2070 Temperature Prediction

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1 假设 Assumption

1. 鱼群会自己向舒适温度区间游动
2. 鱼群适应的温度范围不会改变

2 Prediction Interval

A prediction interval is a type of confidence interval (CI) used with predictions in regression analysis; it is a range of values that predicts the value of a new observation, based on your existing model.

The formula of prediction interval:

$$\widehat{y_h} \pm t_{\frac{\alpha}{2},n-2} \cdot \sqrt{MSE(1 + \frac{1}{n} + \frac{(x_h - \overline{x})^2}{\sum(s_i - \overline{x})^2}}$$

3 温度预测

```
# import data from datafile
datafileCSV <- read.csv("/Users/qianli/Downloads/datafile.csv")
```

```
# 初步处理数据，转化西经为负数，东经为正数
library(dplyr)
data <- datafileCSV
# only need West latitude and North longitude
dataWest <- data %>% filter(grepl("W",Longitude) & grepl("N",Latitude))
dataEast <- data %>% filter(grepl("E",Longitude) & grepl("N",Latitude))
# Convert each column to numeric data
dataWest[,1] <- as.numeric(substr(dataWest[,1], 1, nchar(dataWest[,1])-1))
dataEast[,1] <- as.numeric(substr(dataEast[,1], 1, nchar(dataEast[,1])-1))
dataWest[,2] <- as.numeric(substr(dataWest[,2], 1, nchar(dataWest[,2])-1))
dataEast[,2] <- as.numeric(substr(dataEast[,2], 1, nchar(dataEast[,2])-1))
dataWest[,3] <- as.numeric(substr(dataWest[,3], 5,8))
dataEast[,3] <- as.numeric(substr(dataEast[,3], 5,8))
dataWest[,1] <- -dataWest[,1]
dataTotal <- rbind(dataEast, dataWest)
dataTotal <- na.omit(dataTotal)
```

```
# 设置需要的经纬度范围（可更改）
# Set the bounds of regions here
longitude_lowerbound <- -12
longitude_upperbound <- 10
latitude_lowerbound <- 50
latitude_upperbound <- 80
```

```
# 提取每年平均温度
# Only require data from -12-10E and 50-80N
dataTotal <- dataTotal %>%
  filter(Longitude <= longitude_upperbound &
           Longitude >= longitude_lowerbound &
           Latitude <= latitude_upperbound &
           Latitude >= latitude_lowerbound)
```

```
# 把同地点 1981-2020 的温度数据拷贝一份副本
dataTotal2 <- dataTotal %>% arrange(Longitude, Latitude) %>% group_by(Longitude, Latitude, Time) %>%
# 同地点 1981-2020 的温度数据
```

```
dataTotal <- dataTotal %>% arrange(Longitude, Latitude) %>% group_by(Longitude, Latitude, Time) %>% s
library(tidyverse)
# 以地点为主列，把每年的温度放到右边（每列即年份），结果如下所示
dataTotal <- dataTotal %>% pivot_wider(names_from = Time, values_from = avg_temperature)
dataTotal
```

```
## # A tibble: 660 x 37
## # Groups:   Longitude, Latitude [660]
##    Longitude Latitude `1981` `1982` `1983` `1984` `1985` `1986` `1987` `1988`
##        <dbl>    <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>
##  1     -11.5     50.5  11.9    13.0   13.0   13.1   12.7  12.2    12.9   12.6
##  2     -11.5     51.5  11.5    12.6   12.6   12.8   12.3  11.8    12.5   12.2
##  3     -11.5     52.5  11.4    12.4   12.2   12.5   12.0  11.6    12.2   11.9
##  4     -11.5     53.5  11.2    12.1   11.9   12.2   11.7  11.4    11.8   11.6
##  5     -11.5     54.5  11.0    11.9   11.6   11.9   11.5  11.2    11.5   11.4
##  6     -11.5     55.5  10.7    11.7   11.4   11.6   11.3  11.1    11.3   11.3
##  7     -11.5     56.5  10.4    11.5   11.2   11.5   11.1  10.9    11.2   11.2
##  8     -11.5     57.5  10.0    11.1   10.8   11.1   10.8  10.7    10.9   11.0
##  9     -11.5     58.5   9.68   10.6   10.4   10.7   10.4  10.3    10.6   10.6
## 10     -11.5     59.5   9.25   10.2   10.1   10.3   10.1   9.99   10.2   10.2
## # ... with 650 more rows, and 27 more variables: 1989 <dbl>, 1990 <dbl>,
## #   1991 <dbl>, 1992 <dbl>, 1993 <dbl>, 1994 <dbl>, 1995 <dbl>, 1996 <dbl>,
## #   1997 <dbl>, 1998 <dbl>, 1999 <dbl>, 2000 <dbl>, 2001 <dbl>, 2002 <dbl>,
## #   2003 <dbl>, 2004 <dbl>, 2005 <dbl>, 2006 <dbl>, 2007 <dbl>, 2008 <dbl>,
## #   2009 <dbl>, 2010 <dbl>, 2011 <dbl>, 2012 <dbl>, 2013 <dbl>, 2014 <dbl>,
## #   2015 <dbl>
```

```
# 用 r 内置 prediction 做一个预测 2070 年温度的区间
year <- seq(1981, 2015)
new.year <-  data.frame(
  # 这个地方可以调整年份
  year = c(2070)
)
# 创建一个 data frame 存储 prediction 出来的数据
Prediction <- as.data.frame(matrix(data = NA, nrow = 660, ncol = 3))
# 因为总共有 660 个 location，所以重复 660 次计算
for (i in 1:660) {
  temperature <- as.integer(dataTotal[i,3:37])
  model <- lm(temperature ~ year)
  Prediction[i,] <- predict(model, newdata = new.year, interval = "prediction")
}
```

```
colnames(Prediction) <- c("Expected", "Lower_bound", "Upper_bound")
dataMerge <- cbind(dataTotal, Prediction)
# 找出合适 Meckerel (M) 和 Herring (H) 生存的温度的海域
M <- dataMerge %>% filter(Lower_bound < 9.6 & Upper_bound > 8.86) %>% select(Longitude, Latitude, Exp
H <- dataMerge %>% filter(Lower_bound < 9.8 & Upper_bound > 8.8) %>% select(Longitude, Latitude, Expe
# Expected Value
ME <- dataMerge %>% filter(Expected < 9.6 & Expected > 8.86) %>% select(Longitude, Latitude, Expected
HE <- dataMerge %>% filter(Expected < 9.8 & Expected > 8.8) %>% select(Longitude, Latitude, Expected,
```

```
# 大概看一下边界
cat("Mackerel Range \n")
```

```
## Mackerel Range
```

```
cbind(summary(M[,1]),summary(M[,2]))
```

```
##    Longitude           Latitude
##  "Min.   :-11.500  " "Min.   :50.50  "
##  "1st Qu.: -2.750  " "1st Qu.:57.50  "
##  "Median :  1.500  " "Median :62.50  "
##  "Mean   :  1.375  " "Mean   :62.15  "
##  "3rd Qu.:  6.500  " "3rd Qu.:66.50  "
##  "Max.   :  9.500  " "Max.   :75.50  "
```

```
# 大概看一下边界
cat("Herring Range \n")
```

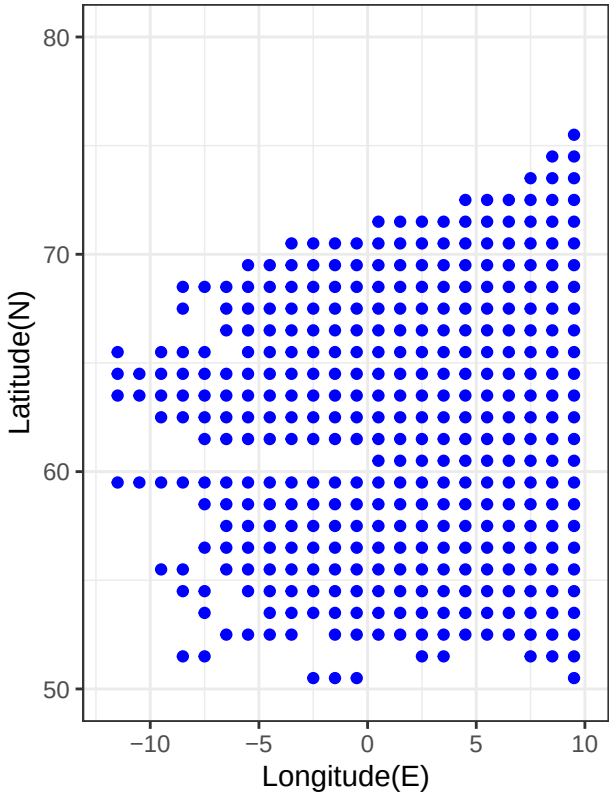
```
## Herring Range
```

```
cbind(summary(H[,1]), summary(H[,2]))
```

```
##    Longitude           Latitude
##  "Min.   :-11.500  " "Min.   :50.50  "
##  "1st Qu.: -3.500  " "1st Qu.:56.50  "
##  "Median :  1.500  " "Median :62.50  "
##  "Mean   :  1.157  " "Mean   :61.88  "
##  "3rd Qu.:  6.500  " "3rd Qu.:66.50  "
##  "Max.   :  9.500  " "Max.   :75.50  "
```

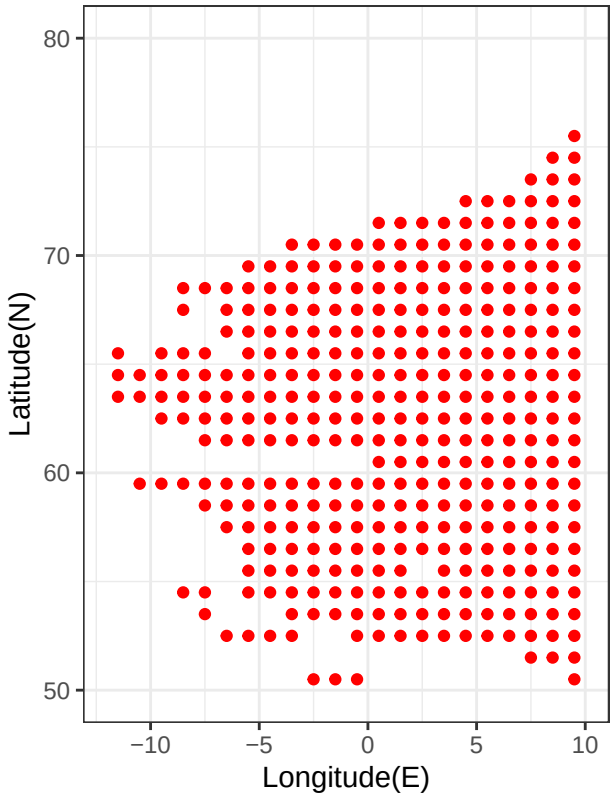
```
library(ggplot2)
p <- ggplot(H, aes(Longitude, Latitude)) + geom_point(col = "blue") + theme_bw() + coord_fixed(ratio
  ggtitle("Herring Possible Distribution (Suitable Temperature) in 2070") +
  theme(plot.title = element_text(hjust = 0.5))
p
```

Herring Possible Distribution (Suitable Temperature) in 2070

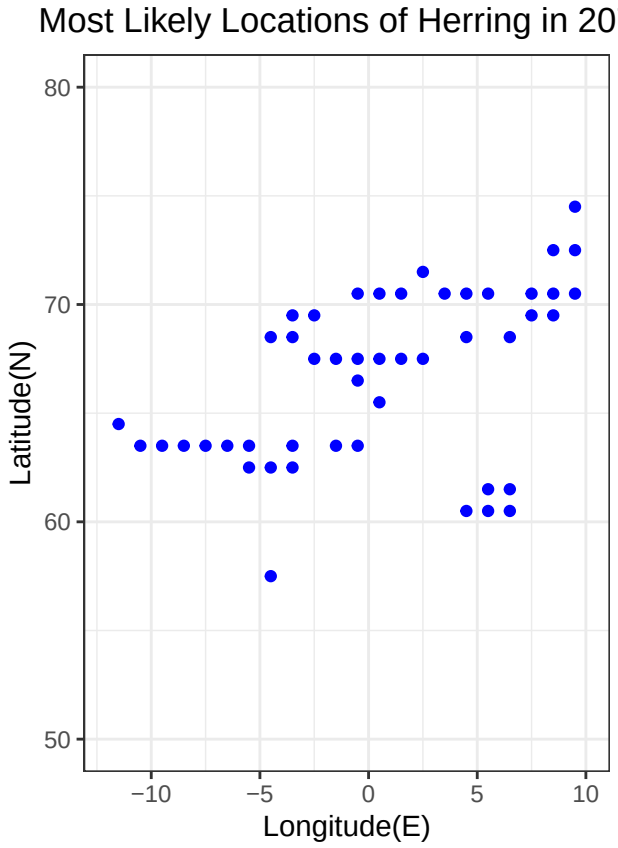



```
p <- ggplot(M, aes(Longitude, Latitude)) +
  geom_point(col = "red") +
  theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) +
  xlab("Longitude(E)") +
  ylab("Latitude(N)") +
  ggtitle("Mackerel Possible Distribution (Suitable Temperature) in 2070") +
  theme(plot.title = element_text(hjust = 0.5))
p
```

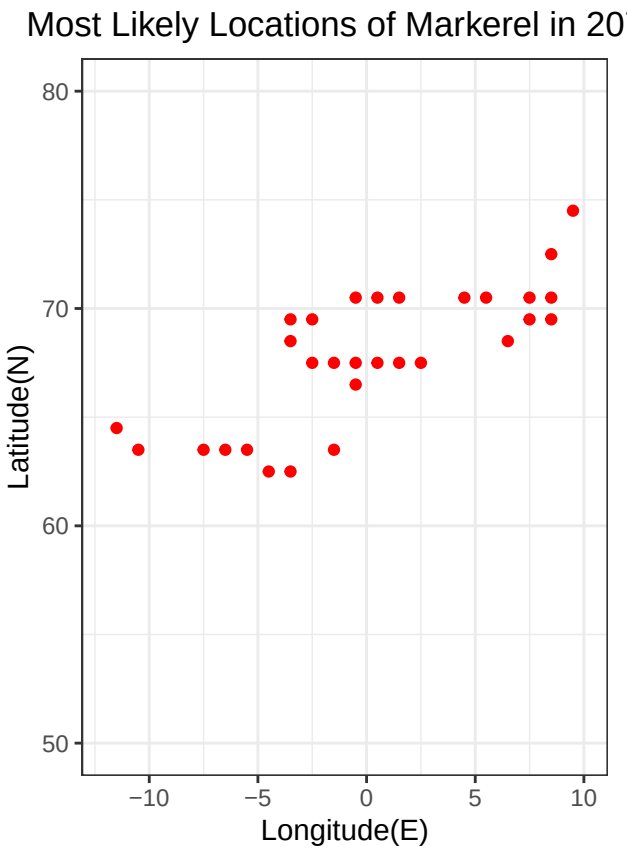
Mackerel Possible Distribution (Suitable Temperature) in 2070



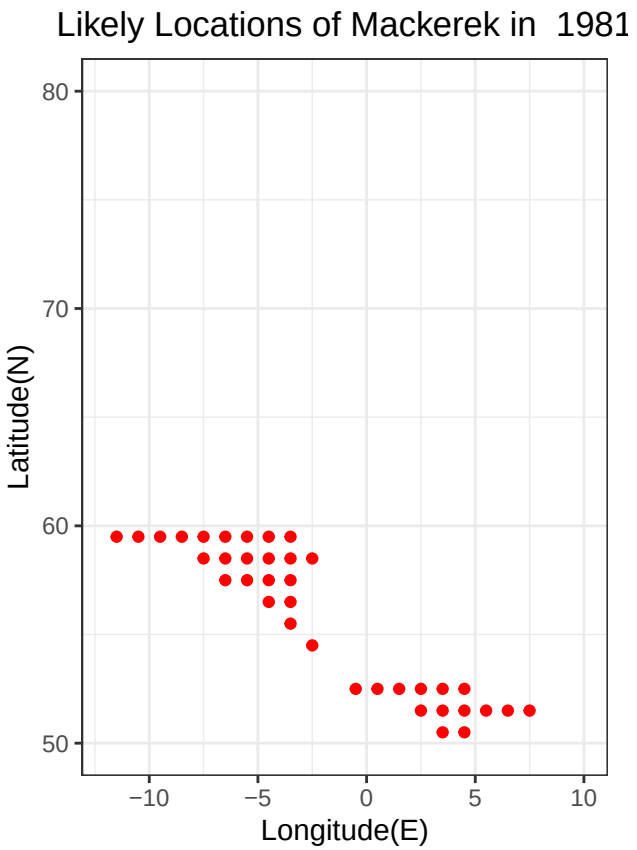

```
p <- ggplot(HE, aes(Longitude, Latitude)) + geom_point(col = "blue") + theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +  ylab("Latitud
  ggtitle("Most Likely Locations of Herring in 2070") +
  theme(plot.title = element_text(hjust = 0.5))
p
```

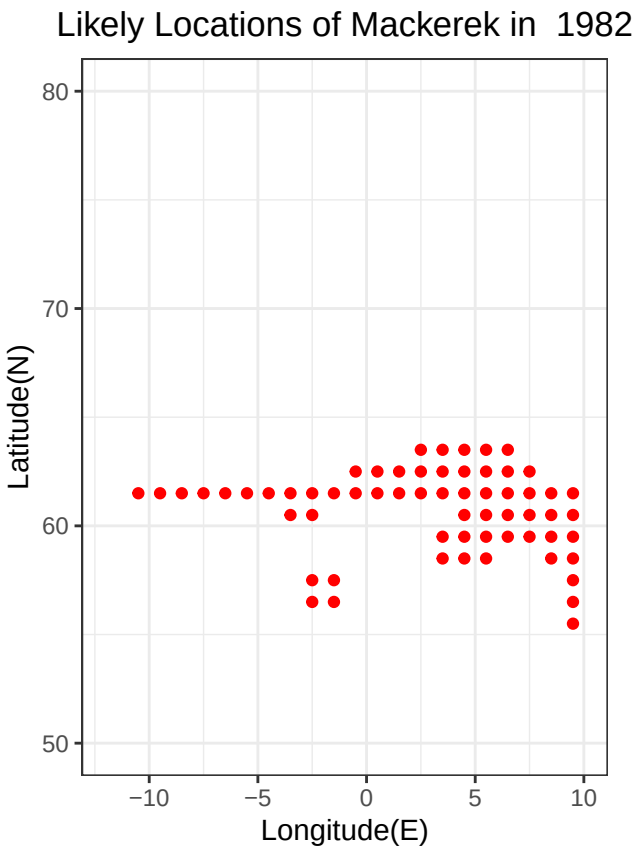


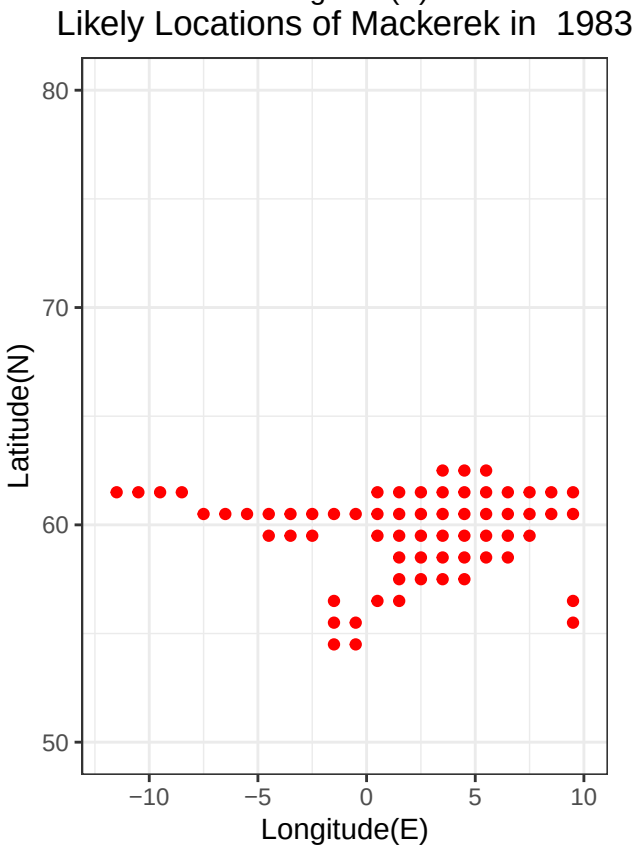

```
p <- ggplot(ME, aes(Longitude, Latitude)) + geom_point(col = "red") + theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +  ylab("Latitud
  ggtitle("Most Likely Locations of Markerel in 2070") +
  theme(plot.title = element_text(hjust = 0.5))
p
```

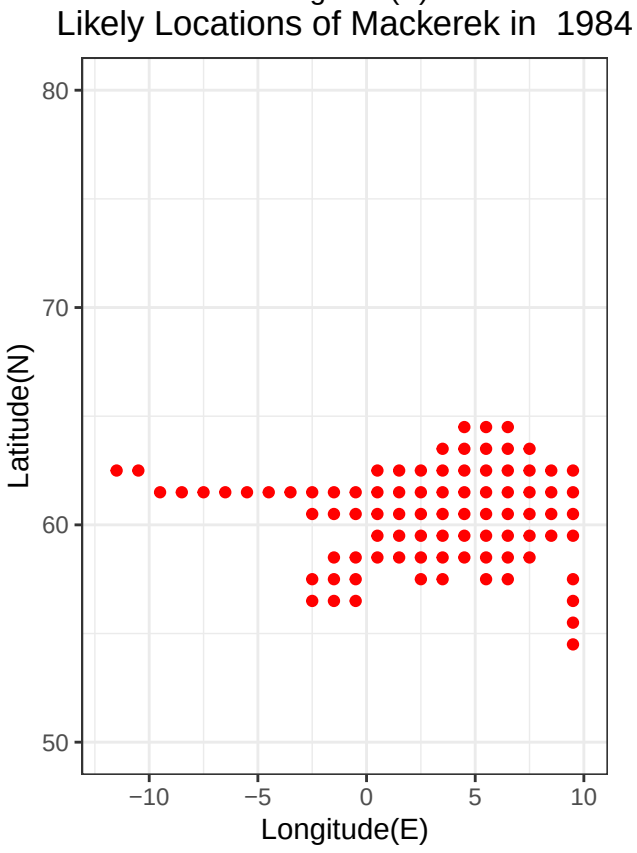


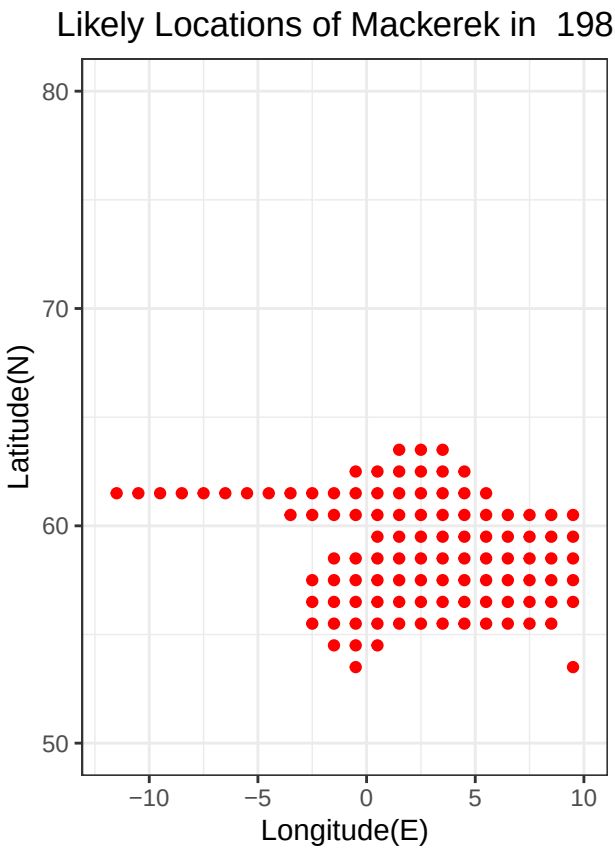

```
for (i in 1981:2014) {

M1981 <- dataTotal2 %>% filter(avg_temperature < 9.6 & avg_temperature > 8.86 & Time == i)
pM1981 <- ggplot(M1981, aes(Longitude, Latitude)) +
  geom_point(col = "red") +
  theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +
  ylab("Latitude(N)") +
  ggtitle(paste("Likely Locations of Mackerek in ", i)) +
  theme(plot.title = element_text(hjust = 0.5))
print(pM1981)
}
```

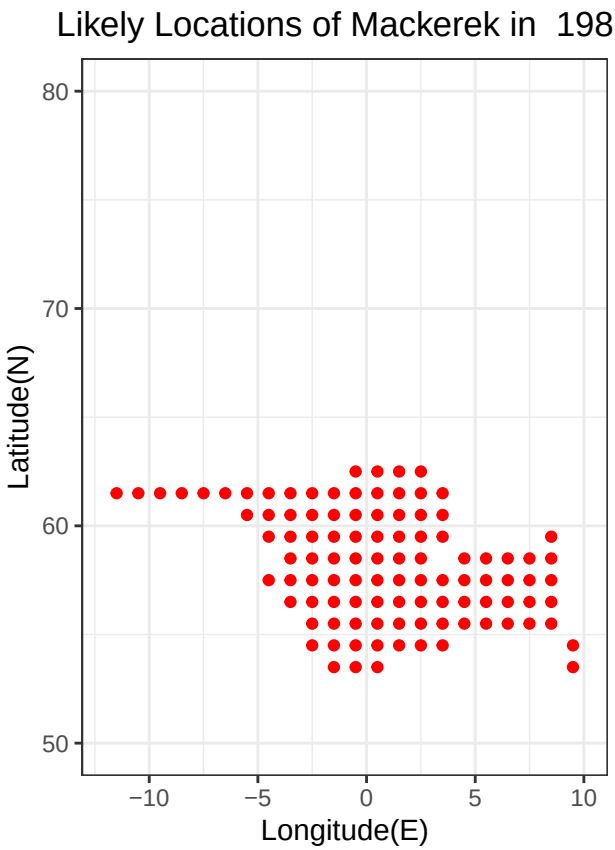

Likely Locations of Mackerek in 1981
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

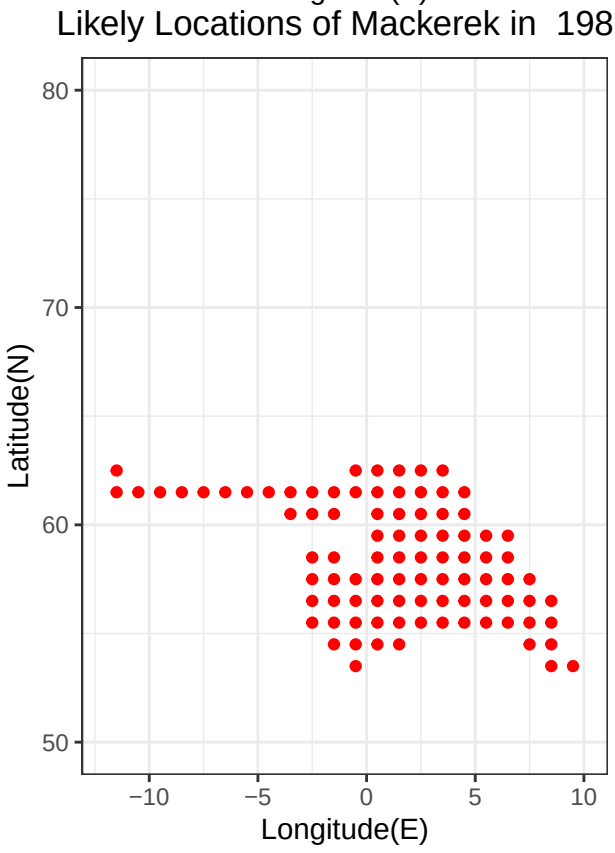

Likely Locations of Mackerek in 1982
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

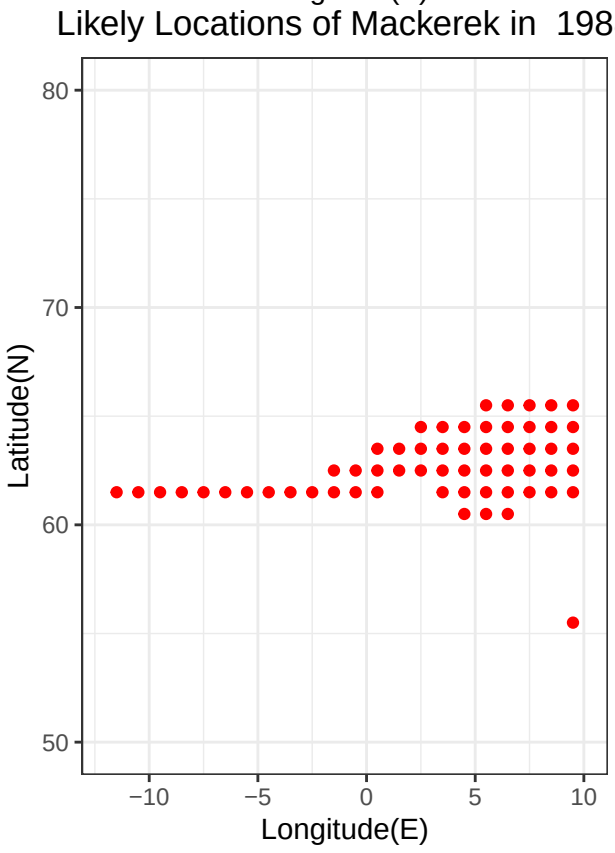

Likely Locations of Mackerek in 1983
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

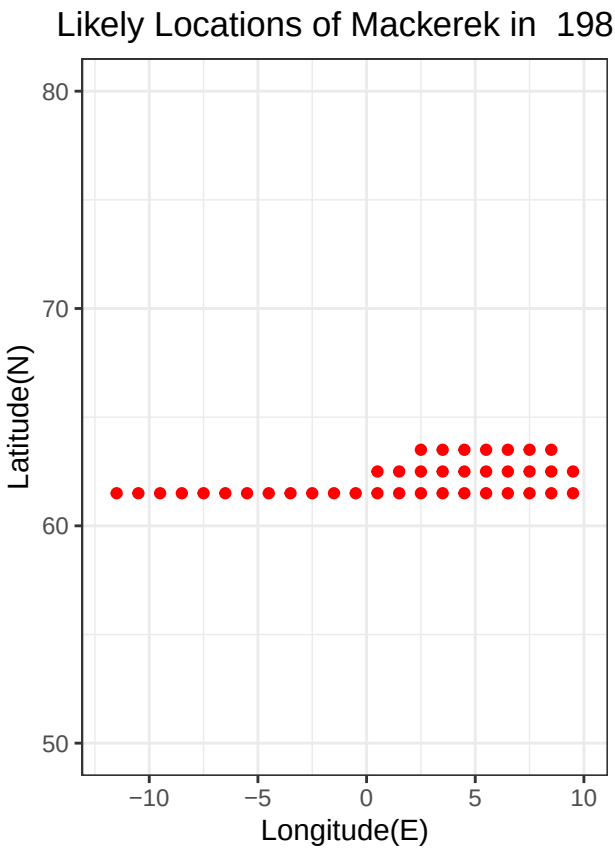

Likely Locations of Mackerek in 1984
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

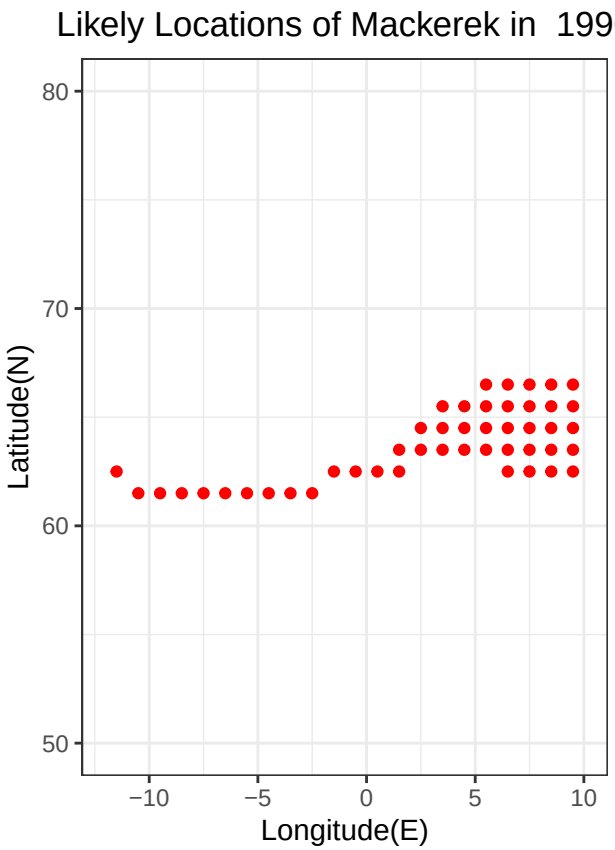

Likely Locations of Mackerek in 1985
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

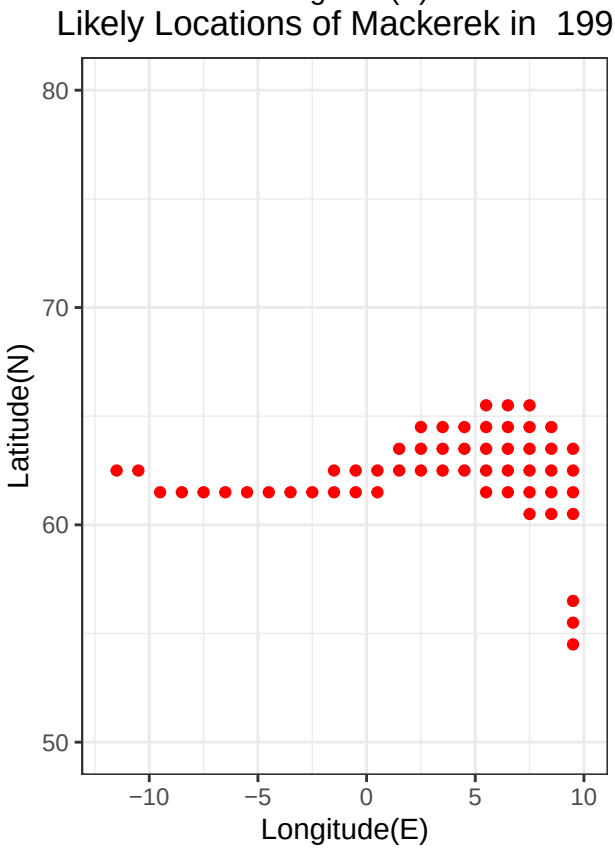

Likely Locations of Mackerek in 1986
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

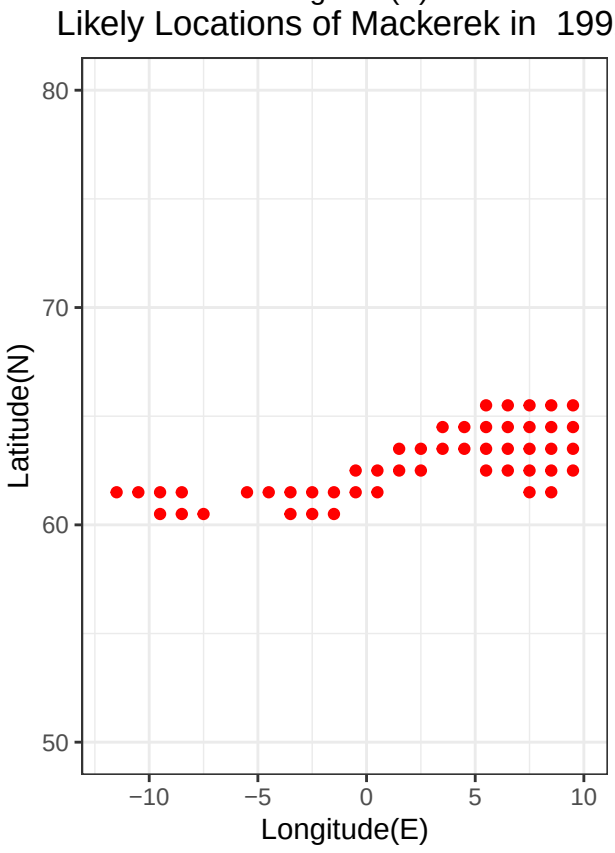

Likely Locations of Mackerek in 1987
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

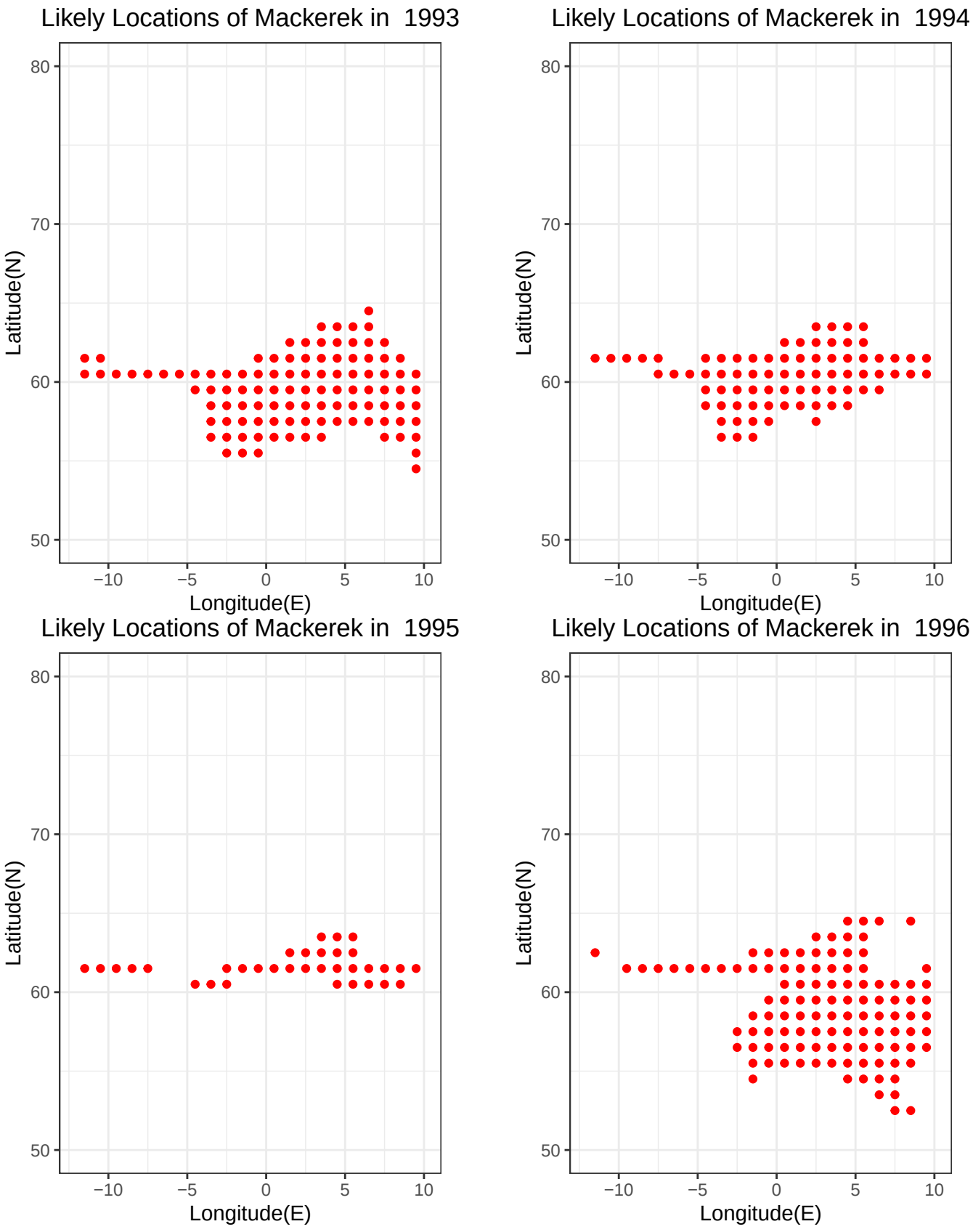

Likely Locations of Mackerek in 1988
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

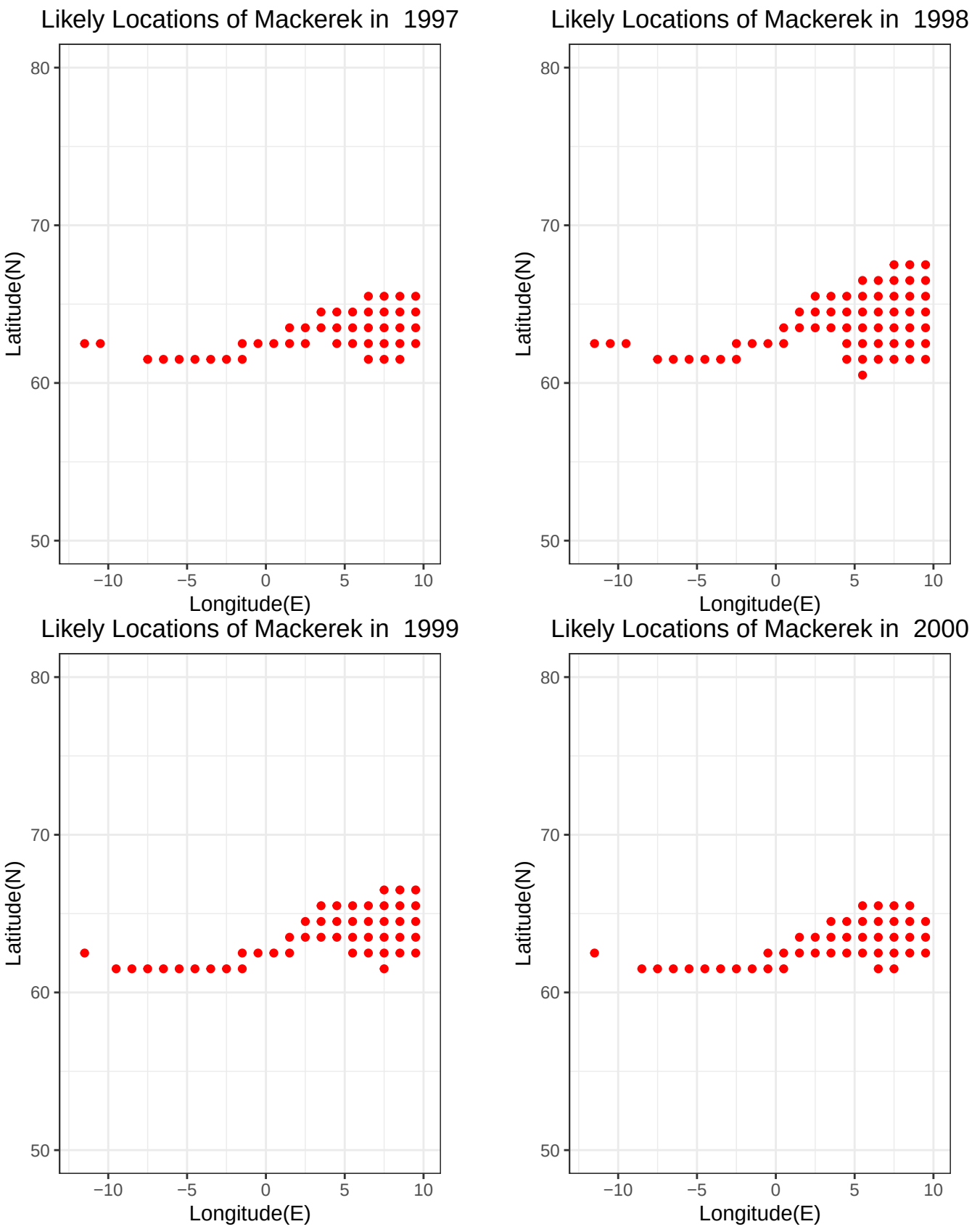

Likely Locations of Mackerek in 1989
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

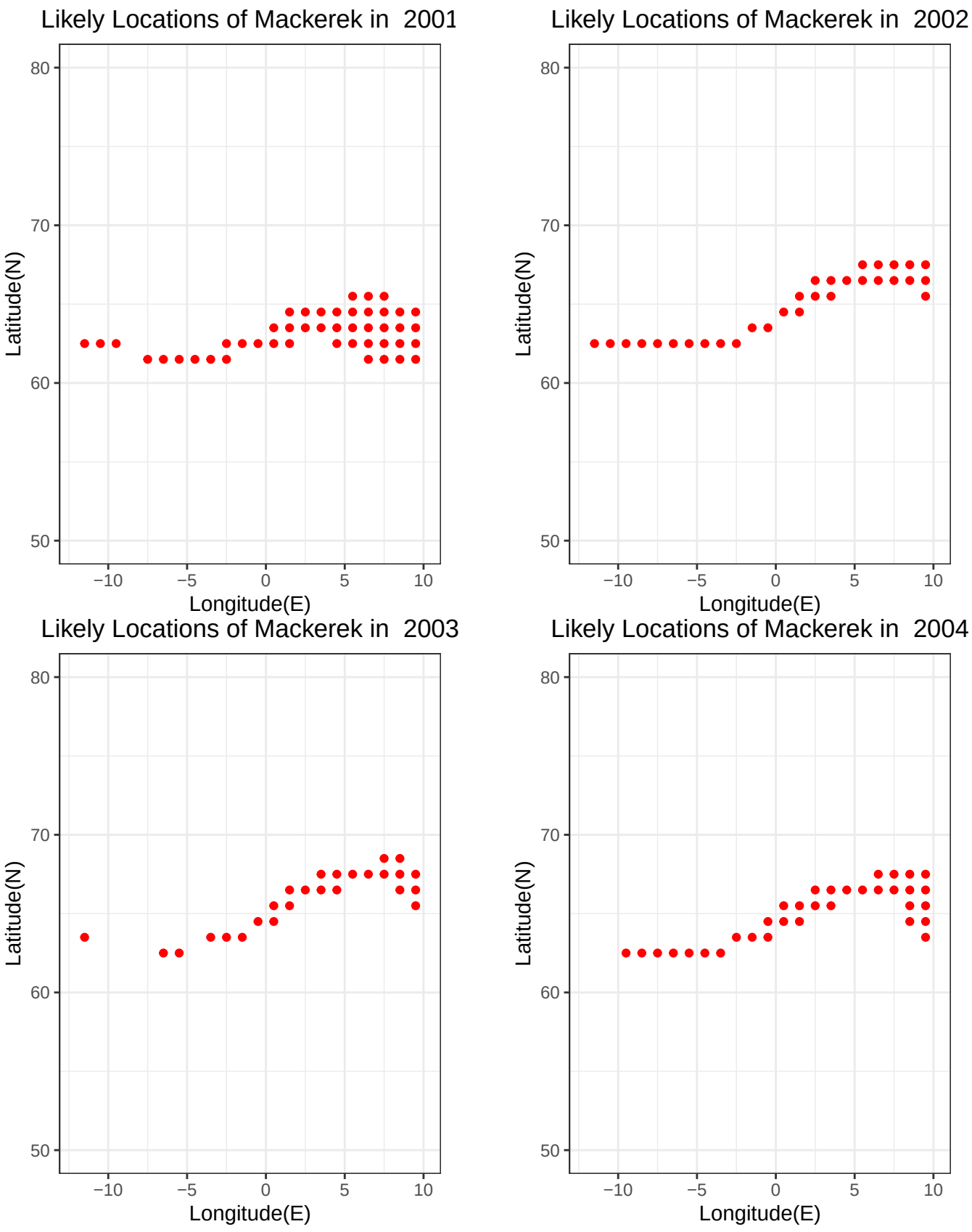

Likely Locations of Mackerek in 1990
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

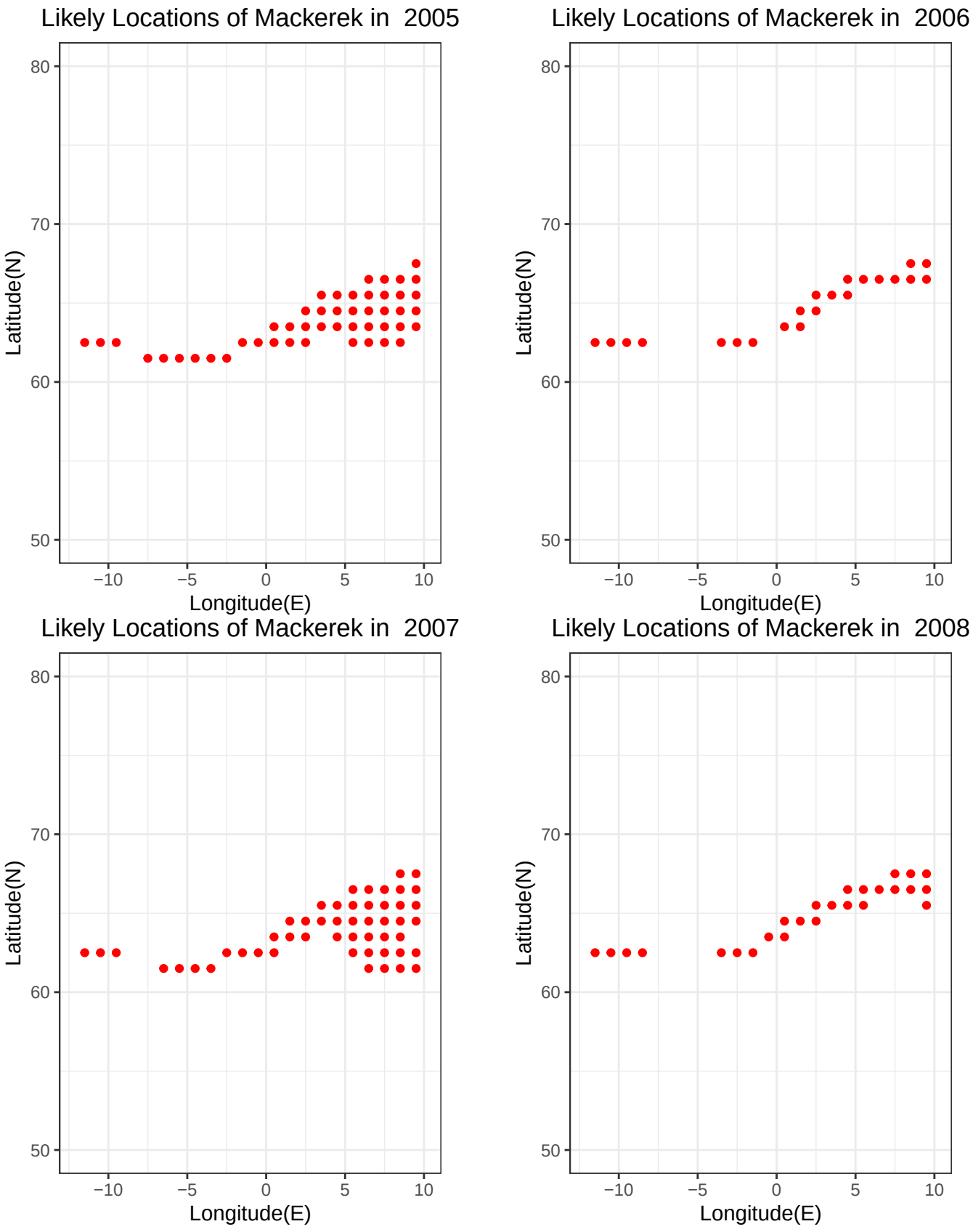

Likely Locations of Mackerek in 1991
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

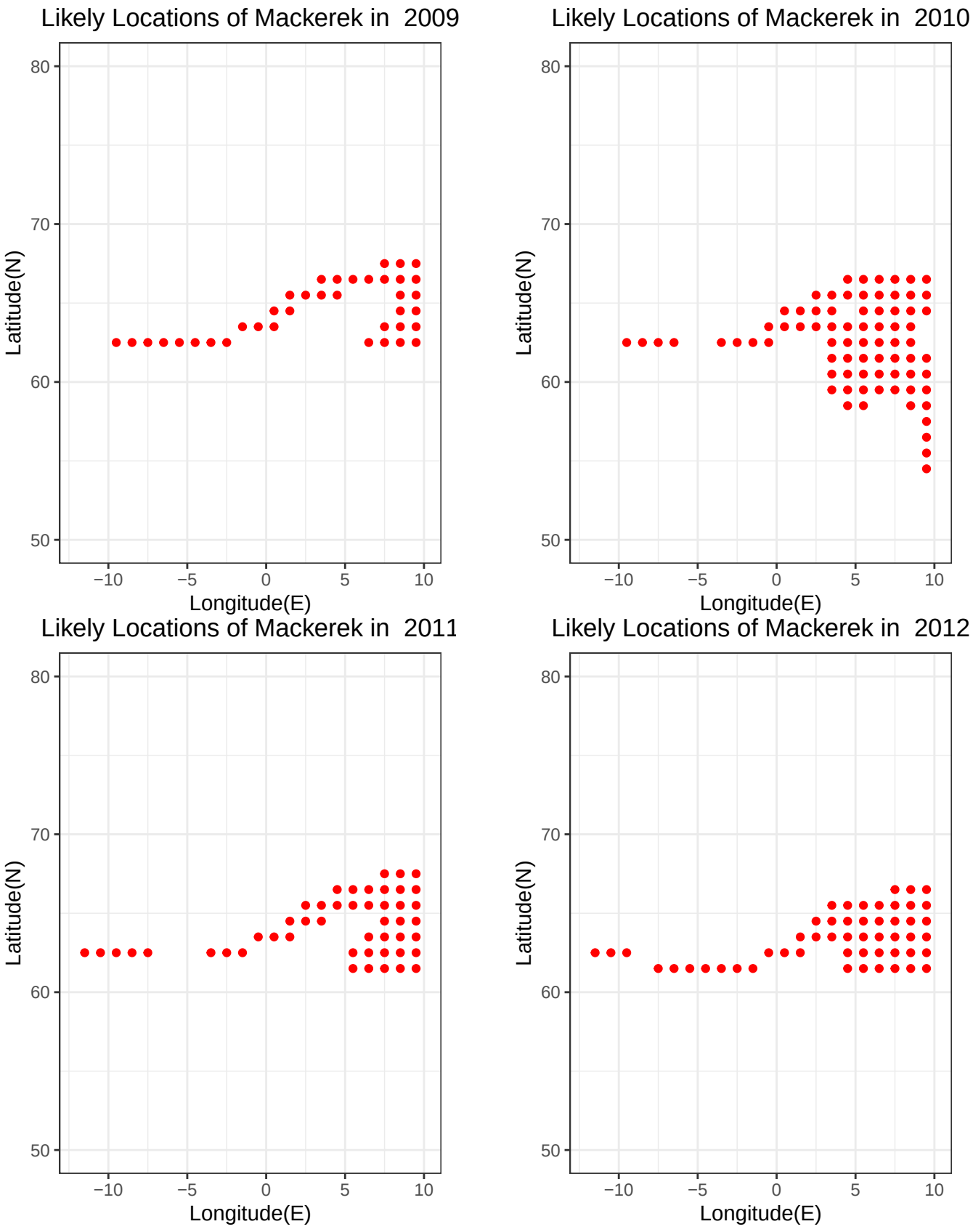

Likely Locations of Mackerek in 1992
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

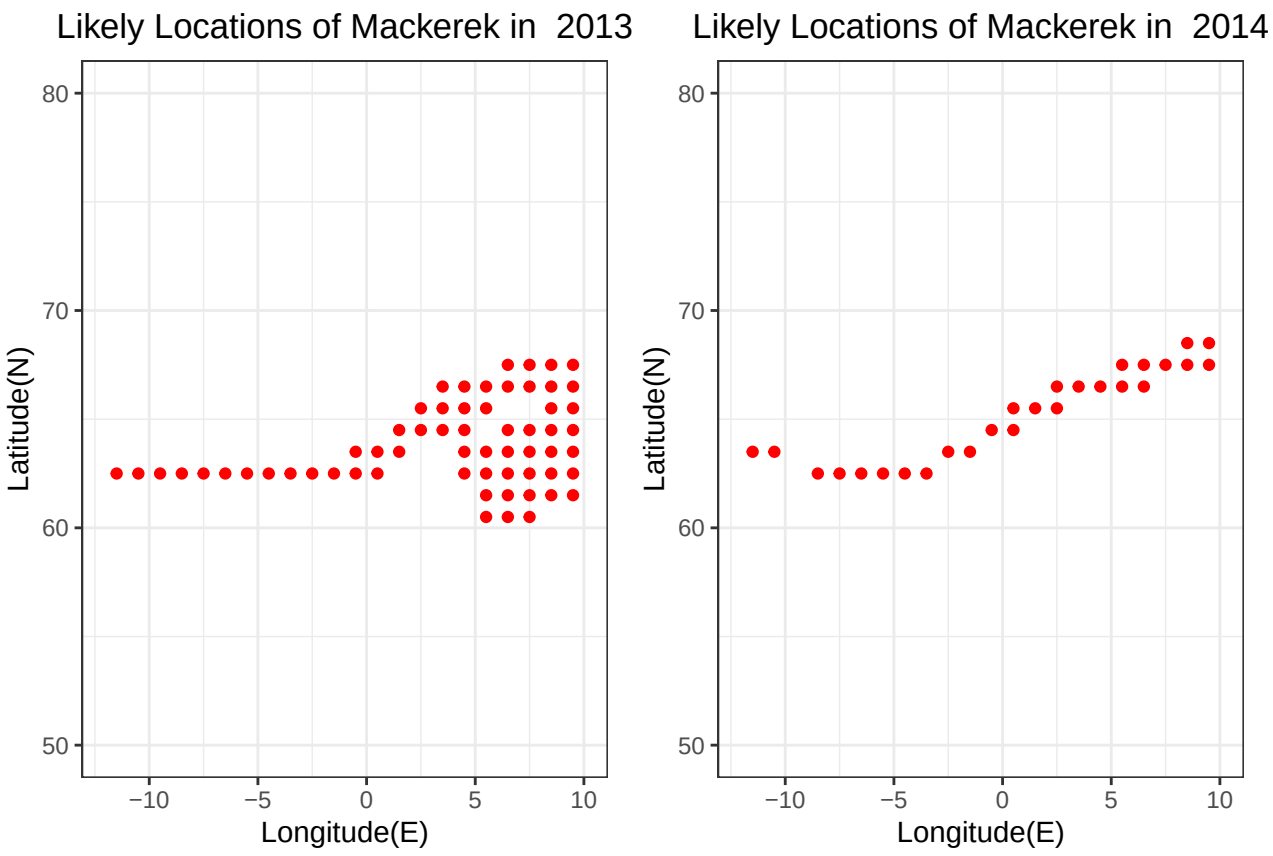

Likely Locations of Mackerek in 1993
Likely Locations of Mackerek in 1994
Likely Locations of Mackerek in 1995
Likely Locations of Mackerek in 1996
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Mackerek in 1997
Likely Locations of Mackerek in 1998
Likely Locations of Mackerek in 1999
Likely Locations of Mackerek in 2000
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Mackerek in 2001
Likely Locations of Mackerek in 2002
Likely Locations of Mackerek in 2003
Likely Locations of Mackerek in 2004
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

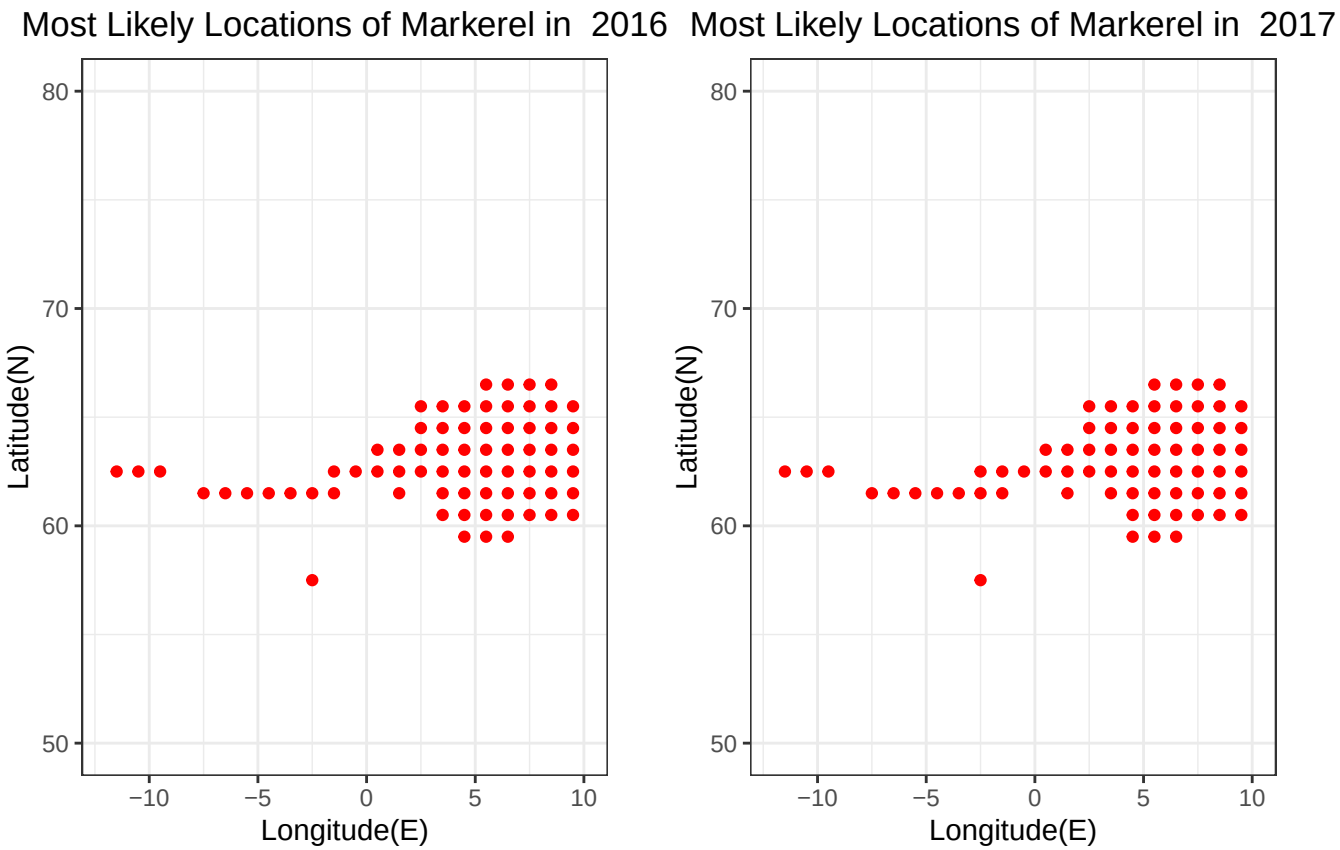

Likely Locations of Mackerek in 2005
Likely Locations of Mackerek in 2006
Likely Locations of Mackerek in 2007
Likely Locations of Mackerek in 2008
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

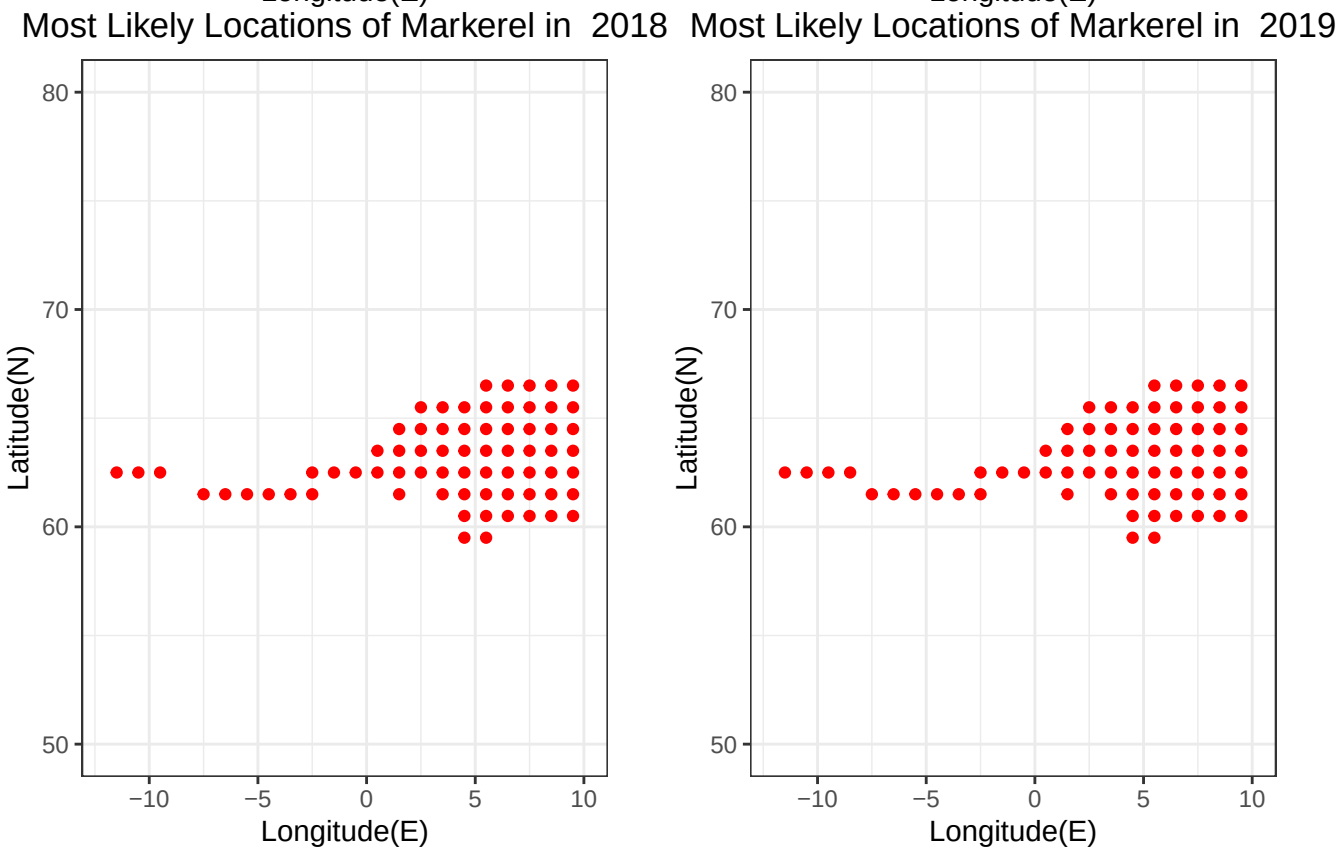

Likely Locations of Mackerek in 2009
Likely Locations of Mackerek in 2010
Likely Locations of Mackerek in 2011
Likely Locations of Mackerek in 2012
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10




```
x <- 2070
for (i in 2016:x) {
  tempYear <- i
  year <- seq(1981, 2015)
  new.year <-  data.frame(
    year = c(tempYear)
  )
  Prediction <- as.data.frame(matrix(data = NA, nrow = 660, ncol = 3))
  for (i in 1:660) {
    temperature <- as.integer(dataTotal[i,3:37])
    model <- lm(temperature ~ year)
    Prediction[i,] <- predict(model, newdata = new.year, interval = "prediction")
  }
  colnames(Prediction) <- c("Expected", "Lower_bound", "Upper_bound")
  dataMerge <- cbind(dataTotal, Prediction)
  M <- dataMerge %>% filter(Lower_bound < 9.6 & Upper_bound > 8.86) %>% select(Longitude, Latitude, E
  H <- dataMerge %>% filter(Lower_bound < 9.8 & Upper_bound > 8.8) %>% select(Longitude, Latitude, Ex
  ME <- dataMerge %>% filter(Expected < 9.6 & Expected > 8.86) %>% select(Longitude, Latitude, Expect
  HE <- dataMerge %>% filter(Expected < 9.8 & Expected > 8.8) %>% select(Longitude, Latitude, Expecte
  library(ggplot2)
  # pH <- ggplot(H, aes(Longitude, Latitude)) + geom_point(col = "blue") + theme_bw() + coord_fixed(r
```

```
  #   ggtitle(paste("Herring Possible Distribution (8.86-9.6C) in ", tempYear)) +
  #   theme(plot.title = element_text(hjust = 0.5))
  # pM <- ggplot(M, aes(Longitude, Latitude)) +
  #   geom_point(col = "red") +
  #   theme_bw() +
  #   coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) +
  #   xlab("Longitude(E)") +
  #   ylab("Latitude(N)") +
  #   ggtitle(paste("Mackerel Possible Distribution (8.8-9.8C) in ", tempYear)) +
  #   theme(plot.title = element_text(hjust = 0.5))
  # pHE <- ggplot(HE, aes(Longitude, Latitude)) + geom_point(col = "blue") + theme_bw() +
  #   coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +  ylab("Lat
  #   ggtitle(paste("Most Likely Locations of Herring in ", tempYear)) +
  #   theme(plot.title = element_text(hjust = 0.5))
  pME <- ggplot(data = ME, aes(Longitude, Latitude)) + geom_point(col = "red") + theme_bw() +
    coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +  ylab("Latit
    ggtitle(paste("Most Likely Locations of Markerel in ", tempYear)) +
    theme(plot.title = element_text(hjust = 0.5))
  # print(pH)
  # print(pM)
  #print(pHE)
  print(pME)
}
```


Most Likely Locations of Markerel in 2016
Most Likely Locations of Markerel in 2017
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2018
Most Likely Locations of Markerel in 2019
Latitude(N)
Longitude(E)
80
70
60
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−5
0
5
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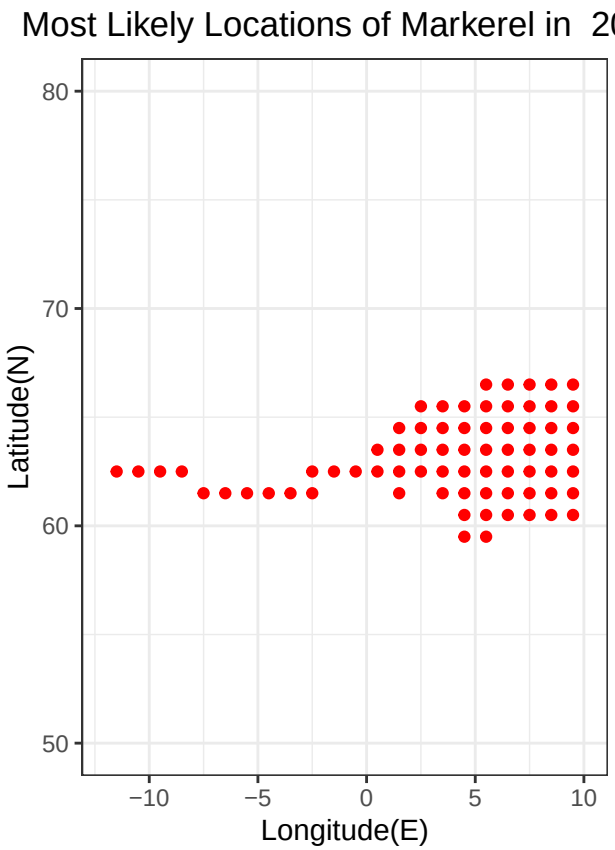
Most Likely Locations of Markerel in 2020
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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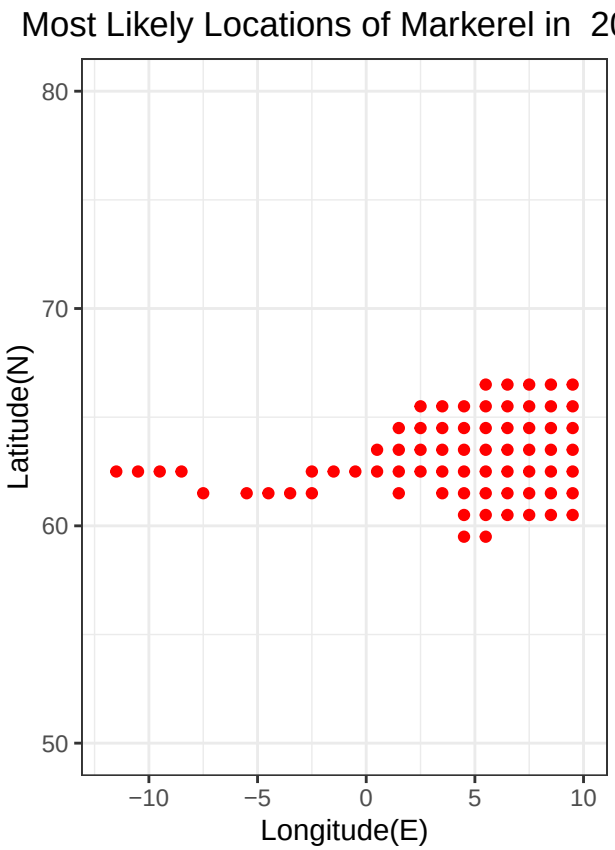
Most Likely Locations of Markerel in 2021
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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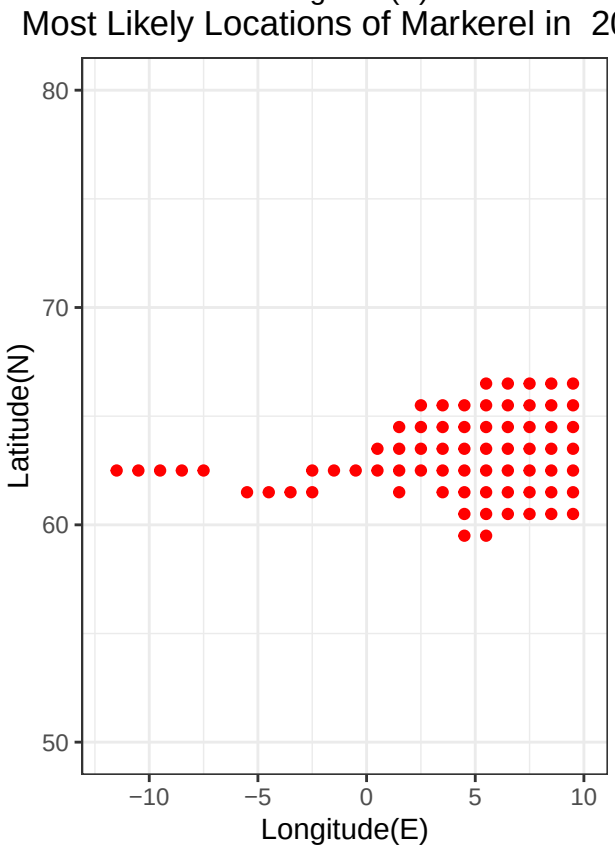
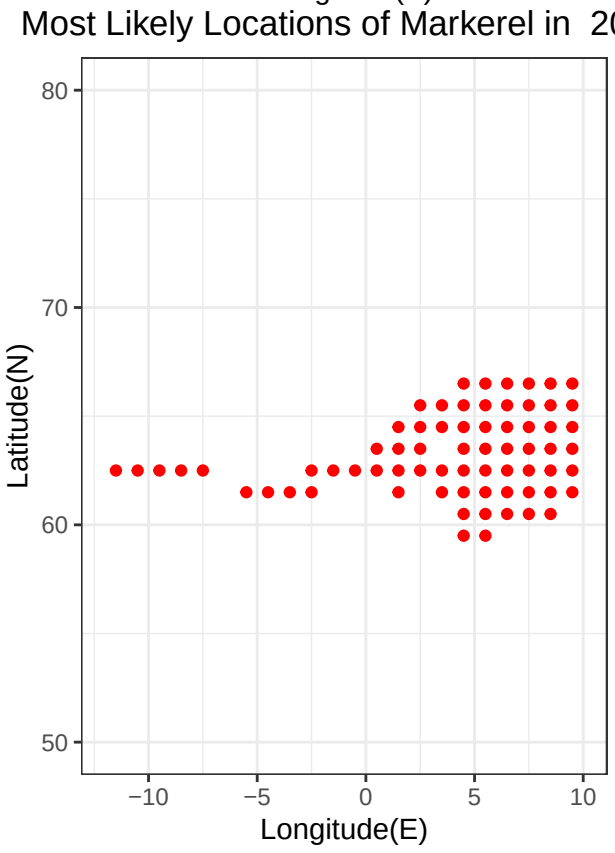

Most Likely Locations of Markerel in 2022
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2023
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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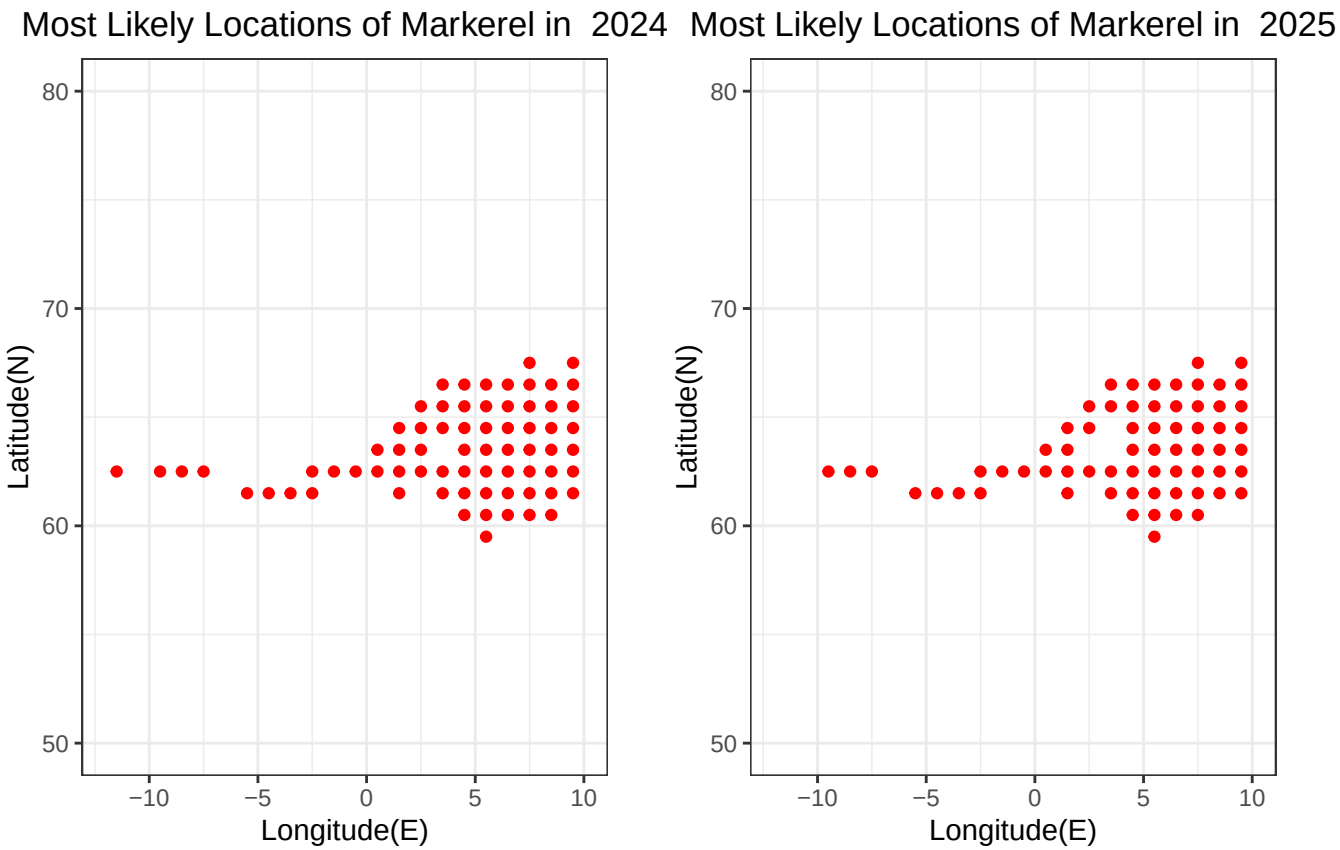
Most Likely Locations of Markerel in 2024
Most Likely Locations of Markerel in 2025
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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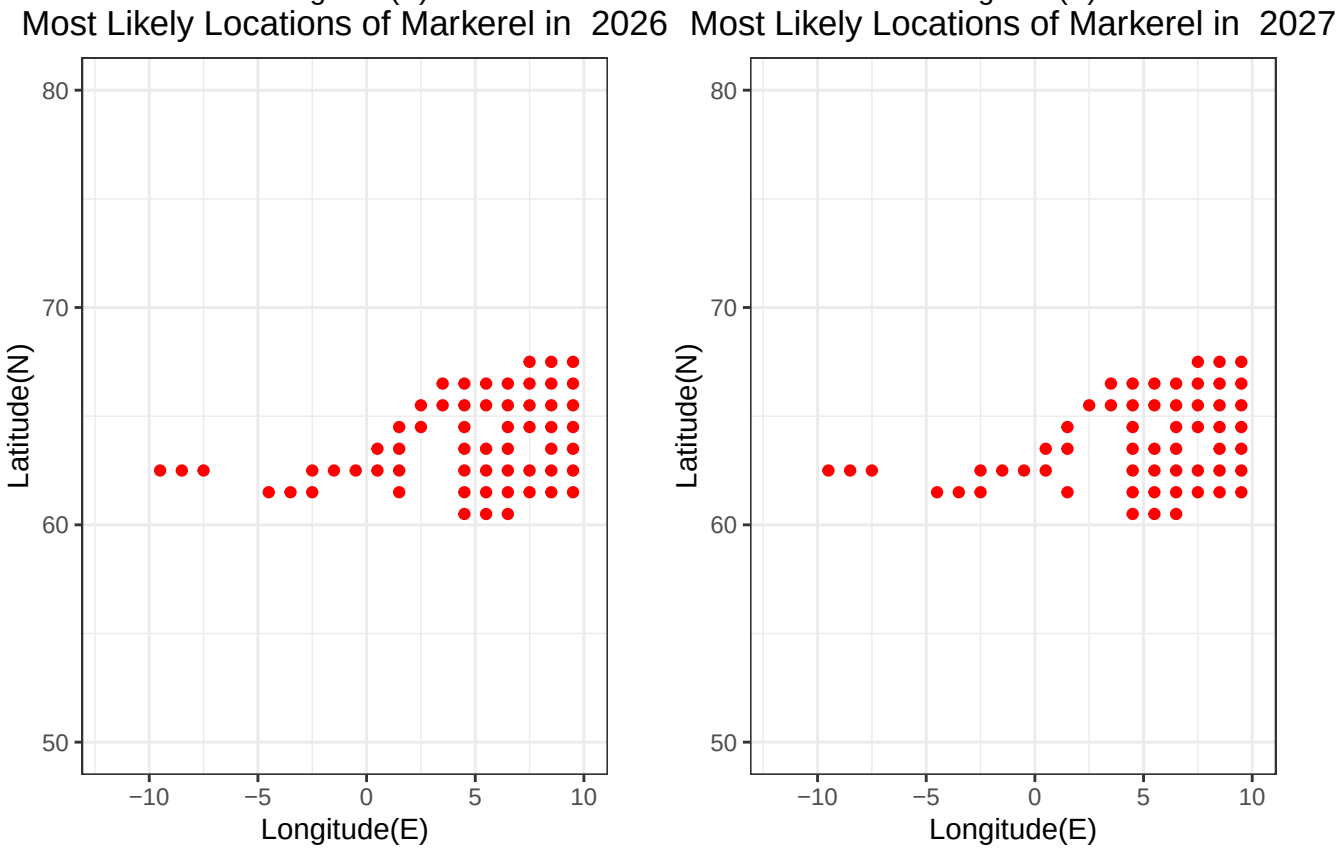
Most Likely Locations of Markerel in 2026
Most Likely Locations of Markerel in 2027
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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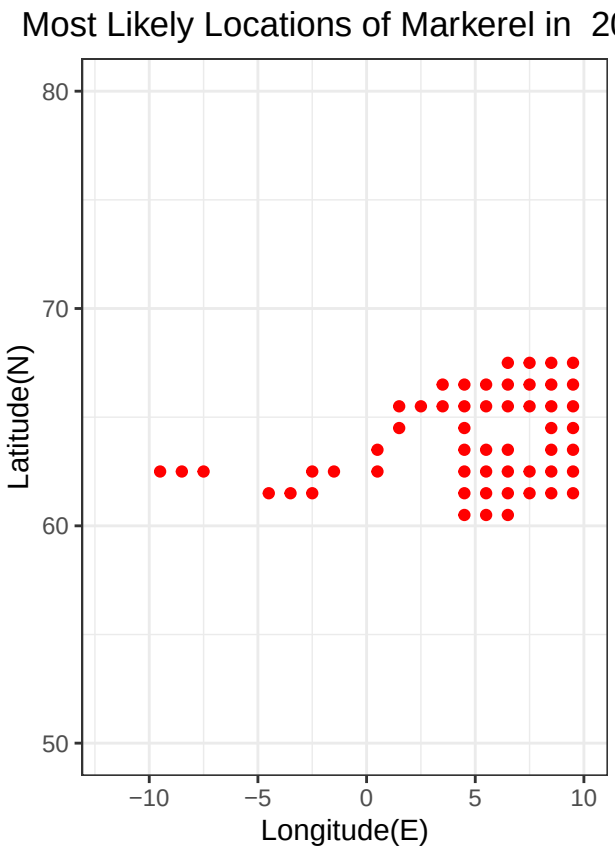
Most Likely Locations of Markerel in 2028
Latitude(N)
Longitude(E)
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70
60
50
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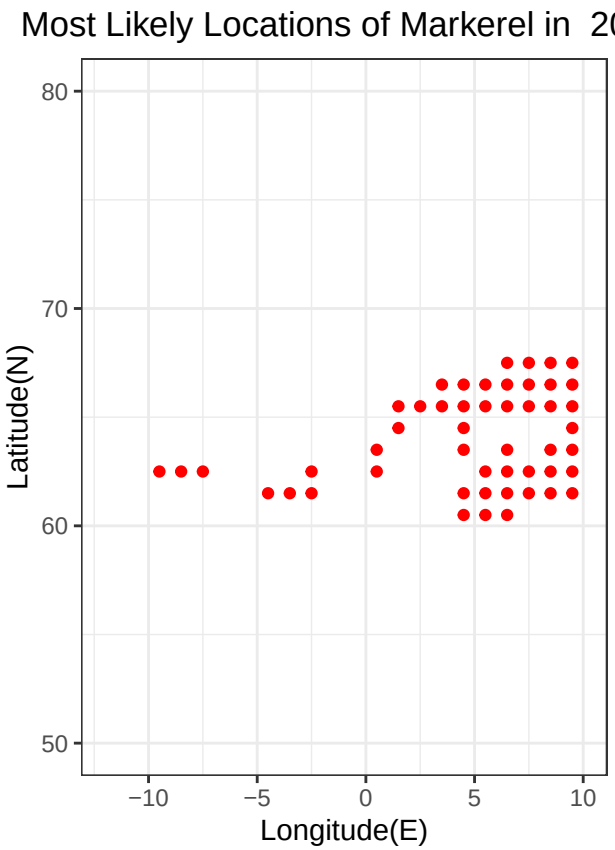
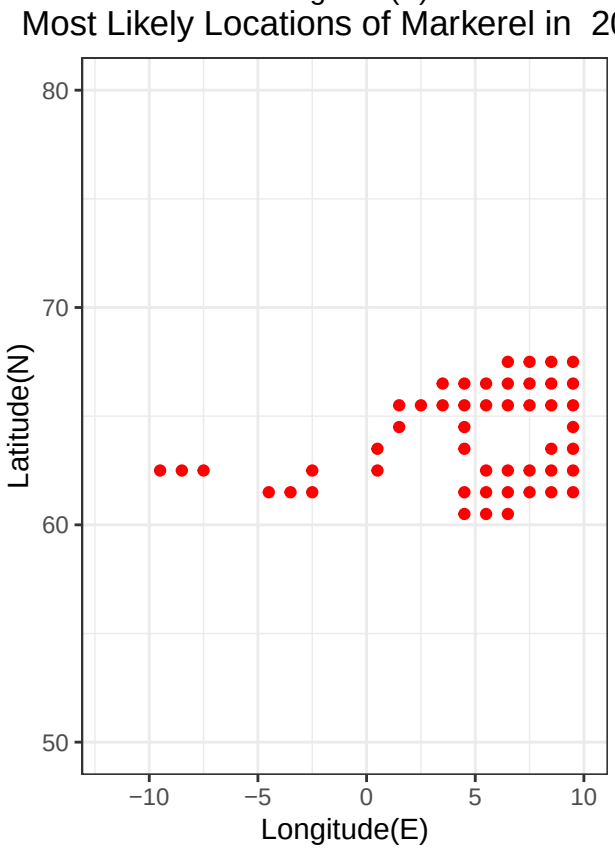
−5
0
5
10


Most Likely Locations of Markerel in 2029
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2030
Latitude(N)
Longitude(E)
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−10
−5
0
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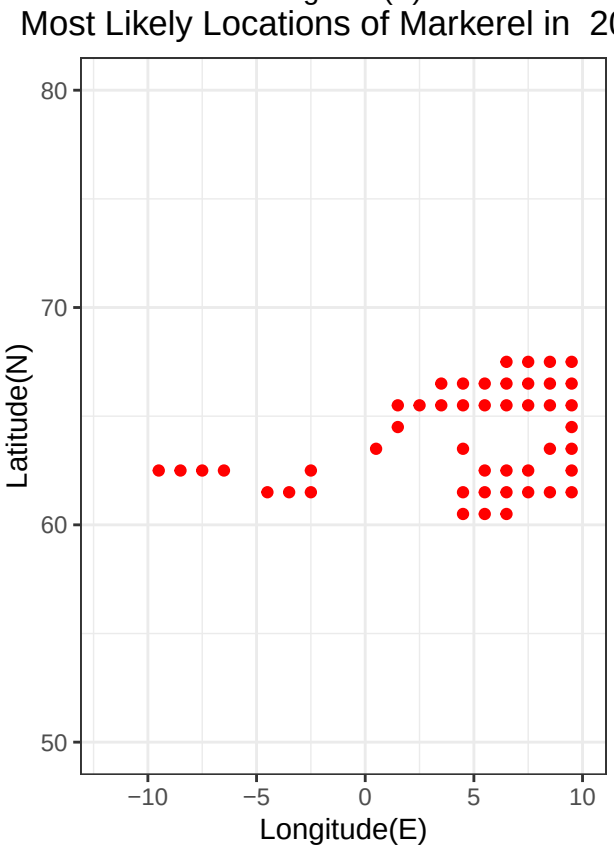
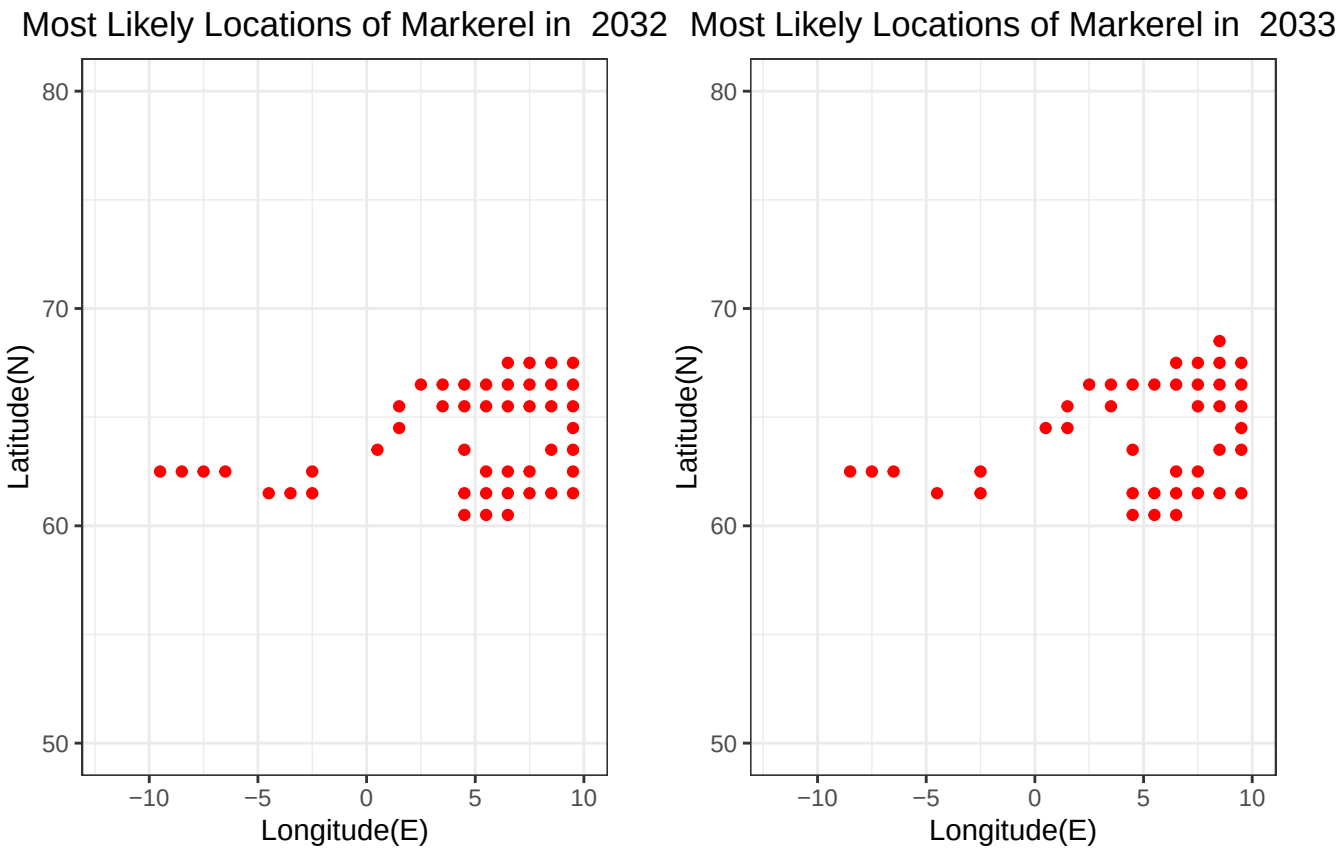

Most Likely Locations of Markerel in 2031
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2032
Most Likely Locations of Markerel in 2033
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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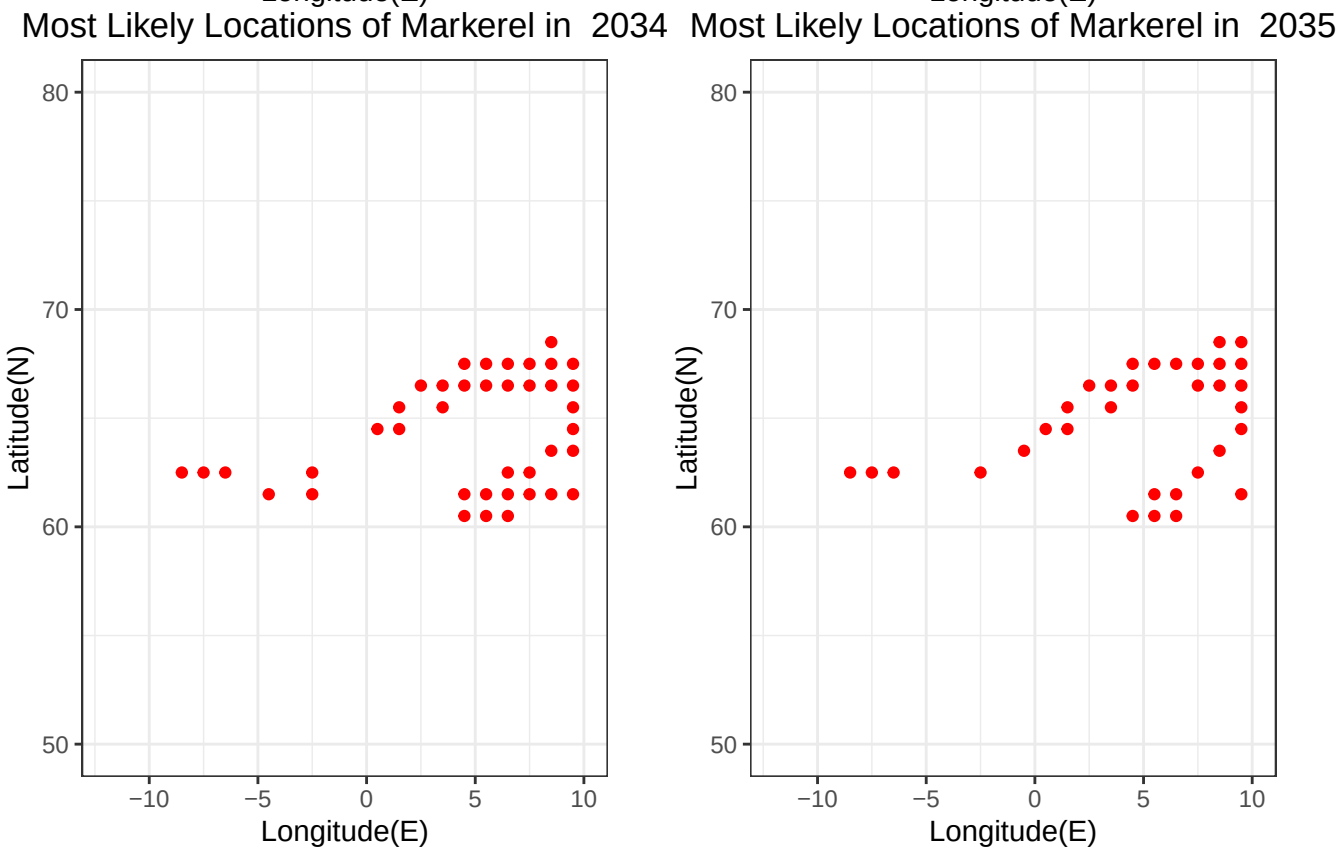
10


Most Likely Locations of Markerel in 2034
Most Likely Locations of Markerel in 2035
Latitude(N)
Longitude(E)
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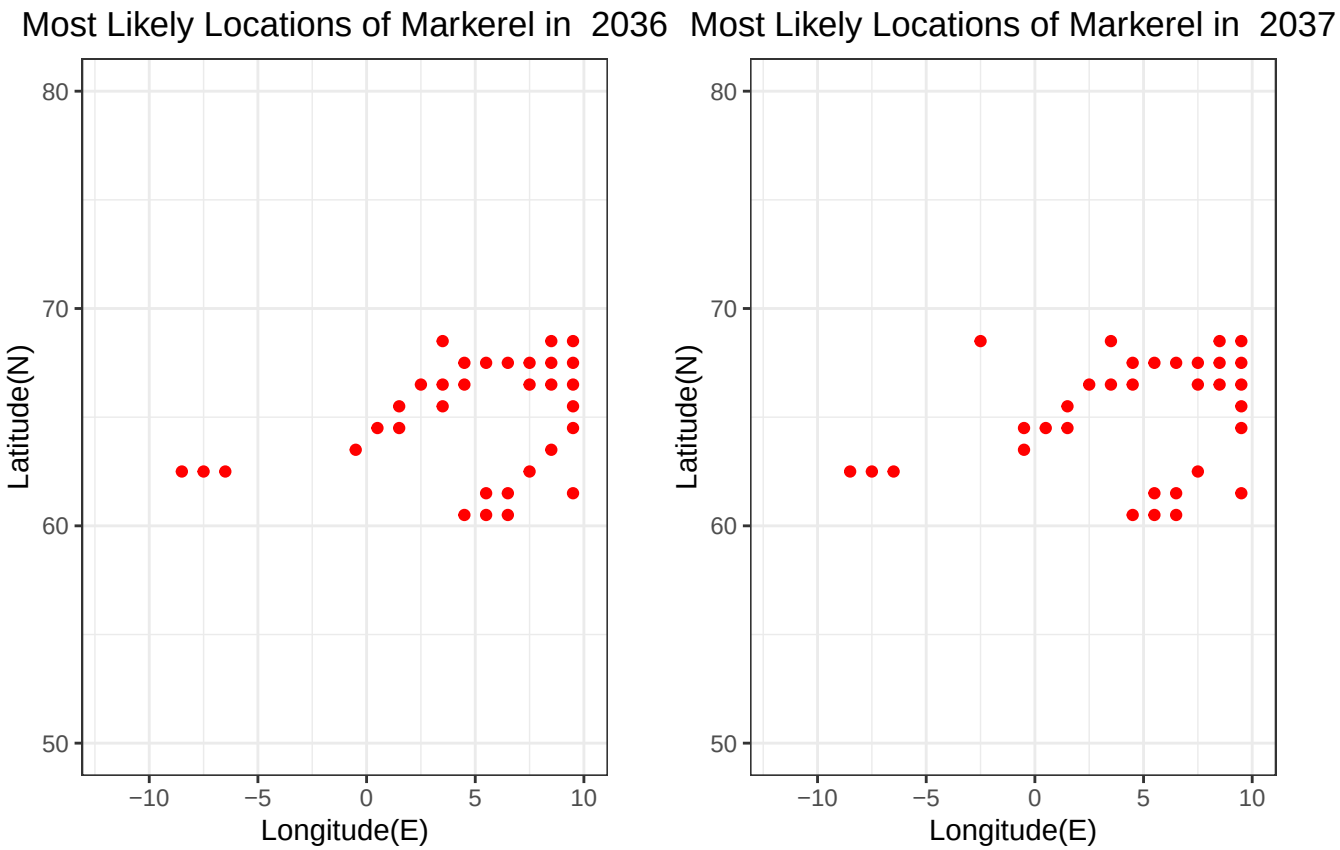
Most Likely Locations of Markerel in 2036
Most Likely Locations of Markerel in 2037
Latitude(N)
Longitude(E)
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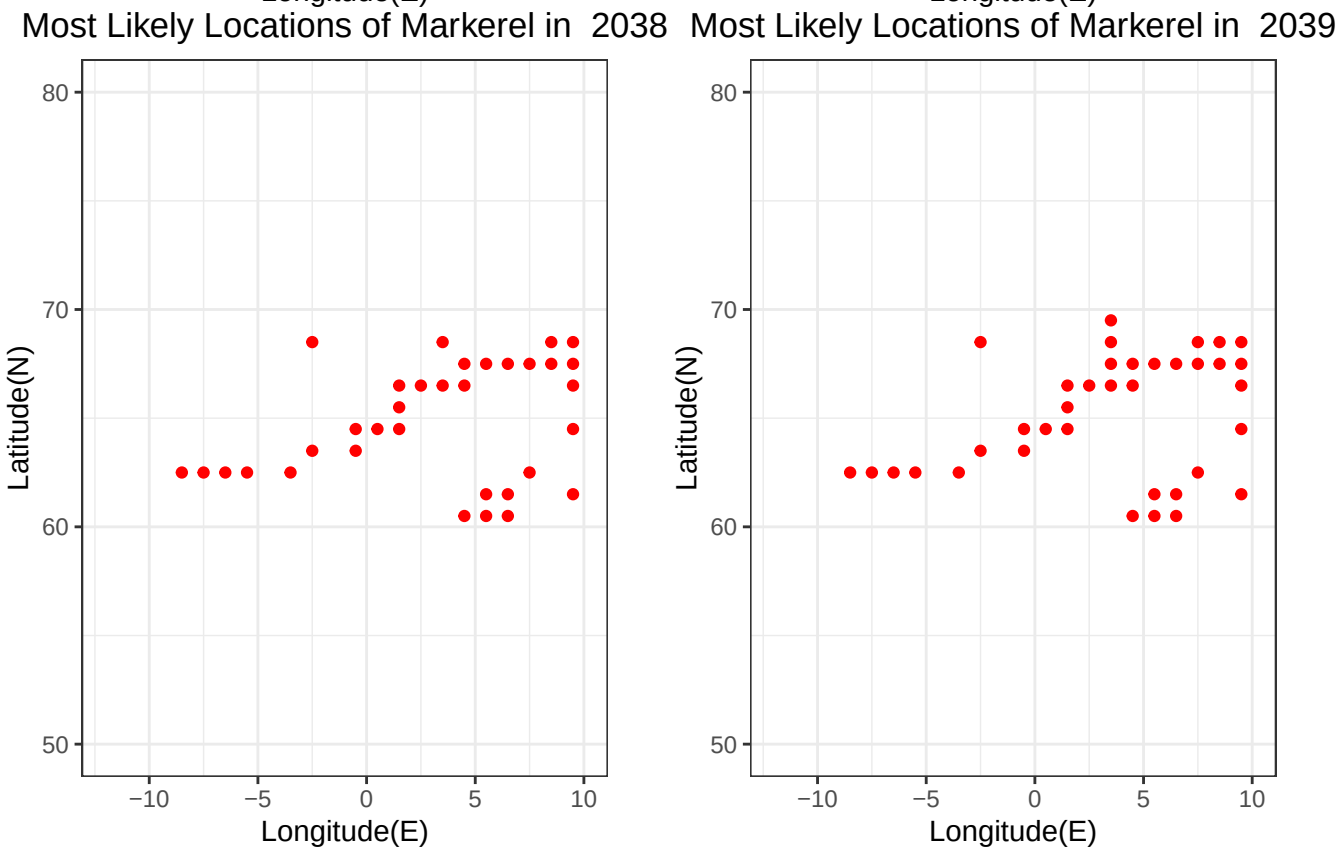
Most Likely Locations of Markerel in 2038
Most Likely Locations of Markerel in 2039
Latitude(N)
Longitude(E)
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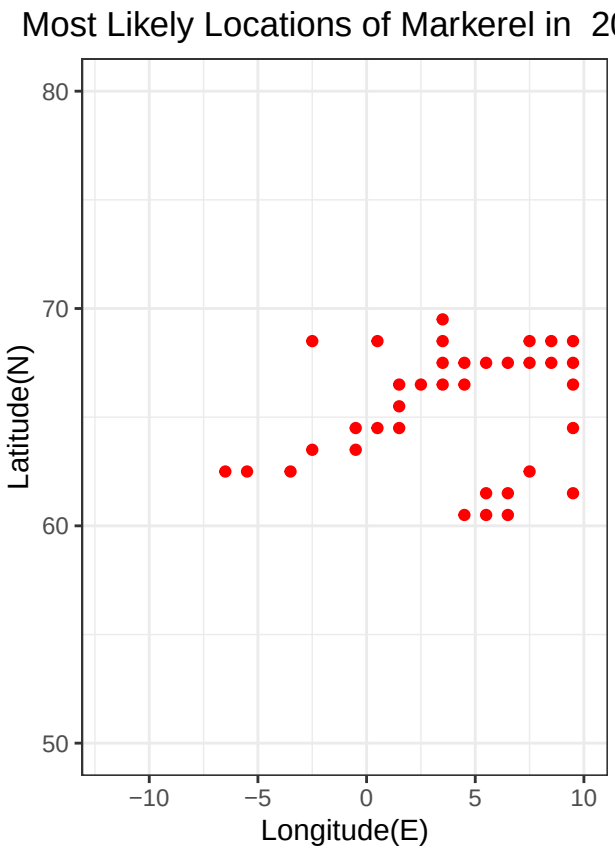
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2040
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
0
5
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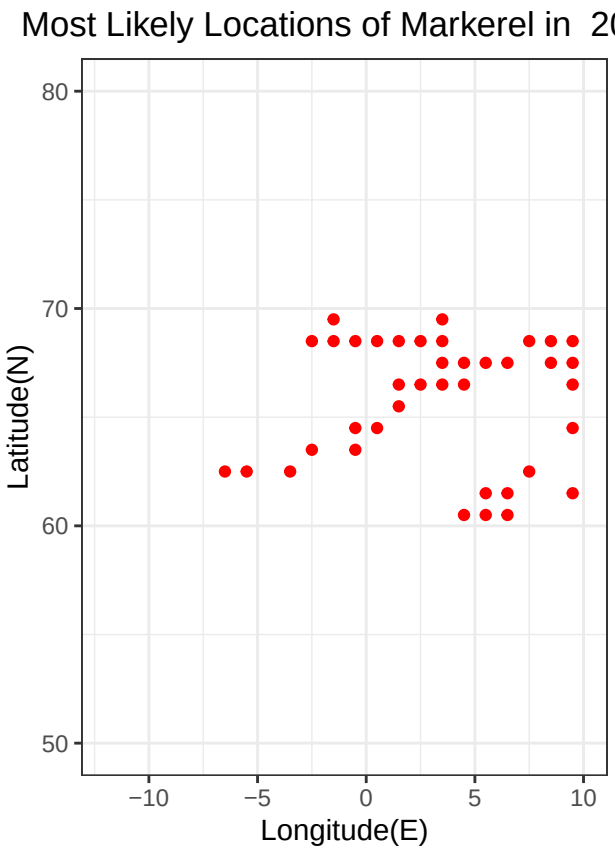
Most Likely Locations of Markerel in 2041
Latitude(N)
Longitude(E)
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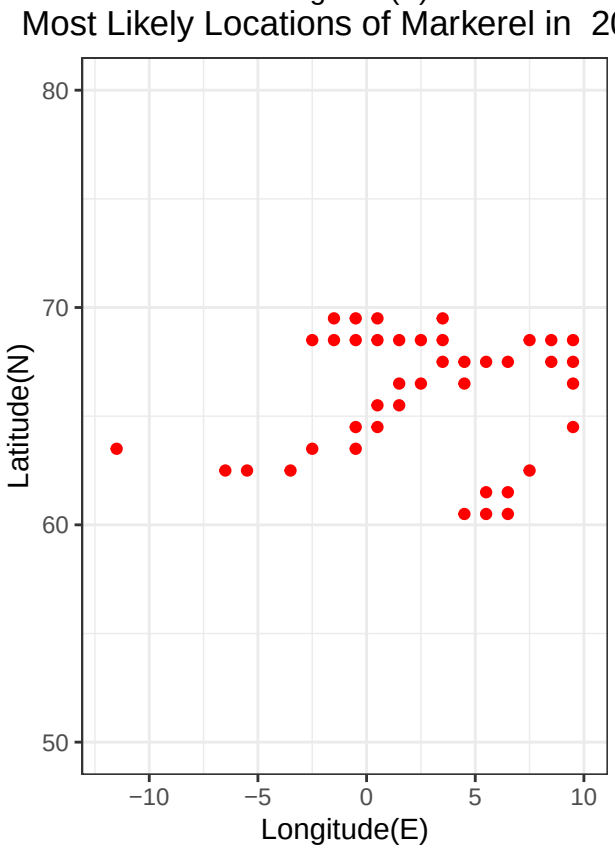
Most Likely Locations of Markerel in 2042
Latitude(N)
Longitude(E)
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70
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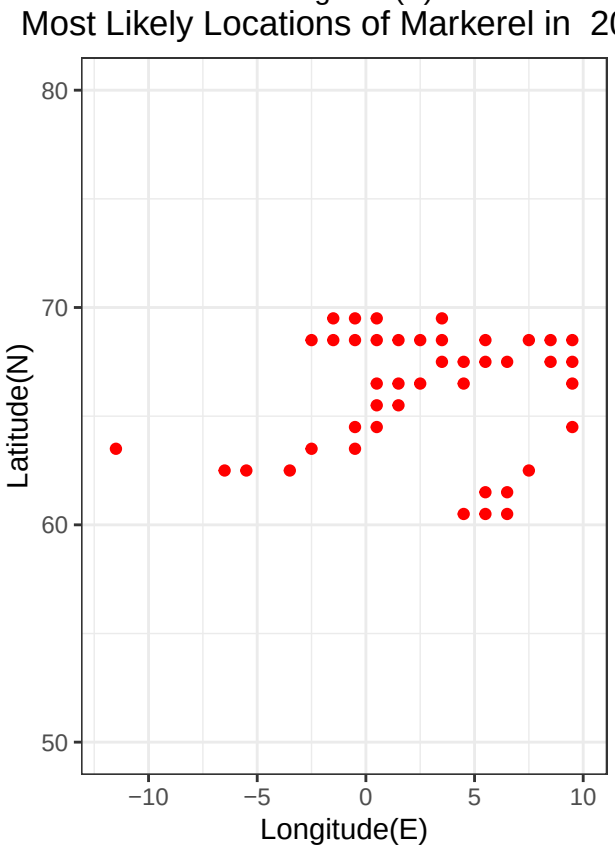
Most Likely Locations of Markerel in 2043
Latitude(N)
Longitude(E)
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60
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5
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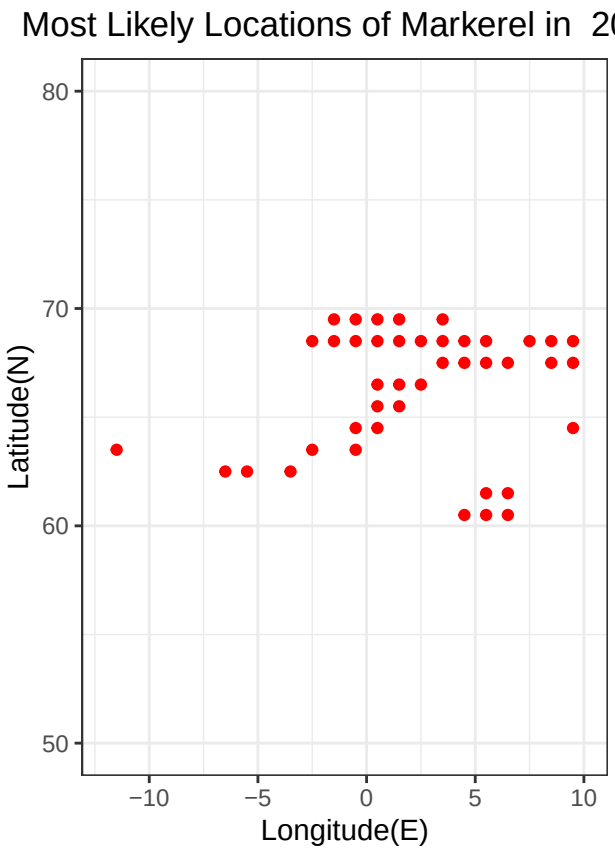
Most Likely Locations of Markerel in 2044
Latitude(N)
Longitude(E)
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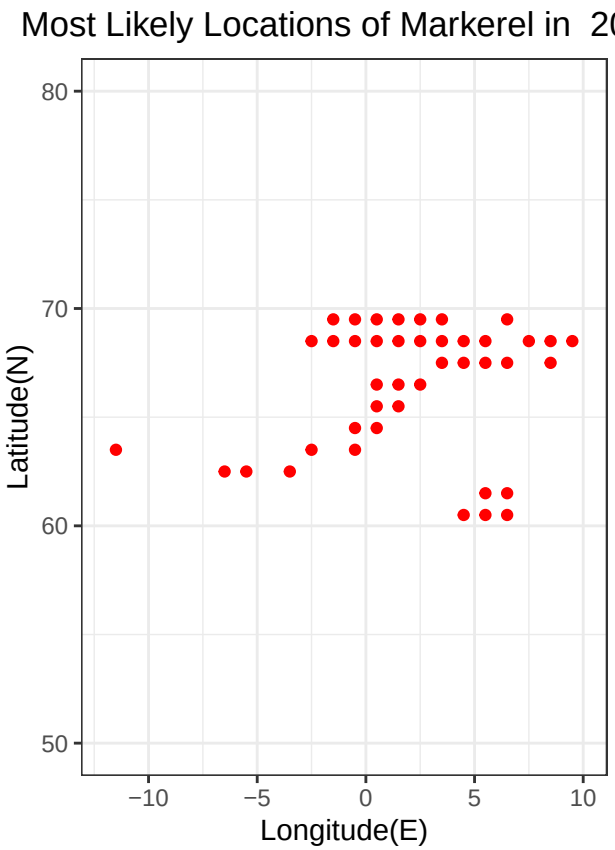
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2045
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
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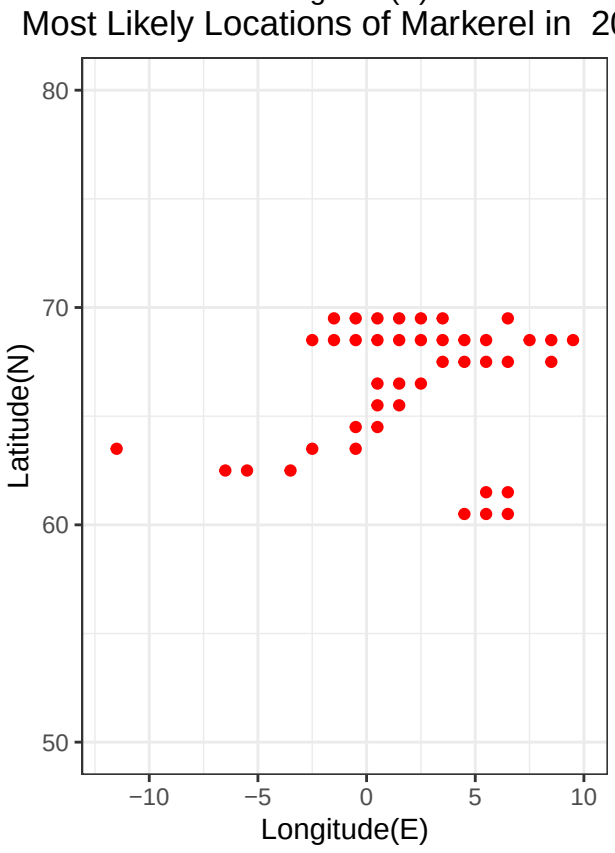
5
10


Most Likely Locations of Markerel in 2046
Latitude(N)
Longitude(E)
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70
60
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−10
−5
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5
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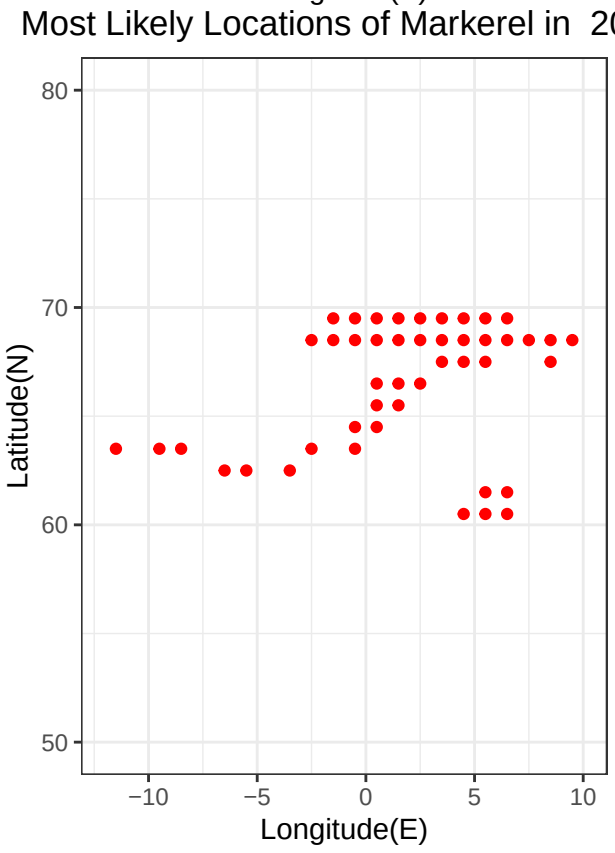
Most Likely Locations of Markerel in 2047
Latitude(N)
Longitude(E)
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60
50
−10
−5
0
5
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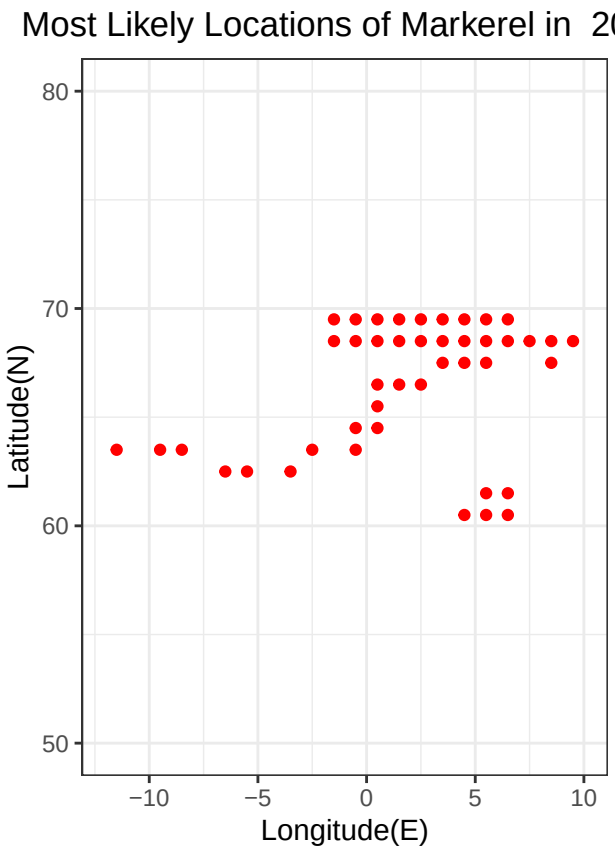
Most Likely Locations of Markerel in 2048
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
0
5
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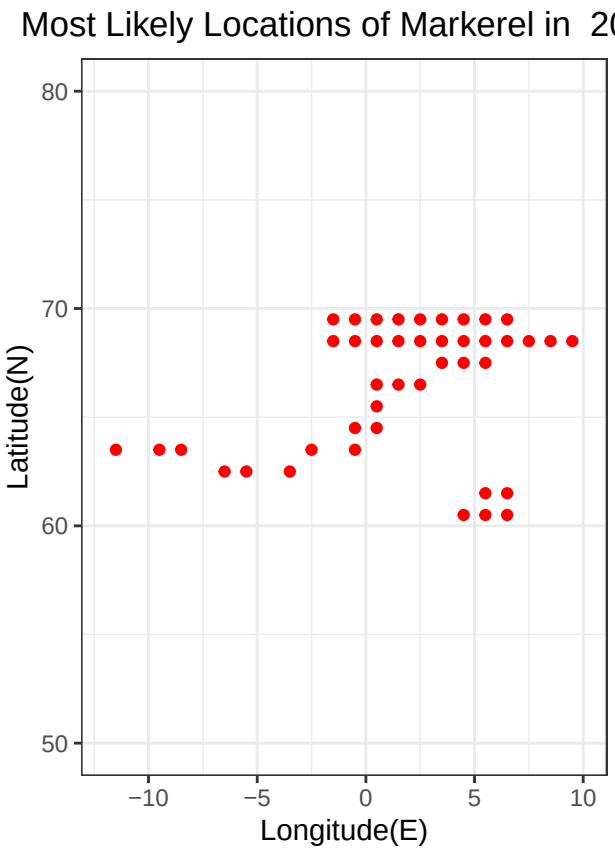
Most Likely Locations of Markerel in 2049
Latitude(N)
Longitude(E)
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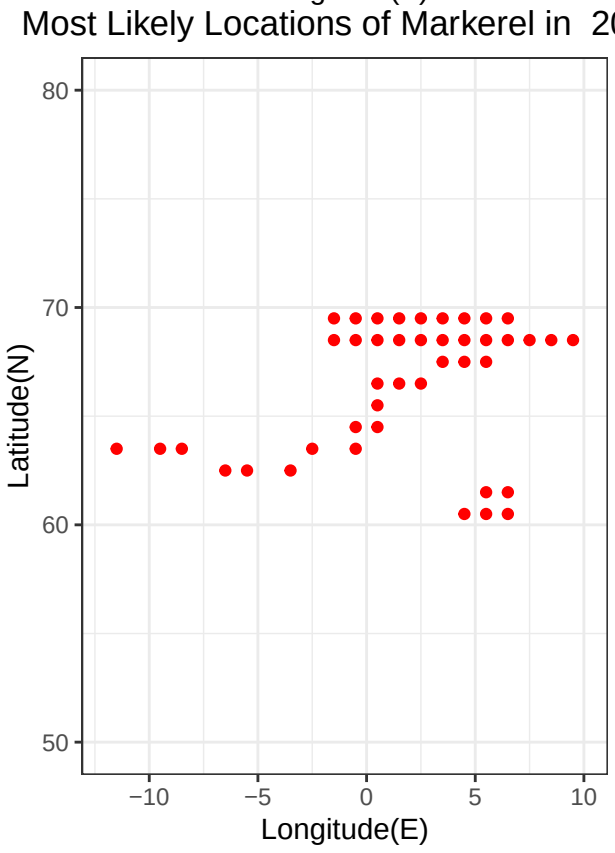
Most Likely Locations of Markerel in 2050
Latitude(N)
Longitude(E)
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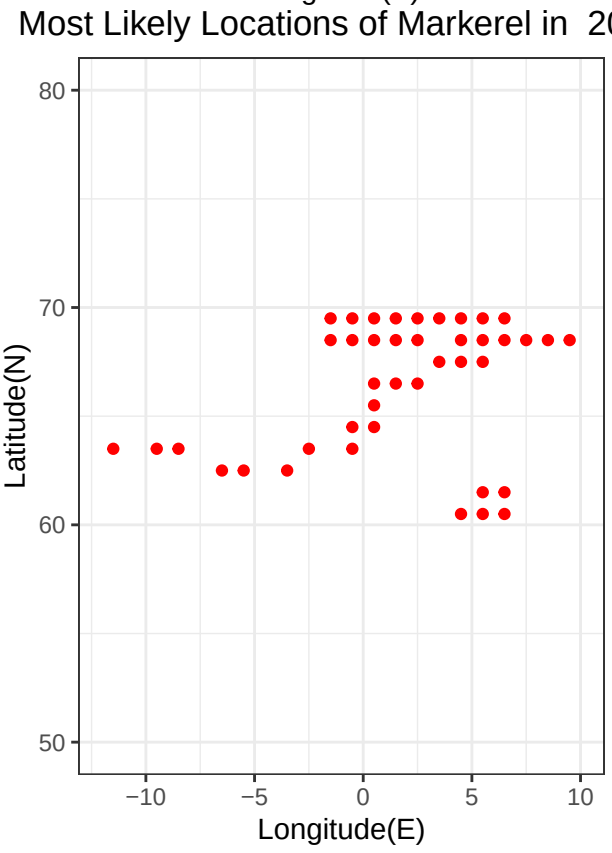
Most Likely Locations of Markerel in 2051
Latitude(N)
Longitude(E)
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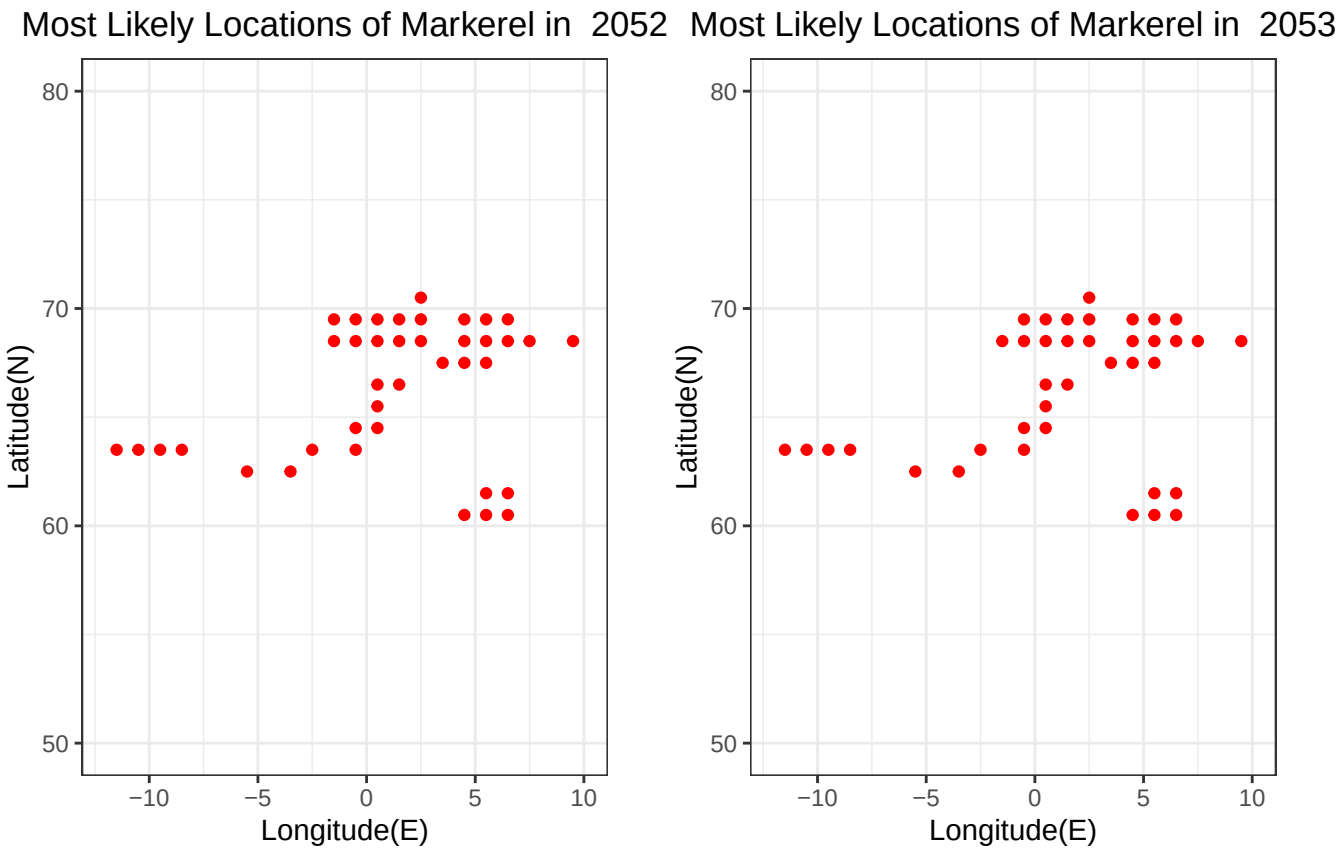
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2052
Most Likely Locations of Markerel in 2053
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
0
5
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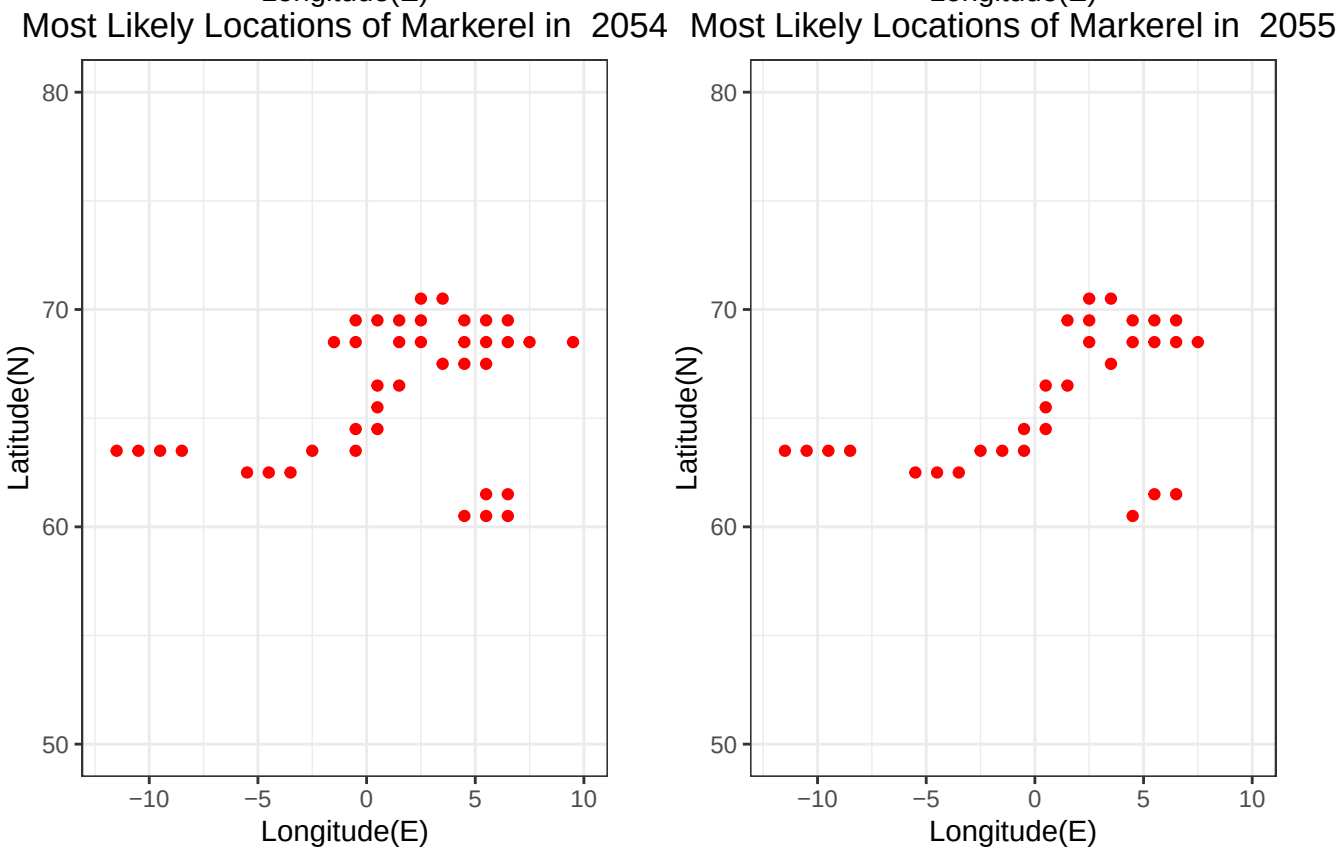
Most Likely Locations of Markerel in 2054
Most Likely Locations of Markerel in 2055
Latitude(N)
Longitude(E)
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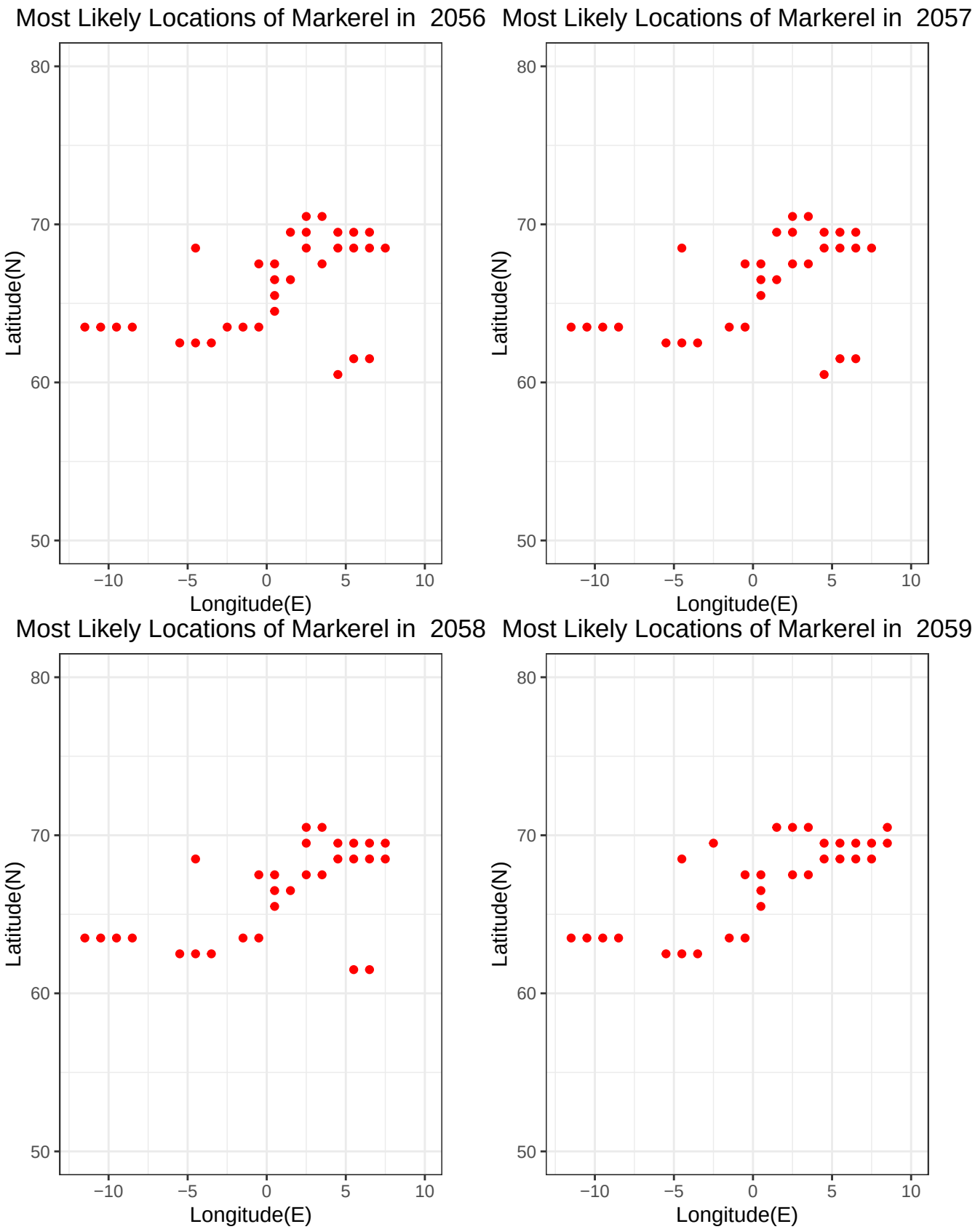
Most Likely Locations of Markerel in 2056
Most Likely Locations of Markerel in 2057
Most Likely Locations of Markerel in 2058
Most Likely Locations of Markerel in 2059
Latitude(N)
Longitude(E)
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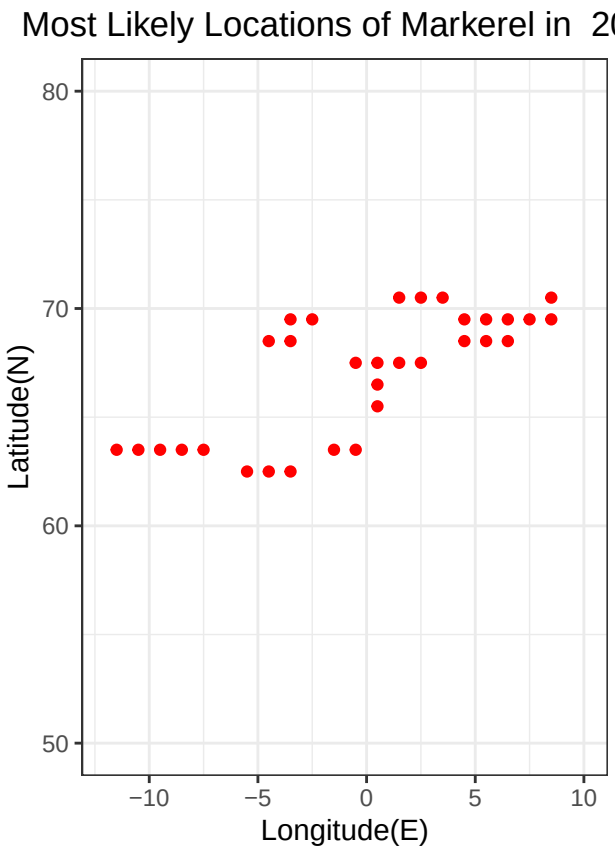
Most Likely Locations of Markerel in 2060
Latitude(N)
Longitude(E)
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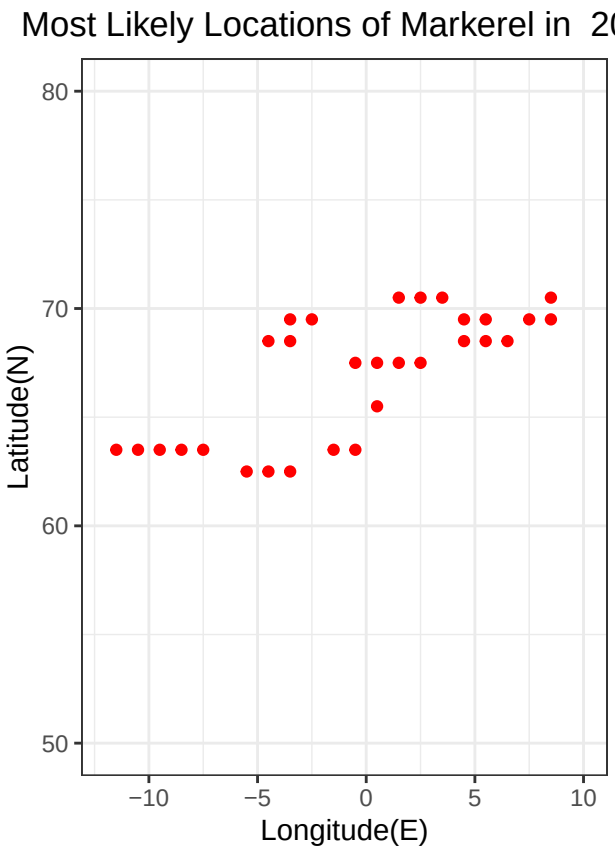
Most Likely Locations of Markerel in 2061
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
0
5
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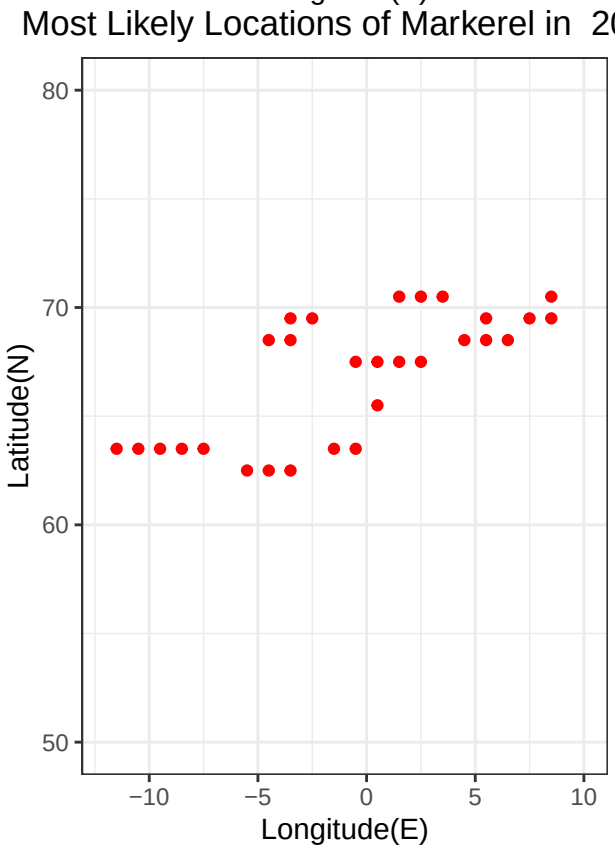
Most Likely Locations of Markerel in 2062
Latitude(N)
Longitude(E)
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70
60
50
−10
−5
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5
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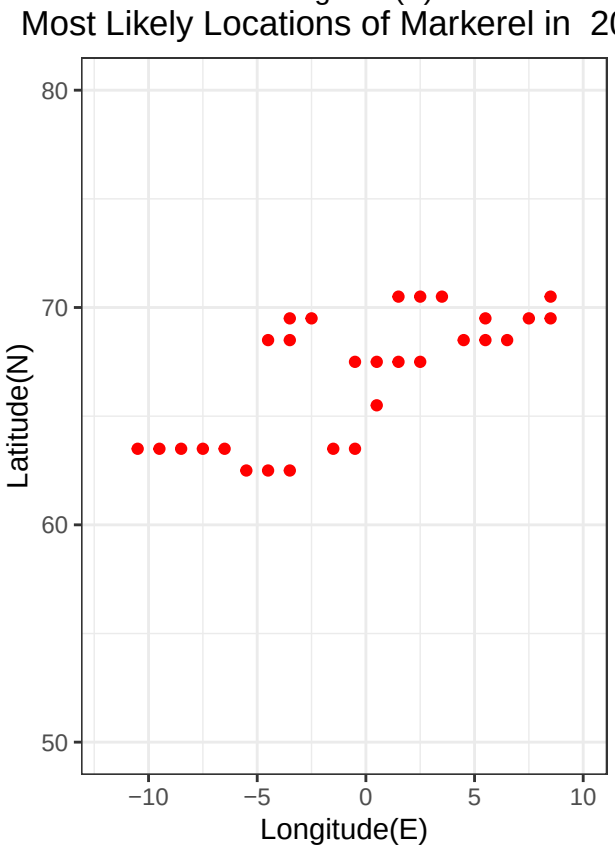
Most Likely Locations of Markerel in 2063
Latitude(N)
Longitude(E)
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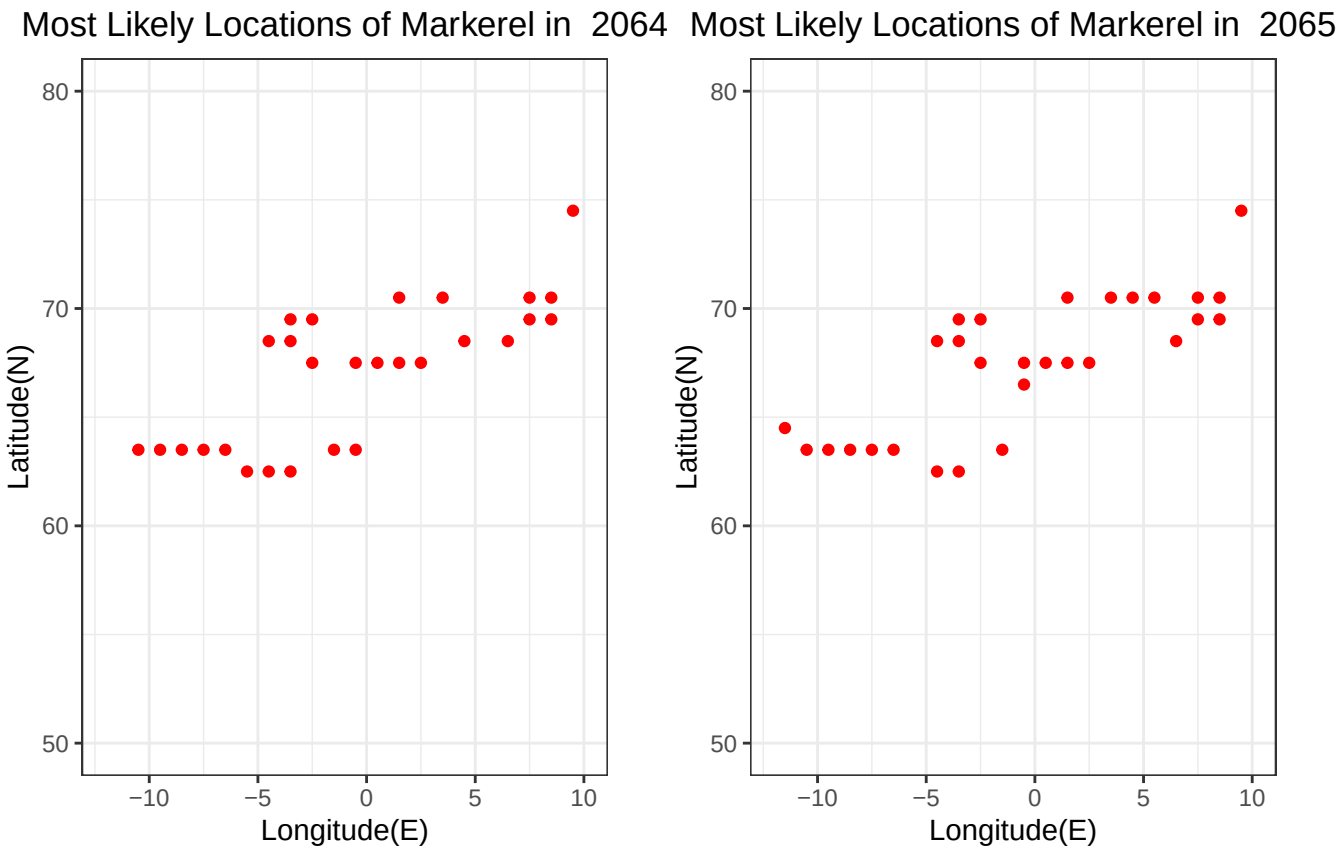
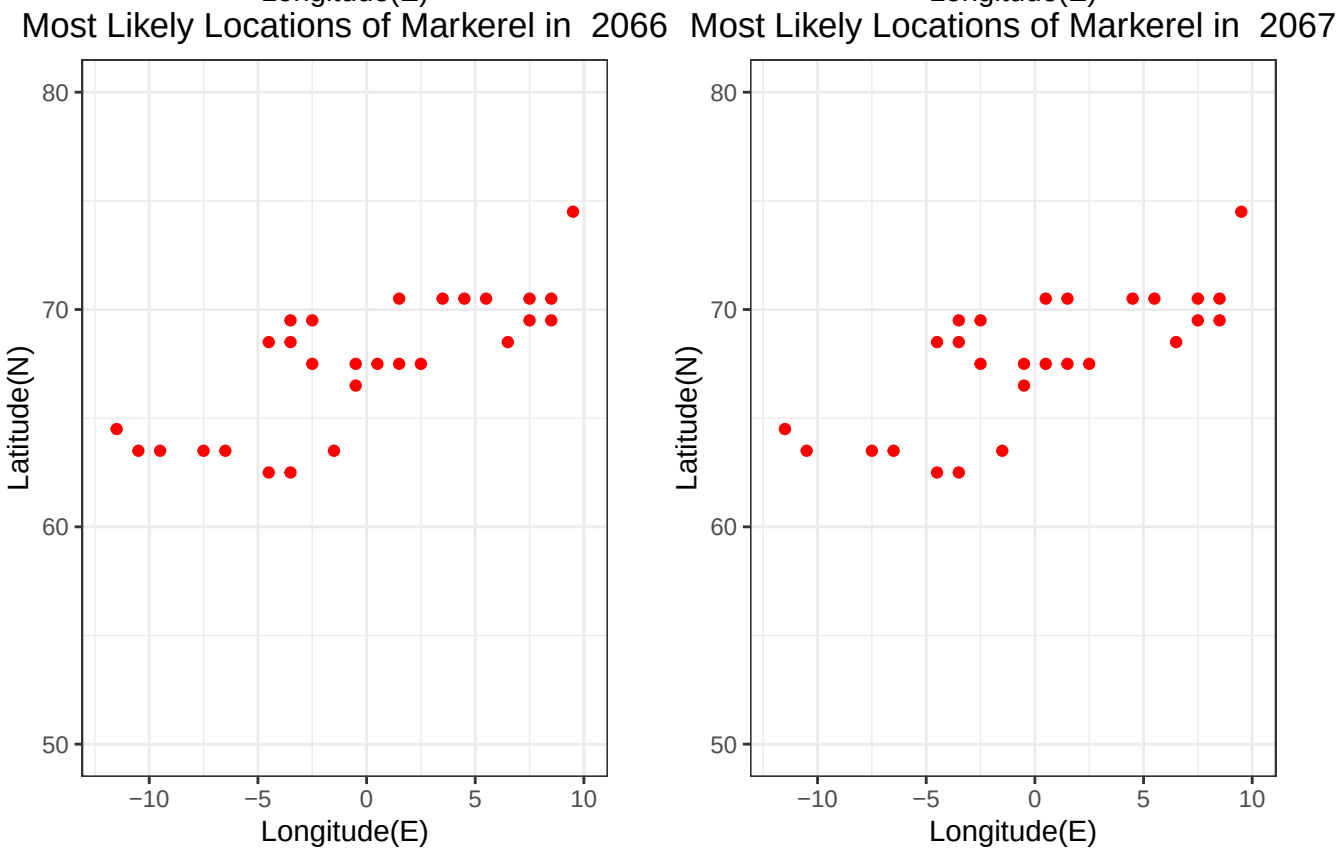
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2064
Most Likely Locations of Markerel in 2065
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Markerel in 2066
Most Likely Locations of Markerel in 2067
Latitude(N)
Longitude(E)
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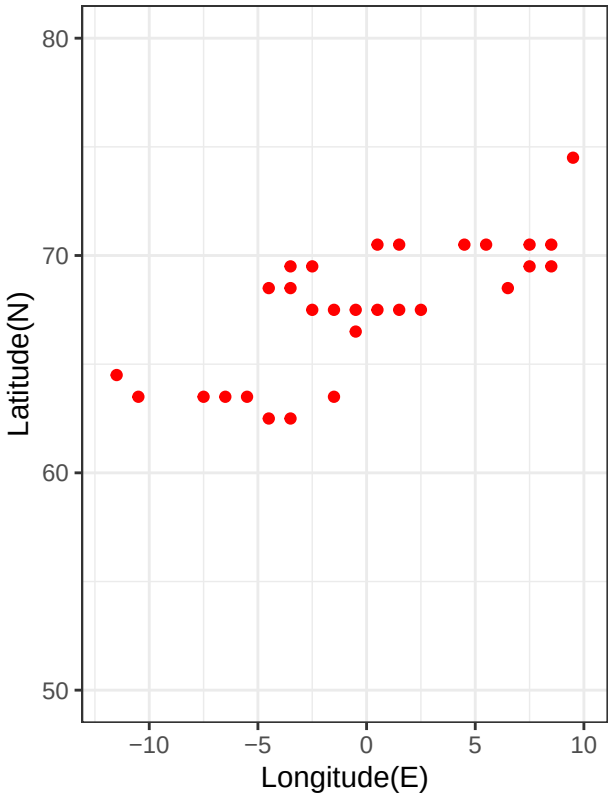
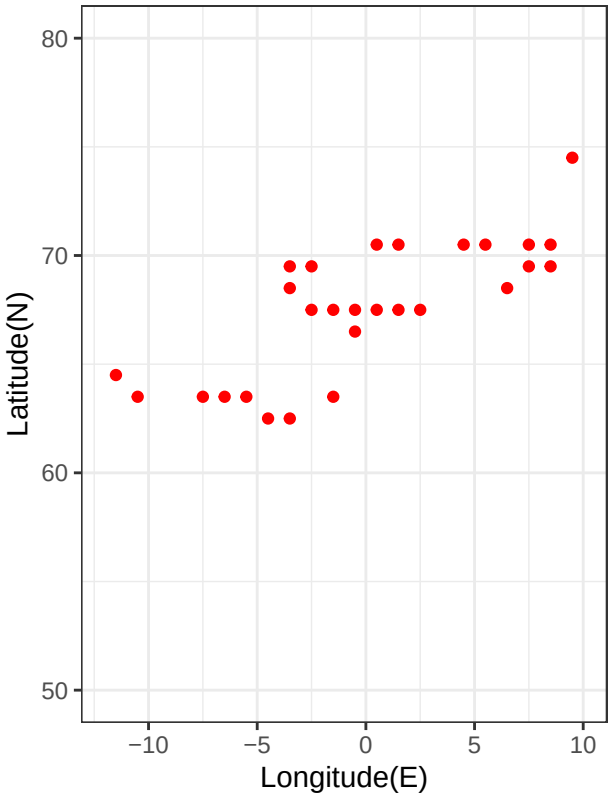
70
60
50
−10
−5
0
5
10

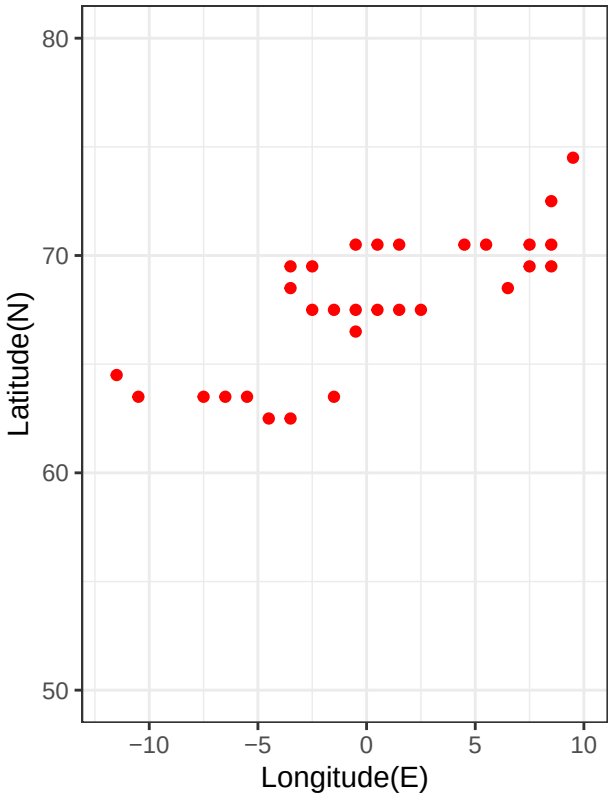
Most Likely Locations of Markerel in 2068



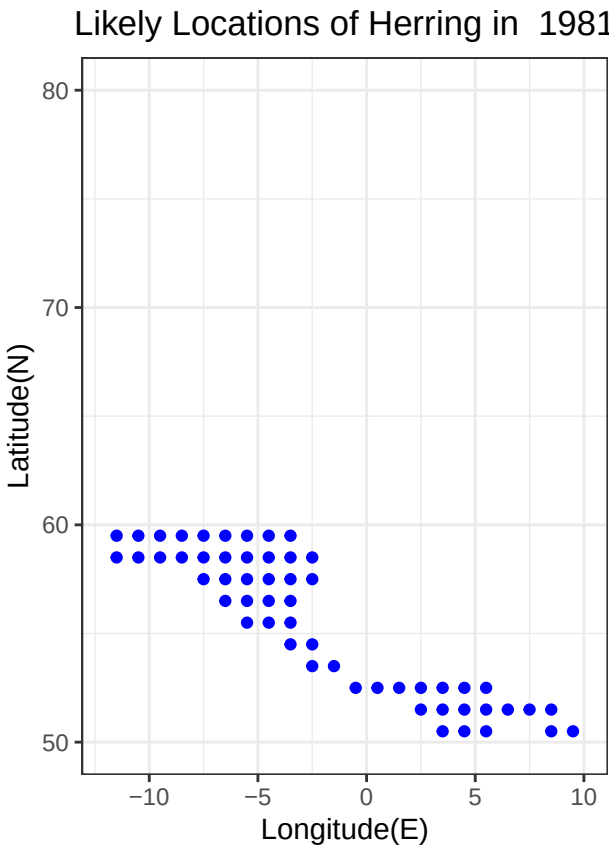
Most Likely Locations of Markerel in 2069

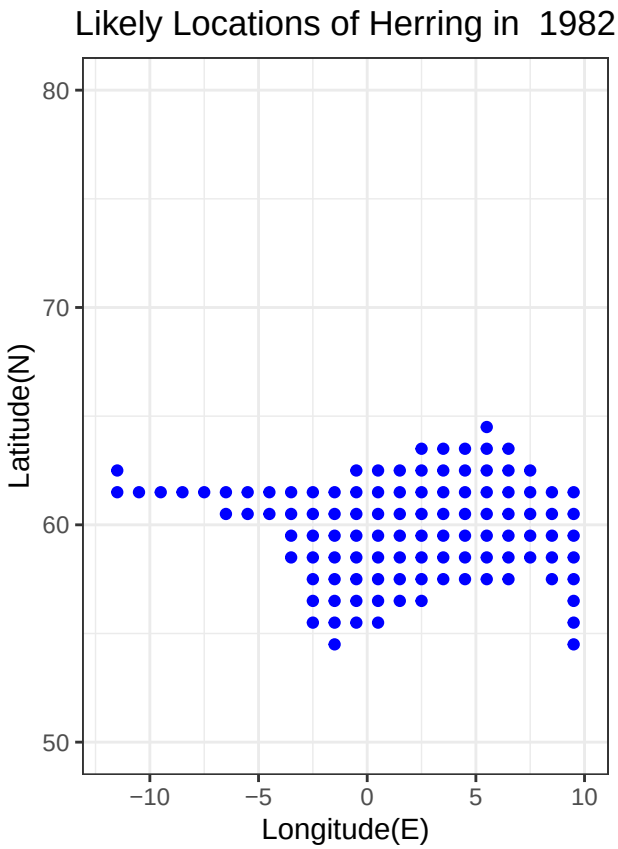


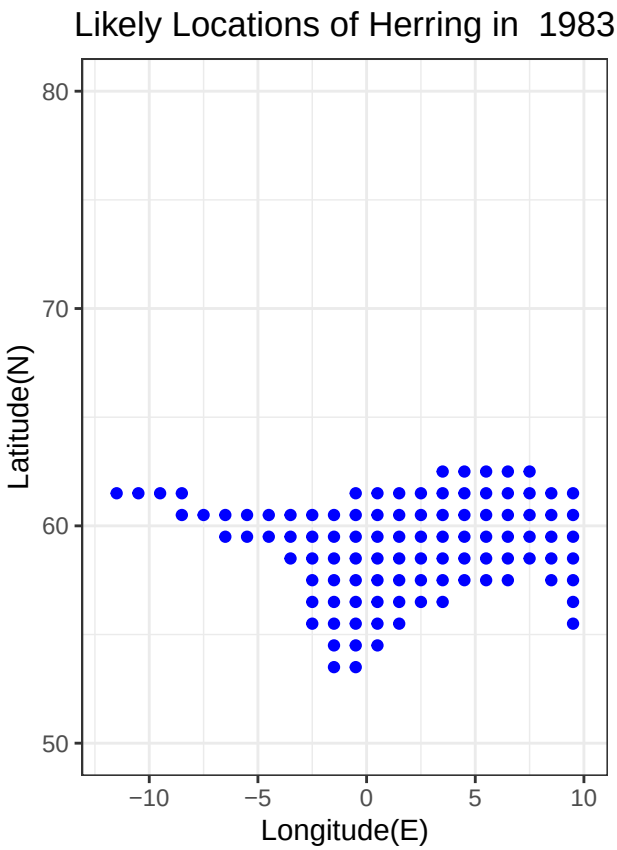
Most Likely Locations of Markerel in 2070

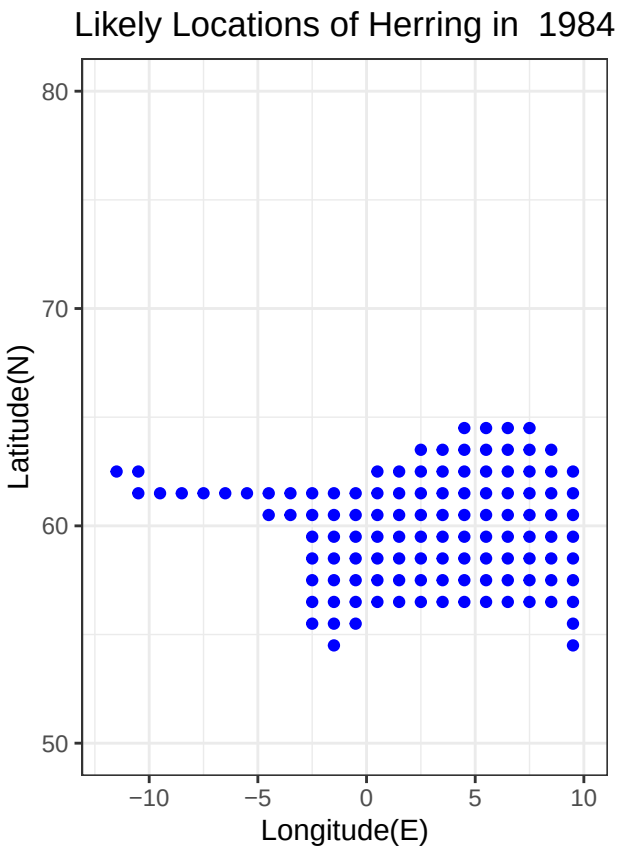


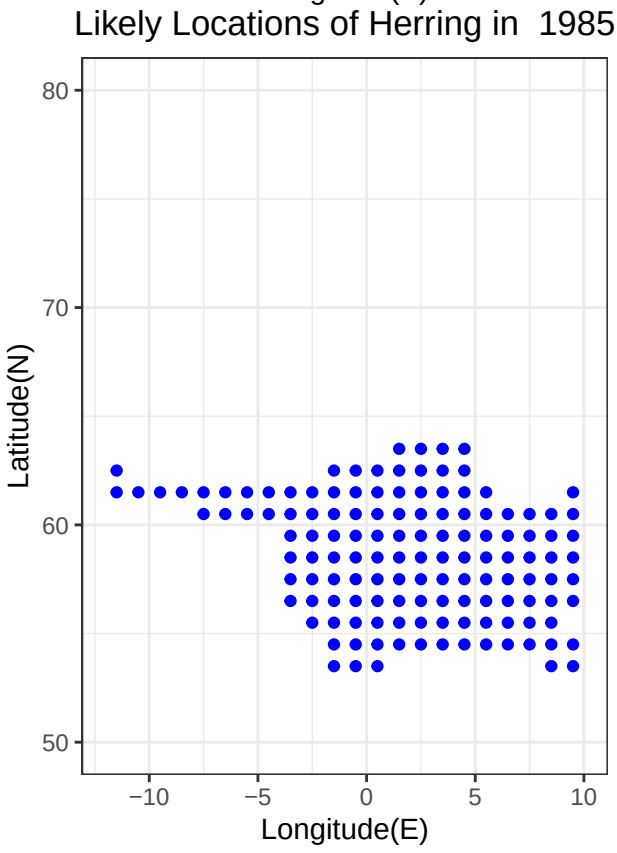
```
for (i in 1981:2015) {
H1981 <- dataTotal2 %>% filter(avg_temperature < 9.8 & avg_temperature > 8.8 & Time == i)
pH1981 <- ggplot(H1981, aes(Longitude, Latitude)) +
  geom_point(col = "blue") +
  theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +
  ylab("Latitude(N)") +
  ggtitle(paste("Likely Locations of Herring in ", i)) +
  theme(plot.title = element_text(hjust = 0.5))
print(pH1981)
}
```

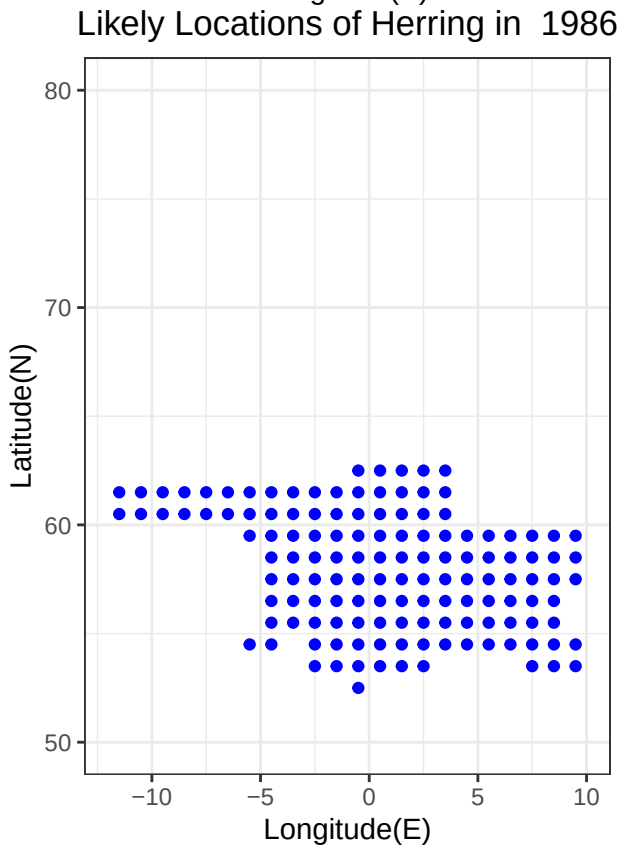


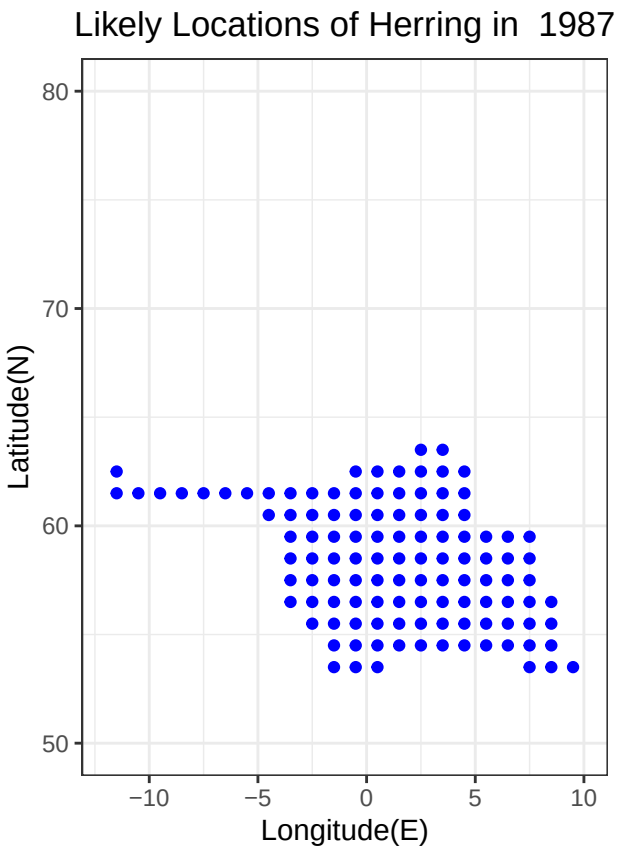


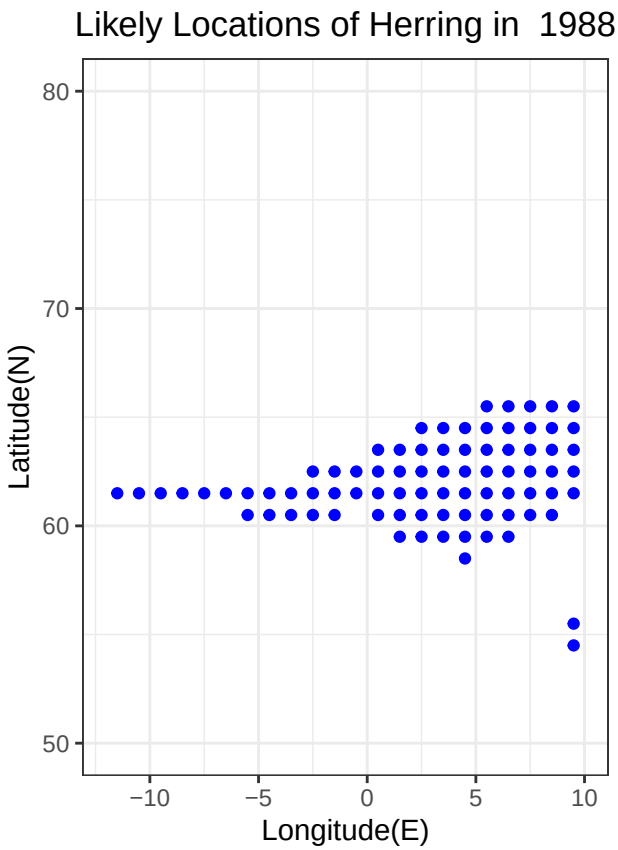

Likely Locations of Herring in 1983
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

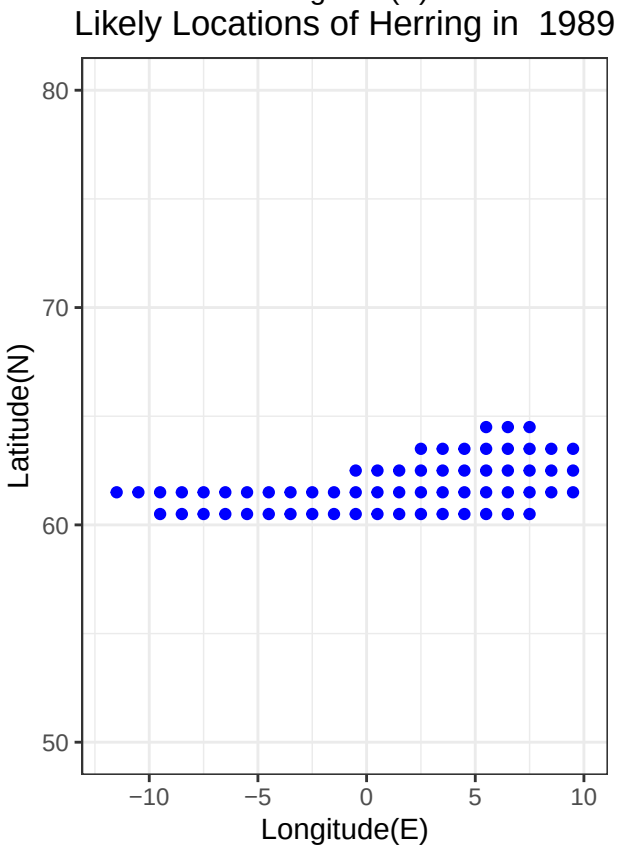

Likely Locations of Herring in 1984
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

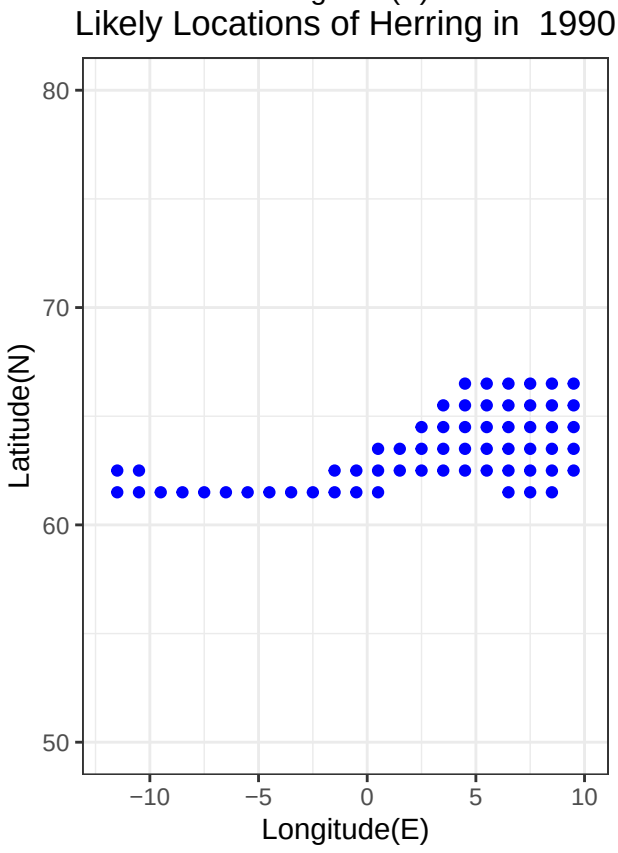

Likely Locations of Herring in 1985
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

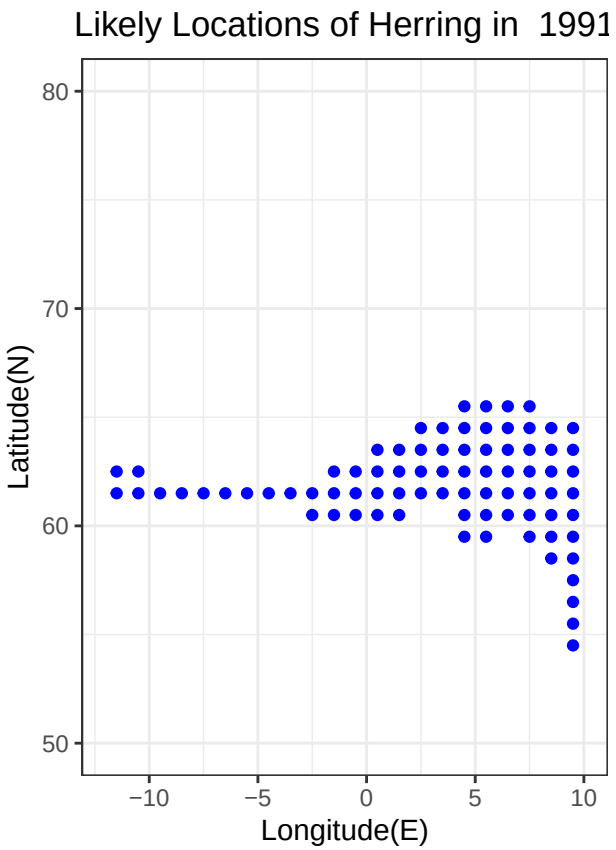

Likely Locations of Herring in 1986
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

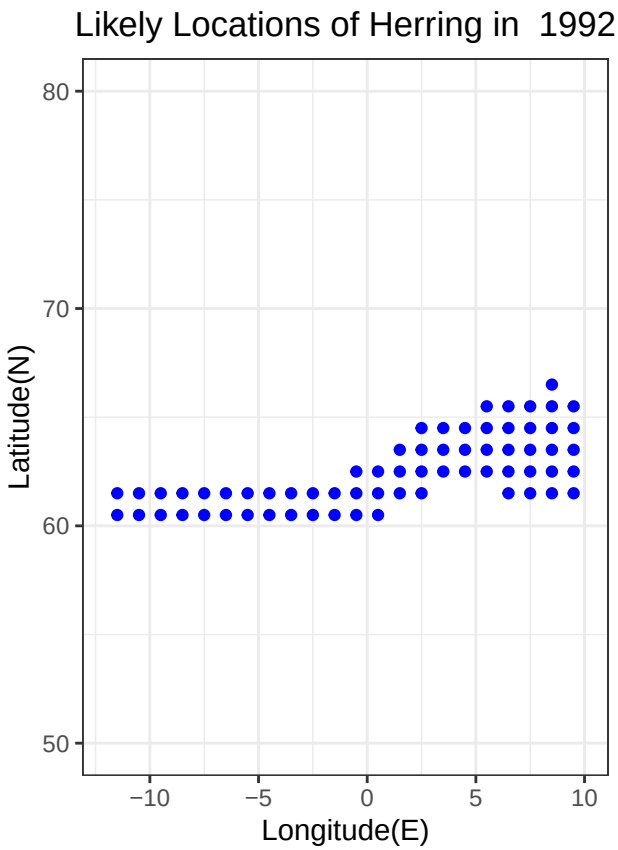

Likely Locations of Herring in 1987
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1988
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1989
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1990
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1991
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1992
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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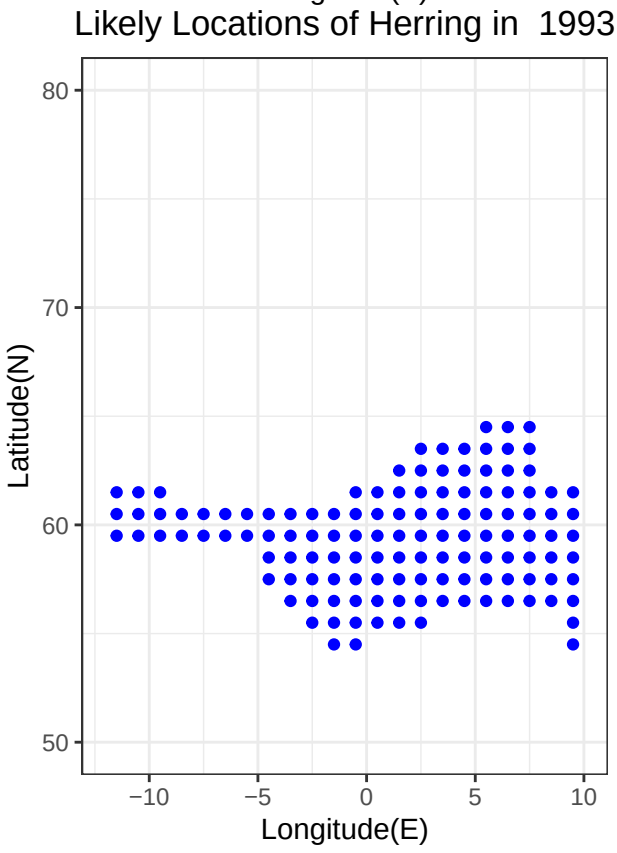
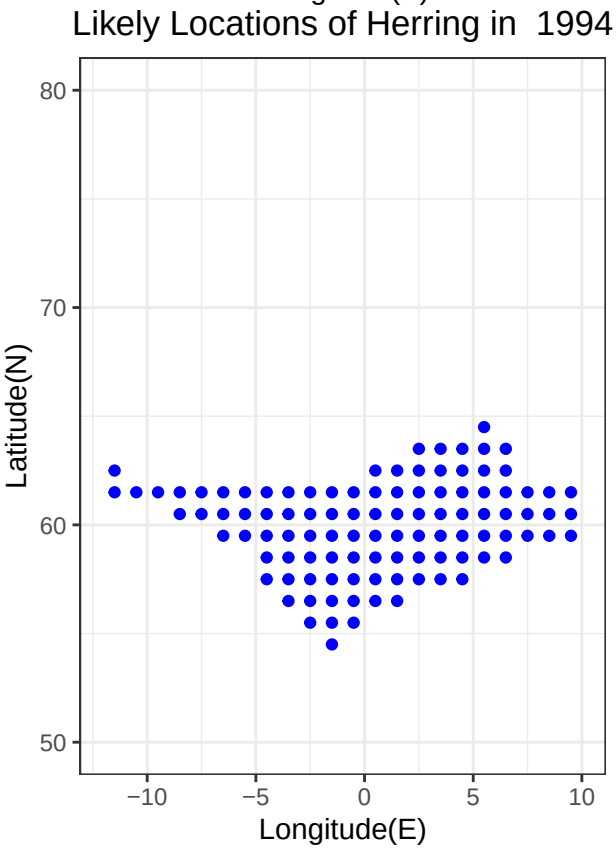

Likely Locations of Herring in 1993
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1994
Latitude(N)
Longitude(E)
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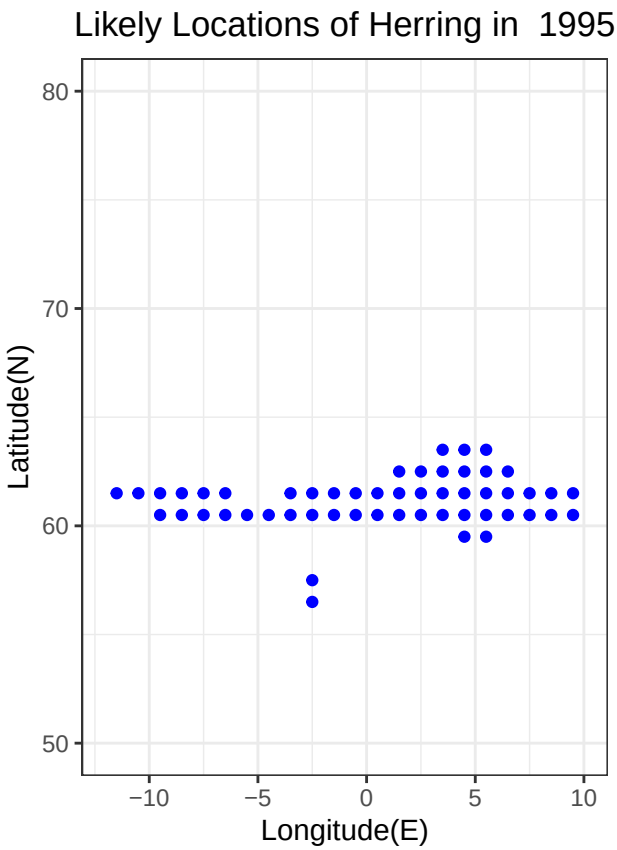
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1995
Latitude(N)
Longitude(E)
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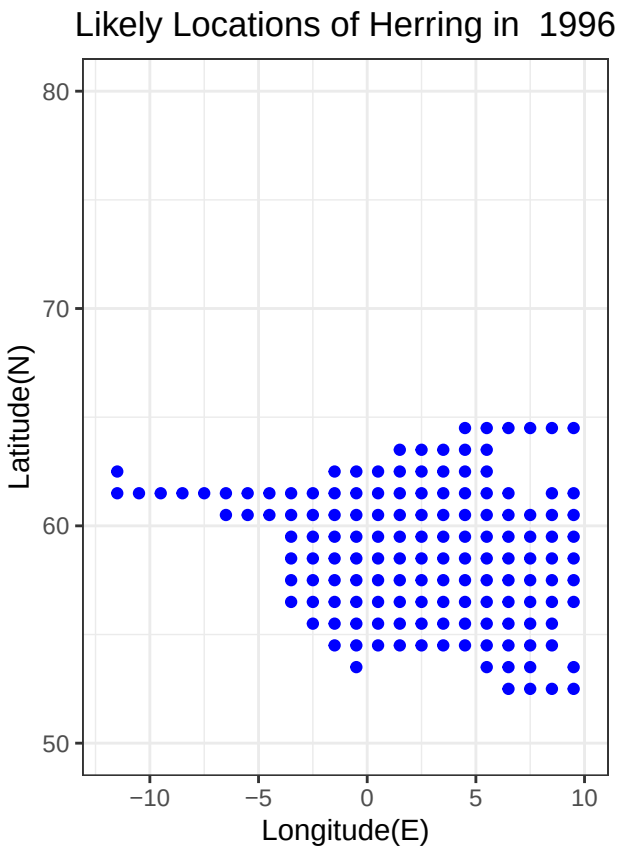
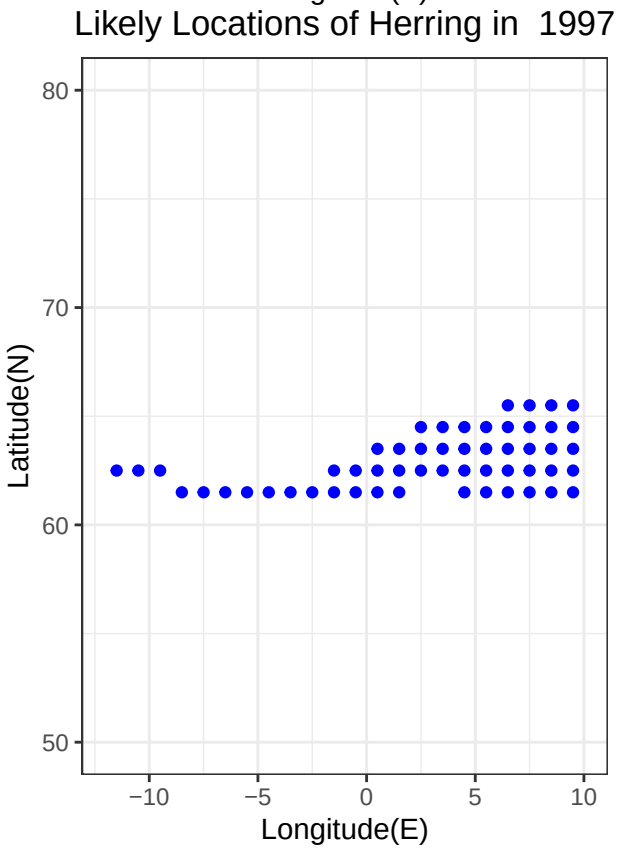
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1996
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1997
Latitude(N)
Longitude(E)
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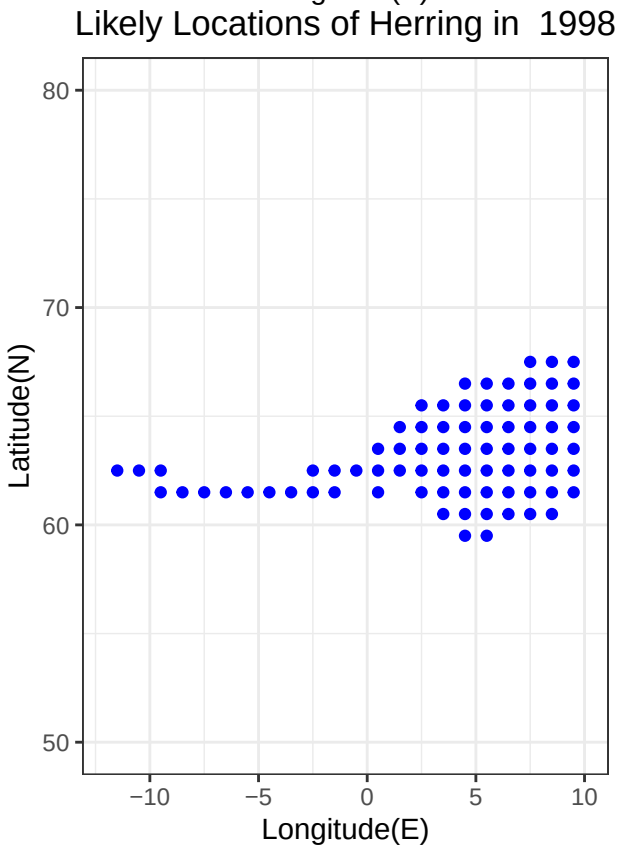
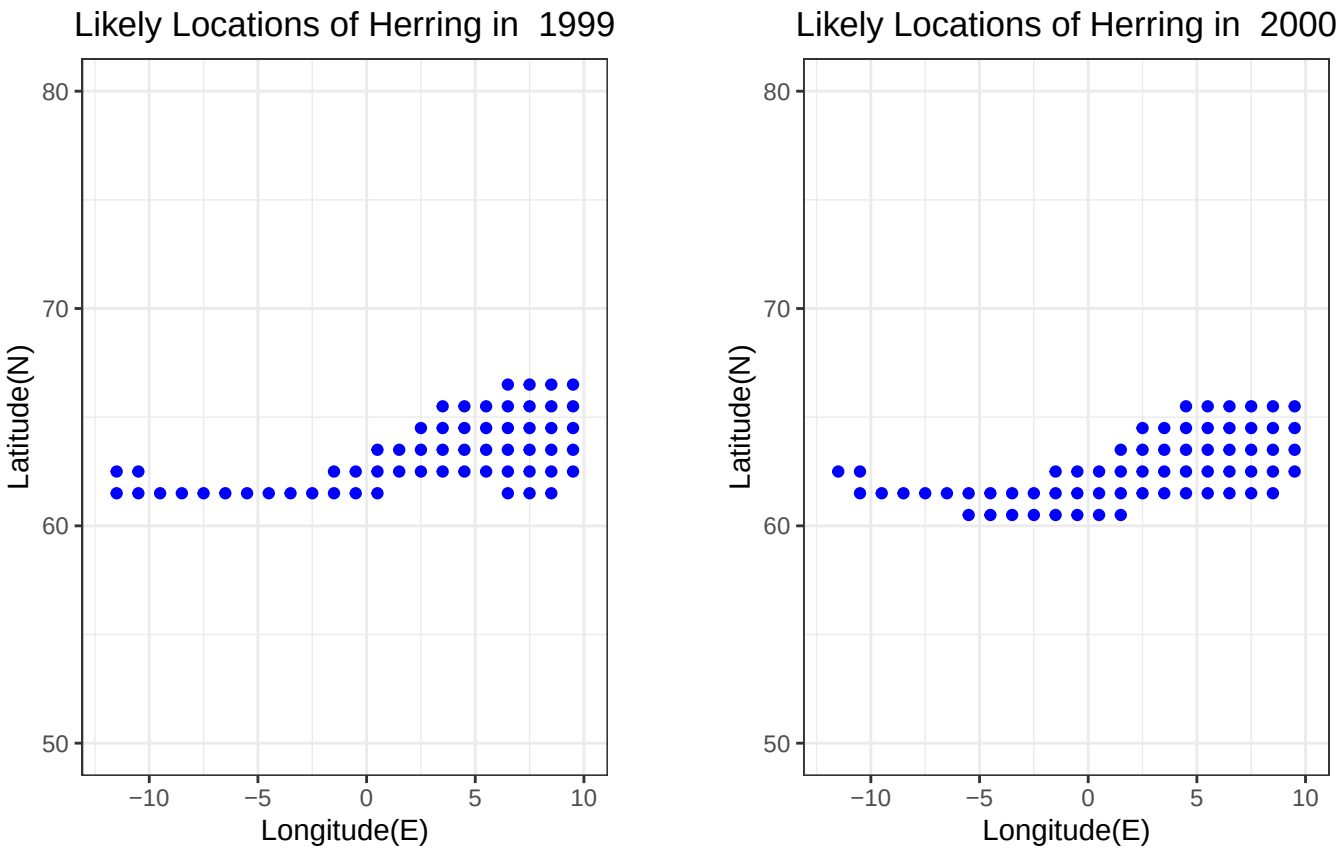
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1998
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 1999
Likely Locations of Herring in 2000
Likely Locations of Herring in 2001
Likely Locations of Herring in 2002
Latitude(N)
Longitude(E)
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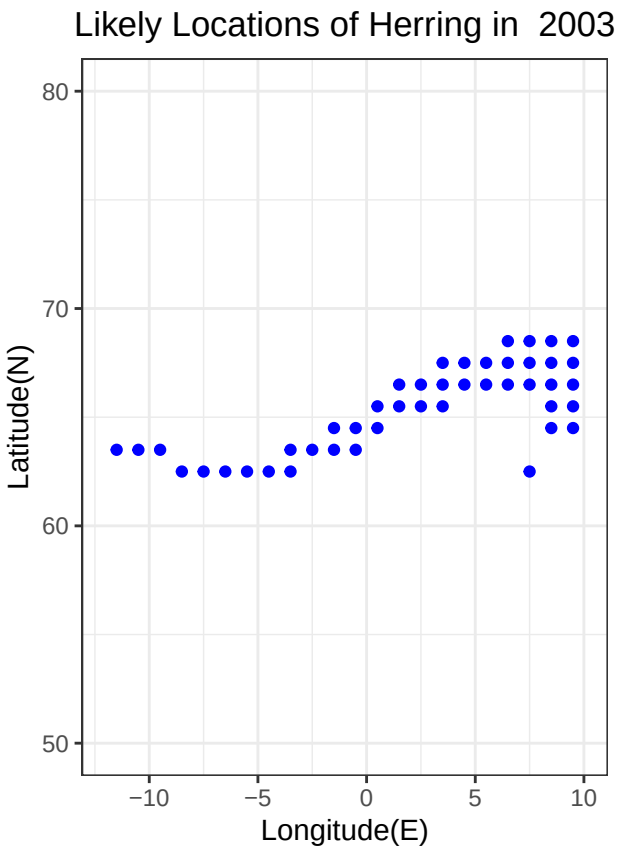
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2003
Latitude(N)
Longitude(E)
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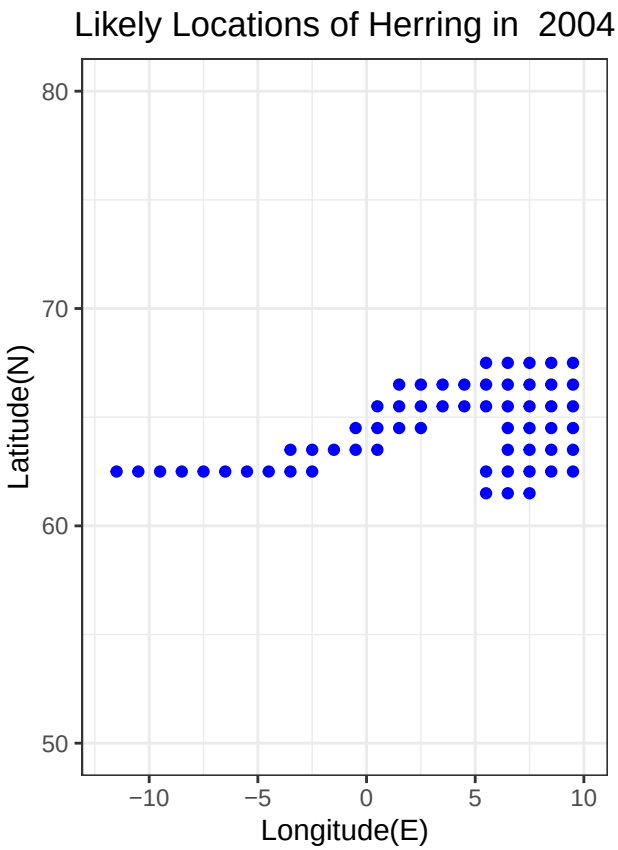
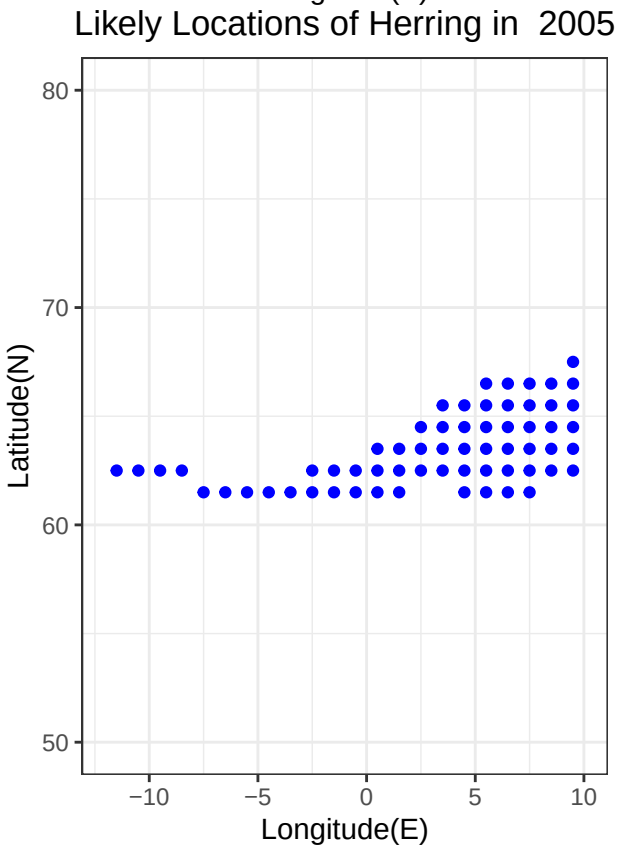
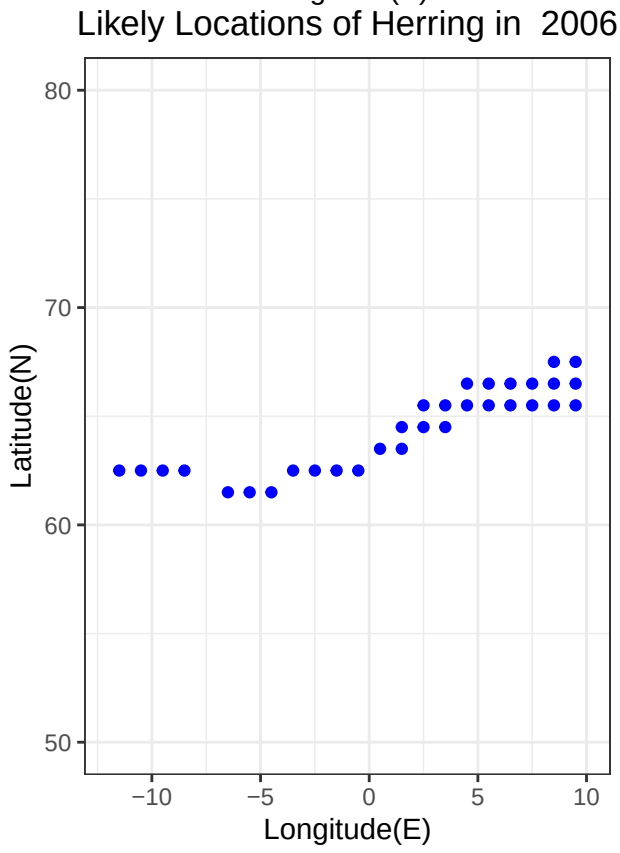
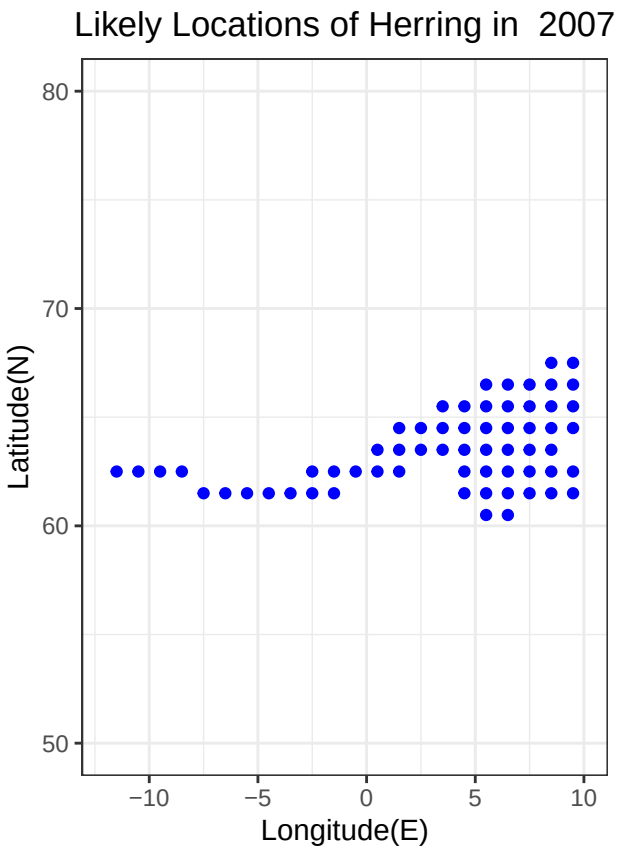
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2004
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2005
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2006
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2007
Latitude(N)
Longitude(E)
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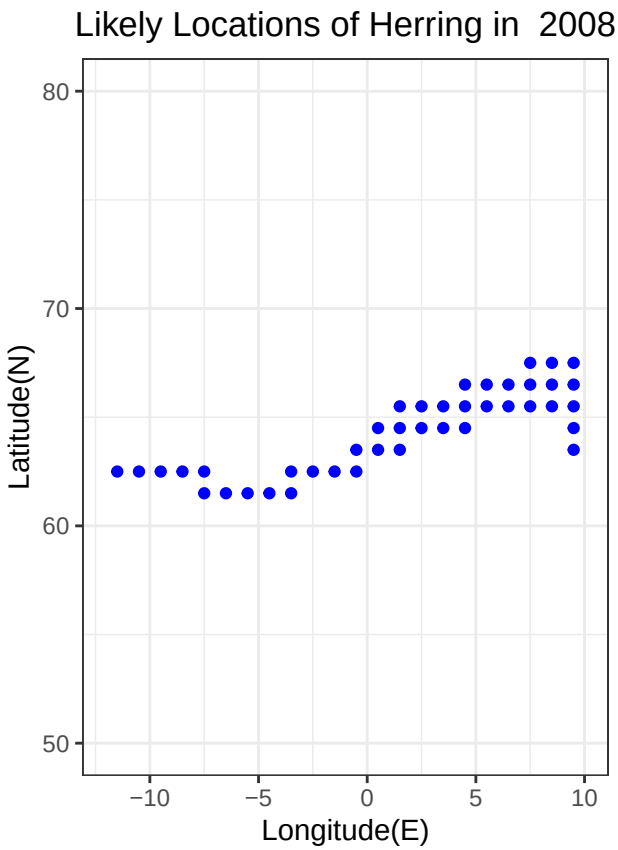
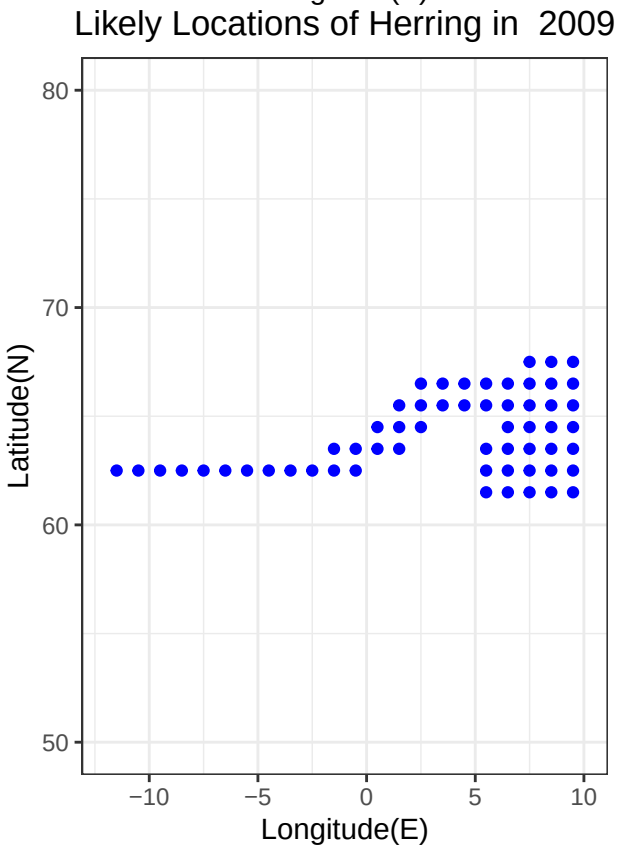
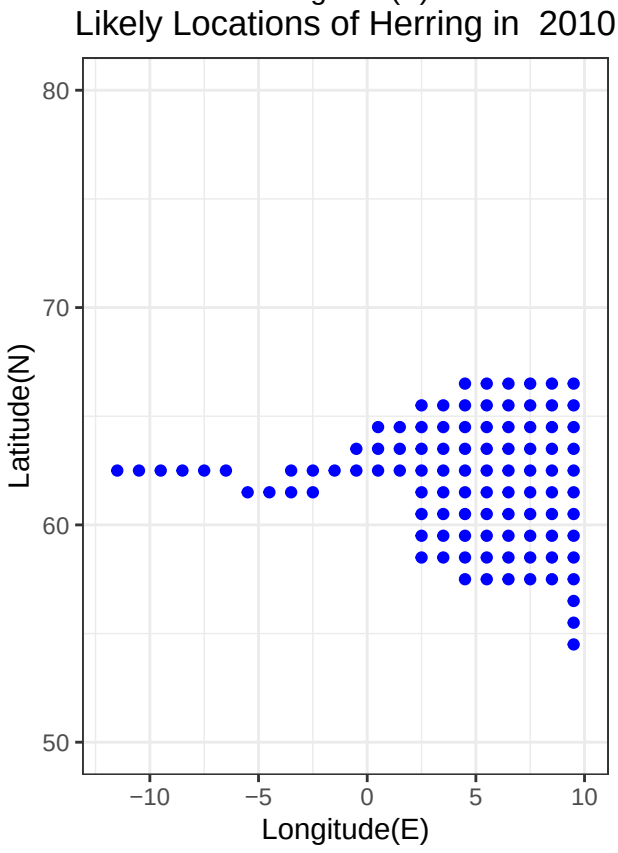
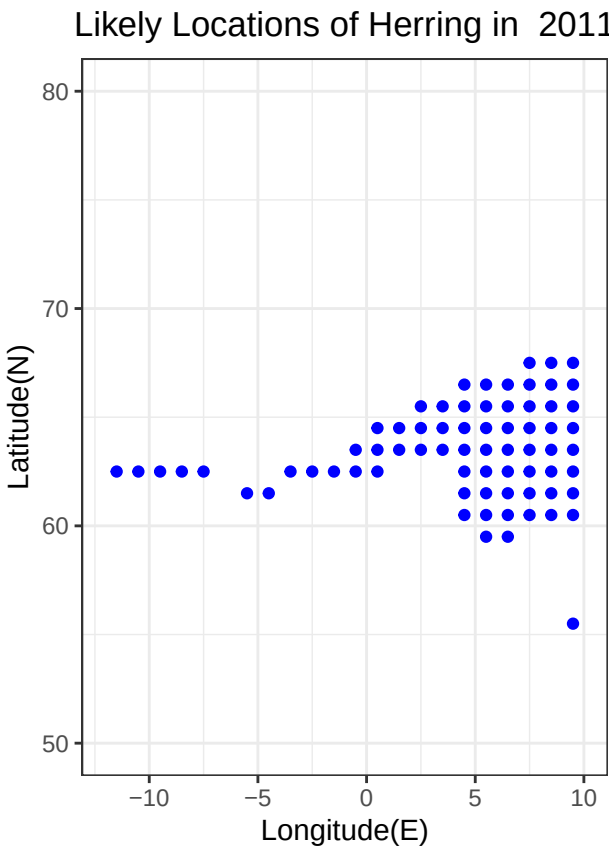
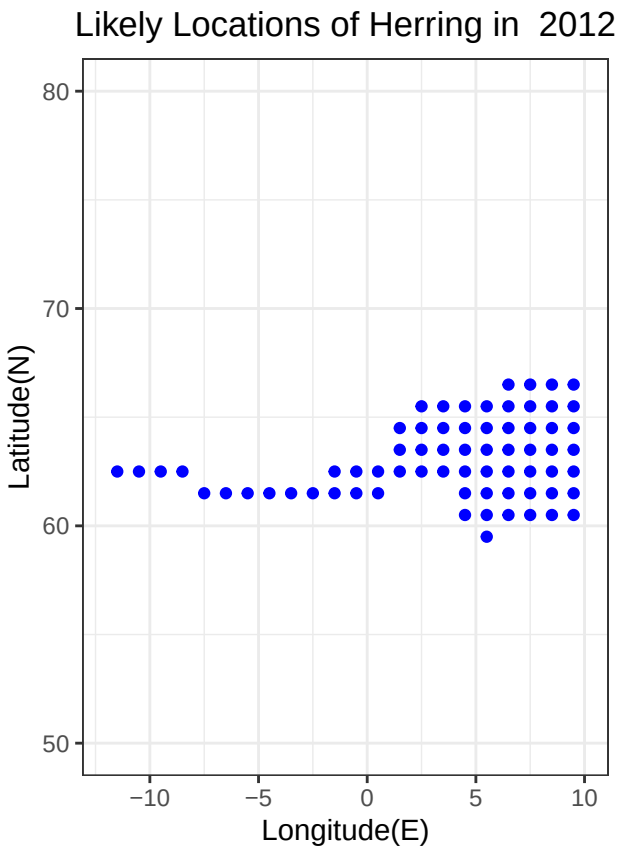
70
60
50
−10
−5
0
5
10

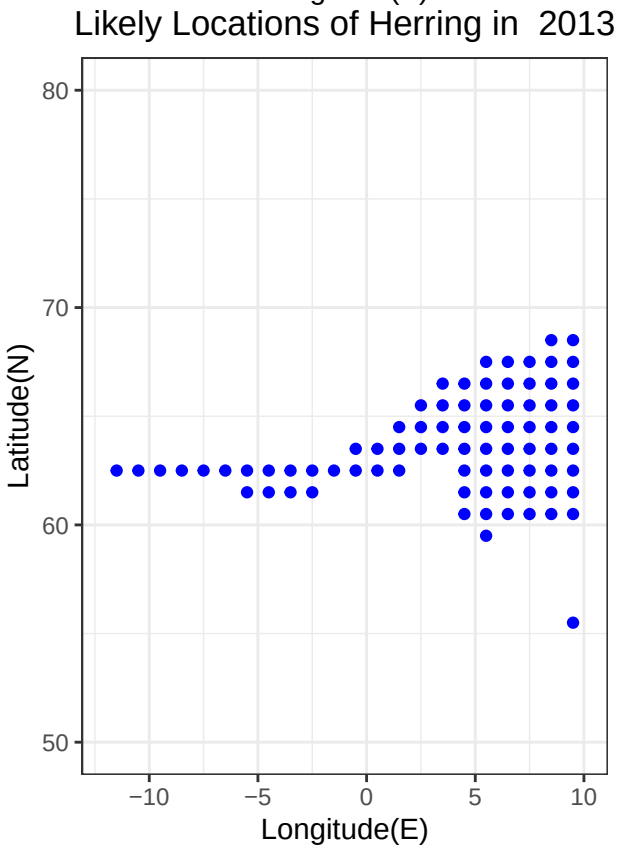

Likely Locations of Herring in 2008
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

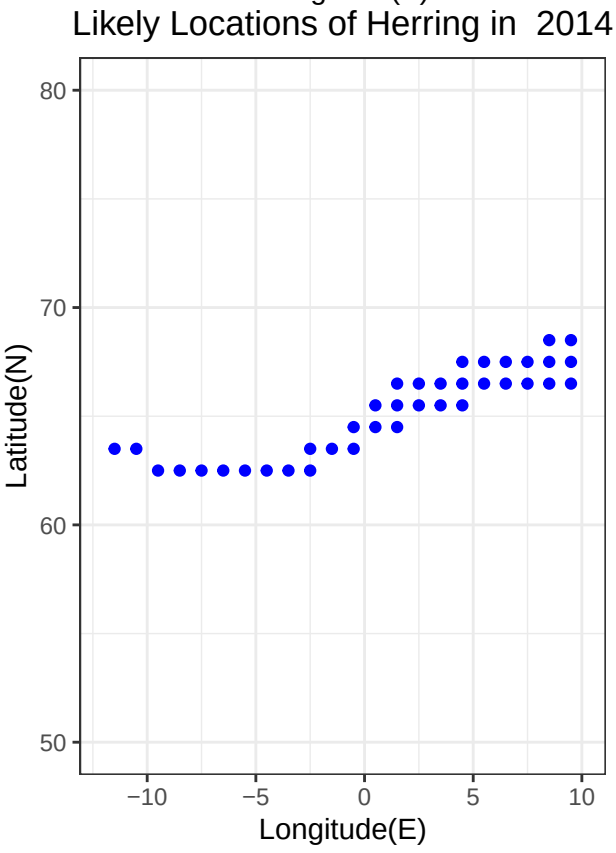

Likely Locations of Herring in 2009
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

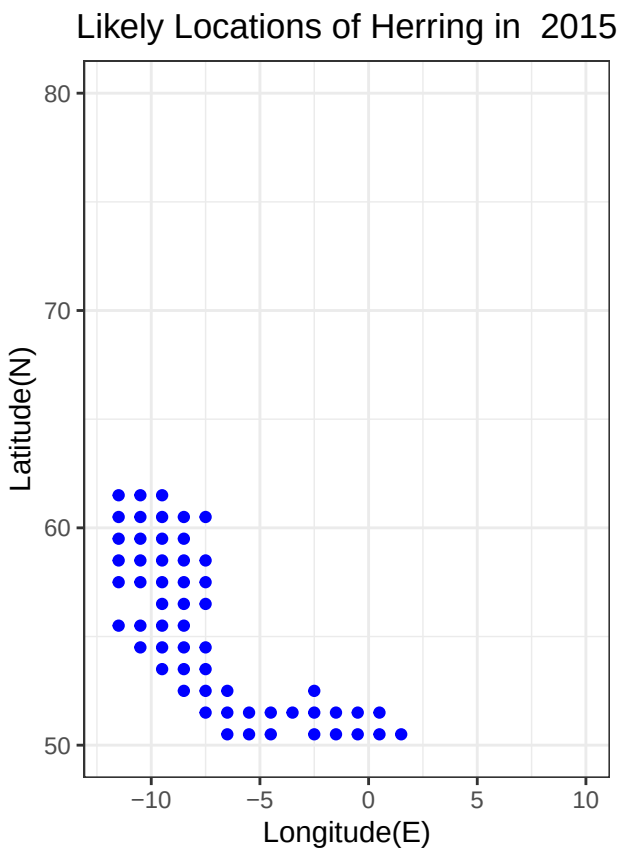

Likely Locations of Herring in 2010
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2011
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Herring in 2012
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

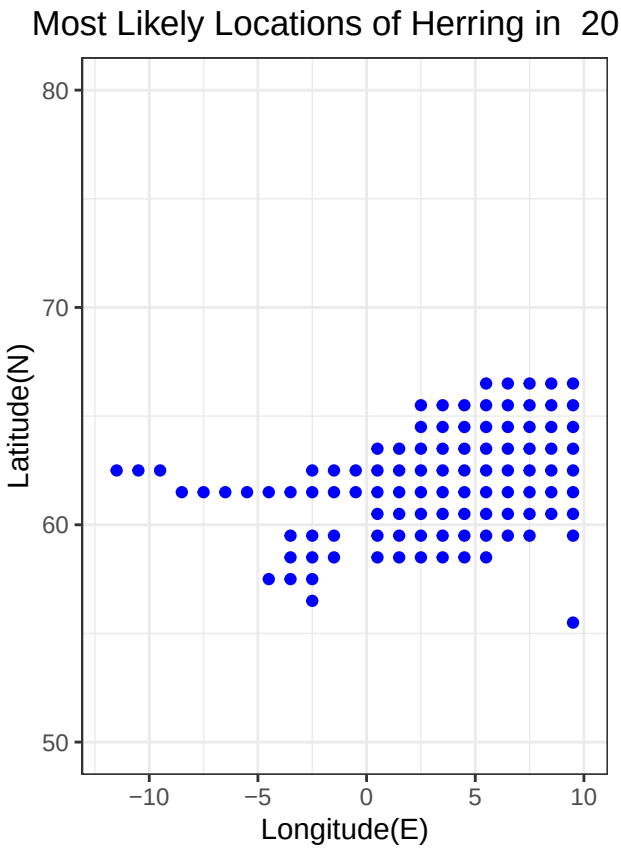

Likely Locations of Herring in 2013
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

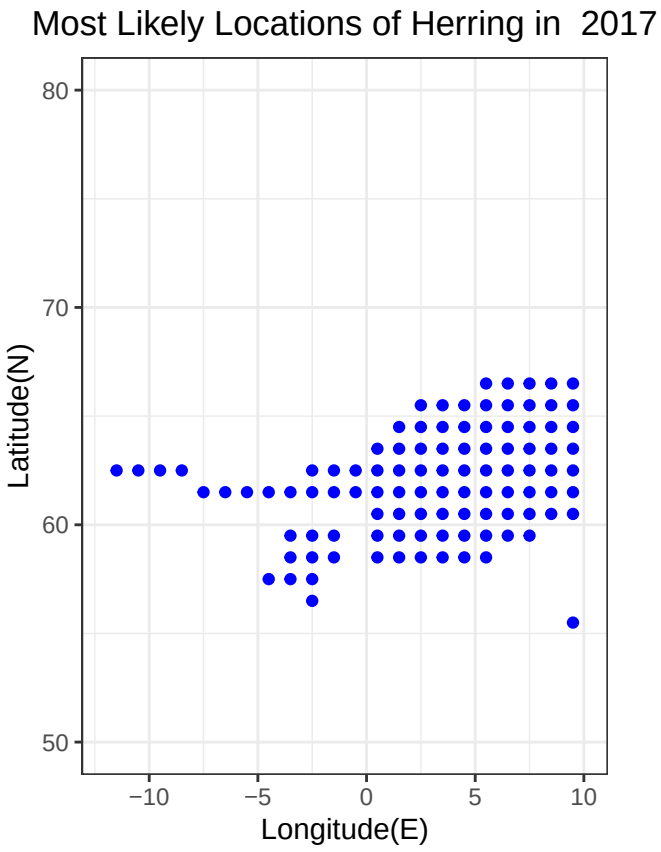

Likely Locations of Herring in 2014
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

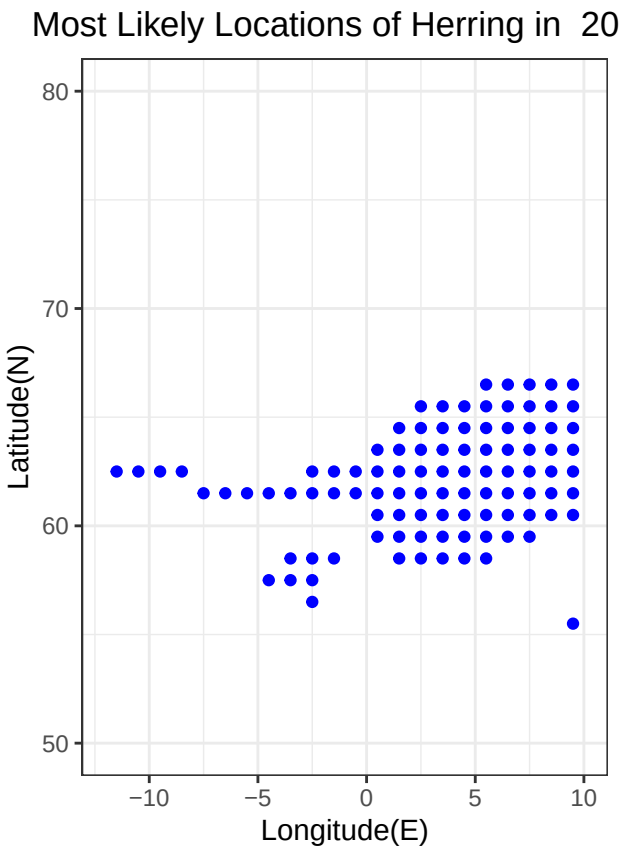


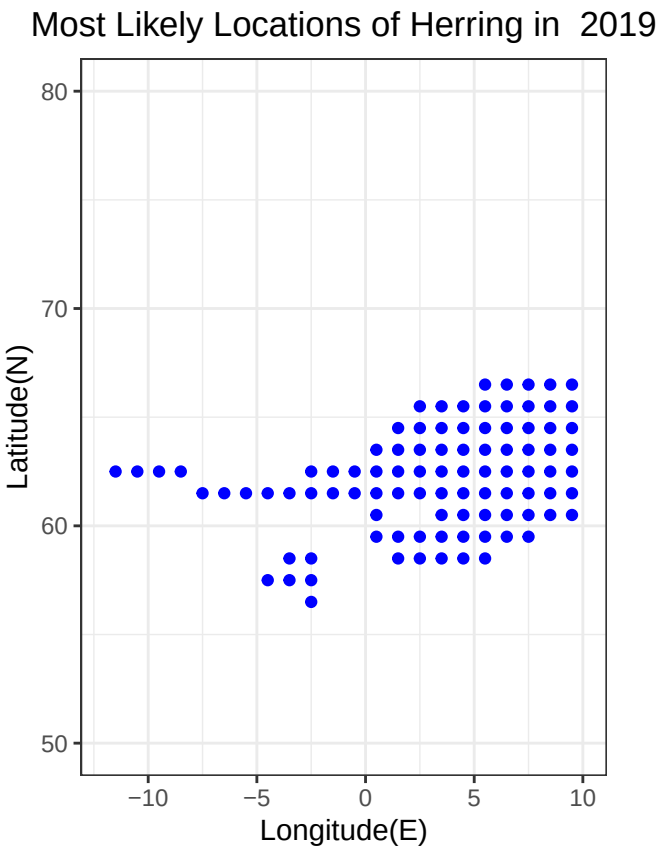

```
x <- 2072
for (i in 2016:x) {
  tempYear <- i
  year <- seq(1981, 2015)
  new.year <-  data.frame(
    year = c(tempYear)
  )
  Prediction <- as.data.frame(matrix(data = NA, nrow = 660, ncol = 3))
  for (i in 1:660) {
    temperature <- as.integer(dataTotal[i,3:37])
    model <- lm(temperature ~ year)
    Prediction[i,] <- predict(model, newdata = new.year, interval = "prediction")
  }
  colnames(Prediction) <- c("Expected", "Lower_bound", "Upper_bound")
  dataMerge <- cbind(dataTotal, Prediction)
  M <- dataMerge %>% filter(Lower_bound < 9.6 & Upper_bound > 8.86) %>% select(Longitude, Latitude, E
  H <- dataMerge %>% filter(Lower_bound < 9.8 & Upper_bound > 8.8) %>% select(Longitude, Latitude, Ex
  ME <- dataMerge %>% filter(Expected < 9.6 & Expected > 8.86) %>% select(Longitude, Latitude, Expect
  HE <- dataMerge %>% filter(Expected < 9.8 & Expected > 8.8) %>% select(Longitude, Latitude, Expecte
  library(ggplot2)
  pHE <- ggplot(HE, aes(Longitude, Latitude)) + geom_point(col = "blue") + theme_bw() +
```

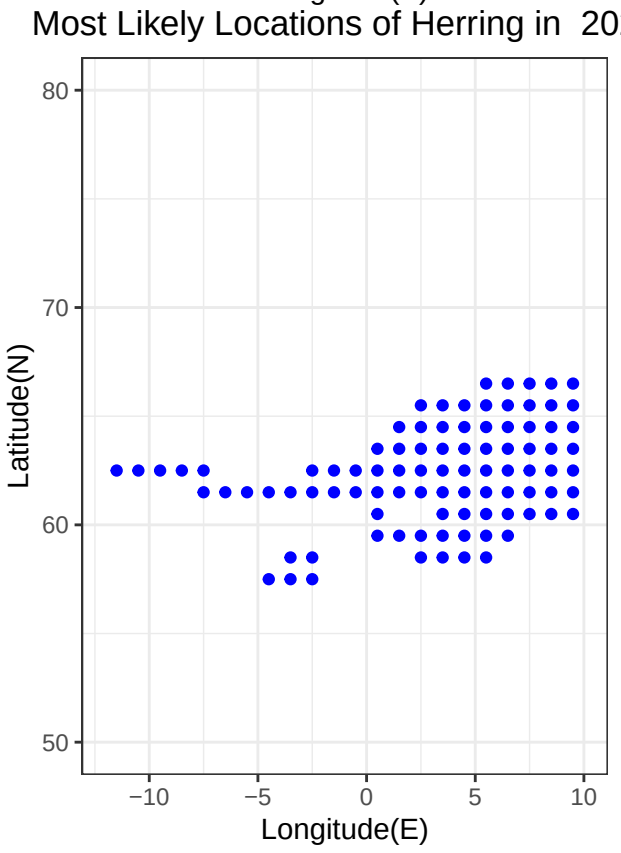
```
    coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +  ylab("Latit
    ggtitle(paste("Most Likely Locations of Herring in ", tempYear)) +
    theme(plot.title = element_text(hjust = 0.5))
  # print(pH)
  # print(pM)
  print(pHE)
  # print(pME)
}
```

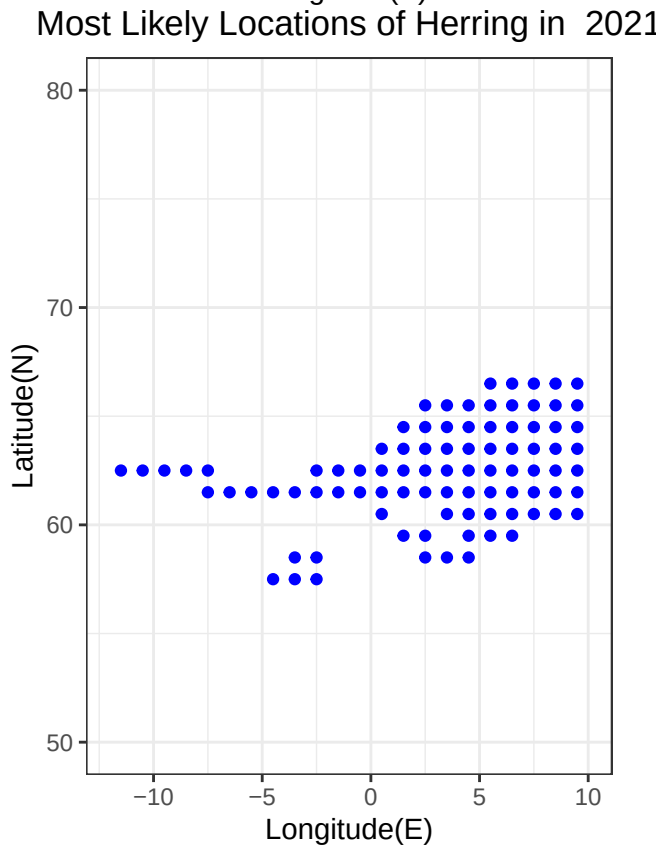





Most Likely Locations of Herring in 2018
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2019
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2020
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2021
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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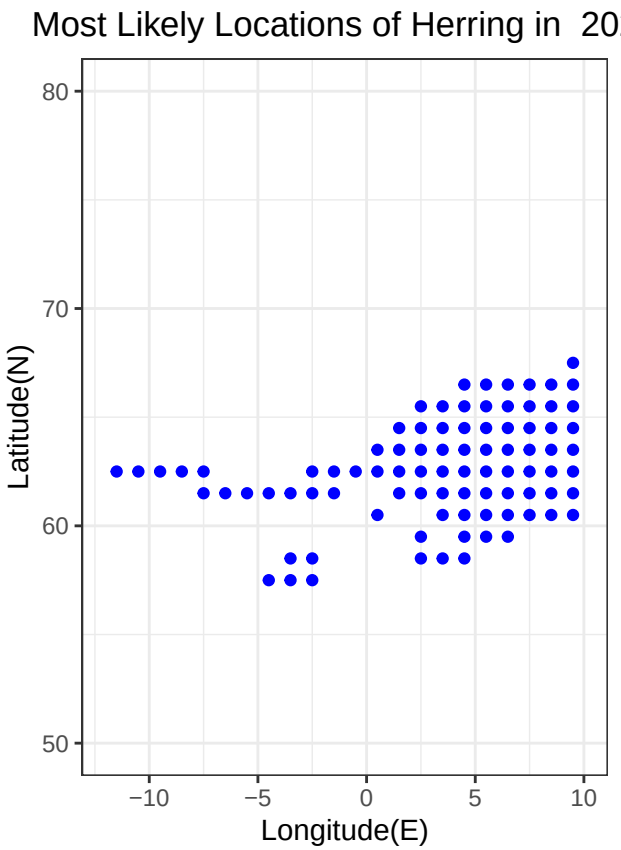
Most Likely Locations of Herring in 2022
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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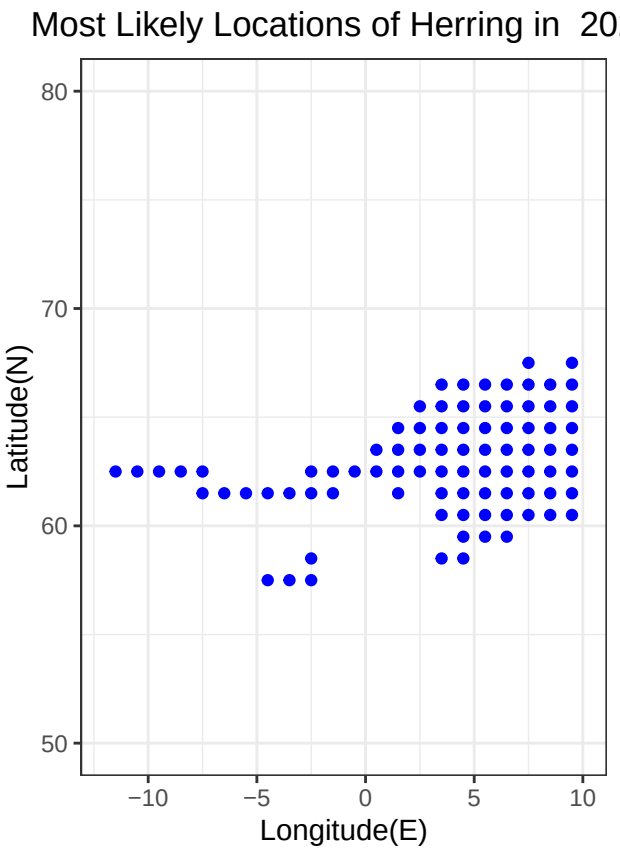
Most Likely Locations of Herring in 2023
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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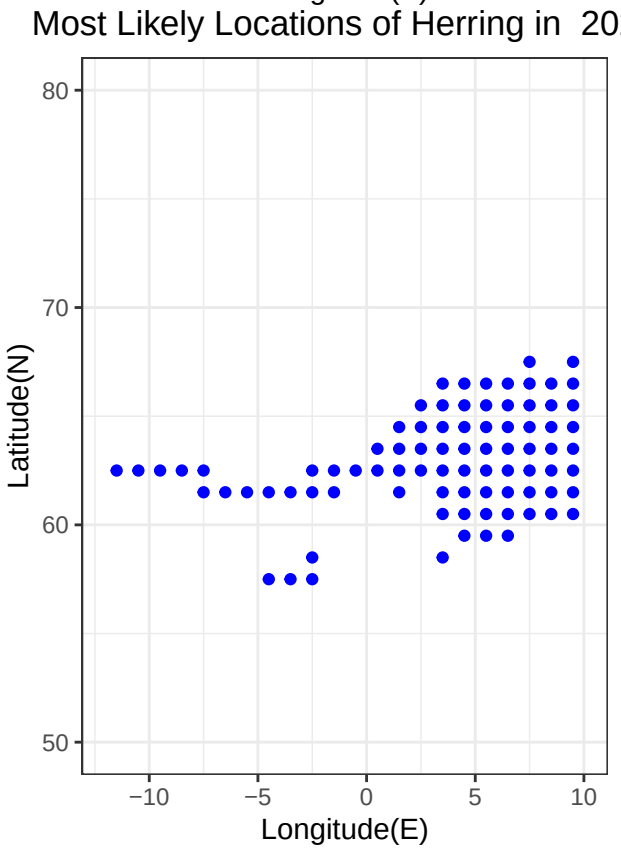
Most Likely Locations of Herring in 2024
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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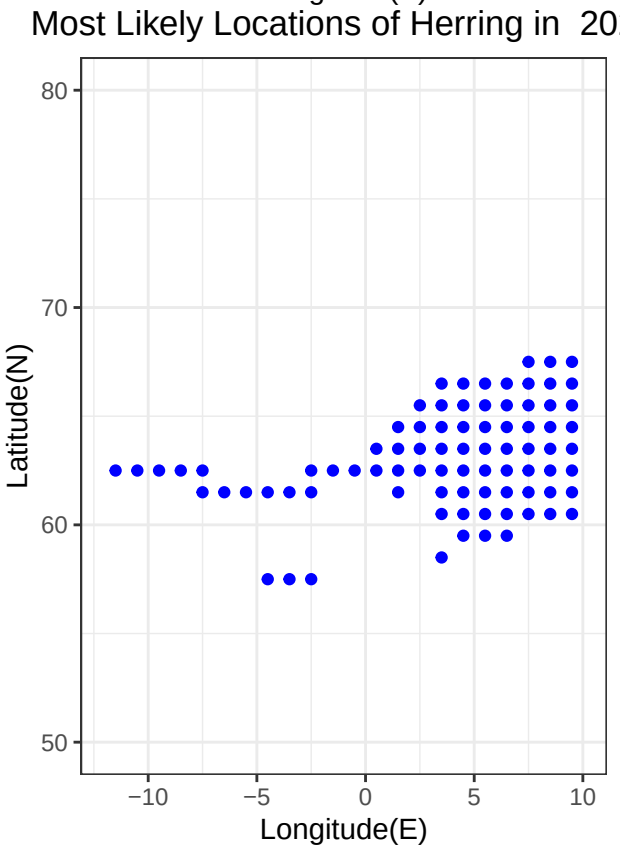
Most Likely Locations of Herring in 2025
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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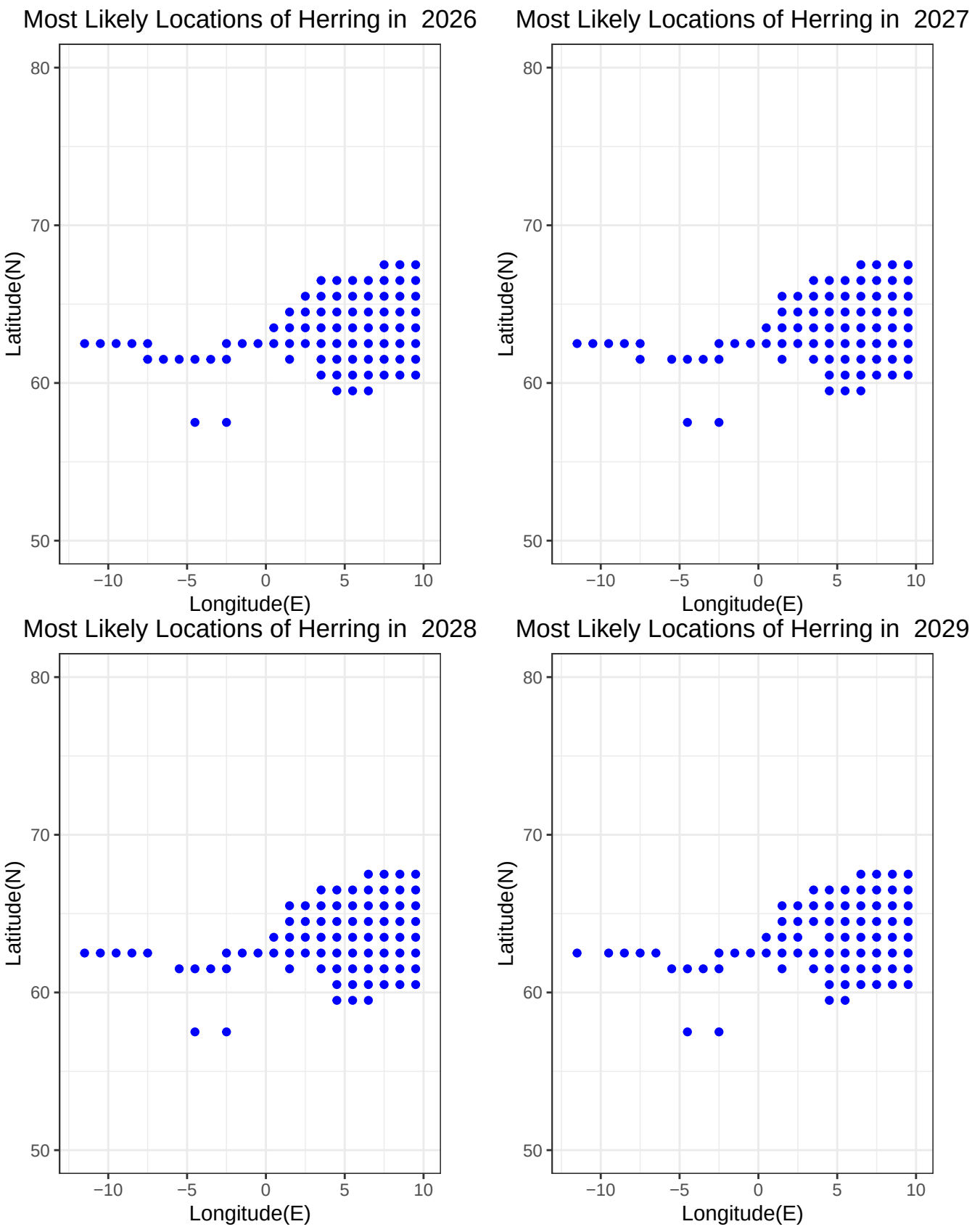
Most Likely Locations of Herring in 2026
Most Likely Locations of Herring in 2027
Most Likely Locations of Herring in 2028
Most Likely Locations of Herring in 2029
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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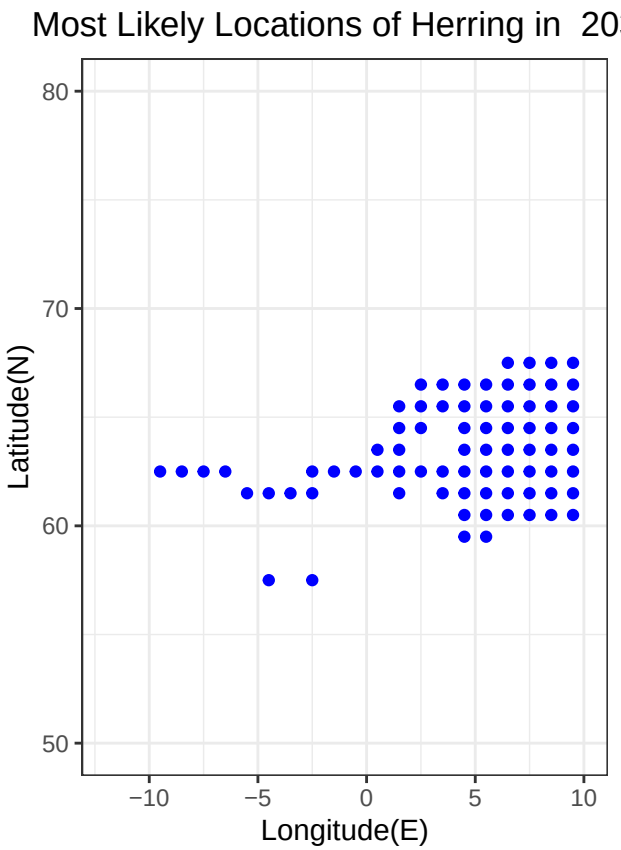
Most Likely Locations of Herring in 2030
Latitude(N)
Longitude(E)
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70
60
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−10
−5
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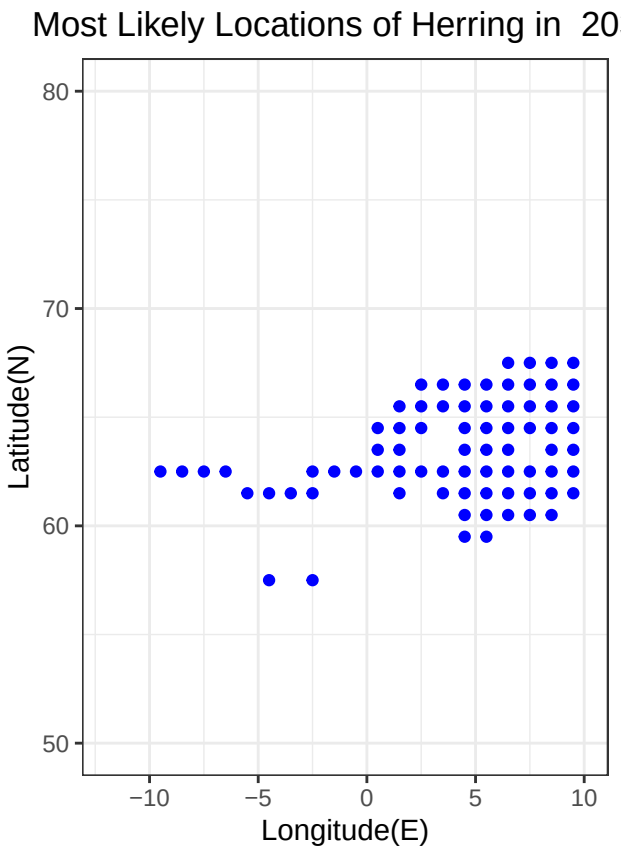
Most Likely Locations of Herring in 2031
Latitude(N)
Longitude(E)
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60
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−10
−5
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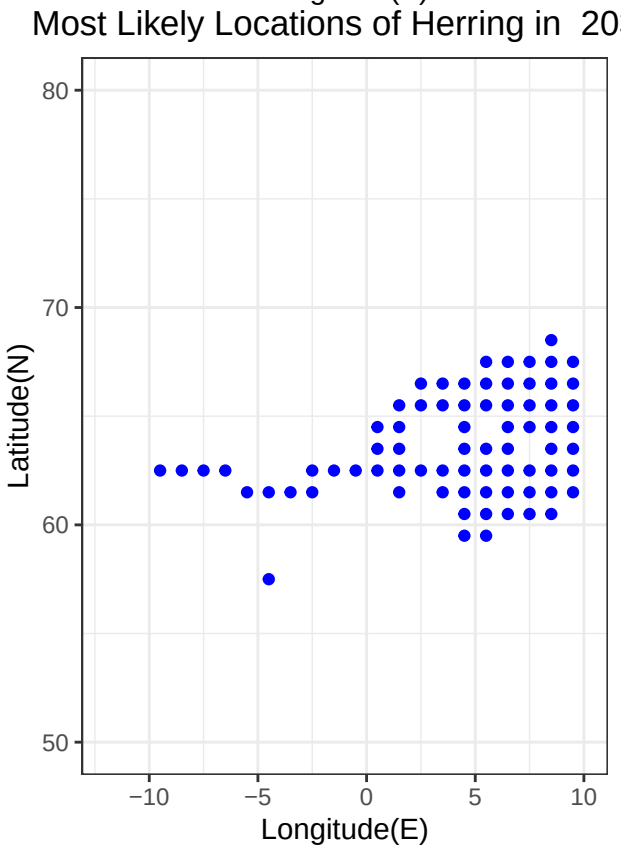
Most Likely Locations of Herring in 2032
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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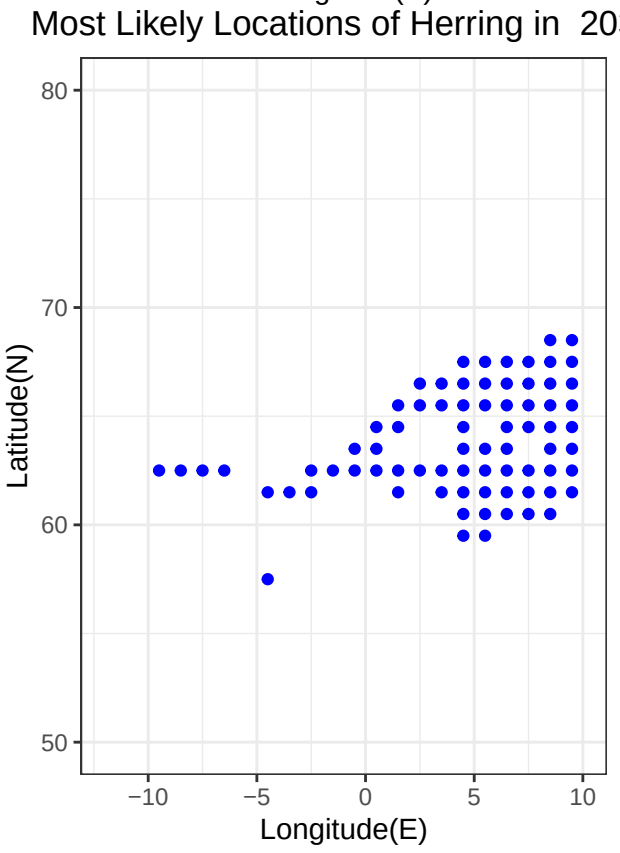
Most Likely Locations of Herring in 2033
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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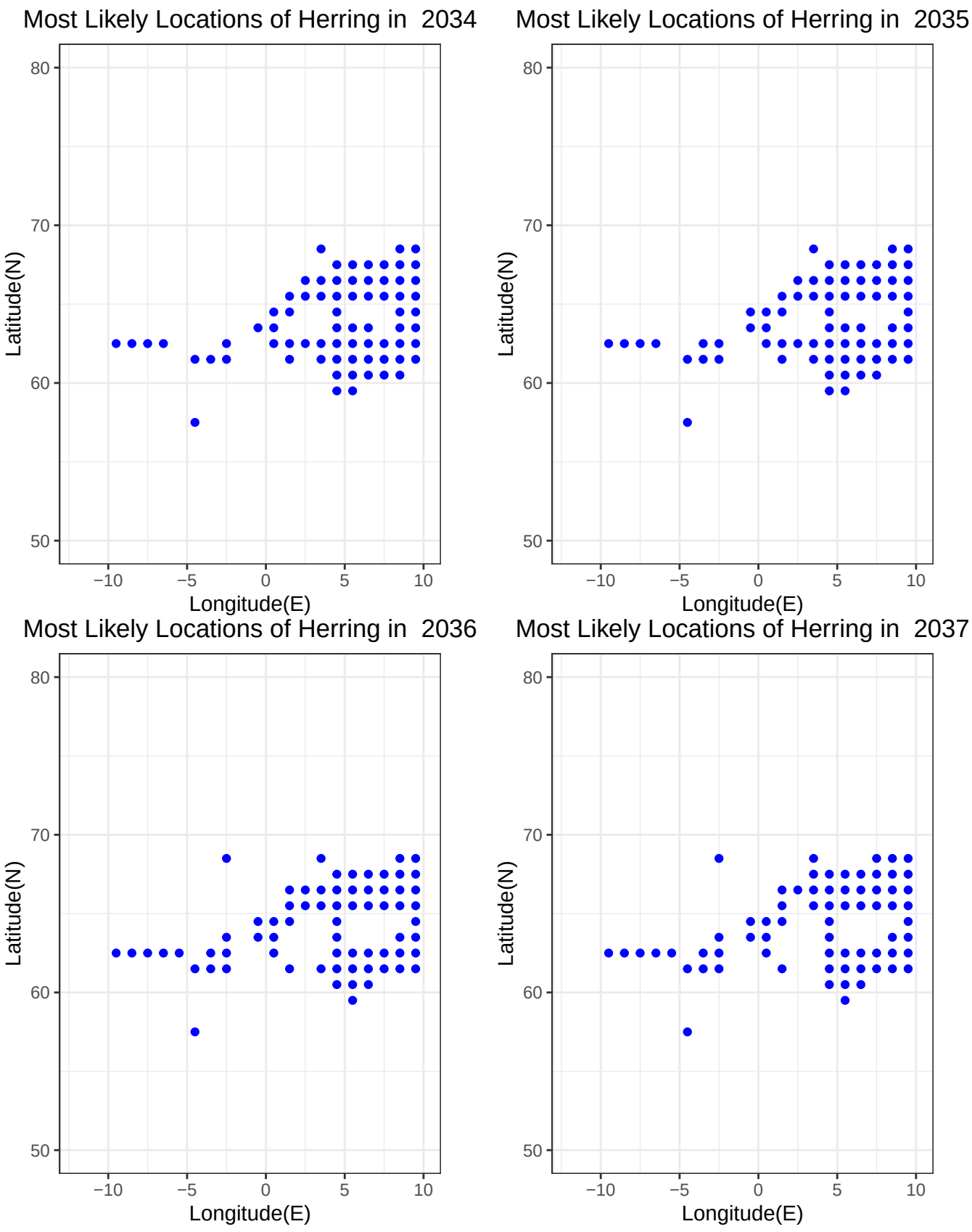
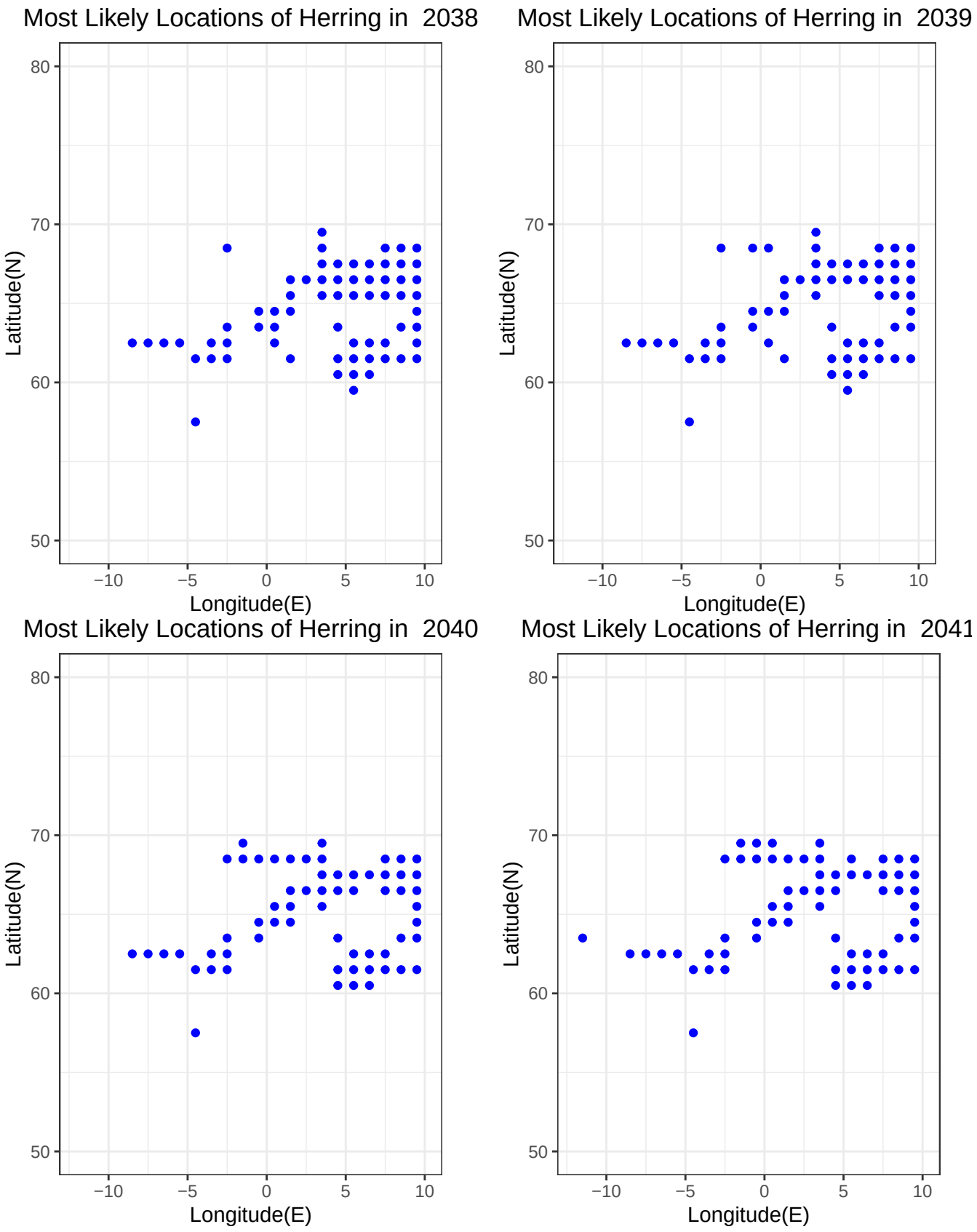
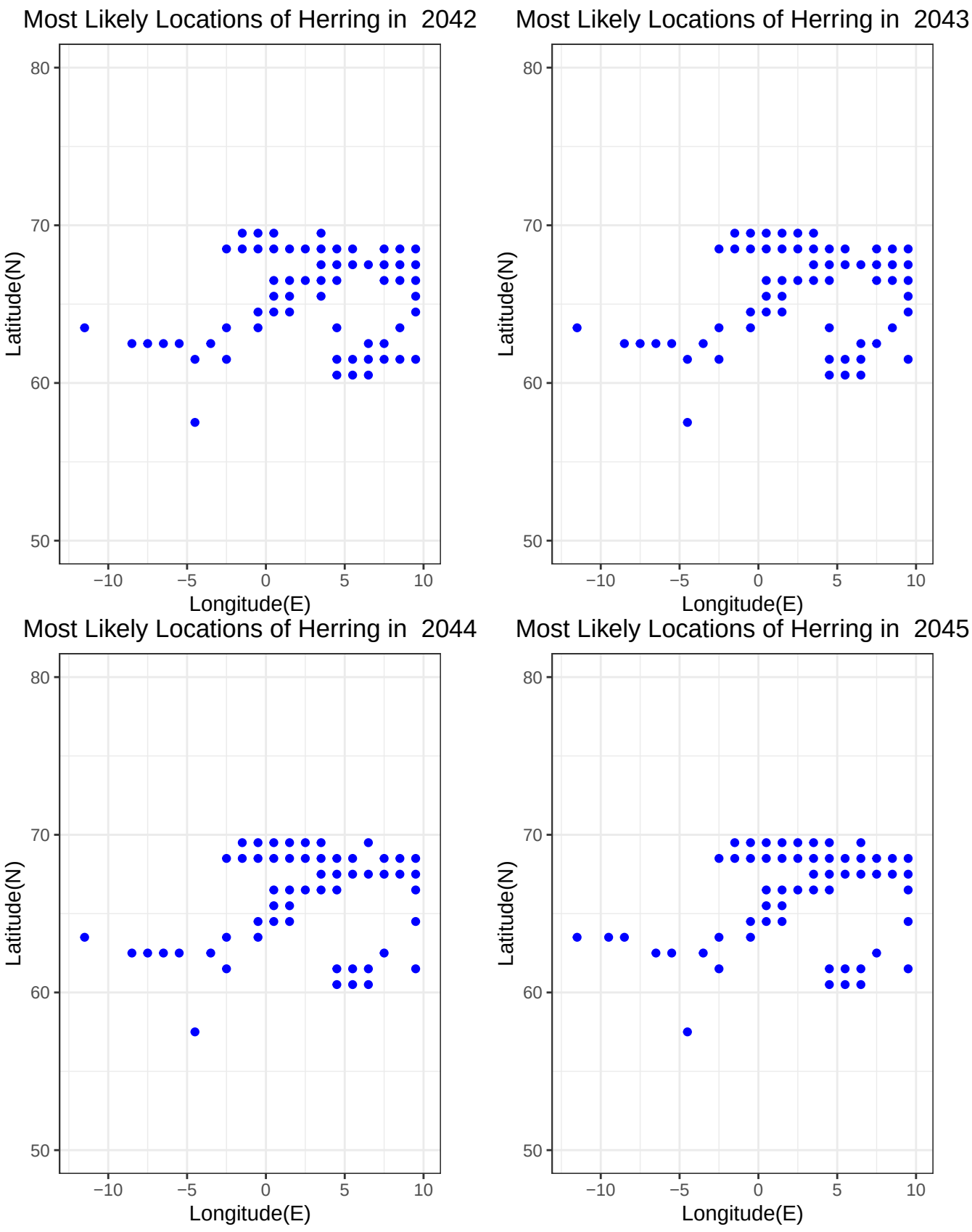
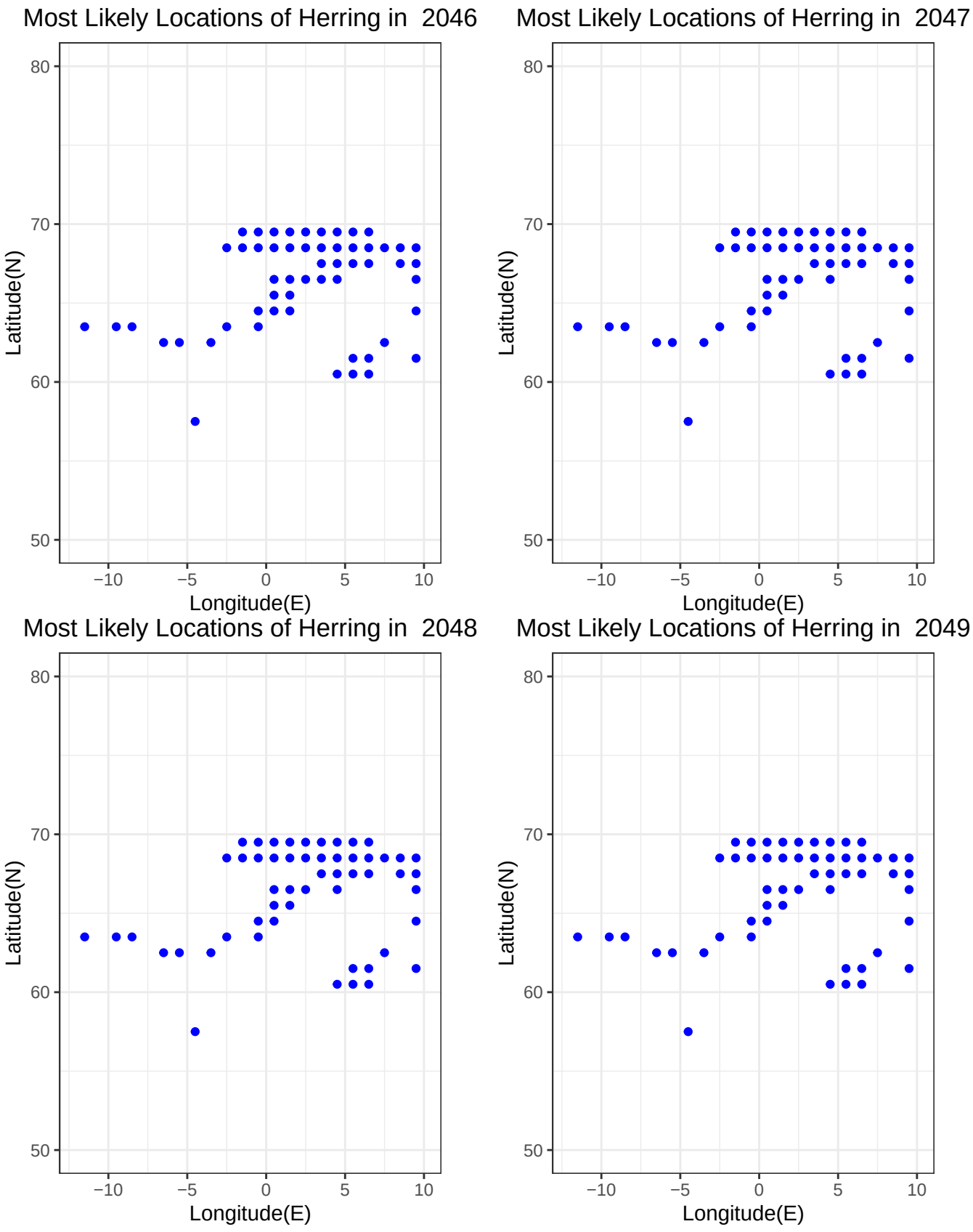
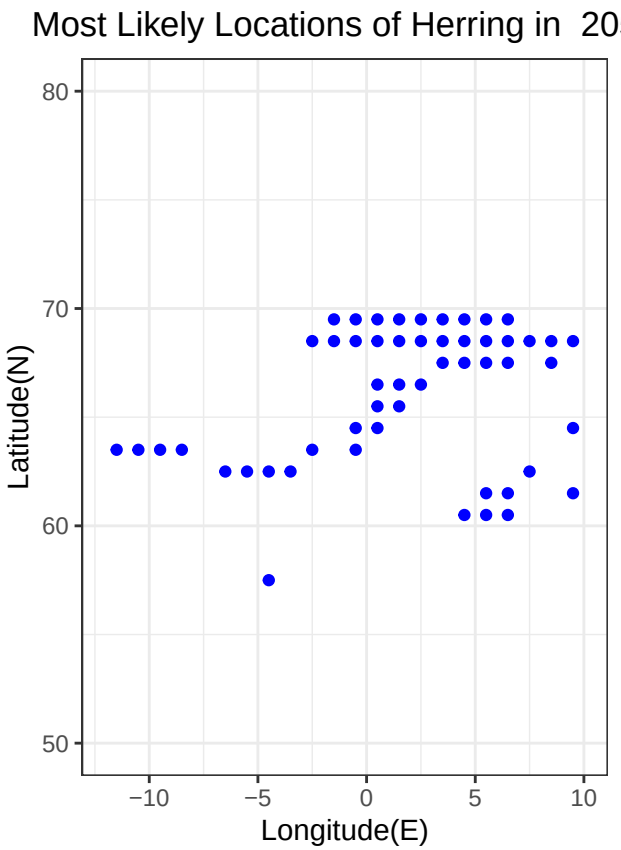
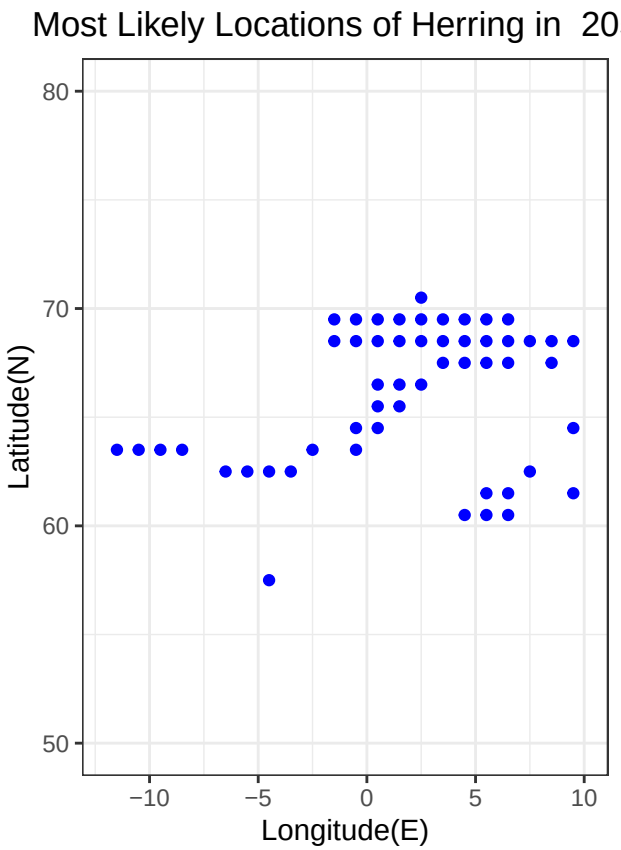

Most Likely Locations of Herring in 2034
Most Likely Locations of Herring in 2035
Most Likely Locations of Herring in 2036
Most Likely Locations of Herring in 2037
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2038
Most Likely Locations of Herring in 2039
Most Likely Locations of Herring in 2040
Most Likely Locations of Herring in 2041
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2042
Most Likely Locations of Herring in 2043
Most Likely Locations of Herring in 2044
Most Likely Locations of Herring in 2045
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2046
Most Likely Locations of Herring in 2047
Most Likely Locations of Herring in 2048
Most Likely Locations of Herring in 2049
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2050
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2051
Latitude(N)
Longitude(E)
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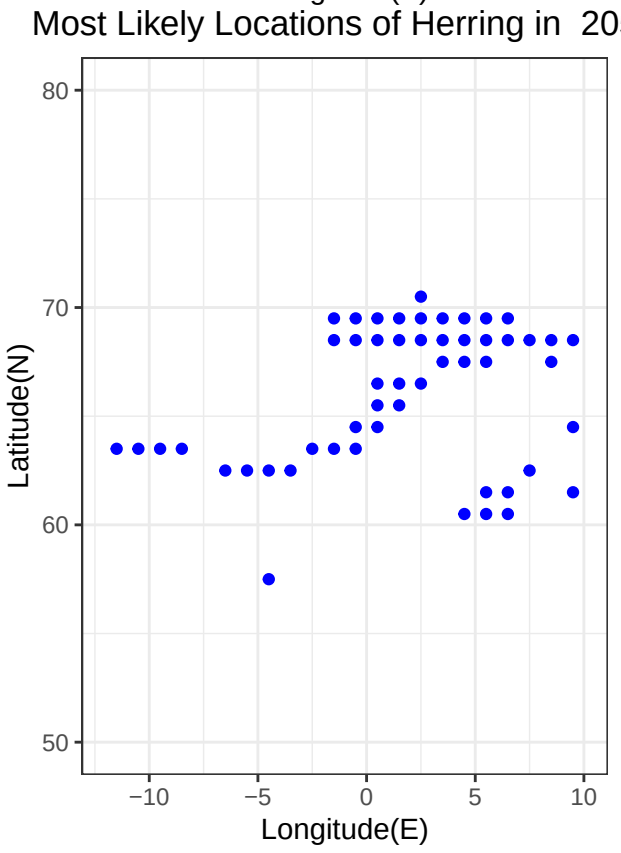
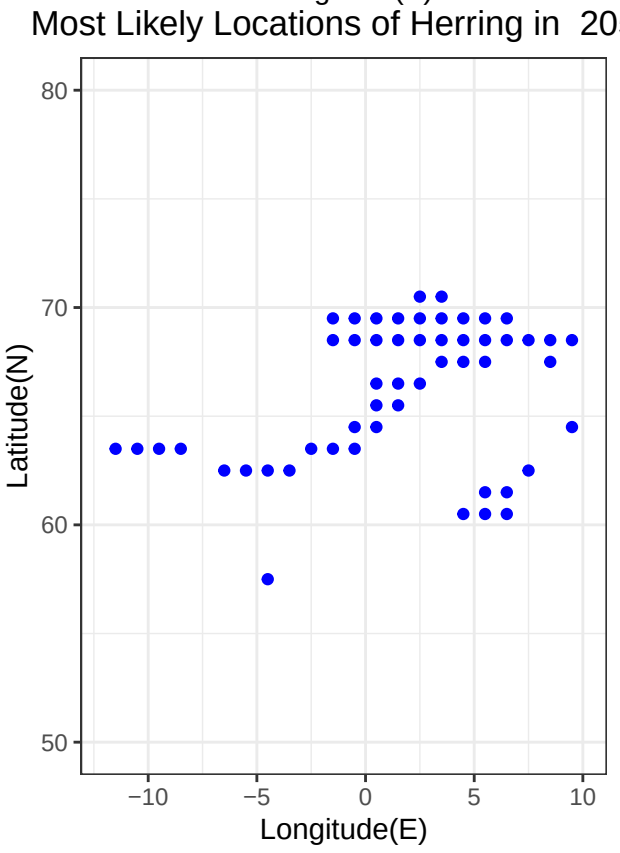
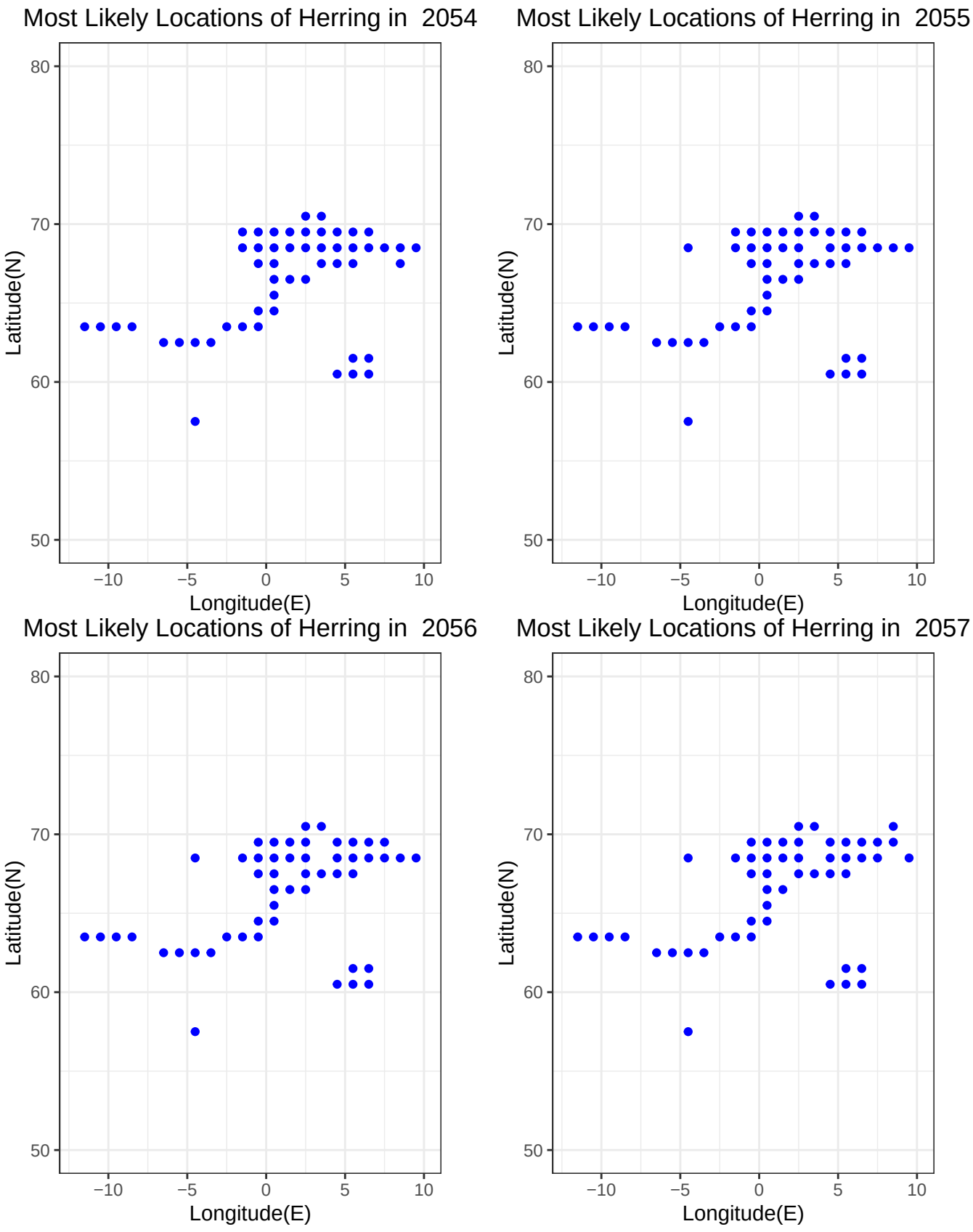
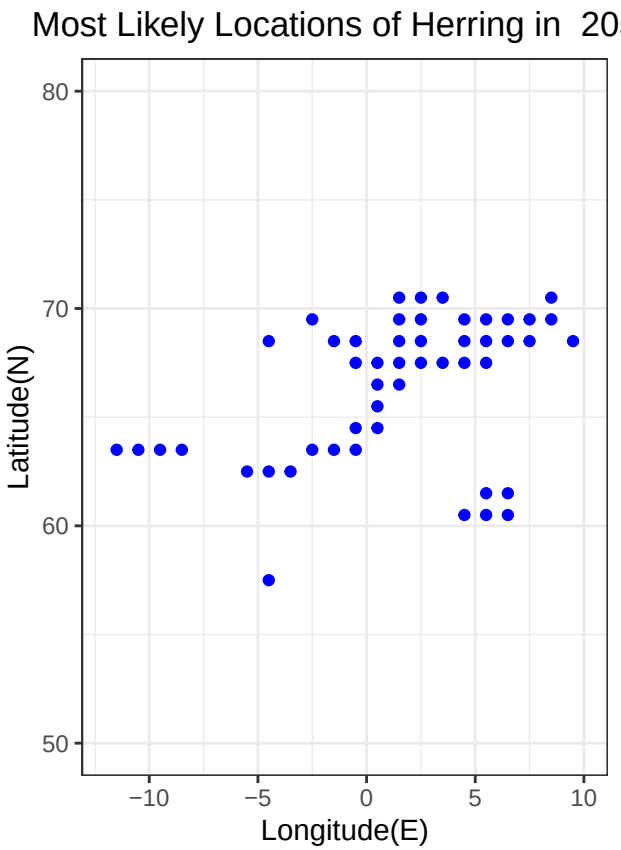
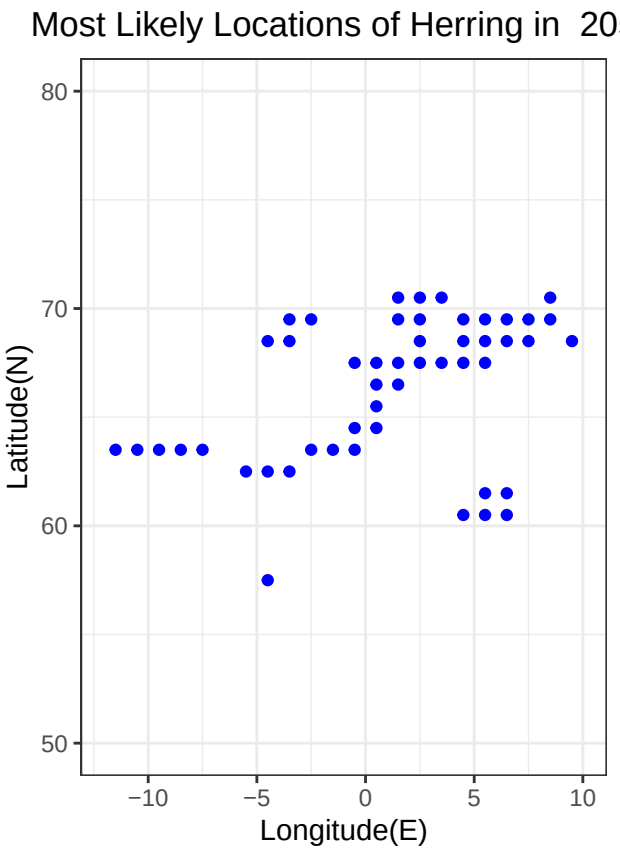
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2052
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2053
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2054
Most Likely Locations of Herring in 2055
Most Likely Locations of Herring in 2056
Most Likely Locations of Herring in 2057
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2058
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2059
Latitude(N)
Longitude(E)
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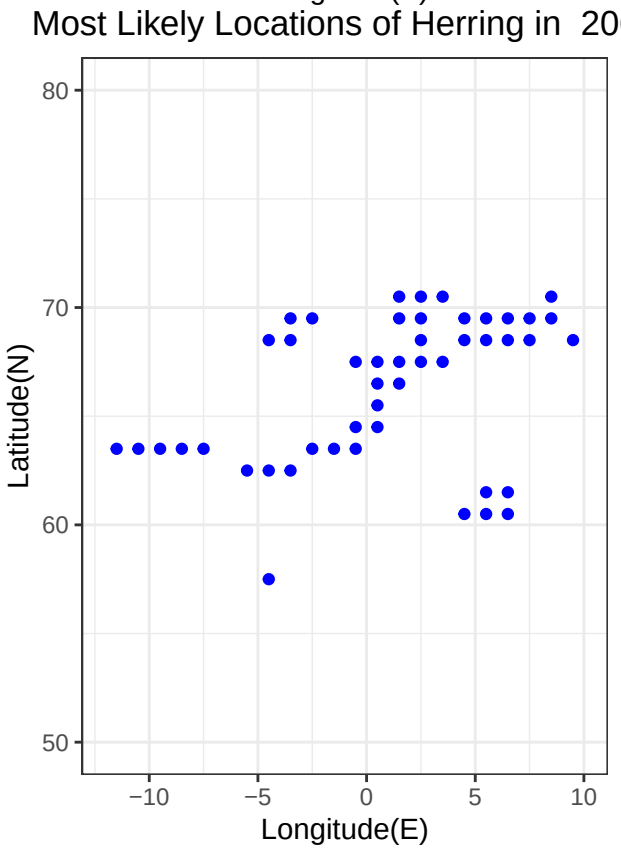
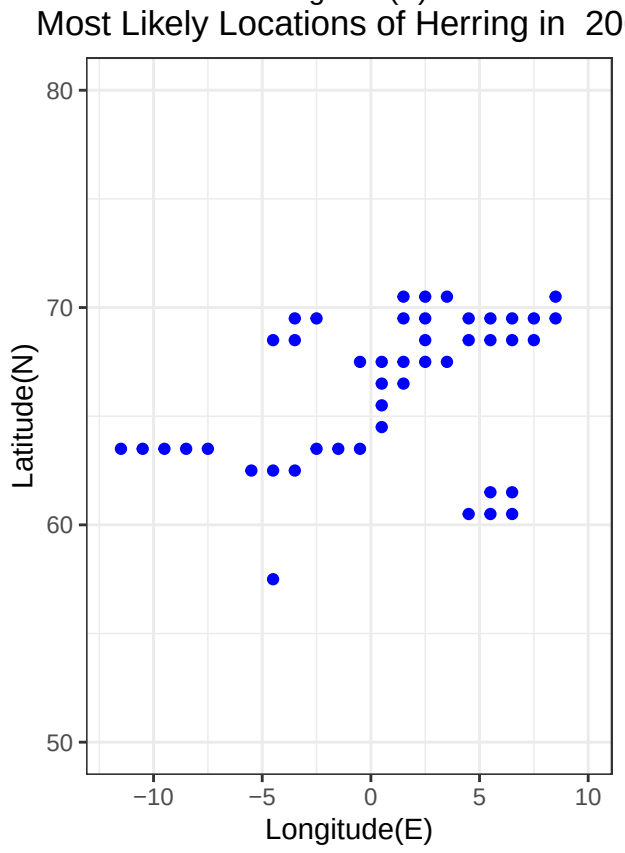
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2060
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2061
Latitude(N)
Longitude(E)
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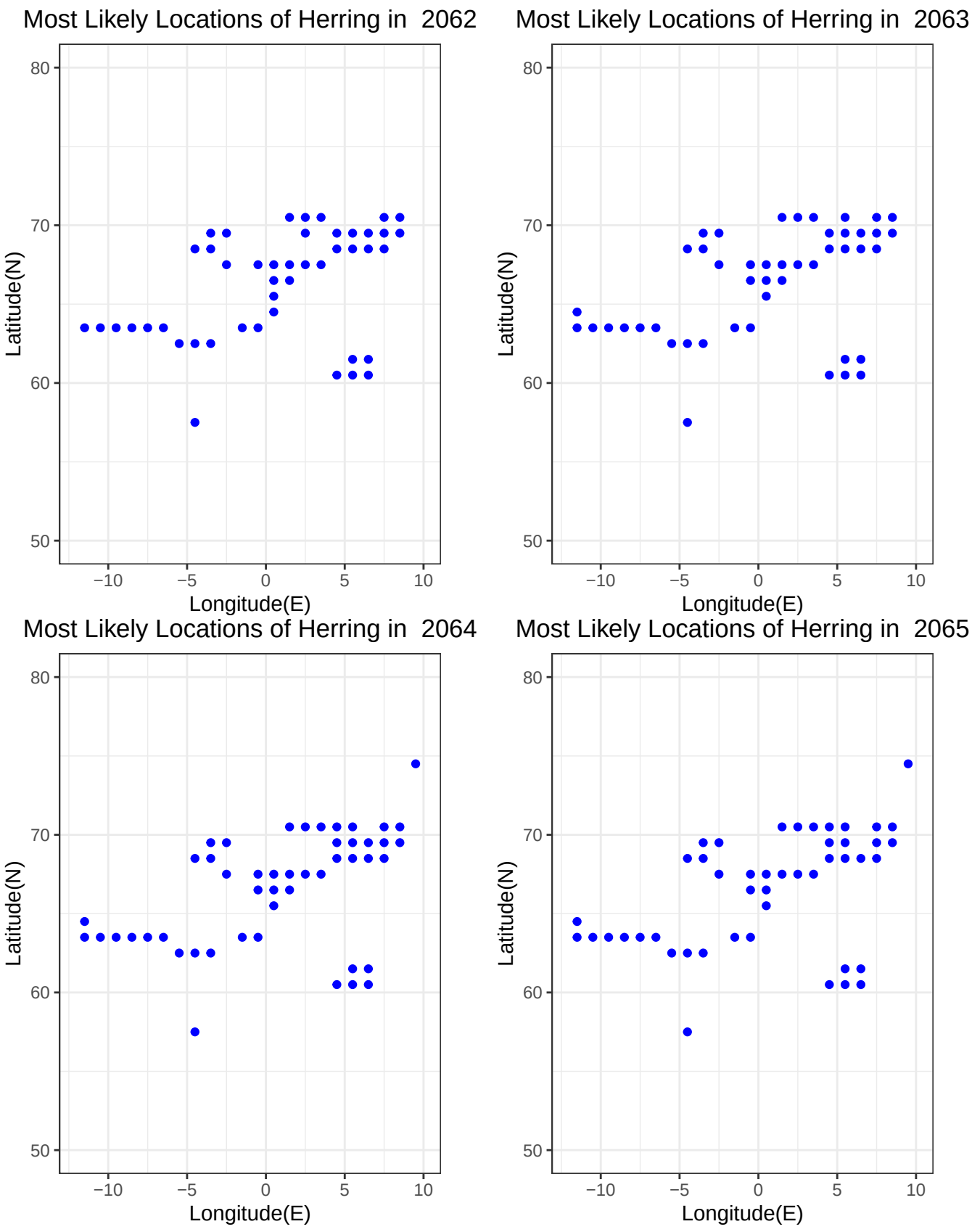
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2062
Most Likely Locations of Herring in 2063
Most Likely Locations of Herring in 2064
Most Likely Locations of Herring in 2065
Latitude(N)
Longitude(E)
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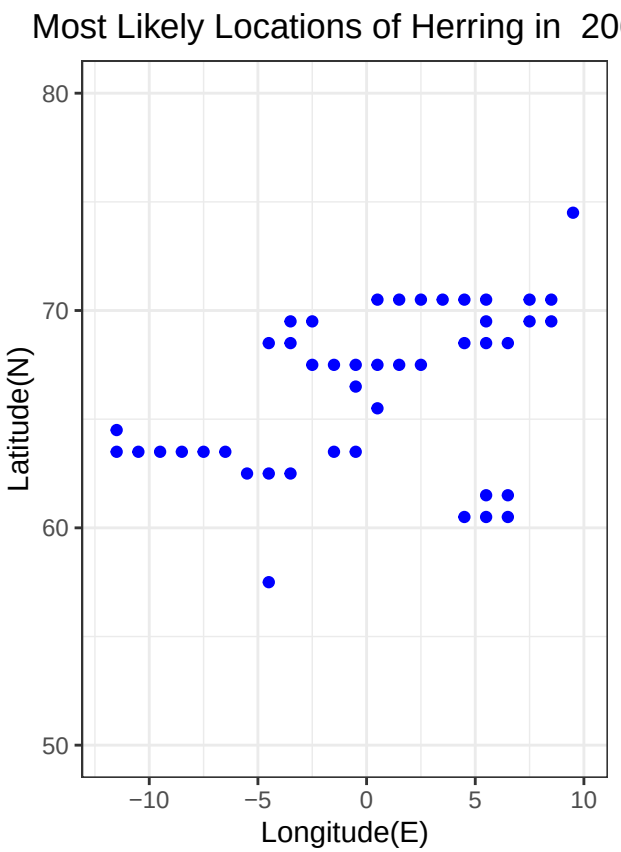
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2066
Latitude(N)
Longitude(E)
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60
50
−10
−5
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5
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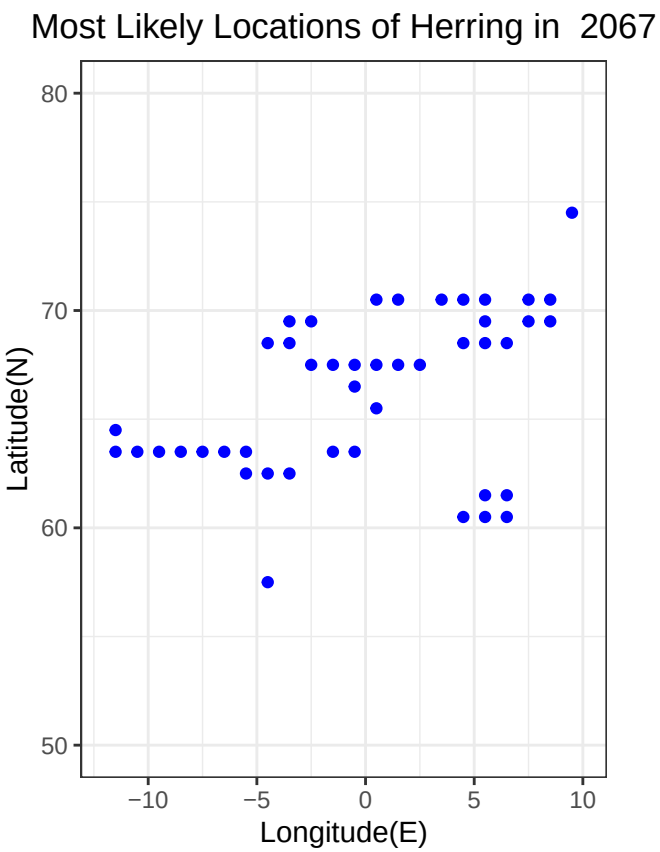
Most Likely Locations of Herring in 2067
Latitude(N)
Longitude(E)
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60
50
−10
−5
0
5
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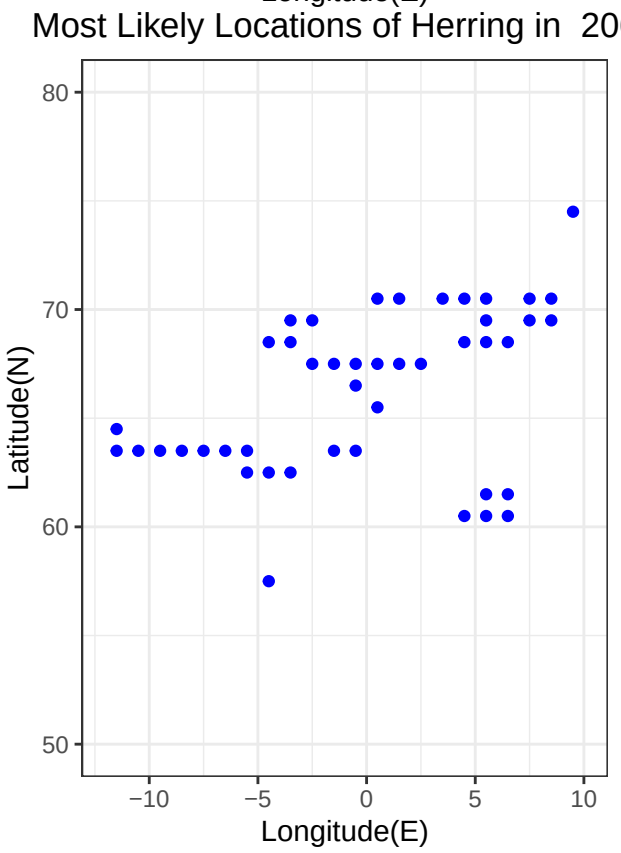
Most Likely Locations of Herring in 2068
Latitude(N)
Longitude(E)
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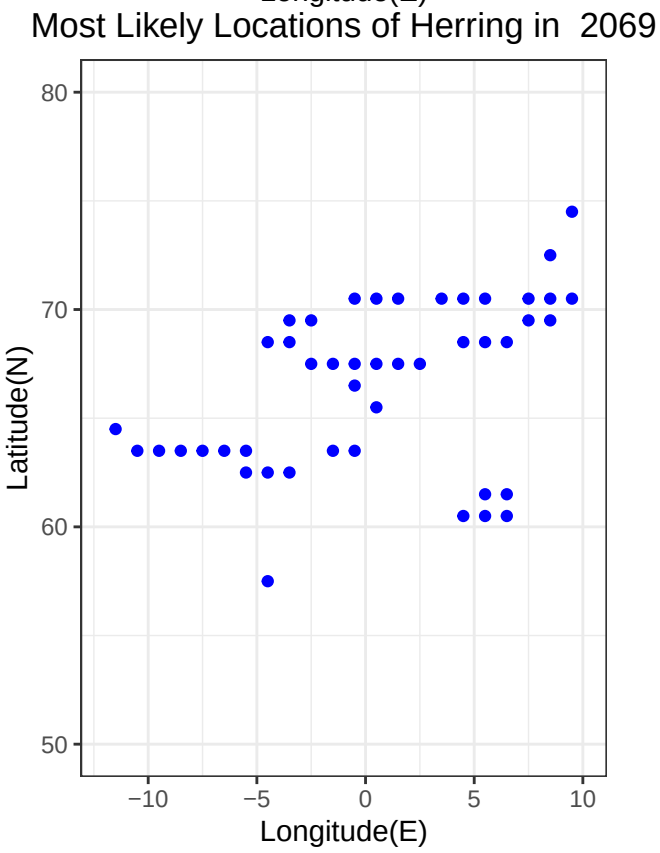
70
60
50
−10
−5
0
5
10


Most Likely Locations of Herring in 2069
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
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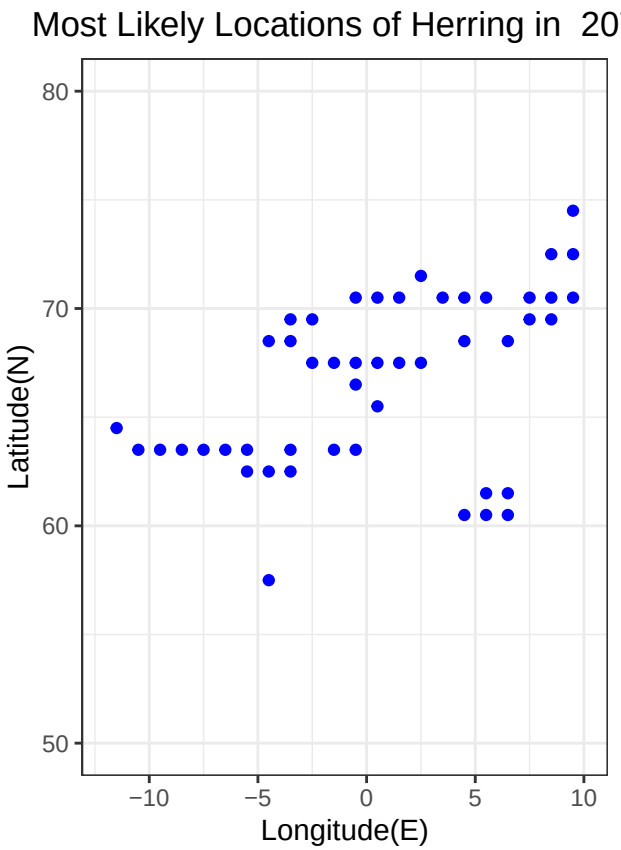
Most Likely Locations of Herring in 2070
Latitude(N)
Longitude(E)
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60
50
−10
−5
0
5
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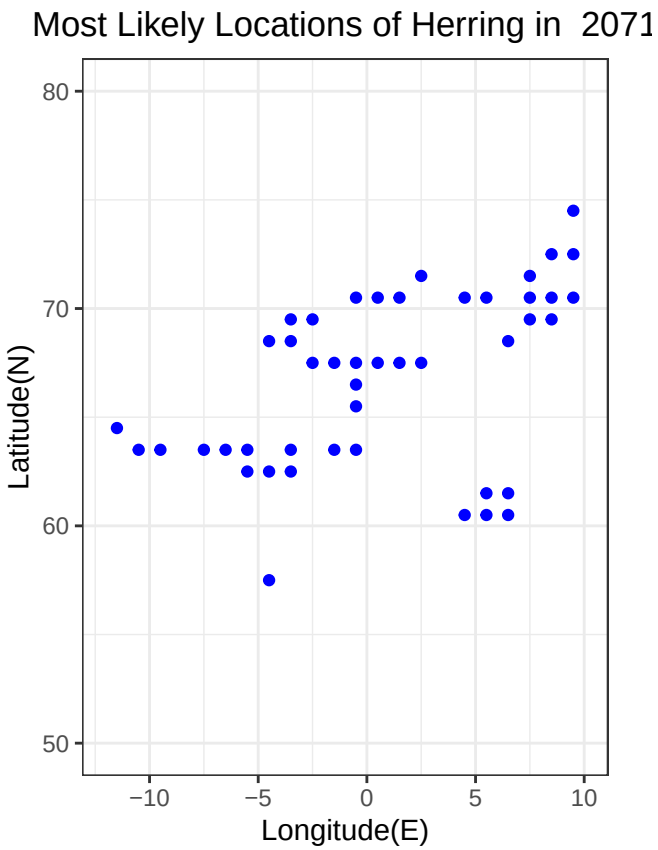
Most Likely Locations of Herring in 2071
Latitude(N)
Longitude(E)
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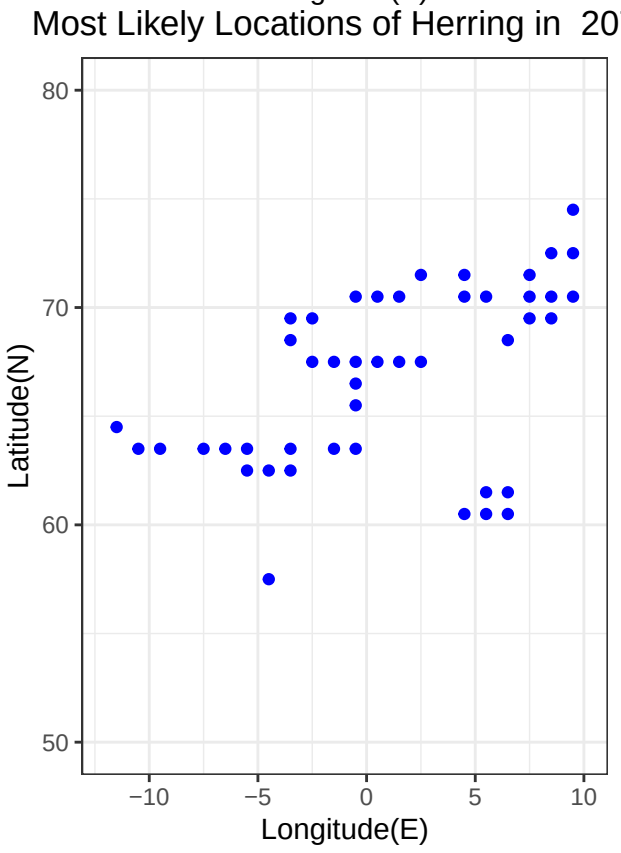
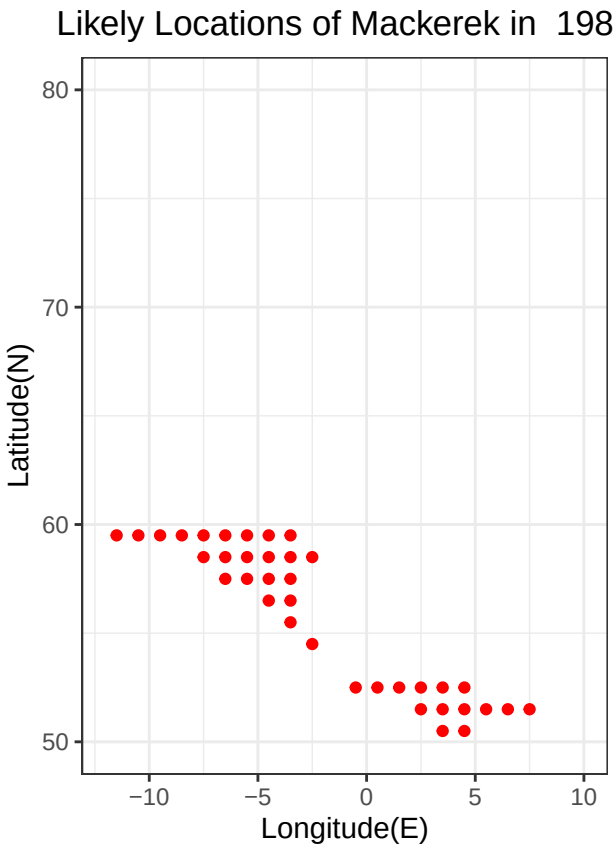
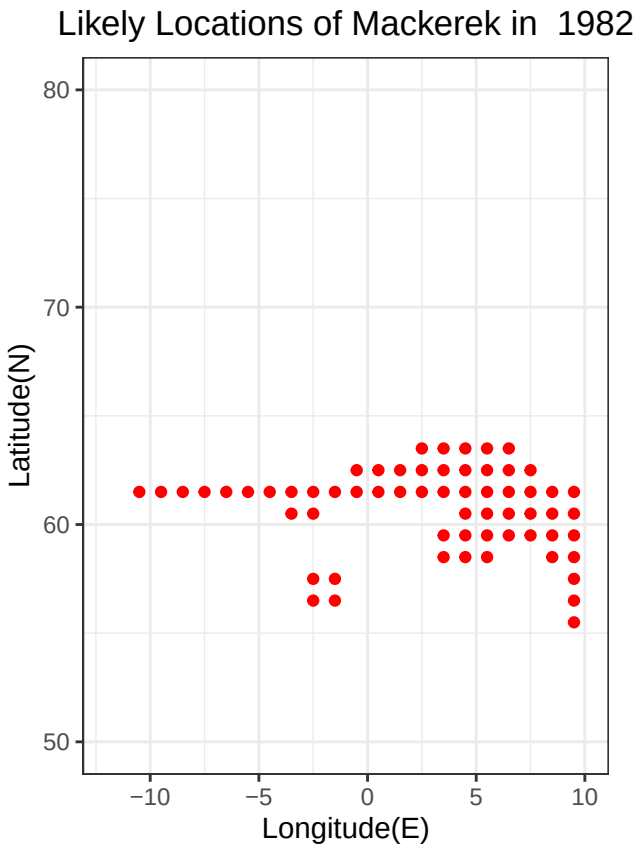
60
50
−10
−5
0
5
10

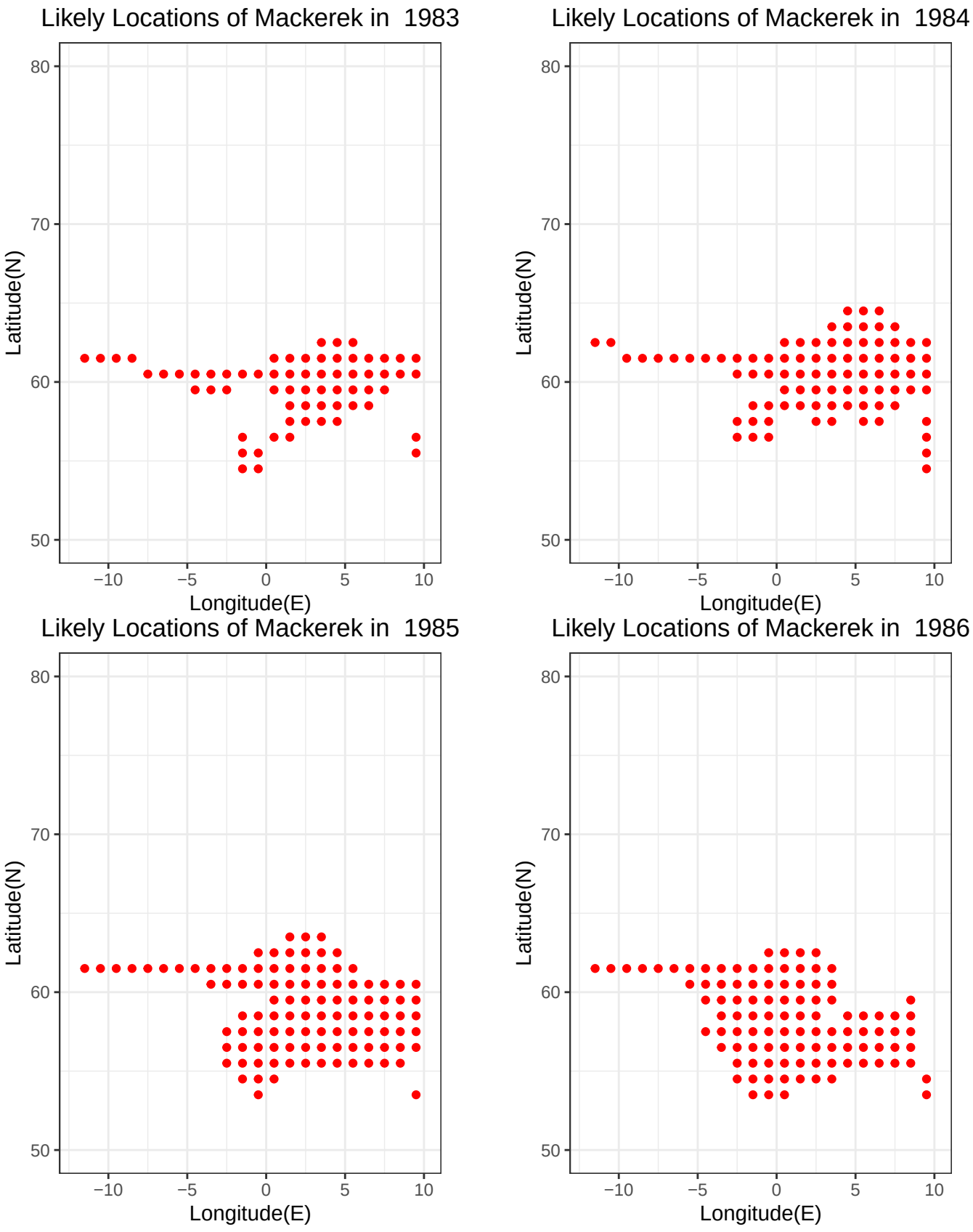

Most Likely Locations of Herring in 2072
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10

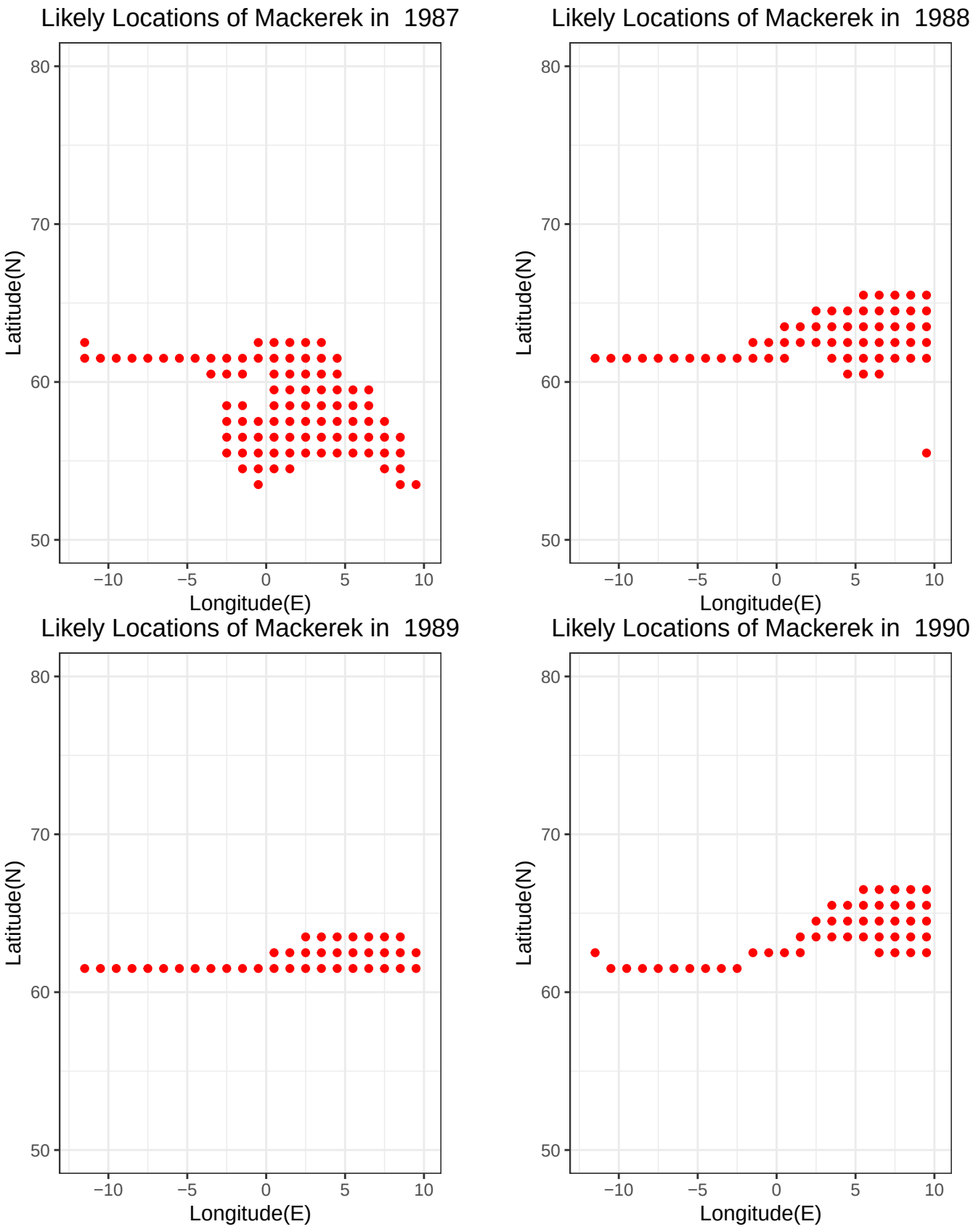
```
for (i in 1981:2015) {

M1981 <- dataTotal2 %>% filter(avg_temperature < 9.6 & avg_temperature > 8.86 & Time == i)
pM1981 <- ggplot(M1981, aes(Longitude, Latitude)) +
  geom_point(col = "red") +
  theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +
  ylab("Latitude(N)") +
  ggtitle(paste("Likely Locations of Mackerek in ", i)) +
  theme(plot.title = element_text(hjust = 0.5))
print(pM1981)
}
```






Likely Locations of Mackerek in 1983
Likely Locations of Mackerek in 1984
Likely Locations of Mackerek in 1985
Likely Locations of Mackerek in 1986
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10


Likely Locations of Mackerek in 1987
Likely Locations of Mackerek in 1988
Likely Locations of Mackerek in 1989
Likely Locations of Mackerek in 1990
Latitude(N)
Longitude(E)
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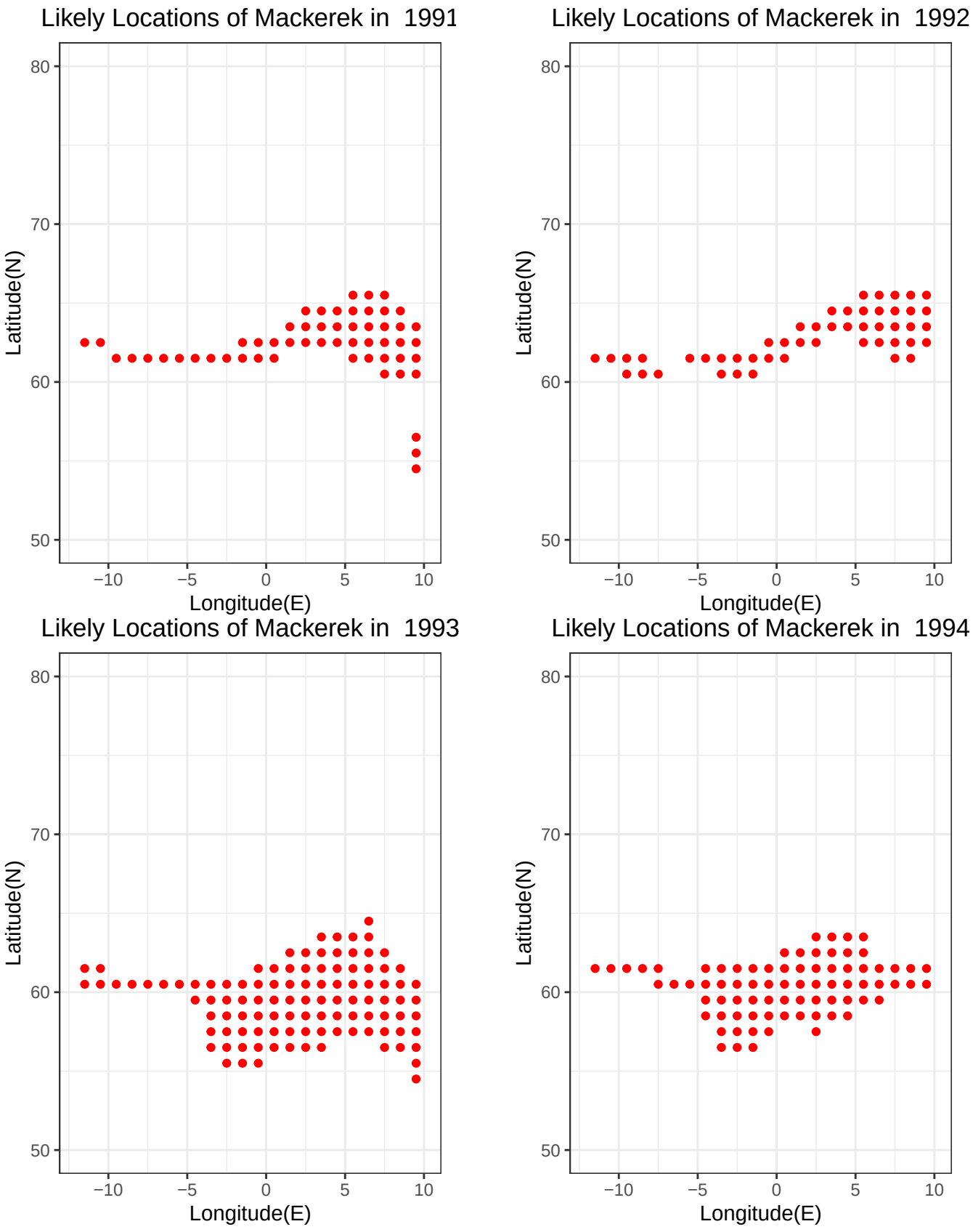
60
50
−10
−5
0
5
10


Likely Locations of Mackerek in 1991
Likely Locations of Mackerek in 1992
Likely Locations of Mackerek in 1993
Likely Locations of Mackerek in 1994
Latitude(N)
Longitude(E)
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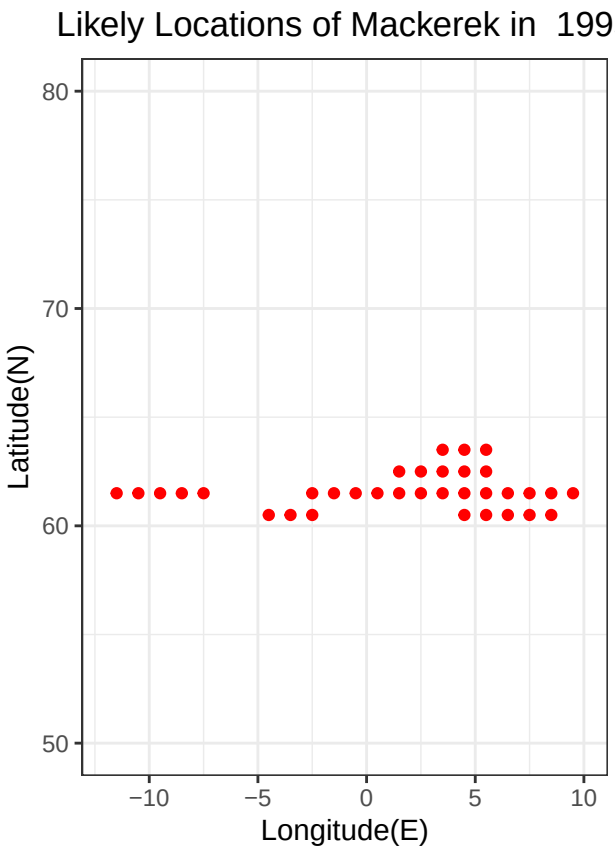
10


Likely Locations of Mackerek in 1995
Latitude(N)
Longitude(E)
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−10
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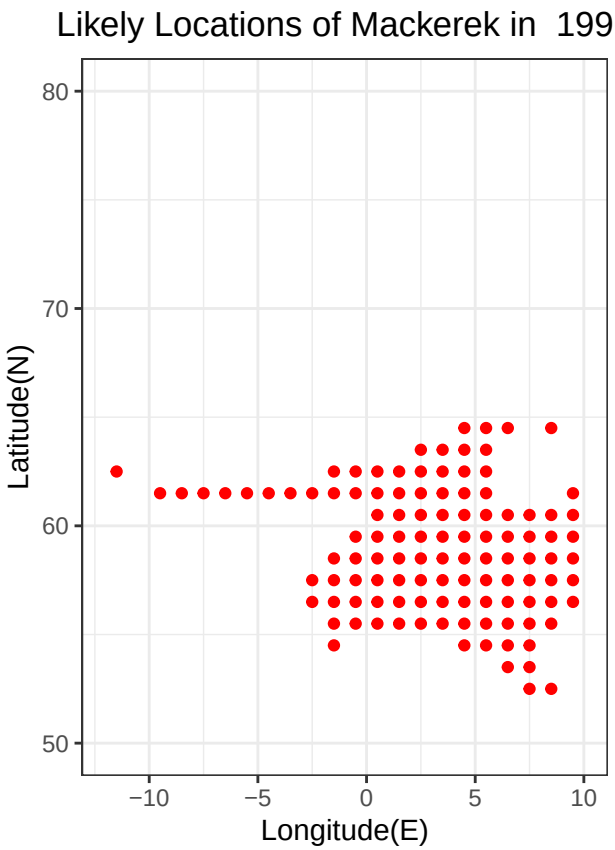
Likely Locations of Mackerek in 1996
Latitude(N)
Longitude(E)
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60
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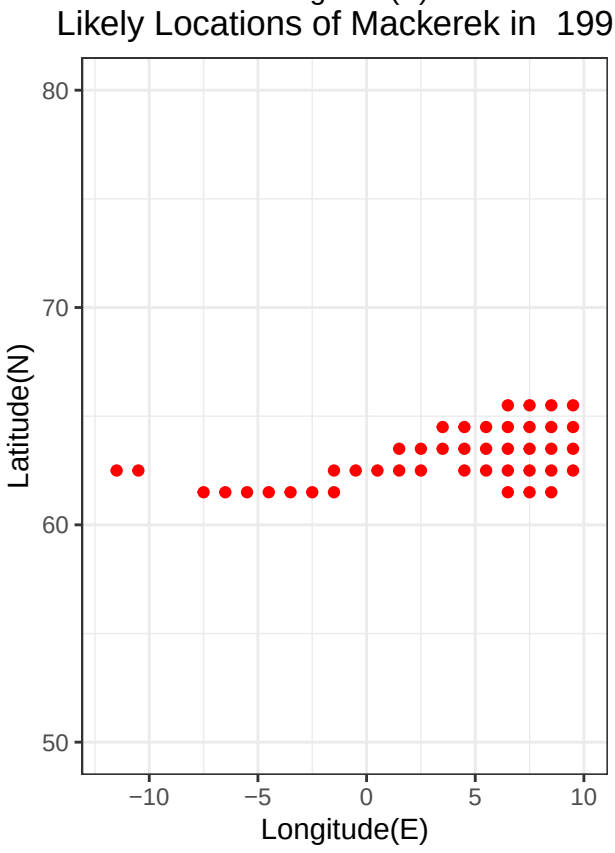
−10
−5
0
5
10


Likely Locations of Mackerek in 1997
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
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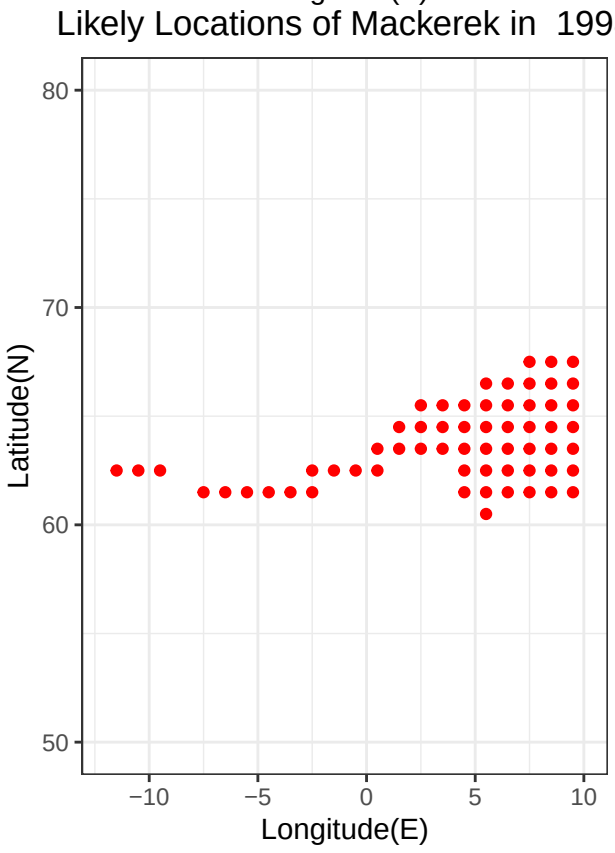
Likely Locations of Mackerek in 1998
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Longitude(E)
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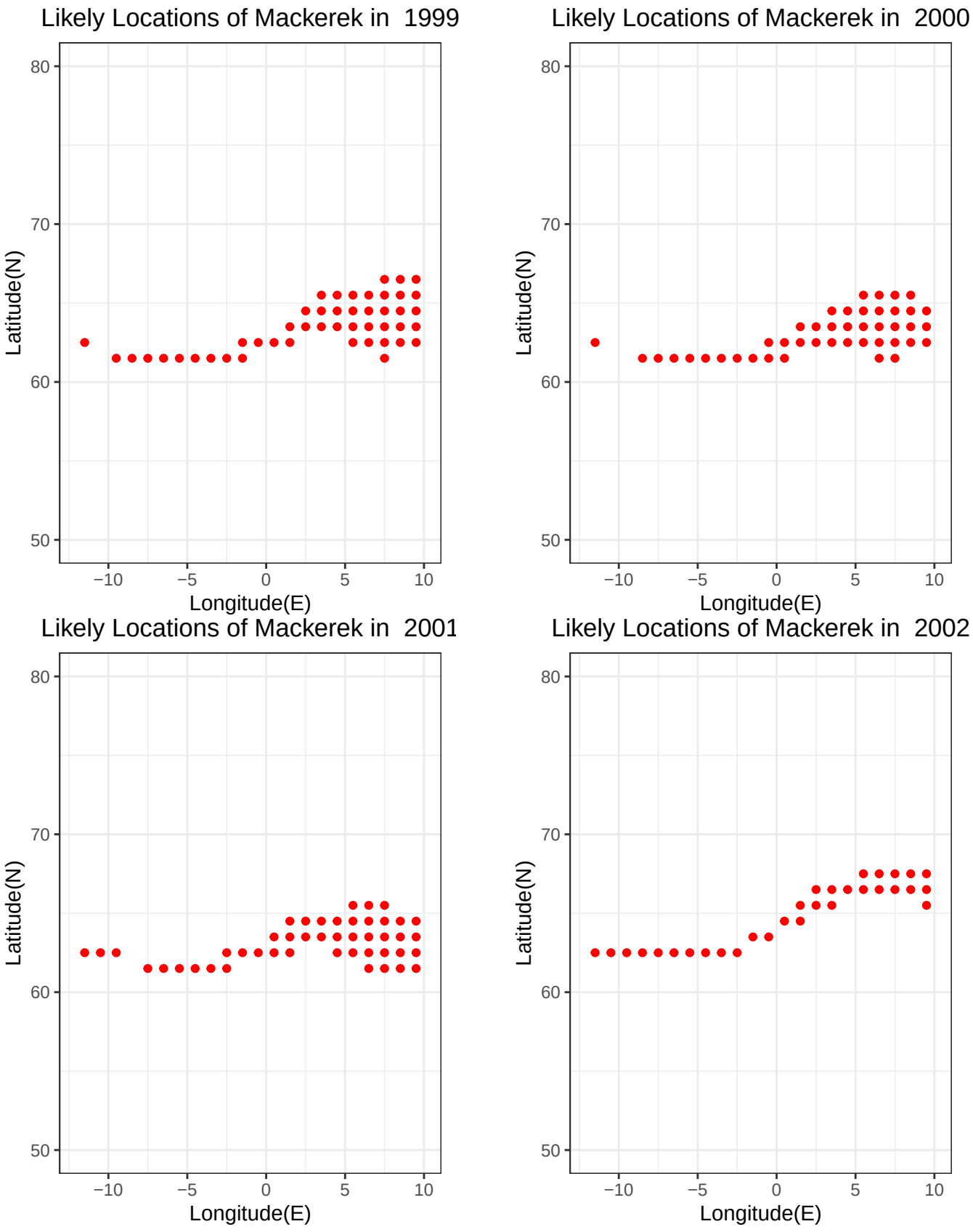
Likely Locations of Mackerek in 1999
Likely Locations of Mackerek in 2000
Likely Locations of Mackerek in 2001
Likely Locations of Mackerek in 2002
Latitude(N)
Longitude(E)
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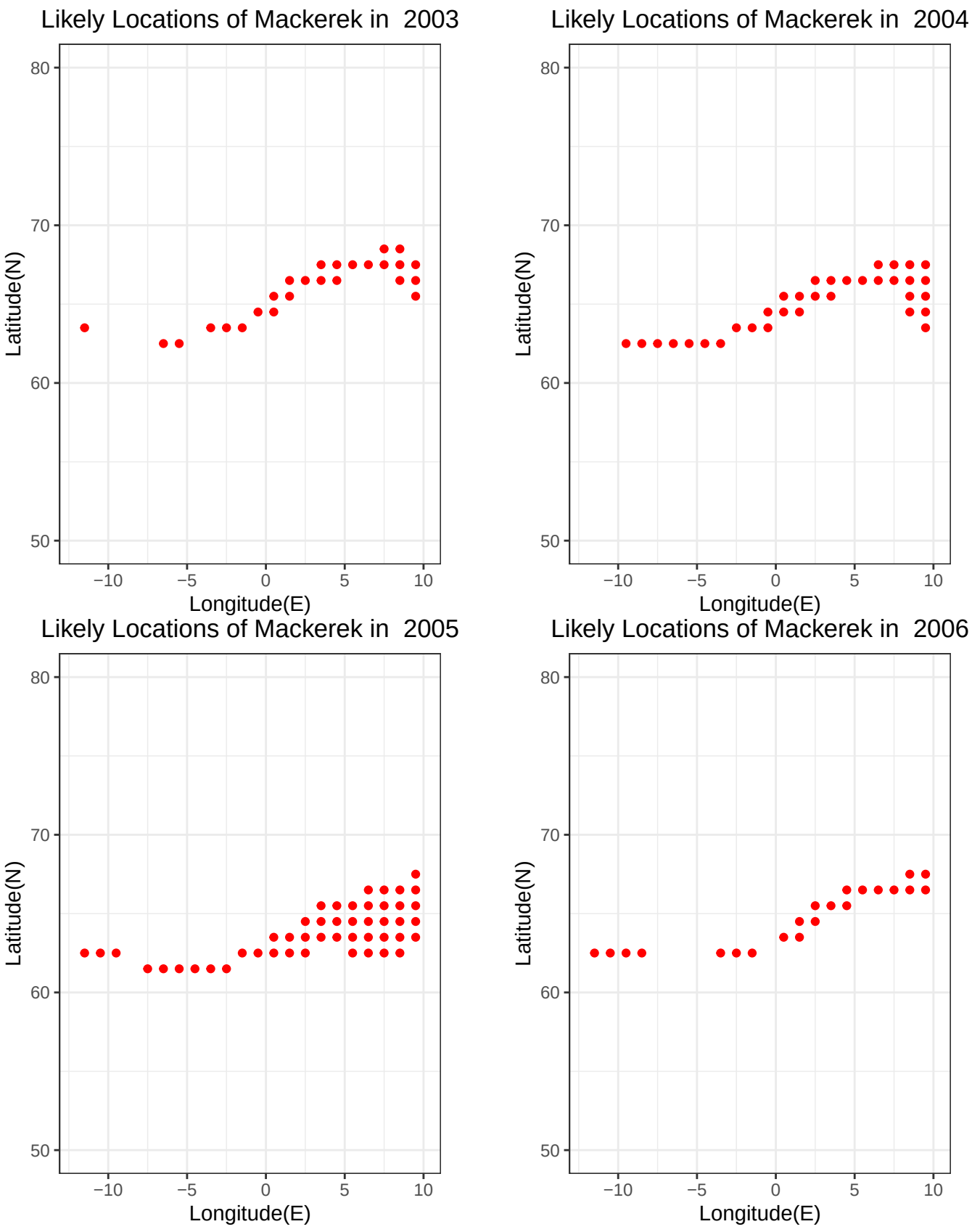
Likely Locations of Mackerek in 2003
Likely Locations of Mackerek in 2004
Likely Locations of Mackerek in 2005
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Longitude(E)
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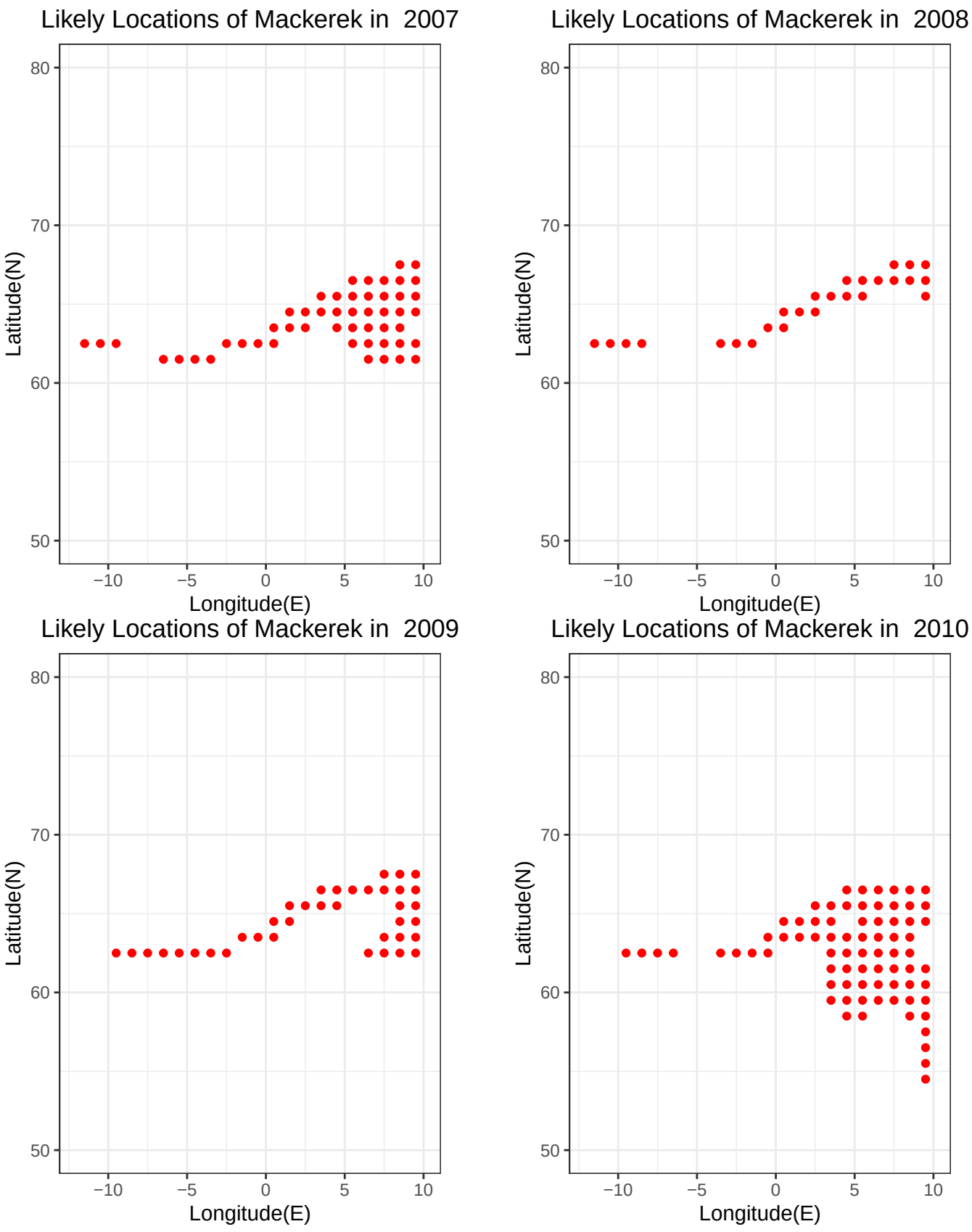
Likely Locations of Mackerek in 2007
Likely Locations of Mackerek in 2008
Likely Locations of Mackerek in 2009
Likely Locations of Mackerek in 2010
Latitude(N)
Longitude(E)
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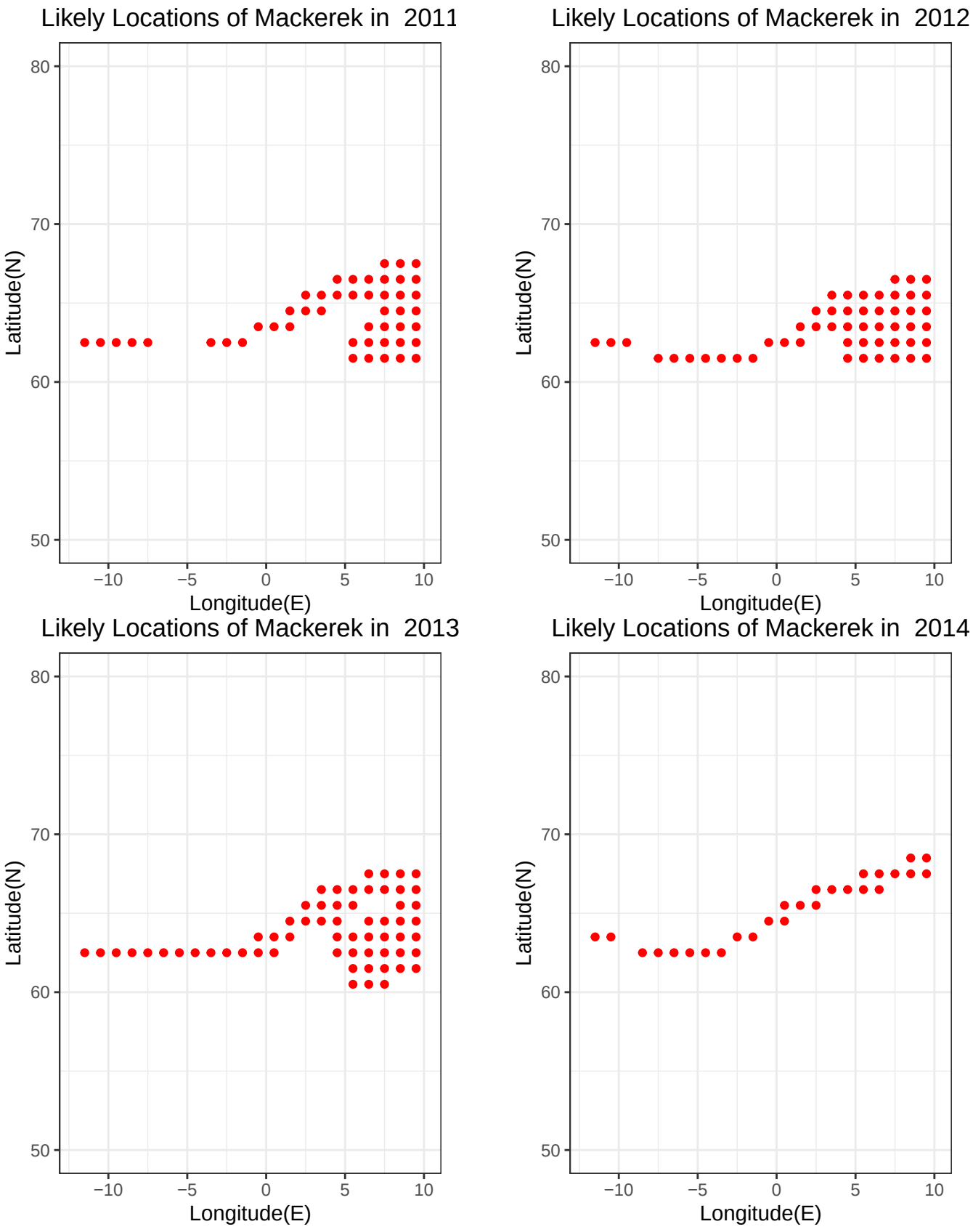
Likely Locations of Mackerek in 2011
Likely Locations of Mackerek in 2012
Likely Locations of Mackerek in 2013
Likely Locations of Mackerek in 2014
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Longitude(E)
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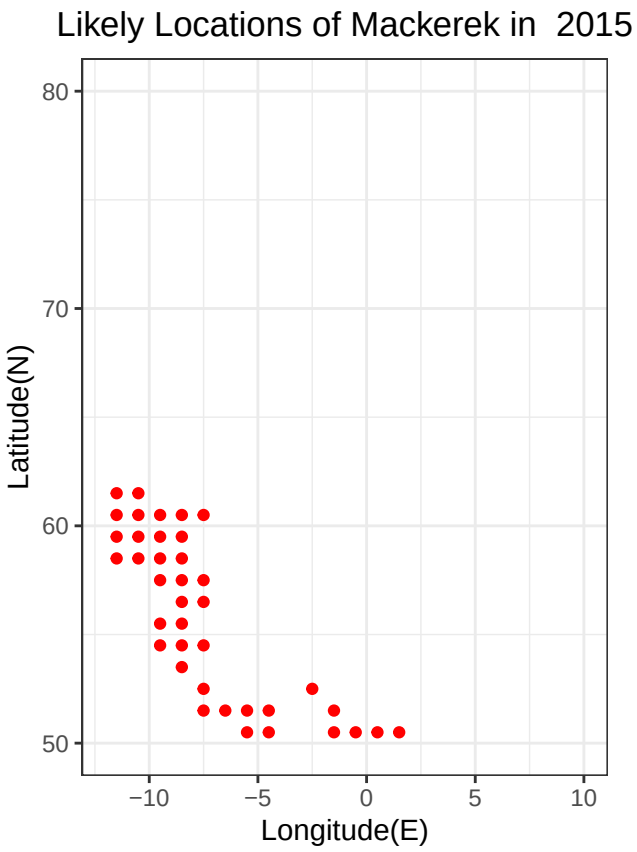
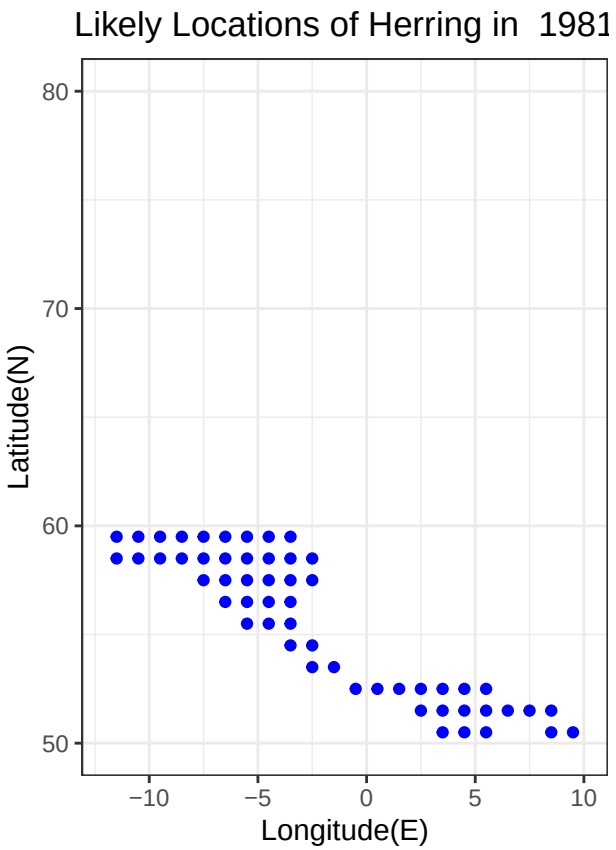



```
for (i in 1981:2015) {
H1981 <- dataTotal2 %>% filter(avg_temperature < 9.8 & avg_temperature > 8.8 & Time == i)
pH1981 <- ggplot(H1981, aes(Longitude, Latitude)) +
  geom_point(col = "blue") +
  theme_bw() +
  coord_fixed(ratio = 1, xlim = c(-12, 10), ylim = c(50, 80)) + xlab("Longitude(E)") +
  ylab("Latitude(N)") +
  ggtitle(paste("Likely Locations of Herring in ", i)) +
  theme(plot.title = element_text(hjust = 0.5))
print(pH1981)
}
```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Longitude(E)
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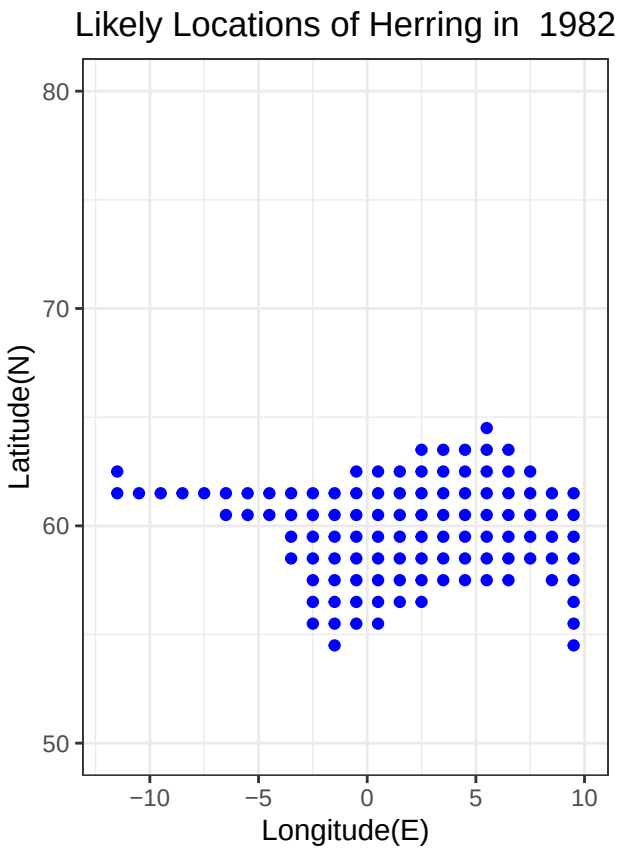
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Latitude(N)
Longitude(E)
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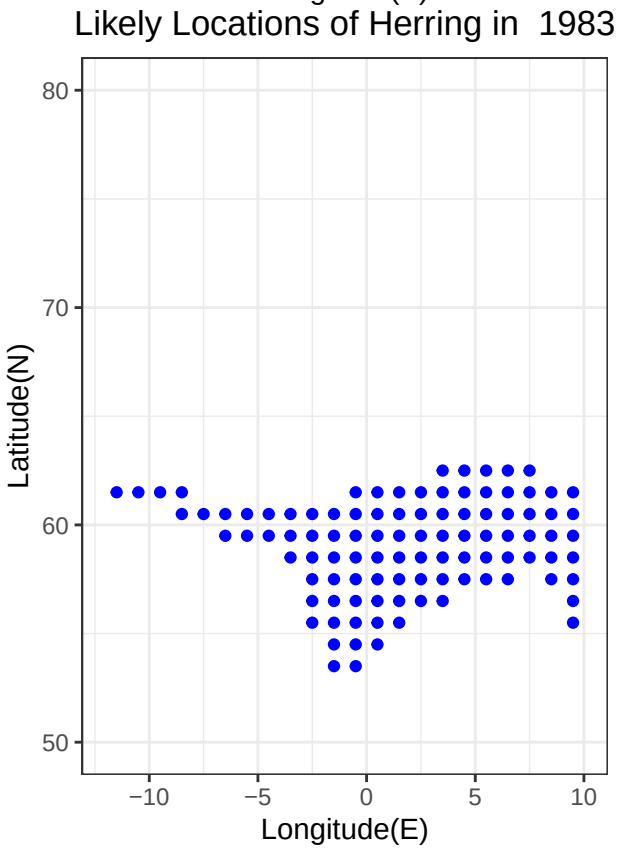
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Latitude(N)
Longitude(E)
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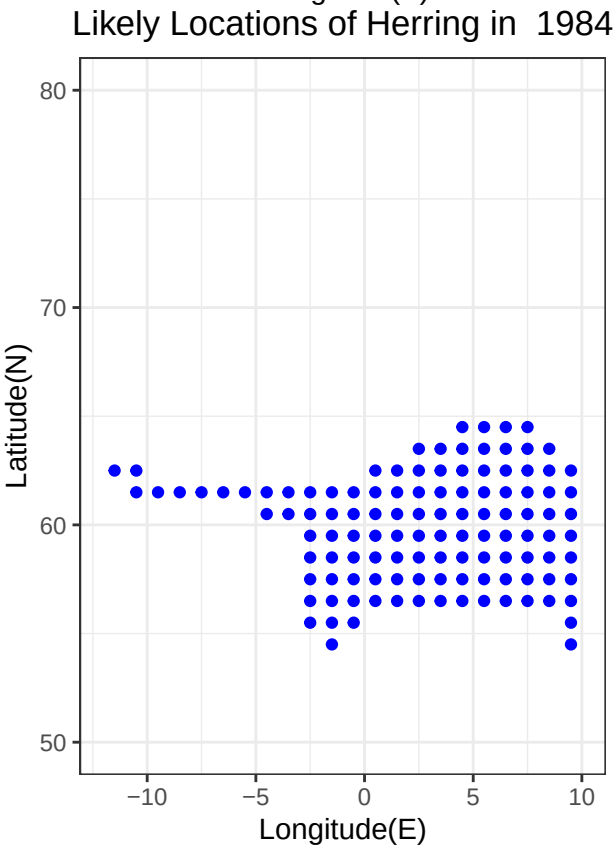
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Longitude(E)
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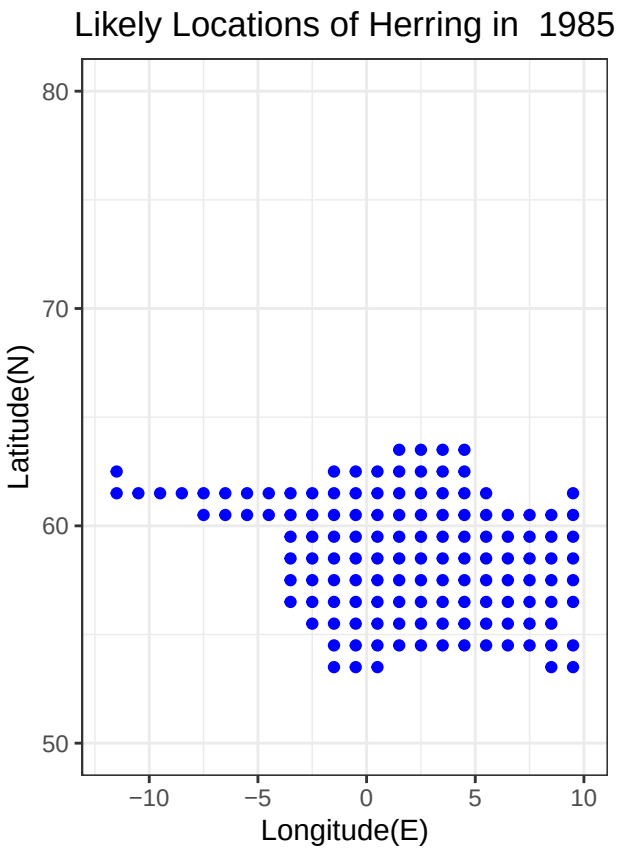
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Longitude(E)
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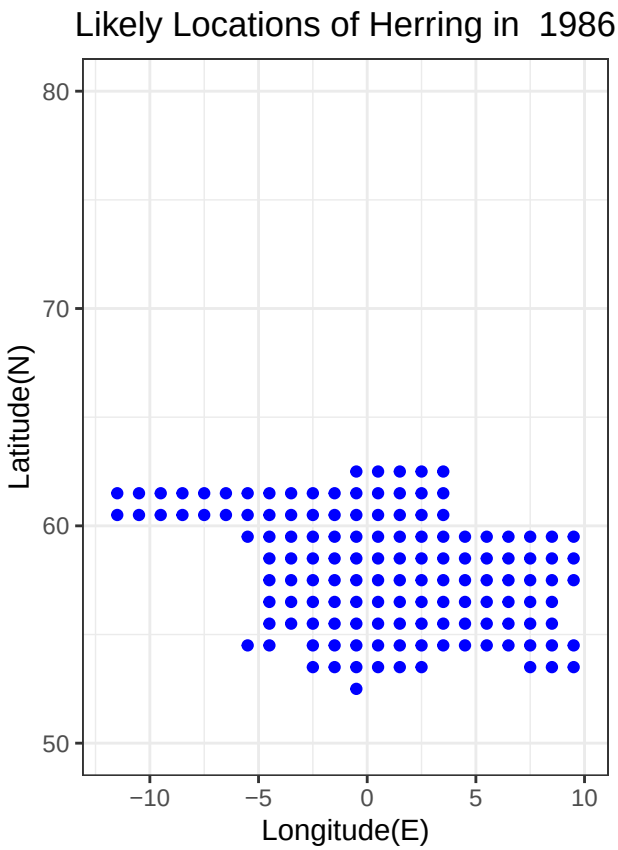
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Longitude(E)
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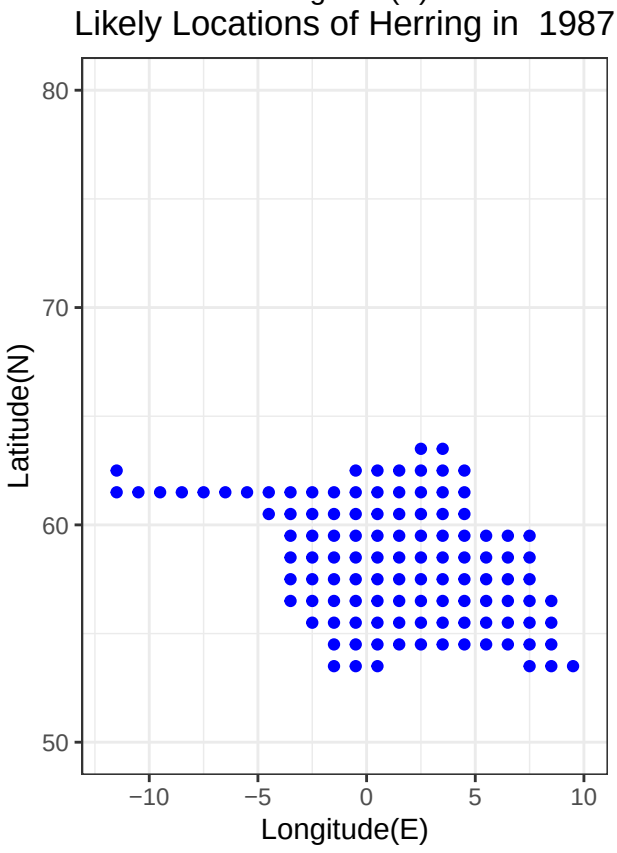
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Longitude(E)
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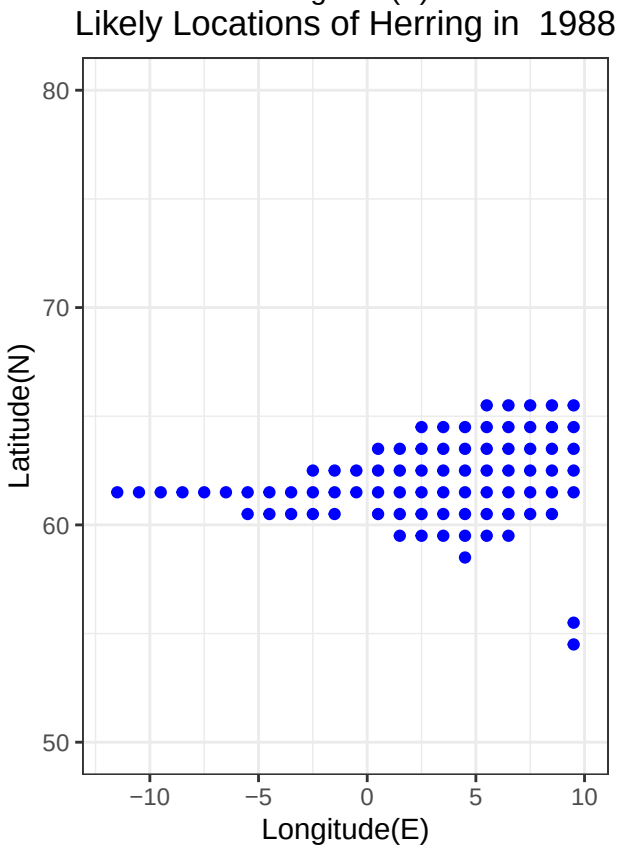
Likely Locations of Herring in 1988
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Longitude(E)
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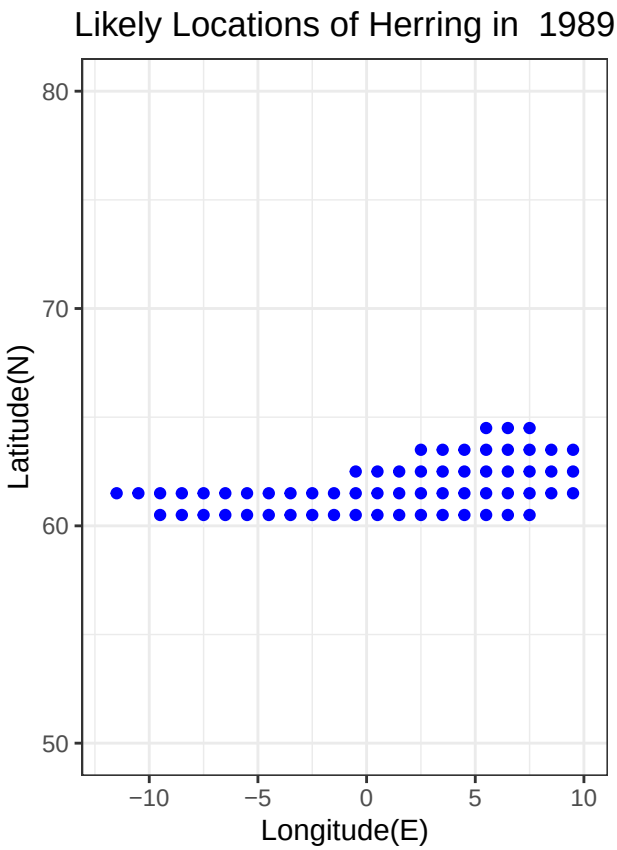
Likely Locations of Herring in 1989
Latitude(N)
Longitude(E)
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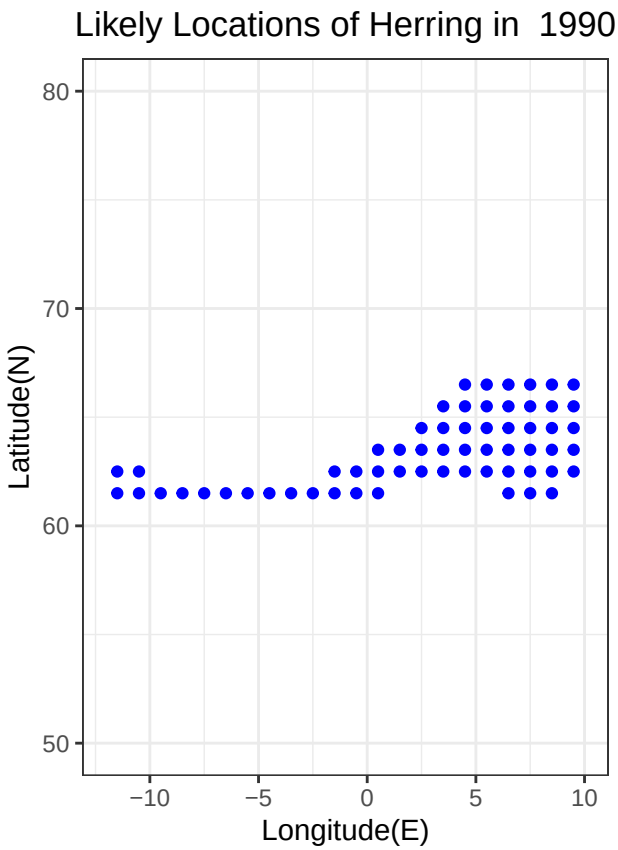
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Latitude(N)
Longitude(E)
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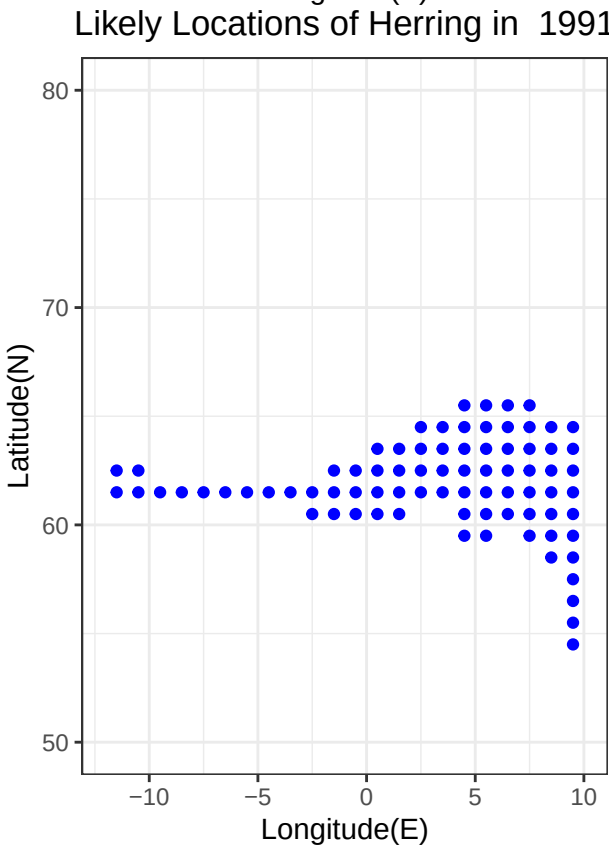
Likely Locations of Herring in 1991
Latitude(N)
Longitude(E)
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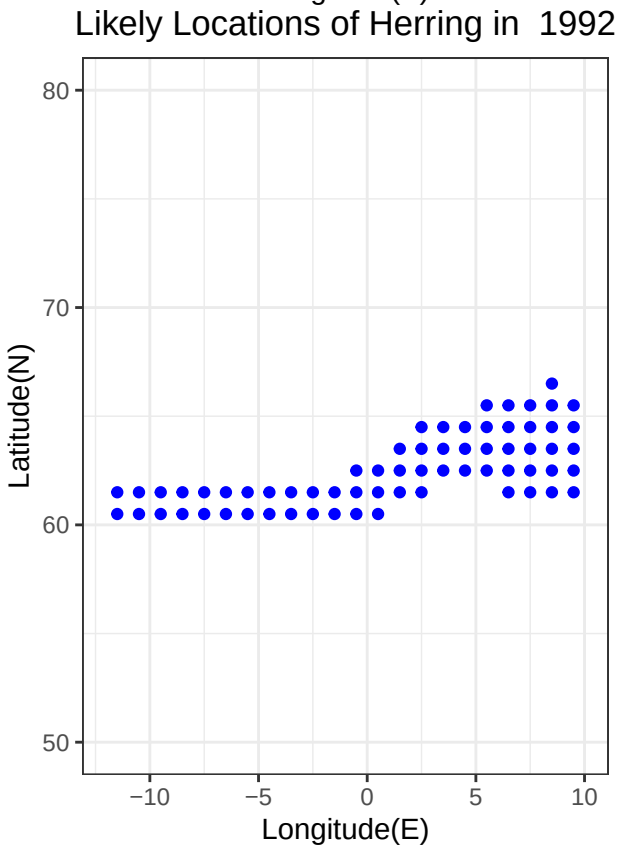
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Latitude(N)
Longitude(E)
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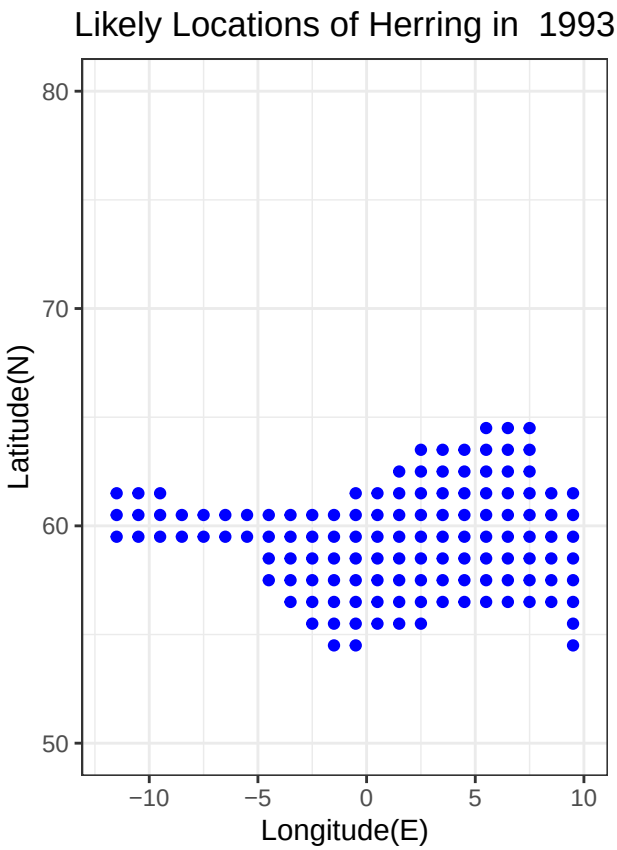
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Latitude(N)
Longitude(E)
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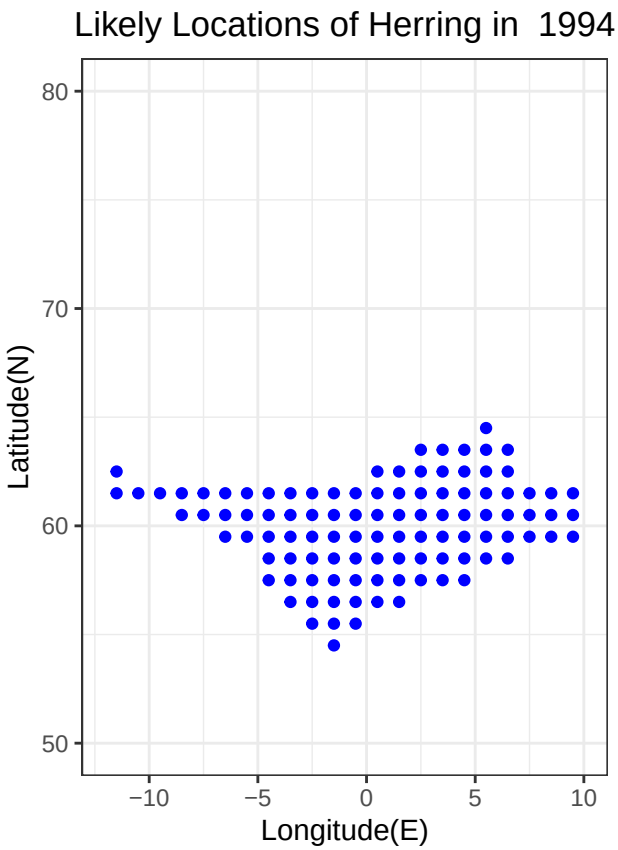
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Latitude(N)
Longitude(E)
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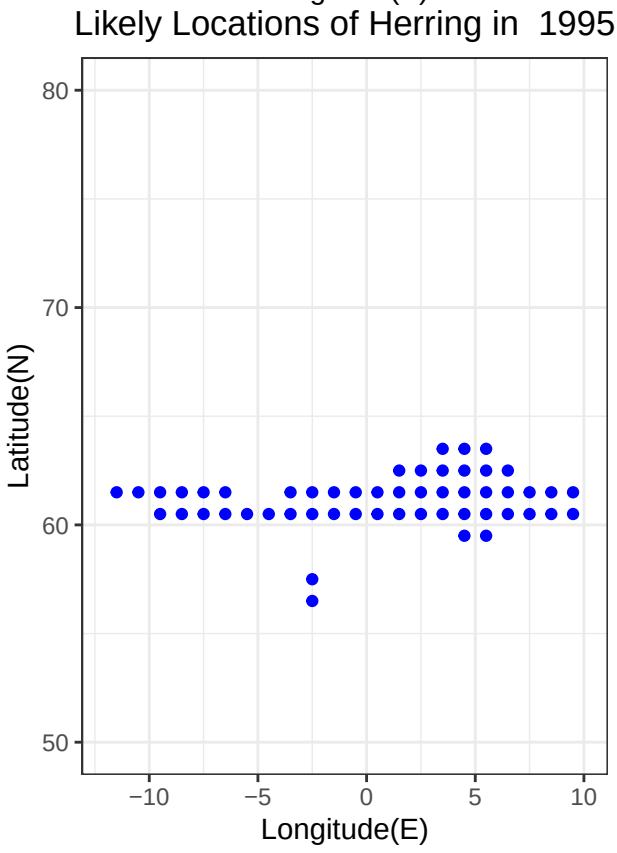
Likely Locations of Herring in 1995
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Longitude(E)
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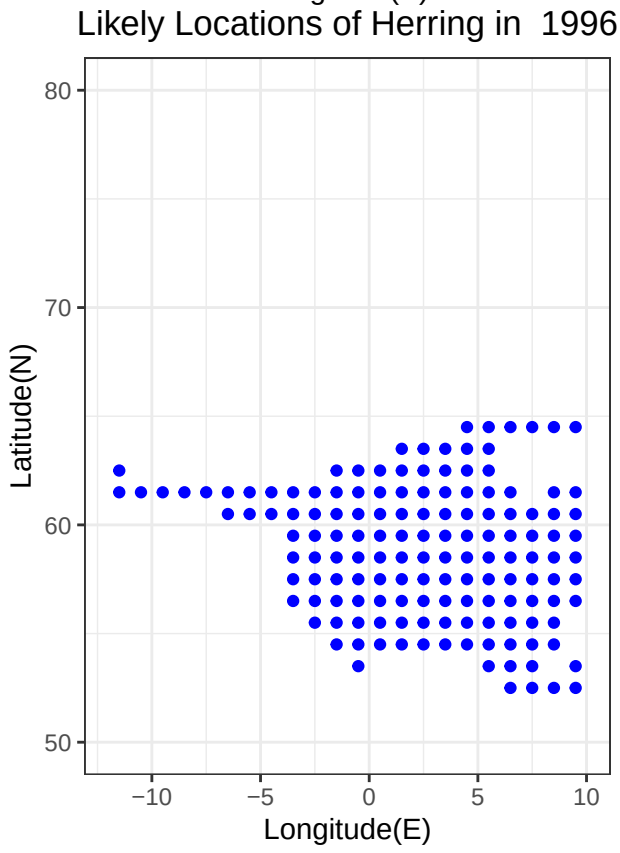
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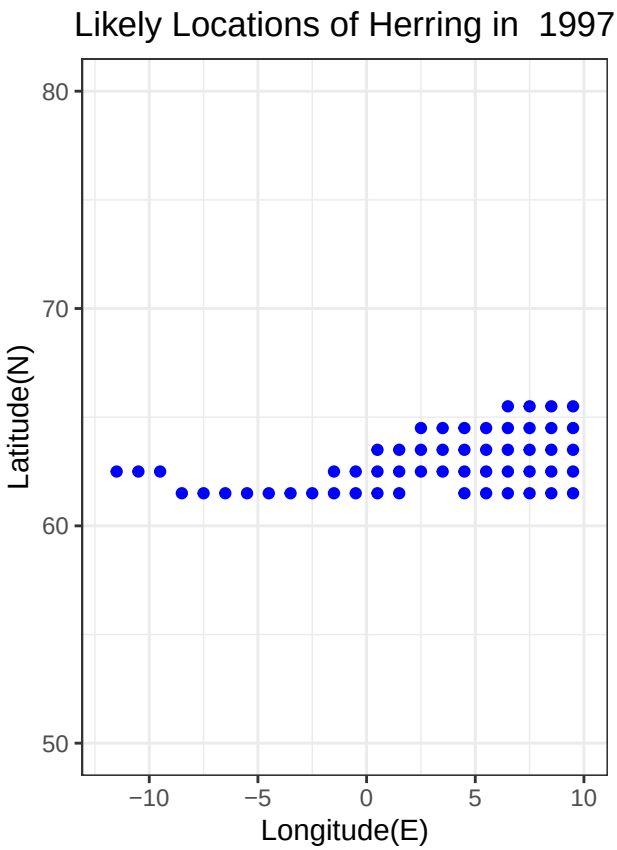
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Longitude(E)
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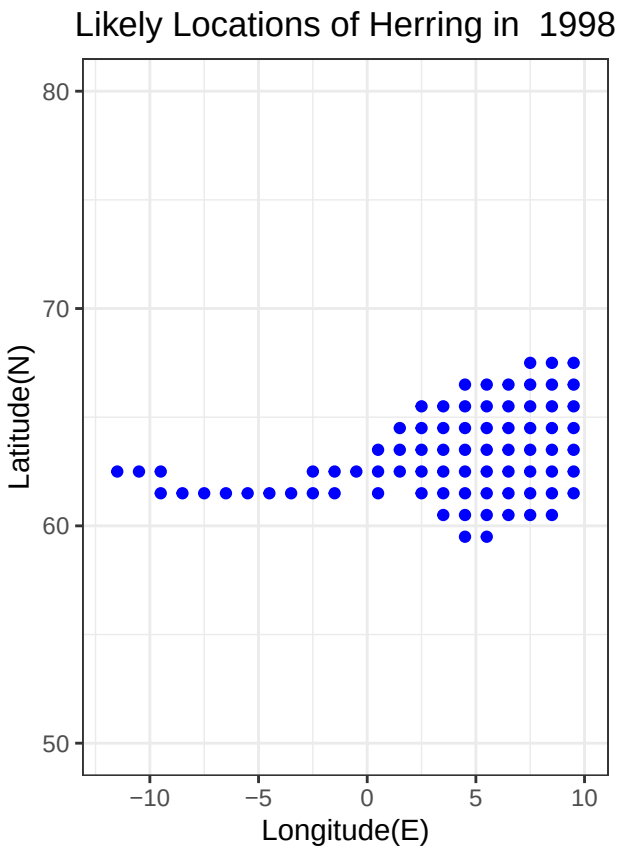
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Latitude(N)
Longitude(E)
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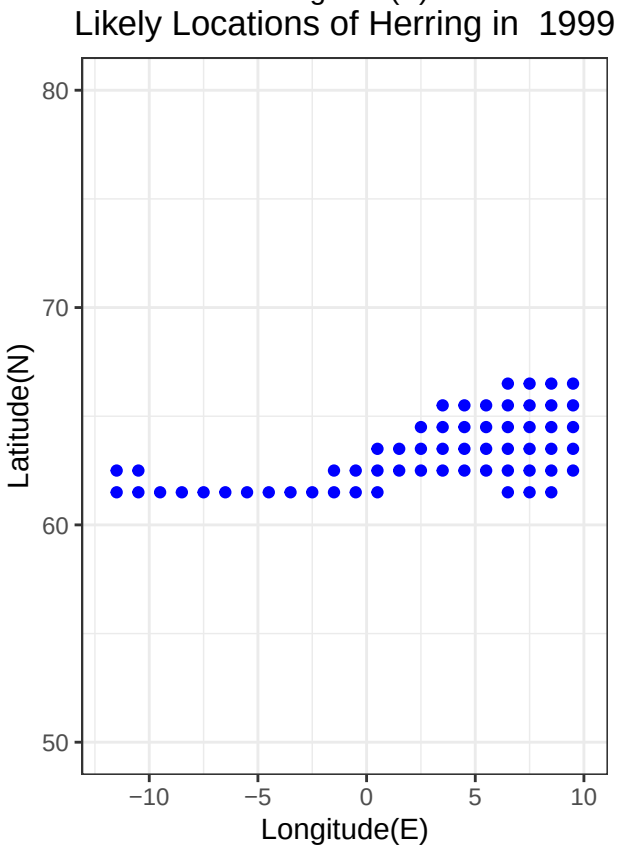
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Longitude(E)
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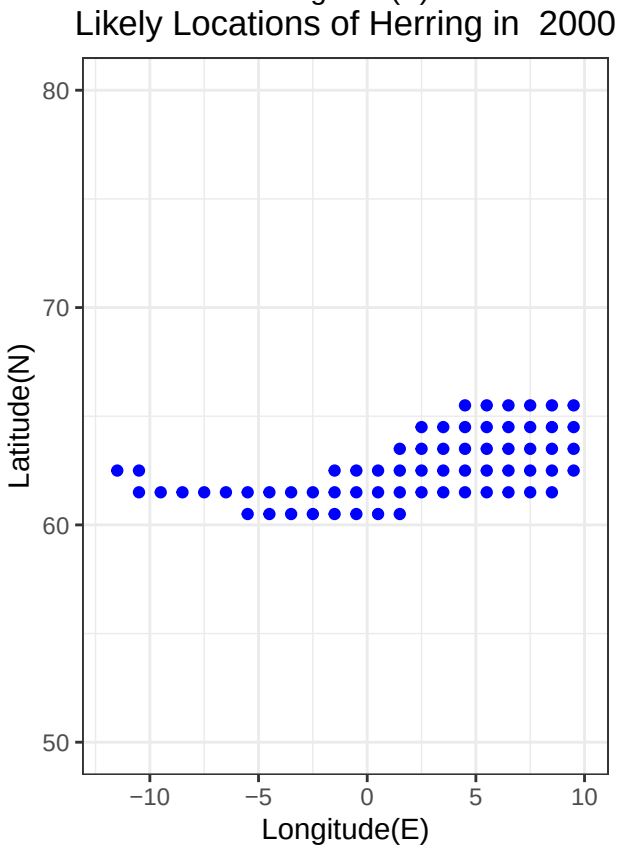
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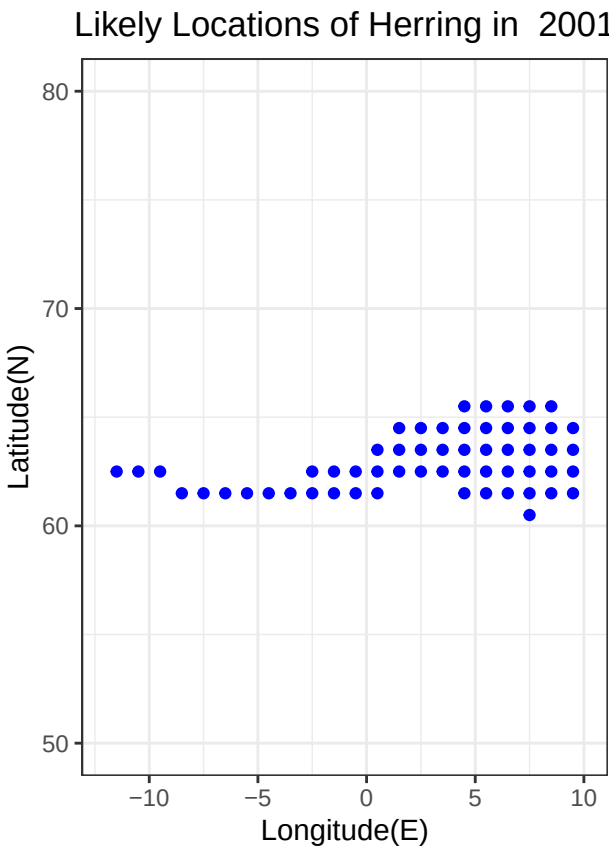
Likely Locations of Herring in 2001
Latitude(N)
Longitude(E)
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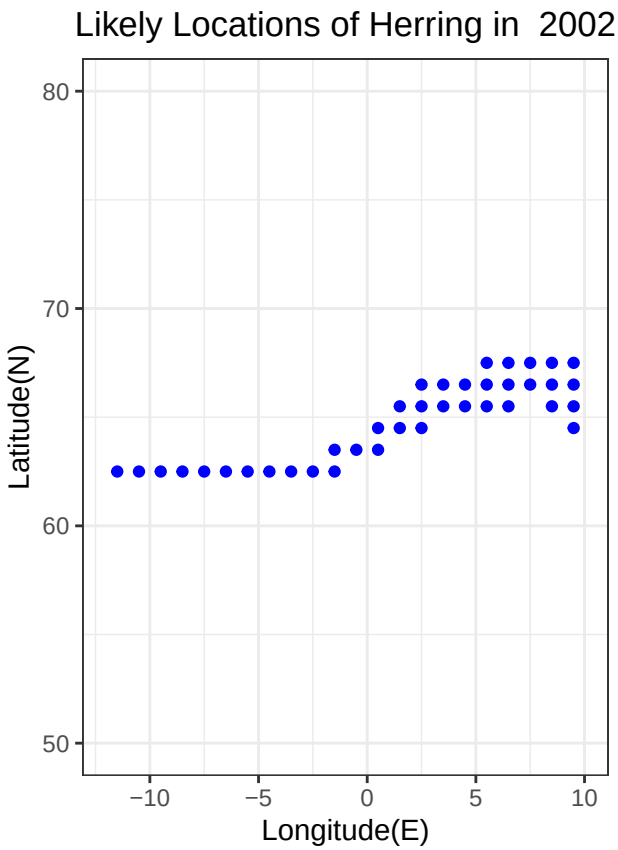
Likely Locations of Herring in 2002
Latitude(N)
Longitude(E)
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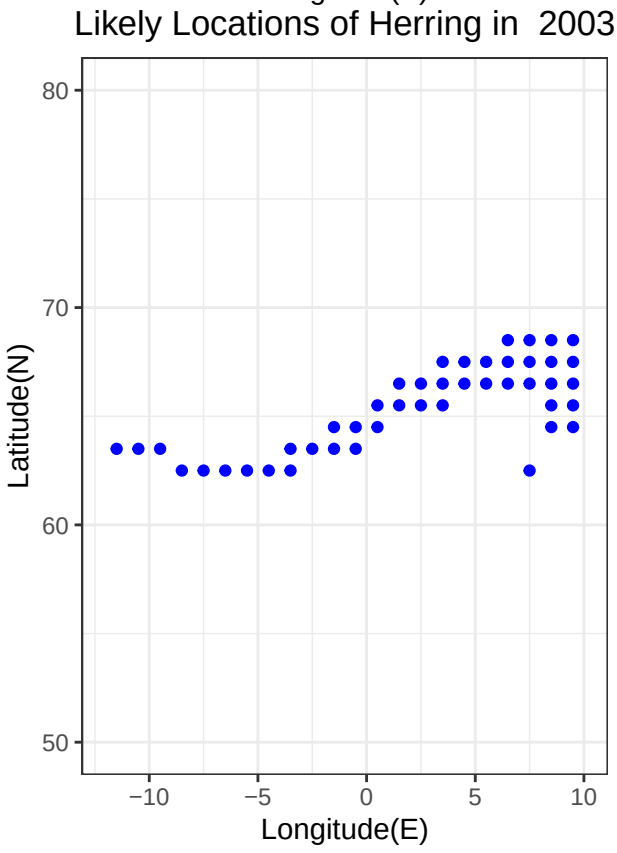
Likely Locations of Herring in 2003
Latitude(N)
Longitude(E)
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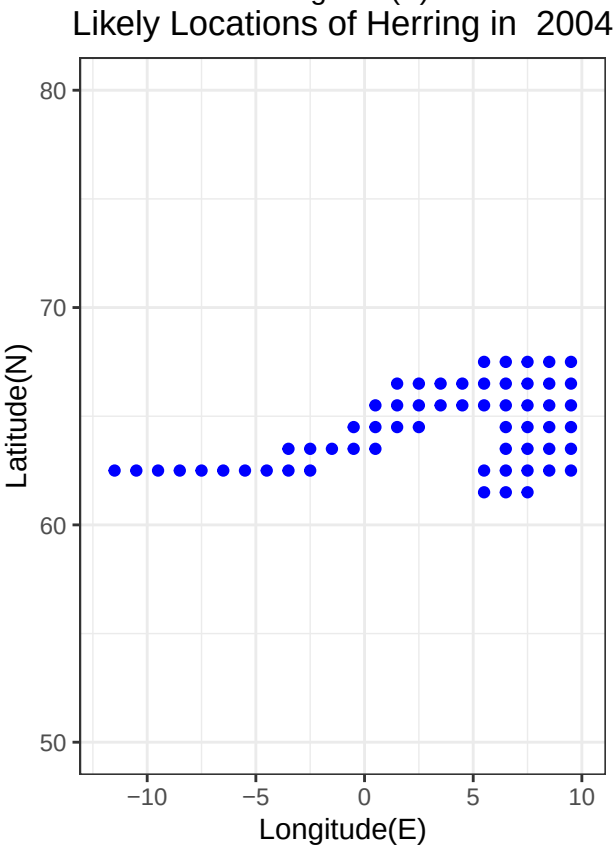
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Longitude(E)
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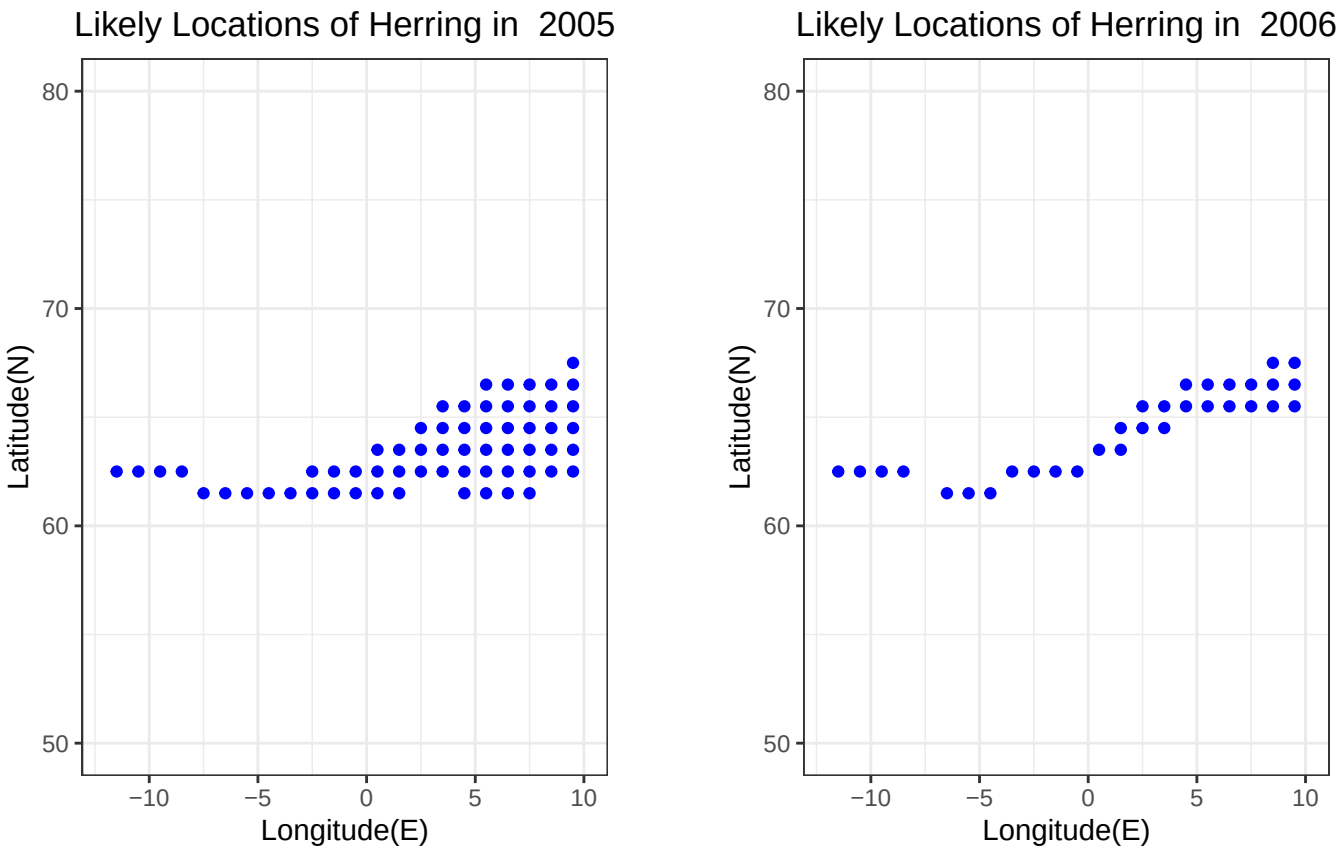
Likely Locations of Herring in 2005
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Longitude(E)
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Likely Locations of Herring in 2006
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Longitude(E)
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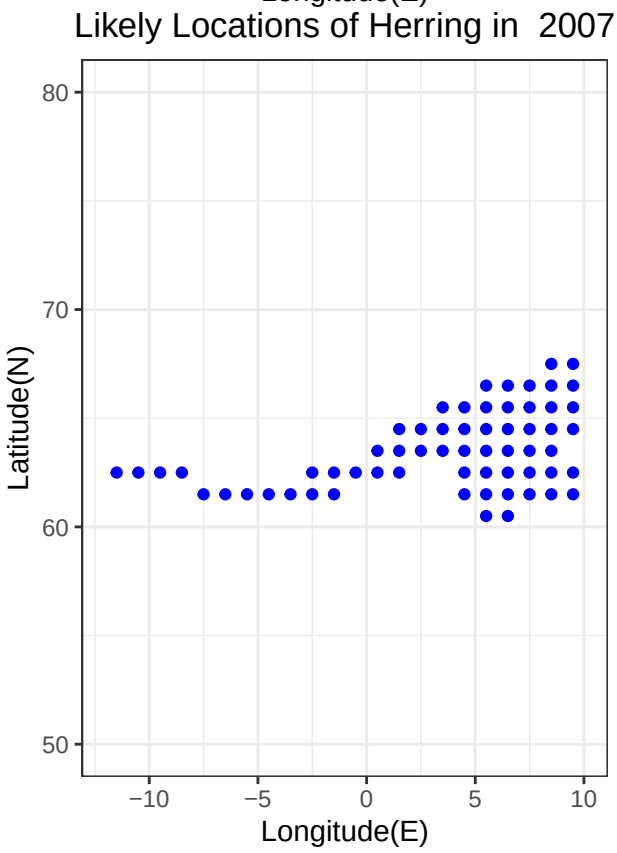
Likely Locations of Herring in 2007
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Longitude(E)
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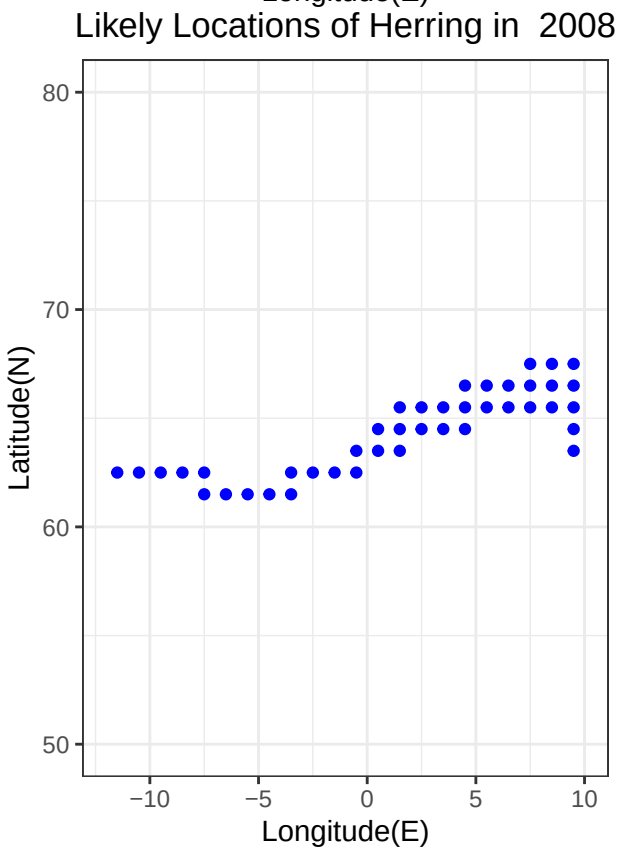
Likely Locations of Herring in 2008
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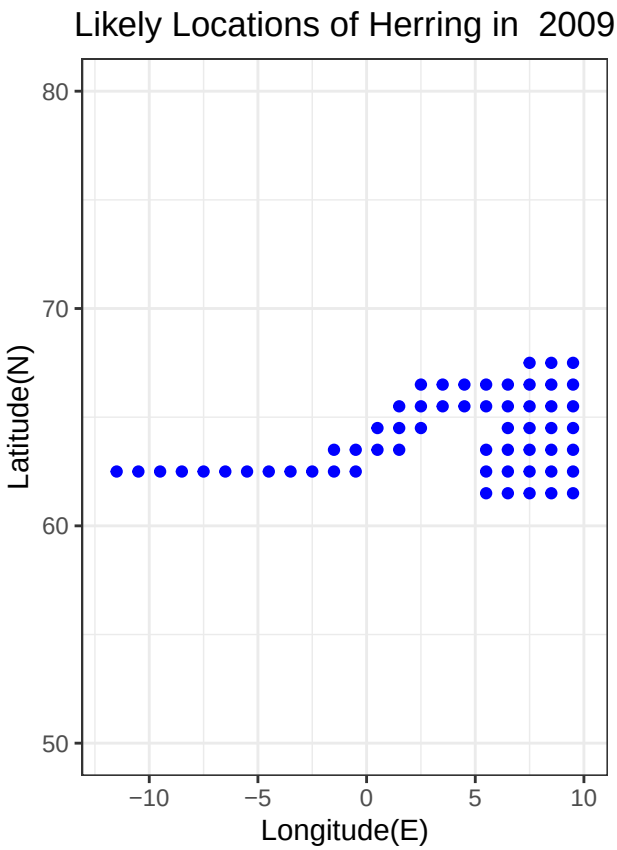
Likely Locations of Herring in 2009
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Longitude(E)
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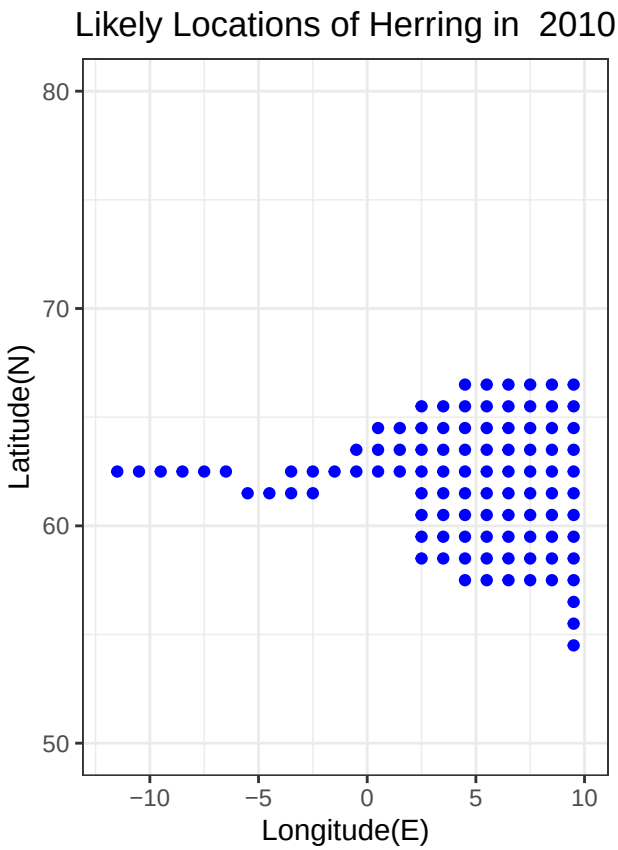
Likely Locations of Herring in 2010
Latitude(N)
Longitude(E)
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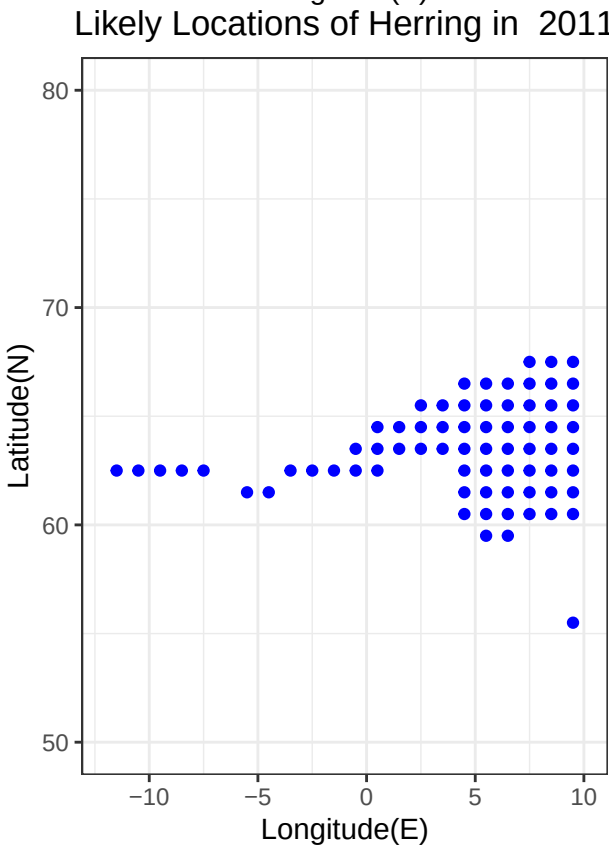
Likely Locations of Herring in 2011
Latitude(N)
Longitude(E)
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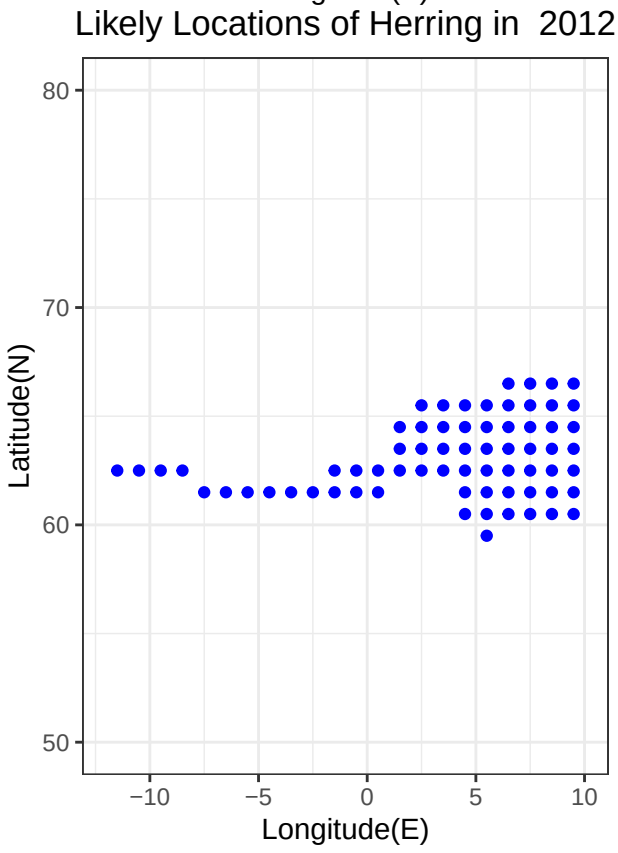
Likely Locations of Herring in 2012
Latitude(N)
Longitude(E)
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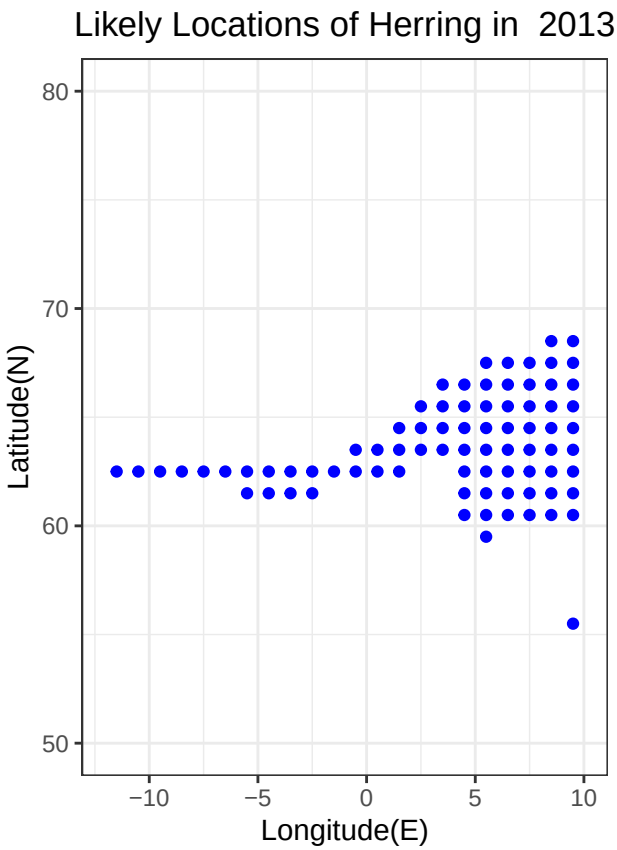
Likely Locations of Herring in 2013
Latitude(N)
Longitude(E)
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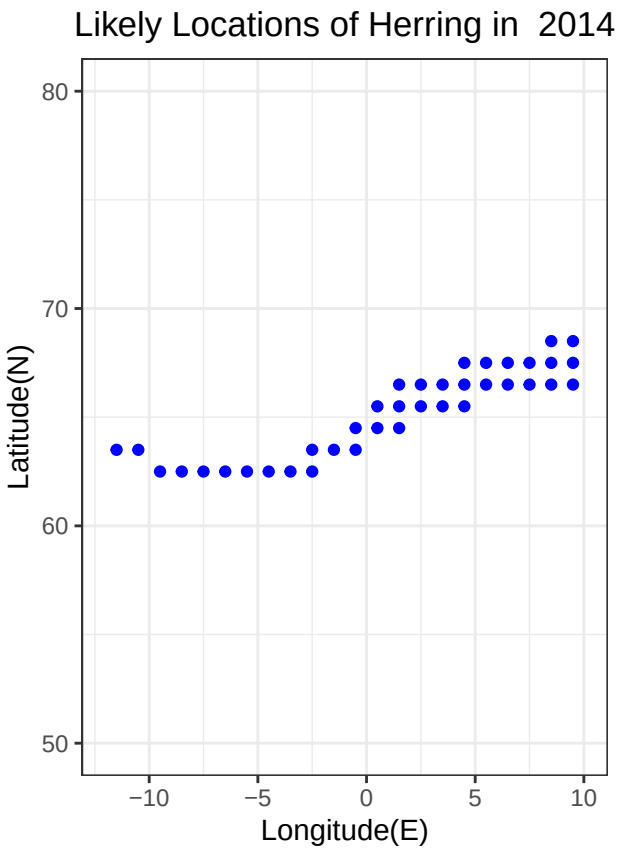
Likely Locations of Herring in 2014
Latitude(N)
Longitude(E)
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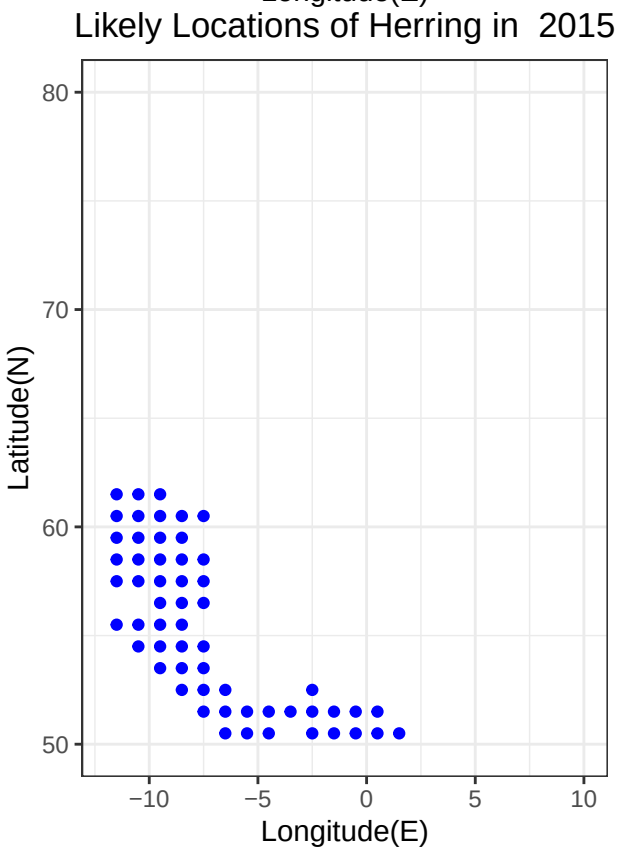
Likely Locations of Herring in 2015
Latitude(N)
Longitude(E)
80
70
60
50
−10
−5
0
5
10