NONLINEAR MODELING IN R WITH GAMS

Interpreting GAM outputs

Noam Ross
Senior Research Scientist, EcoHealth Alliance

GAM Summaries

```
mod_hwy <- gam(hw.mpg ~ s(weight) + s(
               s(price) + s(comp.ratio
               s(width) + fuel + cylin
               data = mpg, method = "R
```

```
summary(mod_hwy)
```

GAM Summaries (2)

GAM Summaries (3)

```
summary(mod_hwy)
```

```
Family: gaussian
Link function: identity

Formula:
hw.mpg ~ s(weight) + s(rpm) + s(price) +
  s(comp.ratio) + s(width) + fuel
```

GAM Summaries (4)

```
summary(mod_hwy)
```

```
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   23.873      3.531   6.760 1.89e-10 ***
fuelgas        7.571      3.922   1.931   0.0551 .
 ---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0
```

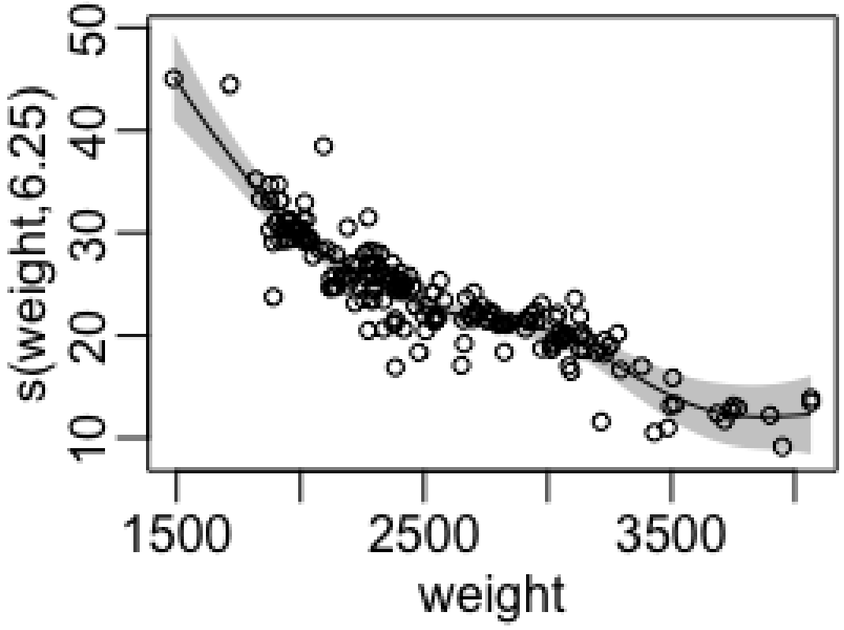
GAM Summaries (5)

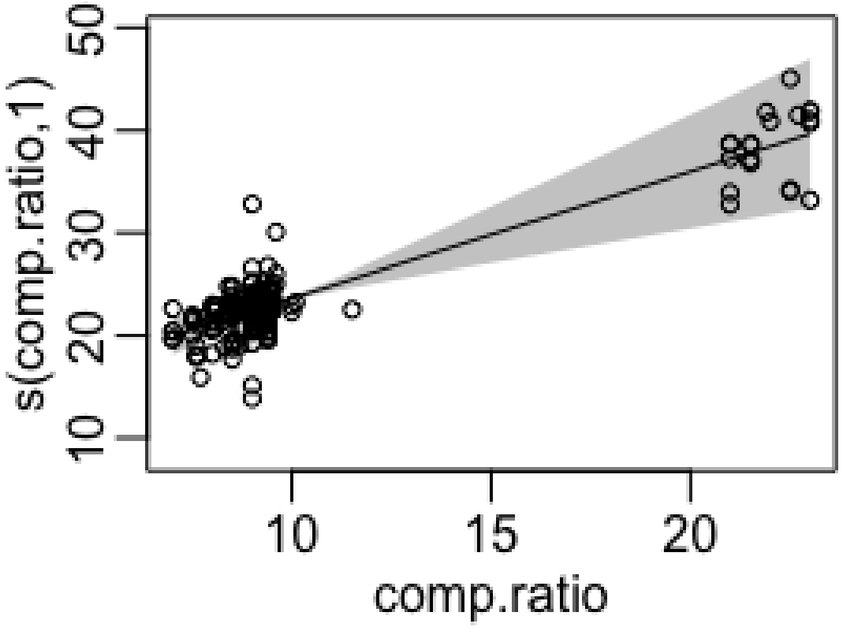
```
summary(mod_hwy)
```

```
Approximate significance of smooth terms:
                edf Ref.df      F  p-value
s(weight)     6.254  7.439 20.909  < 2e-16 ***
s(rpm)        7.499  8.285  8.534 2.07e-09 ***
s(price)      2.681  3.421  1.678    0.155
s(comp.ratio) 1.000  1.001 18.923 2.22e-05 ***
s(width)      1.001  1.001  0.357    0.551
 ---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0
```

Effective Degrees of Freedom

```
Approximate significance of smooth terms:
                edf Ref.df      F  p-value
s(weight)     6.254  7.439 20.909  < 2e-16 ***  <--
s(rpm)        7.499  8.285  8.534 2.07e-09 ***
s(price)      2.681  3.421  1.678    0.155
s(comp.ratio) 1.000  1.001 18.923 2.22e-05 ***  <--
s(width)      1.001  1.001  0.357    0.551
```



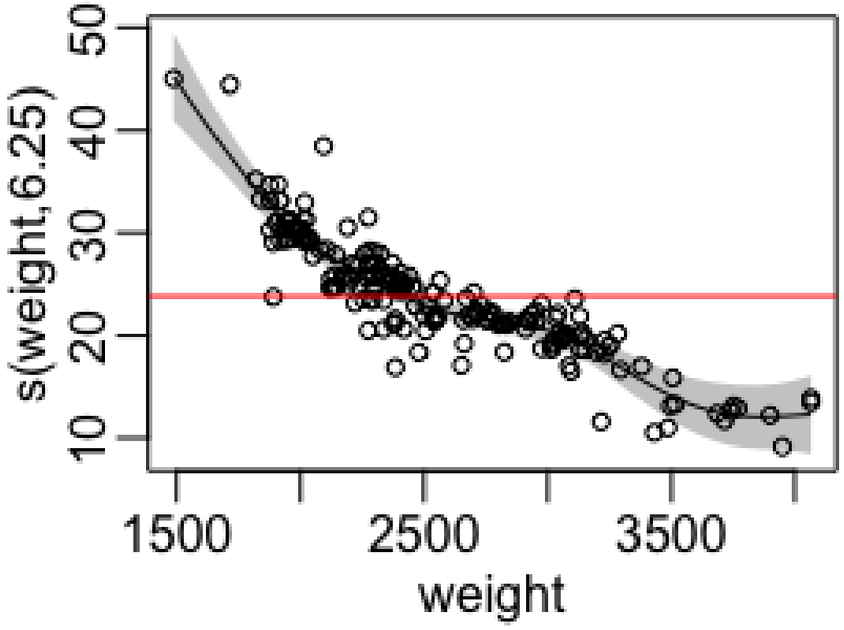


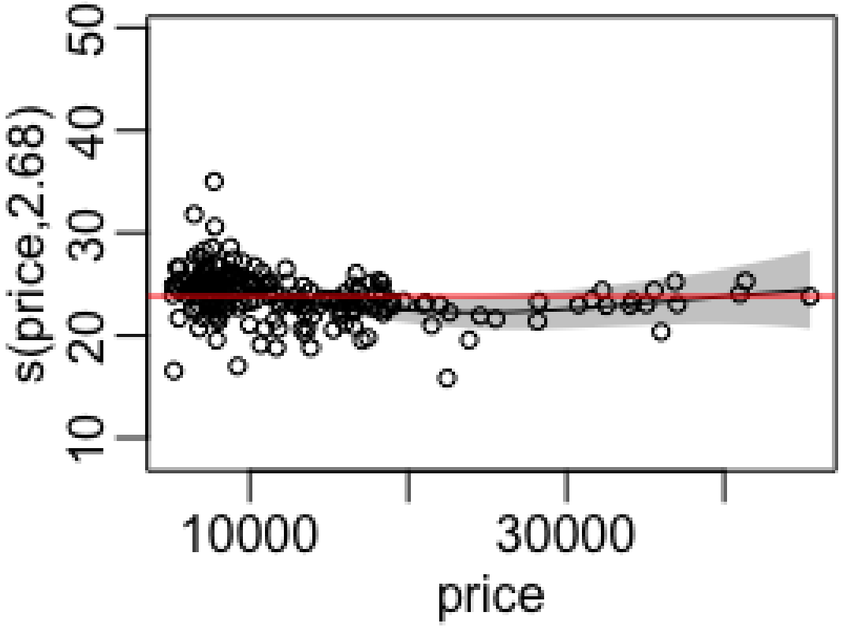
Significance of Smooth Terms

```
Approximate significance of smooth terms:
                edf Ref.df      F  p-value
s(weight)     6.254  7.439 20.909  < 2e-16 ***
s(rpm)        7.499  8.285  8.534 2.07e-09 ***
s(price)      2.681  3.421  1.678    0.155
s(comp.ratio) 1.000  1.001 18.923 2.22e-05 ***
s(width)      1.001  1.001  0.357    0.551
 ---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0
```

Significance of Smooth Terms (2)

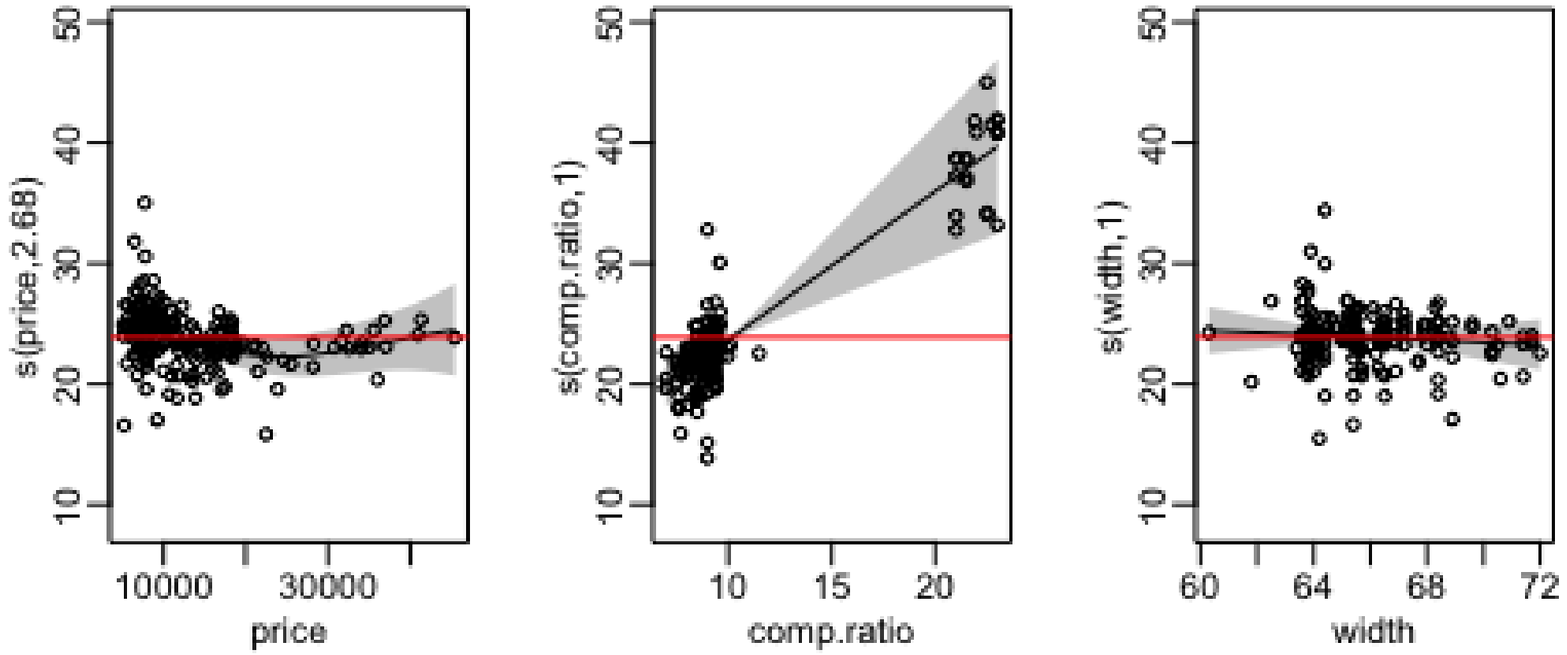
```
Approximate significance of smooth terms:
                edf Ref.df      F  p-value
s(weight)     6.254  7.439 20.909  < 2e-16 ***  <--
s(rpm)        7.499  8.285  8.534 2.07e-09 ***
s(price)      2.681  3.421  1.678    0.155      <--
s(comp.ratio) 1.000  1.001 18.923 2.22e-05 ***
s(width)      1.001  1.001  0.357    0.551
```





Significance and Effective Degress of Freedom

```
Approximate significance of smooth terms:
                edf Ref.df      F  p-value
s(weight)     6.254  7.439 20.909  < 2e-16 ***
s(rpm)        7.499  8.285  8.534 2.07e-09 ***
s(price)      2.681  3.421  1.678    0.155      <--
s(comp.ratio) 1.000  1.001 18.923 2.22e-05 ***  <--
s(width)      1.001  1.001  0.357    0.551      <--
```



NONLINEAR MODELING IN R WITH GAMS

Let's practice!

NONLINEAR MODELING IN R WITH GAMS

Visualizing GAMs

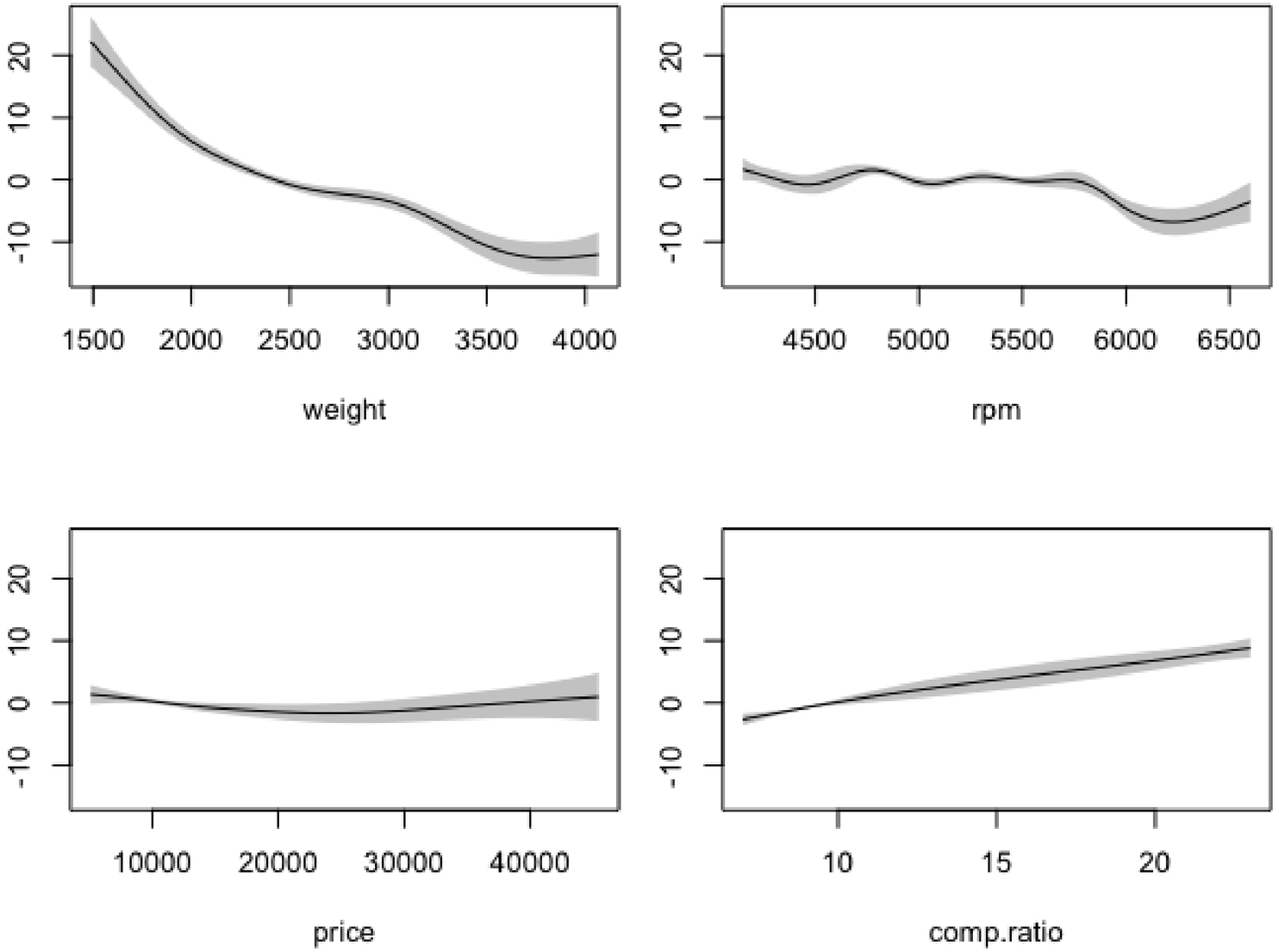
Noam Ross
Senior Research Scientist, EcoHealth Alliance

The Plot Command

```
plot(gam_model)
```

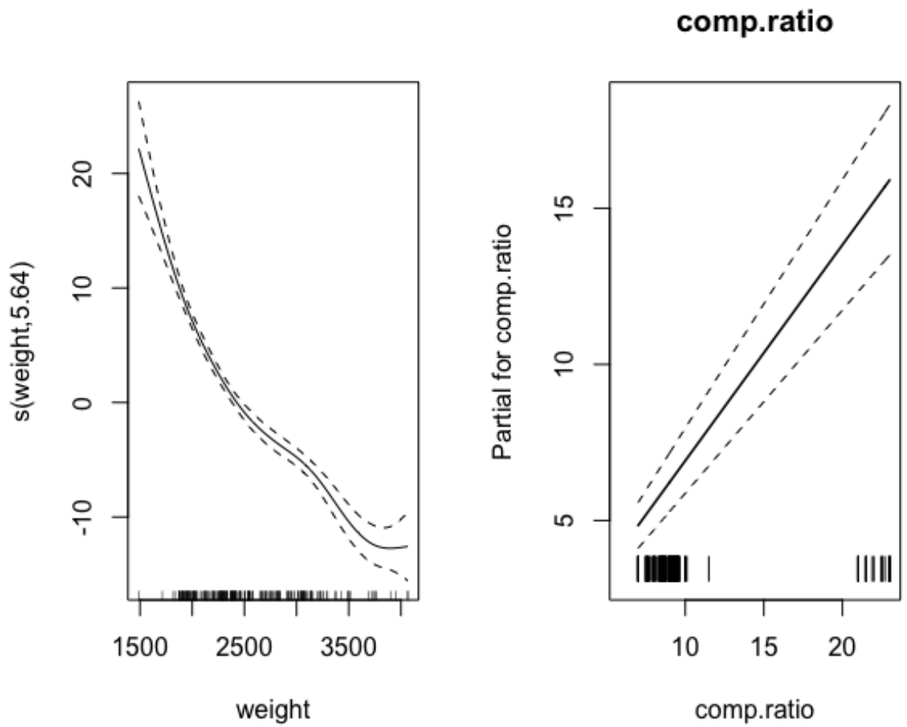
```
?plot.gam
```

Partial Effect Plots



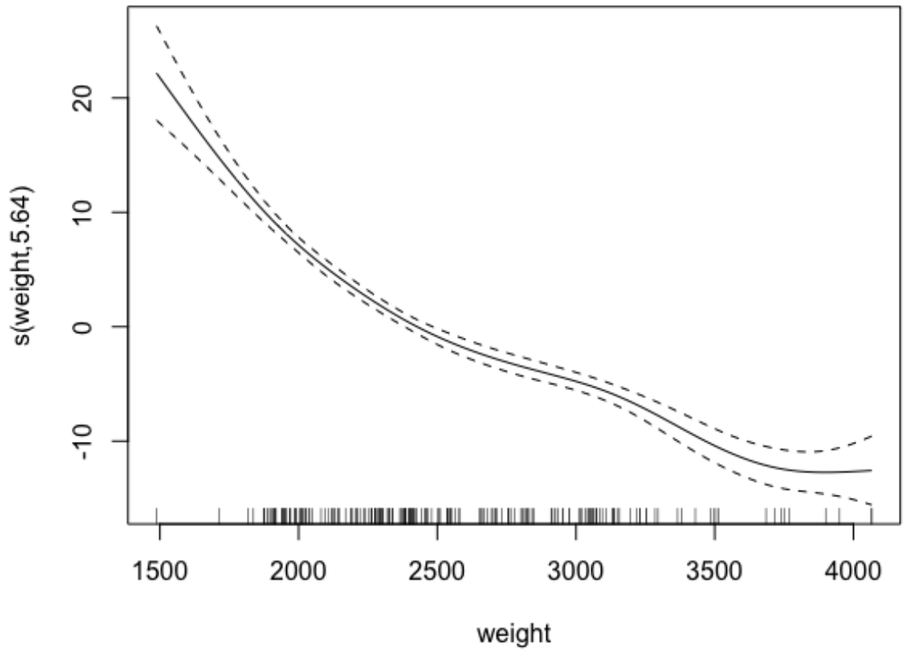
Selecting partial effects

```
plot(gam_model, select = c(2, 3))

plot(gam_model, pages = 1)

plot(gam_model, pages = 1, all.terms = TRUE)
```



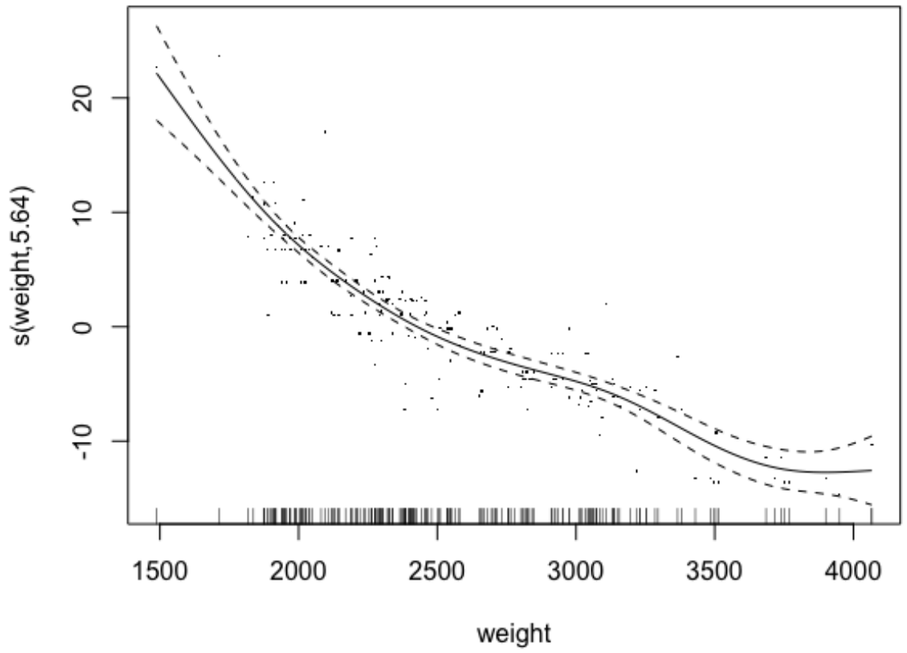
Showing data on the plots

```
plot(gam_model, rug = TRUE)
```



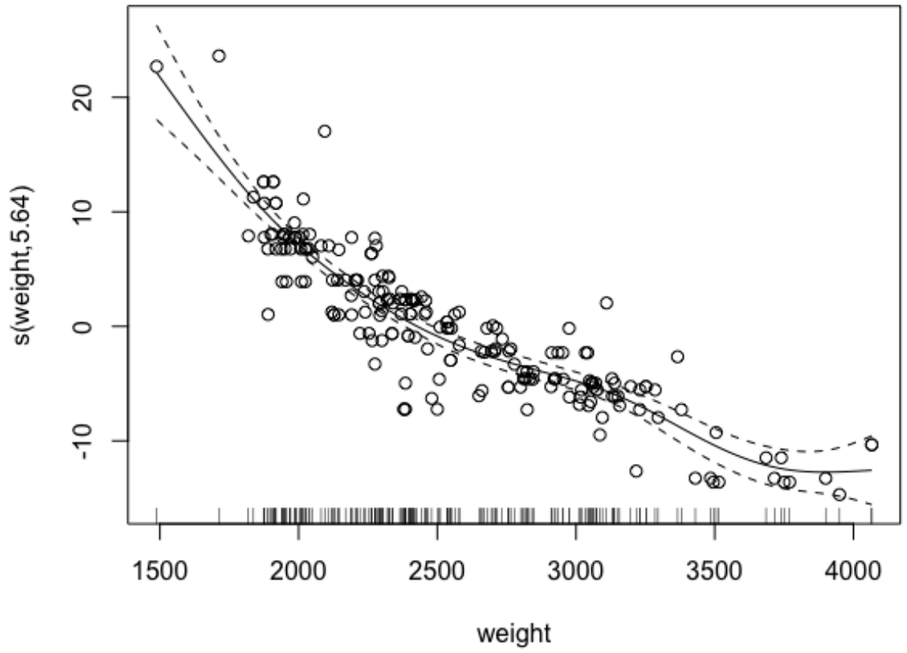
Showing data on the plots (2)

```
plot(gam_model, residuals = TRUE)
```



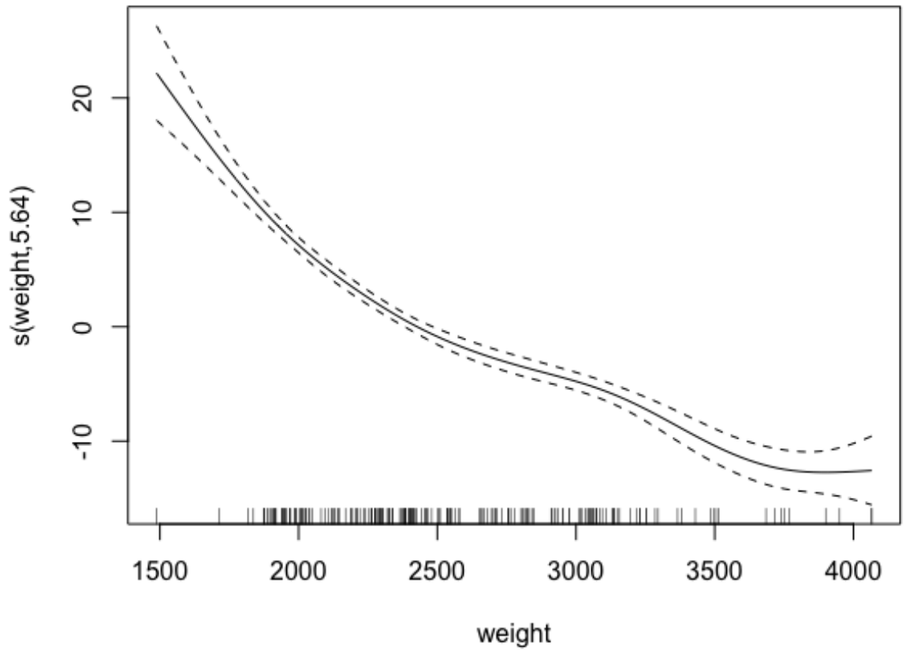
Showing data on the plots (3)

```
plot(gam_model, rug = TRUE, residuals = TRUE,
     pch = 1, cex = 1)
```



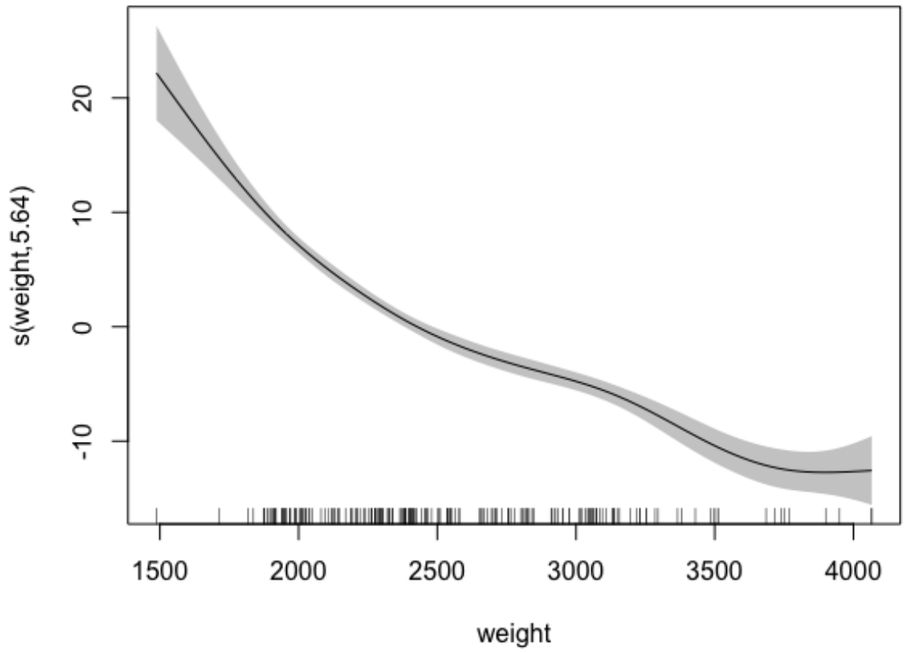
Showing Standard Errors

```
plot(gam_model, se = TRUE)
```



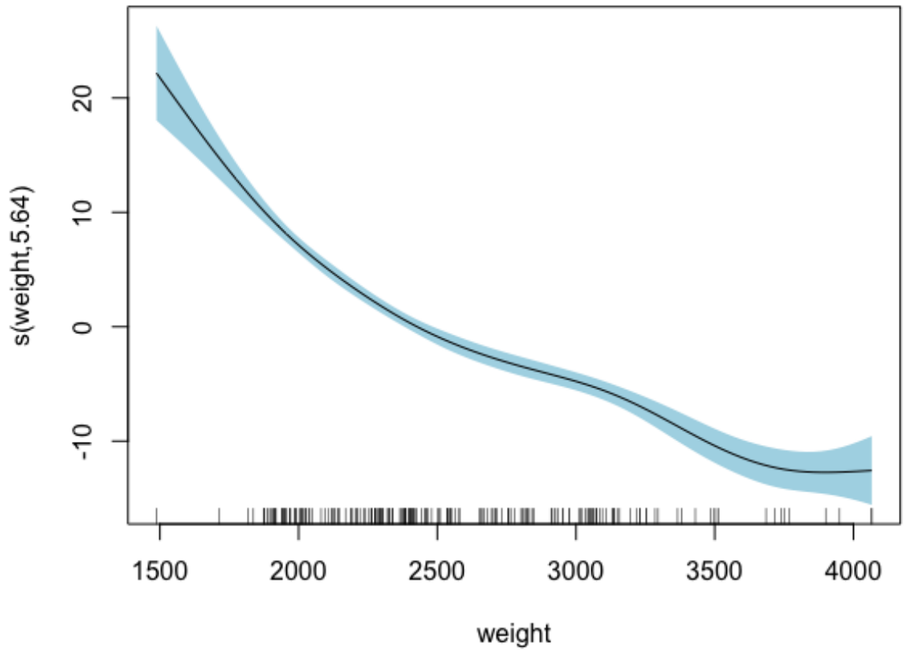
Showing Standard Errors (2)

```
plot(gam_model, shade = TRUE)
```



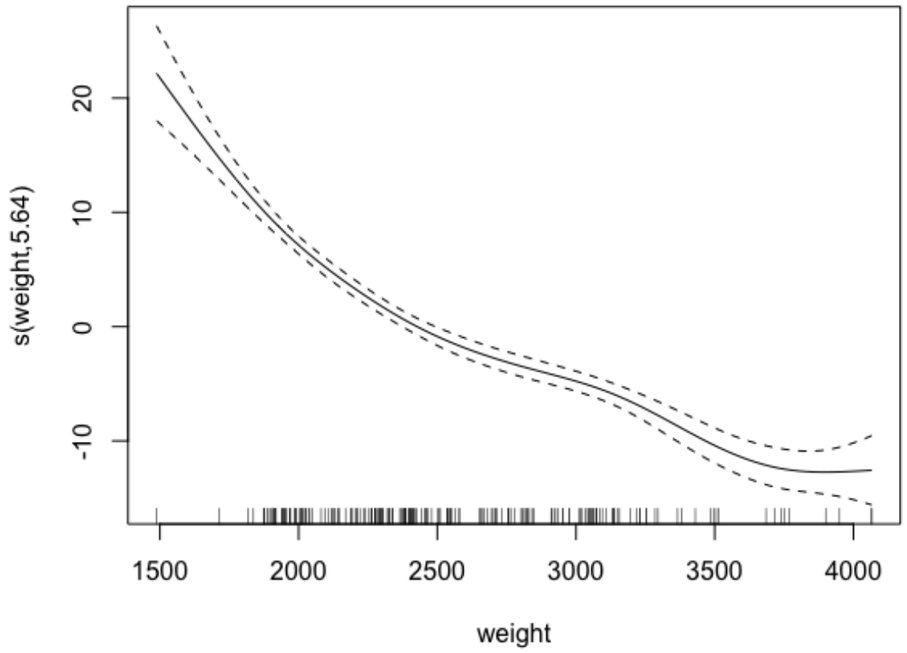
Showing Standard Errors

```
plot(gam_model, shade = TRUE, shade.col = "lightblue")
```



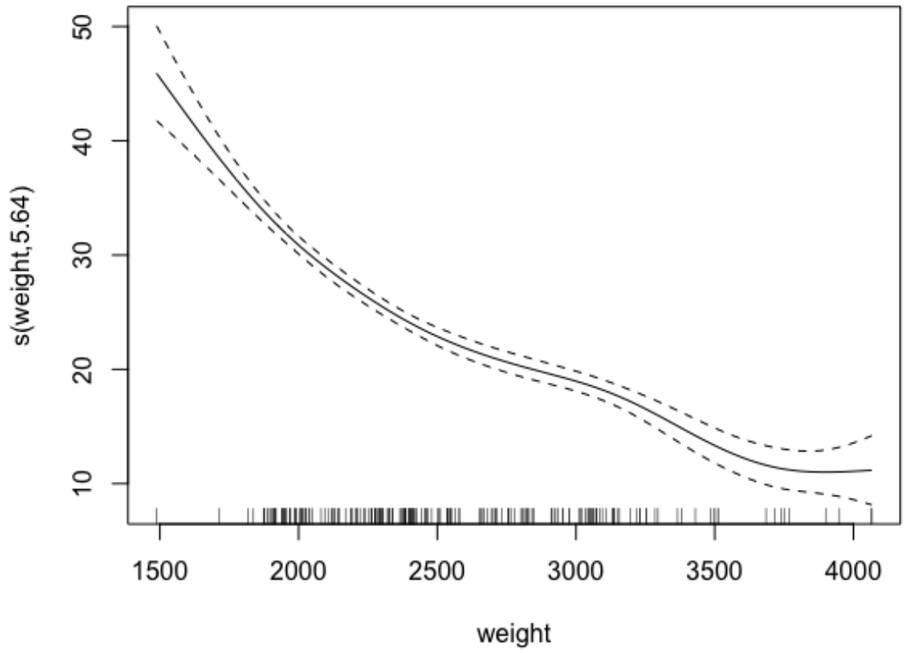
Transforming Standard Errors

```
plot(gam_model, seWithMean = TRUE)
```



Transforming Standard Errors (2)

```
plot(gam_model, seWithMean = TRUE, shift = coef(gam_model)[1])
```



NONLINEAR MODELING IN R WITH GAMS

Now lets make some plots!

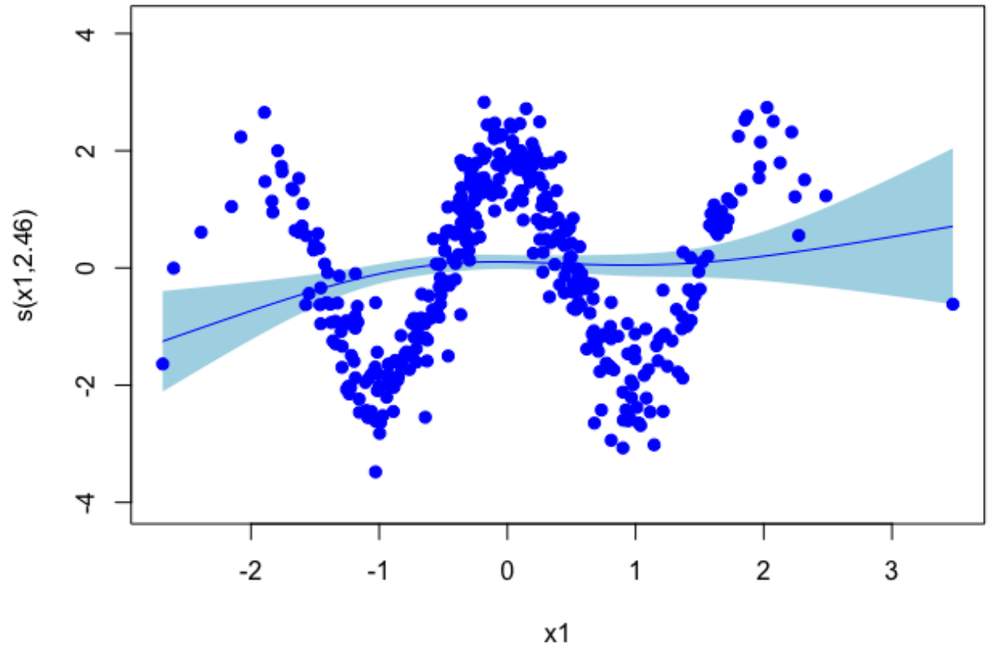
NONLINEAR MODELING IN R WITH GAMS

Model checking with gam.check()

Noam Ross
Senior Research Scientist, EcoHealth Alliance

Pitfall One: Inadequate Basis Number

```
mod <- gam(y ~ s(x1, k = 4) + s(x2, k = 4),
           data = check_data, method = "REML")
```



Running gam.check

```
gam.check(mod)
```

```
Method: REML   Optimizer: outer newton
full convergence after 9 iterations.
Gradient range [-0.0001467222,0.00171085]
(score 784.6012 & scale 2.868607).
Hessian positive definite, eigenvalue range [0.00014,198.5]
Model rank =  7 / 7

Basis dimension (k) checking results. Low p-value
(k-index<1) may indicate that k is too low, especially
if edf is close to k'.

        k'  edf k-index p-value
s(x1) 3.00 1.00    0.35  <2e-16 ***
s(x2) 3.00 2.88    1.00    0.52
 ---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
```

Running gam.check (2)

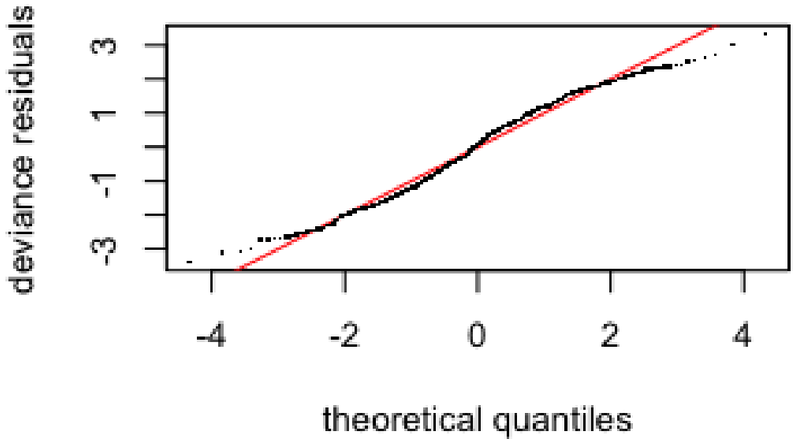
```
mod <- gam(y ~ s(x1, k = 12) + s(x2, k = 4),
           data = dat, method = "REML")
gam.check(mod)
```

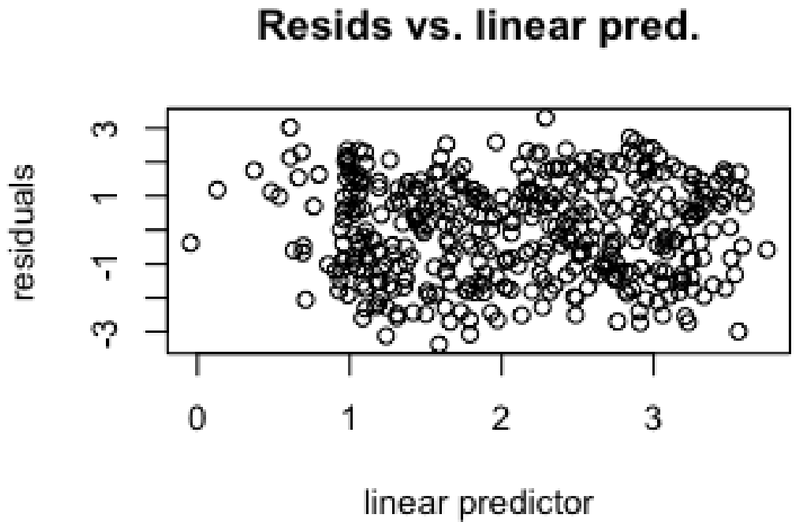
```
...

         k'   edf k-index p-value
s(x1) 11.00 10.85    1.05   0.830
s(x2)  3.00  2.98    0.89   0.015 *

...
```

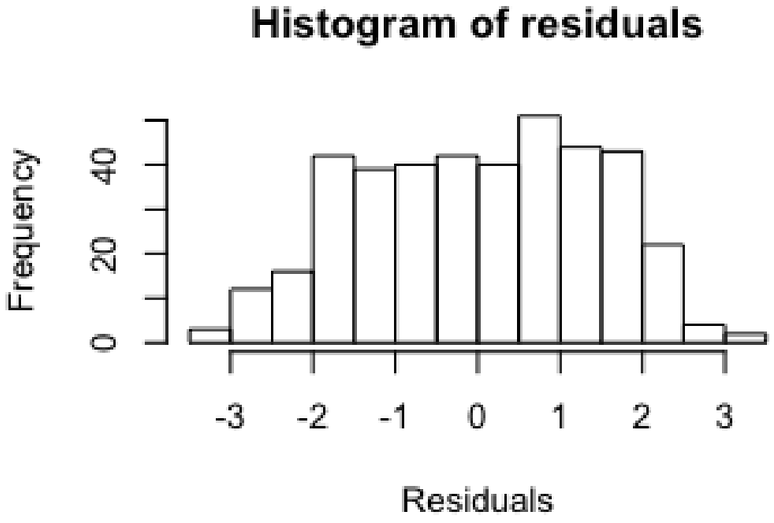
Running gam.check (3)

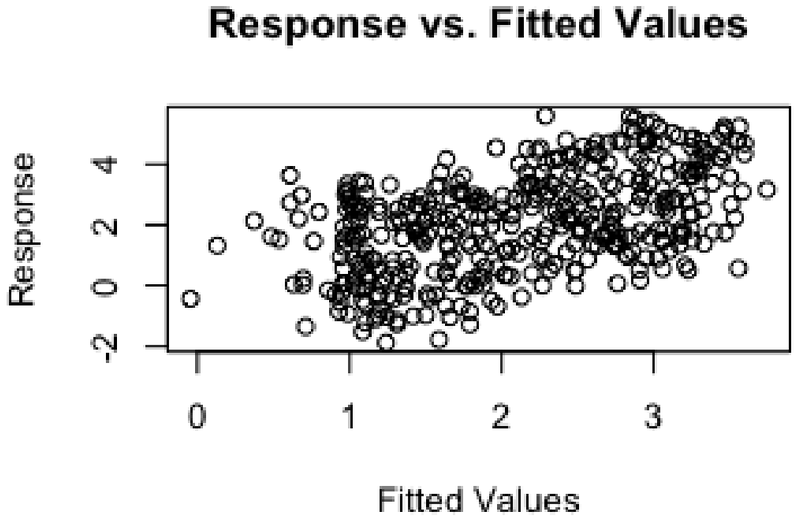
```
mod <- gam(y ~ s(x1, k = 12) + s(x2, k = 12),
           data = dat, method = "REML")
gam.check(mod)
```

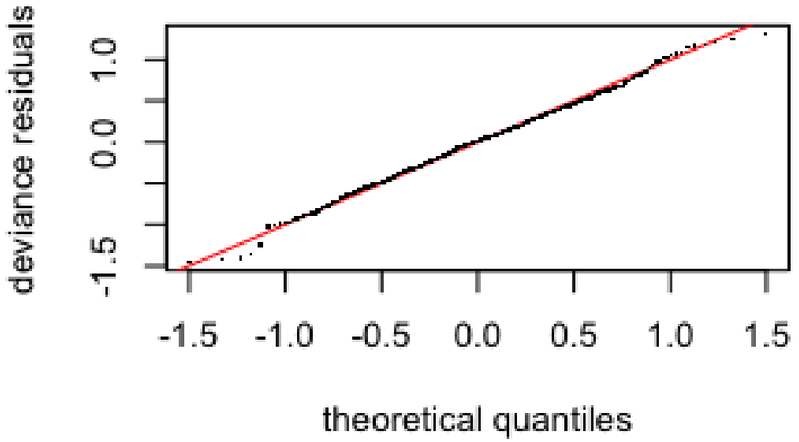
```
...
         k'   edf k-index p-value
s(x1) 11.00 10.86    1.08    0.94
s(x2) 11.00  7.78    0.94    0.12
...
```

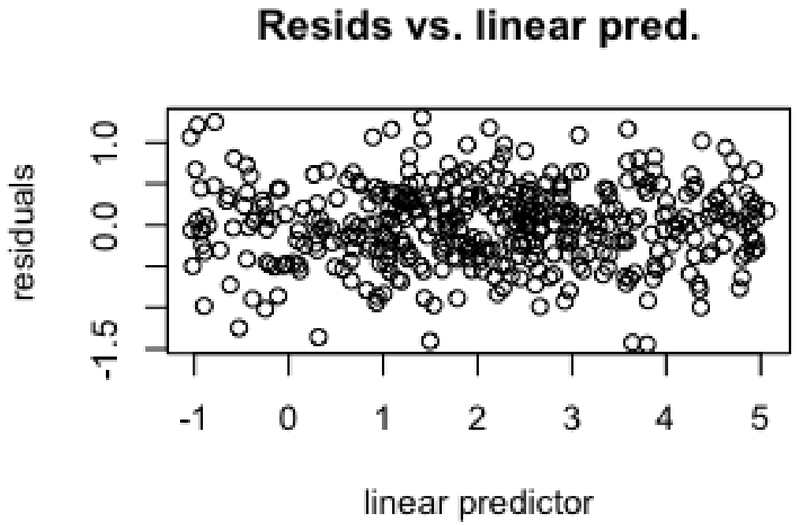

deviance residuals
-3
-1
1
3
-4
-2
0
2
4
theoretical quantiles

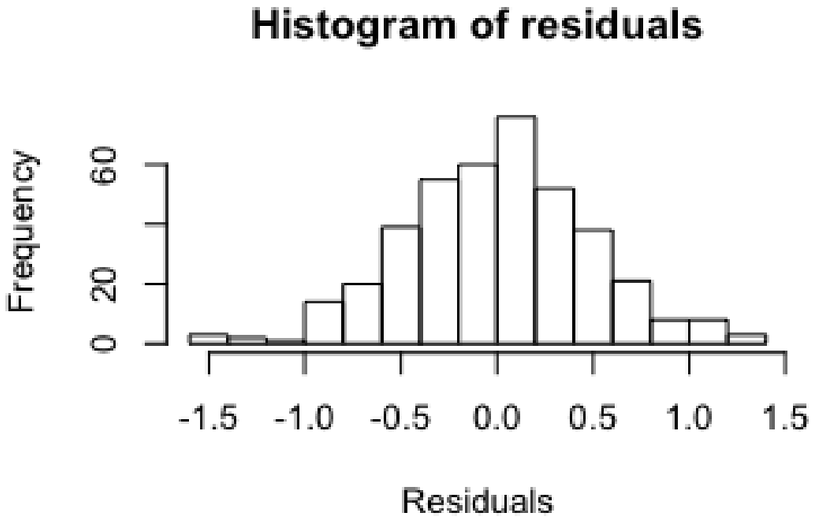

Resids vs. linear pred.
residuals
-3
-1
1
3
0
1
2
3
linear predictor

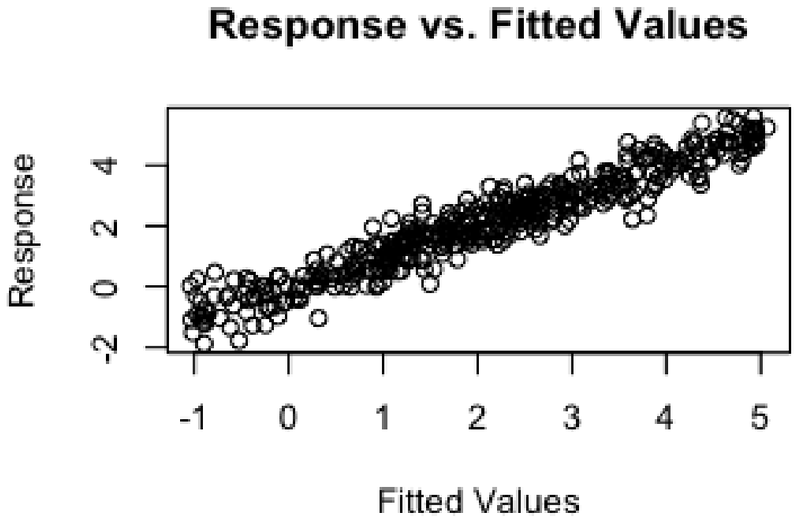

Histogram of residuals
Frequency
0
20
40
-3
-2
-1
0
1
2
3
Residuals


Response vs. Fitted Values
Response
-2
0
2
4
0
1
2
3
Fitted Values


deviance residuals
-1.5
0.0
1.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
theoretical quantiles


Resids vs. linear pred.
residuals
-1.5
0.0
1.0
-1
0
1
2
3
4
5
linear predictor


Histogram of residuals
Frequency
0
20
60
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Residuals


Response vs. Fitted Values
Response
-2
0
2
4
-1
0
1
2
3
4
5
Fitted Values

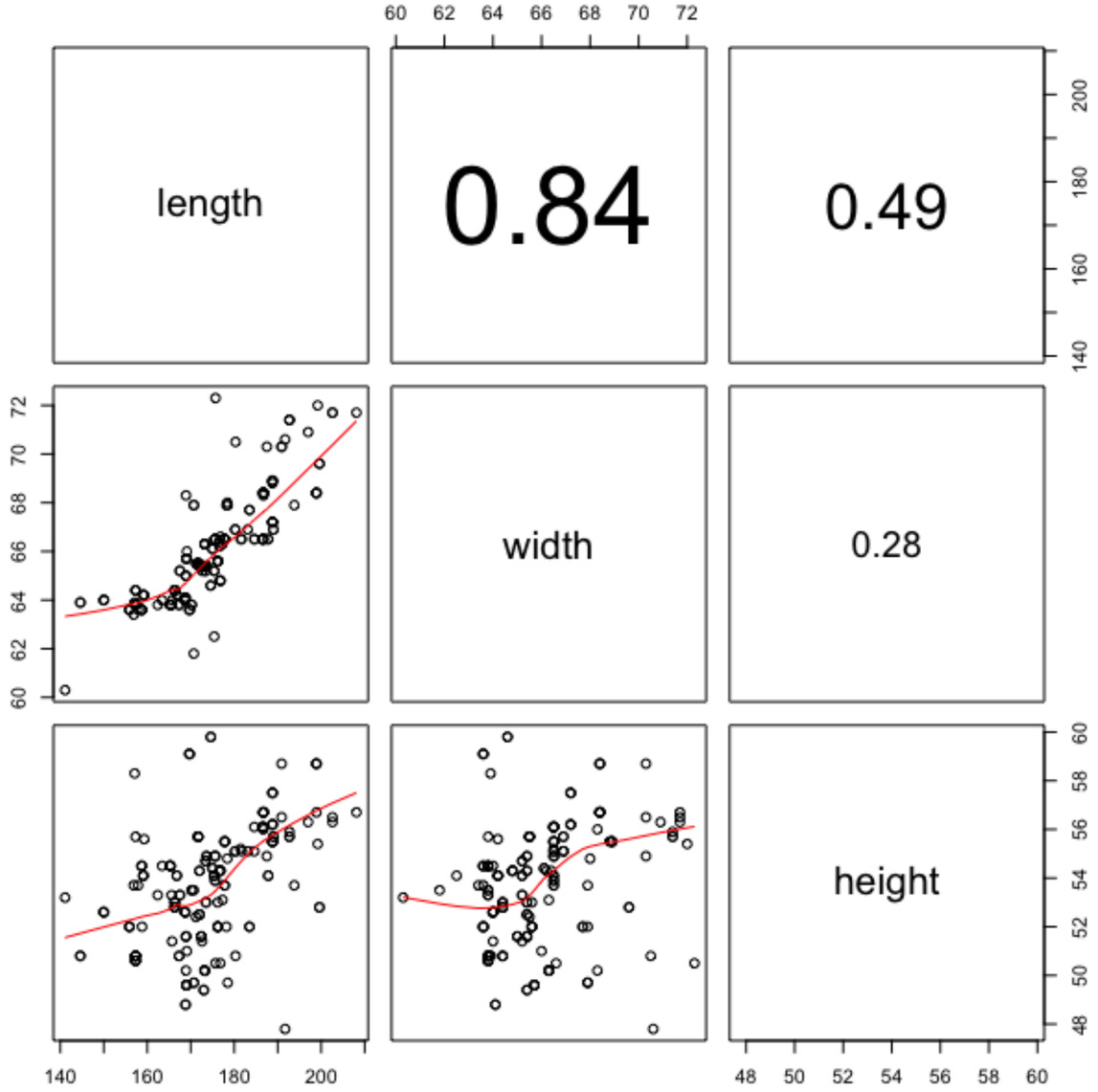
NONLINEAR MODELING IN R WITH GAMS

Let's check some models

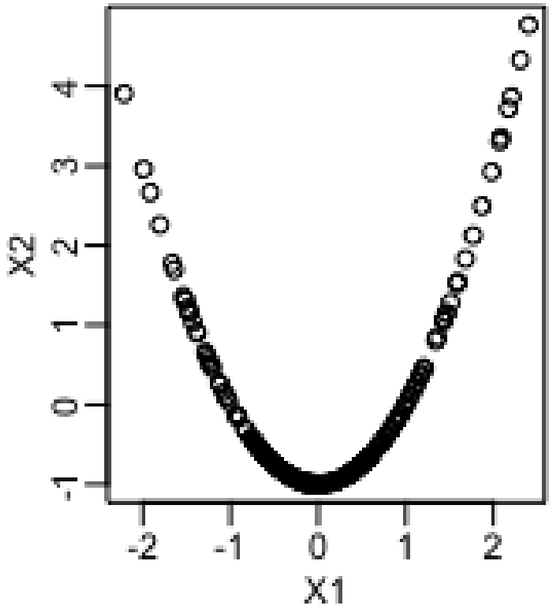
NONLINEAR MODELING IN R WITH GAMS

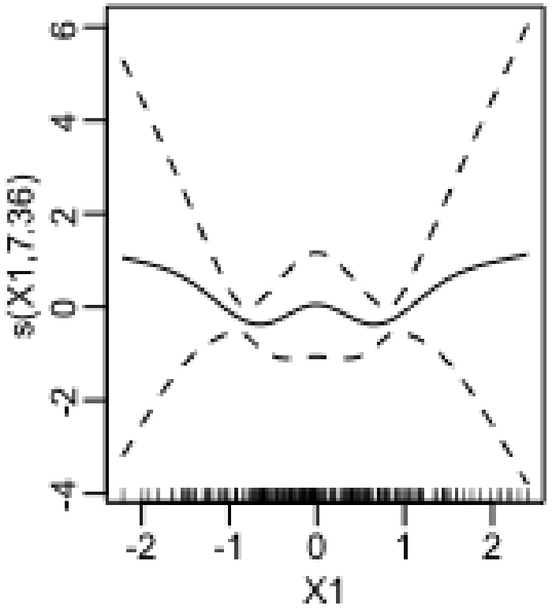
Checking concurvity

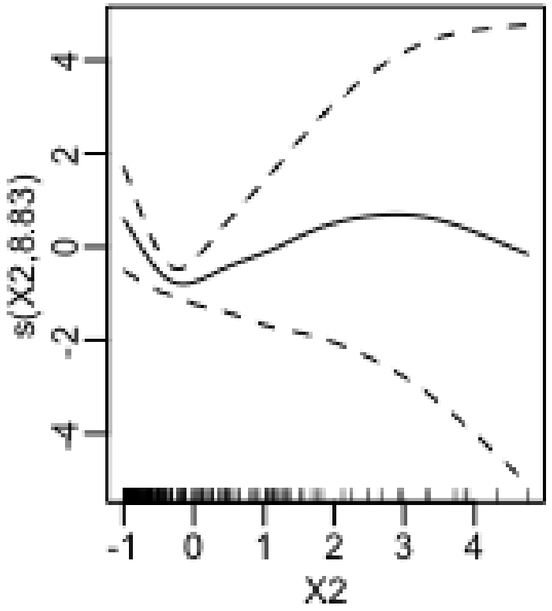
Noam Ross
Senior Research Scientist, EcoHealth Alliance


length
0.84
0.49
width
0.28
height
60 62 64 66 68 70 72
140 160 180 200
48 50 52 54 56 58 60

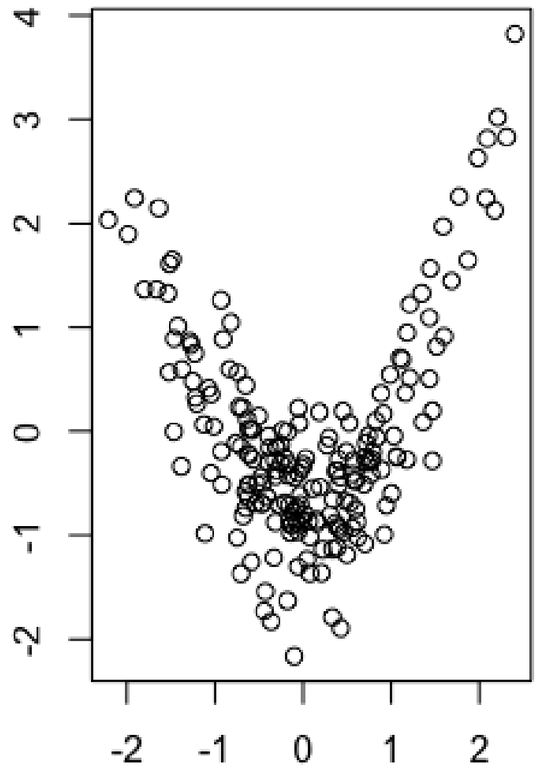
Concurvity







The concurvity() function




```
concurvity(m1, full = TRUE)
```

```
             para s(X1) s(X2)
worst           0  0.84  0.84
observed        0  0.22  0.57
estimate        0  0.28  0.60
```

Pairwise concurvities

```
concurvity(model, full = FALSE)
```

```
$worst
      para s(X1) s(X2)
para     1  0.00  0.00
s(X1)    0  1.00  0.84
s(X2)    0  0.84  1.00

$observed                    |  $estimate
      para s(X1) s(X2)       |        para s(X1) s(X2)
para     1  0.00  0.00       |  para     1  0.00   0.0
s(X1)    0  1.00  0.57       |  s(X1)    0  1.00   0.6
s(X2)    0  0.22  1.00       |  s(X2)    0  0.28   1.0
```

NONLINEAR MODELING IN R WITH GAMS

Let's practice!