15 Spatial-temporal models for orange crowned warblers count data

In Chapters 12 and 13 we explained how to fit models with a spatial correlated random effect. In Chapter 14 we illustrated the use of auto-regressive models for time series. It should not come as a surprise that in this chapter we combine the spatial and temporal elements of Chapters 12–14 and focus on the analysis of spatial-temporal data.

Prerequisite for this chapter: We assume that you are familiar with the principle of spatial-temporal correlation as explained in Chapter 6, Section 6.3. You also need to be familiar with the material discussed in Chapters 12– 14.

15.1 Introduction

The data used in this chapter are taken from Sofaer et al. (2014), who investigated the effect of competition and predation on the numbers of offspring in a population of breeding orange-crowned warblers (*Oreothlypis celata*) on Santa Catalina Island, California, US. The number of young produced in a nest was modelled as a function of population density and annual rainfall. Sampling took place from 2003 to 2009. Figure 15.1 shows the sampling locations for each of the 7 years.

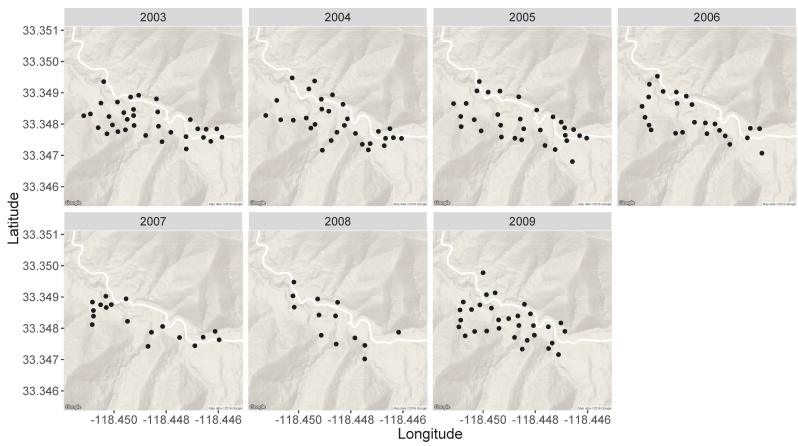

Figure 15.1. Sampling locations on Santa Catalina Island by year.

The R code to create Figure 15.1 is as follows. First we import the data with the `read.table` function. We load the required packages and use the `get_map` function from `ggmap` (Kahle and Wickham 2013) to visualise the sampling locations using Google maps. The rest is a matter of some standard `ggplot2` coding.

```
> OCW <- read.table(file = "OCWarblers.txt",
                    header = TRUE,
                    dec = ".")
> library(ggplot2)
> library(ggmap)
> library(INLA)
> source(file = "HighstatLibV10.R")
> glgmap <- get_map(
               location = c(-118.453, 33.346,
                            -118.444, 33.350),
               maptype = "terrain", zoom = 17)
> p <- ggmap(glgmap)
> p <- p + geom_point(aes(Lon, Lat), data = OCW)
> p <- p + xlab("Longitude") + ylab("Latitude")
> p <- p + facet_wrap(~ Year, nrow = 2)
> p
```

The graph indicates that the sampling locations and the number of observations differ per year. The latter can be also seen from the following `table` output.

```
> table(OCW$Year)

2003 2004 2005 2006 2007 2008 2009
  33   30   31   25   18   13   31
```

We have two covariates, breeding density and annual precipitation. These have the same value for all sampling locations within a year.

We have counts on the number of fledged chicks per nest from 7 years. In each year around 13–33 nests were sampled. There are two covariates.

15.2 Poisson GLM

To investigate whether there is a relationship between the number of fledged chicks and breeding density and annual precipitation, Zuur et al. (2016a) started with the following generalised linear model (GLM) with a Poisson distribution.

$$\begin{aligned} FL_i &\sim Poisson\left(\mu_i\right) \\ \log\left(\mu_i\right) &= \beta_1 + \beta_2 \times BreedingD_i + \beta_3 \times Rain_i \end{aligned} \tag{15.1}$$