# Explanation of the issues around model energetic balance

## Load the data

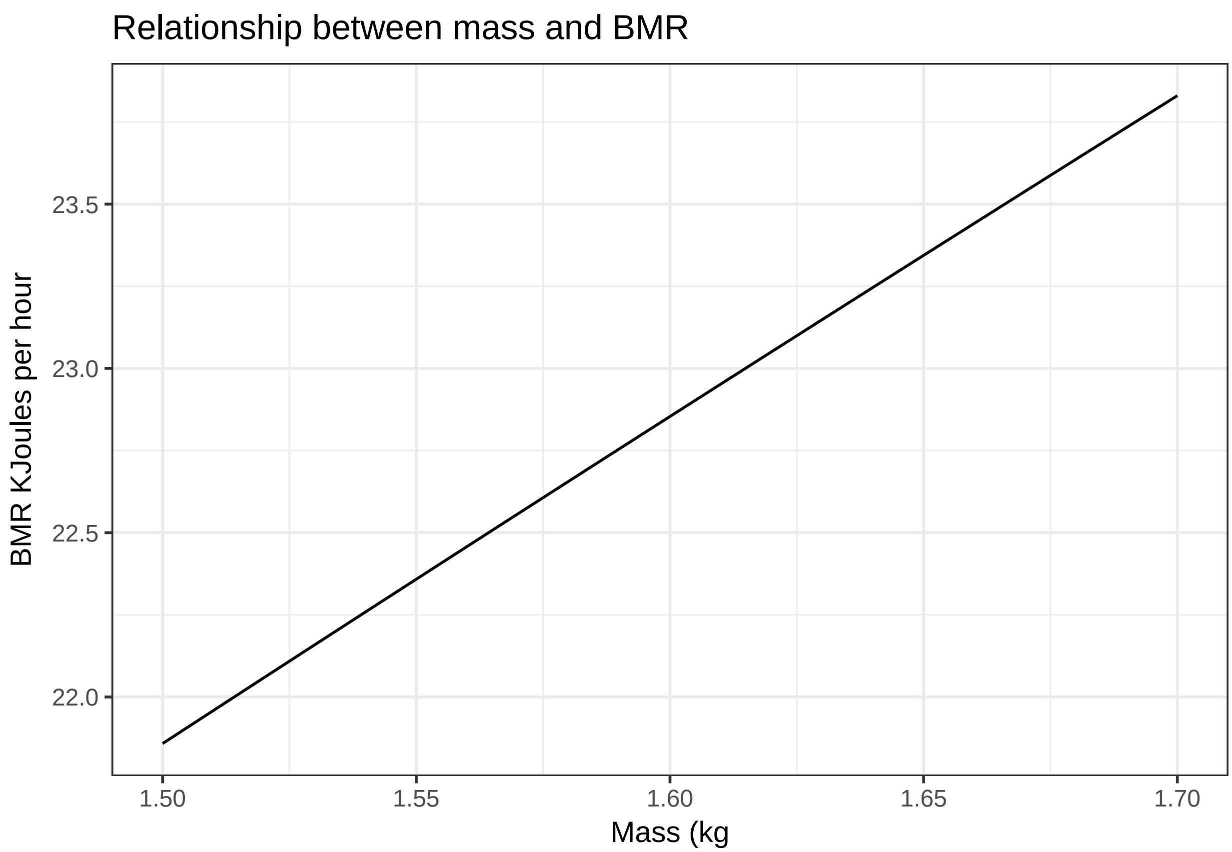
## Basal metabolic rate (BMR)

In the Humbolt paper a simple function for basal metabolic rate is used based on body mass alone. Brant geese weigh between 1.4 and 1.8 kg. The function calculates energy expenditure in joules per second (Watts). It is easier to think in terms of KJ per hour.

```
FBMR <- function(mass)4.59*mass^0.69
FBMR(1.4)
```

```
## [1] 5.7895
```

```
mass<-(1500:1700)/1000
d<-data.frame(mass,bmr=FBMR(mass)*60*60/1000)
g0<-ggplot(d,aes(x=mass,y=bmr))
g0+geom_line()+theme_bw()+labs(x="Mass (kg",y="BMR KJoules per hour",title="Relationship between mass ar
```



## Conversion of energy to fat

A more intuitive way of thinking about energy expenditure is in terms of grams of fat. These two simple functions run the conversions (in the model I use functions so that the calculations can be easily changed throughout by changing the function)

```
FFat2Energy<-function(fat)34.3*fat # g fat to KJoules
FEnergy2Fat<-function(energy)energy/34.3 # KJoules to g fat
```

So the daily energy expenditure in terms of grams of fat is betweeen 13 and 17 grams

```
FEnergy2Fat(20)*24
```

```
## [1] 13.99417
```

```
FEnergy2Fat(25)*24
```

```
## [1] 17.49271
```

## Taking into account temperature and windspeed to calculate BMR

Ellie is working with a more complex equation for BMR that takes into account both temperature and windspeed.

```
FBMR<-function(ftemperature=-10,fwindspeed=2,fmass=1500)
{
TBrant<-7.5
ftemperature[ftemperature>TBrant]<-TBrant
fwindspeed[fwindspeed<0.5]<-0.5
DeltaT<-TBrant-ftemperature
b<-0.0092*fmass^0.66*DeltaT^0.32
a<-4.15-b*sqrt(0.06)
a+b+sqrt(fwindspeed)
}
FBMR(ftemperature=10,fwindspeed=2,fmass=1500)*60*60/1000
```

```
## [1] 20.03117
```

This is in the same ballpark as the Humbolt equation when temperature is set to 10 degrees.

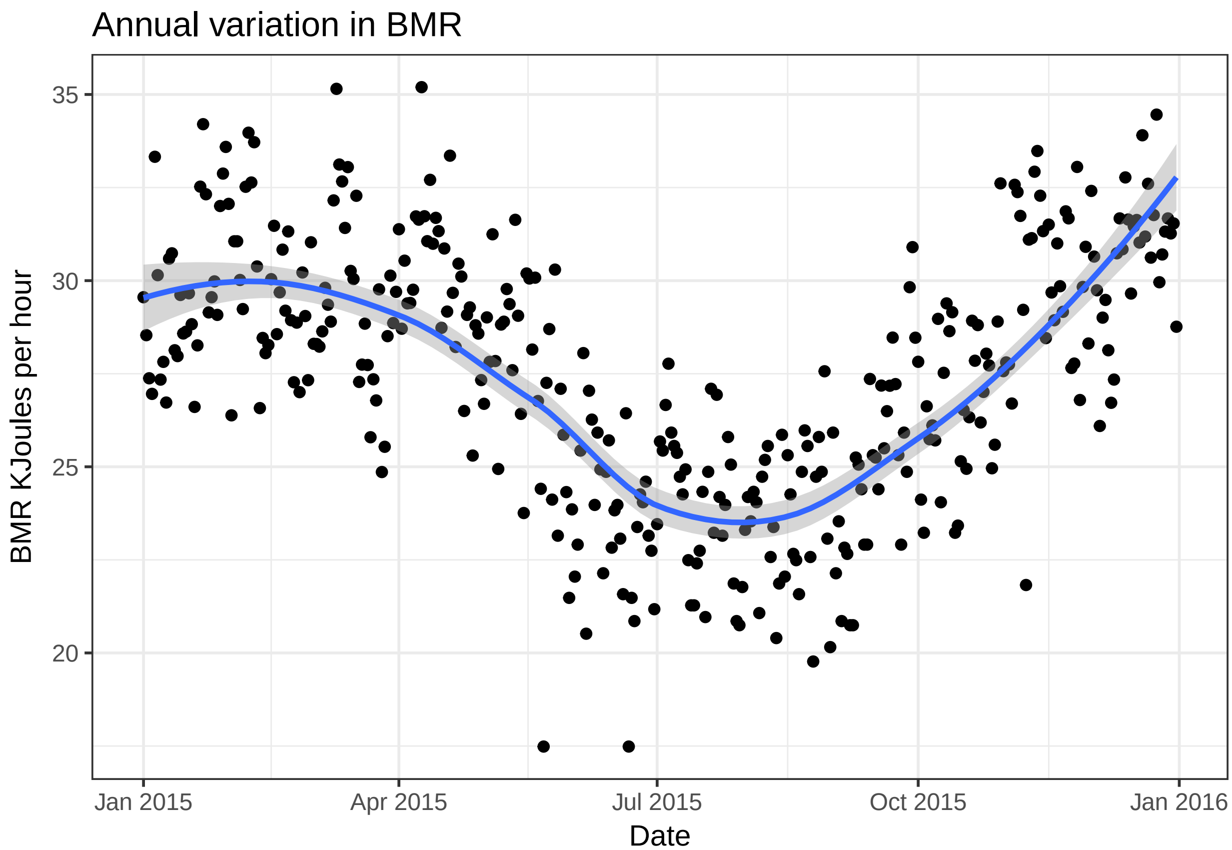
## Testing this against a year's climate data

The model contains daily climate data for the site that can be used to test how this equation behaves over the space of a year.

```
clim<-subset(clim,as.numeric(format(clim$date,'%Y'))==2015)
temperature<-(clim$tmin+clim$tmax)/20
windspeed<-clim$avwind/10
dbmr<-data.frame(date=clim$date,temperature, windspeed, bmr= FBMR(temperature,windspeed)*60*60/1000)

g0<-ggplot(dbmr,aes(x=date,y=bmr))
g0+geom_point()+geom_smooth()+theme_bw()+labs(x="Date",y="BMR KJoules per hour",title="Annual variation
```

```
## `geom_smooth()` using method = 'loess'
```




So on cold, windy days in the winter bmr increases to a maximum of about 35 KJ per hour. This is about 25 g of fat.

```
FEnergy2Fat(35)*24
```

```
## [1] 24.4898
```

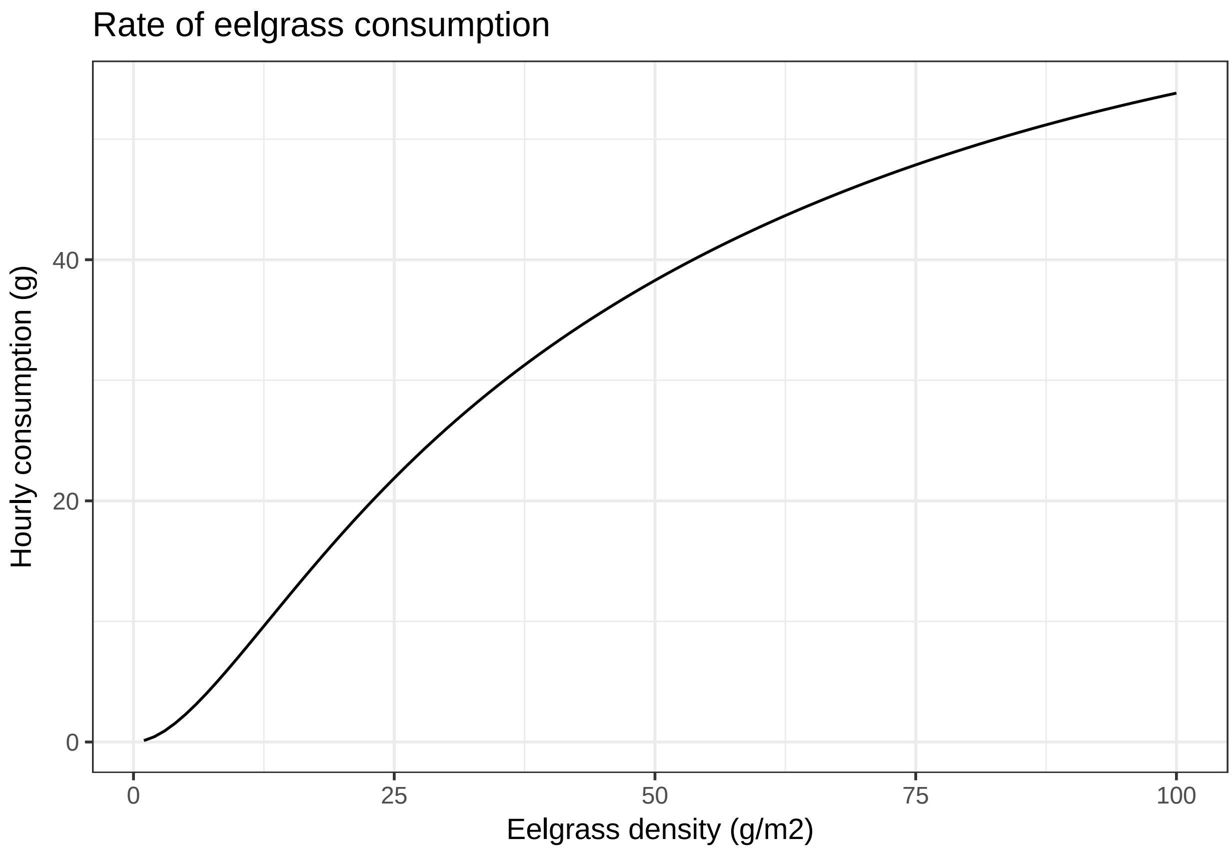
Bird's fat reserves may be around 250g so this implies that they can survive for around ten days without food.

### Consumption function from the Humbolt paper

The functional response in the Humbolt paper gives the dry biomass consumed in one minute as a function of eelgrass density.

```
biomass<-1:100
FConsumption<-function(fbiomass)100*0.01028*(1-exp(-0.105*fbiomass))*(1.0373*(1-exp(-0.0184*fbiomass))/(
d<-data.frame(biomass,consumption=FConsumption(biomass)*3600)

g0<-ggplot(d,aes(x=biomass,y=consumption))
g0+geom_line()+theme_bw()+labs(x="Eelgrass density (g/m2)",y="Hourly consumption (g)",title="Rate of eel
```

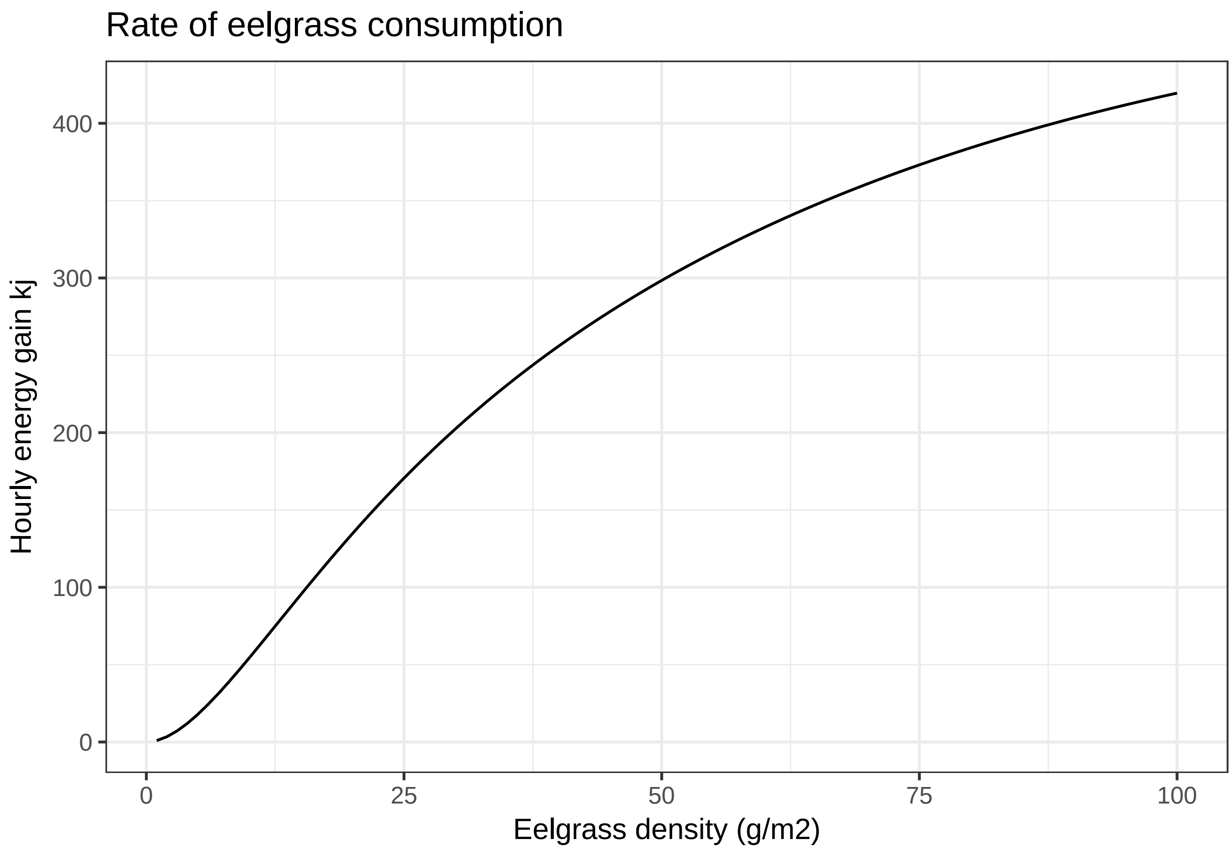



### Converting eelgrass into energy assimilated

Using the function in the Humbolt paper.

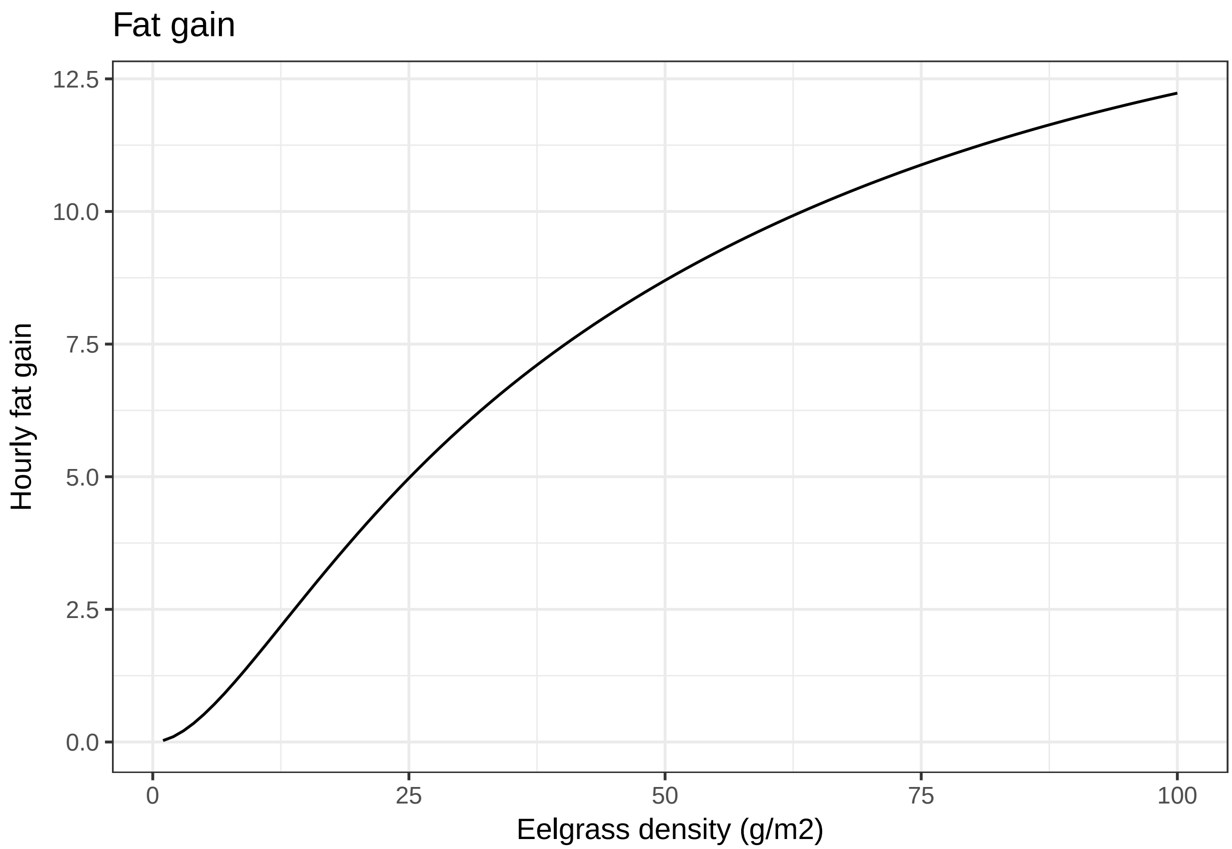
```
FEnergyAssim<-function(consumption, a=0.464, E= 16.8)consumption*a*E
d$energy<-FEnergyAssim(d$consumption)

g0<-ggplot(d,aes(x=biomass,y=energy))
g0+geom_line()+theme_bw()+labs(x="Eelgrass density (g/m2)",y="Hourly energy gain kj",title="Rate of eelg
```




This seems too high as the maximum gain is around ten times the basal metabolic rate. It implies that the potential fat gain (ignoring expenditure) when feeding at peak densities.

```
d$fatgain<-FEnergy2Fat(d$energy)
g0<-ggplot(d,aes(x=biomass,y=fatgain))
g0+geom_line()+theme_bw()+labs(x="Eelgrass density (g/m2)",y="Hourly fat gain",title="Fat gain")
```




This is very high.

### Number of hours feeding per day needed to break even

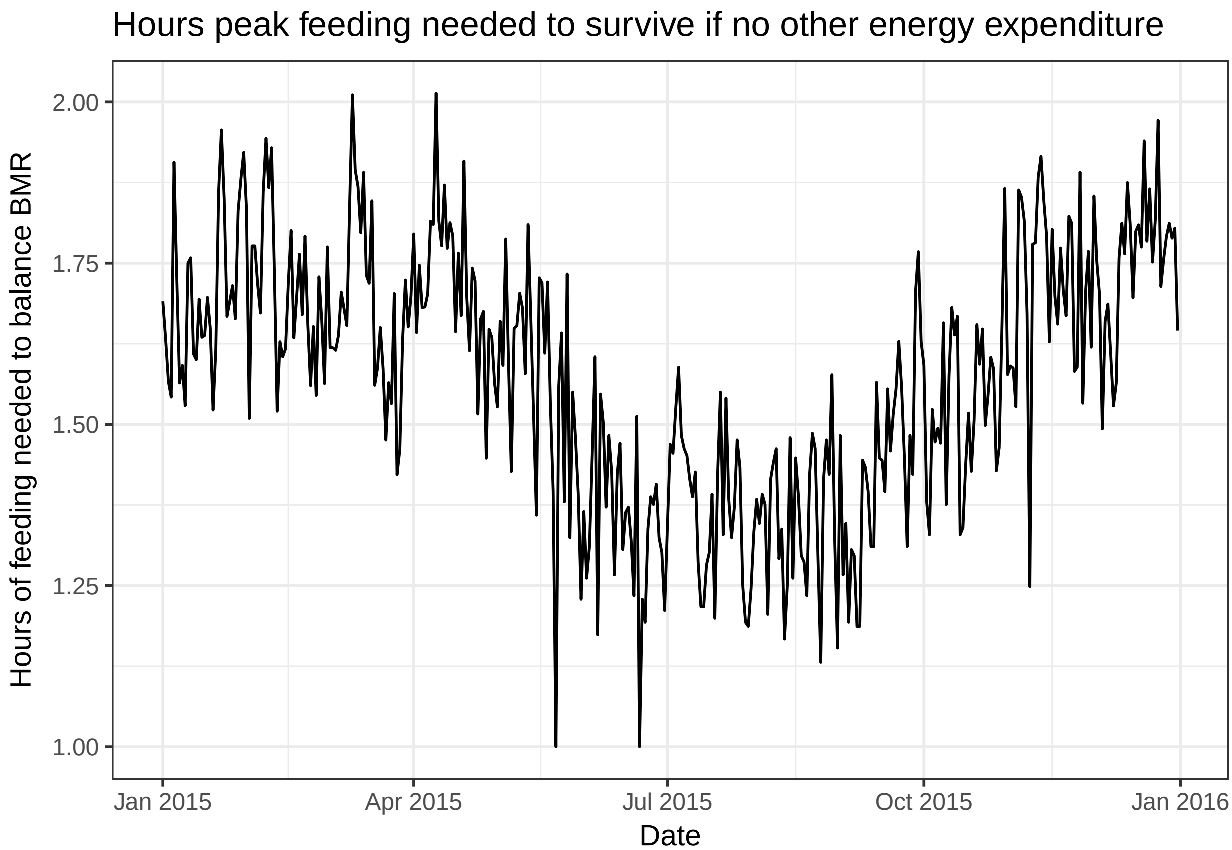
```
hourlymax<-FEnergyAssim(FConsumption(100)*3600)
hourlymax
```

```
## [1] 419.5216
```

```
max(dbmr$bmr)
```

```
## [1] 35.19686
```

```
dbmr$hours<-dbmr$bmr*24/hourlymax
g0<-ggplot(dbmr,aes(x=date,y=hours))
g0+geom_line()+theme_bw()+labs(x="Date",y="Hours of feeding needed to balance BMR",title="Hours peak fe
```




### The daily maximum energy gain in the Humboldt paper

This is also problematic as it implies that birds can gain over 60g of fat per day.

```
dailymax<-1713*1.5^0.72
dailymax
```

```
## [1] 2293.734
```

```
FEnergy2Fat(dailymax)
```

```
## [1] 66.87271
```

I would have expected the maximum to be around 15 to 20g if the birds take around two to three weeks to gain enough energy for migration.