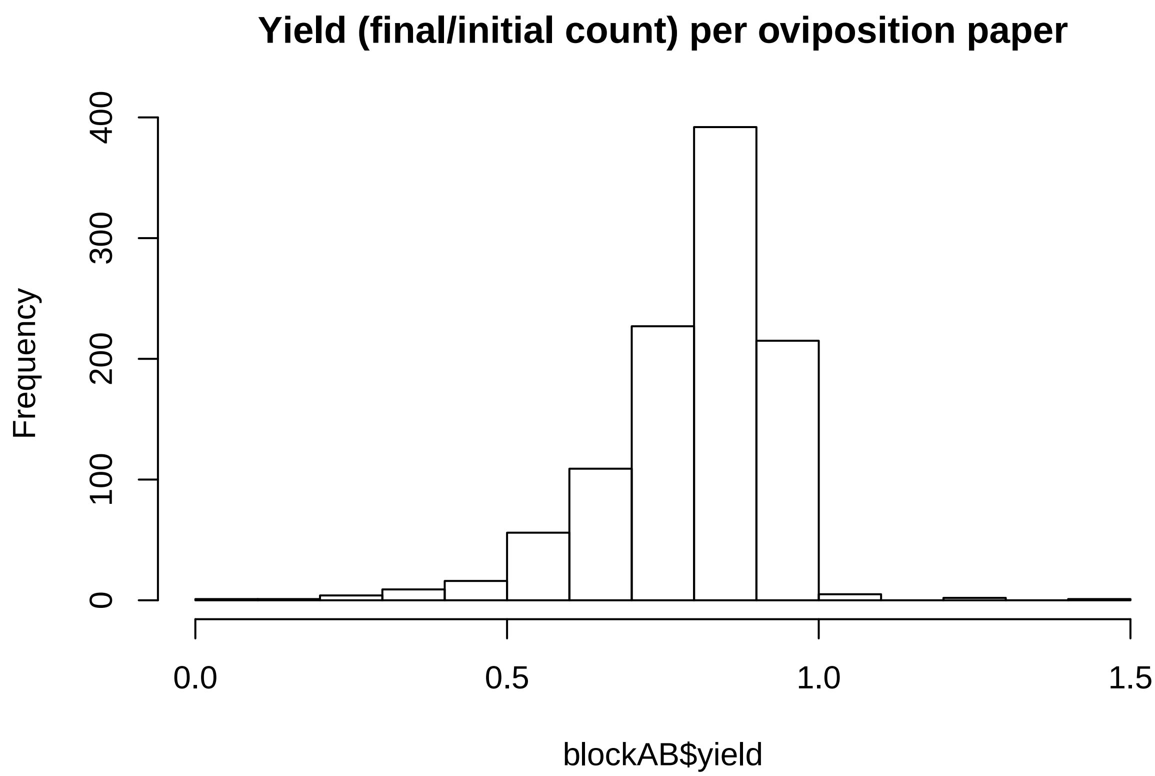
CPP_analysis

```r
library("drc") #3.0.1
library("knitr")
library("tidyverse") #1.2.1
library("stringr")
```

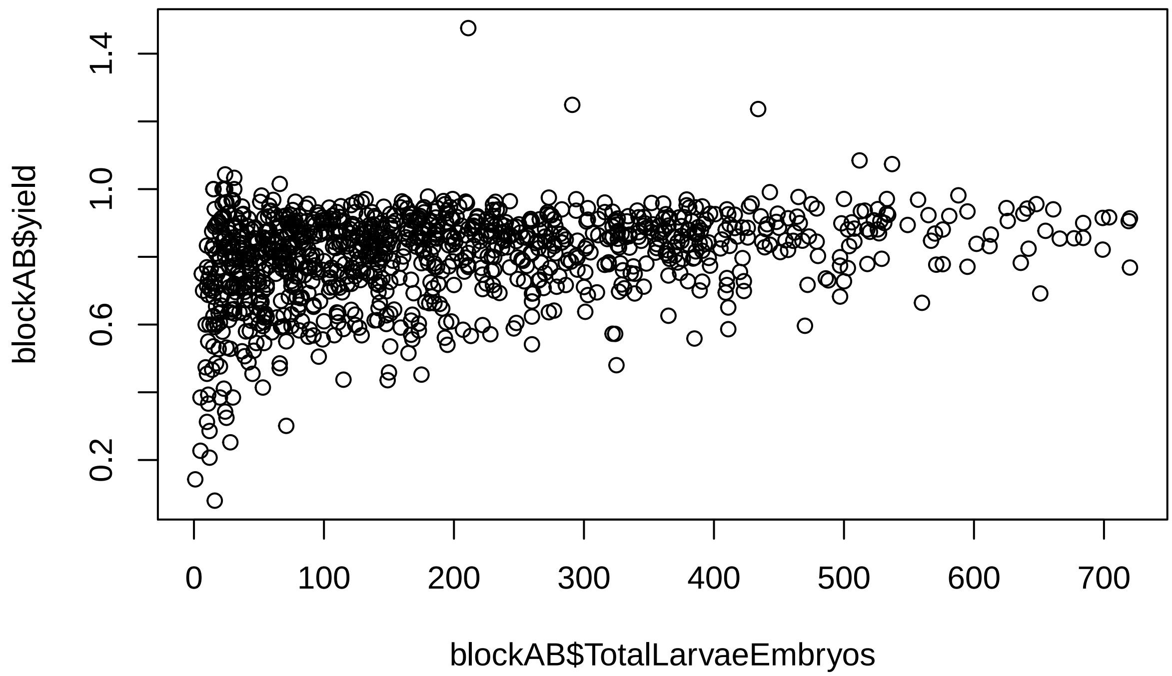
```r
all_data<-data.frame(read.csv("CPP_experiment_data_collated.csv"))
#Filter out empty/discarded oviposition papers
blockAB<-dplyr::filter(all_data, TotalLarvaeEmbryos>0)
```

```r
DI_summary <- blockAB %>%
  group_by(CageID) %>%
  summarise(pop=first(Population), pp=mean(Photoperiod), lat=mean(Lat), block=first(Block), country=firs
DI_summary$total<-DI_summary$h1+DI_summary$h2+DI_summary$emb
DI_summary$DI<-DI_summary$emb/DI_summary$total
```

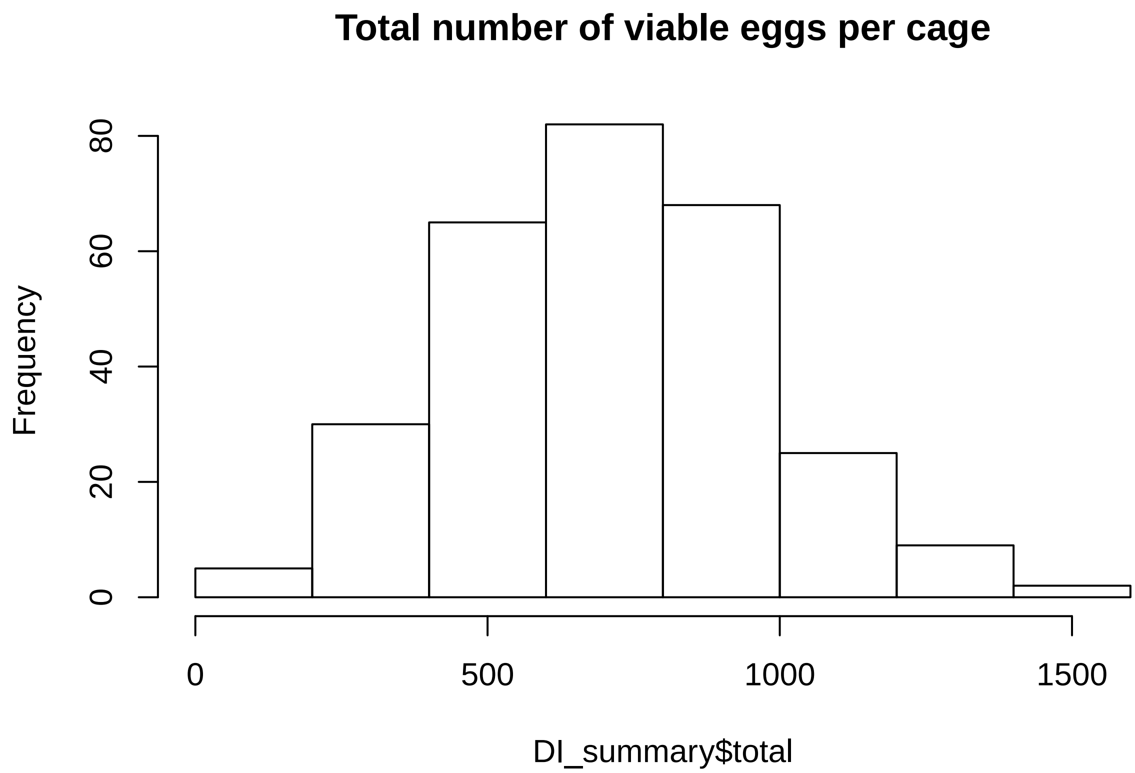
```r
#Calculate yield/fraction of initial count
blockAB$yield <- blockAB$TotalLarvaeEmbryos/blockAB$InitialEggs
hist(blockAB$yield, main="Yield (final/initial count) per oviposition paper")
```



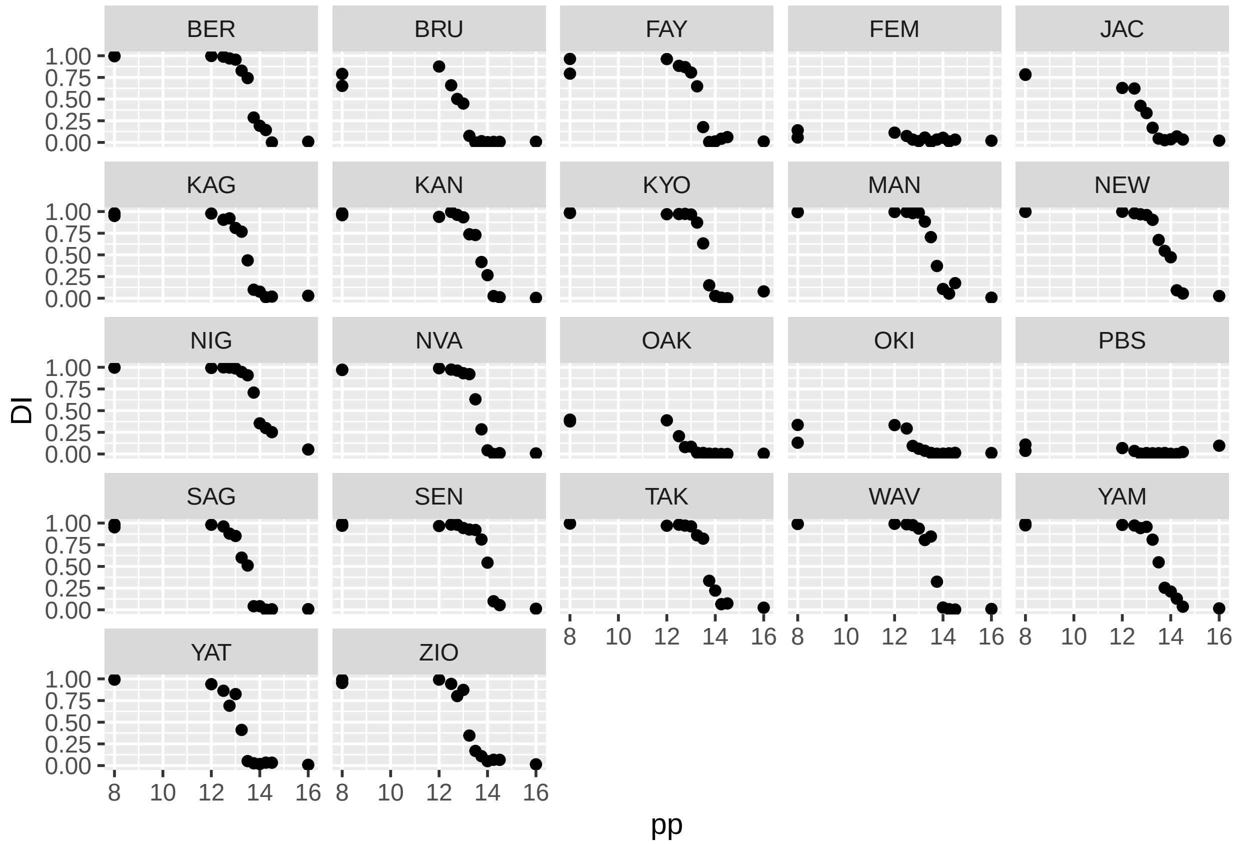
```r
plot(blockAB$yield ~ blockAB$TotalLarvaeEmbryos)
```



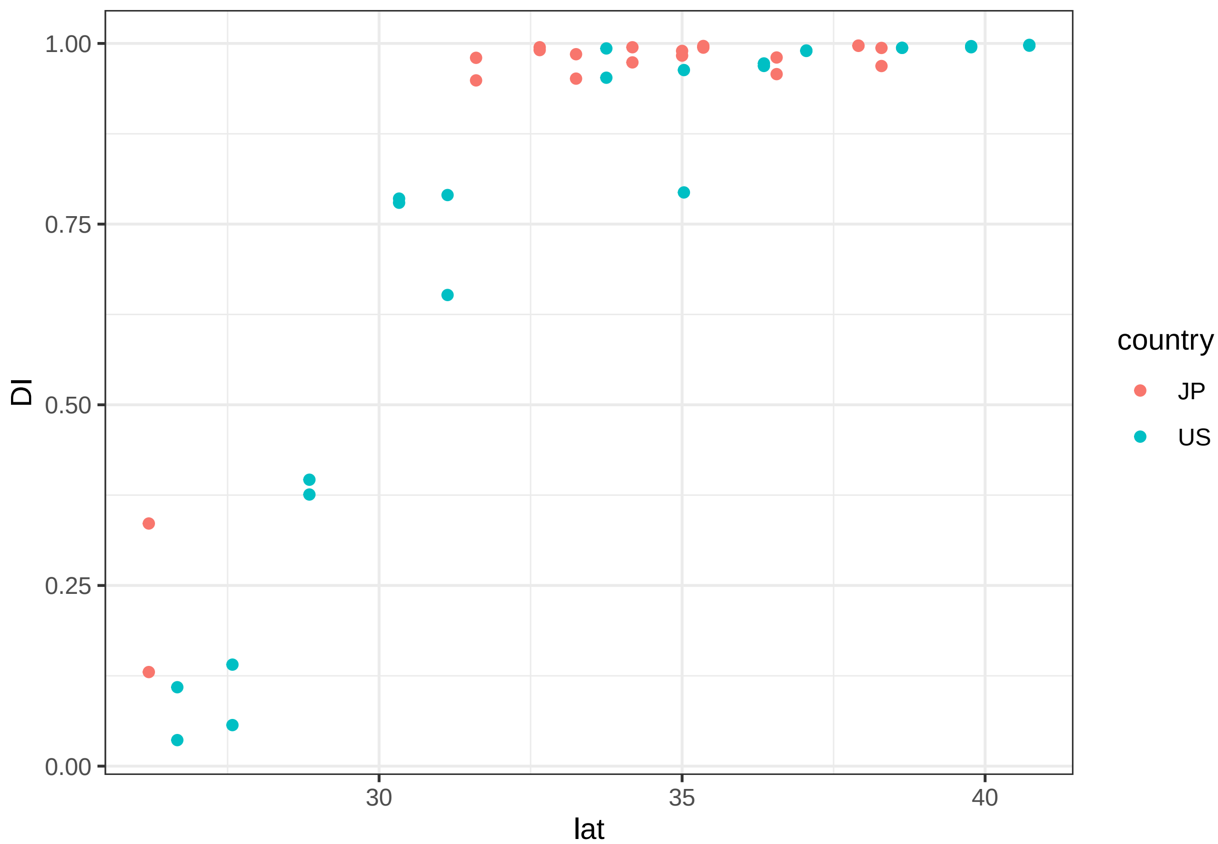

```r
hist(DI_summary$total, main="Total number of viable eggs per cage")
```




```r
#plot with DI at 8 h shown as TWO DIFFERENT points (corresponding to two cabinets)
ggplot(DI_summary, aes(x=pp, y=DI, group=pop)) + geom_point() + facet_wrap(~pop)
```




```
DI_short<-filter(DI_summary, pp==8)
ggplot(DI_short, aes(x=lat, y=DI, color=country)) + geom_point() + theme_bw()
```



Calculating CPP values

5-parameter logistic regression explanation from here: https://www.mathworks.com/matlabcentral/fileexchange/38043-five-parameters-logistic-regression-there-and-back-again The 5 parameters are:

-Minimum asymptote. In a bioassay where you have a standard curve, this can be thought of as the response value at 0 standard concentration.

-Hill's slope. The Hill's slope refers to the steepness of the curve. It could either be positive or negative.

-Inflection point. The inflection point is defined as the point on the curve where the curvature changes direction or signs. C is the concentration of analyte where y=(D-A)/2.

-Maximum asymptote. In an bioassay where you have a standard curve, this can be thought of as the response value for infinite standard concentration.

-Asymmetry factor. When E=1 we have a symmetrical curve around inflection point and so we have a four-parameters logistic equation.

BUT unsure what equation is being used here and which parameter is which.

```
#From Kevin Emerson

# the following fits the models of the given function using data from the
# data.frame d separately for the various treatments using a 5 parameter
# logistic model
```

```r
d.model.fit <- drm(DI ~ pp, data = DI_summary, curveid = pop, fct = LL.5())
#plot(d.model.fit, log = "")

# output the parameters of the model fits:
summary(d.model.fit)
```

```
## Warning in sqrt(diag(varMat)): NaNs produced
```

```
##
## Model fitted: Generalized log-logistic (ED50 as parameter) (5 parms)
##
## Parameter estimates:
##
##           Estimate  Std. Error  t-value   p-value
## b:BER  7.9988e+01  3.2827e+01   2.4367 0.0158188 *
## b:BRU  5.2967e+01  1.0813e+01   4.8983 2.180e-06 ***
## b:KAG  6.4252e+01  1.5716e+01   4.0882 6.601e-05 ***
## b:KAN  4.1378e+01  9.0899e+00   4.5520 9.881e-06 ***
## b:KYO  9.4595e+01  2.3466e+01   4.0312 8.253e-05 ***
## b:NVA  7.0774e+01          NA       NA        NA
## b:OAK  3.6361e+02  3.4875e+02   1.0426 0.2985586
## b:PBS  4.4081e+00          NA       NA        NA
## b:SAG  4.9832e+01  8.1950e+00   6.0808 7.242e-09 ***
## b:SEN  7.9975e+01  1.7514e+01   4.5664 9.295e-06 ***
## b:WAV  1.0288e+02  4.6586e+01   2.2083 0.0285140 *
## b:FAY  9.4049e+01  2.3719e+01   3.9651 0.0001066 ***
## b:FEM  2.8694e+02  2.4002e+03   0.1195 0.9049764
## b:JAC  3.1626e+01  7.2878e+00   4.3396 2.401e-05 ***
## b:MAN  6.4249e+01  1.4864e+01   4.3225 2.577e-05 ***
## b:NEW  3.7514e+01  6.0142e+00   6.2375 3.209e-09 ***
## b:NIG  7.4634e+01  2.3022e+01   3.2418 0.0014207 **
## b:OKI  1.7783e+02  1.8944e+02   0.9387 0.3491599
## b:TAK  3.4104e+02  1.9370e+03   0.1761 0.8604402
## b:YAM  1.4943e+02  1.5990e+02   0.9345 0.3513207
## b:YAT  7.1614e+01  2.5620e+01   2.7953 0.0057612 **
## b:ZIO  2.4876e+02  1.6429e+02   1.5141 0.1317950
## c:BER  1.3739e-02  4.7609e-02   0.2886 0.7732505
## c:BRU  3.3967e-03  2.1060e-02   0.1613 0.8720529
## c:KAG  2.6217e-02  2.6722e-02   0.9811 0.3278833
## c:KAN -1.5413e-02  4.1125e-02  -0.3748 0.7082690
## c:KYO  4.1342e-02  2.5511e-02   1.6206 0.1069004
## c:NVA  1.5390e-03  2.5899e-02   0.0594 0.9526839
## c:OAK  2.3792e-02  1.6835e-02   1.4132 0.1593571
## c:PBS  3.1982e-05          NA       NA        NA
## c:SAG -5.2523e-03  2.6856e-02  -0.1956 0.8451701
## c:SEN  2.5282e-02  3.5842e-02   0.7054 0.4815066
## c:WAV  3.7110e-03  2.7647e-02   0.1342 0.8933750
## c:FAY  2.4132e-02  2.3008e-02   1.0488 0.2956998
## c:FEM  2.9058e-02  1.6864e-02   1.7231 0.0866336 .
## c:JAC  3.0506e-02  2.3141e-02   1.3183 0.1891149
## c:MAN  6.8924e-02  2.8611e-02   2.4090 0.0170272 *
## c:NEW  6.9547e-03  4.3022e-02   0.1617 0.8717633
## c:NIG  1.9634e-01  3.3390e-02   5.8801 2.016e-08 ***
```

```
## c:OKI  2.0712e-02  1.7894e-02   1.1575 0.2486282    
## c:TAK  3.2543e-02  4.8938e-02   0.6650 0.5069284    
## c:YAM  7.1317e-03  5.1585e-02   0.1383 0.8901995    
## c:YAT  1.8793e-02  2.2512e-02   0.8348 0.4049519    
## c:ZIO  5.2924e-02  2.7226e-02   1.9439 0.0535061 .  
## d:BER  9.8624e-01  2.4148e-02  40.8411 < 2.2e-16 ***
## d:BRU  7.5849e-01  3.0120e-02  25.1827 < 2.2e-16 ***
## d:KAG  9.4579e-01  2.5082e-02  37.7083 < 2.2e-16 ***
## d:KAN  9.7508e-01  2.4997e-02  39.0076 < 2.2e-16 ***
## d:KYO  9.7560e-01  2.1280e-02  45.8458 < 2.2e-16 ***
## d:NVA  9.7670e-01  2.1002e-02  46.5044 < 2.2e-16 ***
## d:OAK  3.8691e-01  2.9169e-02  13.2645 < 2.2e-16 ***
## d:PBS  8.0891e-01  8.0492e+00   0.1005 0.9200654    
## d:SAG  9.6611e-01  2.6415e-02  36.5738 < 2.2e-16 ***
## d:SEN  9.6483e-01  1.9238e-02  50.1515 < 2.2e-16 ***
## d:WAV  9.6361e-01  2.3009e-02  41.8800 < 2.2e-16 ***
## d:FAY  8.9327e-01  2.3082e-02  38.6989 < 2.2e-16 ***
## d:FEM  1.0383e-01  2.9205e-02   3.5553 0.0004850 ***
## d:JAC  7.6164e-01  3.4881e-02  21.8352 < 2.2e-16 ***
## d:MAN  9.9658e-01  2.2396e-02  44.4983 < 2.2e-16 ***
## d:NEW  1.0022e+00  2.4575e-02  40.7824 < 2.2e-16 ***
## d:NIG  9.9221e-01  2.1352e-02  46.4692 < 2.2e-16 ***
## d:OKI  2.7546e-01  2.6160e-02  10.5298 < 2.2e-16 ***
## d:TAK  9.6226e-01  2.1321e-02  45.1316 < 2.2e-16 ***
## d:YAM  9.7191e-01  2.2631e-02  42.9457 < 2.2e-16 ***
## d:YAT  9.2383e-01  3.2466e-02  28.4555 < 2.2e-16 ***
## d:ZIO  9.3888e-01  2.2719e-02  41.3251 < 2.2e-16 ***
## e:BER  1.3525e+01  1.9086e-01  70.8638 < 2.2e-16 ***
## e:BRU  1.3526e+01  4.8779e-01  27.7282 < 2.2e-16 ***
## e:KAG  1.3797e+01  4.0682e-01  33.9130 < 2.2e-16 ***
## e:KAN  1.4281e+01  8.3777e-01  17.0461 < 2.2e-16 ***
## e:KYO  1.3742e+01  2.2859e-01  60.1183 < 2.2e-16 ***
## e:NVA  1.3908e+01          NA       NA        NA    
## e:OAK  1.2573e+01          NA       NA        NA    
## e:PBS  2.6105e+00  1.1118e+01   0.2348 0.8146415    
## e:SAG  1.3947e+01  3.6731e-01  37.9692 < 2.2e-16 ***
## e:SEN  1.4394e+01  4.1861e-01  34.3847 < 2.2e-16 ***
## e:WAV  1.3871e+01  4.1571e-01  33.3661 < 2.2e-16 ***
## e:FAY  1.3523e+01  2.0945e-01  64.5638 < 2.2e-16 ***
## e:FEM  1.2609e+01  1.2733e+00   9.9023 < 2.2e-16 ***
## e:JAC  1.3719e+01  8.1663e-01  16.7989 < 2.2e-16 ***
## e:MAN  1.4057e+01  6.0772e-01  23.1298 < 2.2e-16 ***
## e:NEW  1.4434e+01  5.5435e-01  26.0378 < 2.2e-16 ***
## e:NIG  1.4291e+01          NA       NA        NA    
## e:OKI  1.2892e+01  1.7209e+00   7.4917 3.170e-12 ***
## e:TAK  1.3463e+01  1.8341e-01  73.4039 < 2.2e-16 ***
## e:YAM  1.3225e+01  1.3434e-01  98.4400 < 2.2e-16 ***
## e:YAT  1.3568e+01  3.3517e-01  40.4807 < 2.2e-16 ***
## e:ZIO  1.3036e+01  7.0520e-02 184.8510 < 2.2e-16 ***
## f:BER  6.4929e-01  5.4339e-01   1.1949 0.2337333    
## f:BRU  6.4215e+00  1.0208e+01   0.6291 0.5301263    
## f:KAG  3.7290e+00  5.5416e+00   0.6729 0.5018907    
## f:KAN  3.9050e+00  7.5782e+00   0.5153 0.6069969    
## f:KYO  2.8470e+00  3.2637e+00   0.8723 0.3842203    
```

```
## f:NVA  3.4513e+00          NA       NA        NA
## f:OAK  6.0291e+00          NA       NA        NA
## f:PBS  4.8920e-01          NA       NA        NA
## f:SAG  4.8363e+00  5.1857e+00   0.9326 0.3522913
## f:SEN  6.1926e+00  1.1883e+01   0.5211 0.6029218
## f:WAV  3.1196e+00  7.1830e+00   0.4343 0.6646001
## f:FAY  2.6988e+00  2.8514e+00   0.9465 0.3452086
## f:FEM  6.2470e+00  2.1883e+02   0.0285 0.9772576
## f:JAC  5.7799e+00  8.6726e+00   0.6665 0.5059912
## f:MAN  5.2375e+00  1.1796e+01   0.4440 0.6575852
## f:NEW  3.7625e+00  4.2953e+00   0.8760 0.3822477
## f:NIG  8.0606e+00          NA       NA        NA
## f:OKI  9.3468e+00  1.9285e+02   0.0485 0.9614000
## f:TAK  1.4215e-01  8.8407e-01   0.1608 0.8724429
## f:YAM  2.0305e-01  2.7776e-01   0.7310 0.4657325
## f:YAT  4.9822e+00  6.2436e+00   0.7980 0.4259679
## f:ZIO  2.5220e-01  2.2694e-01   1.1113 0.2679542
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error:
##
##  0.05052736 (176 degrees of freedom)
```

```
# estimate the 50% intercept
ED(d.model.fit, 50)
```

```
##
## Estimated effective doses
##
##           Estimate Std. Error
## e:BER:50 13.634739   0.037667
## e:BRU:50 12.982262   0.044682
## e:FAY:50 13.347562   0.027659
## e:FEM:50 12.515233   0.169317
## e:JAC:50 12.853335   0.068114
## e:KAG:50 13.459766   0.032242
## e:KAN:50 13.726218   0.044296
## e:KYO:50 13.556308   0.025833
## e:MAN:50 13.635184   0.032150
## e:NEW:50 13.832184   0.049731
## e:NIG:50 13.836928   0.034698
## e:NVA:50 13.616051   0.026960
## e:OAK:50 12.500115   0.015293
## e:OKI:50 12.707540   0.062737
## e:PBS:50  3.380362  15.121018
## e:SAG:50 13.432878   0.036573
## e:SEN:50 14.014999   0.028215
## e:TAK:50 13.656812   0.073857
## e:WAV:50 13.684416   0.023425
## e:YAM:50 13.527382   0.046699
## e:YAT:50 13.212448   0.033473
## e:ZIO:50 13.177073   0.030279
```

```r
cpp_values<-data.frame(ED(d.model.fit, 50))
```

```
##
## Estimated effective doses
##
##            Estimate Std. Error
## e:BER:50 13.634739   0.037667
## e:BRU:50 12.982262   0.044682
## e:FAY:50 13.347562   0.027659
## e:FEM:50 12.515233   0.169317
## e:JAC:50 12.853335   0.068114
## e:KAG:50 13.459766   0.032242
## e:KAN:50 13.726218   0.044296
## e:KYO:50 13.556308   0.025833
## e:MAN:50 13.635184   0.032150
## e:NEW:50 13.832184   0.049731
## e:NIG:50 13.836928   0.034698
## e:NVA:50 13.616051   0.026960
## e:OAK:50 12.500115   0.015293
## e:OKI:50 12.707540   0.062737
## e:PBS:50  3.380362  15.121018
## e:SAG:50 13.432878   0.036573
## e:SEN:50 14.014999   0.028215
## e:TAK:50 13.656812   0.073857
## e:WAV:50 13.684416   0.023425
## e:YAM:50 13.527382   0.046699
## e:YAT:50 13.212448   0.033473
## e:ZIO:50 13.177073   0.030279
```

#Recalculating CPP values for 2008 photoperiod response curves

```r
DI_summary_2008<-data.frame(read.csv("CPP_2008.csv"))
d.model.fit.2008 <- drm(DI ~ PP, data = DI_summary_2008, curveid = POP, fct = LL.5())

#plot(d.model.fit.2008, log = "")
# output the parameters of the model fits:
summary(d.model.fit)
```

```
## Warning in sqrt(diag(varMat)): NaNs produced
```

```
##
## Model fitted: Generalized log-logistic (ED50 as parameter) (5 parms)
##
## Parameter estimates:
##
##           Estimate  Std. Error  t-value   p-value
## b:BER  7.9988e+01  3.2827e+01   2.4367 0.0158188 *
## b:BRU  5.2967e+01  1.0813e+01   4.8983 2.180e-06 ***
## b:KAG  6.4252e+01  1.5716e+01   4.0882 6.601e-05 ***
## b:KAN  4.1378e+01  9.0899e+00   4.5520 9.881e-06 ***
## b:KYO  9.4595e+01  2.3466e+01   4.0312 8.253e-05 ***
## b:NVA  7.0774e+01          NA       NA        NA
```

```
## b:OAK  3.6361e+02  3.4875e+02   1.0426 0.2985586    
## b:PBS  4.4081e+00          NA       NA        NA    
## b:SAG  4.9832e+01  8.1950e+00   6.0808 7.242e-09 ***
## b:SEN  7.9975e+01  1.7514e+01   4.5664 9.295e-06 ***
## b:WAV  1.0288e+02  4.6586e+01   2.2083 0.0285140 *  
## b:FAY  9.4049e+01  2.3719e+01   3.9651 0.0001066 ***
## b:FEM  2.8694e+02  2.4002e+03   0.1195 0.9049764    
## b:JAC  3.1626e+01  7.2878e+00   4.3396 2.401e-05 ***
## b:MAN  6.4249e+01  1.4864e+01   4.3225 2.577e-05 ***
## b:NEW  3.7514e+01  6.0142e+00   6.2375 3.209e-09 ***
## b:NIG  7.4634e+01  2.3022e+01   3.2418 0.0014207 ** 
## b:OKI  1.7783e+02  1.8944e+02   0.9387 0.3491599    
## b:TAK  3.4104e+02  1.9370e+03   0.1761 0.8604402    
## b:YAM  1.4943e+02  1.5990e+02   0.9345 0.3513207    
## b:YAT  7.1614e+01  2.5620e+01   2.7953 0.0057612 ** 
## b:ZIO  2.4876e+02  1.6429e+02   1.5141 0.1317950    
## c:BER  1.3739e-02  4.7609e-02   0.2886 0.7732505    
## c:BRU  3.3967e-03  2.1060e-02   0.1613 0.8720529    
## c:KAG  2.6217e-02  2.6722e-02   0.9811 0.3278833    
## c:KAN -1.5413e-02  4.1125e-02  -0.3748 0.7082690    
## c:KYO  4.1342e-02  2.5511e-02   1.6206 0.1069004    
## c:NVA  1.5390e-03  2.5899e-02   0.0594 0.9526839    
## c:OAK  2.3792e-02  1.6835e-02   1.4132 0.1593571    
## c:PBS  3.1982e-05          NA       NA        NA    
## c:SAG -5.2523e-03  2.6856e-02  -0.1956 0.8451701    
## c:SEN  2.5282e-02  3.5842e-02   0.7054 0.4815066    
## c:WAV  3.7110e-03  2.7647e-02   0.1342 0.8933750    
## c:FAY  2.4132e-02  2.3008e-02   1.0488 0.2956998    
## c:FEM  2.9058e-02  1.6864e-02   1.7231 0.0866336 .  
## c:JAC  3.0506e-02  2.3141e-02   1.3183 0.1891149    
## c:MAN  6.8924e-02  2.8611e-02   2.4090 0.0170272 *  
## c:NEW  6.9547e-03  4.3022e-02   0.1617 0.8717633    
## c:NIG  1.9634e-01  3.3390e-02   5.8801 2.016e-08 ***
## c:OKI  2.0712e-02  1.7894e-02   1.1575 0.2486282    
## c:TAK  3.2543e-02  4.8938e-02   0.6650 0.5069284    
## c:YAM  7.1317e-03  5.1585e-02   0.1383 0.8901995    
## c:YAT  1.8793e-02  2.2512e-02   0.8348 0.4049519    
## c:ZIO  5.2924e-02  2.7226e-02   1.9439 0.0535061 .  
## d:BER  9.8624e-01  2.4148e-02  40.8411 < 2.2e-16 ***
## d:BRU  7.5849e-01  3.0120e-02  25.1827 < 2.2e-16 ***
## d:KAG  9.4579e-01  2.5082e-02  37.7083 < 2.2e-16 ***
## d:KAN  9.7508e-01  2.4997e-02  39.0076 < 2.2e-16 ***
## d:KYO  9.7560e-01  2.1280e-02  45.8458 < 2.2e-16 ***
## d:NVA  9.7670e-01  2.1002e-02  46.5044 < 2.2e-16 ***
## d:OAK  3.8691e-01  2.9169e-02  13.2645 < 2.2e-16 ***
## d:PBS  8.0891e-01  8.0492e+00   0.1005 0.9200654    
## d:SAG  9.6611e-01  2.6415e-02  36.5738 < 2.2e-16 ***
## d:SEN  9.6483e-01  1.9238e-02  50.1515 < 2.2e-16 ***
## d:WAV  9.6361e-01  2.3009e-02  41.8800 < 2.2e-16 ***
## d:FAY  8.9327e-01  2.3082e-02  38.6989 < 2.2e-16 ***
## d:FEM  1.0383e-01  2.9205e-02   3.5553 0.0004850 ***
## d:JAC  7.6164e-01  3.4881e-02  21.8352 < 2.2e-16 ***
## d:MAN  9.9658e-01  2.2396e-02  44.4983 < 2.2e-16 ***
## d:NEW  1.0022e+00  2.4575e-02  40.7824 < 2.2e-16 ***
```

```
## d:NIG  9.9221e-01  2.1352e-02  46.4692 < 2.2e-16 ***
## d:OKI  2.7546e-01  2.6160e-02  10.5298 < 2.2e-16 ***
## d:TAK  9.6226e-01  2.1321e-02  45.1316 < 2.2e-16 ***
## d:YAM  9.7191e-01  2.2631e-02  42.9457 < 2.2e-16 ***
## d:YAT  9.2383e-01  3.2466e-02  28.4555 < 2.2e-16 ***
## d:ZIO  9.3888e-01  2.2719e-02  41.3251 < 2.2e-16 ***
## e:BER  1.3525e+01  1.9086e-01  70.8638 < 2.2e-16 ***
## e:BRU  1.3526e+01  4.8779e-01  27.7282 < 2.2e-16 ***
## e:KAG  1.3797e+01  4.0682e-01  33.9130 < 2.2e-16 ***
## e:KAN  1.4281e+01  8.3777e-01  17.0461 < 2.2e-16 ***
## e:KYO  1.3742e+01  2.2859e-01  60.1183 < 2.2e-16 ***
## e:NVA  1.3908e+01          NA       NA        NA
## e:OAK  1.2573e+01          NA       NA        NA
## e:PBS  2.6105e+00  1.1118e+01   0.2348 0.8146415
## e:SAG  1.3947e+01  3.6731e-01  37.9692 < 2.2e-16 ***
## e:SEN  1.4394e+01  4.1861e-01  34.3847 < 2.2e-16 ***
## e:WAV  1.3871e+01  4.1571e-01  33.3661 < 2.2e-16 ***
## e:FAY  1.3523e+01  2.0945e-01  64.5638 < 2.2e-16 ***
## e:FEM  1.2609e+01  1.2733e+00   9.9023 < 2.2e-16 ***
## e:JAC  1.3719e+01  8.1663e-01  16.7989 < 2.2e-16 ***
## e:MAN  1.4057e+01  6.0772e-01  23.1298 < 2.2e-16 ***
## e:NEW  1.4434e+01  5.5435e-01  26.0378 < 2.2e-16 ***
## e:NIG  1.4291e+01          NA       NA        NA
## e:OKI  1.2892e+01  1.7209e+00   7.4917 3.170e-12 ***
## e:TAK  1.3463e+01  1.8341e-01  73.4039 < 2.2e-16 ***
## e:YAM  1.3225e+01  1.3434e-01  98.4400 < 2.2e-16 ***
## e:YAT  1.3568e+01  3.3517e-01  40.4807 < 2.2e-16 ***
## e:ZIO  1.3036e+01  7.0520e-02 184.8510 < 2.2e-16 ***
## f:BER  6.4929e-01  5.4339e-01   1.1949 0.2337333
## f:BRU  6.4215e+00  1.0208e+01   0.6291 0.5301263
## f:KAG  3.7290e+00  5.5416e+00   0.6729 0.5018907
## f:KAN  3.9050e+00  7.5782e+00   0.5153 0.6069969
## f:KYO  2.8470e+00  3.2637e+00   0.8723 0.3842203
## f:NVA  3.4513e+00          NA       NA        NA
## f:OAK  6.0291e+00          NA       NA        NA
## f:PBS  4.8920e-01          NA       NA        NA
## f:SAG  4.8363e+00  5.1857e+00   0.9326 0.3522913
## f:SEN  6.1926e+00  1.1883e+01   0.5211 0.6029218
## f:WAV  3.1196e+00  7.1830e+00   0.4343 0.6646001
## f:FAY  2.6988e+00  2.8514e+00   0.9465 0.3452086
## f:FEM  6.2470e+00  2.1883e+02   0.0285 0.9772576
## f:JAC  5.7799e+00  8.6726e+00   0.6665 0.5059912
## f:MAN  5.2375e+00  1.1796e+01   0.4440 0.6575852
## f:NEW  3.7625e+00  4.2953e+00   0.8760 0.3822477
## f:NIG  8.0606e+00          NA       NA        NA
## f:OKI  9.3468e+00  1.9285e+02   0.0485 0.9614000
## f:TAK  1.4215e-01  8.8407e-01   0.1608 0.8724429
## f:YAM  2.0305e-01  2.7776e-01   0.7310 0.4657325
## f:YAT  4.9822e+00  6.2436e+00   0.7980 0.4259679
## f:ZIO  2.5220e-01  2.2694e-01   1.1113 0.2679542
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error:
```

```
##
##  0.05052736 (176 degrees of freedom)
```

```
# estimate the 50% intercept
ED(d.model.fit.2008, 50)
```

```
##
## Estimated effective doses
##
##             Estimate Std. Error
## e:AIZ:50 13.806582   0.094648
## e:BER:50 13.385906   0.106289
## e:BRU:50 12.680203   0.042773
## e:FAY:50 13.115362   0.051960
## e:FEM:50 12.460949   0.763928
## e:HIR:50 13.109018   0.095792
## e:JAC:50 12.676583   0.079645
## e:KAG:50 13.289087   0.068472
## e:KHO:50 13.397439   0.059210
## e:MAN:50 13.387414   0.098544
## e:NEW:50 13.803646   0.127020
## e:NVA:50 13.101533   0.074561
## e:OAK:50 12.306981   0.116486
## e:SAK:50 13.666097   0.074481
## e:SHI:50 13.118710   0.118779
## e:TAN:50 12.651265   0.095153
## e:TOK:50 13.292825   0.041599
## e:UTS:50 13.586773   0.043814
## e:WAV:50 13.433493   0.087641
```

```
cpp_values_2008<-data.frame(ED(d.model.fit.2008, 50))
```


```
##
## Estimated effective doses
##
##             Estimate Std. Error
## e:AIZ:50 13.806582   0.094648
## e:BER:50 13.385906   0.106289
## e:BRU:50 12.680203   0.042773
## e:FAY:50 13.115362   0.051960
## e:FEM:50 12.460949   0.763928
## e:HIR:50 13.109018   0.095792
## e:JAC:50 12.676583   0.079645
## e:KAG:50 13.289087   0.068472
## e:KHO:50 13.397439   0.059210
## e:MAN:50 13.387414   0.098544
## e:NEW:50 13.803646   0.127020
## e:NVA:50 13.101533   0.074561
## e:OAK:50 12.306981   0.116486
## e:SAK:50 13.666097   0.074481
## e:SHI:50 13.118710   0.118779
## e:TAN:50 12.651265   0.095153
## e:TOK:50 13.292825   0.041599
```

```
## e:UTS:50 13.586773   0.043814
## e:WAV:50 13.433493   0.087641
```

#Combine and format CPP value tables from 1988, 2008 and 2018

```r
cpp_2019<-data.frame(ED(d.model.fit, 50))
```

```
##
## Estimated effective doses
##
##            Estimate Std. Error
## e:BER:50 13.634739   0.037667
## e:BRU:50 12.982262   0.044682
## e:FAY:50 13.347562   0.027659
## e:FEM:50 12.515233   0.169317
## e:JAC:50 12.853335   0.068114
## e:KAG:50 13.459766   0.032242
## e:KAN:50 13.726218   0.044296
## e:KYO:50 13.556308   0.025833
## e:MAN:50 13.635184   0.032150
## e:NEW:50 13.832184   0.049731
## e:NIG:50 13.836928   0.034698
## e:NVA:50 13.616051   0.026960
## e:OAK:50 12.500115   0.015293
## e:OKI:50 12.707540   0.062737
## e:PBS:50  3.380362  15.121018
## e:SAG:50 13.432878   0.036573
## e:SEN:50 14.014999   0.028215
## e:TAK:50 13.656812   0.073857
## e:WAV:50 13.684416   0.023425
## e:YAM:50 13.527382   0.046699
## e:YAT:50 13.212448   0.033473
## e:ZIO:50 13.177073   0.030279
```

```r
cpp_2019<-rownames_to_column(cpp_2019, var="pop")
cpp_2019$pop<-str_sub(cpp_2019$pop,3,5)
popdata_2019<-DI_summary %>% group_by(pop) %>%
  summarize(lat=first(lat), country=first(country))
cpp_2019<-right_join(cpp_2019, popdata_2019, by="pop")
```

```
## Warning: Column `pop` joining character vector and factor, coercing into
## character vector
```

```r
#drop PBS from this list for now; CPP estimate doesn't make sense
cpp_2019<-filter(cpp_2019, pop!="PBS")
cpp_2019$year<-rep("2019", nrow(cpp_2019))

cpp_2008<-data.frame(ED(d.model.fit.2008, 50)) %>% rownames_to_column(var="pop")
```

```
##
## Estimated effective doses
##
```

```
##           Estimate Std. Error
## e:AIZ:50 13.806582   0.094648
## e:BER:50 13.385906   0.106289
## e:BRU:50 12.680203   0.042773
## e:FAY:50 13.115362   0.051960
## e:FEM:50 12.460949   0.763928
## e:HIR:50 13.109018   0.095792
## e:JAC:50 12.676583   0.079645
## e:KAG:50 13.289087   0.068472
## e:KHO:50 13.397439   0.059210
## e:MAN:50 13.387414   0.098544
## e:NEW:50 13.803646   0.127020
## e:NVA:50 13.101533   0.074561
## e:OAK:50 12.306981   0.116486
## e:SAK:50 13.666097   0.074481
## e:SHI:50 13.118710   0.118779
## e:TAN:50 12.651265   0.095153
## e:TOK:50 13.292825   0.041599
## e:UTS:50 13.586773   0.043814
## e:WAV:50 13.433493   0.087641
```

```
cpp_2008$pop<-str_sub(cpp_2008$pop,3,5)
popdata_2008<-DI_summary_2008 %>% group_by(POP) %>%
  summarize(lat=first(LAT), country=first(COUNTRY), year=first(YEAR))
colnames(popdata_2008)[1]<-"pop"
cpp_2008<-right_join(cpp_2008, popdata_2008, by="pop")
```

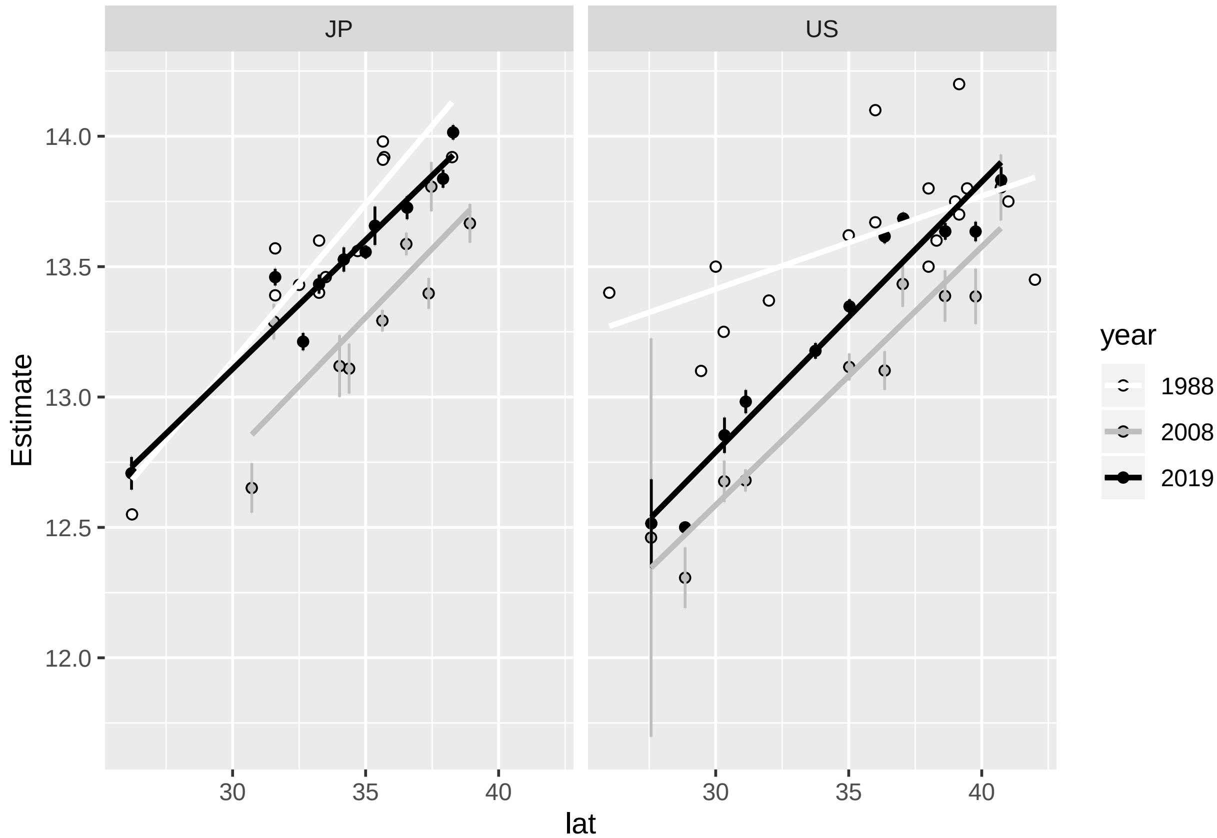
```
## Warning: Column `pop` joining character vector and factor, coercing into
## character vector
```

```
cpp_1988<-data.frame(read.csv("CPP_1988.csv"))
cpp_1988$pop<-na_if(cpp_1988$pop, "NA")
cpp_1988$Std..Error<-na_if(cpp_1988$Std..Error, "NA")


cpp_2<-rbind(cpp_1988, cpp_2008, cpp_2019)
```

CPP by country and latitude

```
ggplot(cpp_2, aes(x=lat, y=Estimate, fill=year, color=year)) +
  scale_color_manual(values=c("white","gray","black")) +
  scale_fill_manual(values=c("white","gray","black"))+
  geom_point(shape=21, color="black") +
  geom_errorbar(aes(ymin=Estimate-Std..Error, ymax=Estimate+Std..Error), na.rm=TRUE) +
  facet_grid(~country) + stat_smooth(method=lm, se=FALSE)
```



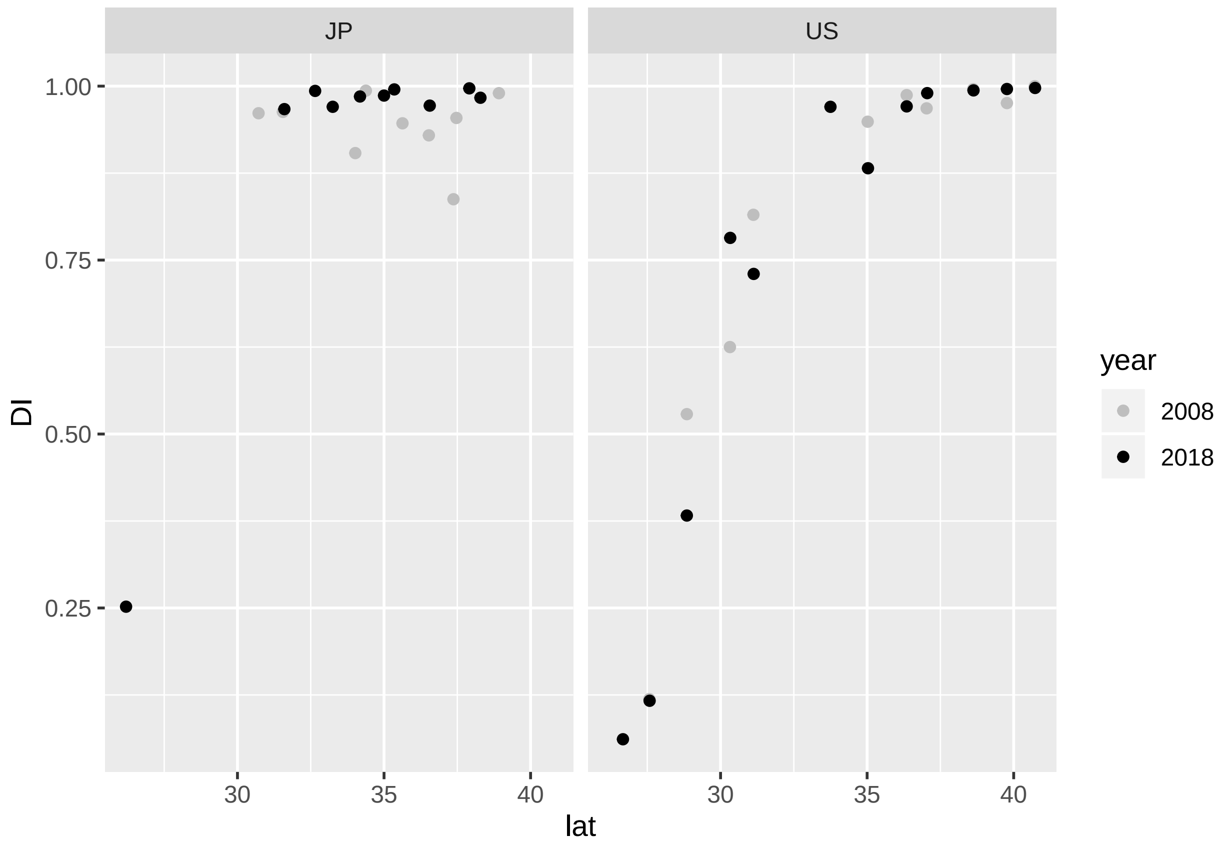

```
ggplot(cpp_2, aes(x=lat, y=Estimate, color=country)) +
  geom_point() +
  geom_errorbar(aes(ymin=Estimate-Std..Error, ymax=Estimate+Std..Error), na.rm=TRUE) +
  facet_grid(~year) + stat_smooth(method=lm, se=FALSE)
```


```
DI_short_2008<-filter(DI_summary_2008, PP==8)
names(DI_short_2008)<-c("pop","country","lat","pp","year","DI")

DI_short_2018<-filter(DI_summary, pp==8) %>% group_by(pop) %>%
  summarize(country=first(country), lat=first(lat), pp=first(pp), emb=sum(emb), total=sum(total))
DI_short_2018$DI<-DI_short_2018$emb/DI_short_2018$total
DI_short_2018<-DI_short_2018[,c(1:4,7)]
DI_short_2018$year<-rep("2018",nrow(DI_short_2018))
DI_short_2018<-DI_short_2018[,c(1,2,3,4,6,5)]

DI_short_2<-rbind(DI_short_2008, DI_short_2018)

ggplot(DI_short_2, aes(x=lat, y=DI, color=year)) + scale_color_manual(values=c("gray","black")) + geom_p
```


JP
US
DI
1.00
0.75
0.50
0.25
30
35
40
lat
year
2008
2018