Comparing von Bertalanffy Growth Functions

Preliminaries

```
> library(FSAdata)      # for Croaker2 data
> library(FSA)          # for vbStarts(), residPlot(), extraSS(), lrt(), vbFuns(), filterD(), col2rbgt()
> library(dplyr)        # for mutate()
```

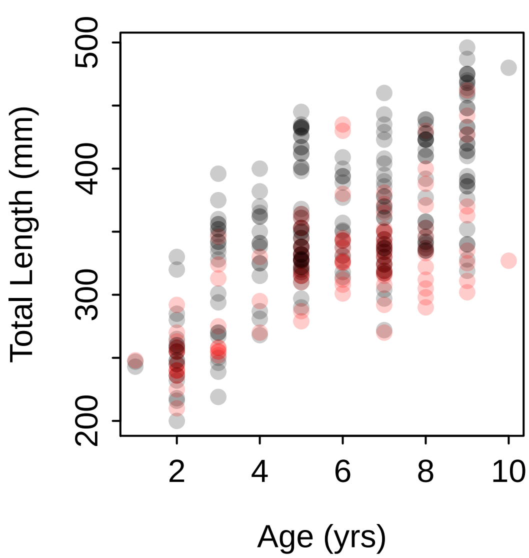
Loading the Data and Some Preparations

```
> data(Croaker2)
> str(Croaker2)
'data.frame':   318 obs. of  3 variables:
 $ age: int  1 1 1 2 2 2 2 2 2 2 ...
 $ tl : int  243 247 248 330 320 285 280 265 260 248 ...
 $ sex: Factor w/ 2 levels "F","M": 1 1 2 1 1 1 1 1 1 1 ...
```

```
> Croaker2 <- mutate(Croaker2,logTL=log(tl))
```

Exploratory Plot

```
> clr1 <- c("black","red")
> clr2 <- col2rgbt(clr1,1/5)
> xlbl <- "Age (yrs)"
> ylbl <- "Total Length (mm)"
> plot(tl~age,data=Croaker2,pch=19,col=clr2[sex],xlab=xlbl,ylab=ylbl)
```

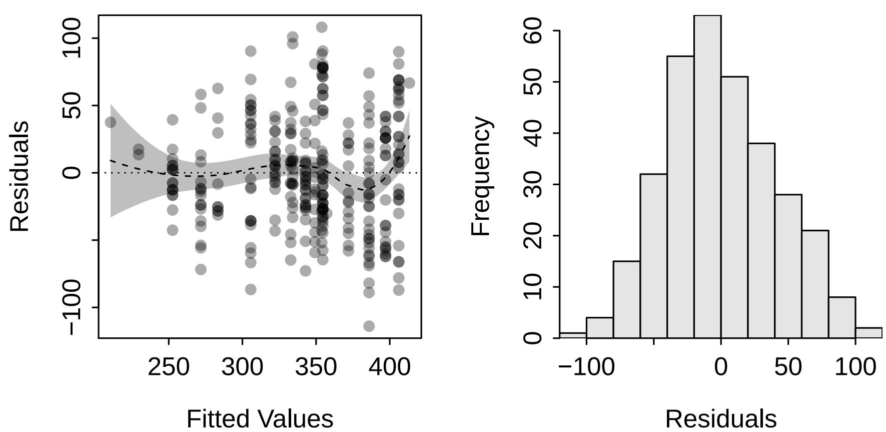


Fitting Most Complex Model and Checking Assumptions

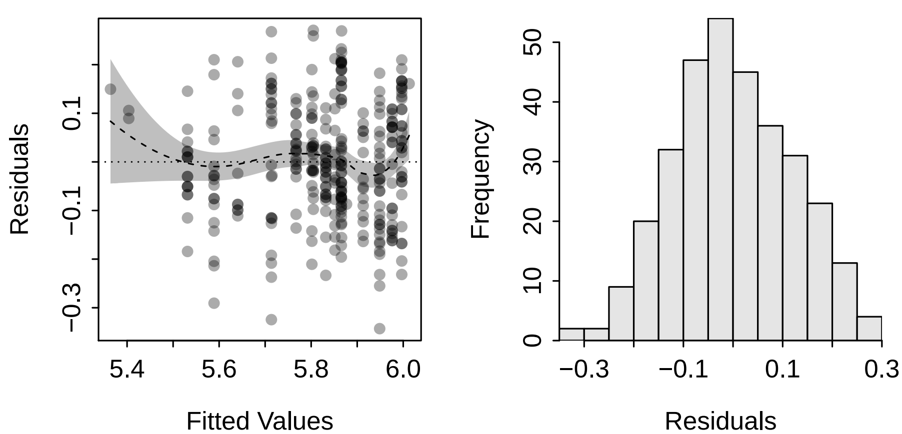
```
> ( svOm <- vbStarts(tl~age,data=Croaker2) )
$Linf
[1] 434.697

$K
[1] 0.1837369

$t0
[1] -3.541856
```

```
> ( svLKt <- Map(rep,svOm,c(2,2,2)) )
$Linf
[1] 434.697 434.697

$K
[1] 0.1837369 0.1837369

$t0
[1] -3.541856 -3.541856
```

```
> vbLKt <- tl~Linf[sex]*(1-exp(-K[sex]*(age-t0[sex])))
> fitLKt <- nls(vbLKt,data=Croaker2,start=svLKt)
> residPlot(fitLKt,col=col2rgbt("black",1/3))
```




```
> vbLKt <- logTL~log(Linf[sex]*(1-exp(-K[sex]*(age-t0[sex]))))
> fitLKt <- nls(vbLKt,data=Croaker2,start=svLKt)
> residPlot(fitLKt,col=col2rgbt("black",1/3))
```



Are There Any Differences?

```
> vbOm <- logTL~log(Linf*(1-exp(-K*(age-t0))))
> fitOm <- nls(vbOm,data=Croaker2,start=svOm)
```

```
> extraSS(fitOm,com=fitLKt,sim.name="{Omega}",com.name="{Linf,K,t0}")
Model 1: {Omega}
Model A: {Linf,K,t0}

    DfO    RSSO DfA    RSSA Df      SS      F    Pr(>F)
1vA 315 5.23971 312 4.44264  3 0.79707 18.659 3.705e-11
```

```
> lrt(fitOm,com=fitLKt,sim.name="{Omega}",com.name="{Linf,K,t0}")
Model 1: {Omega}
Model A: {Linf,K,t0}

    DfO logLikO DfA logLikA Df  logLik  Chisq Pr(>Chisq)
1vA 315 201.597 312 227.835  3 -26.238 52.476  2.372e-11
```

Is the Most Complex Model Warranted?

```
> vbLK <- logTL~log(Linf[sex]*(1-exp(-K[sex]*(age-t0))))
> ( svLK <- Map(rep,svOm,c(2,2,1)) )
$Linf
[1] 434.697 434.697

$K
[1] 0.1837369 0.1837369

$t0
[1] -3.541856
```

```
> fitLK <- nls(vbLK,data=Croaker2,start=svLK)
> vbLt <- logTL~log(Linf[sex]*(1-exp(-K*(age-t0[sex]))))
> svLt <- Map(rep,svOm,c(2,1,2))
> fitLt <- nls(vbLt,data=Croaker2,start=svLt)
> vbKt <- logTL~log(Linf*(1-exp(-K[sex]*(age-t0[sex]))))
> svKt <- Map(rep,svOm,c(1,2,2))
> fitKt <- nls(vbKt,data=Croaker2,start=svKt)
> extraSS(fitLK,fitLt,fitKt,com=fitLKt,com.name="{Linf,K,t0}",
          sim.names=c("{Linf,K}","{Linf,t0}","{K,t0}"))
Model 1: {Linf,K}
Model 2: {Linf,t0}
Model 3: {K,t0}
Model A: {Linf,K,t0}

    DfO     RSSO DfA     RSSA Df       SS      F Pr(>F)
1vA 313 4.442641 312 4.442639  1 0.000002 0.0001 0.9916
2vA 313 4.444957 312 4.442639  1 0.002318 0.1628 0.6869
3vA 313 4.476736 312 4.442639  1 0.034097 2.3946 0.1228
```

Can the Model be Reduced to Only One Parameter that Differs?

```
> vbL <- logTL~log(Linf[sex]*(1-exp(-K*(age-t0))))
> ( svL <- Map(rep,svOm,c(2,1,1)) )
$Linf
[1] 434.697 434.697

$K
[1] 0.1837369

$t0
[1] -3.541856
```

```
> fitL <- nls(vbL,data=Croaker2,start=svL)
> vbK <- logTL~log(Linf*(1-exp(-K[sex]*(age-t0))))
> svK <- Map(rep,svOm,c(1,2,1))
> fitK <- nls(vbK,data=Croaker2,start=svK)
> extraSS(fitL,fitK,com=fitLK,com.name="{Linf,K}",sim.names=c("{Linf}","{K}"))
Model 1: {Linf}
Model 2: {K}
Model A: {Linf,K}

    DfO     RSSO DfA     RSSA Df       SS       F   Pr(>F)
1vA 314 4.484252 313 4.442641  1 0.041612  2.9317 0.087847
2vA 314 4.621667 313 4.442641  1 0.179027 12.6131 0.000442
```

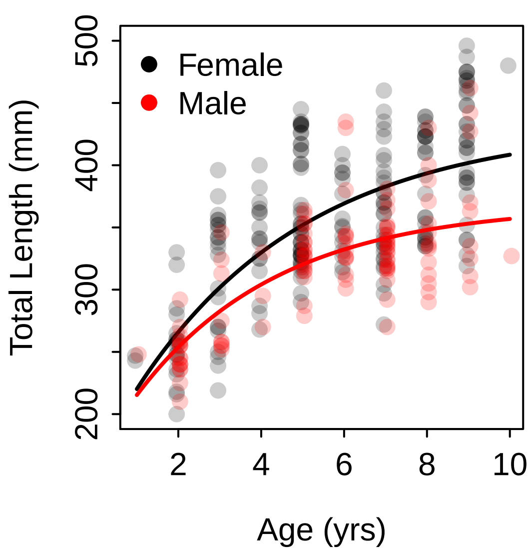
Summarize Final Model

```
> summary(fitL,correlation=TRUE)

Formula: logTL ~ log(Linf[sex] * (1 - exp(-K * (age - t0))))

Parameters:
       Estimate Std. Error t value Pr(>|t|)
Linf1 425.37158   17.13519  24.824  < 2e-16
Linf2 384.21649   15.65097  24.549  < 2e-16
K       0.24825    0.05315   4.671 4.45e-06
t0     -2.12303    0.66226  -3.206  0.00149

Residual standard error: 0.1195 on 314 degrees of freedom

Correlation of Parameter Estimates:
      Linf1 Linf2 K
Linf2  0.94
K     -0.95 -0.93
t0    -0.87 -0.85  0.97

Number of iterations to convergence: 4
Achieved convergence tolerance: 1.809e-06
```

```
> round(cbind(coef(fitL),confint(fitL)),3)
Waiting for profiling to be done...
                2.5%   97.5%
Linf1 425.372 400.090 481.671
Linf2 384.216 360.721 435.082
K       0.248   0.144   0.357
t0     -2.123  -3.986  -1.108
```

```
> vb <- vbFuns("typical")
> # Females
> crF <- filterD(Croaker2,sex=="F")
> svF <- list(Linf=425,K=0.25,t0=-2)
> fitF <- nls(logTL~log(vb(age,Linf,K,t0)),data=crF,start=svF)
> # Males
> crM <- filterD(Croaker2,sex=="M")
> svM <- list(Linf=385,K=0.25,t0=-2)
> fitM <- nls(logTL~log(vb(age,Linf,K,t0)),data=crM,start=svM)
```

```
> offset <- 0.04
> # Females
> plot(tl~I(age-offset),data=crF,pch=19,col=clr2[1],ylim=c(200,500),xlab=xlbl,ylab=ylbl)
> curve(vb(x-offset,coef(fitF)),from=1,to=10,col=clr1[1],lwd=2,add=TRUE)
> # Males
> points(tl~I(age+offset),data=crM,pch=19,col=clr2[2])
> curve(vb(x+offset,coef(fitM)),from=1,to=10,col=clr1[2],lwd=2,add=TRUE)
> legend("topleft",c("Female","Male"),pch=19,col=clr1,bty="n")
```



Using Information Criterion

Fit the Only Other Model not Fit Above

```
> vbt <- logTL~log(Linf*(1-exp(-K*(age-t0[sex]))))
> svt <- Map(rep,svOm,c(1,1,2))
> fitt <- nls(vbt,data=Croaker2,start=svt)
```

AICc Table

```
> library(AICcmodavg)
> ms <- list(fitOm,fitL,fitK,fitt,fitLK,fitLt,fitKt,fitLKt)
> mnames <- c("{Omega}","{Linf}","{K}","{t0}","{Linf,K}","{Linf,t0}","{K,t0}","{Linf,K,t0}")
> aictab(ms,mnames)

Model selection based on AICc:

            K    AICc Delta_AICc AICcWt Cum.Wt     LL
{Linf,K}    6 -443.40       0.00   0.31   0.31 227.84
{Linf,t0}   6 -443.23       0.17   0.29   0.60 227.75
{Linf}      5 -442.51       0.89   0.20   0.80 226.35
{Linf,K,t0} 7 -441.31       2.09   0.11   0.91 227.84
{K,t0}      6 -440.97       2.43   0.09   1.00 226.62
{K}         5 -432.91      10.49   0.00   1.00 221.55
{t0}        5 -422.44      20.96   0.00   1.00 216.31
{Omega}     4 -395.07      48.33   0.00   1.00 201.60
```