Onlinebeispiel 11.11. Ringfundanalysen zur Mortalitätsschätzung von juvenilen und adulten Stockenten (*Anas platyrhynchos*)

Kapitel 11.11 aus Henle, K., A. Grimm-Seyfarth & B. Gruber: Erfassung und Analyse von Tierpopulationen. Ulmer Verlag

Annegret Grimm-Seyfarth

17.03.2025

Hier stellen wir einen Ringfund-Datensatz von Stockenten im San Luis Valley in Colorado vor. Bei diesem Datensatz werden Jung- und Alttiere unterschieden [Modell H1 von Brownie et al. (1985)]. Dazu nutzen wir den Datensatz `brownie`, der im R-Paket RMark enthalten ist (Laake 2013). Erläuterungen finden sich in Laake und Rexstad (2013).

```r
# check.packages function: install and load multiple R packages.
# Function from: https://gist.github.com/smithdanielle/9913897
check.packages <- function(pkg){
  new.pkg <- pkg[!(pkg %in% installed.packages()[, "Package"])]
  if (length(new.pkg))
    install.packages(new.pkg, dependencies = TRUE, type = "source")
  sapply(pkg, require, character.only = TRUE)
}

# benoetigte R pakete
pakete <- c("RMark", "ggplot2", "scales")

# Pruefe und installiere
check.packages(pakete)
```

```
##   RMark ggplot2  scales
##    TRUE    TRUE    TRUE
```

Weitere Informationen zur Nutzung des Paketes finden sich hier:

https://cran.r-project.org/web/packages/RMark/RMark.pdf

Die Annahmen des Modells entsprechen denjenigen von Kap. 11.11 Modell 1, außer, dass Jungvögel im ersten Lebensjahr und adulte Vögel eine unterschiedliche Überlebens- und Rückmelderate aufweisen. Damit kann dem Umstand Rechnung getragen werden, dass Jungvögel häufig eine erheblich höhere Mortalität aufweisen als Altvögel.

Der Datensatz ist im RMark-Paket (Laake 2013) als Beispiel integriert.

```r
data("brownie")
head(brownie)
```

```
##                       ch freq ReleaseAge
## 1 100000000000000000  194      Adult
## 2 110000000000000000   10      Adult
## 3 100100000000000000   13      Adult
## 4 100001000000000000    6      Adult
## 5 100000010000000000    1      Adult
## 6 100000000100000000    1      Adult
```

Die Standardsortierreihenfolge von `RealeaseAge` (also Alter der Beringung) ist alphabetisch, folglich: Adult, Young. Daher ist `initial.ages=c(1,0)`.

Seber-Modell

Das Modell wird indiziert mit `model = "Recovery"` und geht auf Seber (1982) zurück. Details finden sich in Kap. 11.11 des Buches.

```r
br <- process.data(brownie,model="Recovery",groups="ReleaseAge",
                age.var=1,initial.ages=c(1,0))
br.ddl <- make.design.data(br,parameters=list(S=list(age.bins=c(0,1,10)),
                                            r=list(age.bins=c(0,1,10))),right=FALSE)
mod <- mark(br,br.ddl,
         model.parameters=list(S=list(formula=~-1+age:time,link="sin"),
                              r=list(formula=~-1+age:time,link="sin")),delete=TRUE)
```

```
##
## Output summary for Recovery model
## Name : S(~-1 + age:time)r(~-1 + age:time)
##
## Npar :  36  (unadjusted=34)
## -2lnL:  20650.4
## AICc :  20722.57  (unadjusted=20718.554)
##
## Beta
##                      estimate        se        lcl        ucl
## S:age[0,1):time1   -0.0524422 0.1197360 -0.2871248  0.1822404
## S:age[1,10]:time1   0.1587910 0.2310324 -0.2940325  0.6116145
## S:age[0,1):time2    0.0179450 0.1404892 -0.2574139  0.2933039
## S:age[1,10]:time2   0.2819136 0.1581189 -0.0279994  0.5918267
## S:age[0,1):time3    0.1068958 0.1348956 -0.1574996  0.3712912
## S:age[1,10]:time3   0.2546993 0.1520851 -0.0433876  0.5527862
## S:age[0,1):time4    0.1901312 0.1467219 -0.0974438  0.4777062
## S:age[1,10]:time4   0.8299177 0.3112315  0.2199040  1.4399313
## S:age[0,1):time5   -0.0396180 0.1226790 -0.2800688  0.2008328
## S:age[1,10]:time5   0.3112329 0.1528194  0.0117068  0.6107591
## S:age[0,1):time6    0.3152910 0.1527867  0.0158290  0.6147530
## S:age[1,10]:time6   0.1102410 0.1174256 -0.1199132  0.3403952
## S:age[0,1):time7   -0.0661525 0.1368479 -0.3343743  0.2020694
## S:age[1,10]:time7   0.1528413 0.1352256 -0.1122010  0.4178835
## S:age[0,1):time8   -0.1810555 0.2405947 -0.6526212  0.2905102
## S:age[1,10]:time8   0.1312970 0.2709540 -0.3997730  0.6623669
## S:age[0,1):time9   -0.9704075 0.0000000 -0.9704075 -0.9704075
## S:age[1,10]:time9   0.6348851 0.0000000  0.6348851  0.6348851
```

```
## r:age[0,1]:time1  -0.7370072 0.0657534 -0.8658839 -0.6081306
## r:age[1,10]:time1 -0.9178808 0.1342331 -1.1809776 -0.6547839
## r:age[0,1]:time2  -0.4141168 0.1048338 -0.6195911 -0.2086426
## r:age[1,10]:time2 -0.5535649 0.1401776 -0.8283130 -0.2788168
## r:age[0,1]:time3  -0.7418334 0.0782929 -0.8952874 -0.5883793
## r:age[1,10]:time3 -0.7539230 0.1036715 -0.9571191 -0.5507268
## r:age[0,1]:time4  -0.3808179 0.1262967 -0.6283593 -0.1332764
## r:age[1,10]:time4  0.0279097 0.8754164 -1.6879064  1.7437259
## r:age[0,1]:time5  -0.7078708 0.0662433 -0.8377075 -0.5780340
## r:age[1,10]:time5 -0.7753296 0.1107999 -0.9924973 -0.5581618
## r:age[0,1]:time6  -0.4475529 0.1393160 -0.7206123 -0.1744935
## r:age[1,10]:time6 -0.7975261 0.0750974 -0.9447170 -0.6503352
## r:age[0,1]:time7  -0.6293785 0.0755380 -0.7774330 -0.4813241
## r:age[1,10]:time7 -0.6785647 0.0940936 -0.8629882 -0.4941412
## r:age[0,1]:time8  -0.7004668 0.1019671 -0.9003222 -0.5006114
## r:age[1,10]:time8 -0.6326258 0.1738164 -0.9733059 -0.2919456
## r:age[0,1]:time9  -0.8696024 0.0000000 -0.8696024 -0.8696024
## r:age[1,10]:time9 -0.3451764 0.0000000 -0.3451764 -0.3451764
##
##
## Real Parameter S
## Group:ReleaseAgeAdult
##           1         2         3         4         5         6         7       8
## 1 0.5790623 0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 2           0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 3                     0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 4                               0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 5                                         0.6531163 0.5550089 0.5761235 0.56546
## 6                                                   0.5550089 0.5761235 0.56546
## 7                                                             0.5761235 0.56546
## 8                                                                       0.56546
## 9
##           9
## 1 0.7965425
## 2 0.7965425
## 3 0.7965425
## 4 0.7965425
## 5 0.7965425
## 6 0.7965425
## 7 0.7965425
## 8 0.7965425
## 9 0.7965425
##
## Group:ReleaseAgeYoung
##           1         2         3         4         5         6         7
## 1 0.4737909 0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235
## 2           0.5089720 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235
## 3                     0.5533462 0.8689379 0.6531163 0.5550089 0.5761235
## 4                               0.5944939 0.6531163 0.5550089 0.5761235
## 5                                         0.4801962 0.5550089 0.5761235
## 6                                                   0.6550466 0.5761235
## 7                                                             0.4669479
## 8
## 9
```

```
##          8         9
## 1 0.565460 0.7965425
## 2 0.565460 0.7965425
## 3 0.565460 0.7965425
## 4 0.565460 0.7965425
## 5 0.565460 0.7965425
## 6 0.565460 0.7965425
## 7 0.565460 0.7965425
## 8 0.409966 0.7965425
## 9          0.0874420
##
##
## Real Parameter r
## Group:ReleaseAgeAdult
##           1         2         3         4         5         6         7
## 1 0.102842 0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 2          0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 3                    0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 4                              0.5139531 0.1500243 0.1421849 0.1861618
## 5                                        0.1500243 0.1421849 0.1861618
## 6                                                  0.1421849 0.1861618
## 7                                                            0.1861618
## 8
## 9
##           8         9
## 1 0.2043678 0.3308187
## 2 0.2043678 0.3308187
## 3 0.2043678 0.3308187
## 4 0.2043678 0.3308187
## 5 0.2043678 0.3308187
## 6 0.2043678 0.3308187
## 7 0.2043678 0.3308187
## 8 0.2043678 0.3308187
## 9           0.3308187
##
## Group:ReleaseAgeYoung
##            1         2         3         4         5         6         7
## 1 0.1639626 0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 2           0.2988092 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 3                     0.1621797 0.5139531 0.1500243 0.1421849 0.1861618
## 4                               0.3141601 0.1500243 0.1421849 0.1861618
## 5                                         0.1748912 0.1421849 0.1861618
## 6                                                   0.2836196 0.1861618
## 7                                                             0.2056788
## 8
## 9
##           8         9
## 1 0.2043678 0.3308187
## 2 0.2043678 0.3308187
## 3 0.2043678 0.3308187
## 4 0.2043678 0.3308187
## 5 0.2043678 0.3308187
## 6 0.2043678 0.3308187
## 7 0.2043678 0.3308187
```

```
## 8 0.1777127 0.3308187
## 9          0.1179638
```

summary(mod)

```
## Output summary for Recovery model
## Name : S(~-1 + age:time)r(~-1 + age:time)
##
## Npar :  36  (unadjusted=34)
## -2lnL:  20650.4
## AICc :  20722.57  (unadjusted=20718.554)
##
## Beta
##                      estimate         se         lcl         ucl
## S:age[0,1]:time1  -0.0524422 0.1197360 -0.2871248  0.1822404
## S:age[1,10]:time1  0.1587910 0.2310324 -0.2940325  0.6116145
## S:age[0,1]:time2   0.0179450 0.1404892 -0.2574139  0.2933039
## S:age[1,10]:time2  0.2819136 0.1581189 -0.0279994  0.5918267
## S:age[0,1]:time3   0.1068958 0.1348956 -0.1574996  0.3712912
## S:age[1,10]:time3  0.2546993 0.1520851 -0.0433876  0.5527862
## S:age[0,1]:time4   0.1901312 0.1467219 -0.0974438  0.4777062
## S:age[1,10]:time4  0.8299177 0.3112315  0.2199040  1.4399313
## S:age[0,1]:time5  -0.0396180 0.1226790 -0.2800688  0.2008328
## S:age[1,10]:time5  0.3112329 0.1528194  0.0117068  0.6107591
## S:age[0,1]:time6   0.3152910 0.1527867  0.0158290  0.6147530
## S:age[1,10]:time6  0.1102410 0.1174256 -0.1199132  0.3403952
## S:age[0,1]:time7  -0.0661525 0.1368479 -0.3343743  0.2020694
## S:age[1,10]:time7  0.1528413 0.1352256 -0.1122010  0.4178835
## S:age[0,1]:time8  -0.1810555 0.2405947 -0.6526212  0.2905102
## S:age[1,10]:time8  0.1312970 0.2709540 -0.3997730  0.6623669
## S:age[0,1]:time9  -0.9704075 0.0000000 -0.9704075 -0.9704075
## S:age[1,10]:time9  0.6348851 0.0000000  0.6348851  0.6348851
## r:age[0,1]:time1  -0.7370072 0.0657534 -0.8658839 -0.6081306
## r:age[1,10]:time1 -0.9178808 0.1342331 -1.1809776 -0.6547839
## r:age[0,1]:time2  -0.4141168 0.1048338 -0.6195911 -0.2086426
## r:age[1,10]:time2 -0.5535649 0.1401776 -0.8283130 -0.2788168
## r:age[0,1]:time3  -0.7418334 0.0782929 -0.8952874 -0.5883793
## r:age[1,10]:time3 -0.7539230 0.1036715 -0.9571191 -0.5507268
## r:age[0,1]:time4  -0.3808179 0.1262967 -0.6283593 -0.1332764
## r:age[1,10]:time4  0.0279097 0.8754164 -1.6879064  1.7437259
## r:age[0,1]:time5  -0.7078708 0.0662433 -0.8377075 -0.5780340
## r:age[1,10]:time5 -0.7753296 0.1107999 -0.9924973 -0.5581618
## r:age[0,1]:time6  -0.4475529 0.1393160 -0.7206123 -0.1744935
## r:age[1,10]:time6 -0.7975261 0.0750974 -0.9447170 -0.6503352
## r:age[0,1]:time7  -0.6293785 0.0755380 -0.7774330 -0.4813241
## r:age[1,10]:time7 -0.6785647 0.0940936 -0.8629882 -0.4941412
## r:age[0,1]:time8  -0.7004668 0.1019671 -0.9003222 -0.5006114
## r:age[1,10]:time8 -0.6326258 0.1738164 -0.9733059 -0.2919456
## r:age[0,1]:time9  -0.8696024 0.0000000 -0.8696024 -0.8696024
## r:age[1,10]:time9 -0.3451764 0.0000000 -0.3451764 -0.3451764
##
##
## Real Parameter S
## Group:ReleaseAgeAdult
```

```
##                1         2         3         4         5         6         7         8
## 1 0.5790623 0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 2           0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 3                     0.6259772 0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 4                               0.8689379 0.6531163 0.5550089 0.5761235 0.56546
## 5                                         0.6531163 0.5550089 0.5761235 0.56546
## 6                                                   0.5550089 0.5761235 0.56546
## 7                                                             0.5761235 0.56546
## 8                                                                       0.56546
## 9
##            9
## 1 0.7965425
## 2 0.7965425
## 3 0.7965425
## 4 0.7965425
## 5 0.7965425
## 6 0.7965425
## 7 0.7965425
## 8 0.7965425
## 9 0.7965425
##
## Group:ReleaseAgeYoung
##              1         2         3         4         5         6         7
## 1 0.4737909 0.6390971 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235
## 2           0.5089720 0.6259772 0.8689379 0.6531163 0.5550089 0.5761235
## 3                     0.5533462 0.8689379 0.6531163 0.5550089 0.5761235
## 4                               0.5944939 0.6531163 0.5550089 0.5761235
## 5                                         0.4801962 0.5550089 0.5761235
## 6                                                   0.6550466 0.5761235
## 7                                                             0.4669479
## 8
## 9
##           8         9
## 1 0.565460 0.7965425
## 2 0.565460 0.7965425
## 3 0.565460 0.7965425
## 4 0.565460 0.7965425
## 5 0.565460 0.7965425
## 6 0.565460 0.7965425
## 7 0.565460 0.7965425
## 8 0.409966 0.7965425
## 9          0.0874420
##
##
## Real Parameter r
## Group:ReleaseAgeAdult
##            1         2         3         4         5         6         7
## 1 0.102842 0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 2          0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 3                    0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 4                              0.5139531 0.1500243 0.1421849 0.1861618
## 5                                        0.1500243 0.1421849 0.1861618
## 6                                                  0.1421849 0.1861618
## 7                                                            0.1861618
```

```
## 8
## 9
##               8               9
## 1 0.2043678 0.3308187
## 2 0.2043678 0.3308187
## 3 0.2043678 0.3308187
## 4 0.2043678 0.3308187
## 5 0.2043678 0.3308187
## 6 0.2043678 0.3308187
## 7 0.2043678 0.3308187
## 8 0.2043678 0.3308187
## 9           0.3308187
##
## Group:ReleaseAgeYoung
##               1         2         3         4         5         6         7
## 1 0.1639626 0.2371385 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 2           0.2988092 0.1577481 0.5139531 0.1500243 0.1421849 0.1861618
## 3                     0.1621797 0.5139531 0.1500243 0.1421849 0.1861618
## 4                               0.3141601 0.1500243 0.1421849 0.1861618
## 5                                         0.1748912 0.1421849 0.1861618
## 6                                                   0.2836196 0.1861618
## 7                                                             0.2056788
## 8
## 9
##               8               9
## 1 0.2043678 0.3308187
## 2 0.2043678 0.3308187
## 3 0.2043678 0.3308187
## 4 0.2043678 0.3308187
## 5 0.2043678 0.3308187
## 6 0.2043678 0.3308187
## 7 0.2043678 0.3308187
## 8 0.1777127 0.3308187
## 9           0.1179638
```

```r
# konkret die Schätzwerte aufrufen
mod.seber <- mod$results$real
```

Die Überlebensraten der adulten beringten Vögel ist höher als der jung beringten Vögel.

Brownie-Modell

Das Modell wird indiziert mit `model = "Brownie"` und geht auf Brownie et al. (1985) zurück. Details finden sich in Kap. 11.11 des Buches.

```r
br=process.data(brownie,model="Brownie",groups="ReleaseAge",
                age.var=1,initial.ages=c(1,0))
br.ddl=make.design.data(br,
                        parameters=list(S=list(age.bins=c(0,1,10)),

f=list(age.bins=c(0,1,10))),right=FALSE)
mod=mark(br,br.ddl,
```

```
        model.parameters=list(S=list(formula=~-1+age:time,link="sin"),

f=list(formula=~-1+age:time,link="sin")),delete=TRUE)
```

```
##
## Output summary for Brownie model
## Name : S(~-1 + age:time)f(~-1 + age:time)
##
## Npar :  34
## -2lnL:  20650.4
## AICc :  20718.55
##
## Beta
##                       estimate         se          lcl          ucl
## S:age[0,1):time1    3.1940360  0.1197357   2.9593540    3.4287180
## S:age[1,10]:time1   0.1587914  0.2310335  -0.2940342    0.6116170
## S:age[0,1):time2    0.0179451  0.1404891  -0.2574135    0.2933037
## S:age[1,10]:time2   0.2819132  0.1581178  -0.0279978    0.5918241
## S:age[0,1):time3    0.1068983  0.1348944  -0.1574948    0.3712914
## S:age[1,10]:time3   0.2547024  0.1520833  -0.0433810    0.5527857
## S:age[0,1):time4    2.9514637  0.1467212   2.6638901    3.2390373
## S:age[1,10]:time4   0.8299061  0.3112169   0.2199210    1.4398912
## S:age[0,1):time5   -0.0396187  0.1226792  -0.2800699    0.2008325
## S:age[1,10]:time5   0.3112359  0.1528199   0.0117090    0.6107629
## S:age[0,1):time6    0.3152913  0.1527870   0.0158288    0.6147538
## S:age[1,10]:time6   3.0313520  0.1174258   2.8011974    3.2615067
## S:age[0,1):time7   -0.0661528  0.1368479  -0.3343748    0.2020691
## S:age[1,10]:time7   2.9887507  0.1352261   2.7237075    3.2537938
## S:age[0,1):time8    3.3226482  0.2405954   2.8510813    3.7942152
## S:age[1,10]:time8   0.1312962  0.2709570  -0.3997795    0.6623719
## f:age[0,1):time1   -0.9745385  0.0322413  -1.0377315   -0.9113456
## f:age[1,10]:time1  -1.1516087  0.0657952  -1.2805673   -1.0226502
## f:age[0,1):time2   -0.7846148  0.0377426  -0.8585903   -0.7106394
## f:age[1,10]:time2  -0.9770170  0.0328456  -1.0413943   -0.9126396
## f:age[0,1):time3   -1.0257894  0.0297219  -1.0840443   -0.9675344
## f:age[1,10]:time3  -1.0800838  0.0259161  -1.1308792   -1.0292883
## f:age[0,1):time4   -0.8408532  0.0288555  -0.8974100   -0.7842965
## f:age[1,10]:time4  -1.0457100  0.0287229  -1.1020069   -0.9894131
## f:age[0,1):time5   -0.9582416  0.0288795  -1.0148455   -0.9016377
## f:age[1,10]:time5  -2.0310995  0.0226914  -2.0755747   -1.9866243
## f:age[0,1):time6   -0.9345453  0.0294245  -0.9922173   -0.8768733
## f:age[1,10]:time6  -2.0793328  0.0225826  -2.1235948   -2.0350709
## f:age[0,1):time7   -0.8958253  0.0297351  -0.9541060   -0.8375446
## f:age[1,10]:time7  -2.1402777  0.0224472  -2.1842743   -2.0962812
## f:age[0,1):time8   -0.9112772  0.0332228  -0.9763938   -0.8461605
## f:age[1,10]:time8  -2.1759968  0.0282602  -2.2313868   -2.1206069
## f:age[0,1):time9   -0.9022161  0.0532246  -1.0065364   -0.7978959
## f:age[1,10]:time9  -1.0459179  0.0566145  -1.1568823   -0.9349535
##
##
## Real Parameter S
## Group:ReleaseAgeAdult
##             1         2         3         4         5         6         7
```

```
## 1 0.5790625 0.6390969 0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 2           0.6390969 0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 3                     0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 4                               0.868934 0.6531177 0.5550087 0.5761238
## 5                                        0.6531177 0.5550087 0.5761238
## 6                                                  0.5550087 0.5761238
## 7                                                            0.5761238
## 8
##          8
## 1 0.5654596
## 2 0.5654596
## 3 0.5654596
## 4 0.5654596
## 5 0.5654596
## 6 0.5654596
## 7 0.5654596
## 8 0.5654596
##
## Group:ReleaseAgeYoung
##           1         2         3         4         5         6         7
## 1 0.4737904 0.6390969 0.6259787 0.8689340 0.6531177 0.5550087 0.5761238
## 2           0.5089721 0.6259787 0.8689340 0.6531177 0.5550087 0.5761238
## 3                     0.5533474 0.8689340 0.6531177 0.5550087 0.5761238
## 4                               0.5944928 0.6531177 0.5550087 0.5761238
## 5                                         0.4801958 0.5550087 0.5761238
## 6                                                   0.6550467 0.5761238
## 7                                                             0.4669477
## 8
##          8
## 1 0.5654596
## 2 0.5654596
## 3 0.5654596
## 4 0.5654596
## 5 0.5654596
## 6 0.5654596
## 7 0.5654596
## 8 0.4099660
##
##
## Real Parameter f
## Group:ReleaseAgeAdult
##         1        2         3         4         5        6         7        8
## 1 0.04329 0.085584 0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 2         0.085584 0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 3                  0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 4                            0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 5                                      0.0520411 0.063271 0.0789096 0.088806
## 6                                                0.063271 0.0789096 0.088806
## 7                                                         0.0789096 0.088806
## 8                                                                   0.088806
## 9
##           9
## 1 0.0673076
## 2 0.0673076
```

```
## 3 0.0673076
## 4 0.0673076
## 5 0.0673076
## 6 0.0673076
## 7 0.0673076
## 8 0.0673076
## 9 0.0673076
##
## Group:ReleaseAgeYoung
##            1         2         3         4         5         6         7
## 1 0.0862786 0.0855840 0.0590014 0.0673597 0.0520411 0.0632710 0.0789096
## 2           0.1467237 0.0590014 0.0673597 0.0520411 0.0632710 0.0789096
## 3                     0.0724382 0.0673597 0.0520411 0.0632710 0.0789096
## 4                               0.1273938 0.0520411 0.0632710 0.0789096
## 5                                         0.0909091 0.0632710 0.0789096
## 6                                                   0.0978355 0.0789096
## 7                                                             0.1096375
## 8
## 9
##            8         9
## 1 0.0888060 0.0673076
## 2 0.0888060 0.0673076
## 3 0.0888060 0.0673076
## 4 0.0888060 0.0673076
## 5 0.0888060 0.0673076
## 6 0.0888060 0.0673076
## 7 0.0888060 0.0673076
## 8 0.1048565 0.0673076
## 9           0.1076487
```

```r
#mod=mark(br,br.ddl,model.parameters=list(S=list(formula=~-1+age,link="sin"),
#
#f=list(formula=~-1+age,link="sin")),delete=TRUE)
summary(mod)
```

```
## Output summary for Brownie model
## Name : S(~-1 + age:time)f(~-1 + age:time)
##
## Npar :  34
## -2lnL:  20650.4
## AICc :  20718.55
##
## Beta
##                       estimate         se        lcl        ucl
## S:age[0,1]:time1     3.1940360  0.1197357  2.9593540  3.4287180
## S:age[1,10]:time1    0.1587914  0.2310335 -0.2940342  0.6116170
## S:age[0,1]:time2     0.0179451  0.1404891 -0.2574135  0.2933037
## S:age[1,10]:time2    0.2819132  0.1581178 -0.0279978  0.5918241
## S:age[0,1]:time3     0.1068983  0.1348944 -0.1574948  0.3712914
## S:age[1,10]:time3    0.2547024  0.1520833 -0.0433810  0.5527857
## S:age[0,1]:time4     2.9514637  0.1467212  2.6638901  3.2390373
## S:age[1,10]:time4    0.8299061  0.3112169  0.2199210  1.4398912
## S:age[0,1]:time5    -0.0396187  0.1226792 -0.2800699  0.2008325
## S:age[1,10]:time5    0.3112359  0.1528199  0.0117090  0.6107629
```

```
## S:age[0,1]:time6   0.3152913 0.1527870   0.0158288   0.6147538
## S:age[1,10]:time6  3.0313520 0.1174258   2.8011974   3.2615067
## S:age[0,1]:time7  -0.0661528 0.1368479  -0.3343748   0.2020691
## S:age[1,10]:time7  2.9887507 0.1352261   2.7237075   3.2537938
## S:age[0,1]:time8   3.3226482 0.2405954   2.8510813   3.7942152
## S:age[1,10]:time8  0.1312962 0.2709570  -0.3997795   0.6623719
## f:age[0,1]:time1  -0.9745385 0.0322413  -1.0377315  -0.9113456
## f:age[1,10]:time1 -1.1516087 0.0657952  -1.2805673  -1.0226502
## f:age[0,1]:time2  -0.7846148 0.0377426  -0.8585903  -0.7106394
## f:age[1,10]:time2 -0.9770170 0.0328456  -1.0413943  -0.9126396
## f:age[0,1]:time3  -1.0257894 0.0297219  -1.0840443  -0.9675344
## f:age[1,10]:time3 -1.0800838 0.0259161  -1.1308792  -1.0292883
## f:age[0,1]:time4  -0.8408532 0.0288555  -0.8974100  -0.7842965
## f:age[1,10]:time4 -1.0457100 0.0287229  -1.1020069  -0.9894131
## f:age[0,1]:time5  -0.9582416 0.0288795  -1.0148455  -0.9016377
## f:age[1,10]:time5 -2.0310995 0.0226914  -2.0755747  -1.9866243
## f:age[0,1]:time6  -0.9345453 0.0294245  -0.9922173  -0.8768733
## f:age[1,10]:time6 -2.0793328 0.0225826  -2.1235948  -2.0350709
## f:age[0,1]:time7  -0.8958253 0.0297351  -0.9541060  -0.8375446
## f:age[1,10]:time7 -2.1402777 0.0224472  -2.1842743  -2.0962812
## f:age[0,1]:time8  -0.9112772 0.0332228  -0.9763938  -0.8461605
## f:age[1,10]:time8 -2.1759968 0.0282602  -2.2313868  -2.1206069
## f:age[0,1]:time9  -0.9022161 0.0532246  -1.0065364  -0.7978959
## f:age[1,10]:time9 -1.0459179 0.0566145  -1.1568823  -0.9349535
##
##
## Real Parameter S
## Group:ReleaseAgeAdult
##           1         2         3        4         5         6         7
## 1 0.5790625 0.6390969 0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 2           0.6390969 0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 3                     0.6259787 0.868934 0.6531177 0.5550087 0.5761238
## 4                               0.868934 0.6531177 0.5550087 0.5761238
## 5                                        0.6531177 0.5550087 0.5761238
## 6                                                  0.5550087 0.5761238
## 7                                                            0.5761238
## 8
##         8
## 1 0.5654596
## 2 0.5654596
## 3 0.5654596
## 4 0.5654596
## 5 0.5654596
## 6 0.5654596
## 7 0.5654596
## 8 0.5654596
##
## Group:ReleaseAgeYoung
##           1         2         3         4         5         6         7
## 1 0.4737904 0.6390969 0.6259787 0.8689340 0.6531177 0.5550087 0.5761238
## 2           0.5089721 0.6259787 0.8689340 0.6531177 0.5550087 0.5761238
## 3                     0.5533474 0.8689340 0.6531177 0.5550087 0.5761238
## 4                               0.5944928 0.6531177 0.5550087 0.5761238
## 5                                         0.4801958 0.5550087 0.5761238
```

```
## 6                                                          0.6550467 0.5761238
## 7                                                                    0.4669477
## 8
##            8
## 1 0.5654596
## 2 0.5654596
## 3 0.5654596
## 4 0.5654596
## 5 0.5654596
## 6 0.5654596
## 7 0.5654596
## 8 0.4099660
##
##
## Real Parameter f
## Group:ReleaseAgeAdult
##         1        2         3         4         5        6         7        8
## 1 0.04329 0.085584 0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 2         0.085584 0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 3                  0.0590014 0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 4                            0.0673597 0.0520411 0.063271 0.0789096 0.088806
## 5                                      0.0520411 0.063271 0.0789096 0.088806
## 6                                                0.063271 0.0789096 0.088806
## 7                                                         0.0789096 0.088806
## 8                                                                   0.088806
## 9
##           9
## 1 0.0673076
## 2 0.0673076
## 3 0.0673076
## 4 0.0673076
## 5 0.0673076
## 6 0.0673076
## 7 0.0673076
## 8 0.0673076
## 9 0.0673076
##
## Group:ReleaseAgeYoung
##           1         2         3         4         5         6         7
## 1 0.0862786 0.0855840 0.0590014 0.0673597 0.0520411 0.0632710 0.0789096
## 2           0.1467237 0.0590014 0.0673597 0.0520411 0.0632710 0.0789096
## 3                     0.0724382 0.0673597 0.0520411 0.0632710 0.0789096
## 4                               0.1273938 0.0520411 0.0632710 0.0789096
## 5                                         0.0909091 0.0632710 0.0789096
## 6                                                   0.0978355 0.0789096
## 7                                                             0.1096375
## 8
## 9
##           8         9
## 1 0.0888060 0.0673076
## 2 0.0888060 0.0673076
## 3 0.0888060 0.0673076
## 4 0.0888060 0.0673076
## 5 0.0888060 0.0673076
```

```
## 6 0.0888060 0.0673076
## 7 0.0888060 0.0673076
## 8 0.1048565 0.0673076
## 9           0.1076487
```

```
# konkret die Schätzwerte aufrufen
mod.brownie <- mod$results$real
```

Vergleichen wir die Daten aus beiden Modellen miteinander. Dazu nutzen wir das Paket ggplot2 (Wickham 2016).

```
mod.seber.adult <- mod.seber[1:9,]
mod.seber.adult$Occasion <- 1:9
mod.seber.young <- mod.seber[10:18,]
mod.seber.young$Occasion <- 1:9
mod.brownie.adult <- mod.brownie[1:8,]
mod.brownie.adult$Occasion <- 1:8
mod.brownie.young <- mod.brownie[9:16,]
mod.brownie.young$Occasion <- 1:8

# Adult markierte Tiere
ggplot(mod.seber.adult,aes(Occasion,estimate,
                    ymin=lcl,ymax=ucl))+
      geom_errorbar(width=0.2)+geom_point()+geom_line()+
      geom_point(data=mod.brownie.adult,
                 aes(Occasion, estimate, ymin=lcl,ymax=ucl), color="red") +
      scale_y_continuous(labels = label_number(decimal.mark = ",")) +
      scale_x_continuous(breaks = function(x) seq(floor(min(x)), ceiling(max(x)), by = 1),
                        labels = number_format(accuracy = 1)) +
      theme_classic() +
      xlab("\nFanggelegenheit")+ylab("Überlebensrate\n")
```
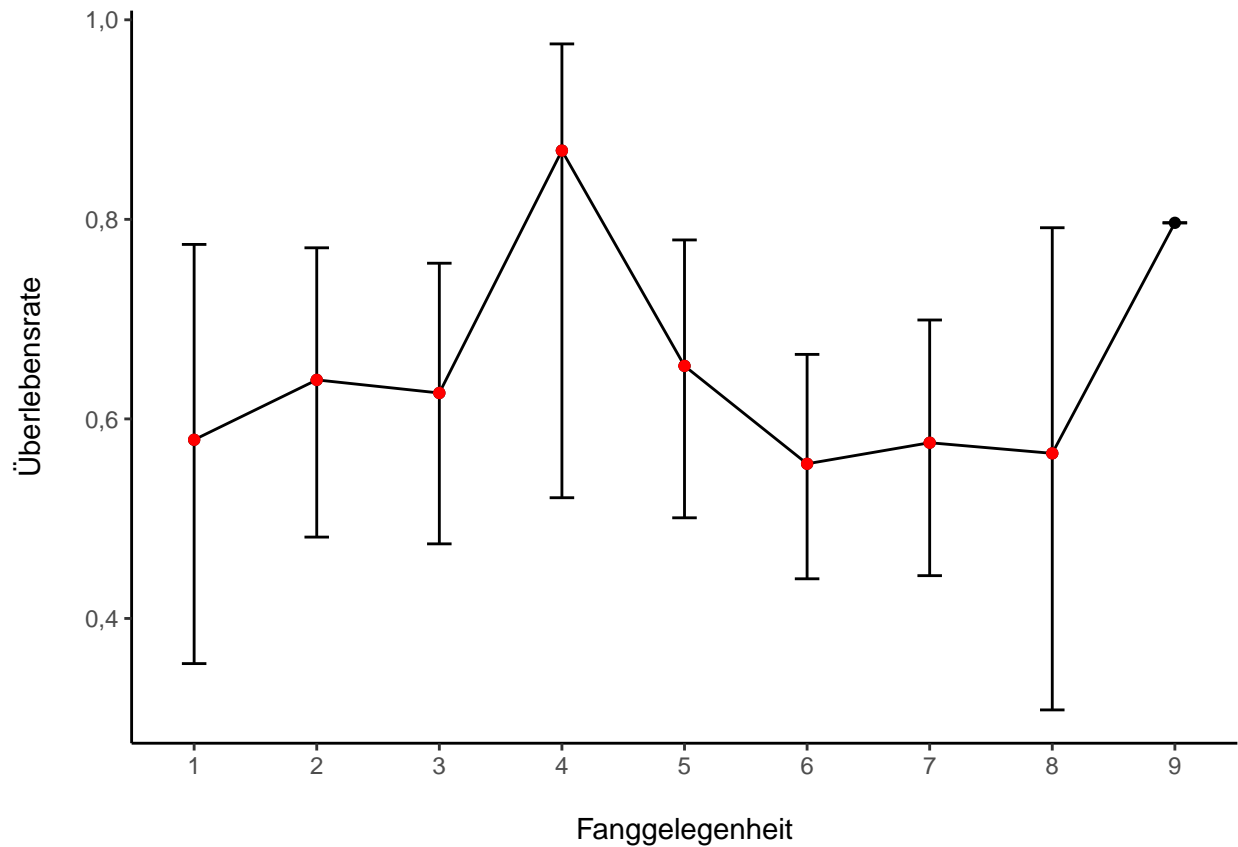
```r
# Juvenil markierte Tiere
ggplot(mod.seber.young,aes(Occasion,estimate,
                    ymin=lcl,ymax=ucl))+
      geom_errorbar(width=0.2)+geom_point()+geom_line()+
      geom_point(data=mod.brownie.young,
                aes(Occasion, estimate, ymin=lcl,ymax=ucl), color="red") +
      scale_y_continuous(labels = label_number(decimal.mark = ",")) +
      scale_x_continuous(breaks = function(x) seq(floor(min(x)), ceiling(max(x)), by = 1),
                      labels = number_format(accuracy = 1)) +
      theme_classic() +
      xlab("\nFanggelegenheit")+ylab("Überlebensrate\n")
```
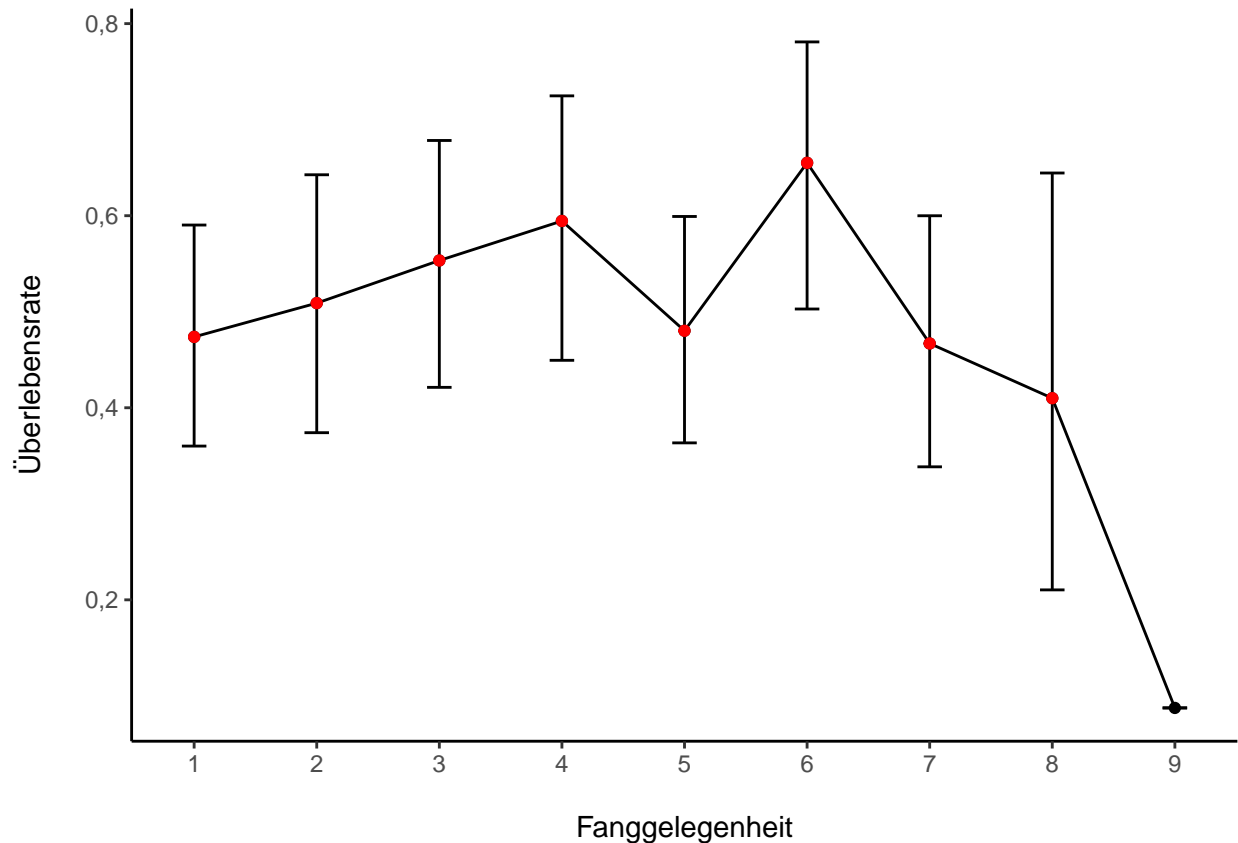
Die schwarzen verbundenen Punkte stellen die Schätzungen von Seber (und deren 95 %-Konfidenzintervall) dar, die roten Punkte die Schätzungen von Brownie. Die berechneten Überlebensraten sind folglich nahezu identisch.

Literaturverzeichnis

Brownie, C., Anderson, D.R., Burnham, K.P., Robson, D.S. (1985): Statistical inference from band recovery data - A handbook (2nd ed.). — US Dept. Inter. Fish Wildl. Serv. Resource Publ. 156: 1–305.

Laake, J., Rexstad, E. (2008): RMark – an alternative approach to building linear models in MARK. — In: Cooch, E., White, G.C. (Hrsg.): — Program MARK: A Gentle Introduction.

Laake, J.L. (2013): RMark: An R interface for analysis of capture-recapture data with MARK. — AFSC Processed Rep 2013-01, 25p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Seattle WA, USA.

Seber, G.A.F. (1982): The estimation of animal abundance and related parameters, Second Edition. — Griffin, London.

Wickham, H. (2016): ggplot2: Elegant graphics for data analysis. — Springer-Verlag, New York.