

# von Bertalanffy Growth Function

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## Preliminaries

### Load Necessary Packages

```
> library(FSA)           # for filterD(), headtail(), col2rgbt(), vbFuns(), vbStart()
> library(dplyr)         # for mutate(), select()
> library(nlstools)      # for nlsBoot()
> library(AICcmodavg)    # for aictab()
```

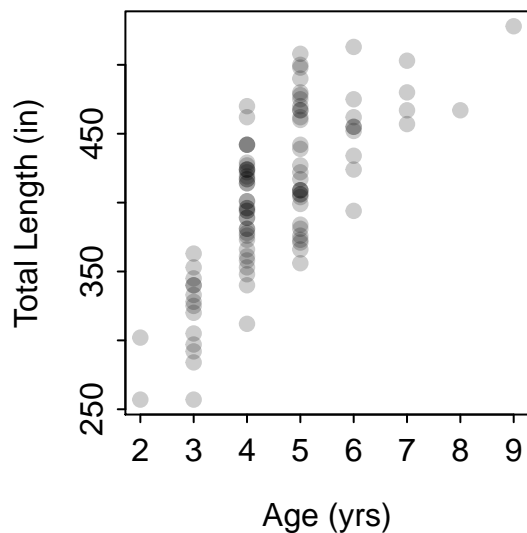
### Load Data and Make Some Preparations

```
> # Set your working directory to where your external data files (and scripts) are located.
> setwd("C:/aaaWork/Web/GitHub/RcourseNunavut2016/Handouts")
> dSC <- read.csv("SawyerCo_reduced.csv")
> wae <- filterD(dSC,waterbody=="NELSON LAKE",species=="Walleye",!is.na(len),!is.na(age))
```

```
> xlbl <- "Age (yrs)"
> ylbl <- "Total Length (in)"
> clr1 <- "black"
> clr2 <- col2rgbt(clr1,1/5)
```

### Quick Summaries

```
> plot(len~age,data=wae,pch=19,col=clr2,xlab=xlbl,ylab=ylbl)
```



```
> Summarize(len~age,data=wae,digits=1)
Warning: RHS variable was converted to a factor.
  age  n nvalid  mean   sd min   Q1 median   Q3 max percZero
1   2   2      2 279.5 31.8 257 268.2 279.5 290.8 302      0
2   3  14     14 320.1 29.6 257 299.0 326.5 340.0 363      0
3   4  36     36 399.3 34.9 312 377.5 398.5 424.0 470      0
4   5  31     31 430.7 44.9 356 401.5 422.0 468.5 508      0
5   6   9      9 451.6 33.2 394 434.0 455.0 462.0 513      0
6   7   4      4 476.8 19.9 457 464.5 473.5 485.8 503      0
7   8   1      1 467.0   NA 467 467.0 467.0 467.0 467      0
8   9   1      1 528.0   NA 528 528.0 528.0 528.0 528      0
```

## Fit Typical VBGF

### Declare a Function

```
> vb <- vbFuns("Typical",msg=TRUE)
You have chosen the 'Typical', 'Traditional', or 'BevertonHolt' parameterization.

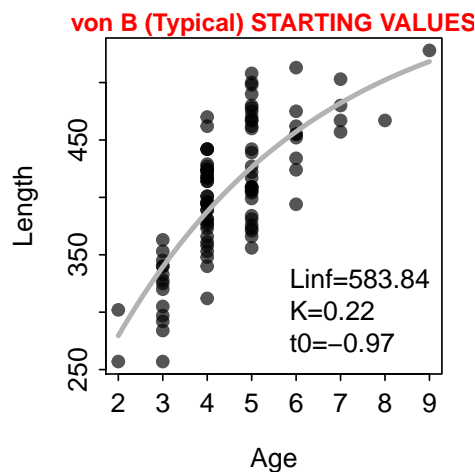
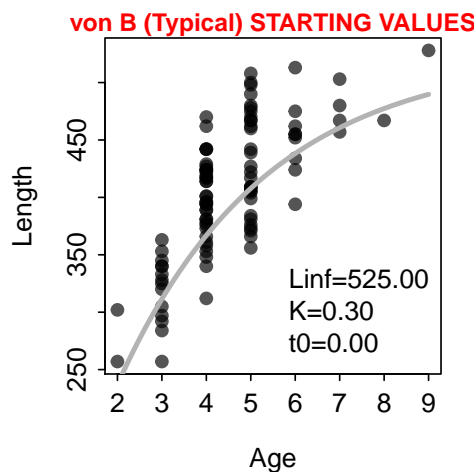
E[L|t] = Linf*(1-exp(-K*(t-t0)))

where Linf = asymptotic mean length
      K = exponential rate of approach to Linf
      t0 = the theoretical age when length = 0 (a modeling artifact)
```

```
> vb
function(t,Linf,K=NULL,t0=NULL) {
  if (length(Linf)==3) { K <- Linf[[2]]
                        t0 <- Linf[[3]]
                        Linf <- Linf[[1]] }
  Linf*(1-exp(-K*(t-t0)))
}
<environment: 0x0b3af0f8>
```

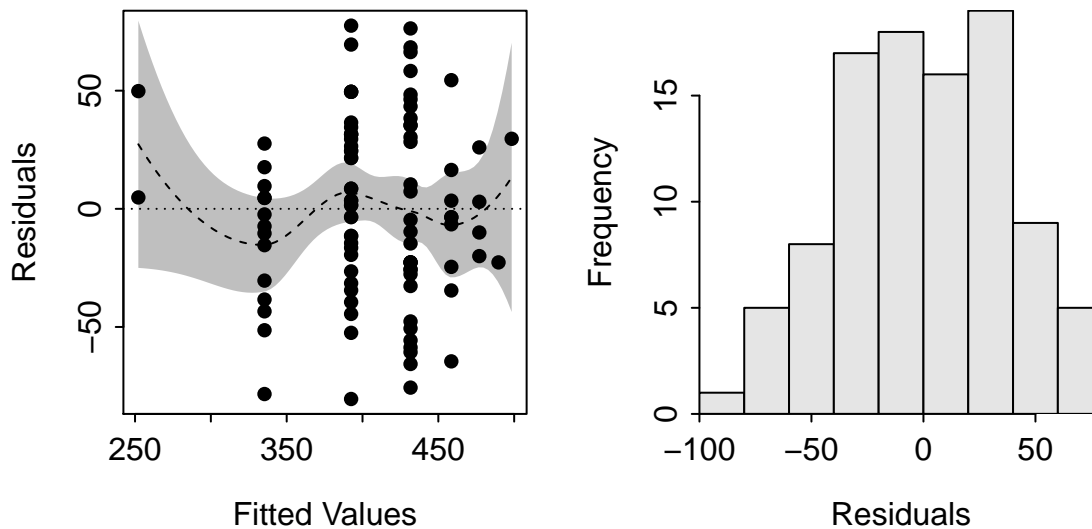
### Find Starting Values

```
> # Demos manual generation with plot ... LEFT plot
> svb <- vbStarts(len~age,data=wae,type="Typical",plot=TRUE,fixed=list(Linf=525,K=0.3,t0=0))
> # Demos automatic generation ... RIGHT plot
> svb <- vbStarts(len~age,data=wae,type="Typical",plot=TRUE)
```



## Fit the Model

```
> fit1 <- nls(len~vb(age,Linf,K,t0),data=wae,start=svb)
> residPlot(fit1)
```



## Summarize the Fit

```
> summary(fit1,correlation=TRUE)
```

Formula:  $\text{len} \sim \text{vb}(\text{age}, \text{Linf}, \text{K}, \text{t0})$

Parameters:

	Estimate	Std. Error	t value	Pr(> t )
Linf	517.3784	31.8747	16.232	< 2e-16
K	0.3765	0.1035	3.639	0.000445
t0	0.2249	0.5244	0.429	0.669063

Residual standard error: 37.56 on 95 degrees of freedom

Correlation of Parameter Estimates:

	Linf	K
K	-0.95	
t0	-0.80	0.94

Number of iterations to convergence: 8

Achieved convergence tolerance: 1.463e-06

```
> ( cf <- coef(fit1) )
      Linf      K      t0
517.3783956 0.3764900 0.2248583
```

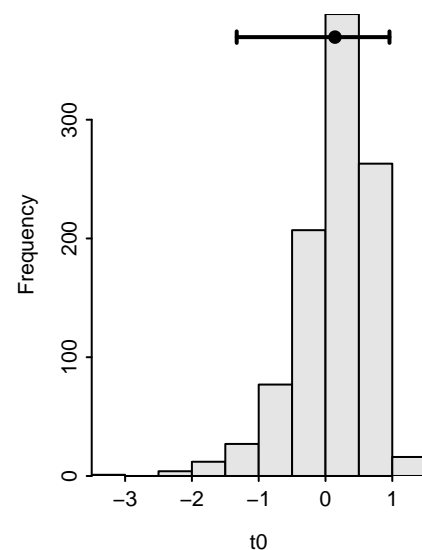
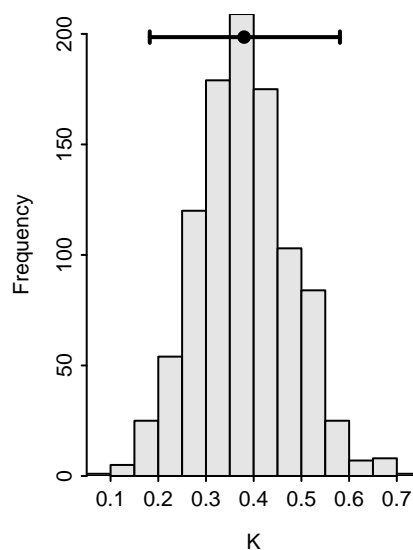
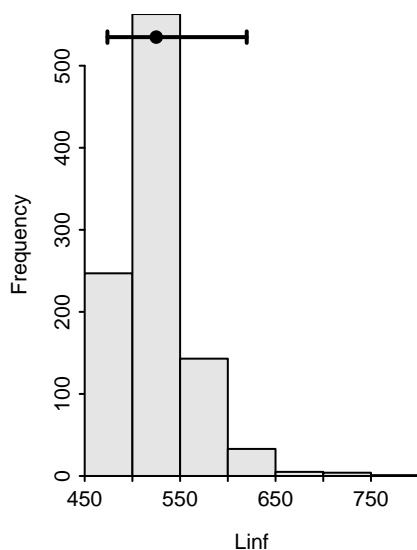
```
> confint(fit1)
Waiting for profiling to be done...
      2.5%      97.5%
Linf 472.3980539 629.8699947
K     0.1831627  0.5889712
t0    -1.3560959  0.9735696
```

```
> boot1 <- nlsBoot(fit1,niter=1000)
Warning in nlsBoot(fit1, niter = 1000): The fit did not converge 4 times during bootstrapping
```

```
> str(boot1)
List of 4
 $ coefboot: num [1:996, 1:3] 584 473 543 532 480 ...
  .. attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:3] "Linf" "K" "t0"
 $ rse      : num [1:996] 36.8 36.5 34.6 40 39.3 ...
 $ bootCI   : num [1:3, 1:3] 518.641 0.377 0.236 473.823 0.182 ...
  .. attr(*, "dimnames")=List of 2
  .. ..$ : chr [1:3] "Linf" "K" "t0"
  .. ..$ : chr [1:3] "Median" "2.5%" "97.5%"
 $ estiboot: num [1:3, 1:2] 524.9511 0.3799 0.142 37.7737 0.0992 ...
  .. attr(*, "dimnames")=List of 2
  .. ..$ : chr [1:3] "Linf" "K" "t0"
  .. ..$ : chr [1:2] "Estimate" "Std. error"
 - attr(*, "class")= chr "nlsBoot"
```

```
> headtail(boot1$coefboot)
      Linf      K      t0
[1,] 583.5195 0.2623084 -0.2765158
[2,] 473.2263 0.5324424 0.6123111
[3,] 543.4278 0.3343795 0.1158536
[994,] 533.8433 0.3469700 0.2342875
[995,] 507.9200 0.4301398 0.4756919
[996,] 480.1709 0.4600134 0.3838285
```

```
> confint(boot1,plot=TRUE,rows=1,cols=3)
      95% LCI      95% UCI
Linf 473.8233134 619.7879874
K     0.1821066 0.5807424
t0    -1.3295883 0.9580000
```



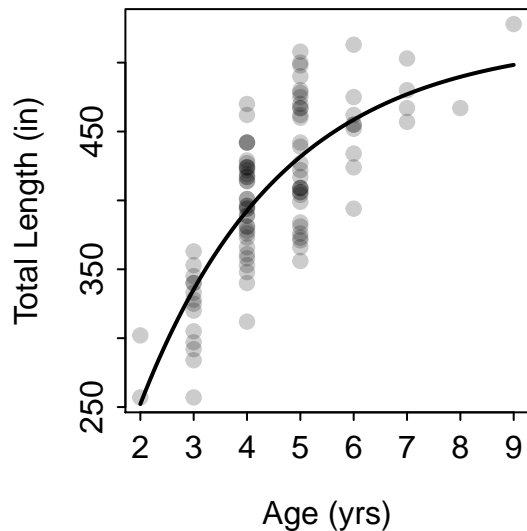
## Make Predictions

```
> ageX <- 5
> predict(fit1,data.frame(age=ageX))
[1] 431.6674

> pv <- apply(boot1$coefboot,MARGIN=1,FUN=vb,t=ageX)
> quantile(pv,c(0.025,0.975))
      2.5%      97.5%
422.7171 440.0841
```

## Visualize the Fit

```
> plot(len~age,data=wae,xlab=xlbl,ylab=ylbl,pch=19,col=clr2)
> curve(vb(x,cf),from=2,to=9,n=500,lwd=2,col=clr1,add=TRUE)
```



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## Fit Gompertz Growth Function

```
> gomp <- GompertzFuns(msg=TRUE)
You have chosen the 'Ricker1' parameterization of the Gompertz function.
```

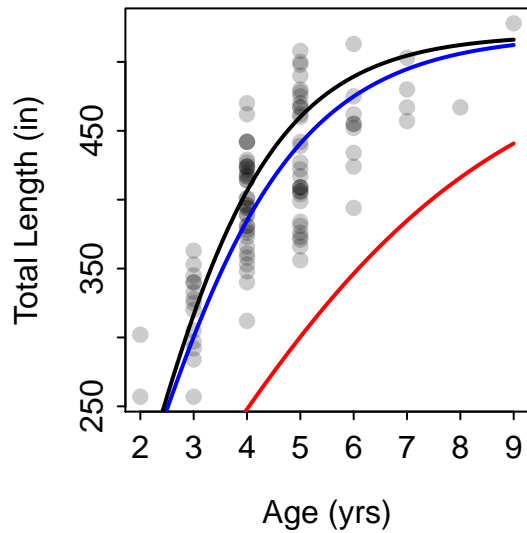
$$E[L|t] = L_{inf} \cdot \exp(-\exp(-g_i \cdot (t - t_i)))$$

where  $L_{inf}$  = asymptotic mean length

$g_i$  = instantaneous growth rate at the inflection point

$t_i$  = time at the inflection point

```
> plot(len~age,data=wae,pch=19,col=clr2,xlab=xlbl,ylab=ylbl)
> curve(gomp(x,Linf=520,gi=0.3,ti=3),from=2,to=9,n=500,lwd=2,add=TRUE,col="red")
> curve(gomp(x,Linf=520,gi=0.6,ti=2),from=2,to=9,n=500,lwd=2,add=TRUE,col="blue")
> curve(gomp(x,Linf=520,gi=0.7,ti=2),from=2,to=9,n=500,lwd=2,add=TRUE,col=clr1)
```



```
> fit2 <- nls(len~gomp(age,Linf,gi,ti),data=wae,start=list(Linf=520,gi=0.7,ti=2))
> aictab(list(fit1,fit2),modnames=c("von Bertalanffy","Gompertz"))
```

Model selection based on AICc:

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Gompertz	4	993.8	0.0	0.55	0.55	-492.68
von Bertalanffy	4	994.2	0.4	0.45	1.00	-492.88

```
> plot(len~age,data=wae,xlab=xlbl,ylab=ybl,pch=19,col=clr2,xlim=c(0,10),ylim=c(0,550))
> curve(vb(x,cf),from=0,to=10,n=500,lwd=4,col=clr1,add=TRUE)
> curve(gomp(x,coef(fit2)),from=0,to=10,n=500,lwd=2,col="red",add=TRUE)
> legend("bottomright",c("von Bertalanffy","Gompertz"),col=c("black","red"),lwd=2,bty="n",cex=0.8)
```

