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Using ringing data to inform a geolocator study: when and which birds to equip?

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ABSTRACT
[...]

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1. Introduction

The Spotted Ground Thrush (Geokichla guttata) was still relatively common on the coastal forest of Kenya in the 70s and 80s, but since, they have become much scarser with an estimated >80% decline between 1980-2000 ((Ndang'ang'a et al. 2008)). The reason for this decline hasn't been fully elluciated but it is suggested that their migration stops or unkown breeding site might be causes because their wintering ground has been protected for the entire period.

The tragedy of the Spotted Ground Thrush is likely not the only one intra-african migrant alhough there is little information available about basic population trend African bird population (**?**). Moreover, afro-tropical migration is complex and diverse (Benson 1982), and are the result of a fine-tuning with the climate and habiat constrains (Hockey 2000). The combined effect of the rapid habitat destruction and climate change impacting the african continent can be expected to affect migrant bird more than resident as their migration route, timing relies on the predicatbility of food which itselft depends on habitat and weather (Vickery et al. 2014). Effective protection of intra-african migrant species, as in the exemple of SGT, has to start with a better understanding their migration: its route, stoppover site, timing, trigger (rain? temperautre, etc), the variability of route, the influence of age and sex...

Uncovering some of these question has been made easier in recent year thanks to the deployment of geolocator (ref). Their low cost, low weight and more recently, their ability to measure additional variable (pressure, temperature etc..) (Meier et al. 2018) have allowed to study various aspect of the migration strategy (McKinnon and Love 2018).

Beside the low spatial resolution achieved, the major limitation with this technology

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is the necessity to recapture the bird equip in the following year(s) to retrieve the data. Optimizing the deployment of geolocator as to maximize the recapture rate of equiped bird is therefore important. DUring the design of the study and planning of deployement, several factor can influence the recapture rate such as location and timing in link with their phenology (breeding, wintering or stopover site), the timing within the season (early, middle or late, or in link with breeding status). The actual individual equiped can also be selected based on sex, age, breeeder/non-breeder size or weight. These factors have to be consider with care in link to the study objective as to not bias the result.

In general, - male : greater site fidelity for shorebird ((Weiser et al. 2015)) - previously tagged individual improve return rate (Weiser et al. 2015) - breeding success improve return rate (Weiser et al. 2015) - early breeder have higher return rate (Weiser et al. 2015)

Because of juvenile mortality and fidelity of breeding/wintering site, most study focus on adult bird.

Blackburn2017 connectivity study equpping paleartic migrant at their wintering site.

All study have focused on the effect of geolocator on bird, here we focus on the pre-deployement analysis using existing ringing database with the aim to optimize the equipement ringing session effort Most study have focus on long-distant migrant with relatively well-known migration timing and route. Here intra-african which have more complex and variable movement. Most study on breeding site, here on wintering site.

In this study, we aims at showing an exemple of how a ringing database can help to plan the equipment of geolocator. The utlimate objectif is optimize the equipement planification as to maximize the recovery rate of the geolocator. The parameters to controle this optimization is how many geolactor can be deploy, when to deploy them, on which bird (age and sex). This has obviously be done in link with the research question and hypothesis of the study.

We are applying this methodology on RCRC two intra-african migrant arriving in mid-May in the coast of kenya and leaving in the last months of the years.

2. Materials and methods

2.1. *Ringing site and database*

Mwamba field study center (3°22'36.3"S 39°59'16.9"E) is located on the coast of Kenya and in the middle of the Northern Zanzibar-Inhambane Coastal Forest Mosaic ecoregion, recognized for its biodiversty value and threats (**?**). Intra-african along this flyway, and locally a green belt along the coast (creek blocking/forest disapeared elswhere). For instance, in 2018, while the rest of the area was expericenced a dry year, the site remained the last one wet which resulted in an higher-than-usual capture of paleartic migrant.

More locally, the stations is located on a residential costal scrub/forest that have benefit from little habitat change over the last 50 years (**?**). The nets are set in the nature trail of the center that has been managed. Evolution of vegetation...

In this study, we use the ringing data collected since 2002, regular ringing session are held and is still ongoing today. Up to begining 2019, the dataset conssits of 3372 entries of 2532 rings covering 96 species. In this study, we used 317 sessions up to 2019.

Ringing effort presents some variability. The sessions are relatively well-spread throughout the years, although with a higher intensity in Spring (see Appendix). Over the years, there is a more heterogeneous distribution: very good coverage between 2003 and 2007, variable from 2008 to 2012 (see Appendix).

For some session, additional information gathered includes starting and closing time (61%), total length of nets (77%), note on weather condition (55%) (see Appendix). In general, sessions start at sunrise (M=06:12 ; SD=00:14) and last until bird activity slows down (M=04:08 ; SD=01:01). In average, sessions uses a total of 154.3424658m (SD= 51.5159682) of nets. We classify weather according to the expected influence it had on the capture rate (none, little, large). We manually checked exterme value for outliar and remove a few ringing session not representative.

We also show the data of the actual ringing session.

2.2. *How many capture possible?*

In the plannification stage, an important question of design is the number of individual that is possible to capture and thus equip during a ringing season. This question has to be asked with regard to the ringing effort planned (i.e. number of session, duration of session, number of nets etc). To address this question, we follow a three steps process described below.

In the first step, we modelled the number of RCRC captured per session using a generalized additive model (GAM) model assuming the number of capture follows a Poisson distribution. The predictors variables tested in the models are (1) year (2) day-of-year (or Julian day), (3) duration of the sessions and (4) total length of nets and (5) starting time. Because the duration, start time and length of nets were missing in many cases, we used multiple imputation method by chained equations (**?**) to generate 30 sets of data without any missing value. For each of these sets, a GAM model is fitted.

In the second step, we address the problem that RCRC can only be equipped once a year. A first approached tested was to model the count of *new** bird (i.e. bird which haven't been captured in the current year) rather than the total number of bird. However, this count depends on how many RCRC have already been equipped earlier in the year. Instead, we preferred to model the probability that a bird captured hasn't been already captured in the current year. This probability is also modelled with a Generalized Linear Model (GLM) using a binomial family and a single explanatory variable consisting of the total number of RCRC captured in the year. We also tested adding the day of the year as explanatory variable but the model was not better

In the third step, we used the two model to predict the number of RCRC that can be captured over one year. This number is estimated from the prediction of the models under various senarios of ringing session. The default scenarios for our ringing season of 2020 is to ring every week for 4 hours using 156m of nets. Using the first model and these information, we can estimate (with uncertainty) the number of RCRC that will be captured along the season. Knowing how many bird have been capture, we used the second model to predict how many unique RCRC can be equipped along the year by multiplying the number of capture by the probability of being a new bird. Finally, assuming that the sessions are independent conditional to the model, we estimate the total number over the year with a cumulative sum along the year. The standard error estimate is computed with basic variance calculus assuming independence of the variables.

This approach was performed under different scenarios where we modify the number of ringing session, total lenght of nets and duration of ringing session.

2.3. *Improve the recapture rate*

The data collected by geolocator can only be retrieved if the bird is recapture in the following years. Consequently, to optimize the study, it is essential to equip the bird that are more likely to be recatpture. Ringing database can inform this decision by providing the recapture rate of bird as a function of the date of equipement but also the sex, age, weight of the bird. Using this information, the ringer can make an informed decision about equipping a captured bird or releasing it without one. This decision has be taken in consideration with regards to the total number of geolocator available and the number of session left.

In this study, we look at two parameters: the time of year and the age class (adult or juvenile). The recapture probability is estimated by modelling the binomial response of weather a captured bird will be recaptured in the following years. This means that we consider that an individual is recaptured if the bird has been recapture at least once in any of the following year and this independently to if it was already been captured in the the past.

The expected number of retrieved geolocator can be computed as the product of the count and recapture rate.

We first model the count of adult and juvenile per session seperatly with the same approach as the total count.

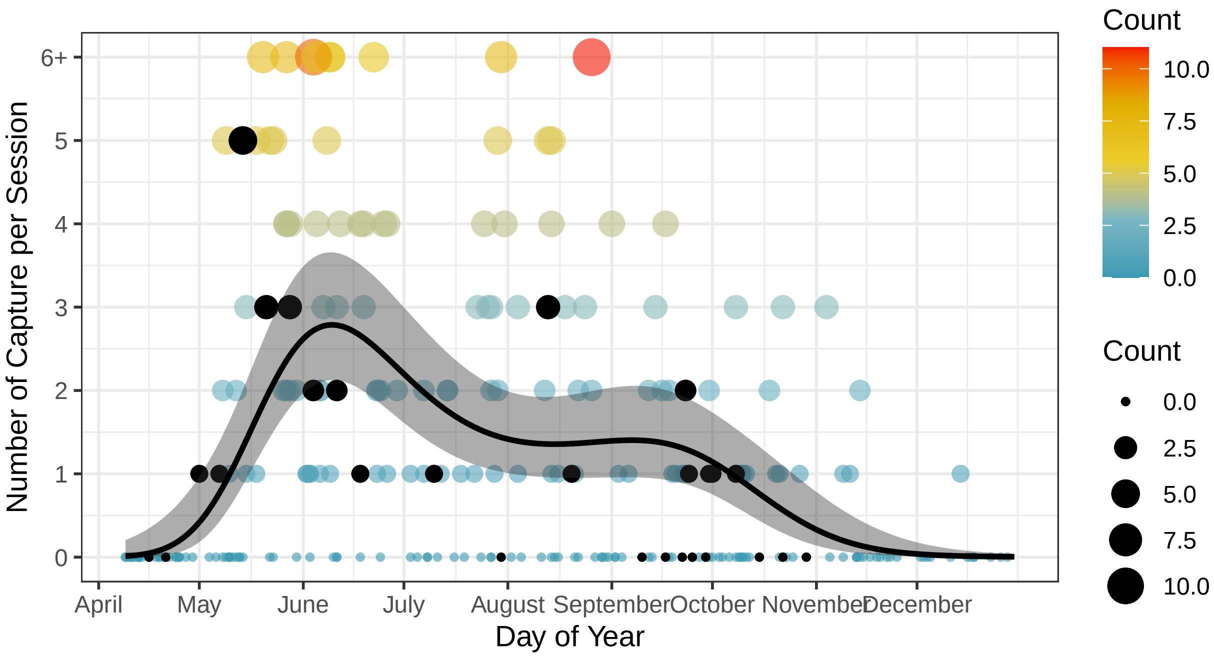
All computation was performed on R [], using the MCGV package for GAM and Mice Package (**?**) for the imputation.

3. Results

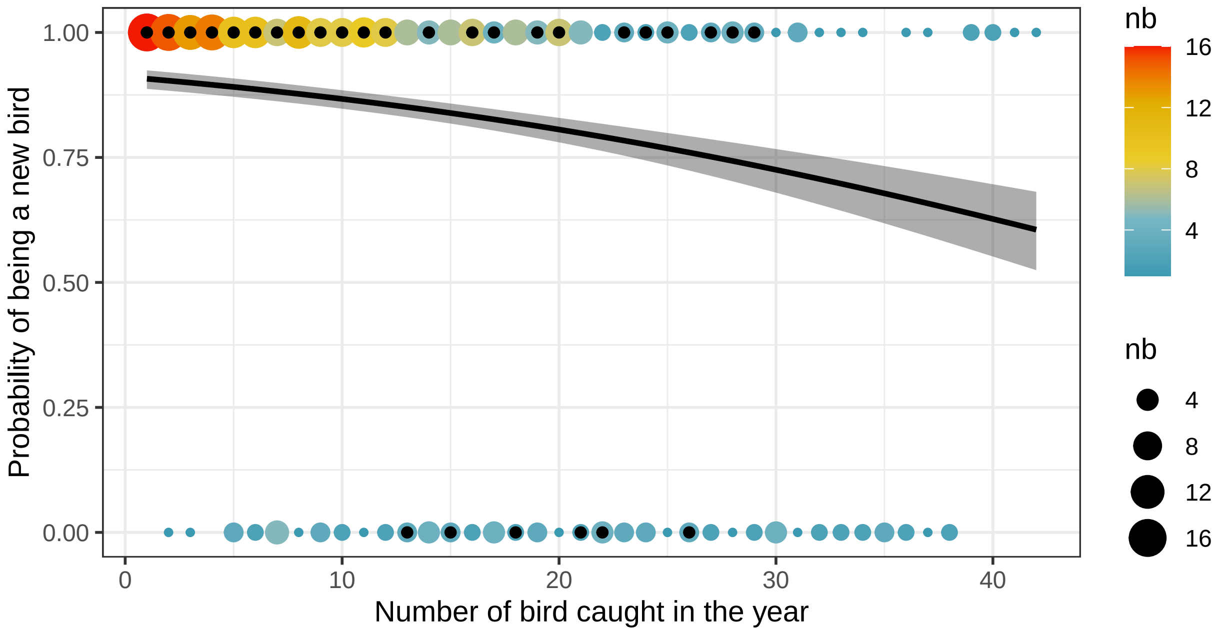
3.1. *How many capture possible*

A GAM model was fitted to the data in order to model the number of RCRC captured for each session. We tested several parametrization of the model, the retained model was `Count ~ s(Julian) + NetsDuration + NetsLength`. Model statistic are presented in SM1 with figure. Year was not included because the data presented a trend which is not [. . .] and the starting time was not retained neither because it was not explaining and even showed a trend in opposite direction (see Appendix).

The fitted model is illustrated in @ref(fig:seasonal-variation-counts) for the default case (Session using 156m of nets and 4hr duration) together with the raw counts data. The model fits a typical migrant phenology curve, with a steep increase in the number in May, peaking in early June with near 3RCRC per session. The second peak of returning bird in mid Septermber is much smaller with only 1.5 bird/session. The counts of 2020 show an early arrival a bird (peak in second half of May), but overall within the range of typical years.



We modelled the recapture probability within a year to be able to extract the number of unique bird during a year. As expected, the model fits a general increase of recapture (decrease in new bird) as the number of previously captured bird increase. The maximum number of RCRC captured in one year is 42.



Testing the

3.2. ***Improve the recapture rate***

Over the 161 unique RCRC captured, 67 (42%) were recapture and 39were recapture in a subsequent year (24%). When assuming each capture-recapture independent of if the bird has already been captured earlier, we have a recapture rate of 47% and 30% for subsequent year only. [this last one is the one used for the model]

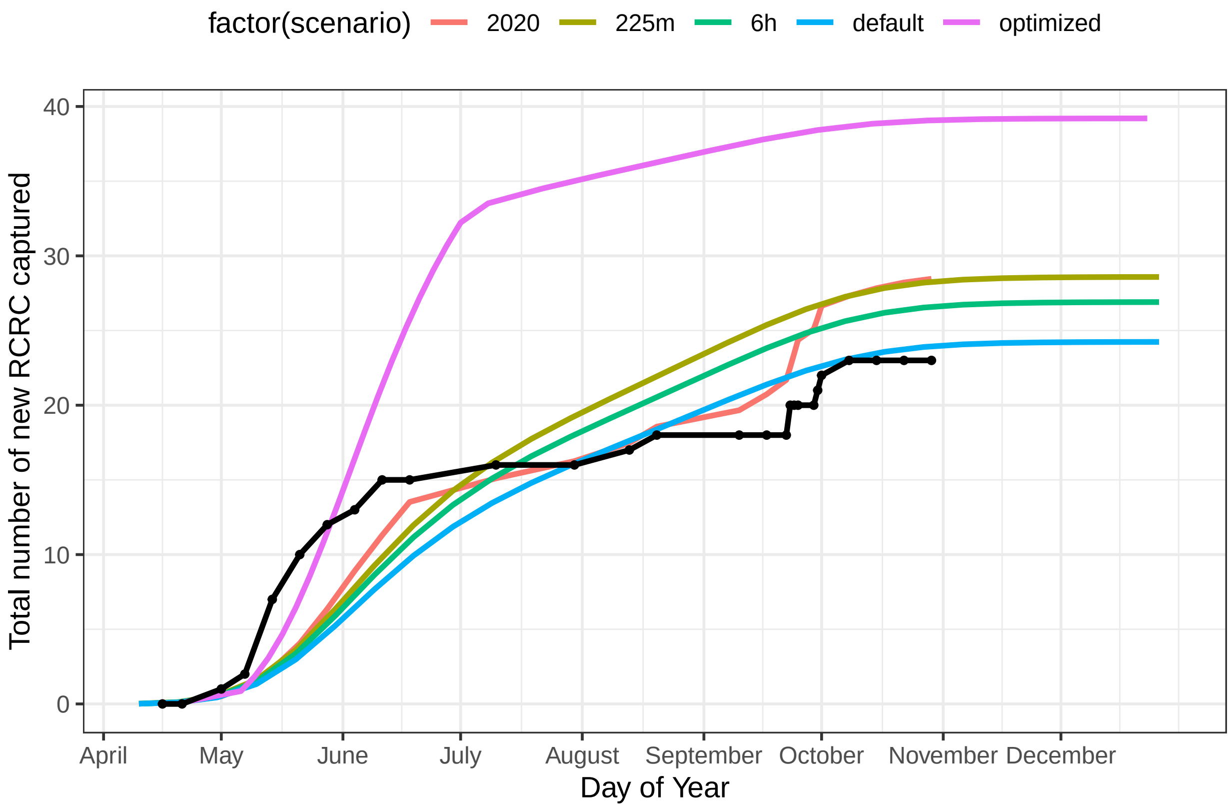
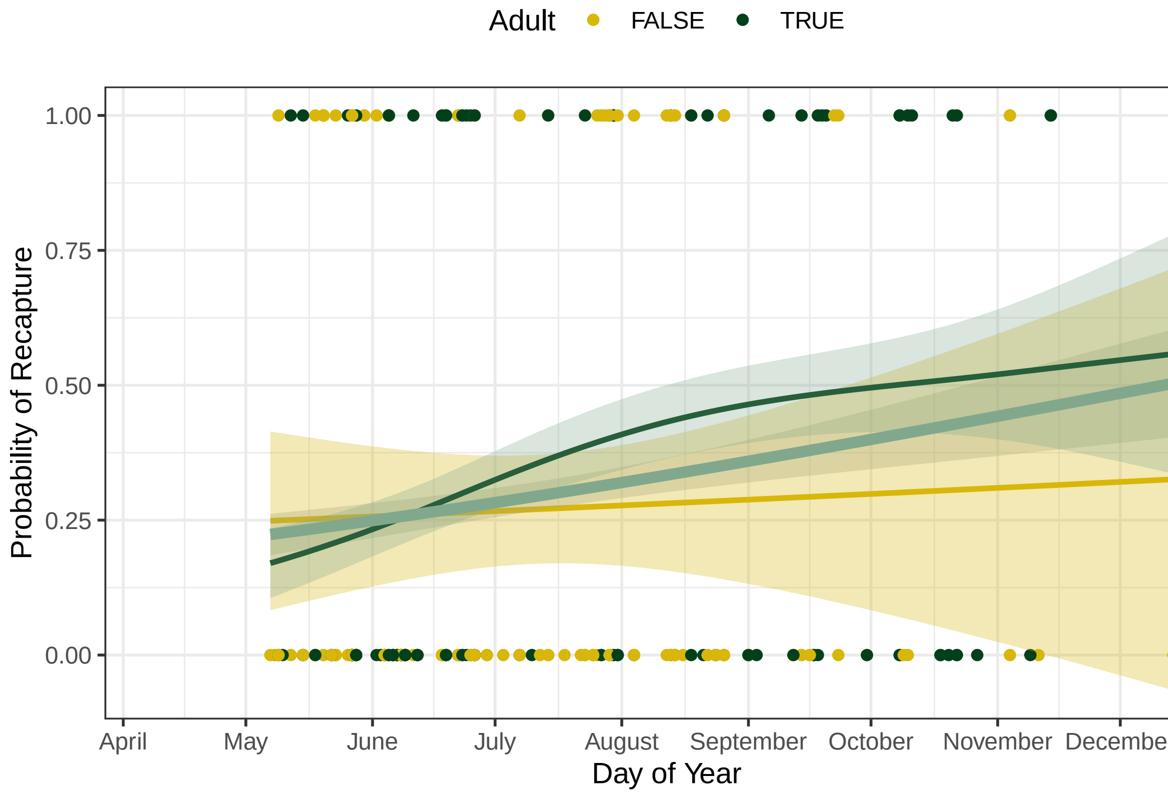


Figure 1. Along the year, the total number of new RCRC capture increase according to the number of session and effort of session (i.e. nets distance, duration).



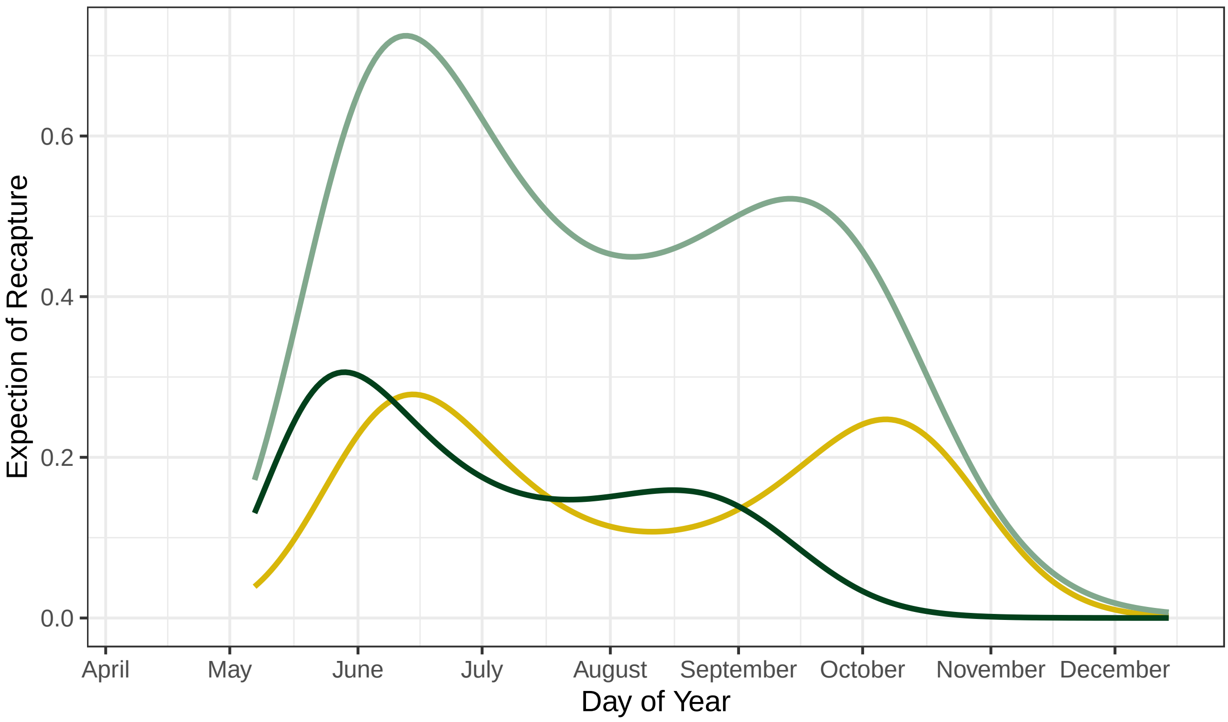
rate-1.pdf

When modelled over time, the recapture rate shows an increase along the year from 25% to almost 50%, although the uncertainty seems relatively large because of the few datapoints in the second half of the season. Separating adult from juvenile allows to identify a different trend for adult which are more likely to be retrap later in the year.

For the purpose of our study, we want to equip 15 RCRC. While waiting for July August seems preferable to increase the retrap rate, the number of capture bird do decrease and might correspond to the same bird (resident). In addition, in order to learn more about the age difference pattern observed in the ringing data, we think that is best to start equipping some bird already in end of June and wait for mid-July to equip the other.

The life history of each RCRC is more complicated to interpreted in this figure because there are many. Some birds are capture several over a single year (only small dots), while other have been capture over 5-10 years (large icon)!

The ringing data indicates that two passage in June and mid-October for adult while juvenile number have only a shallow peak in August. Are the adult moving faster to choose the best location? Are they moving further north then juvenile? These are the sort of questions that we wish to answer with our study with geolocators.


0.6
0.4
0.2
0.0
Expection of Recapture
April
May
June
July
August
September
October
November
December
Day of Year

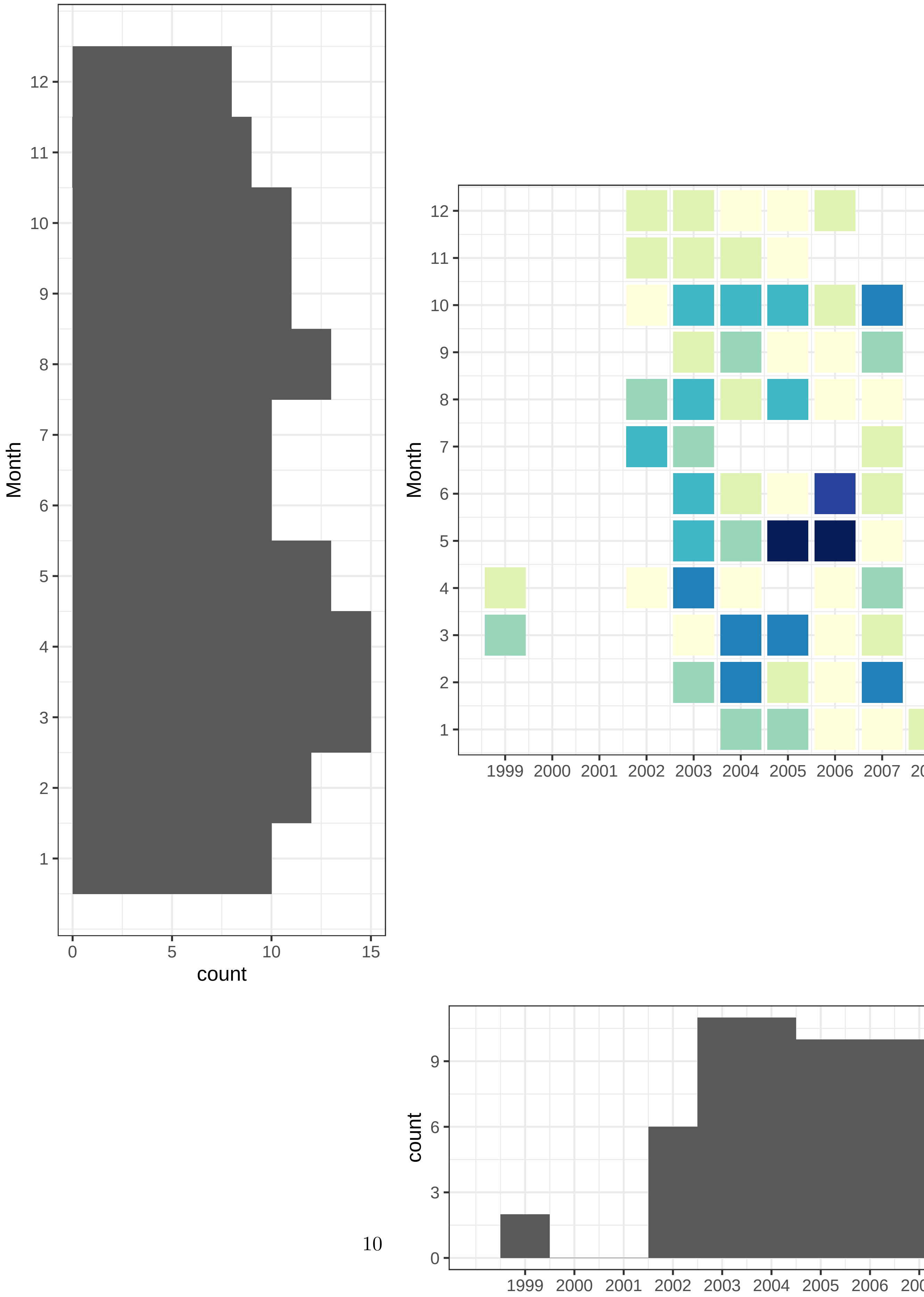


Figure 2. Distribution of the ringing sessions according to year and month. Colorscale indicates the number of ringing session

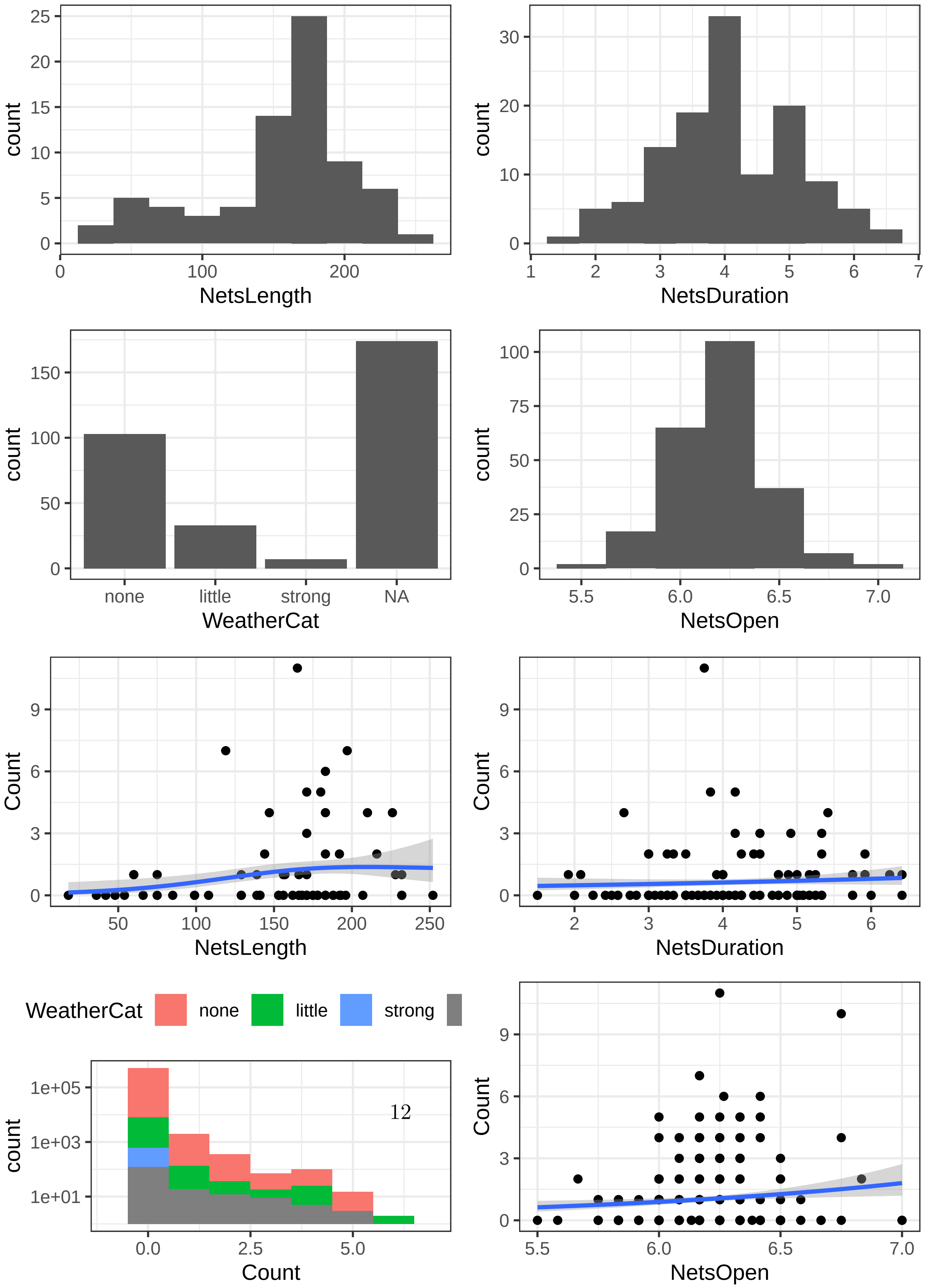
4. Discussion

5. Conclusion

6. Supplementary Materials

6.1. *Data extends*

6.2. *Model*



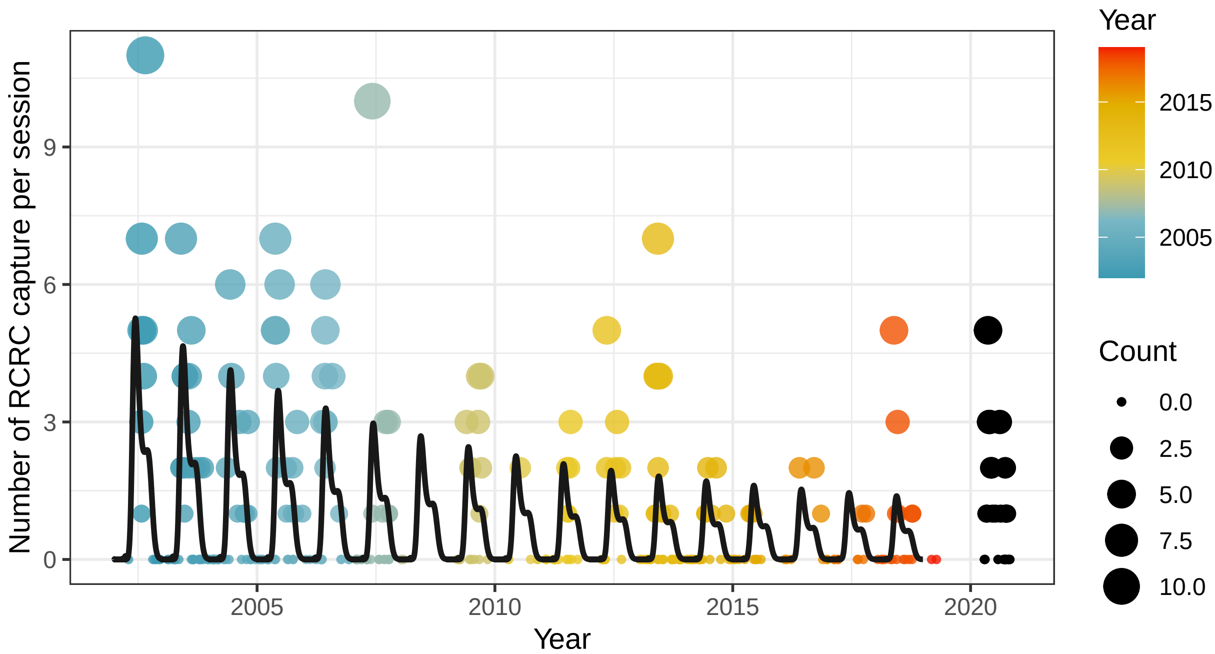
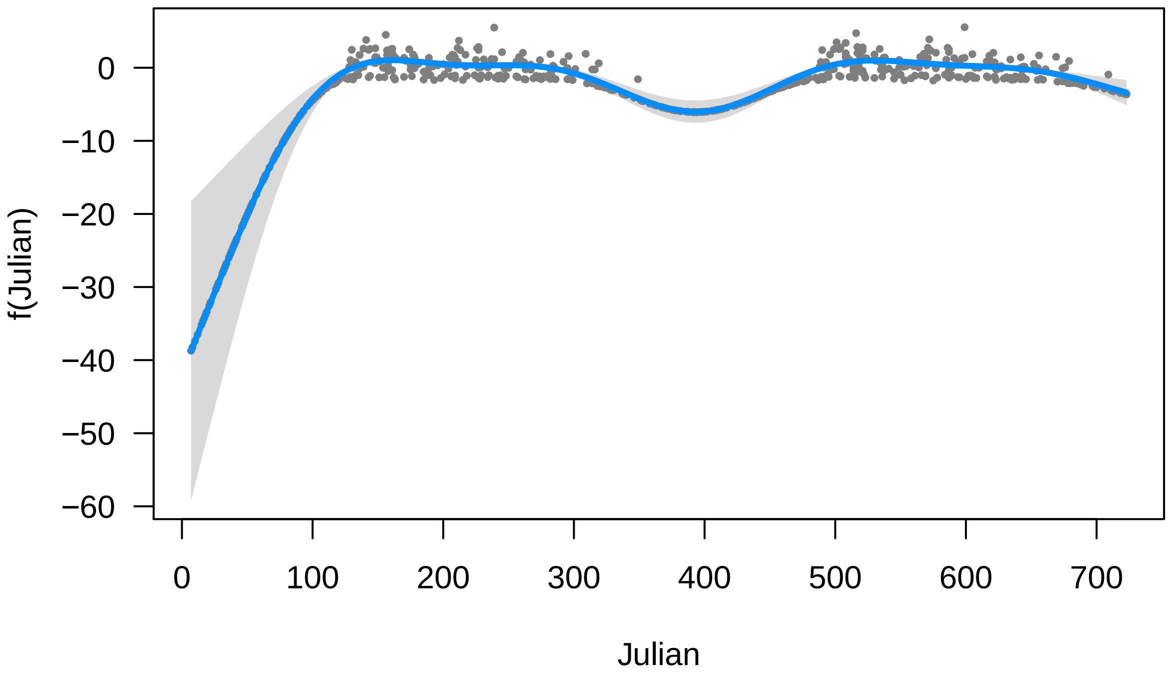


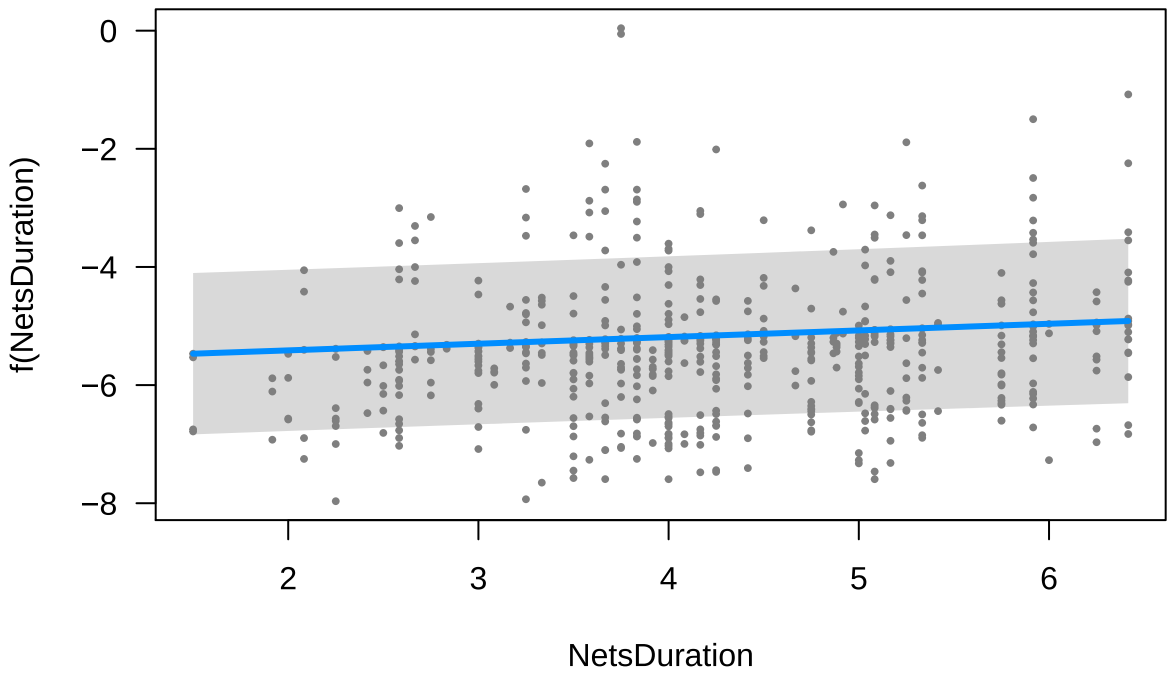
Figure 3. Evolution of the number of Red-capped Robin-chat captured per session over the 20 years of the ringing database. Black line and shaded area are the estimation and uncertainty range [3-IC] of the GAM under the default condition (4hr-156m).

The model fits a rather strong decreasing trend in number at the annual level with a rate of almost 1 bird less per session for every ~5 years.

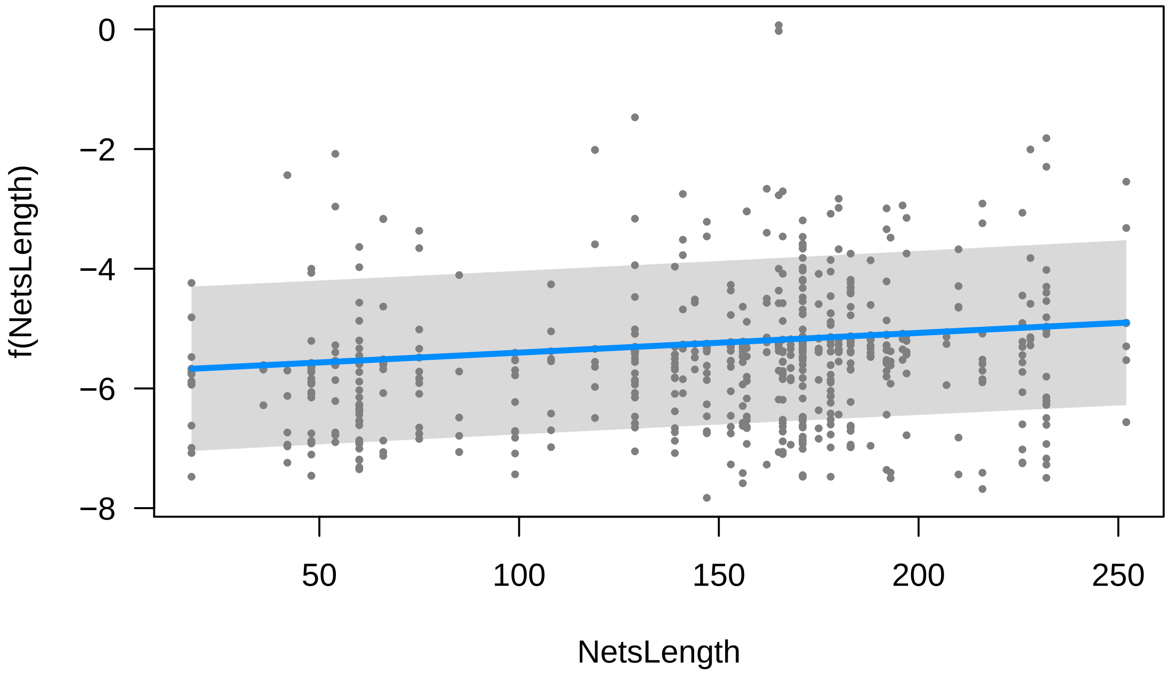
```
##
## Family: poisson
## Link function: log
##
## Formula:
## Count ~ s(Julian) + NetsDuration + NetsLength
##
## Parametric coefficients:
##                Estimate Std. Error z value Pr(>|z|)
## (Intercept)  -4.2823280  0.6808513  -6.290 3.18e-10 ***
## NetsDuration  0.1125829  0.0378916   2.971  0.00297 **
## NetsLength    0.0032957  0.0006992   4.713 2.44e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##              edf Ref.df Chi.sq p-value
```

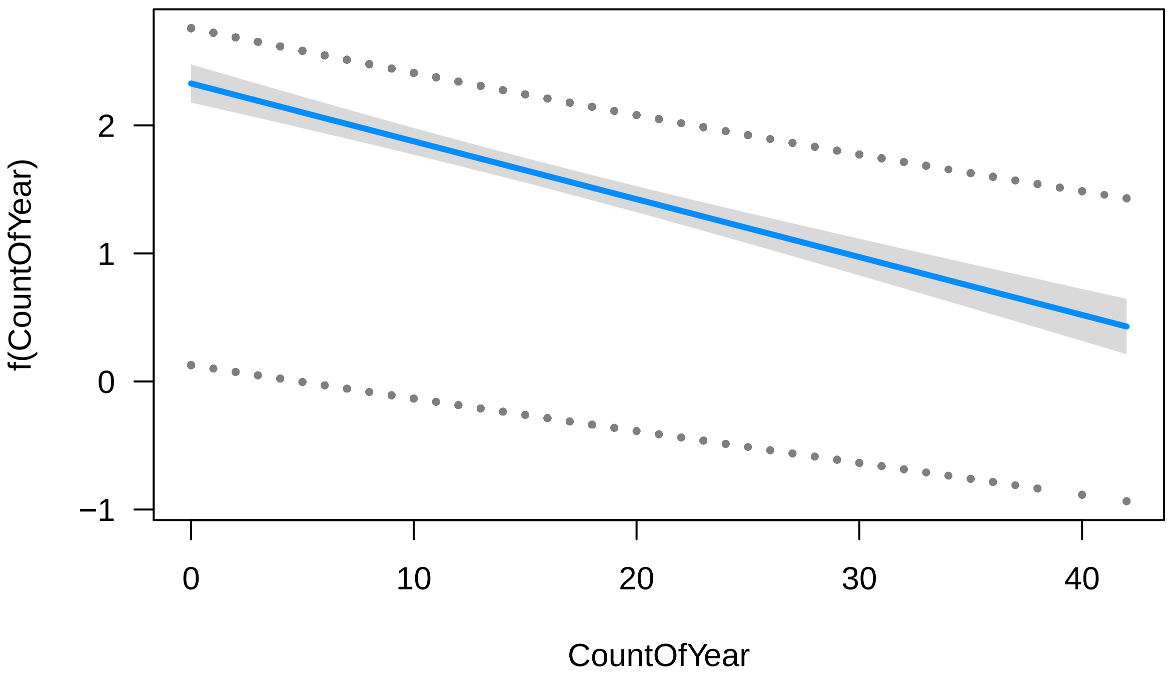
```
## s(Julian) 8.884  8.989  185.2  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.302   Deviance explained = 47.5%
## UBRE = 0.29305  Scale est. = 1         n = 634
```





f(NetsDuration)
0
−2
−4
−6
−8
2
3
4
5
6
NetsDuration

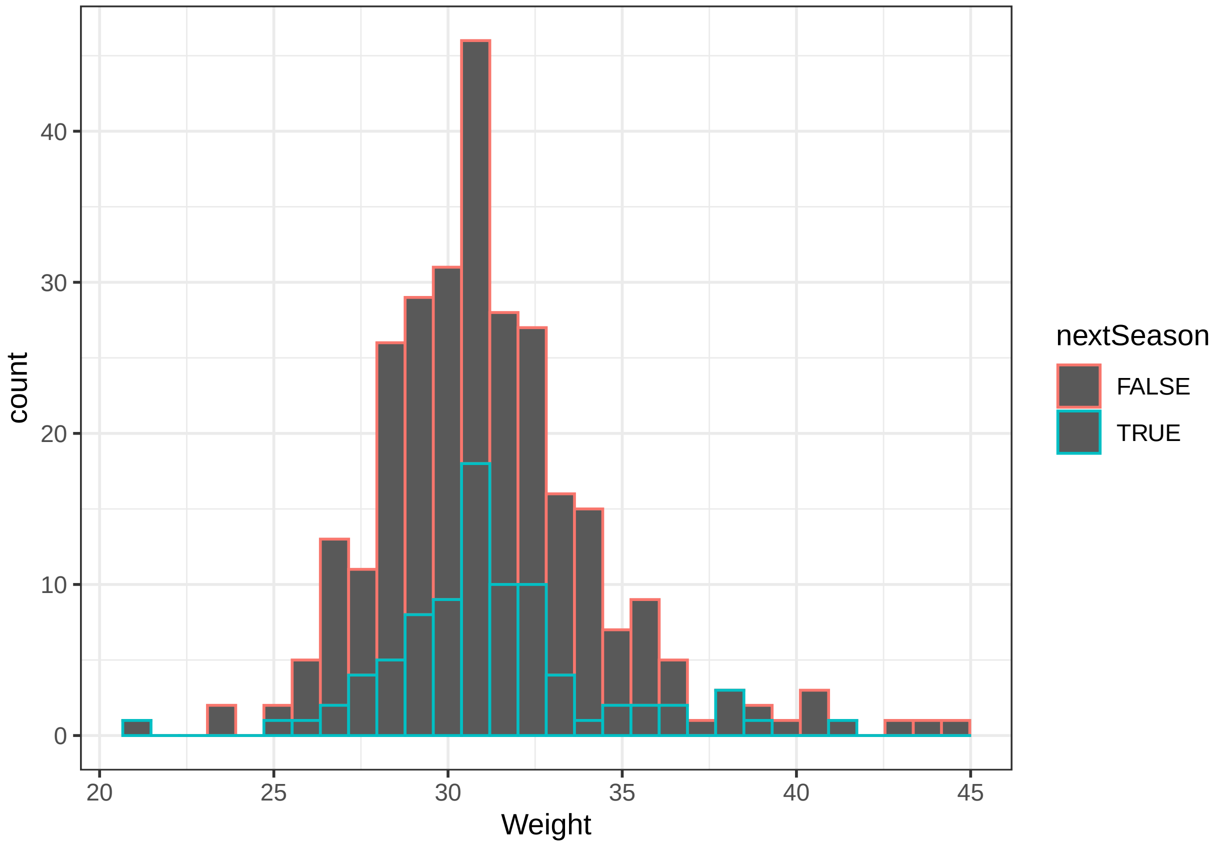

0
−2
−4
−6
−8
f(NetsLength)
50
100
150
200
250
NetsLength

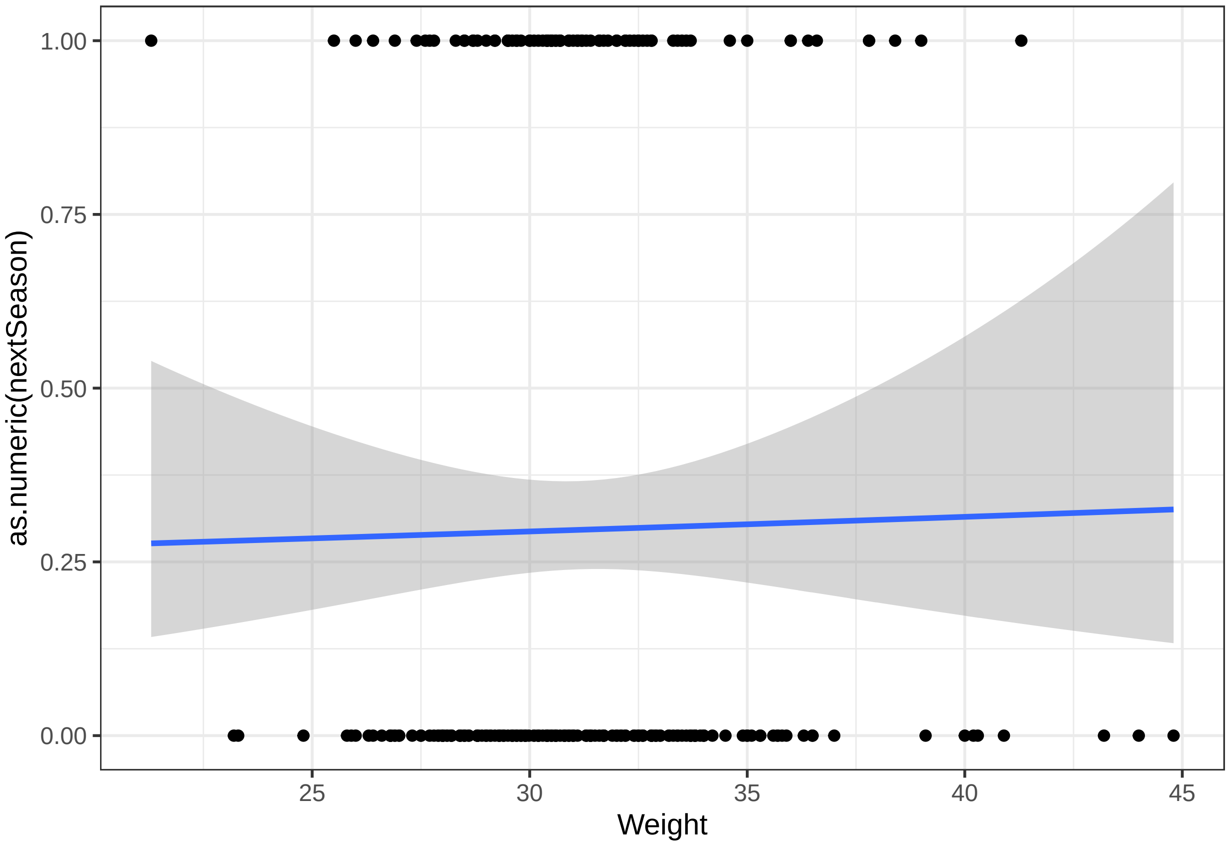



```
##
## Call:
## glm(formula = isFirstOfYear ~ CountOfYear, family = "binomial",
##     data = dmf)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.2001   0.4315   0.4603   0.5688   1.0015
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.32700    0.07587   30.67   <2e-16 ***
## CountOfYear -0.04519    0.00372  -12.15   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 2858.4  on 3371  degrees of freedom
## Residual deviance: 2713.4  on 3370  degrees of freedom
## AIC: 2717.4
##
## Number of Fisher Scoring iterations: 4
```

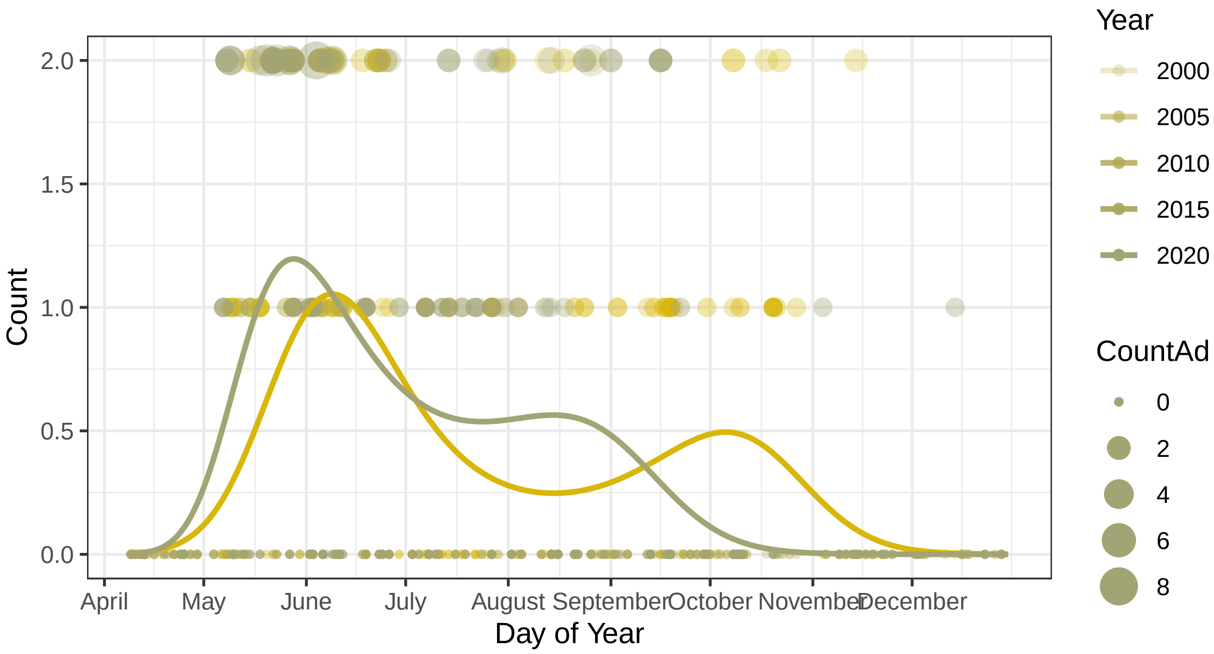
6.3. *Weight*

```
## 'stat_bin()' using 'bins = 30'. Pick better value with 'binwidth'.
```

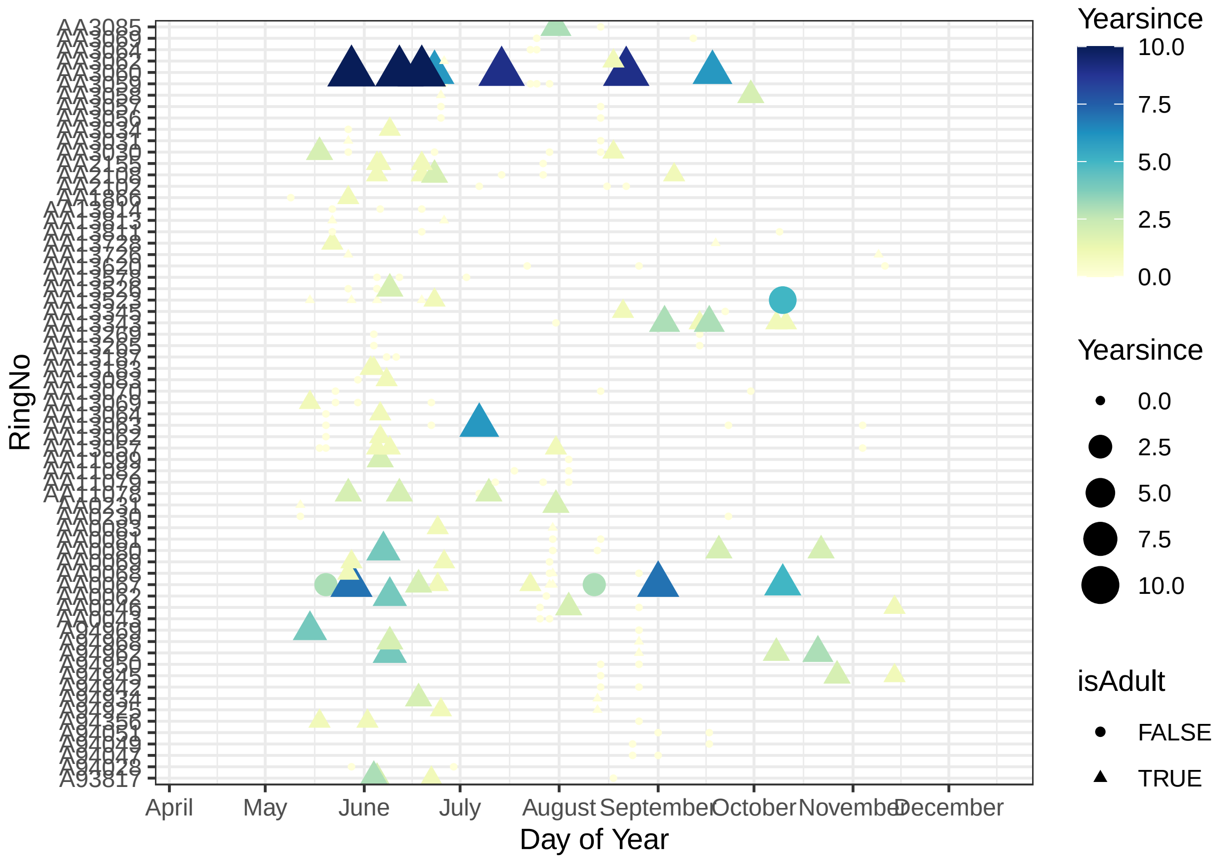




Adult vs Juv count


Year
2000
2005
2010
2015
2020
CountAd
0
2
4
6
8
Count
2.0
1.5
1.0
0.5
0.0
April
May
June
July
August
September
October
November
December
Day of Year

6.4. *Ringing history*



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Disclosure statement

An unnumbered section, e.g. \section*{Disclosure statement}, may be used to declare any potential conflict of interest and included *in the non-anonymous version* before any Notes or References, after any Acknowledgements and before any Funding information.

Funding

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Notes on contributor(s)

An unnumbered section, e.g. `\section*{Notes on contributors}`, may be included *in the non-anonymous version* if required. A photograph may be added if requested.

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