ATS Mortality

Analysis of ATS estimates with declining mortality rate

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This Is A Continuance

see ATS_mortality_2.qmd re data transform and set-up for Stan model.

This report advances Model 1 to Model 2. The difference is

$$\frac{dN/dt}{N} = m_0 e^{m_1 t} \tag{1}$$

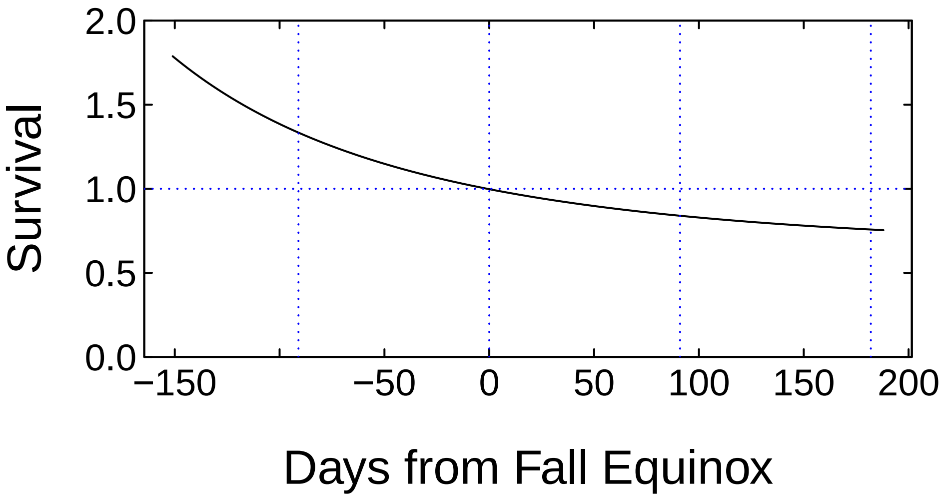
such that the per capita mortality rate for parr and pre-smolts changes exponentially with time. This model predicts abundance at survey date across the lake life of a generation (cohort) of sockeye parr and pre-smolts. The prediction requires integration of Equation 1 and this is performed numerically, resulting in curve that represents the survival from one date to a subsequent date. This allows extrapolation of abundance estimated at a standard day (day zero, autumn equinox) to observation dates.

The parameter of the mortality model are the same for every parr generation. The integration is implemented by calculating the mortality rate for each day across the range of all observation days, then converting that to survival, then extracting the survival from day zero to each observation date. The final step is applying each years estimate of abundance (at day zero) to predict abundance at the observation days in that year.

Plot: Exponential Decline in Mortality

```
n=340; all_days=-151:188
m_0 = 0.00244 ; m_1 =0.00572
surv = exp(-m_0 * exp(-m_1 * all_days)) ;
for(j in 2:n) surv[j] = surv[j] * surv[j-1];
surv=surv/surv[151]
```

```r
  par(tcl = 0.2, las = 1, cex.axis = 1.2, cex.lab = 1.5,
      pch = 20, mgp = c(2.5, 0.2, 0), mai=c(1.,1.,0.75,0.5) );
plot(surv~all_days, type='l', yaxs="i", ylim=c(0,2),
     xlab='Days from Fall Equinox', ylab="Survival"); axis(3,labels=F);axis(4,labels=F);
abline(h=1, v=c(-91,0,91,182),lty="dotted", col='blue')
```




```r
a2 <- readRDS(file='data/OSO ATS setup for Stan.RData')
a <- range(a2$Day)
n_surv = dim(a2)[1] # rows
ndays= 1+(a[2]-a[1]) # 1+(188-(-151)) = 340
# which day, in the range of all days, is each observation.
# this is used to index the survival to and from day zero
day_index=1+(a2$Day-a[1]) # length 116,
  # range 1 to 340; 97,139,194,
all_days <- c(-151:188)  # length 340
n_obs <- as.vector( by( a2$Abundance, INDICES= a2$Smolt_Year, length)) # count obs in each
# 3 3 3 2 3 4 3 3 5 5 5 7 7 9 6 6 7 7 9 4 6 3 3 3.
```

Data is set up corresponding to data block in ATS_ model_2.stan:

> data {
> int<lower=0> N; // n observations, 116
> int<lower=0> n_years; // n years, 24
> int<lower=0> n_obs[n_years]; // n obs each year

vector [N] day ; // obs days, -151 to 188
vector<lower=0> [N] y ; // abundance, ATS obs
vector<lower=0> [N] prec; // regression weights
// for function surv()
vector [340] all_days ; // sequence -151 to 188
int day_index[N] ; // index obs days in all_days
}

```
# basic data is vector of 116 samples for 24 years 1998-2021.
# data as 3 vectors: day, abundance, precision
# data for a year is parsed by a vector for number surveys each year; max 9.

# see ATS_mortality_2.stan
dat2 <- list(
  N =116,                 # n obs
  n_years  = 24,          # n of smolt years
  n_obs    = n_obs,       # n obs in  each smolt year; 24
  day      = a2$Day,      # day of obs; 116, range: -151 188
  y        = a2$Abundance,
  prec     = a2$Weight,   # regression weight
  all_days =all_days,     # -151:188, 340
  day_index = day_index   # obs day in all_days; 116
)
```

Sampling

see ATS_mortality_1.qmd

```
fit2 <- stan(
    file = "ATS_mortality_2.stan", # model in Stan code
    data = dat2,             # data as described in model
    verbose = FALSE,          # debugging
    chains = 4,              # number of Markov chains
    control=list(max_treedepth=20),
    cores = 4,               # number of cores (one per chain)
    warmup = 1000,           # number of warmup iterations per chain
    iter = 5000              # total samples per chain
)
```

`recompiling to avoid crashing R session`

```
Trying to compile a simple C file
```

```
Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
clang -mmacosx-version-min=10.13 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEI
In file included from <built-in>:1:
In file included from /Library/Frameworks/R.framework/Versions/4.2/Resources/library/StanHead
In file included from /Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEige
In file included from /Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEige
/Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEigen/include/Eigen/src/Co
namespace Eigen {
^
/Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEigen/include/Eigen/src/Co
namespace Eigen {
               ^
               ;
In file included from <built-in>:1:
In file included from /Library/Frameworks/R.framework/Versions/4.2/Resources/library/StanHead
In file included from /Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEige
/Library/Frameworks/R.framework/Versions/4.2/Resources/library/RcppEigen/include/Eigen/Core:9
#include <complex>
         ^~~~~~~~~
3 errors generated.
make: *** [foo.o] Error 1
```

```r
print(summary(fit2)$summary[ ,-2], digits=3) # drop se_mean
```

```
             mean       sd     2.5%      25%      50%      75%    97.5%
m0       2.44e+00 2.37e-02 2.39e+00 2.42e+00 2.44e+00 2.46e+00 2.49e+00
m1       5.72e+00 1.86e-01 5.36e+00 5.60e+00 5.72e+00 5.85e+00 6.09e+00
N_0[1]   1.18e+00 4.40e-02 1.09e+00 1.15e+00 1.18e+00 1.21e+00 1.27e+00
N_0[2]   2.30e+00 3.66e-02 2.22e+00 2.27e+00 2.30e+00 2.32e+00 2.37e+00
N_0[3]   2.24e-01 3.78e-02 1.49e-01 1.98e-01 2.24e-01 2.50e-01 2.97e-01
N_0[4]   1.31e+00 4.87e-02 1.21e+00 1.27e+00 1.31e+00 1.34e+00 1.40e+00
N_0[5]   2.83e+00 3.93e-02 2.76e+00 2.81e+00 2.83e+00 2.86e+00 2.91e+00
N_0[6]   1.91e+00 3.36e-02 1.85e+00 1.89e+00 1.91e+00 1.94e+00 1.98e+00
N_0[7]   1.10e+00 4.02e-02 1.02e+00 1.07e+00 1.10e+00 1.13e+00 1.18e+00
N_0[8]   8.61e-01 4.63e-02 7.71e-01 8.30e-01 8.61e-01 8.93e-01 9.53e-01
N_0[9]   3.06e+00 3.31e-02 3.00e+00 3.04e+00 3.06e+00 3.08e+00 3.13e+00
N_0[10]  1.94e+00 3.44e-02 1.87e+00 1.91e+00 1.94e+00 1.96e+00 2.00e+00
N_0[11]  2.40e+00 3.53e-02 2.33e+00 2.37e+00 2.40e+00 2.42e+00 2.46e+00
N_0[12]  9.63e-01 2.65e-02 9.11e-01 9.45e-01 9.63e-01 9.80e-01 1.01e+00
```

```
N_0[13]  7.42e+00 3.22e-02  7.35e+00  7.39e+00  7.42e+00  7.44e+00  7.48e+00
N_0[14]  1.24e+00 2.22e-02  1.19e+00  1.22e+00  1.24e+00  1.25e+00  1.28e+00
N_0[15]  4.94e+00 3.17e-02  4.88e+00  4.92e+00  4.94e+00  4.96e+00  5.00e+00
N_0[16]  3.59e+00 3.06e-02  3.52e+00  3.56e+00  3.59e+00  3.61e+00  3.64e+00
N_0[17]  5.75e+00 2.87e-02  5.69e+00  5.73e+00  5.75e+00  5.77e+00  5.80e+00
N_0[18]  2.81e+00 2.69e-02  2.75e+00  2.79e+00  2.81e+00  2.83e+00  2.86e+00
N_0[19]  9.35e+00 2.70e-02  9.29e+00  9.33e+00  9.35e+00  9.36e+00  9.40e+00
N_0[20]  2.46e+00 3.83e-02  2.39e+00  2.44e+00  2.46e+00  2.49e+00  2.54e+00
N_0[21]  5.26e+00 3.14e-02  5.19e+00  5.23e+00  5.26e+00  5.28e+00  5.32e+00
N_0[22]  1.60e+00 4.19e-02  1.51e+00  1.57e+00  1.60e+00  1.62e+00  1.68e+00
N_0[23]  2.90e+00 5.48e-02  2.80e+00  2.87e+00  2.90e+00  2.94e+00  3.01e+00
N_0[24]  1.71e+00 5.33e-02  1.61e+00  1.68e+00  1.71e+00  1.75e+00  1.82e+00
sigma    7.52e-01 5.25e-03  7.41e-01  7.48e-01  7.52e-01  7.55e-01  7.62e-01
m_0      2.44e-03 2.37e-05  2.39e-03  2.42e-03  2.44e-03  2.46e-03  2.49e-03
m_1      5.72e-03 1.86e-04  5.36e-03  5.60e-03  5.72e-03  5.85e-03  6.09e-03
lp__    -1.19e+04 3.63e+00 -1.19e+04 -1.19e+04 -1.19e+04 -1.19e+04 -1.19e+04
        n_eff Rhat
m0      15324    1
m1      11077    1
N_0[1]  19544    1
N_0[2]  18326    1
N_0[3]  16264    1
N_0[4]  19779    1
N_0[5]  21335    1
N_0[6]  17420    1
N_0[7]  19017    1
N_0[8]  20164    1
N_0[9]  20969    1
N_0[10] 18816    1
N_0[11] 22730    1
N_0[12] 19744    1
N_0[13] 18044    1
N_0[14] 19505    1
N_0[15] 23830    1
N_0[16] 21446    1
N_0[17] 23334    1
N_0[18] 20518    1
N_0[19] 25010    1
N_0[20] 19854    1
N_0[21] 24428    1
N_0[22] 19134    1
N_0[23] 19564    1
N_0[24] 19065    1
```

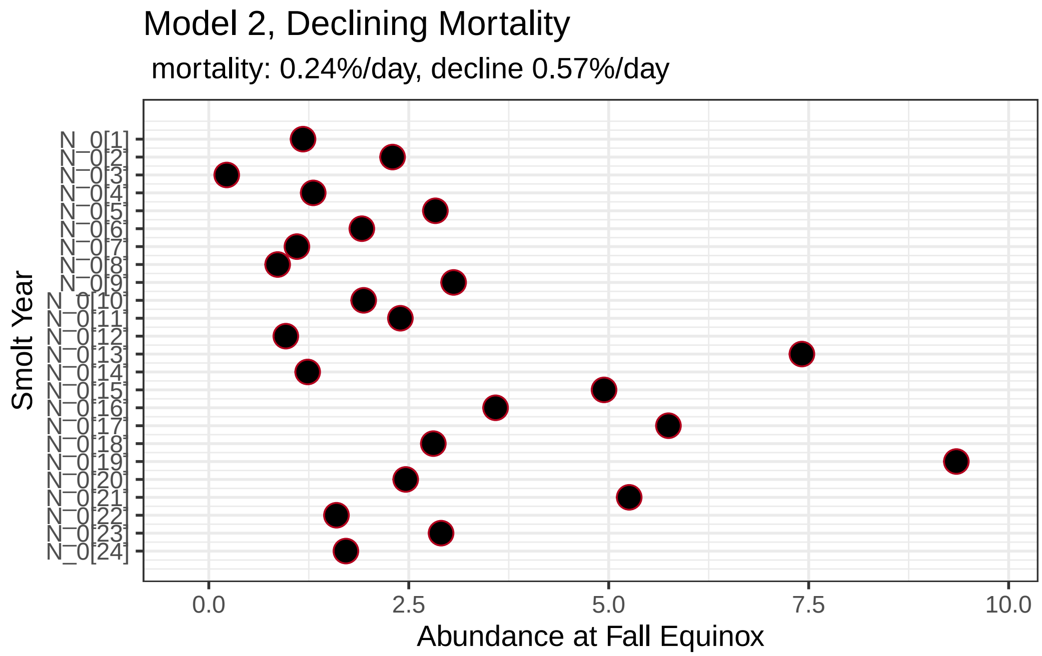
```
sigma   24382    1
m_0     15324    1
m_1     11077    1
lp__     7683    1
```

Plot Fitted Parameters

```
plot(fit2,pars=c("m_0","m_1","m0","m1","sigma","lp__"), include=FALSE, ci_level=0.5)+theme
  labs(y='Smolt Year', x='Abundance at Fall Equinox',title = 'Model 2, Declining Mortality
```

```
ci_level: 0.5 (50% intervals)
```

```
outer_level: 0.95 (95% intervals)
```




```
#pairs(fit2, pars = c("m_0", "sigma", "lp__"), las = 1)
```