Influential factors of days spent at the shelter

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1 Introduction

2 Exploratory Data Analysis

```
'data.frame':   1450 obs. of  7 variables:
 $ animal_type    : chr  "CAT" "DOG" "DOG" "DOG" ...
 $ month          : int  9 6 12 9 11 12 6 1 2 4 ...
 $ year           : int  2017 2017 2016 2017 2016 2016 2017 2017 2017 2017 ...
 $ intake_type    : chr  "STRAY" "STRAY" "STRAY" "STRAY" ...
 $ outcome_type   : chr  "ADOPTION" "EUTHANIZED" "ADOPTION" "ADOPTION" ...
 $ chip_status    : chr  "UNABLE TO SCAN" "SCAN NO CHIP" "SCAN NO CHIP" "SCAN NO CHIP" ...
 $ time_at_shelter: int  9 4 21 4 7 4 4 5 0 15 ...

Column 1 :
[1] "BIRD"     "CAT"      "DOG"      "WILDLIFE"

Column 2 :
 [1] "1"  "2"  "3"  "4"  "5"  "6"  "7"  "8"  "9"  "10" "11" "12"

Column 3 :
[1] "2016" "2017"

Column 4 :
[1] "CONFISCATED"     "OWNER SURRENDER" "STRAY"

Column 5 :
[1] "ADOPTION"          "DIED"              "EUTHANIZED"
[4] "FOSTER"            "RETURNED TO OWNER"

Column 6 :
[1] "SCAN CHIP"      "SCAN NO CHIP"   "UNABLE TO SCAN"
```

All the explanatory variable are categorical variable and each explanatory variable have multiple levels.

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[1] 317
```

Over 300 zeros in raw data may cause overdispersion in Poisson regression. The hurdle model is suggested to fit.

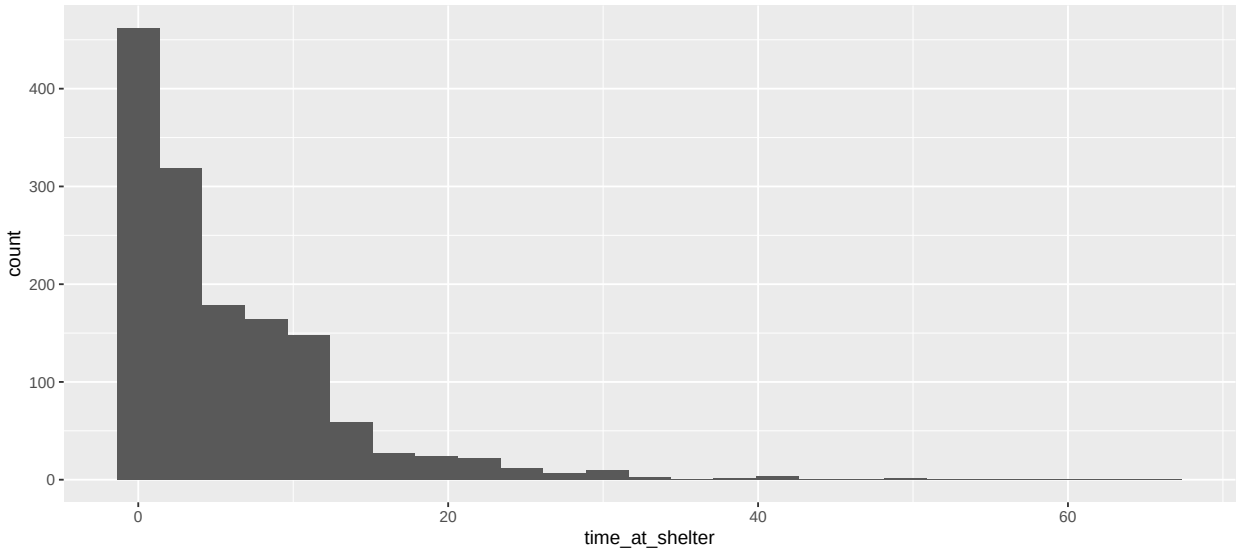


Figure 1: The histogram of day time at shelter

Figure 1 displays the histogram of the response variable, which is days time in the shelter. The histogram shows evidence of right-skewed and Poisson distribution of the response variable.

Figure 2: Pair plots of the variables

Note that year and month are strongly correlated, suggesting multicollinearity. As the data were collected over the period of a year, month and year represent the same variable, namely when the animal was admitted to the shelter. Therefore, year shall be omitted from the model.

The other explanatory variables are all categorical and their box plots are shown. The median time at shelter appears to be low for all the explanatory variables, which is due to the median time at shelter being 4.

Since in Figure1 the response variable is right-skewed, a median of the response variable is calculated. The figures below display the median of each category of the different explanatory variables.

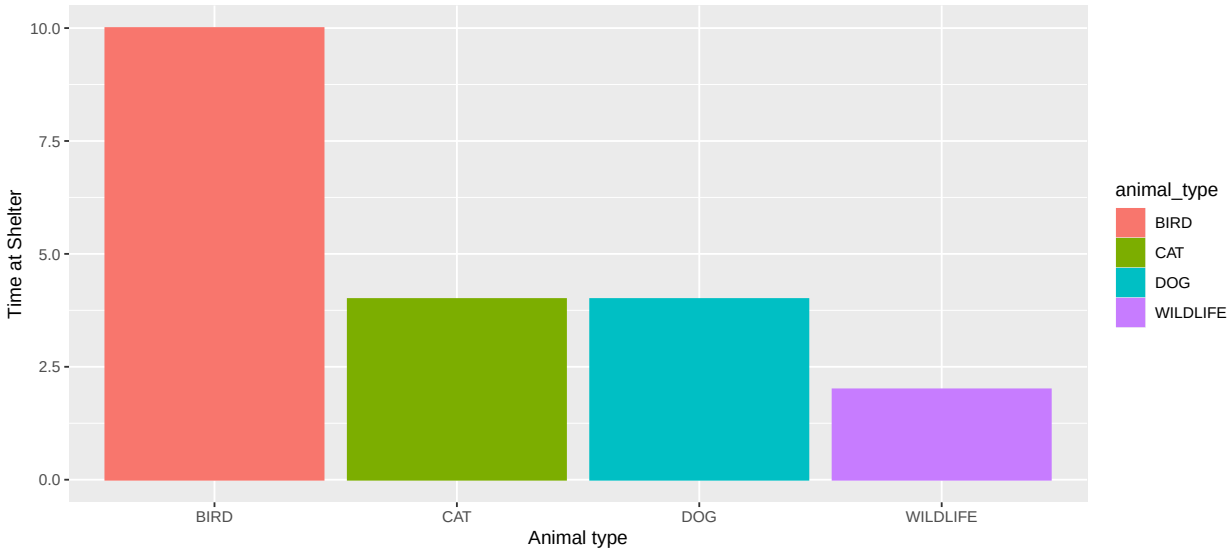


Figure 3: Bar plot of animal type vs time at shelter

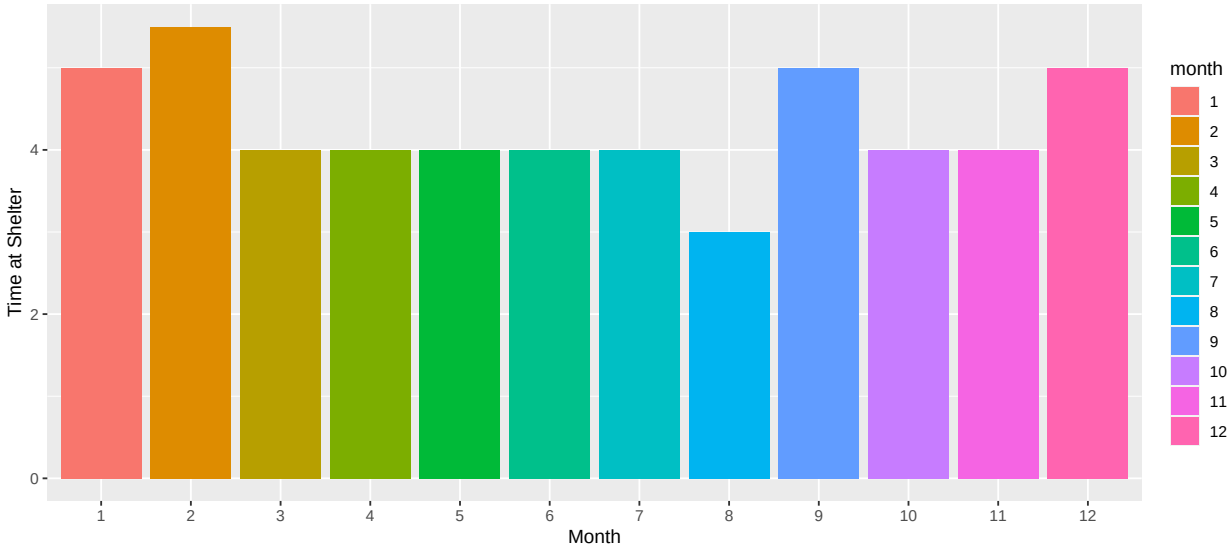


Figure 4: Bar plot of month vs time at shelter

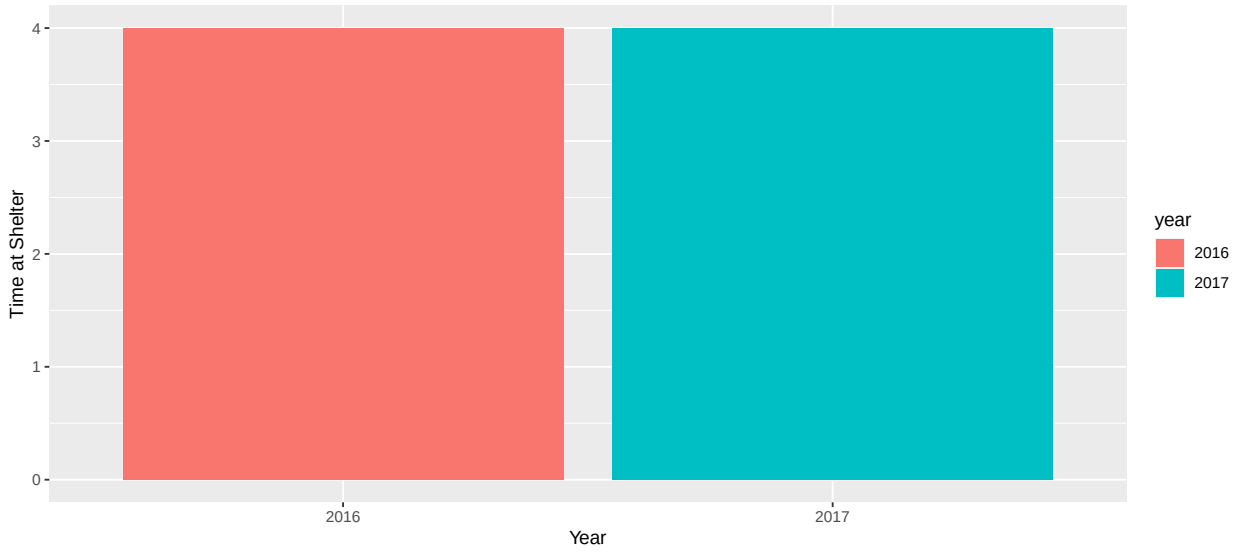


Figure 5: Bar plot of year vs time at shelter

```
[1] FALSE
```

No overlap between the months and years, according to the bar plot5, no obvious difference between two years and the relationship between the response variable and month variable is similar to that relationship between the response variable and the year variable. Therefore, the year variable is removed.

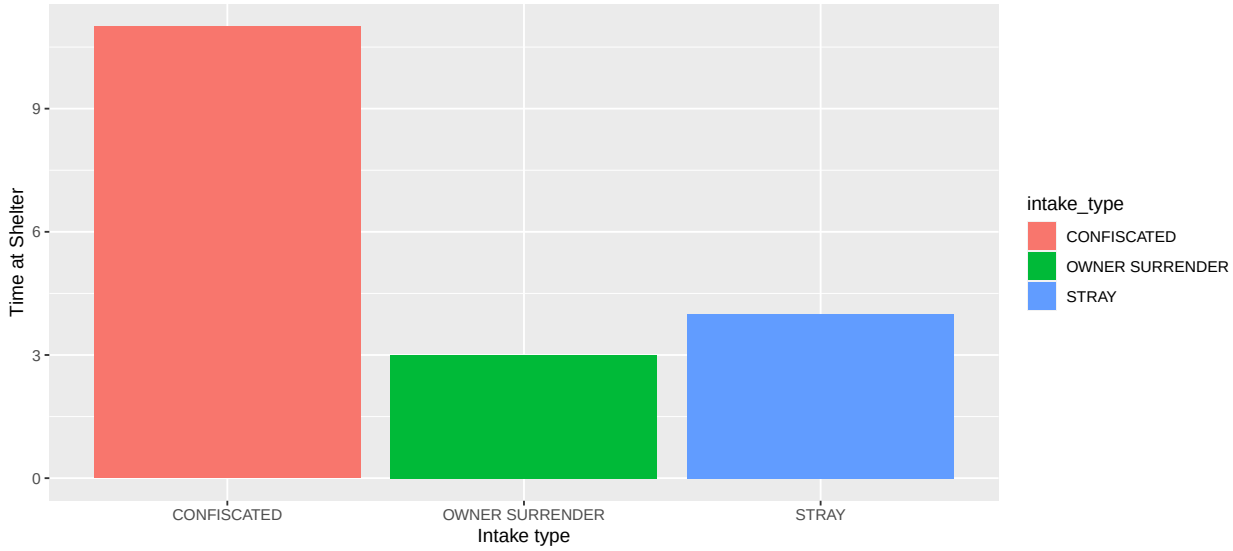


Figure 6: Bar plot of intake type vs time at shelter

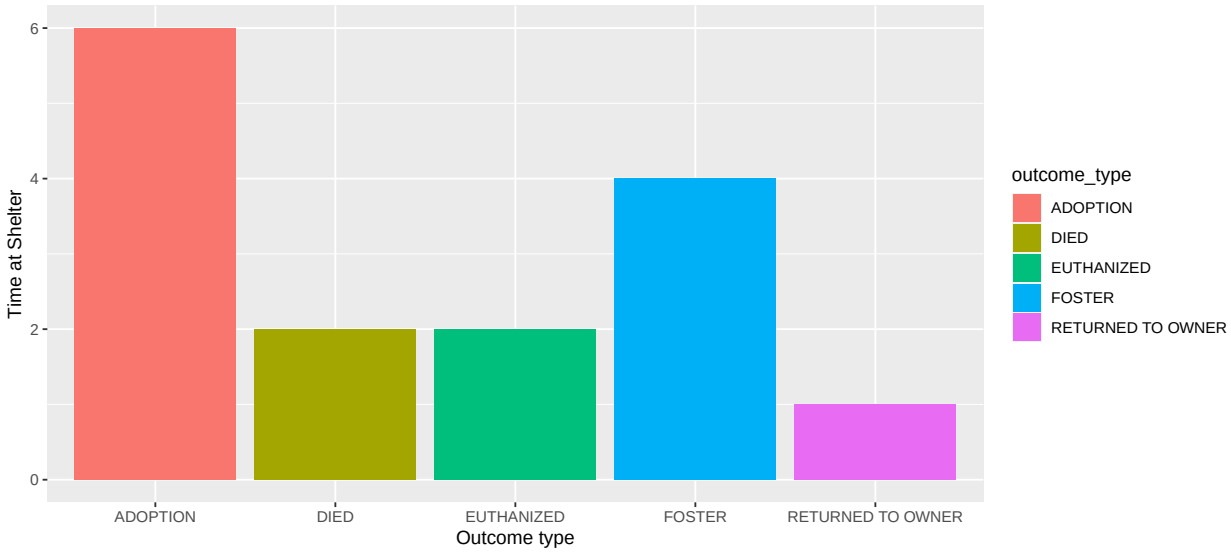


Figure 7: Bar plot of outcome type vs time at shelter

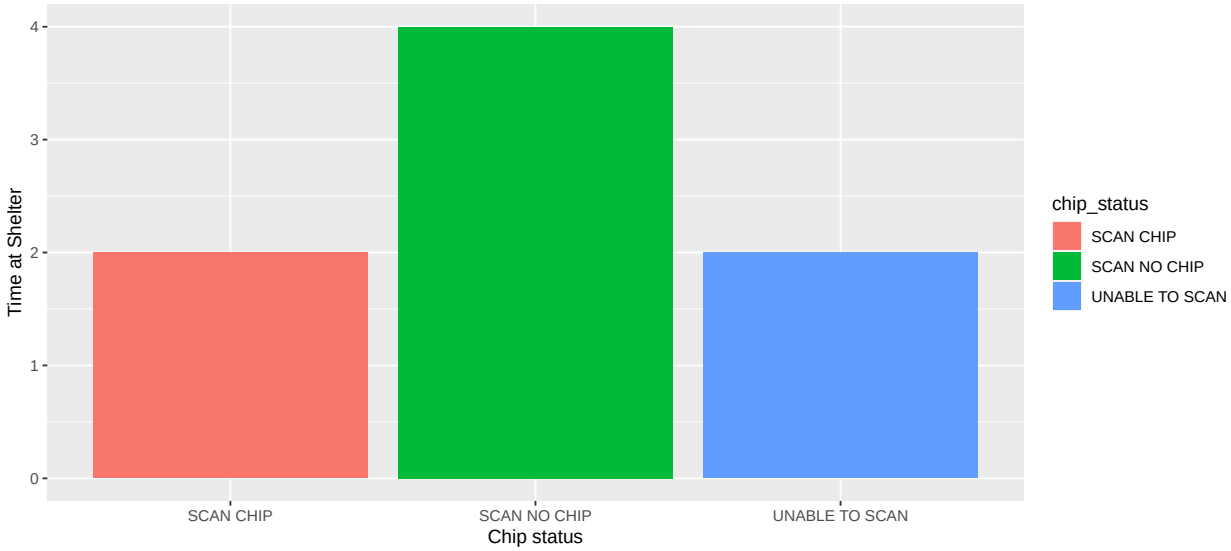


Figure 8: Bar plot of chip status vs time at shelter

3 Formal Data Analysis

3.1 Fitting a Poisson model

```
Call:
glm(formula = time_at_shelter ~ ., family = "poisson", data = data10)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-6.9146  -1.9976  -0.8903   0.6306  12.7550
```

```
Coefficients:
                               Estimate Std. Error z value Pr(>|z|)
(Intercept)                    2.997158   0.197263  15.194  < 2e-16 ***
animal_typeCAT                 0.441668   0.195885   2.255 0.024150 *
animal_typeDOG                 0.485824   0.194425   2.499 0.012462 *
animal_typeWILDLIFE            0.225305   0.231453   0.973 0.330336
month2                         0.075718   0.055370   1.367 0.171470
month3                        -0.132108   0.057115  -2.313 0.020721 *
month4                        -0.193819   0.056691  -3.419 0.000629 ***
month5                        -0.005919   0.052007  -0.114 0.909386
month6                        -0.035721   0.050097  -0.713 0.475818
month7                        -0.057427   0.050613  -1.135 0.256526
month8                        -0.413755   0.058842  -7.032 2.04e-12 ***
month9                        -0.082308   0.056140  -1.466 0.142617
month10                        0.101852   0.051801   1.966 0.049273 *
month11                       -0.055580   0.054389  -1.022 0.306833
month12                        0.114138   0.051633   2.211 0.027065 *
intake_typeOWNER SURRENDER    -1.451530   0.043649 -33.254  < 2e-16 ***
intake_typeSTRAY              -1.031365   0.039395 -26.180  < 2e-16 ***
outcome_typeDIED              -0.649881   0.097578  -6.660 2.74e-11 ***
outcome_typeEUTHANIZED        -0.592552   0.025262 -23.456  < 2e-16 ***
outcome_typeFOSTER            -0.279520   0.076201  -3.668 0.000244 ***
outcome_typeRETURNED TO OWNER -1.531722   0.042358 -36.161  < 2e-16 ***
chip_statusSCAN NO CHIP       -0.171716   0.028935  -5.934 2.95e-09 ***
chip_statusUNABLE TO SCAN     -0.247414   0.068726  -3.600 0.000318 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 10551.2  on 1449  degrees of freedom
Residual deviance:  8079.3  on 1427  degrees of freedom
AIC: 12147

Number of Fisher Scoring iterations: 6


[1] 41
```

The rootogram could be used to check the overdispersion. The line at 0 allows us to easily visualize where the model is over-fitting or under-fitting, if the bar is below the zero line then that value has been under-fitting. And if there is a space between the zero line and the bar then it has been over-fitting. For the model to be fitted correctly, the bar should sit as close to the zero line as possible.

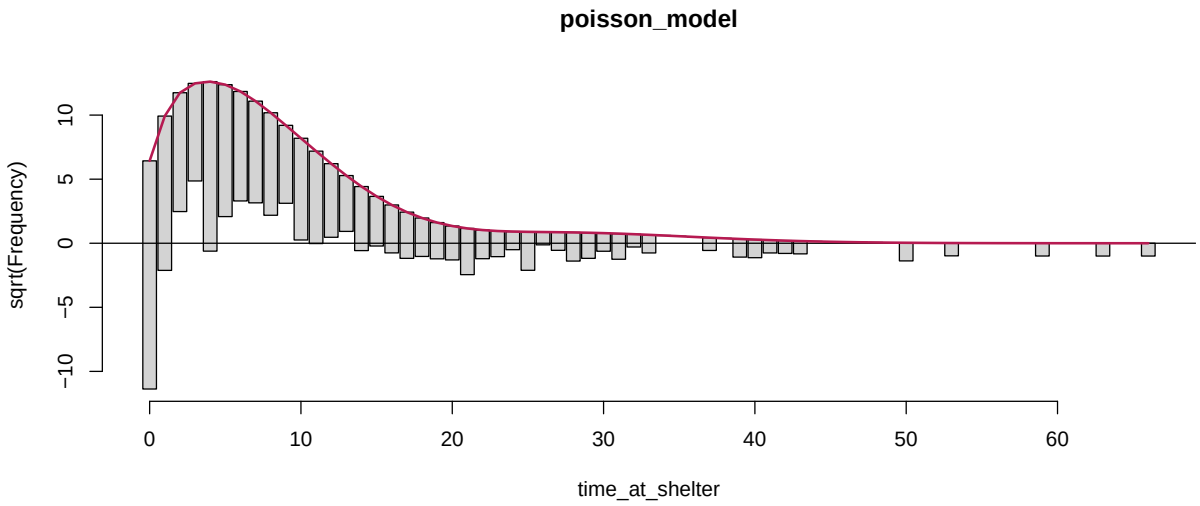


Figure 9: Rootogram of Poisson Model

From Figure9, the Poisson model is severely under-fitting zero counts. There were 317 zero counts observed in the data set but the model only fitted 41. It is also over-fitting the lower positive counts and under-fitting the higher counts, suggesting there is over-dispersion in the model. Hence a hurdle model will be fitted to provide a better fit.

3.2 Fitting a Hurdle model

```
Call:
hurdle(formula = time_at_shelter ~ ., data = data10, dist = "poisson",
    zero.dist = "binomial")

Pearson residuals:
    Min      1Q  Median      3Q     Max
-4.3608 -1.0287 -0.5823  0.4795 14.9926

Count model coefficients (truncated poisson with log link):
                             Estimate Std. Error z value Pr(>|z|)
(Intercept)                 2.9579923  0.1983275  14.915  < 2e-16 ***
animal_typeCAT              0.3743137  0.1965591   1.904 0.056867 .
animal_typeDOG              0.3213099  0.1951832   1.646 0.099723 .
animal_typeWILDLIFE         0.4412799  0.2325810   1.897 0.057786 .
month2                     -0.0007866  0.0555725  -0.014 0.988706
month3                     -0.1913094  0.0574189  -3.332 0.000863 ***
month4                     -0.2968745  0.0570389  -5.205 1.94e-07 ***
month5                     -0.0358694  0.0522504  -0.686 0.492405
month6                     -0.1290100  0.0505296  -2.553 0.010675 *
month7                     -0.0908291  0.0508464  -1.786 0.074043 .
month8                     -0.3531232  0.0594007  -5.945 2.77e-09 ***
month9                     -0.1700644  0.0563869  -3.016 0.002561 **
month10                     0.0425144  0.0518410   0.820 0.412164
month11                    -0.0777278  0.0545280  -1.425 0.154023
month12                     0.0460268  0.0517740   0.889 0.374006
```

```
intake_typeOWNER SURRENDER    -1.1067328  0.0453104 -24.426  < 2e-16 ***
intake_typeSTRAY              -0.7609702  0.0407405 -18.678  < 2e-16 ***
outcome_typeDIED              -0.6233442  0.0998502  -6.243 4.30e-10 ***
outcome_typeEUTHANIZED        -0.2197569  0.0254704  -8.628  < 2e-16 ***
outcome_typeFOSTER            -0.1110361  0.0769153  -1.444 0.148847
outcome_typeRETURNED TO OWNER -0.9857031  0.0450846 -21.863  < 2e-16 ***
chip_statusSCAN NO CHIP       -0.2019465  0.0290236  -6.958 3.45e-12 ***
chip_statusUNABLE TO SCAN     -0.2152199  0.0686741  -3.134 0.001725 **
Zero hurdle model coefficients (binomial with logit link):
                               Estimate Std. Error z value Pr(>|z|)
(Intercept)                    1.905e+01  6.099e+02   0.031    0.975
animal_typeCAT                -1.328e+01  6.099e+02  -0.022    0.983
animal_typeDOG                -1.266e+01  6.099e+02  -0.021    0.983
animal_typeWILDLIFE           -1.454e+01  6.099e+02  -0.024    0.981
month2                         7.990e-01  4.898e-01   1.631    0.103
month3                         3.817e-01  4.040e-01   0.945    0.345
month4                         3.724e-01  4.020e-01   0.926    0.354
month5                        -9.406e-04  3.735e-01  -0.003    0.998
month6                         4.541e-01  3.702e-01   1.227    0.220
month7                         1.809e-01  3.643e-01   0.497    0.620
month8                        -2.548e-01  3.782e-01  -0.674    0.500
month9                         3.331e-01  3.984e-01   0.836    0.403
month10                        3.409e-01  3.981e-01   0.856    0.392
month11                        5.129e-02  4.062e-01   0.126    0.900
month12                        4.482e-01  4.345e-01   1.032    0.302
intake_typeOWNER SURRENDER    -3.171e+00  5.161e-01  -6.143 8.07e-10 ***
intake_typeSTRAY              -2.406e+00  4.857e-01  -4.955 7.25e-07 ***
outcome_typeDIED              -8.929e-01  8.223e-01  -1.086    0.278
outcome_typeEUTHANIZED        -2.999e+00  2.661e-01 -11.273  < 2e-16 ***
outcome_typeFOSTER            -2.137e+00  5.383e-01  -3.969 7.21e-05 ***
outcome_typeRETURNED TO OWNER -4.203e+00  3.115e-01 -13.491  < 2e-16 ***
chip_statusSCAN NO CHIP       -1.024e-01  1.978e-01  -0.518    0.605
chip_statusUNABLE TO SCAN     -6.084e-01  3.793e-01  -1.604    0.109
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Number of iterations in BFGS optimization: 30
Log-likelihood: -5193 on 46 Df

[1] 317
```

The model is fitting the zero counts perfectly because of the model design to be.

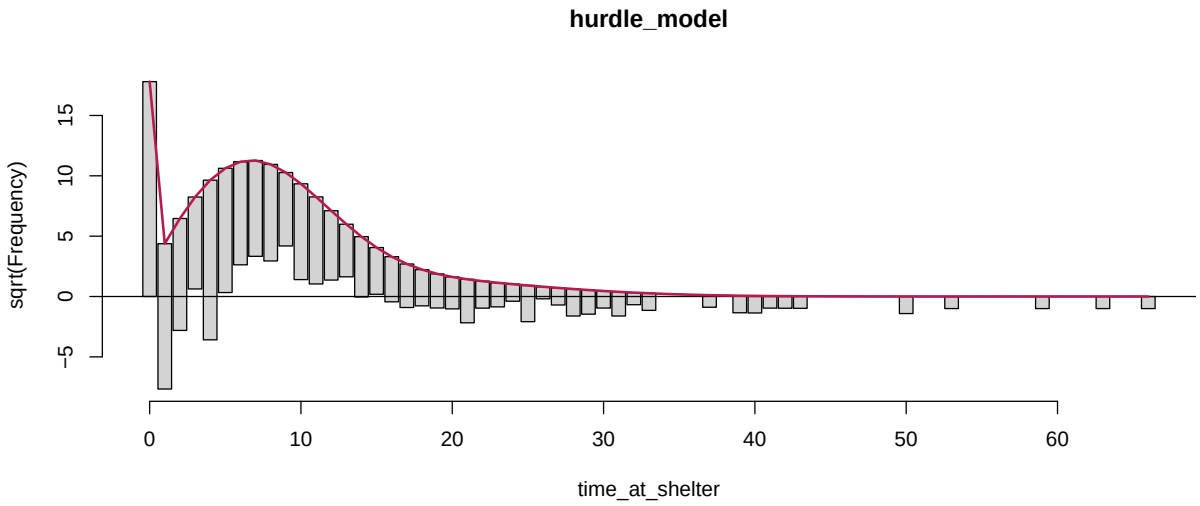


Figure 10: Rootogram of Binomial Hurdle Model

In Figure10 Counts 1,2 and 4 are being severely under-fitted, while 6-9 are being over-fitted. There is also under-fitting at the higher counts which suggests over-dispersion. Therefore, a negative binomial hurdle model shall be fitted to address this.

```
[1] 317
```

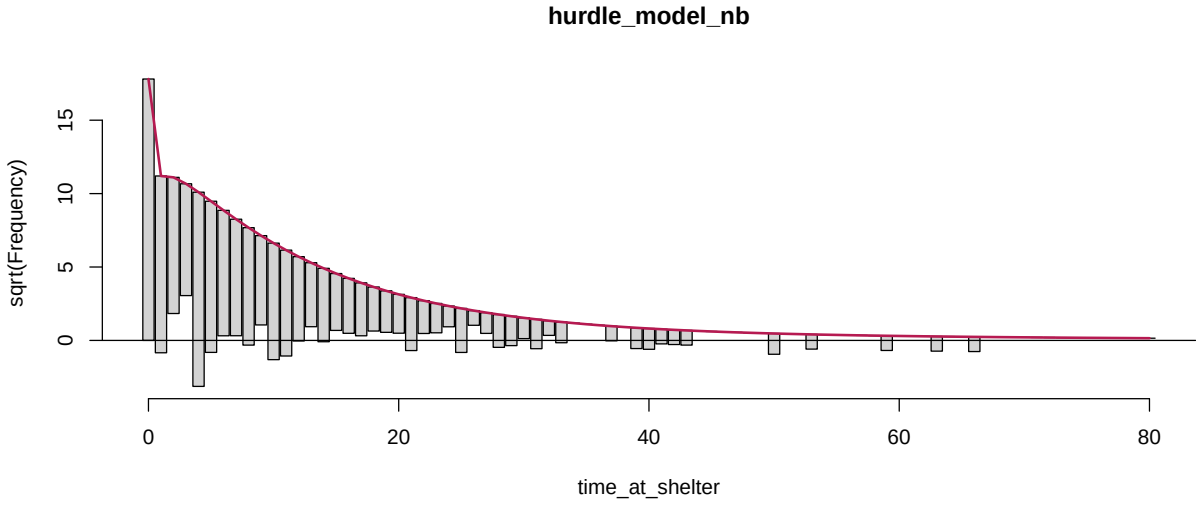


Figure 11: Rootogram of Negative Binomial Hurdle Model

The AIC of the hurdle model is 10478 and the AIC of the negative binomial hurdle model is 7781. From this, the negative binomial model shows a much better fit to the data. However, in Figure11 some values are still being under-fitted.

3.2.1 All subset variable selection using AIC

```
Global model call: hurdle(formula = time_at_shelter ~ ., data = data10, dist = "negbin")
---
Model selection table
    cnt_(Int) cnt_anm_typ cnt_chp_stt cnt_int_typ cnt_otc_typ zer_(Int)
760     2.496           +           +           +           +     19.15
    zer_anm_typ zer_chp_stt zer_int_typ zer_otc_typ df    logLik    AIC delta
760           +           +           +           + 25 -3858.628 7767.3     0
    weight
760      1
Models ranked by AIC(x)
```

Using AIC as a selection criteria, the model with the minimum AIC and hence the best fit for the data is the model with animal type, chip status, intake type and outcome type as the explanatory variables.

3.2.2 p-value and confidence interval

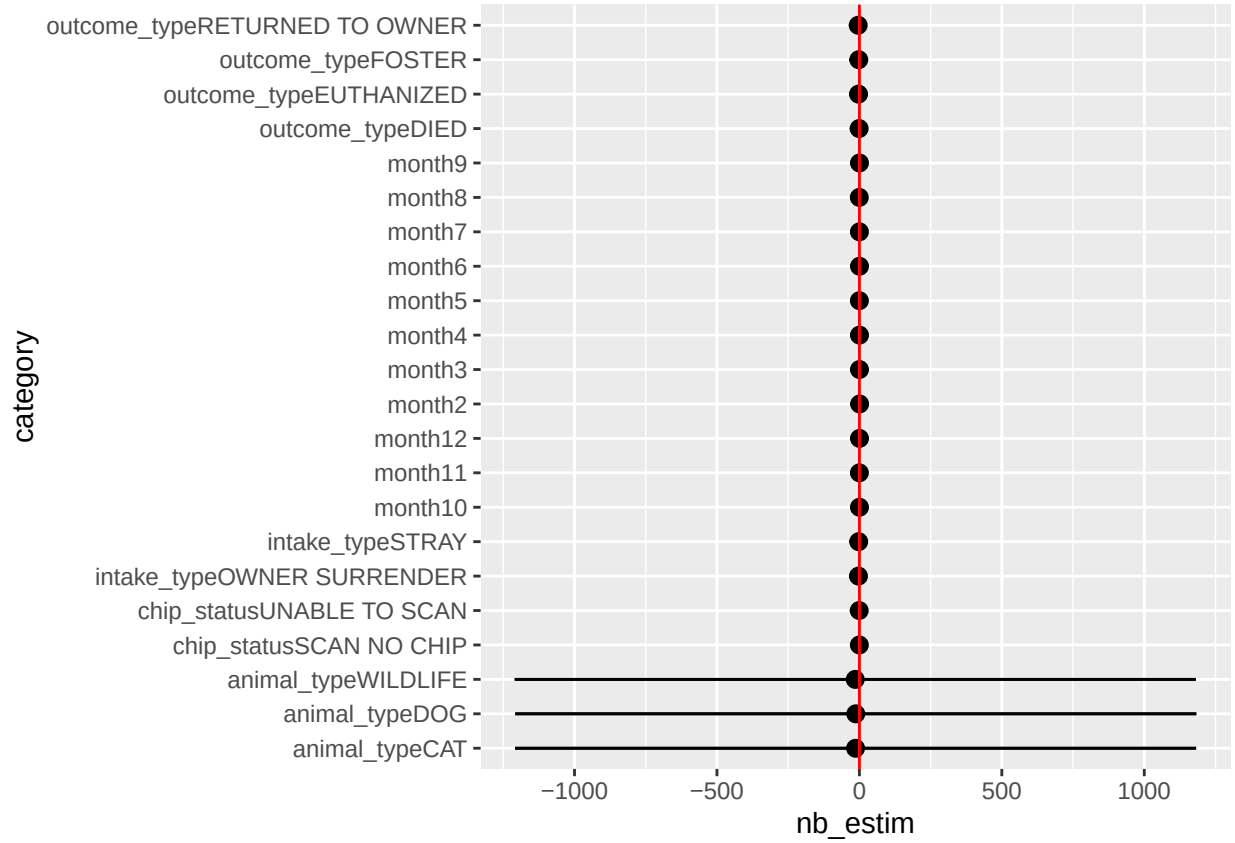
```
Call:
hurdle(formula = time_at_shelter ~ ., data = data10, dist = "negbin")

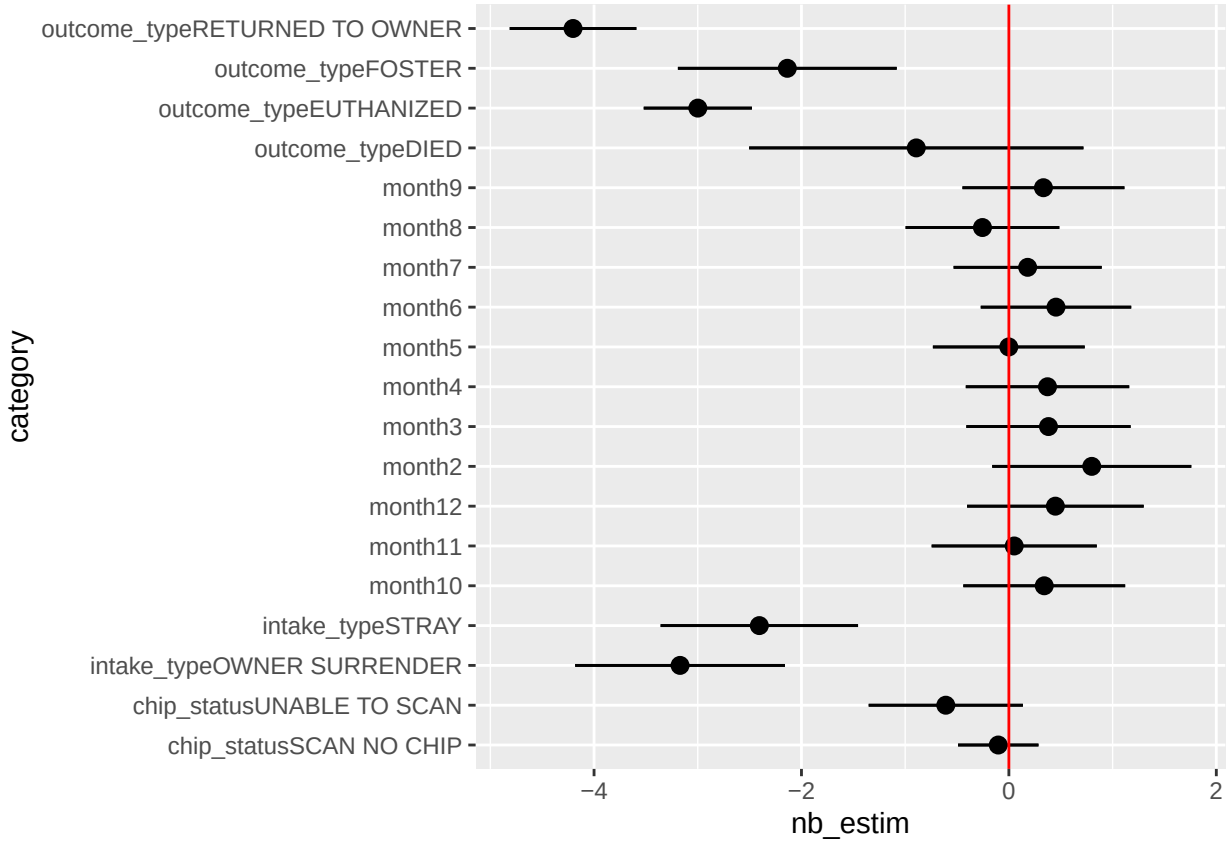
Pearson residuals:
    Min      1Q  Median      3Q     Max
-1.2025 -0.6605 -0.3345  0.2519 11.4077

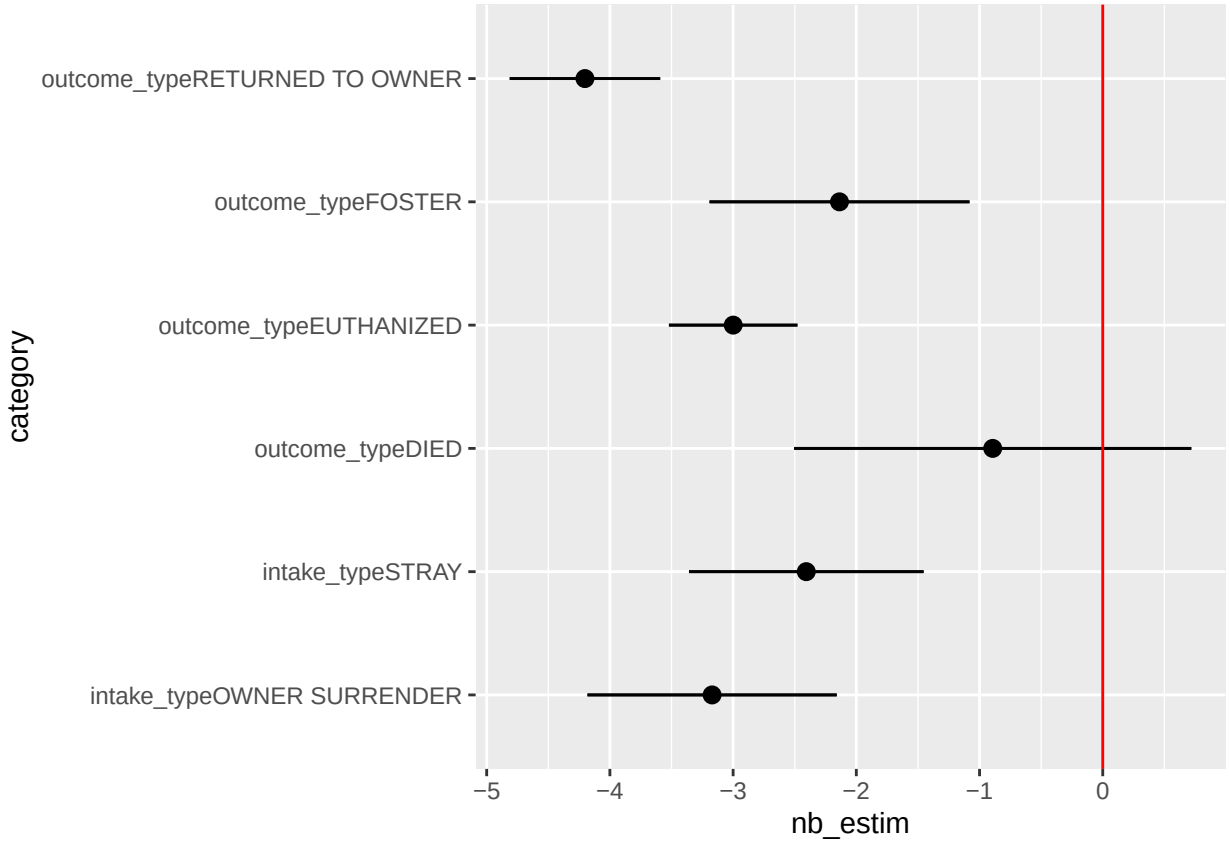
Count model coefficients (truncated negbin with log link):
                              Estimate Std. Error z value Pr(>|z|)
(Intercept)                    2.76685    0.53877   5.135 2.81e-07 ***
animal_typeCAT                 0.74713    0.53868   1.387 0.165449
animal_typeDOG                 0.66189    0.53512   1.237 0.216127
animal_typeWILDLIFE            0.80073    0.62532   1.281 0.200366
month2                         0.03328    0.14736   0.226 0.821310
month3                        -0.17106    0.14399  -1.188 0.234833
month4                        -0.31799    0.14145  -2.248 0.024577 *
month5                        -0.01711    0.13684  -0.125 0.900467
month6                        -0.07499    0.13278  -0.565 0.572243
month7                        -0.06830    0.13254  -0.515 0.606314
month8                        -0.34321    0.14631  -2.346 0.018986 *
month9                        -0.15745    0.14341  -1.098 0.272244
month10                        0.01028    0.13804   0.075 0.940606
month11                       -0.08510    0.14222  -0.598 0.549581
month12                        0.07485    0.13800   0.542 0.587539
intake_typeOWNER SURRENDER    -1.35231    0.13661  -9.899  < 2e-16 ***
intake_typeSTRAY              -0.99326    0.12527  -7.929 2.21e-15 ***
outcome_typeDIED              -0.69165    0.20932  -3.304 0.000952 ***
outcome_typeEUTHANIZED        -0.27166    0.06434  -4.222 2.42e-05 ***
outcome_typeFOSTER            -0.19967    0.19584  -1.020 0.307942
outcome_typeRETURNED TO OWNER -1.18366    0.10428 -11.350  < 2e-16 ***
chip_statusSCAN NO CHIP       -0.18939    0.07286  -2.599 0.009343 **
chip_statusUNABLE TO SCAN     -0.14319    0.17481  -0.819 0.412709
Log(theta)                     0.44129    0.07198   6.131 8.74e-10 ***
Zero hurdle model coefficients (binomial with logit link):
                               Estimate Std. Error z value Pr(>|z|)
```

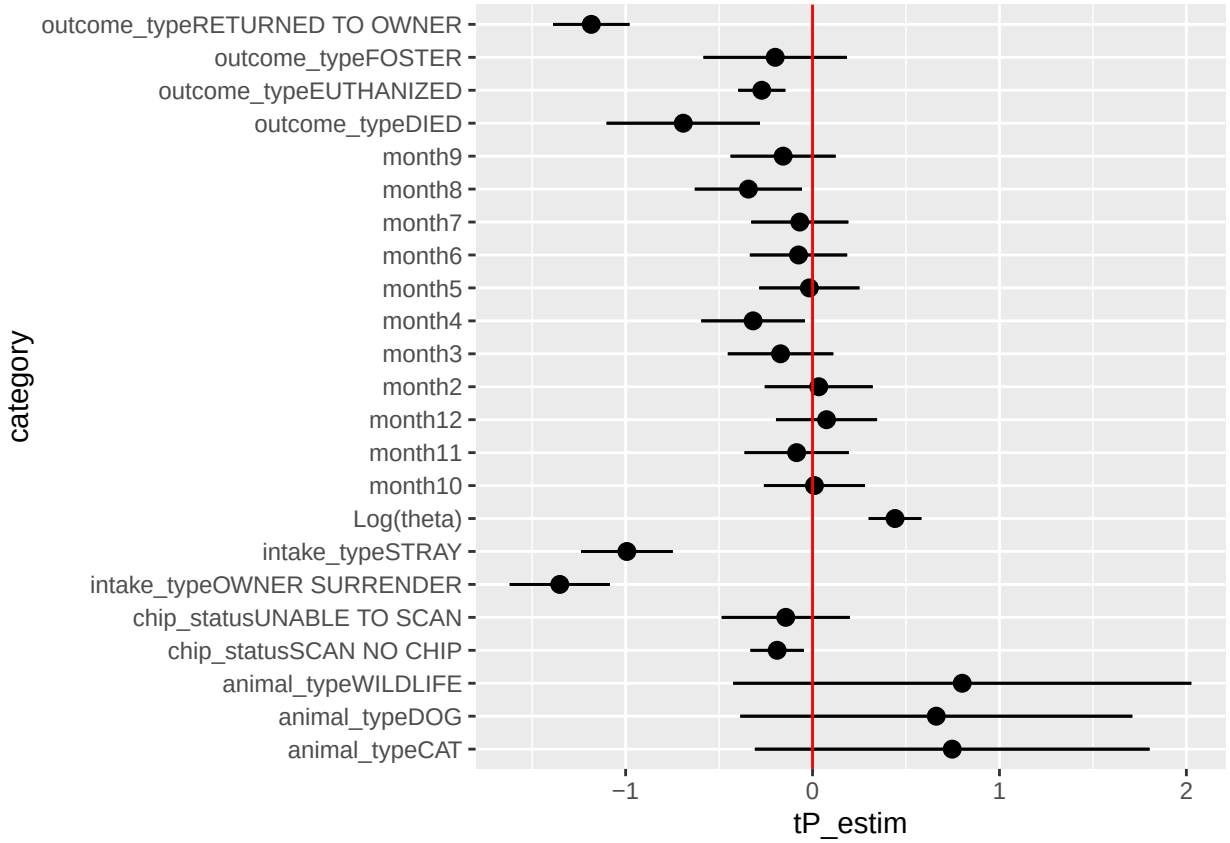
```
(Intercept)                    1.905e+01  6.099e+02   0.031    0.975
animal_typeCAT                -1.328e+01  6.099e+02  -0.022    0.983
animal_typeDOG                -1.266e+01  6.099e+02  -0.021    0.983
animal_typeWILDLIFE           -1.454e+01  6.099e+02  -0.024    0.981
month2                         7.990e-01  4.898e-01   1.631    0.103
month3                         3.817e-01  4.040e-01   0.945    0.345
month4                         3.724e-01  4.020e-01   0.926    0.354
month5                        -9.406e-04  3.735e-01  -0.003    0.998
month6                         4.541e-01  3.702e-01   1.227    0.220
month7                         1.809e-01  3.643e-01   0.497    0.620
month8                        -2.548e-01  3.782e-01  -0.674    0.500
month9                         3.331e-01  3.984e-01   0.836    0.403
month10                        3.409e-01  3.981e-01   0.856    0.392
month11                        5.129e-02  4.062e-01   0.126    0.900
month12                        4.482e-01  4.345e-01   1.032    0.302
intake_typeOWNER SURRENDER    -3.171e+00  5.161e-01  -6.143 8.07e-10 ***
intake_typeSTRAY              -2.406e+00  4.857e-01  -4.955 7.25e-07 ***
outcome_typeDIED              -8.929e-01  8.223e-01  -1.086    0.278
outcome_typeEUTHANIZED        -2.999e+00  2.661e-01 -11.273  < 2e-16 ***
outcome_typeFOSTER            -2.137e+00  5.383e-01  -3.969 7.21e-05 ***
outcome_typeRETURNED TO OWNER -4.203e+00  3.115e-01 -13.491  < 2e-16 ***
chip_statusSCAN NO CHIP       -1.024e-01  1.978e-01  -0.518    0.605
chip_statusUNABLE TO SCAN     -6.084e-01  3.793e-01  -1.604    0.109
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

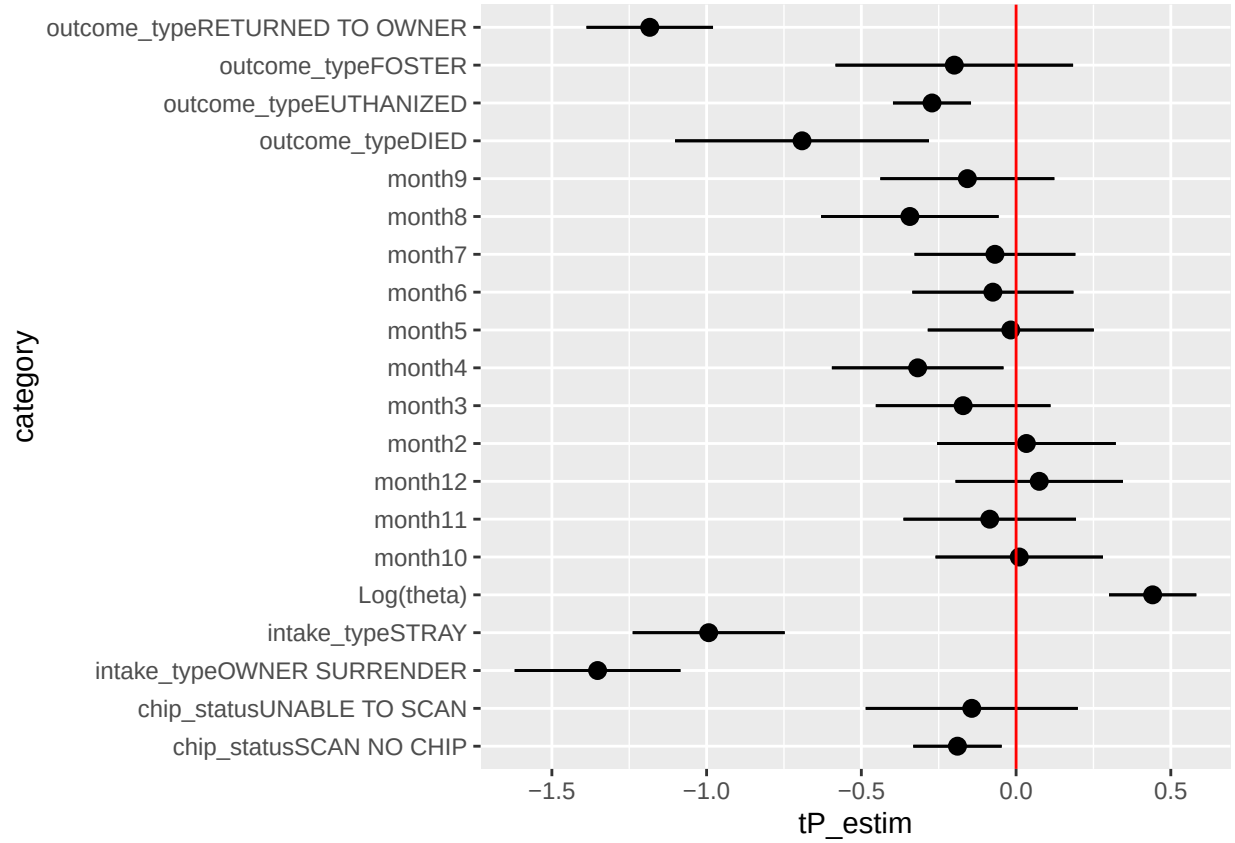
Theta: count = 1.5547
Number of iterations in BFGS optimization: 30
Log-likelihood: -3843 on 47 Df
```


outcome_typeRETURNED TO OWNER
outcome_typeFOSTER
outcome_typeEUTHANIZED
outcome_typeDIED
month9
month8
month7
month6
month5
month4
month3
month2
month12
month11
month10
intake_typeSTRAY
intake_typeOWNER SURRENDER
chip_statusUNABLE TO SCAN
chip_statusSCAN NO CHIP
animal_typeWILDLIFE
animal_typeDOG
animal_typeCAT
category
−1000
−500
0
500
1000
nb_estim


outcome_typeRETURNED TO OWNER
outcome_typeFOSTER
outcome_typeEUTHANIZED
outcome_typeDIED
month9
month8
month7
month6
month5
month4
month3
month2
month12
month11
month10
intake_typeSTRAY
intake_typeOWNER SURRENDER
chip_statusUNABLE TO SCAN
chip_statusSCAN NO CHIP
category
−4
−2
0
2
nb_estim


outcome_typeRETURNED TO OWNER
outcome_typeFOSTER
outcome_typeEUTHANIZED
outcome_typeDIED
intake_typeSTRAY
intake_typeOWNER SURRENDER
category
−5
−4
−3
−2
−1
0
nb_estim


outcome_typeRETURNED TO OWNER
outcome_typeFOSTER
outcome_typeEUTHANIZED
outcome_typeDIED
month9
month8
month7
month6
month5
month4
month3
month2
month12
month11
month10
Log(theta)
intake_typeSTRAY
intake_typeOWNER SURRENDER
chip_statusUNABLE TO SCAN
chip_statusSCAN NO CHIP
animal_typeWILDLIFE
animal_typeDOG
animal_typeCAT
category
−1
0
1
2
tP_estim



3.3 Model checking

4 Conclusions