04
## polygon 23         105   273020000  2.88e-04
## polygon 24         67    238816000  2.52e-04
## polygon 25         72    240998000  2.54e-04
## polygon 26         51    207196000  2.19e-04
## polygon 27         81    175770000  1.85e-04
## polygon 28         72    186213000  1.96e-04
## polygon 29         60    170593000  1.80e-04
## polygon 30         52    171879000  1.81e-04
## polygon 31         62    174668000  1.84e-04
## polygon 32         55    163246000  1.72e-04
## polygon 33         63    151745000  1.60e-04
## polygon 34         62    164385000  1.73e-04
## polygon 35         70    155140000  1.64e-04
## polygon 36         63    152920000  1.61e-04
## polygon 37         72    134301000  1.42e-04
## polygon 38         88    135277000  1.43e-04
## polygon 39         93    128722000  1.36e-04
## polygon 40         45    127343000  1.34e-04
## polygon 41         84    130472000  1.38e-04
## polygon 42         49    114370000  1.21e-04
## polygon 43         44    106635000  1.12e-04
## polygon 44         53    102951000  1.09e-04
## polygon 45         52    100309000  1.06e-04
## polygon 46         45    95770200  1.01e-04
## polygon 47         43    95377600  1.01e-04
## polygon 48         39    92824200  9.79e-05
## polygon 49         47    81225900  8.57e-05
## polygon 50         40    80617200  8.50e-05
## polygon 51         64    83219400  8.78e-05

```

## polygon 52	33	76223000	8.04e-05
## polygon 53	34	67360500	7.10e-05
## polygon 54	54	68347400	7.21e-05
## polygon 55	44	64136400	6.76e-05
## polygon 56	42	66265500	6.99e-05
## polygon 57	29	62988400	6.64e-05
## polygon 58	31	59626500	6.29e-05
## polygon 59	25	54751800	5.77e-05
## polygon 60	31	55352900	5.84e-05
## polygon 61	30	53162300	5.61e-05
## polygon 62	44	57621600	6.08e-05
## polygon 63	26	56707500	5.98e-05
## polygon 64	36	56979200	6.01e-05
## polygon 65	32	55472500	5.85e-05
## polygon 66	21	50455600	5.32e-05
## polygon 67	40	51039400	5.38e-05
## polygon 68	26	53043500	5.59e-05
## polygon 69	29	51938100	5.48e-05
## polygon 70	27	50295800	5.30e-05
## polygon 71	33	47938300	5.06e-05
## polygon 72	18	44300200	4.67e-05
## polygon 73	25	45691800	4.82e-05
## polygon 74	29	43313200	4.57e-05
## polygon 75	36	46561100	4.91e-05
## polygon 76	31	46220100	4.87e-05
## polygon 77	26	40401700	4.26e-05
## polygon 78	30	43204000	4.56e-05
## polygon 79	26	41430100	4.37e-05
## polygon 80	25	36988000	3.90e-05
## polygon 81	28	37700100	3.98e-05
## polygon 82	20	35892800	3.79e-05
## polygon 83	34	38217700	4.03e-05
## polygon 84	21	34874700	3.68e-05
## polygon 85	25	33536100	3.54e-05
## polygon 86	30	36738900	3.87e-05
## polygon 87	30	35393400	3.73e-05
## polygon 88	23	32140100	3.39e-05
## polygon 89	28	31469400	3.32e-05
## polygon 90	23	32736900	3.45e-05
## polygon 91	28	34117200	3.60e-05
## polygon 92	20	31802600	3.35e-05
## polygon 93	26	30659000	3.23e-05
## polygon 94	24	29572700	3.12e-05
## polygon 95	27	27289800	2.88e-05
## polygon 96	16	23094400	2.44e-05
## polygon 97	23	24218600	2.55e-05
## polygon 98	18	21846600	2.30e-05
## polygon 99	14	23702300	2.50e-05
## polygon 100	21	24325800	2.57e-05
## polygon 101	23	22590100	2.38e-05
## polygon 102	24	19177800	2.02e-05
## polygon 103	22	18657800	1.97e-05
## polygon 104	15	17454800	1.84e-05
## polygon 105	14	16276800	1.72e-05

## polygon 106	13	15792300	1.67e-05
## polygon 107	17	16117900	1.70e-05
## polygon 108	12	16217100	1.71e-05
## polygon 109	19	16610700	1.75e-05
## polygon 110	18	16809400	1.77e-05
## polygon 111	15	15096400	1.59e-05
## polygon 112	14	14571400	1.54e-05
## polygon 113	11	13567300	1.43e-05
## polygon 114	16	13623600	1.44e-05
## polygon 115	15	13657400	1.44e-05
## polygon 116	18	14346200	1.51e-05
## polygon 117	15	12418500	1.31e-05
## polygon 118	22	13085700	1.38e-05
## polygon 119	11	13446800	1.42e-05
## polygon 120	14	13234700	1.40e-05
## polygon 121	15	13532800	1.43e-05
## polygon 122	16	12575800	1.33e-05
## polygon 123	15	13060700	1.38e-05
## polygon 124	15	11766100	1.24e-05
## polygon 125	18	11038100	1.16e-05
## polygon 126	12	12863200	1.36e-05
## polygon 127	19	11135700	1.17e-05
## polygon 128	11	10881600	1.15e-05
## polygon 129	14	12500500	1.32e-05
## polygon 130	12	10733900	1.13e-05
## polygon 131	15	11201200	1.18e-05
## polygon 132	13	10674100	1.13e-05
## polygon 133	13	9776920	1.03e-05
## polygon 134	14	10503500	1.11e-05
## polygon 135	12	9391460	9.90e-06
## polygon 136	10	9402110	9.92e-06
## polygon 137	9	9160880	9.66e-06
## polygon 138	11	8674110	9.15e-06
## polygon 139	12	9159420	9.66e-06
## polygon 140	14	8676590	9.15e-06
## polygon 141	12	9527540	1.00e-05
## polygon 142	12	8797870	9.28e-06
## polygon 143	11	8837670	9.32e-06
## polygon 144	13	9067690	9.56e-06
## polygon 145	12	7950440	8.38e-06
## polygon 146	9	8727650	9.20e-06
## polygon 147	8	8565660	9.03e-06
## polygon 148	8	6790020	7.16e-06
## polygon 149	11	6780640	7.15e-06
## polygon 150	11	7326980	7.73e-06
## polygon 151	10	6152880	6.49e-06
## polygon 152	13	6721370	7.09e-06
## polygon 153	8	6343870	6.69e-06
## polygon 154	11	6807170	7.18e-06
## polygon 155	10	6927150	7.31e-06
## polygon 156	9	6352310	6.70e-06
## polygon 157	13	6217600	6.56e-06
## polygon 158	15	6263440	6.61e-06
## polygon 159	11	5769240	6.08e-06

## polygon 160	8	5965270	6.29e-06
## polygon 161	10	6826030	7.20e-06
## polygon 162	10	5749960	6.06e-06
## polygon 163	15	5352810	5.64e-06
## polygon 164	9	5781470	6.10e-06
## polygon 165	13	5358790	5.65e-06
## polygon 166	10	6016930	6.35e-06
## polygon 167	9	5928820	6.25e-06
## polygon 168	8	5424110	5.72e-06
## polygon 169	9	5468680	5.77e-06
## polygon 170	11	5209670	5.49e-06
## polygon 171	9	4705250	4.96e-06
## polygon 172	9	4891810	5.16e-06
## polygon 173	11	5295110	5.58e-06
## polygon 174	7	4839440	5.10e-06
## polygon 175	7	4322930	4.56e-06
## polygon 176	7	4514530	4.76e-06
## polygon 177	7	4573450	4.82e-06
## polygon 178	9	5080950	5.36e-06
## polygon 179	12	4492120	4.74e-06
## polygon 180	8	4783060	5.04e-06
## polygon 181	8	3800770	4.01e-06
## polygon 182	5	4657790	4.91e-06
## polygon 183	11	4323150	4.56e-06
## polygon 184	9	3549270	3.74e-06
## polygon 185	6	4103470	4.33e-06
## polygon 186	8	3898980	4.11e-06
## polygon 187	8	4009440	4.23e-06
## polygon 188	9	3672080	3.87e-06
## polygon 189	11	3540120	3.73e-06
## polygon 190	6	3790670	4.00e-06
## polygon 191	8	3695580	3.90e-06
## polygon 192	7	3708650	3.91e-06
## polygon 193	7	3843670	4.05e-06
## polygon 194	7	3157020	3.33e-06
## polygon 195	9	2913680	3.07e-06
## polygon 196	9	3368170	3.55e-06
## polygon 197	7	3190600	3.36e-06
## polygon 198	6	3073660	3.24e-06
## polygon 199	9	3016490	3.18e-06
## polygon 200	8	3129780	3.30e-06
## polygon 201	6	3101410	3.27e-06
## polygon 202	7	2895440	3.05e-06
## polygon 203	8	2998870	3.16e-06
## polygon 204	7	2619570	2.76e-06
## polygon 205	10	3007320	3.17e-06
## polygon 206	7	2324090	2.45e-06
## polygon 207	10	2935450	3.10e-06
## polygon 208	10	2523640	2.66e-06
## polygon 209	6	2232050	2.35e-06
## polygon 210	6	2131190	2.25e-06
## polygon 211	6	1679950	1.77e-06
## polygon 212	6	2226470	2.35e-06
## polygon 213	8	2267800	2.39e-06

## polygon 214	6	2584690	2.73e-06
## polygon 215	5	2151150	2.27e-06
## polygon 216	6	1536960	1.62e-06
## polygon 217	6	2616700	2.76e-06
## polygon 218	7	2205520	2.33e-06
## polygon 219	8	2008210	2.12e-06
## polygon 220	5	2181540	2.30e-06
## polygon 221	7	2700450	2.85e-06
## polygon 222	7	2493440	2.63e-06
## polygon 223	7	2752380	2.90e-06
## polygon 224	5	2036350	2.15e-06
## polygon 225	5	2344480	2.47e-06
## polygon 226	5	1786340	1.88e-06
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## polygon 234	5	1891180	1.99e-06
## polygon 235	5	1957860	2.06e-06
## polygon 236	7	2335470	2.46e-06
## polygon 237	4	2055120	2.17e-06
## polygon 238	6	1829730	1.93e-06
## polygon 239	5	1807400	1.91e-06
## polygon 240	5	2014070	2.12e-06
## polygon 241	5	1882630	1.99e-06
## polygon 242	5	1928800	2.03e-06
## polygon 243	5	2010320	2.12e-06
## polygon 244	5	1521870	1.60e-06
## polygon 245	6	1935590	2.04e-06
## polygon 246	5	1647440	1.74e-06
## polygon 247	4	1518380	1.60e-06
## polygon 248	6	1623490	1.71e-06
## polygon 249	5	1654240	1.74e-06
## polygon 250	5	1691180	1.78e-06
## polygon 251	3	765559	8.07e-07
## polygon 252	6	1792550	1.89e-06
## polygon 253	5	1428170	1.51e-06
## polygon 254	5	1356230	1.43e-06
## polygon 255	5	1536990	1.62e-06
## polygon 256	5	1188700	1.25e-06
## polygon 257	4	846360	8.93e-07
## polygon 258	5	1449400	1.53e-06
## polygon 259	4	1654610	1.74e-06
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## polygon 261	4	1163890	1.23e-06
## polygon 262	7	1548860	1.63e-06
## polygon 263	6	1317820	1.39e-06
## polygon 264	5	1220870	1.29e-06
## polygon 265	4	1251210	1.32e-06
## polygon 266	6	1443280	1.52e-06
## polygon 267	5	1430870	1.51e-06

## polygon 268	5	1201830	1.27e-06
## polygon 269	7	1083120	1.14e-06
## polygon 270	5	1315200	1.39e-06
## polygon 271	5	1173590	1.24e-06
## polygon 272	5	1283640	1.35e-06
## polygon 273	5	1243830	1.31e-06
## polygon 274	5	1418840	1.50e-06
## polygon 275	6	1194150	1.26e-06
## polygon 276	3	732692	7.73e-07
## polygon 277	4	724047	7.64e-07
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## polygon 280	5	1080070	1.14e-06
## polygon 281	5	1105010	1.17e-06
## polygon 282	4	1101910	1.16e-06
## polygon 283	5	1202270	1.27e-06
## polygon 284	5	1193280	1.26e-06
## polygon 285	5	1104420	1.16e-06
## polygon 286	5	1337410	1.41e-06
## polygon 287	6	1293100	1.36e-06
## polygon 288	4	715019	7.54e-07
## polygon 289	3	772725	8.15e-07
## polygon 290	4	856683	9.03e-07
## polygon 291	4	986692	1.04e-06
## polygon 292	4	808047	8.52e-07
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## polygon 295	5	997422	1.05e-06
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## polygon 298	4	1072900	1.13e-06
## polygon 299	5	1071650	1.13e-06
## polygon 300	4	937949	9.89e-07
## polygon 301	4	714701	7.54e-07
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## polygon 303	4	965776	1.02e-06
## polygon 304	4	875646	9.23e-07
## polygon 305	4	682625	7.20e-07
## polygon 306	4	799391	8.43e-07
## polygon 307	4	915082	9.65e-07
## polygon 308	4	647125	6.82e-07
## polygon 309	5	850200	8.97e-07
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## polygon 312	4	702365	7.41e-07
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## polygon 315	4	604921	6.38e-07
## polygon 316	4	564256	5.95e-07
## polygon 317	5	943607	9.95e-07
## polygon 318	4	725841	7.65e-07
## polygon 319	4	838391	8.84e-07
## polygon 320	4	725920	7.66e-07
## polygon 321	4	607726	6.41e-07

## polygon 322	3	377075	3.98e-07
## polygon 323	4	801044	8.45e-07
## polygon 324	4	707601	7.46e-07
## polygon 325	4	701275	7.40e-07
## polygon 326	3	567574	5.99e-07
## polygon 327	4	656976	6.93e-07
## polygon 328	4	697610	7.36e-07
## polygon 329	3	429629	4.53e-07
## polygon 330	4	692723	7.31e-07
## polygon 331	5	1123680	1.18e-06
## polygon 332	4	638721	6.74e-07
## polygon 333	4	649515	6.85e-07
## polygon 334	5	885457	9.34e-07
## polygon 335	3	397429	4.19e-07
## polygon 336	3	311243	3.28e-07
## polygon 337	4	692962	7.31e-07
## polygon 338	4	637359	6.72e-07
## polygon 339	3	347030	3.66e-07
## polygon 340	4	545022	5.75e-07
## polygon 341	4	630075	6.64e-07
## polygon 342	4	682861	7.20e-07
## polygon 343	4	582135	6.14e-07
## polygon 344	4	685738	7.23e-07
## polygon 345	3	666827	7.03e-07
## polygon 346	4	638063	6.73e-07
## polygon 347	3	415934	4.39e-07
## polygon 348	3	496699	5.24e-07
## polygon 349	4	523038	5.52e-07
## polygon 350	4	629200	6.64e-07
## polygon 351	4	545075	5.75e-07
## polygon 352	4	523200	5.52e-07
## polygon 353	4	534278	5.63e-07
## polygon 354	4	617265	6.51e-07
## polygon 355	4	554460	5.85e-07
## polygon 356	3	422197	4.45e-07
## polygon 357	4	450587	4.75e-07
## polygon 358	3	506804	5.34e-07
## polygon 359	4	666360	7.03e-07
## polygon 360	4	648581	6.84e-07
## polygon 361	3	453422	4.78e-07
## polygon 362	4	572761	6.04e-07
## polygon 363	4	515850	5.44e-07
## polygon 364	4	501575	5.29e-07
## polygon 365	4	501226	5.29e-07
## polygon 366	4	601941	6.35e-07
## polygon 367	4	593073	6.25e-07
## polygon 368	3	427855	4.51e-07
## polygon 369	3	295928	3.12e-07
## polygon 370	4	640706	6.76e-07
## polygon 371	5	714352	7.53e-07
## polygon 372	4	494594	5.22e-07
## polygon 373	3	413224	4.36e-07
## polygon 374	3	254908	2.69e-07
## polygon 375	4	458639	4.84e-07

```

## polygon 376          3      374163      3.95e-07
## polygon 377          4      514470      5.43e-07
## polygon 378          4      419372      4.42e-07
## polygon 379          3      405491      4.28e-07
## enclosing rectangle: [273874.9, 1870573.4] x [369042.8, 1735666.4] units
##                               (1597000 x 1367000 units)
## Window area = 9.48262e+11 square units
## Fraction of frame area: 0.435
##
## Dummy quadrature points:
##       64 x 64 grid of dummy points, plus 4 corner points
##       dummy spacing: 24948.41 x 21353.49 units
##
## Original dummy parameters: =
## Planar point pattern: 1899 points
## Average intensity 2e-09 points per square unit
## Window: polygonal boundary
## 379 separate polygons (2 holes)
##           vertices      area relative.area
## polygon 1          5454  889865000000  9.38e-01
## polygon 2          2129  319023000000  3.36e-02
## polygon 3 (hole)    55   -49871200  -5.26e-05
## polygon 4 (hole)    21   -15073400  -1.59e-05
## polygon 5          751   6476610000  6.83e-03
## polygon 6          764   2633530000  2.78e-03
## polygon 7          379   2286840000  2.41e-03
## polygon 8          281   1397560000  1.47e-03
## polygon 9          155   1020880000  1.08e-03
## polygon 10         178   822976000  8.68e-04
## polygon 11         189   531172000  5.60e-04
## polygon 12         135   523600000  5.52e-04
## polygon 13         93    429077000  4.52e-04
## polygon 14         59    375017000  3.95e-04
## polygon 15         80    366555000  3.87e-04
## polygon 16         130   389457000  4.11e-04
## polygon 17         129   361761000  3.81e-04
## polygon 18         73    325642000  3.43e-04
## polygon 19         72    284295000  3.00e-04
## polygon 20         98    291606000  3.08e-04
## polygon 21         87    301693000  3.18e-04
## polygon 22         60    271131000  2.86e-04
## polygon 23         105   273020000  2.88e-04
## polygon 24         67    238816000  2.52e-04
## polygon 25         72    240998000  2.54e-04
## polygon 26         51    207196000  2.19e-04
## polygon 27         81    175770000  1.85e-04
## polygon 28         72    186213000  1.96e-04
## polygon 29         60    170593000  1.80e-04
## polygon 30         52    171879000  1.81e-04
## polygon 31         62    174668000  1.84e-04
## polygon 32         55    163246000  1.72e-04
## polygon 33         63    151745000  1.60e-04
## polygon 34         62    164385000  1.73e-04
## polygon 35         70    155140000  1.64e-04

```

## polygon 36	63	152920000	1.61e-04
## polygon 37	72	134301000	1.42e-04
## polygon 38	88	135277000	1.43e-04
## polygon 39	93	128722000	1.36e-04
## polygon 40	45	127343000	1.34e-04
## polygon 41	84	130472000	1.38e-04
## polygon 42	49	114370000	1.21e-04
## polygon 43	44	106635000	1.12e-04
## polygon 44	53	102951000	1.09e-04
## polygon 45	52	100309000	1.06e-04
## polygon 46	45	95770200	1.01e-04
## polygon 47	43	95377600	1.01e-04
## polygon 48	39	92824200	9.79e-05
## polygon 49	47	81225900	8.57e-05
## polygon 50	40	80617200	8.50e-05
## polygon 51	64	83219400	8.78e-05
## polygon 52	33	76223000	8.04e-05
## polygon 53	34	67360500	7.10e-05
## polygon 54	54	68347400	7.21e-05
## polygon 55	44	64136400	6.76e-05
## polygon 56	42	66265500	6.99e-05
## polygon 57	29	62988400	6.64e-05
## polygon 58	31	59626500	6.29e-05
## polygon 59	25	54751800	5.77e-05
## polygon 60	31	55352900	5.84e-05
## polygon 61	30	53162300	5.61e-05
## polygon 62	44	57621600	6.08e-05
## polygon 63	26	56707500	5.98e-05
## polygon 64	36	56979200	6.01e-05
## polygon 65	32	55472500	5.85e-05
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## polygon 67	40	51039400	5.38e-05
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## polygon 69	29	51938100	5.48e-05
## polygon 70	27	50295800	5.30e-05
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## polygon 72	18	44300200	4.67e-05
## polygon 73	25	45691800	4.82e-05
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## polygon 75	36	46561100	4.91e-05
## polygon 76	31	46220100	4.87e-05
## polygon 77	26	40401700	4.26e-05
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## polygon 79	26	41430100	4.37e-05
## polygon 80	25	36988000	3.90e-05
## polygon 81	28	37700100	3.98e-05
## polygon 82	20	35892800	3.79e-05
## polygon 83	34	38217700	4.03e-05
## polygon 84	21	34874700	3.68e-05
## polygon 85	25	33536100	3.54e-05
## polygon 86	30	36738900	3.87e-05
## polygon 87	30	35393400	3.73e-05
## polygon 88	23	32140100	3.39e-05
## polygon 89	28	31469400	3.32e-05

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## polygon 91	28	34117200	3.60e-05
## polygon 92	20	31802600	3.35e-05
## polygon 93	26	30659000	3.23e-05
## polygon 94	24	29572700	3.12e-05
## polygon 95	27	27289800	2.88e-05
## polygon 96	16	23094400	2.44e-05
## polygon 97	23	24218600	2.55e-05
## polygon 98	18	21846600	2.30e-05
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## polygon 117	15	12418500	1.31e-05
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## polygon 122	16	12575800	1.33e-05
## polygon 123	15	13060700	1.38e-05
## polygon 124	15	11766100	1.24e-05
## polygon 125	18	11038100	1.16e-05
## polygon 126	12	12863200	1.36e-05
## polygon 127	19	11135700	1.17e-05
## polygon 128	11	10881600	1.15e-05
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## polygon 194	7	3157020	3.33e-06
## polygon 195	9	2913680	3.07e-06
## polygon 196	9	3368170	3.55e-06
## polygon 197	7	3190600	3.36e-06

## polygon 198	6	3073660	3.24e-06
## polygon 199	9	3016490	3.18e-06
## polygon 200	8	3129780	3.30e-06
## polygon 201	6	3101410	3.27e-06
## polygon 202	7	2895440	3.05e-06
## polygon 203	8	2998870	3.16e-06
## polygon 204	7	2619570	2.76e-06
## polygon 205	10	3007320	3.17e-06
## polygon 206	7	2324090	2.45e-06
## polygon 207	10	2935450	3.10e-06
## polygon 208	10	2523640	2.66e-06
## polygon 209	6	2232050	2.35e-06
## polygon 210	6	2131190	2.25e-06
## polygon 211	6	1679950	1.77e-06
## polygon 212	6	2226470	2.35e-06
## polygon 213	8	2267800	2.39e-06
## polygon 214	6	2584690	2.73e-06
## polygon 215	5	2151150	2.27e-06
## polygon 216	6	1536960	1.62e-06
## polygon 217	6	2616700	2.76e-06
## polygon 218	7	2205520	2.33e-06
## polygon 219	8	2008210	2.12e-06
## polygon 220	5	2181540	2.30e-06
## polygon 221	7	2700450	2.85e-06
## polygon 222	7	2493440	2.63e-06
## polygon 223	7	2752380	2.90e-06
## polygon 224	5	2036350	2.15e-06
## polygon 225	5	2344480	2.47e-06
## polygon 226	5	1786340	1.88e-06
## polygon 227	8	2269610	2.39e-06
## polygon 228	6	1857450	1.96e-06
## polygon 229	5	1978280	2.09e-06
## polygon 230	5	1944240	2.05e-06
## polygon 231	6	2728340	2.88e-06
## polygon 232	8	1905200	2.01e-06
## polygon 233	7	2258780	2.38e-06
## polygon 234	5	1891180	1.99e-06
## polygon 235	5	1957860	2.06e-06
## polygon 236	7	2335470	2.46e-06
## polygon 237	4	2055120	2.17e-06
## polygon 238	6	1829730	1.93e-06
## polygon 239	5	1807400	1.91e-06
## polygon 240	5	2014070	2.12e-06
## polygon 241	5	1882630	1.99e-06
## polygon 242	5	1928800	2.03e-06
## polygon 243	5	2010320	2.12e-06
## polygon 244	5	1521870	1.60e-06
## polygon 245	6	1935590	2.04e-06
## polygon 246	5	1647440	1.74e-06
## polygon 247	4	1518380	1.60e-06
## polygon 248	6	1623490	1.71e-06
## polygon 249	5	1654240	1.74e-06
## polygon 250	5	1691180	1.78e-06
## polygon 251	3	765559	8.07e-07

## polygon 252	6	1792550	1.89e-06
## polygon 253	5	1428170	1.51e-06
## polygon 254	5	1356230	1.43e-06
## polygon 255	5	1536990	1.62e-06
## polygon 256	5	1188700	1.25e-06
## polygon 257	4	846360	8.93e-07
## polygon 258	5	1449400	1.53e-06
## polygon 259	4	1654610	1.74e-06
## polygon 260	6	1472190	1.55e-06
## polygon 261	4	1163890	1.23e-06
## polygon 262	7	1548860	1.63e-06
## polygon 263	6	1317820	1.39e-06
## polygon 264	5	1220870	1.29e-06
## polygon 265	4	1251210	1.32e-06
## polygon 266	6	1443280	1.52e-06
## polygon 267	5	1430870	1.51e-06
## polygon 268	5	1201830	1.27e-06
## polygon 269	7	1083120	1.14e-06
## polygon 270	5	1315200	1.39e-06
## polygon 271	5	1173590	1.24e-06
## polygon 272	5	1283640	1.35e-06
## polygon 273	5	1243830	1.31e-06
## polygon 274	5	1418840	1.50e-06
## polygon 275	6	1194150	1.26e-06
## polygon 276	3	732692	7.73e-07
## polygon 277	4	724047	7.64e-07
## polygon 278	4	1110880	1.17e-06
## polygon 279	4	1068690	1.13e-06
## polygon 280	5	1080070	1.14e-06
## polygon 281	5	1105010	1.17e-06
## polygon 282	4	1101910	1.16e-06
## polygon 283	5	1202270	1.27e-06
## polygon 284	5	1193280	1.26e-06
## polygon 285	5	1104420	1.16e-06
## polygon 286	5	1337410	1.41e-06
## polygon 287	6	1293100	1.36e-06
## polygon 288	4	715019	7.54e-07
## polygon 289	3	772725	8.15e-07
## polygon 290	4	856683	9.03e-07
## polygon 291	4	986692	1.04e-06
## polygon 292	4	808047	8.52e-07
## polygon 293	4	740351	7.81e-07
## polygon 294	4	839774	8.86e-07
## polygon 295	5	997422	1.05e-06
## polygon 296	4	841098	8.87e-07
## polygon 297	7	1180430	1.24e-06
## polygon 298	4	1072900	1.13e-06
## polygon 299	5	1071650	1.13e-06
## polygon 300	4	937949	9.89e-07
## polygon 301	4	714701	7.54e-07
## polygon 302	4	854803	9.01e-07
## polygon 303	4	965776	1.02e-06
## polygon 304	4	875646	9.23e-07
## polygon 305	4	682625	7.20e-07

## polygon 306	4	799391	8.43e-07
## polygon 307	4	915082	9.65e-07
## polygon 308	4	647125	6.82e-07
## polygon 309	5	850200	8.97e-07
## polygon 310	4	856777	9.04e-07
## polygon 311	5	926662	9.77e-07
## polygon 312	4	702365	7.41e-07
## polygon 313	4	877724	9.26e-07
## polygon 314	4	625455	6.60e-07
## polygon 315	4	604921	6.38e-07
## polygon 316	4	564256	5.95e-07
## polygon 317	5	943607	9.95e-07
## polygon 318	4	725841	7.65e-07
## polygon 319	4	838391	8.84e-07
## polygon 320	4	725920	7.66e-07
## polygon 321	4	607726	6.41e-07
## polygon 322	3	377075	3.98e-07
## polygon 323	4	801044	8.45e-07
## polygon 324	4	707601	7.46e-07
## polygon 325	4	701275	7.40e-07
## polygon 326	3	567574	5.99e-07
## polygon 327	4	656976	6.93e-07
## polygon 328	4	697610	7.36e-07
## polygon 329	3	429629	4.53e-07
## polygon 330	4	692723	7.31e-07
## polygon 331	5	1123680	1.18e-06
## polygon 332	4	638721	6.74e-07
## polygon 333	4	649515	6.85e-07
## polygon 334	5	885457	9.34e-07
## polygon 335	3	397429	4.19e-07
## polygon 336	3	311243	3.28e-07
## polygon 337	4	692962	7.31e-07
## polygon 338	4	637359	6.72e-07
## polygon 339	3	347030	3.66e-07
## polygon 340	4	545022	5.75e-07
## polygon 341	4	630075	6.64e-07
## polygon 342	4	682861	7.20e-07
## polygon 343	4	582135	6.14e-07
## polygon 344	4	685738	7.23e-07
## polygon 345	3	666827	7.03e-07
## polygon 346	4	638063	6.73e-07
## polygon 347	3	415934	4.39e-07
## polygon 348	3	496699	5.24e-07
## polygon 349	4	523038	5.52e-07
## polygon 350	4	629200	6.64e-07
## polygon 351	4	545075	5.75e-07
## polygon 352	4	523200	5.52e-07
## polygon 353	4	534278	5.63e-07
## polygon 354	4	617265	6.51e-07
## polygon 355	4	554460	5.85e-07
## polygon 356	3	422197	4.45e-07
## polygon 357	4	450587	4.75e-07
## polygon 358	3	506804	5.34e-07
## polygon 359	4	666360	7.03e-07

```

## polygon 360          4      648581      6.84e-07
## polygon 361          3      453422      4.78e-07
## polygon 362          4      572761      6.04e-07
## polygon 363          4      515850      5.44e-07
## polygon 364          4      501575      5.29e-07
## polygon 365          4      501226      5.29e-07
## polygon 366          4      601941      6.35e-07
## polygon 367          4      593073      6.25e-07
## polygon 368          3      427855      4.51e-07
## polygon 369          3      295928      3.12e-07
## polygon 370          4      640706      6.76e-07
## polygon 371          5      714352      7.53e-07
## polygon 372          4      494594      5.22e-07
## polygon 373          3      413224      4.36e-07
## polygon 374          3      254908      2.69e-07
## polygon 375          4      458639      4.84e-07
## polygon 376          3      374163      3.95e-07
## polygon 377          4      514470      5.43e-07
## polygon 378          4      419372      4.42e-07
## polygon 379          3      405491      4.28e-07
## enclosing rectangle: [273874.9, 1870573.4] x [369042.8, 1735666.4] units
##                               (1597000 x 1367000 units)
## Window area = 9.48262e+11 square units
## Fraction of frame area: 0.435
## Quadrature weights:
##           (counting weights based on 64 x 64 array of rectangular tiles)
## All weights:
##   range: [35500000, 5.33e+08] total: 9.45e+11
## Weights on data points:
##   range: [35500000, 2.66e+08] total: 3.46e+10
## Weights on dummy points:
##   range: [35500000, 5.33e+08] total: 9.1e+11
## -----
## FITTED :
##
## Nonstationary Poisson process
##
## ---- Intensity: ----
##
## Log intensity: ~HFI
## Model depends on external covariate 'HFI'
## Covariates provided:
##   Elevation: im
##   Forest: im
##   HFI: im
##   Dist_Water: im
##
## Fitted trend coefficients:
## (Intercept)      HFI
## -23.31421      5.98177
##
##             Estimate      S.E.    CI95.lo    CI95.hi Ztest      Zval
## (Intercept) -23.31421 0.1058336 -23.521645 -23.106785 *** -220.29132
## HFI          5.98177 0.2148471  5.560677  6.402862 ***  27.84199

```

```

##
## ----- gory details -----
##
## Fitted regular parameters (theta):
## (Intercept)      HFI
## -23.31421      5.98177
##
## Fitted exp(theta):
## (Intercept)      HFI
## 7.494890e-11  3.961408e+02
## Problem:
##   Values of the covariate 'HFI' were NA or undefined at 0.56% (12 out of 2137) of the quadrature points

fitHFIexp <- ppm(parks_ppp~HFI + exp(HFI), data=DATA)

## Warning: Values of the covariate 'HFI' were NA or undefined at 0.56% (12 out of
## 2137) of the quadrature points. Occurred while executing: ppm.ppp(Q =
## parks_ppp, trend = ~HFI + exp(HFI), data = list(new("SpatialPolygons",
## summary(fitHFIexp)

## Point process model
## Fitted to data: parks_ppp
## Fitting method: maximum likelihood (Berman-Turner approximation)
## Model was fitted using glm()
## Algorithm converged
## Call:
## ppm.formula(Q = parks_ppp ~ HFI + exp(HFI), data = DATA)
## Edge correction: "border"
## [border correction distance r = 0 ]
##
## -----
## Quadrature scheme (Berman-Turner) = data + dummy + weights
##
## Data pattern:
## Planar point pattern: 238 points
## Average intensity 2.51e-10 points per square unit
## Window: polygonal boundary
## 379 separate polygons (2 holes)
##           vertices      area relative.area
## polygon 1          5454 889865000000    9.38e-01
## polygon 2          2129 319023000000   3.36e-02
## polygon 3 (hole)     55 -49871200   -5.26e-05
## polygon 4 (hole)     21 -15073400   -1.59e-05
## polygon 5          751 6476610000    6.83e-03
## polygon 6          764 2633530000    2.78e-03
## polygon 7          379 2286840000    2.41e-03
## polygon 8          281 1397560000    1.47e-03
## polygon 9          155 1020880000    1.08e-03
## polygon 10         178 822976000    8.68e-04
## polygon 11         189 531172000    5.60e-04
## polygon 12         135 523600000    5.52e-04
## polygon 13          93 429077000    4.52e-04
## polygon 14          59 375017000    3.95e-04

```

## polygon 15	80	366555000	3.87e-04
## polygon 16	130	389457000	4.11e-04
## polygon 17	129	361761000	3.81e-04
## polygon 18	73	325642000	3.43e-04
## polygon 19	72	284295000	3.00e-04
## polygon 20	98	291606000	3.08e-04
## polygon 21	87	301693000	3.18e-04
## polygon 22	60	271131000	2.86e-04
## polygon 23	105	273020000	2.88e-04
## polygon 24	67	238816000	2.52e-04
## polygon 25	72	240998000	2.54e-04
## polygon 26	51	207196000	2.19e-04
## polygon 27	81	175770000	1.85e-04
## polygon 28	72	186213000	1.96e-04
## polygon 29	60	170593000	1.80e-04
## polygon 30	52	171879000	1.81e-04
## polygon 31	62	174668000	1.84e-04
## polygon 32	55	163246000	1.72e-04
## polygon 33	63	151745000	1.60e-04
## polygon 34	62	164385000	1.73e-04
## polygon 35	70	155140000	1.64e-04
## polygon 36	63	152920000	1.61e-04
## polygon 37	72	134301000	1.42e-04
## polygon 38	88	135277000	1.43e-04
## polygon 39	93	128722000	1.36e-04
## polygon 40	45	127343000	1.34e-04
## polygon 41	84	130472000	1.38e-04
## polygon 42	49	114370000	1.21e-04
## polygon 43	44	106635000	1.12e-04
## polygon 44	53	102951000	1.09e-04
## polygon 45	52	100309000	1.06e-04
## polygon 46	45	95770200	1.01e-04
## polygon 47	43	95377600	1.01e-04
## polygon 48	39	92824200	9.79e-05
## polygon 49	47	81225900	8.57e-05
## polygon 50	40	80617200	8.50e-05
## polygon 51	64	83219400	8.78e-05
## polygon 52	33	76223000	8.04e-05
## polygon 53	34	67360500	7.10e-05
## polygon 54	54	68347400	7.21e-05
## polygon 55	44	64136400	6.76e-05
## polygon 56	42	66265500	6.99e-05
## polygon 57	29	62988400	6.64e-05
## polygon 58	31	59626500	6.29e-05
## polygon 59	25	54751800	5.77e-05
## polygon 60	31	55352900	5.84e-05
## polygon 61	30	53162300	5.61e-05
## polygon 62	44	57621600	6.08e-05
## polygon 63	26	56707500	5.98e-05
## polygon 64	36	56979200	6.01e-05
## polygon 65	32	55472500	5.85e-05
## polygon 66	21	50455600	5.32e-05
## polygon 67	40	51039400	5.38e-05
## polygon 68	26	53043500	5.59e-05

## polygon 69	29	51938100	5.48e-05
## polygon 70	27	50295800	5.30e-05
## polygon 71	33	47938300	5.06e-05
## polygon 72	18	44300200	4.67e-05
## polygon 73	25	45691800	4.82e-05
## polygon 74	29	43313200	4.57e-05
## polygon 75	36	46561100	4.91e-05
## polygon 76	31	46220100	4.87e-05
## polygon 77	26	40401700	4.26e-05
## polygon 78	30	43204000	4.56e-05
## polygon 79	26	41430100	4.37e-05
## polygon 80	25	36988000	3.90e-05
## polygon 81	28	37700100	3.98e-05
## polygon 82	20	35892800	3.79e-05
## polygon 83	34	38217700	4.03e-05
## polygon 84	21	34874700	3.68e-05
## polygon 85	25	33536100	3.54e-05
## polygon 86	30	36738900	3.87e-05
## polygon 87	30	35393400	3.73e-05
## polygon 88	23	32140100	3.39e-05
## polygon 89	28	31469400	3.32e-05
## polygon 90	23	32736900	3.45e-05
## polygon 91	28	34117200	3.60e-05
## polygon 92	20	31802600	3.35e-05
## polygon 93	26	30659000	3.23e-05
## polygon 94	24	29572700	3.12e-05
## polygon 95	27	27289800	2.88e-05
## polygon 96	16	23094400	2.44e-05
## polygon 97	23	24218600	2.55e-05
## polygon 98	18	21846600	2.30e-05
## polygon 99	14	23702300	2.50e-05
## polygon 100	21	24325800	2.57e-05
## polygon 101	23	22590100	2.38e-05
## polygon 102	24	19177800	2.02e-05
## polygon 103	22	18657800	1.97e-05
## polygon 104	15	17454800	1.84e-05
## polygon 105	14	16276800	1.72e-05
## polygon 106	13	15792300	1.67e-05
## polygon 107	17	16117900	1.70e-05
## polygon 108	12	16217100	1.71e-05
## polygon 109	19	16610700	1.75e-05
## polygon 110	18	16809400	1.77e-05
## polygon 111	15	15096400	1.59e-05
## polygon 112	14	14571400	1.54e-05
## polygon 113	11	13567300	1.43e-05
## polygon 114	16	13623600	1.44e-05
## polygon 115	15	13657400	1.44e-05
## polygon 116	18	14346200	1.51e-05
## polygon 117	15	12418500	1.31e-05
## polygon 118	22	13085700	1.38e-05
## polygon 119	11	13446800	1.42e-05
## polygon 120	14	13234700	1.40e-05
## polygon 121	15	13532800	1.43e-05
## polygon 122	16	12575800	1.33e-05

## polygon 123	15	13060700	1.38e-05
## polygon 124	15	11766100	1.24e-05
## polygon 125	18	11038100	1.16e-05
## polygon 126	12	12863200	1.36e-05
## polygon 127	19	11135700	1.17e-05
## polygon 128	11	10881600	1.15e-05
## polygon 129	14	12500500	1.32e-05
## polygon 130	12	10733900	1.13e-05
## polygon 131	15	11201200	1.18e-05
## polygon 132	13	10674100	1.13e-05
## polygon 133	13	9776920	1.03e-05
## polygon 134	14	10503500	1.11e-05
## polygon 135	12	9391460	9.90e-06
## polygon 136	10	9402110	9.92e-06
## polygon 137	9	9160880	9.66e-06
## polygon 138	11	8674110	9.15e-06
## polygon 139	12	9159420	9.66e-06
## polygon 140	14	8676590	9.15e-06
## polygon 141	12	9527540	1.00e-05
## polygon 142	12	8797870	9.28e-06
## polygon 143	11	8837670	9.32e-06
## polygon 144	13	9067690	9.56e-06
## polygon 145	12	7950440	8.38e-06
## polygon 146	9	8727650	9.20e-06
## polygon 147	8	8565660	9.03e-06
## polygon 148	8	6790020	7.16e-06
## polygon 149	11	6780640	7.15e-06
## polygon 150	11	7326980	7.73e-06
## polygon 151	10	6152880	6.49e-06
## polygon 152	13	6721370	7.09e-06
## polygon 153	8	6343870	6.69e-06
## polygon 154	11	6807170	7.18e-06
## polygon 155	10	6927150	7.31e-06
## polygon 156	9	6352310	6.70e-06
## polygon 157	13	6217600	6.56e-06
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## polygon 159	11	5769240	6.08e-06
## polygon 160	8	5965270	6.29e-06
## polygon 161	10	6826030	7.20e-06
## polygon 162	10	5749960	6.06e-06
## polygon 163	15	5352810	5.64e-06
## polygon 164	9	5781470	6.10e-06
## polygon 165	13	5358790	5.65e-06
## polygon 166	10	6016930	6.35e-06
## polygon 167	9	5928820	6.25e-06
## polygon 168	8	5424110	5.72e-06
## polygon 169	9	5468680	5.77e-06
## polygon 170	11	5209670	5.49e-06
## polygon 171	9	4705250	4.96e-06
## polygon 172	9	4891810	5.16e-06
## polygon 173	11	5295110	5.58e-06
## polygon 174	7	4839440	5.10e-06
## polygon 175	7	4322930	4.56e-06
## polygon 176	7	4514530	4.76e-06

## polygon 177	7	4573450	4.82e-06
## polygon 178	9	5080950	5.36e-06
## polygon 179	12	4492120	4.74e-06
## polygon 180	8	4783060	5.04e-06
## polygon 181	8	3800770	4.01e-06
## polygon 182	5	4657790	4.91e-06
## polygon 183	11	4323150	4.56e-06
## polygon 184	9	3549270	3.74e-06
## polygon 185	6	4103470	4.33e-06
## polygon 186	8	3898980	4.11e-06
## polygon 187	8	4009440	4.23e-06
## polygon 188	9	3672080	3.87e-06
## polygon 189	11	3540120	3.73e-06
## polygon 190	6	3790670	4.00e-06
## polygon 191	8	3695580	3.90e-06
## polygon 192	7	3708650	3.91e-06
## polygon 193	7	3843670	4.05e-06
## polygon 194	7	3157020	3.33e-06
## polygon 195	9	2913680	3.07e-06
## polygon 196	9	3368170	3.55e-06
## polygon 197	7	3190600	3.36e-06
## polygon 198	6	3073660	3.24e-06
## polygon 199	9	3016490	3.18e-06
## polygon 200	8	3129780	3.30e-06
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## polygon 217	6	2616700	2.76e-06
## polygon 218	7	2205520	2.33e-06
## polygon 219	8	2008210	2.12e-06
## polygon 220	5	2181540	2.30e-06
## polygon 221	7	2700450	2.85e-06
## polygon 222	7	2493440	2.63e-06
## polygon 223	7	2752380	2.90e-06
## polygon 224	5	2036350	2.15e-06
## polygon 225	5	2344480	2.47e-06
## polygon 226	5	1786340	1.88e-06
## polygon 227	8	2269610	2.39e-06
## polygon 228	6	1857450	1.96e-06
## polygon 229	5	1978280	2.09e-06
## polygon 230	5	1944240	2.05e-06

## polygon 231	6	2728340	2.88e-06
## polygon 232	8	1905200	2.01e-06
## polygon 233	7	2258780	2.38e-06
## polygon 234	5	1891180	1.99e-06
## polygon 235	5	1957860	2.06e-06
## polygon 236	7	2335470	2.46e-06
## polygon 237	4	2055120	2.17e-06
## polygon 238	6	1829730	1.93e-06
## polygon 239	5	1807400	1.91e-06
## polygon 240	5	2014070	2.12e-06
## polygon 241	5	1882630	1.99e-06
## polygon 242	5	1928800	2.03e-06
## polygon 243	5	2010320	2.12e-06
## polygon 244	5	1521870	1.60e-06
## polygon 245	6	1935590	2.04e-06
## polygon 246	5	1647440	1.74e-06
## polygon 247	4	1518380	1.60e-06
## polygon 248	6	1623490	1.71e-06
## polygon 249	5	1654240	1.74e-06
## polygon 250	5	1691180	1.78e-06
## polygon 251	3	765559	8.07e-07
## polygon 252	6	1792550	1.89e-06
## polygon 253	5	1428170	1.51e-06
## polygon 254	5	1356230	1.43e-06
## polygon 255	5	1536990	1.62e-06
## polygon 256	5	1188700	1.25e-06
## polygon 257	4	846360	8.93e-07
## polygon 258	5	1449400	1.53e-06
## polygon 259	4	1654610	1.74e-06
## polygon 260	6	1472190	1.55e-06
## polygon 261	4	1163890	1.23e-06
## polygon 262	7	1548860	1.63e-06
## polygon 263	6	1317820	1.39e-06
## polygon 264	5	1220870	1.29e-06
## polygon 265	4	1251210	1.32e-06
## polygon 266	6	1443280	1.52e-06
## polygon 267	5	1430870	1.51e-06
## polygon 268	5	1201830	1.27e-06
## polygon 269	7	1083120	1.14e-06
## polygon 270	5	1315200	1.39e-06
## polygon 271	5	1173590	1.24e-06
## polygon 272	5	1283640	1.35e-06
## polygon 273	5	1243830	1.31e-06
## polygon 274	5	1418840	1.50e-06
## polygon 275	6	1194150	1.26e-06
## polygon 276	3	732692	7.73e-07
## polygon 277	4	724047	7.64e-07
## polygon 278	4	1110880	1.17e-06
## polygon 279	4	1068690	1.13e-06
## polygon 280	5	1080070	1.14e-06
## polygon 281	5	1105010	1.17e-06
## polygon 282	4	1101910	1.16e-06
## polygon 283	5	1202270	1.27e-06
## polygon 284	5	1193280	1.26e-06

## polygon 285	5	1104420	1.16e-06
## polygon 286	5	1337410	1.41e-06
## polygon 287	6	1293100	1.36e-06
## polygon 288	4	715019	7.54e-07
## polygon 289	3	772725	8.15e-07
## polygon 290	4	856683	9.03e-07
## polygon 291	4	986692	1.04e-06
## polygon 292	4	808047	8.52e-07
## polygon 293	4	740351	7.81e-07
## polygon 294	4	839774	8.86e-07
## polygon 295	5	997422	1.05e-06
## polygon 296	4	841098	8.87e-07
## polygon 297	7	1180430	1.24e-06
## polygon 298	4	1072900	1.13e-06
## polygon 299	5	1071650	1.13e-06
## polygon 300	4	937949	9.89e-07
## polygon 301	4	714701	7.54e-07
## polygon 302	4	854803	9.01e-07
## polygon 303	4	965776	1.02e-06
## polygon 304	4	875646	9.23e-07
## polygon 305	4	682625	7.20e-07
## polygon 306	4	799391	8.43e-07
## polygon 307	4	915082	9.65e-07
## polygon 308	4	647125	6.82e-07
## polygon 309	5	850200	8.97e-07
## polygon 310	4	856777	9.04e-07
## polygon 311	5	926662	9.77e-07
## polygon 312	4	702365	7.41e-07
## polygon 313	4	877724	9.26e-07
## polygon 314	4	625455	6.60e-07
## polygon 315	4	604921	6.38e-07
## polygon 316	4	564256	5.95e-07
## polygon 317	5	943607	9.95e-07
## polygon 318	4	725841	7.65e-07
## polygon 319	4	838391	8.84e-07
## polygon 320	4	725920	7.66e-07
## polygon 321	4	607726	6.41e-07
## polygon 322	3	377075	3.98e-07
## polygon 323	4	801044	8.45e-07
## polygon 324	4	707601	7.46e-07
## polygon 325	4	701275	7.40e-07
## polygon 326	3	567574	5.99e-07
## polygon 327	4	656976	6.93e-07
## polygon 328	4	697610	7.36e-07
## polygon 329	3	429629	4.53e-07
## polygon 330	4	692723	7.31e-07
## polygon 331	5	1123680	1.18e-06
## polygon 332	4	638721	6.74e-07
## polygon 333	4	649515	6.85e-07
## polygon 334	5	885457	9.34e-07
## polygon 335	3	397429	4.19e-07
## polygon 336	3	311243	3.28e-07
## polygon 337	4	692962	7.31e-07
## polygon 338	4	637359	6.72e-07

```

## polygon 339          3    347030    3.66e-07
## polygon 340          4    545022    5.75e-07
## polygon 341          4    630075    6.64e-07
## polygon 342          4    682861    7.20e-07
## polygon 343          4    582135    6.14e-07
## polygon 344          4    685738    7.23e-07
## polygon 345          3    666827    7.03e-07
## polygon 346          4    638063    6.73e-07
## polygon 347          3    415934    4.39e-07
## polygon 348          3    496699    5.24e-07
## polygon 349          4    523038    5.52e-07
## polygon 350          4    629200    6.64e-07
## polygon 351          4    545075    5.75e-07
## polygon 352          4    523200    5.52e-07
## polygon 353          4    534278    5.63e-07
## polygon 354          4    617265    6.51e-07
## polygon 355          4    554460    5.85e-07
## polygon 356          3    422197    4.45e-07
## polygon 357          4    450587    4.75e-07
## polygon 358          3    506804    5.34e-07
## polygon 359          4    666360    7.03e-07
## polygon 360          4    648581    6.84e-07
## polygon 361          3    453422    4.78e-07
## polygon 362          4    572761    6.04e-07
## polygon 363          4    515850    5.44e-07
## polygon 364          4    501575    5.29e-07
## polygon 365          4    501226    5.29e-07
## polygon 366          4    601941    6.35e-07
## polygon 367          4    593073    6.25e-07
## polygon 368          3    427855    4.51e-07
## polygon 369          3    295928    3.12e-07
## polygon 370          4    640706    6.76e-07
## polygon 371          5    714352    7.53e-07
## polygon 372          4    494594    5.22e-07
## polygon 373          3    413224    4.36e-07
## polygon 374          3    254908    2.69e-07
## polygon 375          4    458639    4.84e-07
## polygon 376          3    374163    3.95e-07
## polygon 377          4    514470    5.43e-07
## polygon 378          4    419372    4.42e-07
## polygon 379          3    405491    4.28e-07
## enclosing rectangle: [273874.9, 1870573.4] x [369042.8, 1735666.4] units
##                               (1597000 x 1367000 units)
## Window area = 9.48262e+11 square units
## Fraction of frame area: 0.435
##
## Dummy quadrature points:
##       64 x 64 grid of dummy points, plus 4 corner points
##       dummy spacing: 24948.41 x 21353.49 units
##
## Original dummy parameters: =
## Planar point pattern: 1899 points
## Average intensity 2e-09 points per square unit
## Window: polygonal boundary

```

```

## 379 separate polygons (2 holes)
##           vertices      area relative.area
## polygon 1          5454 889865000000  9.38e-01
## polygon 2          2129 31902300000  3.36e-02
## polygon 3 (hole)    55   -49871200 -5.26e-05
## polygon 4 (hole)    21   -15073400 -1.59e-05
## polygon 5          751   6476610000  6.83e-03
## polygon 6          764   2633530000  2.78e-03
## polygon 7          379   2286840000  2.41e-03
## polygon 8          281   1397560000  1.47e-03
## polygon 9          155   1020880000  1.08e-03
## polygon 10         178   822976000  8.68e-04
## polygon 11         189   531172000  5.60e-04
## polygon 12         135   523600000  5.52e-04
## polygon 13         93    429077000  4.52e-04
## polygon 14         59    375017000  3.95e-04
## polygon 15         80    366555000  3.87e-04
## polygon 16         130   389457000  4.11e-04
## polygon 17         129   361761000  3.81e-04
## polygon 18         73    325642000  3.43e-04
## polygon 19         72    284295000  3.00e-04
## polygon 20         98    291606000  3.08e-04
## polygon 21         87    301693000  3.18e-04
## polygon 22         60    271131000  2.86e-04
## polygon 23         105   273020000  2.88e-04
## polygon 24         67    238816000  2.52e-04
## polygon 25         72    240998000  2.54e-04
## polygon 26         51    207196000  2.19e-04
## polygon 27         81    175770000  1.85e-04
## polygon 28         72    186213000  1.96e-04
## polygon 29         60    170593000  1.80e-04
## polygon 30         52    171879000  1.81e-04
## polygon 31         62    174668000  1.84e-04
## polygon 32         55    163246000  1.72e-04
## polygon 33         63    151745000  1.60e-04
## polygon 34         62    164385000  1.73e-04
## polygon 35         70    155140000  1.64e-04
## polygon 36         63    152920000  1.61e-04
## polygon 37         72    134301000  1.42e-04
## polygon 38         88    135277000  1.43e-04
## polygon 39         93    128722000  1.36e-04
## polygon 40         45    127343000  1.34e-04
## polygon 41         84    130472000  1.38e-04
## polygon 42         49    114370000  1.21e-04
## polygon 43         44    106635000  1.12e-04
## polygon 44         53    102951000  1.09e-04
## polygon 45         52    100309000  1.06e-04
## polygon 46         45    95770200  1.01e-04
## polygon 47         43    95377600  1.01e-04
## polygon 48         39    92824200  9.79e-05
## polygon 49         47    81225900  8.57e-05
## polygon 50         40    80617200  8.50e-05
## polygon 51         64    83219400  8.78e-05
## polygon 52         33    76223000  8.04e-05

```

## polygon 53	34	67360500	7.10e-05
## polygon 54	54	68347400	7.21e-05
## polygon 55	44	64136400	6.76e-05
## polygon 56	42	66265500	6.99e-05
## polygon 57	29	62988400	6.64e-05
## polygon 58	31	59626500	6.29e-05
## polygon 59	25	54751800	5.77e-05
## polygon 60	31	55352900	5.84e-05
## polygon 61	30	53162300	5.61e-05
## polygon 62	44	57621600	6.08e-05
## polygon 63	26	56707500	5.98e-05
## polygon 64	36	56979200	6.01e-05
## polygon 65	32	55472500	5.85e-05
## polygon 66	21	50455600	5.32e-05
## polygon 67	40	51039400	5.38e-05
## polygon 68	26	53043500	5.59e-05
## polygon 69	29	51938100	5.48e-05
## polygon 70	27	50295800	5.30e-05
## polygon 71	33	47938300	5.06e-05
## polygon 72	18	44300200	4.67e-05
## polygon 73	25	45691800	4.82e-05
## polygon 74	29	43313200	4.57e-05
## polygon 75	36	46561100	4.91e-05
## polygon 76	31	46220100	4.87e-05
## polygon 77	26	40401700	4.26e-05
## polygon 78	30	43204000	4.56e-05
## polygon 79	26	41430100	4.37e-05
## polygon 80	25	36988000	3.90e-05
## polygon 81	28	37700100	3.98e-05
## polygon 82	20	35892800	3.79e-05
## polygon 83	34	38217700	4.03e-05
## polygon 84	21	34874700	3.68e-05
## polygon 85	25	33536100	3.54e-05
## polygon 86	30	36738900	3.87e-05
## polygon 87	30	35393400	3.73e-05
## polygon 88	23	32140100	3.39e-05
## polygon 89	28	31469400	3.32e-05
## polygon 90	23	32736900	3.45e-05
## polygon 91	28	34117200	3.60e-05
## polygon 92	20	31802600	3.35e-05
## polygon 93	26	30659000	3.23e-05
## polygon 94	24	29572700	3.12e-05
## polygon 95	27	27289800	2.88e-05
## polygon 96	16	23094400	2.44e-05
## polygon 97	23	24218600	2.55e-05
## polygon 98	18	21846600	2.30e-05
## polygon 99	14	23702300	2.50e-05
## polygon 100	21	24325800	2.57e-05
## polygon 101	23	22590100	2.38e-05
## polygon 102	24	19177800	2.02e-05
## polygon 103	22	18657800	1.97e-05
## polygon 104	15	17454800	1.84e-05
## polygon 105	14	16276800	1.72e-05
## polygon 106	13	15792300	1.67e-05

## polygon 107	17	16117900	1.70e-05
## polygon 108	12	16217100	1.71e-05
## polygon 109	19	16610700	1.75e-05
## polygon 110	18	16809400	1.77e-05
## polygon 111	15	15096400	1.59e-05
## polygon 112	14	14571400	1.54e-05
## polygon 113	11	13567300	1.43e-05
## polygon 114	16	13623600	1.44e-05
## polygon 115	15	13657400	1.44e-05
## polygon 116	18	14346200	1.51e-05
## polygon 117	15	12418500	1.31e-05
## polygon 118	22	13085700	1.38e-05
## polygon 119	11	13446800	1.42e-05
## polygon 120	14	13234700	1.40e-05
## polygon 121	15	13532800	1.43e-05
## polygon 122	16	12575800	1.33e-05
## polygon 123	15	13060700	1.38e-05
## polygon 124	15	11766100	1.24e-05
## polygon 125	18	11038100	1.16e-05
## polygon 126	12	12863200	1.36e-05
## polygon 127	19	11135700	1.17e-05
## polygon 128	11	10881600	1.15e-05
## polygon 129	14	12500500	1.32e-05
## polygon 130	12	10733900	1.13e-05
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## polygon 132	13	10674100	1.13e-05
## polygon 133	13	9776920	1.03e-05
## polygon 134	14	10503500	1.11e-05
## polygon 135	12	9391460	9.90e-06
## polygon 136	10	9402110	9.92e-06
## polygon 137	9	9160880	9.66e-06
## polygon 138	11	8674110	9.15e-06
## polygon 139	12	9159420	9.66e-06
## polygon 140	14	8676590	9.15e-06
## polygon 141	12	9527540	1.00e-05
## polygon 142	12	8797870	9.28e-06
## polygon 143	11	8837670	9.32e-06
## polygon 144	13	9067690	9.56e-06
## polygon 145	12	7950440	8.38e-06
## polygon 146	9	8727650	9.20e-06
## polygon 147	8	8565660	9.03e-06
## polygon 148	8	6790020	7.16e-06
## polygon 149	11	6780640	7.15e-06
## polygon 150	11	7326980	7.73e-06
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## polygon 159	11	5769240	6.08e-06
## polygon 160	8	5965270	6.29e-06

## polygon 161	10	6826030	7.20e-06
## polygon 162	10	5749960	6.06e-06
## polygon 163	15	5352810	5.64e-06
## polygon 164	9	5781470	6.10e-06
## polygon 165	13	5358790	5.65e-06
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## polygon 175	7	4322930	4.56e-06
## polygon 176	7	4514530	4.76e-06
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## polygon 180	8	4783060	5.04e-06
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## polygon 185	6	4103470	4.33e-06
## polygon 186	8	3898980	4.11e-06
## polygon 187	8	4009440	4.23e-06
## polygon 188	9	3672080	3.87e-06
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## polygon 192	7	3708650	3.91e-06
## polygon 193	7	3843670	4.05e-06
## polygon 194	7	3157020	3.33e-06
## polygon 195	9	2913680	3.07e-06
## polygon 196	9	3368170	3.55e-06
## polygon 197	7	3190600	3.36e-06
## polygon 198	6	3073660	3.24e-06
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## polygon 204	7	2619570	2.76e-06
## polygon 205	10	3007320	3.17e-06
## polygon 206	7	2324090	2.45e-06
## polygon 207	10	2935450	3.10e-06
## polygon 208	10	2523640	2.66e-06
## polygon 209	6	2232050	2.35e-06
## polygon 210	6	2131190	2.25e-06
## polygon 211	6	1679950	1.77e-06
## polygon 212	6	2226470	2.35e-06
## polygon 213	8	2267800	2.39e-06
## polygon 214	6	2584690	2.73e-06

## polygon 215	5	2151150	2.27e-06
## polygon 216	6	1536960	1.62e-06
## polygon 217	6	2616700	2.76e-06
## polygon 218	7	2205520	2.33e-06
## polygon 219	8	2008210	2.12e-06
## polygon 220	5	2181540	2.30e-06
## polygon 221	7	2700450	2.85e-06
## polygon 222	7	2493440	2.63e-06
## polygon 223	7	2752380	2.90e-06
## polygon 224	5	2036350	2.15e-06
## polygon 225	5	2344480	2.47e-06
## polygon 226	5	1786340	1.88e-06
## polygon 227	8	2269610	2.39e-06
## polygon 228	6	1857450	1.96e-06
## polygon 229	5	1978280	2.09e-06
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## polygon 232	8	1905200	2.01e-06
## polygon 233	7	2258780	2.38e-06
## polygon 234	5	1891180	1.99e-06
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## polygon 236	7	2335470	2.46e-06
## polygon 237	4	2055120	2.17e-06
## polygon 238	6	1829730	1.93e-06
## polygon 239	5	1807400	1.91e-06
## polygon 240	5	2014070	2.12e-06
## polygon 241	5	1882630	1.99e-06
## polygon 242	5	1928800	2.03e-06
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## polygon 244	5	1521870	1.60e-06
## polygon 245	6	1935590	2.04e-06
## polygon 246	5	1647440	1.74e-06
## polygon 247	4	1518380	1.60e-06
## polygon 248	6	1623490	1.71e-06
## polygon 249	5	1654240	1.74e-06
## polygon 250	5	1691180	1.78e-06
## polygon 251	3	765559	8.07e-07
## polygon 252	6	1792550	1.89e-06
## polygon 253	5	1428170	1.51e-06
## polygon 254	5	1356230	1.43e-06
## polygon 255	5	1536990	1.62e-06
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## polygon 260	6	1472190	1.55e-06
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## polygon 265	4	1251210	1.32e-06
## polygon 266	6	1443280	1.52e-06
## polygon 267	5	1430870	1.51e-06
## polygon 268	5	1201830	1.27e-06

## polygon 269	7	1083120	1.14e-06
## polygon 270	5	1315200	1.39e-06
## polygon 271	5	1173590	1.24e-06
## polygon 272	5	1283640	1.35e-06
## polygon 273	5	1243830	1.31e-06
## polygon 274	5	1418840	1.50e-06
## polygon 275	6	1194150	1.26e-06
## polygon 276	3	732692	7.73e-07
## polygon 277	4	724047	7.64e-07
## polygon 278	4	1110880	1.17e-06
## polygon 279	4	1068690	1.13e-06
## polygon 280	5	1080070	1.14e-06
## polygon 281	5	1105010	1.17e-06
## polygon 282	4	1101910	1.16e-06
## polygon 283	5	1202270	1.27e-06
## polygon 284	5	1193280	1.26e-06
## polygon 285	5	1104420	1.16e-06
## polygon 286	5	1337410	1.41e-06
## polygon 287	6	1293100	1.36e-06
## polygon 288	4	715019	7.54e-07
## polygon 289	3	772725	8.15e-07
## polygon 290	4	856683	9.03e-07
## polygon 291	4	986692	1.04e-06
## polygon 292	4	808047	8.52e-07
## polygon 293	4	740351	7.81e-07
## polygon 294	4	839774	8.86e-07
## polygon 295	5	997422	1.05e-06
## polygon 296	4	841098	8.87e-07
## polygon 297	7	1180430	1.24e-06
## polygon 298	4	1072900	1.13e-06
## polygon 299	5	1071650	1.13e-06
## polygon 300	4	937949	9.89e-07
## polygon 301	4	714701	7.54e-07
## polygon 302	4	854803	9.01e-07
## polygon 303	4	965776	1.02e-06
## polygon 304	4	875646	9.23e-07
## polygon 305	4	682625	7.20e-07
## polygon 306	4	799391	8.43e-07
## polygon 307	4	915082	9.65e-07
## polygon 308	4	647125	6.82e-07
## polygon 309	5	850200	8.97e-07
## polygon 310	4	856777	9.04e-07
## polygon 311	5	926662	9.77e-07
## polygon 312	4	702365	7.41e-07
## polygon 313	4	877724	9.26e-07
## polygon 314	4	625455	6.60e-07
## polygon 315	4	604921	6.38e-07
## polygon 316	4	564256	5.95e-07
## polygon 317	5	943607	9.95e-07
## polygon 318	4	725841	7.65e-07
## polygon 319	4	838391	8.84e-07
## polygon 320	4	725920	7.66e-07
## polygon 321	4	607726	6.41e-07
## polygon 322	3	377075	3.98e-07

## polygon 323	4	801044	8.45e-07
## polygon 324	4	707601	7.46e-07
## polygon 325	4	701275	7.40e-07
## polygon 326	3	567574	5.99e-07
## polygon 327	4	656976	6.93e-07
## polygon 328	4	697610	7.36e-07
## polygon 329	3	429629	4.53e-07
## polygon 330	4	692723	7.31e-07
## polygon 331	5	1123680	1.18e-06
## polygon 332	4	638721	6.74e-07
## polygon 333	4	649515	6.85e-07
## polygon 334	5	885457	9.34e-07
## polygon 335	3	397429	4.19e-07
## polygon 336	3	311243	3.28e-07
## polygon 337	4	692962	7.31e-07
## polygon 338	4	637359	6.72e-07
## polygon 339	3	347030	3.66e-07
## polygon 340	4	545022	5.75e-07
## polygon 341	4	630075	6.64e-07
## polygon 342	4	682861	7.20e-07
## polygon 343	4	582135	6.14e-07
## polygon 344	4	685738	7.23e-07
## polygon 345	3	666827	7.03e-07
## polygon 346	4	638063	6.73e-07
## polygon 347	3	415934	4.39e-07
## polygon 348	3	496699	5.24e-07
## polygon 349	4	523038	5.52e-07
## polygon 350	4	629200	6.64e-07
## polygon 351	4	545075	5.75e-07
## polygon 352	4	523200	5.52e-07
## polygon 353	4	534278	5.63e-07
## polygon 354	4	617265	6.51e-07
## polygon 355	4	554460	5.85e-07
## polygon 356	3	422197	4.45e-07
## polygon 357	4	450587	4.75e-07
## polygon 358	3	506804	5.34e-07
## polygon 359	4	666360	7.03e-07
## polygon 360	4	648581	6.84e-07
## polygon 361	3	453422	4.78e-07
## polygon 362	4	572761	6.04e-07
## polygon 363	4	515850	5.44e-07
## polygon 364	4	501575	5.29e-07
## polygon 365	4	501226	5.29e-07
## polygon 366	4	601941	6.35e-07
## polygon 367	4	593073	6.25e-07
## polygon 368	3	427855	4.51e-07
## polygon 369	3	295928	3.12e-07
## polygon 370	4	640706	6.76e-07
## polygon 371	5	714352	7.53e-07
## polygon 372	4	494594	5.22e-07
## polygon 373	3	413224	4.36e-07
## polygon 374	3	254908	2.69e-07
## polygon 375	4	458639	4.84e-07
## polygon 376	3	374163	3.95e-07

```

## polygon 377          4      514470      5.43e-07
## polygon 378          4      419372      4.42e-07
## polygon 379          3      405491      4.28e-07
## enclosing rectangle: [273874.9, 1870573.4] x [369042.8, 1735666.4] units
##                               (1597000 x 1367000 units)
## Window area = 9.48262e+11 square units
## Fraction of frame area: 0.435
## Quadrature weights:
##   (counting weights based on 64 x 64 array of rectangular tiles)
## All weights:
##   range: [35500000, 5.33e+08] total: 9.45e+11
## Weights on data points:
##   range: [35500000, 2.66e+08] total: 3.46e+10
## Weights on dummy points:
##   range: [35500000, 5.33e+08] total: 9.1e+11
## -----
## FITTED :
##
## Nonstationary Poisson process
##
## ----- Intensity: -----
##
## Log intensity: ~HFI + exp(HFI)
## Model depends on external covariate 'HFI'
## Covariates provided:
##   Elevation: im
##   Forest: im
##   HFI: im
##   Dist_Water: im
##
## Fitted trend coefficients:
## (Intercept)      HFI      exp(HFI)
## -13.71641     22.17067    -10.35893
##
##           Estimate      S.E.    CI95.lo    CI95.hi   Ztest      Zval
## (Intercept) -13.71641  1.404309 -16.46881 -10.964015 *** -9.767372
## HFI         22.17067  2.382441  17.50117  26.840165 ***  9.305861
## exp(HFI)    -10.35893 1.522442 -13.34286 -7.374997 *** -6.804153
##
## ----- gory details -----
##
## Fitted regular parameters (theta):
## (Intercept)      HFI      exp(HFI)
## -13.71641     22.17067    -10.35893
##
## Fitted exp(theta):
## (Intercept)      HFI      exp(HFI)
## 1.104176e-06  4.252045e+09 3.170841e-05
## Problem:
## Values of the covariate 'HFI' were NA or undefined at 0.56% (12 out of 2137) of the quadrature point

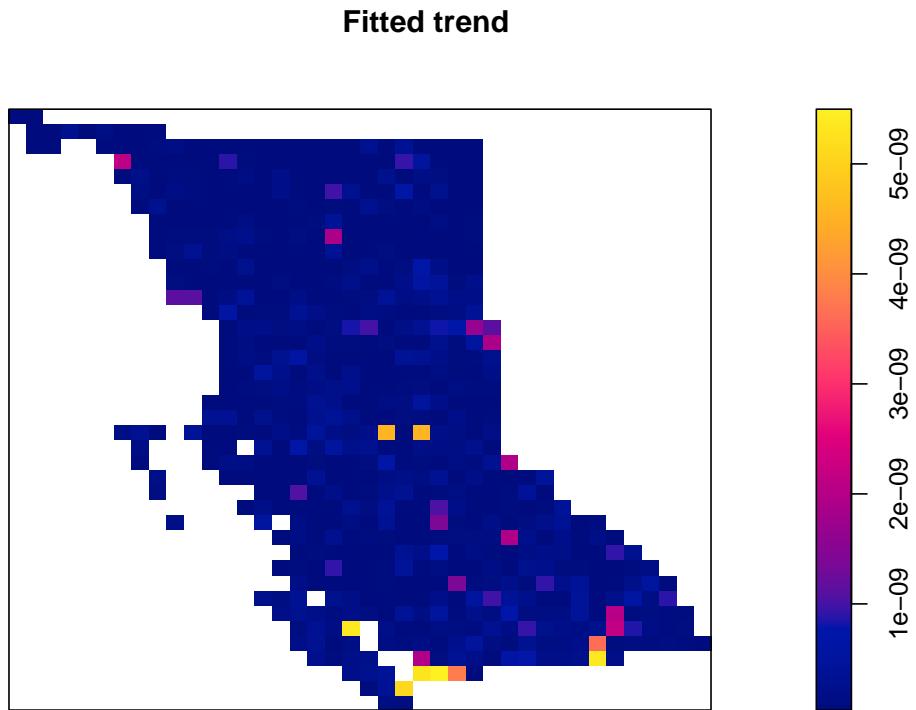
AIC(fitHFI); AIC(fitHFIexp)

## [1] 10468.83

```

```
## [1] 10420.78
```

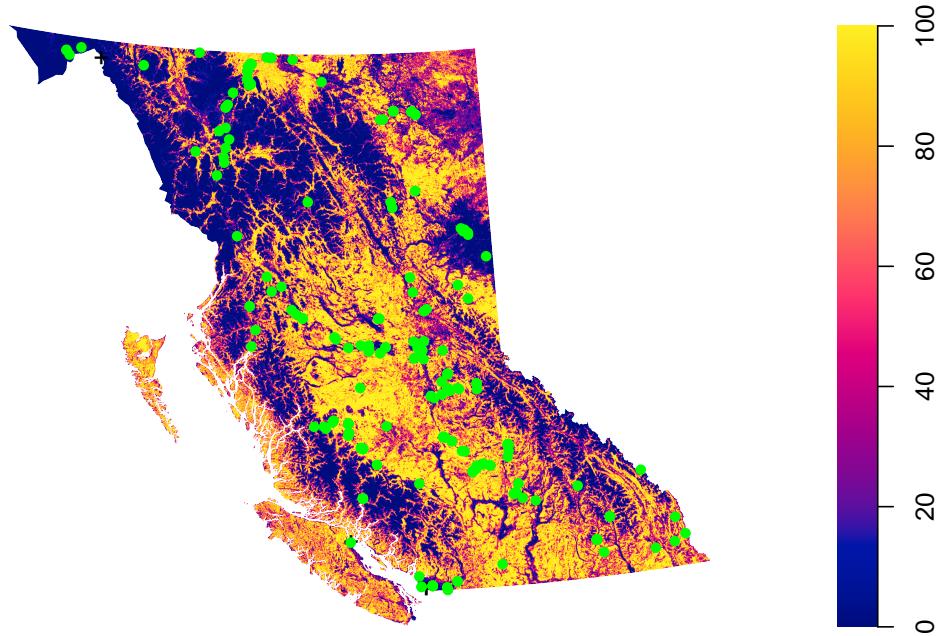
```
plot(fitHFIexp, se = F, superimpose = F)
```



Forest Cover

```
plot(DATA$Forest, box = F, par(cex.main = 2), main = "Forest")
plot(parks_ppp, pch = 16, cex = 0.9, col = "green", use.marks = F, add = T)
```

Forest



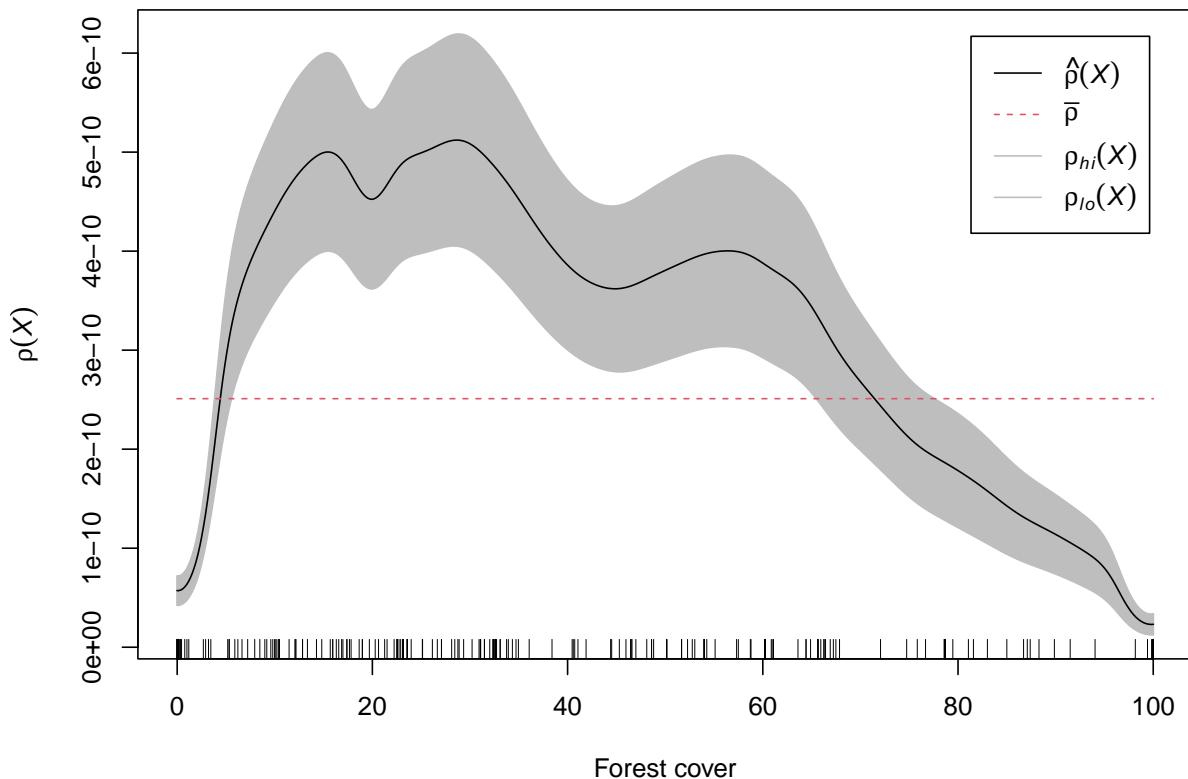
1. To add : Add other covariates together - side by side

```
#load the spatstat package
library(spatstat)

#Estimate Rho for Forest Cover
rho_elev <- rhohat(parks_ppp, DATA$Forest)

#Estimate Rho
#rho_grad <- rhohat(b ei, bei.extra$grad)

#par(mfrow = c(1,2))
plot(rho_elev,
      main = "",
      xlab = "Forest cover")
```



```
#plot(rho_grad,
#      main = "",
#      xlab = "Gradient (degrees)")
```

There seems to be non-linear relationship between forest cover and number of red lions observed. The observance increase with increase in forest cover at intermediate coverage and then it decreases.

Next is to observe if there is any correlation between the covariates (collinearity in the covariates dataset). This is necessary to avoid any identifiability issues in modeling the data.

2. Fix issues with collinearity

```
#Check for collinearity
x <- DATA$HFI
y <- DATA$Forest
#Y<- solapply(x,y,scaletointerval.im)
#im.apply(Y, cor.im,na.rm=TRUE,fun.handles.na=TRUE, check=TRUE)

#FUNC <- function(x,y){
#  cor.im(x,y)
#}
```

```
#class(y)

#plot(DATA$HFI$v ~ DATA$Forest$v,
#      xlab = "HFI",
#      ylab = "Forest",
#      pch = 16,
#      cex = 0.3,
#      col = "#046C9A")
```

3. Finalize and summarize about other two variables - elevation and water.

Model Fitting

Try different models - linear and quadratic, do necessary anova and other tests for model selection and validation

Model with Forest

```
#Fit the PPP model
fit <- ppm(parks_ppp ~ Forest + I(Forest^2), data=DATA)

fit

## Nonstationary Poisson process
## Fitted to point pattern dataset 'parks_ppp'
##
## Log intensity: ~Forest + I(Forest^2)
##
## Fitted trend coefficients:
## (Intercept) Forest I(Forest^2)
## -2.225373e+01 3.996522e-02 -5.280288e-04
##
##             Estimate      S.E.    CI95.lo    CI95.hi Ztest
## (Intercept) -2.225373e+01 1.330469e-01 -2.251450e+01 -2.199297e+01 *** 
## Forest       3.996522e-02 7.091557e-03  2.606603e-02  5.386442e-02 *** 
## I(Forest^2) -5.280288e-04 7.699618e-05 -6.789385e-04 -3.771191e-04 *** 
##
##             Zval
## (Intercept) -167.262353
## Forest       5.635606
## I(Forest^2) -6.857857
```

All variables look significant.

```
#Plot the model predictions
plot(fit,
      se = FALSE,
      superimpose = FALSE)

#Overlay the red fox locations
```

```

plot(parks_ppp,
      pch = 16,
      cex = 0.6,
      cols = "white",
      add = TRUE)

## Warning in plot.ppp(parks_ppp, pch = 16, cex = 0.6, cols = "white", add =
## TRUE): 4 illegal points also plotted

```

```

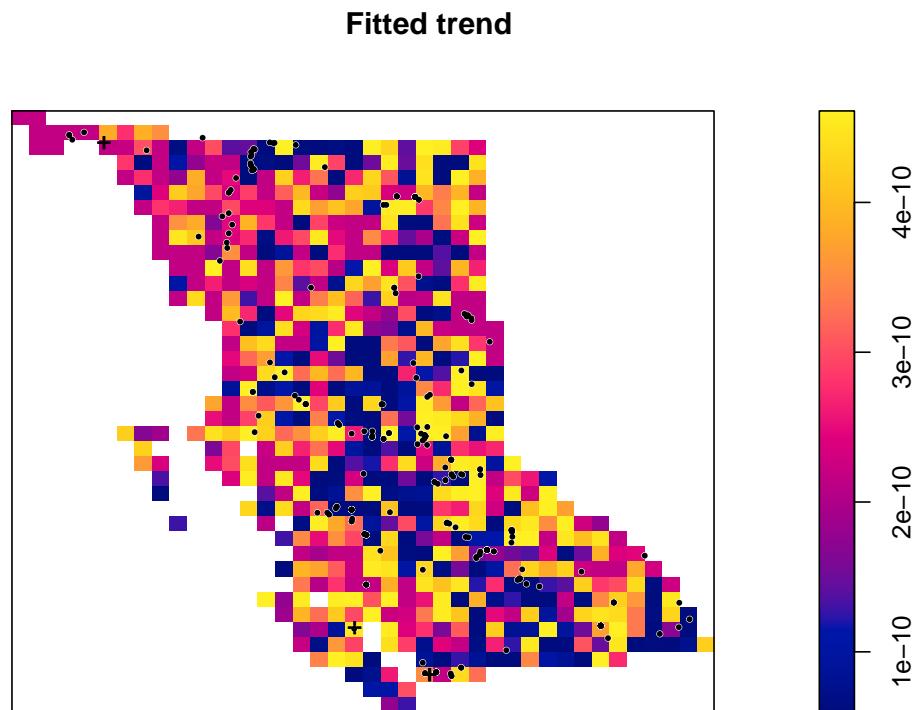
plot(parks_ppp,
      pch = 16,
      cex = 0.5,
      cols = "black",
      add = TRUE)

```

```

## Warning in plot.ppp(parks_ppp, pch = 16, cex = 0.5, cols = "black", add =
## TRUE): 4 illegal points also plotted

```



Does not look like a good fit for all points and also not easy to interpret.

Analyze - linear+quad, AIC

Validate if we need GAM - 5. linear vs gam - table: evaluate, AIC, visualize

Results: Length: Describe your statistical findings. Tables and figures should be used throughout. Length: As long as necessary.

Findings from EDA

model: Tablulate observations -4. table to summarize models - linear+quad, AIC

model: GAM - Table if necessary

Discussion: Provide a brief summary of your findings. Length: ca. 1 page.

References: Include references to all necessary literature.

1. Data: GBIF.org (09 April 2023) GBIF Occurrence Download <https://doi.org/10.15468/dl.p6tsaa>
2. Research topics: <https://cwf-fcf.org/en/resources/encyclopedias/fauna/mammals/red-fox.html>