

[3] studbookR: Census

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Introduction

The following census and census-event analyses are available:

- Census
- Births
- Deaths
- Neonatal mortality
- Migration

studbookR provides functions to analyse *census* (population size at census data), and *census-events* (events between census dates e.g. births).

Census(-event) analyses set the default time period to the first and last year as observed in the provided data. A subset of this period can be selected by providing the first and/or last year to the analyses. The period 1992 to 2002 is used in this vignette.

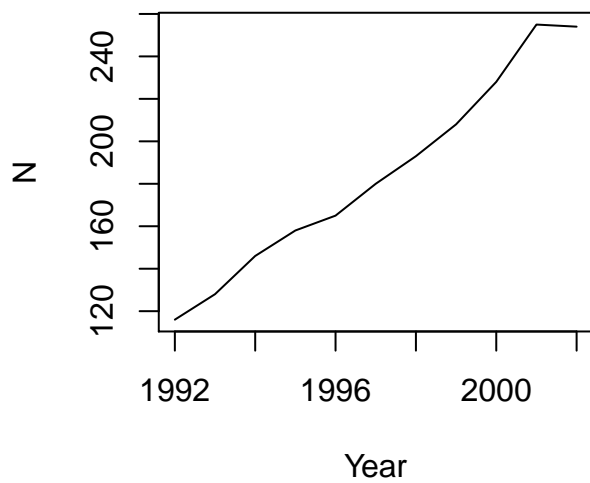
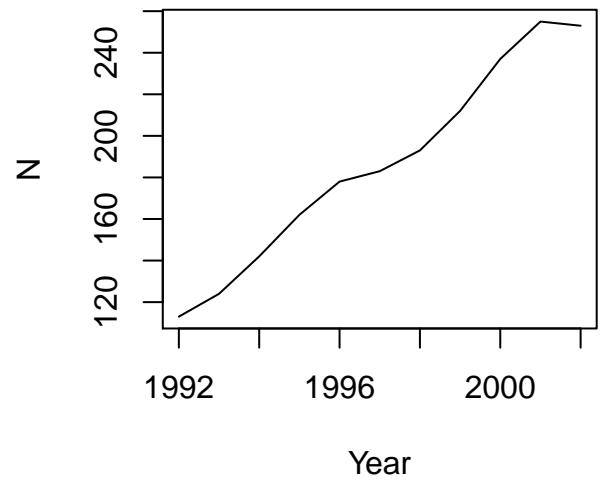
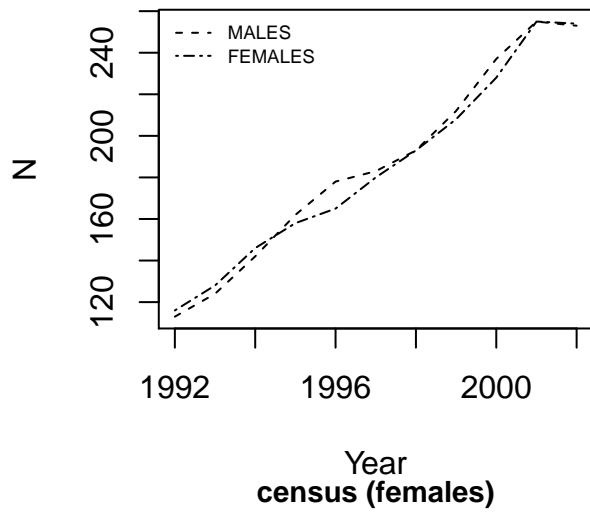
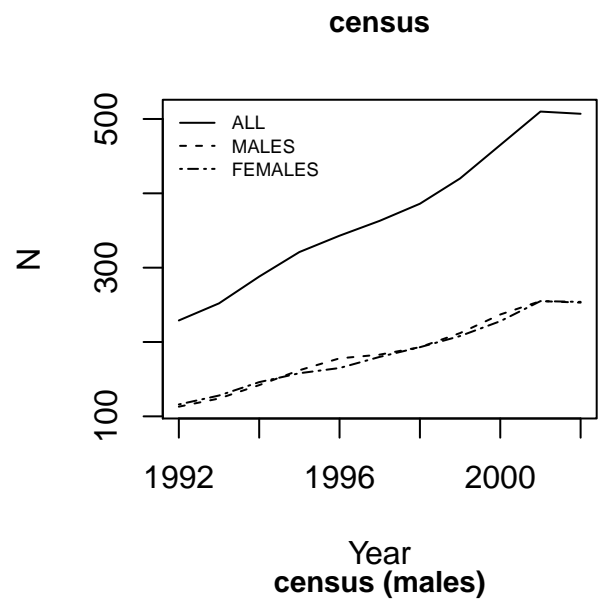
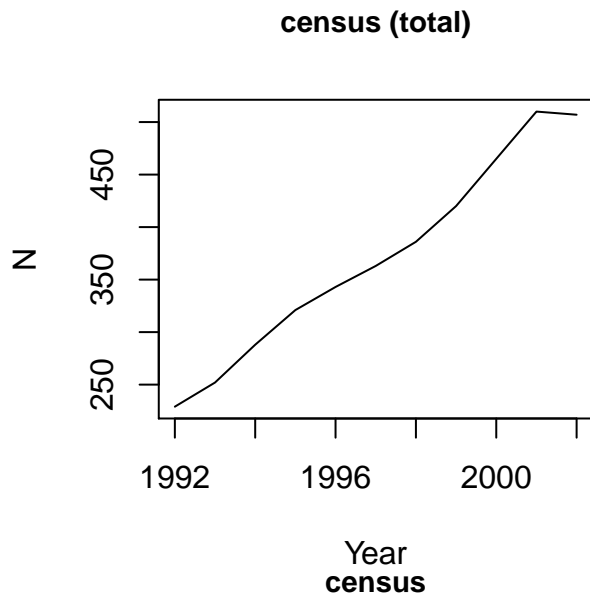
Census

Census analysis produces graphs with numbers of males, females and total (=all) population size at census dates.

Trends in population growth (λ and r) and/or sex ratio are estimated. The following example analyses population growth.

```
studbook.census(1992,2002,analyse='growth')
```

```
## =====
## Census
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##      ALL MALES FEMALES  SEXRATIO
## 1992 229   113      116 0.5065502
## 1993 252   124      128 0.5079365
## 1994 288   142      146 0.5069444
## 1995 321   162      158 0.4937500
## 1996 343   178      165 0.4810496
## 1997 363   183      180 0.4958678
## 1998 386   193      193 0.5000000
## 1999 420   212      208 0.4952381
## 2000 465   237      228 0.4903226
## 2001 510   255      255 0.5000000
## 2002 507   253      254 0.5009862
```



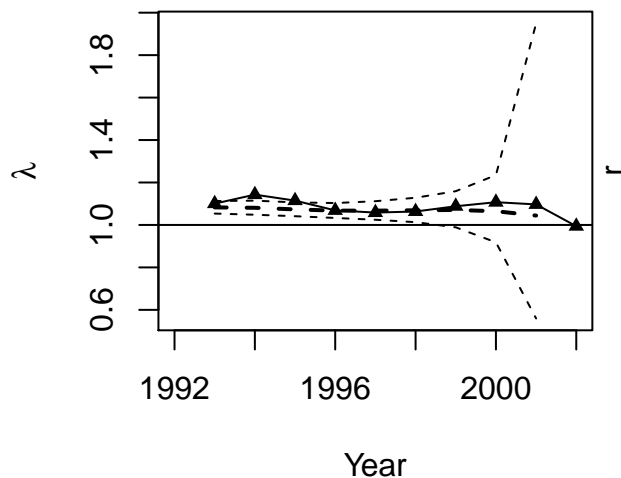
=====

```

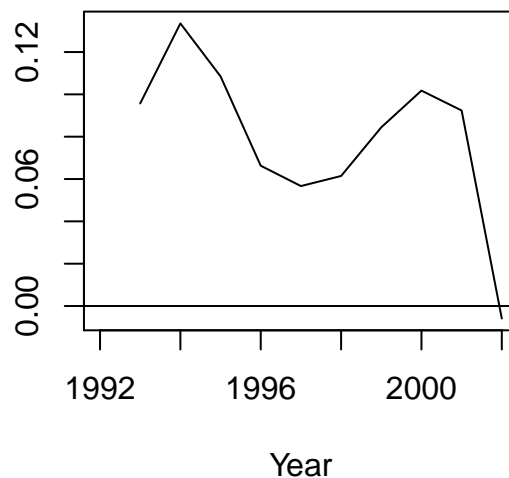
## Finite and instantaneous rates of change ( ALL )
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##      N      LAMBDA  GEOMEAN GEOMEAN_LWR GEOMEAN_UPR      r
## 1992 229          NA        NA          NA        NA        NA
## 1993 252 1.1004367 1.082723   1.0536567   1.112591 0.095707084
## 1994 288 1.1428571 1.080772   1.0481348   1.114426 0.133531393
## 1995 321 1.1145833 1.073253   1.0411761   1.106317 0.108480643
## 1996 343 1.0685358 1.067475   1.0329343   1.103170 0.066289324
## 1997 363 1.0583090 1.067298   1.0245442   1.111836 0.056672387
## 1998 386 1.0633609 1.069105   1.0131337   1.128168 0.061434535
## 1999 420 1.0880829 1.070546   0.9888509   1.158990 0.084417342
## 2000 465 1.1071429 1.064763   0.9181431   1.234797 0.101782694
## 2001 510 1.0967742 1.044185   0.5592818   1.949505 0.092373320
## 2002 507 0.9941176          NA          NA        NA -0.005899722
##
## Summary
##      LAMBDA      r
## Min.   :0.9941   Min.   :-0.00590
## 1st Qu.:1.0647   1st Qu.: 0.06265
## Median :1.0924   Median : 0.08840
## Mean   :1.0834   Mean   : 0.07948
## 3rd Qu.:1.1055   3rd Qu.: 0.10026
## Max.   :1.1429   Max.   : 0.13353
## NA's   :1       NA's   :1

```

Finite rates of change (ALL)



Instantaneous rate of change (ALL)



```

## =====
## Finite and instantaneous rates of change ( MALES )
## =====
##
## Time Series:
## Start = 1992

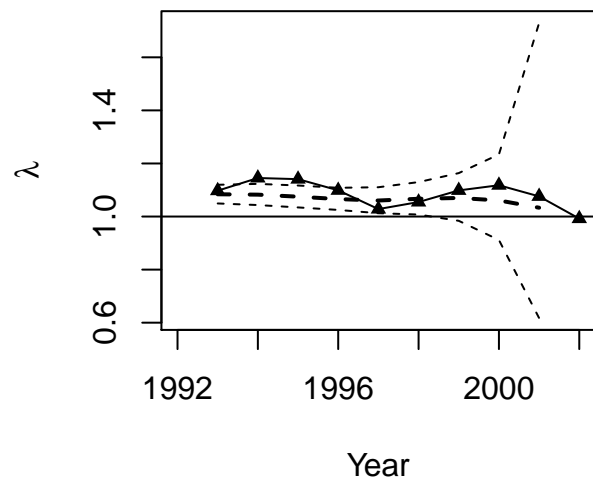
```

```

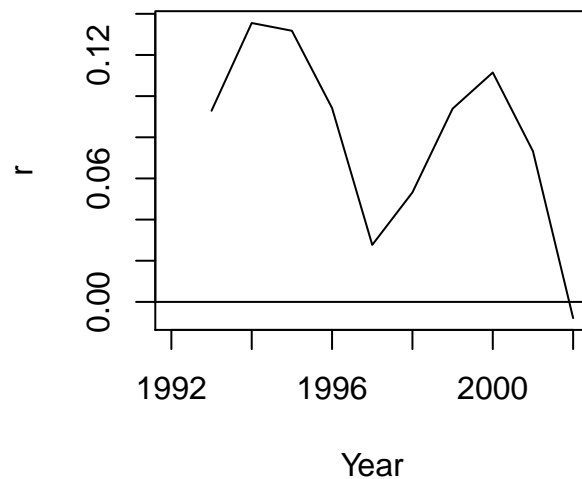
## End = 2002
## Frequency = 1
##      N      LAMBDA  GEOMEAN GEOMEAN_LWR GEOMEAN_UPR      r
## 1992 113      NA      NA      NA      NA      NA
## 1993 124 1.0973451 1.083937 1.0493147 1.119703 0.092893747
## 1994 142 1.1451613 1.082458 1.0433160 1.123068 0.135545492
## 1995 162 1.1408451 1.074865 1.0343316 1.116987 0.131769278
## 1996 178 1.0987654 1.065756 1.0248548 1.108290 0.094187215
## 1997 183 1.0280899 1.060352 1.0125582 1.110402 0.027702603
## 1998 193 1.0546448 1.066925 1.0075319 1.129819 0.053204036
## 1999 212 1.0984456 1.070017 0.9838870 1.163688 0.093896086
## 2000 237 1.1179245 1.060706 0.9116957 1.234070 0.111473866
## 2001 255 1.0759494 1.033204 0.6172824 1.729372 0.073203404
## 2002 253 0.9921569      NA      NA      NA -0.007874056
##
## Summary
##      LAMBDA      r
## Min.   :0.9922   Min.   :-0.007874
## 1st Qu.:1.0600   1st Qu.: 0.058204
## Median :1.0979   Median : 0.093395
## Mean   :1.0849   Mean    : 0.080600
## 3rd Qu.:1.1131   3rd Qu.: 0.107152
## Max.   :1.1452   Max.    : 0.135546
## NA's   :1       NA's    :1

```

Finite rates of change (MALES)



Instantaneous rate of change (MALES)



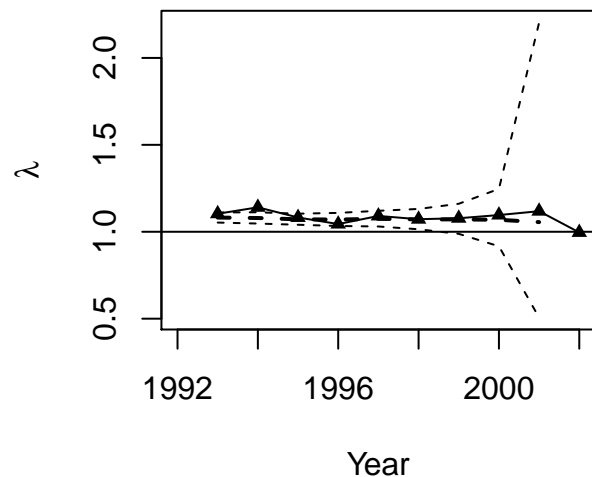
```

## =====
## Finite and instantaneous rates of change ( FEMALES )
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##      N      LAMBDA  GEOMEAN GEOMEAN_LWR GEOMEAN_UPR      r
## 1992 116      NA      NA      NA      NA      NA
## 1993 128 1.1034483 1.081528 1.0528500 1.110986 0.098440073

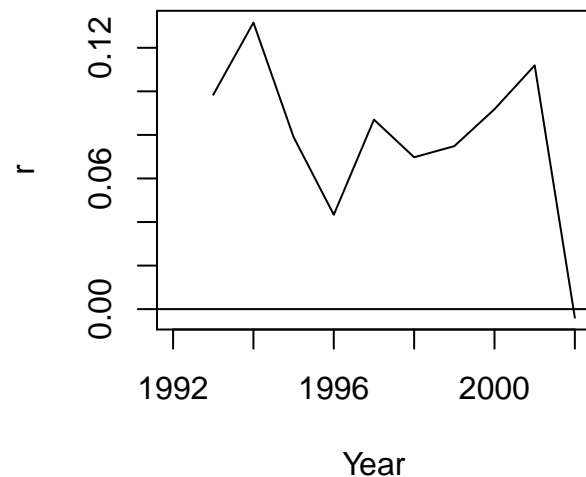
```

```
## 1994 146 1.1406250 1.079119 1.0471384 1.112076 0.131576358
## 1995 158 1.0821918 1.071668 1.0403721 1.103905 0.078988411
## 1996 165 1.0443038 1.070173 1.0331650 1.108506 0.043350441
## 1997 180 1.0909091 1.074546 1.0304011 1.120582 0.087011377
## 1998 193 1.0722222 1.071303 1.0144464 1.131346 0.069733338
## 1999 208 1.0777202 1.071073 0.9880420 1.161082 0.074847891
## 2000 228 1.0961538 1.068866 0.9165191 1.246538 0.091807549
## 2001 255 1.1184211 1.055479 0.5056074 2.203360 0.111917916
## 2002 254 0.9960784 NA NA NA -0.003929278
##
## Summary
## LAMBDA r
## Min. :0.9961 Min. :-0.003929
## 1st Qu.:1.0736 1st Qu.: 0.071012
## Median :1.0866 Median : 0.083000
## Mean :1.0822 Mean : 0.078374
## 3rd Qu.:1.1016 3rd Qu.: 0.096782
## Max. :1.1406 Max. : 0.131576
## NA's :1 NA's :1
```

Finite rates of change (FEMALES)



Instantaneous rate of change (FEMALES)



Births

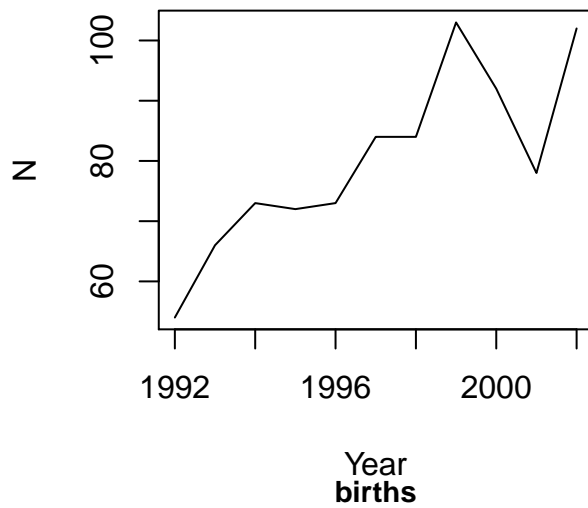
Birth “census” refers to birth counts between census dates. Trends in birth rates and/or sex ratio are estimated. The following example analyses sex ratio.

```
studbook.births(1992,2002,analyse='sexratio')
```

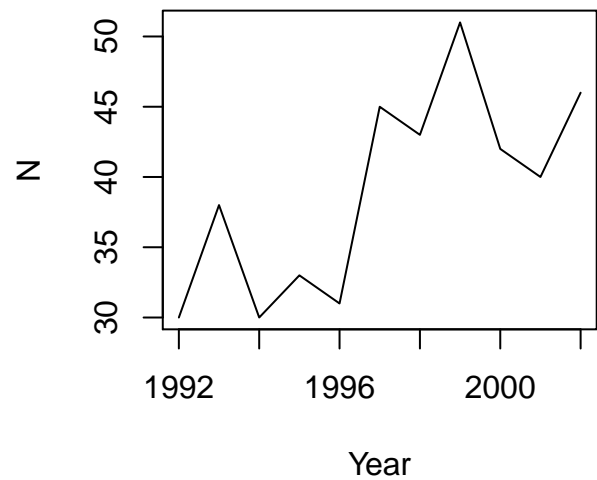
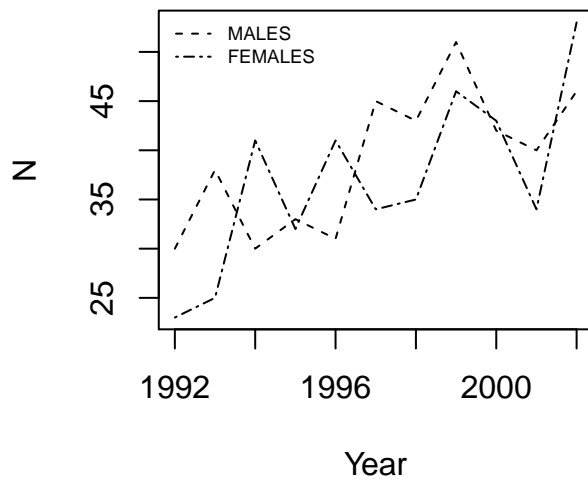
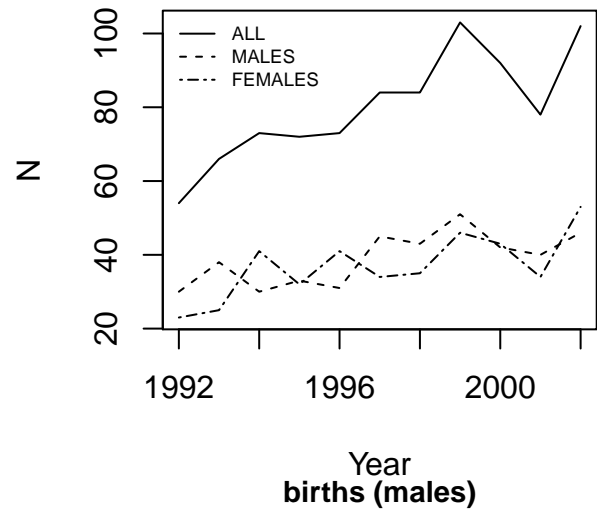
```
## =====
## Census of births
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
```

##		ALL	MALES	FEMALES	SEXRATIO
##	1992	54	30	23	0.4339623
##	1993	66	38	25	0.3968254
##	1994	73	30	41	0.5774648
##	1995	72	33	32	0.4923077
##	1996	73	31	41	0.5694444
##	1997	84	45	34	0.4303797
##	1998	84	43	35	0.4487179
##	1999	103	51	46	0.4742268
##	2000	92	42	43	0.5058824
##	2001	78	40	34	0.4594595
##	2002	102	46	53	0.5353535

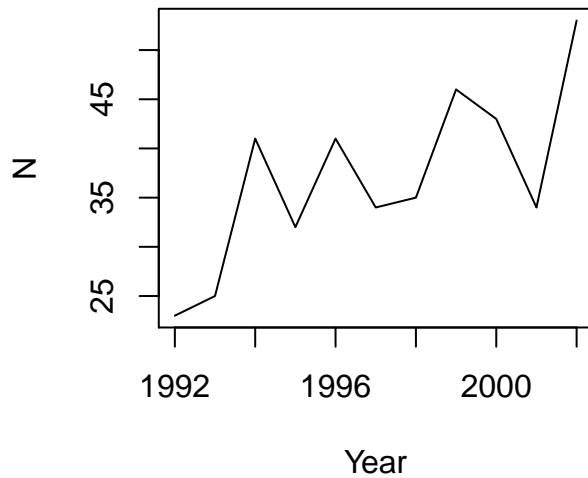
births (total)



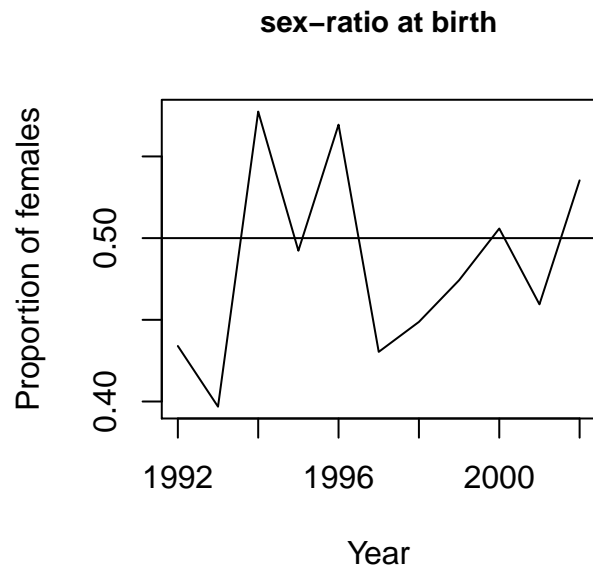
births



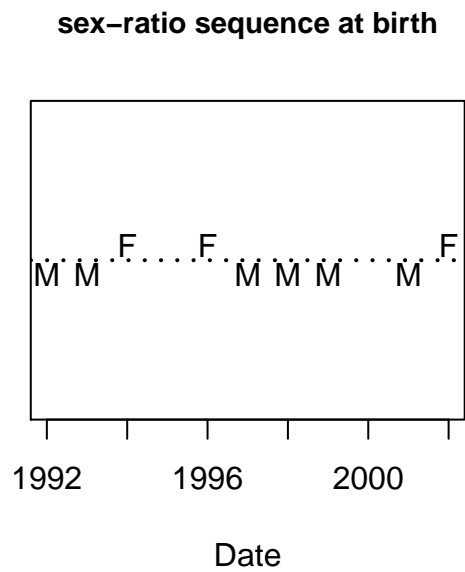
births (females)



```
## =====
## Sex-ratio at birth
## =====
##
##
## Sex-ratio [ n = 11 ]
## -----
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.3968  0.4413  0.4742  0.4840  0.5206  0.5775
## -----
##
## Percentiles 2.5-97.5% : 0.405214 0.5754597
## Sampling variance    : 0.003414236
## Standard deviation    : 0.05843146
## Standard error of mean : 0.01761775
## Weighted [ n = 11 ]
## -----
## Arithmetic mean      : 0.4868421 [sd = 0.05400075 ]
## Median               : 0.4742268
## Geometric mean       : 0.483876 [ NA , NA ]
## -----
## - Longest consecutive stretch of non-missing values: 1992-2002
## - Weighted against CENSUS (zero values excluded).
##
##
## Total number of males : 429
## Total number of females: 407
## Proportion of females : 0.4868421
##
## Binomial test over totals:
## -----
## p = 0.4676758
## H0: Equal sex-ratio is not rejected
```



```
##
## =====
## Runs test (tseries)
## =====
##
## sex-ratio runs: [MMF.FMMM.MF]
## . = equal
## Runs Test
##
## data: as.factor(runs)
## Standard Normal = -0.8165, p-value = 0.4142
## alternative hypothesis: two.sided
##
## H0: sequences are not random is not rejected
```



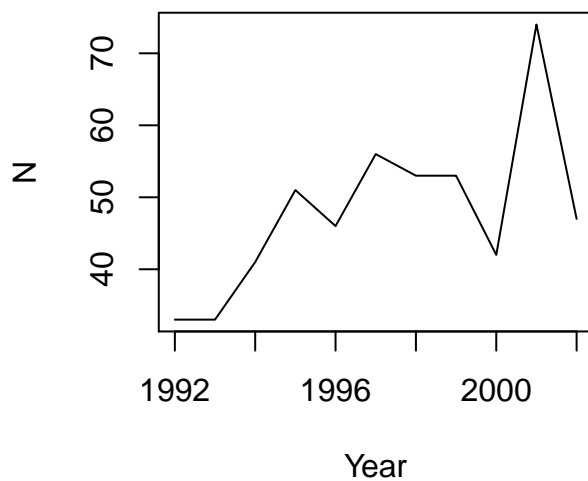
Deaths

Death “census” refers to death counts between census dates. Trends in death rates, birth-death rates and/or sex ratio are estimated. The following example analyses death rates.

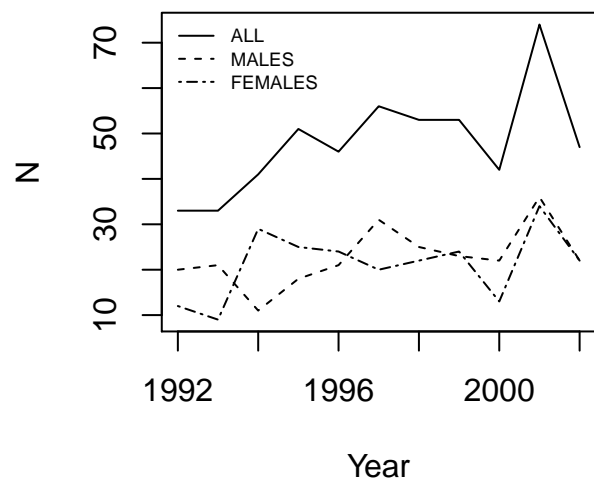
```
studbook.deaths(1992,2002,analyse='deathrate')
```

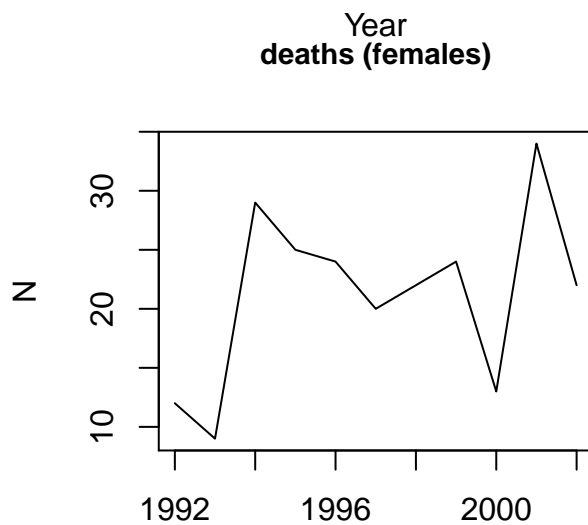
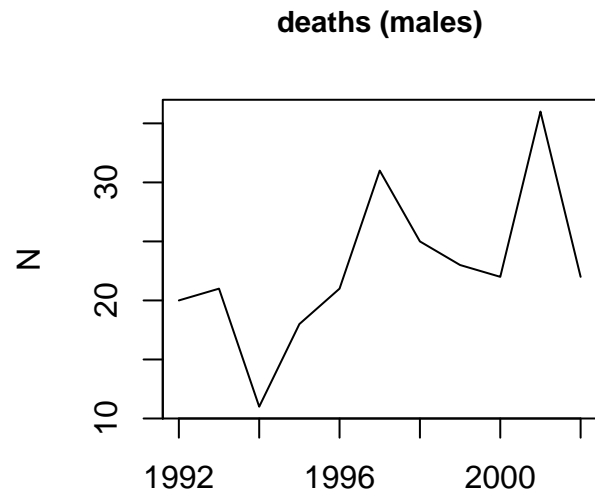
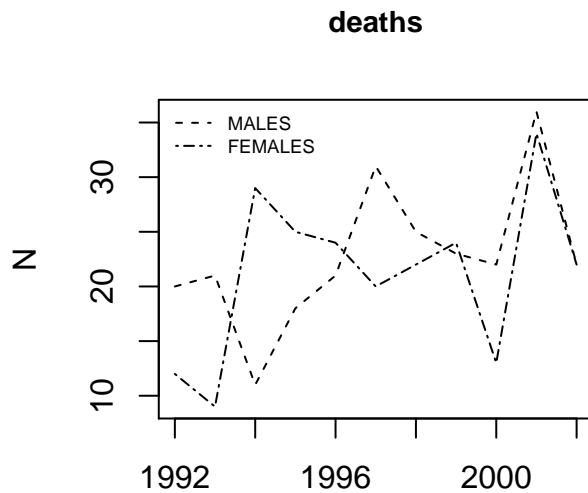
```
## =====  
## Census of deaths  
## =====  
##  
## Time Series:  
## Start = 1992  
## End = 2002  
## Frequency = 1  
##      ALL MALES FEMALES  SEXRATIO  
## 1992  33    20      12 0.3750000  
## 1993  33    21       9 0.3000000  
## 1994  41    11      29 0.7250000  
## 1995  51    18      25 0.5813953  
## 1996  46    21      24 0.5333333  
## 1997  56    31      20 0.3921569  
## 1998  53    25      22 0.4680851  
## 1999  53    23      24 0.5106383  
## 2000  42    22      13 0.3714286  
## 2001  74    36      34 0.4857143  
## 2002  47    22      22 0.5000000
```

deaths (total)



deaths





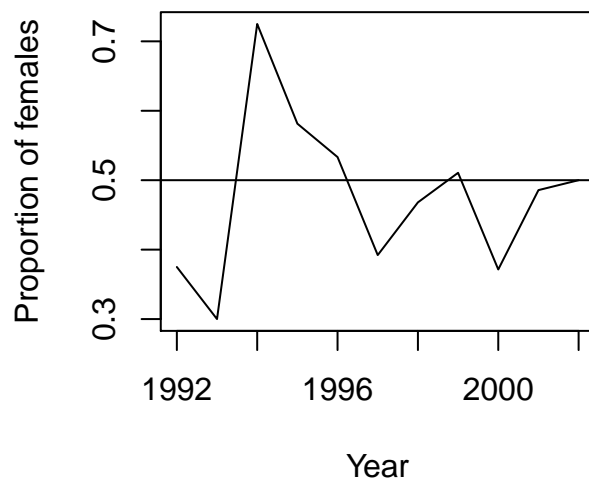
```
## =====
## Sex-ratio at death
## =====
##
##
## Sex-ratio [ n = 11 ]
## -----
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##      0.3000  0.3836  0.4857  0.4766  0.5220  0.7250
## -----
##
## Percentiles 2.5-97.5% : 0.3178571 0.6890988
## Sampling variance    : 0.01374668
## Standard deviation    : 0.1172462
## Standard error of mean : 0.03535107
## Weighted [ n = 11 ]
## -----
## Arithmetic mean      : 0.4834711 [sd = 0.1034282 ]
```

```

## Median                : 0.4857143
## Geometric mean        : 0.472664  [ NA , NA ]
## -----
## - Longest consecutive stretch of non-missing values: 1992-2002
## - Weighted against CENSUS (zero values excluded).
##
##
## Total number of males : 250
## Total number of females: 234
## Proportion of females : 0.4834711
##
## Binomial test over totals:
## -----
## p = 0.4953939
## H0: Equal sex-ratio is not rejected

```

sex-ratio at death



```

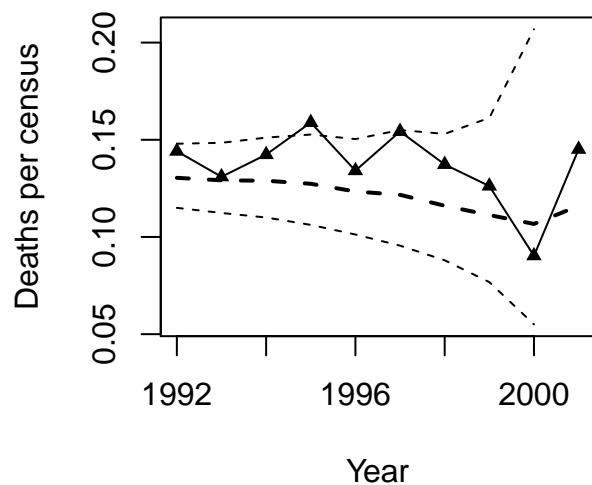
## =====
## Death rate
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##


|         | DEATHS | CENSUS | RATE       | GEOMEAN   | GEOMEAN_LWR | GEOMEAN_UPR |
|---------|--------|--------|------------|-----------|-------------|-------------|
| ## 1992 | 33     | 229    | 0.14410480 | 0.1304328 | 0.11498265  | 0.1479591   |
| ## 1993 | 33     | 252    | 0.13095238 | 0.1291391 | 0.11234694  | 0.1484412   |
| ## 1994 | 41     | 288    | 0.14236111 | 0.1289392 | 0.11001670  | 0.1511163   |
| ## 1995 | 51     | 321    | 0.15887850 | 0.1273530 | 0.10621212  | 0.1527018   |
| ## 1996 | 46     | 343    | 0.13411079 | 0.1233920 | 0.10125984  | 0.1503614   |
| ## 1997 | 56     | 363    | 0.15426997 | 0.1216907 | 0.09552839  | 0.1550181   |
| ## 1998 | 53     | 386    | 0.13730570 | 0.1160520 | 0.08800985  | 0.1530291   |
| ## 1999 | 53     | 420    | 0.12619048 | 0.1112740 | 0.07677969  | 0.1612653   |
| ## 2000 | 42     | 465    | 0.09032258 | 0.1067045 | 0.05504063  | 0.2068625   |
| ## 2001 | 74     | 510    | 0.14509804 | 0.1159780 | 0.00673352  | 1.9976035   |
| ## 2002 | 47     | 507    | 0.09270217 | NA        | NA          | NA          |


```

```
##
## Deaths per census [ n = 10 ]
## -----
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.09032 0.13170 0.13980 0.13640 0.14480 0.15890
## -----
##
## Percentiles 2.5-97.5% : 0.09839286 0.1578416
## Sampling variance      : 0.0003620286
## Standard deviation     : 0.01902705
## Standard error of mean : 0.006016881
## Coefficient of variation: 13.9536 %
##
## Weighted [ n = 10 ]
## -----
## Arithmetic mean        : 0.1347498 [sd = 0.01958328 ]
## Median                  : 0.1373057
## Geometric mean         : 0.1330933 [ NA , NA ]
## -----
## - Longest consecutive stretch of non-missing values: 1992-2001
## - Weighted against CENSUS (zero values excluded).
```

Death rate



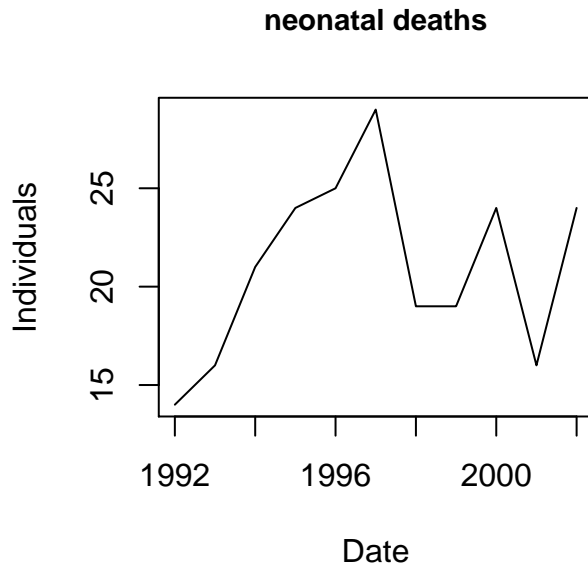
```
## [1] TRUE
```

Neonatal mortality

Neonatal mortality “census” refers to neonatal death counts between census dates. The neonatal stage is assumed to be “defined” by the program that generated the data set.

```
studbook.neonatalDeaths(1992,2002)
```

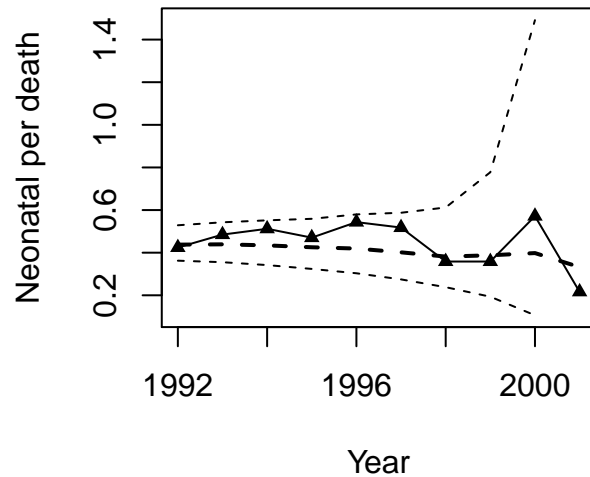
```
## =====
## Neonatal mortality
## =====
```



```
## =====
## neonatal/total death rate
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##      NEONATAL DEATH      RATE    GEOMEAN GEOMEAN_LWR GEOMEAN_UPR
## 1992         14      33 0.4242424 0.4377610 0.36250328 0.5286427
## 1993         16      33 0.4848485 0.4391363 0.35539234 0.5426136
## 1994         21      41 0.5121951 0.4343310 0.34183699 0.5518520
## 1995         24      51 0.4705882 0.4254701 0.32385474 0.5589691
## 1996         25      46 0.5434783 0.4193879 0.30346332 0.5795962
## 1997         29      56 0.5178571 0.4016565 0.27465247 0.5873895
## 1998         19      53 0.3584906 0.3817542 0.23808154 0.6121275
## 1999         19      53 0.3584906 0.3878023 0.19340557 0.7775918
## 2000         24      42 0.5714286 0.3980960 0.10628055 1.4911520
## 2001         16      74 0.2162162 0.3322774 0.00141372 78.0976961
## 2002         24      47 0.5106383          NA          NA          NA
##
## Neonatal per death [ n = 10 ]
## -----
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.2162  0.3749  0.4777  0.4458  0.5164  0.5714
## -----
##
## Percentiles 2.5-97.5% : 0.2482279 0.5651398
## Sampling variance      : 0.0117203
## Standard deviation     : 0.1082603
## Standard error of mean : 0.03423492
## Coefficient of variation: 24.2854 %
##
## Weighted [ n = 10 ]
## -----
## Arithmetic mean          : 0.4294606 [sd = 0.1139906 ]
```

```
## Median                : 0.4705882
## Geometric mean        : 0.4110372  [ NA , NA ]
## -----
## - Longest consecutive stretch of non-missing values: 1992-2001
## - Weighted against DEATH (zero values excluded).
```

neonatal/total death rate



```
## =====
## neonatal/birth rate
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##
```

	NEONATAL	BIRTH	RATE	GEOMEAN	GEOMEAN_LWR	GEOMEAN_UPR
## 1992	14	33	0.4242424	0.4377610	0.36250328	0.5286427
## 1993	16	33	0.4848485	0.4391363	0.35539234	0.5426136
## 1994	21	41	0.5121951	0.4343310	0.34183699	0.5518520
## 1995	24	51	0.4705882	0.4254701	0.32385474	0.5589691
## 1996	25	46	0.5434783	0.4193879	0.30346332	0.5795962
## 1997	29	56	0.5178571	0.4016565	0.27465247	0.5873895
## 1998	19	53	0.3584906	0.3817542	0.23808154	0.6121275
## 1999	19	53	0.3584906	0.3878023	0.19340557	0.7775918
## 2000	24	42	0.5714286	0.3980960	0.10628055	1.4911520
## 2001	16	74	0.2162162	0.3322774	0.00141372	78.0976961
## 2002	24	47	0.5106383	NA	NA	NA

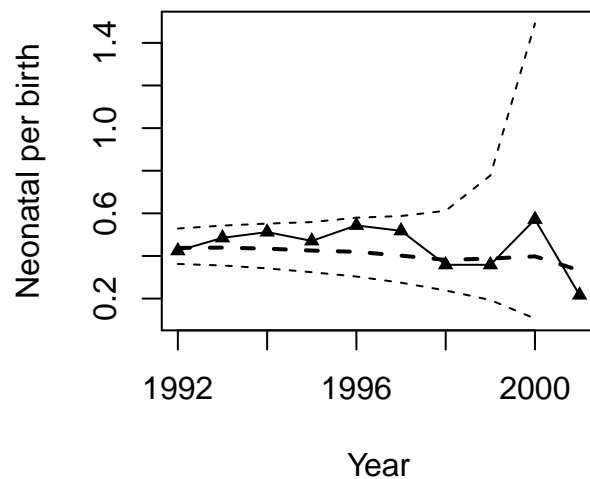
```
##
## Neonatal per birth [ n = 10 ]
## -----
##
```

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
##	0.2162	0.3749	0.4777	0.4458	0.5164	0.5714

```
## -----
##
## Percentiles 2.5-97.5% : 0.2482279 0.5651398
## Sampling variance      : 0.0117203
## Standard deviation     : 0.1082603
```

```
## Standard error of mean : 0.03423492
## Coefficient of variation: 24.2854 %
##
## Weighted [ n = 10 ]
## -----
## Arithmetic mean      : 0.4294606 [sd = 0.1139906 ]
## Median               : 0.4705882
## Geometric mean       : 0.4110372 [ NA , NA ]
## -----
## - Longest consecutive stretch of non-missing values: 1992-2001
## - Weighted against BIRTH (zero values excluded).
```

neonatal/birth rate



```
## [1] FALSE
```

Migration

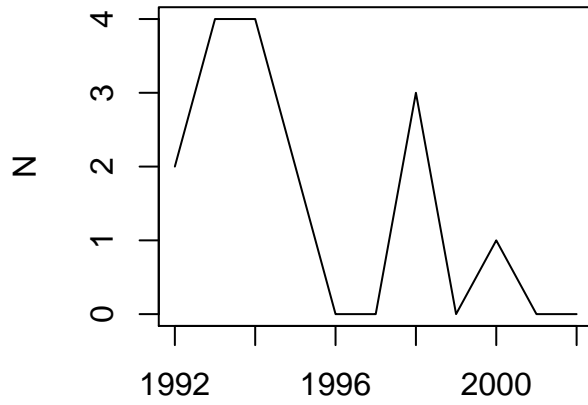
Migration in `studbookR` is considered as individuals that either enter (*immigration*) or leave (*emigration*) the population under study. Immigration distinguishes between individuals that originate from the original (wild) population and those that are born in subpopulations (e.g. zoo regions)

```
studbook.immigration(first=1992,2002)
```

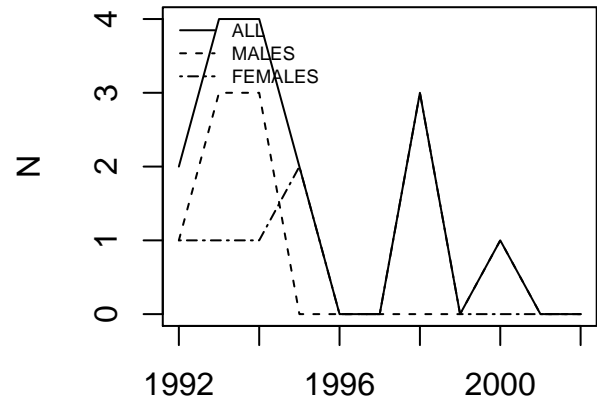
```
## =====
## Census of imports
## =====
##
## Time Series:
## Start = 1992
## End = 2002
## Frequency = 1
##      ALL MALES FEMALES SEXRATIO
## 1992      2      1      1      0.50
## 1993      4      3      1      0.25
## 1994      4      3      1      0.25
## 1995      2      0      2      1.00
```

##	1996	0	0	0	NaN
##	1997	0	0	0	NaN
##	1998	3	0	3	1.00
##	1999	0	0	0	NaN
##	2000	1	1	0	0.00
##	2001	0	0	0	NaN
##	2002	0	0	0	NaN

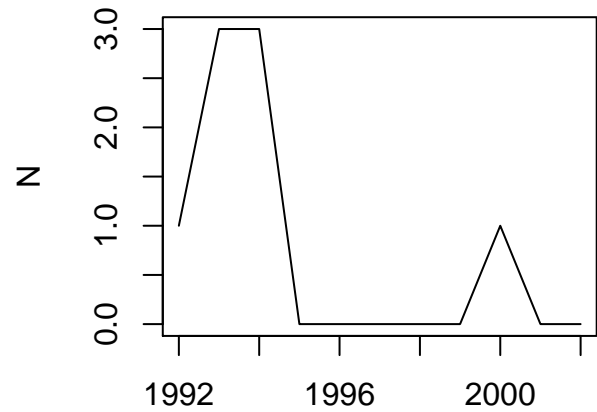
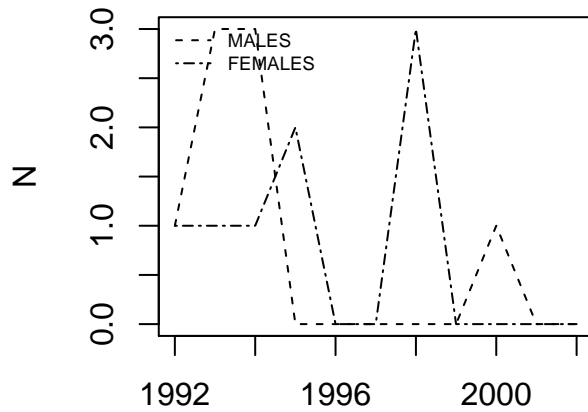
immigration.all (total)



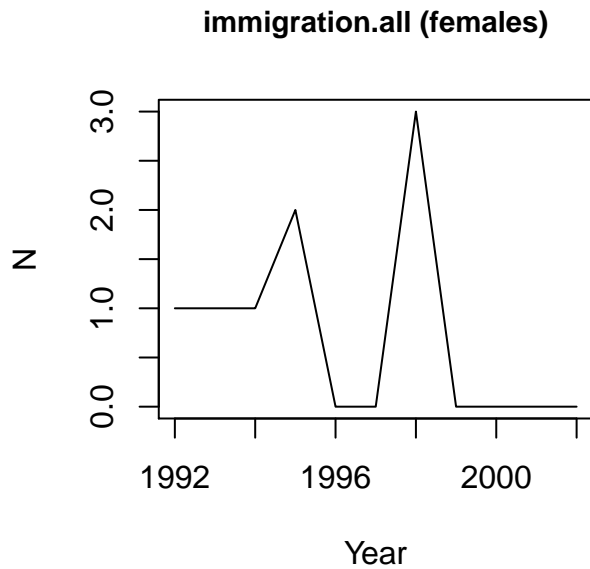
immigration.all



immigration.all (males)



Year



```
## [1] TRUE
```

Studbook ecology

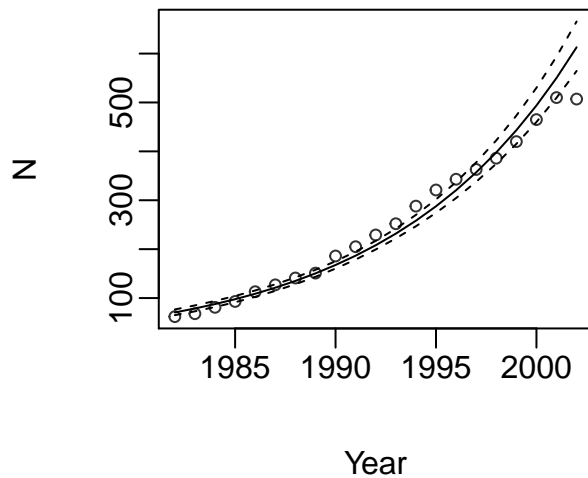
An exponential or logistic growth model can be fitted to the census data (for total or sexes separately). The time period to be included in the model can be (optionally) set. In addition, the logistic model supports a population projection after the last census date.

```
studbook.ecology(sex='all',model='exponential',first=1982,last=2002) # Time period 1980-2000
```

```
## =====
## Exponential growth curve
## =====
##
## Call:
## lm(formula = Y ~ X, data = data_set, weights = data_W)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.18971 -0.06007  0.01647  0.08372  0.10962
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.099e+02  6.710e+00 -31.29  <2e-16 ***
## X              1.081e-01  3.368e-03  32.08  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09346 on 19 degrees of freedom
## Multiple R-squared:  0.9819, Adjusted R-squared:  0.9809
## F-statistic: 1029 on 1 and 19 DF,  p-value: < 2.2e-16
##
##              2.5 %      97.5 %
## (Intercept) -223.9532839 -195.8667892
```

```
## X          0.1010063    0.1151059
## logLik: 21.02678      AIC: -36.05356 (df: 3 )
```

Log linear regression (all)



```
##
## Shapiro-Wilk normality test
##
## data: residuals(data.fit)
## W = 0.92798, p-value = 0.1254
##
## [p < 0.05: non-normal distribution]
##
## Durbin-Watson test for non-independence
## lag Autocorrelation D-W Statistic p-value
## 1 0.701543 0.2783232 0
## Alternative hypothesis: rho != 0
## [p < 0.05: no correlation between residuals]
##
## Non-constant Variance Score Test
## Variance formula: ~ fitted.values
## Chisquare = 0.04966386 Df = 1 p = 0.8236492
## [p < 0.05: residuals are heteroscedastic]
##
## Bonferonni outlier test
##
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
## rstudent unadjusted p-value Bonferonni p
## 37 -2.538474 0.02059 0.43238
## [p < 0.05: residual point is outlier]
##
## Potentially influential observations of
## lm(formula = Y ~ X, data = data_set, weights = data_W) :
##
## dfb.1_ dfb.X dffit cov.r cook.d hat
## 37 1.01_* -1.01_* -1.18_* 0.73 0.54 0.18
```

```
studbook.ecology(sex='female',model='logistic',first=1982,last=2002,
                 project.years=10) # 10 year projection
```

```
## =====
## Logistic growth curve
## =====
##
## Census data      : 1982 - 2002
## Carrying capacity (K): 414.4272
## Half K reached (-A/r): 1998.583 (SE: 1.151077 )
## r[max]          : 0.1447143 (SE: 0.007379579 )
## N[0]            : 34.47381 (year: 1982 )
## AIC             : 127.0852 (df: 4 )
## r[max] = intrinsic rate of change
##
##
## Pearson's Chi-Square test:
## -----
## X2 = 1.437529 , p = 1 (df= 20 )
## H0: Samples are from the same distribution => not rejected
```

Logistic growth (female)

