

Seminoff EPac green turtle Stable Isotope Data Analysis

Lisa Komoroske

2016-12-14

Metadata from Jeff

Site - an ordinal code for each site

Site code - 3 letter code for each site

Location - location of turtle capture

LAB ID - self explanatory

Collection Date - self explanatory

Run Date - self explanatory

%N - elemental concentration of N. that is, how much each sample is made up of nitrogen. this is used as a diagnostic to know sample quality (anything outside of ~9-17% N raises a red flag)

%C - elemental concentration of C. that is, how much each sample is made up of carbon. this is used as a diagnostic to know sample quality (anything outside of ~40-60% C raises a red flag)

d15N - stable isotope value for N

d13C - stable isotope value for C

Color - rarely filled in. This is largely for the Galapagos and Colombia, where black turtles (eastern Pacific stock) and yellow turtles (west pacific origins) co-exist. Safe to say that anything that is not filled in here would be a 'black' morph.

SCL - straight carapace length

CCL - curved carapace length

Setup (code/output silenced)

Load Required Libraries (code/output silenced)

Read in data (code/output silenced)

Coarse data QC checks to note obvious data structure problems, etc.:

str(data) *#all look like appropriate categories*

```
## 'data.frame': 718 obs. of 17 variables:
```

```
## $ SITE_No : int 1 1 1 1 1 1 1 1 1 1 ...
```

```
## $ SITE_CODE : Factor w/ 22 levels "BLA","BMA","CIN",...: 22 22 22 22 22 22 22 22 22 22 ...
```

```
## $ Ordered_SITE: Factor w/ 22 levels "1-SGR","2-SBN",...: 1 1 1 1 1 1 1 1 1 1 ...
```

```
## $ Habitat_Type: Factor w/ 3 levels "coastal","insular",...: 1 1 1 1 1 1 1 1 1 1 ...
```

```
## $ Location      : Factor w/ 22 levels "Bahia de los Angeles, Gulf of California, Mexico",...: 21 2
1 21 21 21 21 21 21 21 21 ...
## $ LABID         : Factor w/ 718 levels "101","102","103",...: 640 148 149 150 162 163 164 168 175
176 ...
## $ Collect_Date: POSIXlt, format: "2010-06-18" "2011-07-14" ...
## $ Run_Date     : POSIXlt, format: NA "2014-02-09" ...
## $ Percent_N    : num  15.9 15.7 15.2 15.5 14.7 15.2 15.4 16.4 17 14.9 ...
## $ Percent_C    : num  45.6 45.5 47 45.4 47 46.5 45.3 45.7 46.7 45.4 ...
## $ d15N         : num  15.4 15.8 15.6 16 18.1 15.3 16.8 16.5 17.1 18.8 ...
## $ d13C         : num  -16.8 -15.1 -15.6 -14.4 -13.3 -18.9 -13.7 -16 -15.8 -17.9 ...
## $ COLOR        : Factor w/ 3 levels "", "BLACK", "YELLOW": 1 1 1 1 1 1 1 1 1 1 ...
## $ SCL          : num  44 57.6 54.3 63.2 96.8 71.1 66.1 NA 54.8 53.6 ...
## $ CCL          : num  46.9 62.6 59.3 67.2 101 76.8 69.6 60.6 61.8 56.2 ...
## $ Alt.ID       : Factor w/ 104 levels "", " ", "100", "105",...: 1 1 1 1 1 1 1 1 1 1 ...
## $ Notes        : Factor w/ 3 levels "", " ", "no measurements taken, confirmed in SDB Binder": 1 1
...
```

```
dim(data)
```

```
## [1] 718 17
```

```
head(data)
```

```
## SITE_No SITE_CODE Ordered_SITE Habitat_Type Location LABID
## 1 1 SGR 1-SGR coastal San Gabriel River 94379
## 2 1 SGR 1-SGR coastal San Gabriel River 106875
## 3 1 SGR 1-SGR coastal San Gabriel River 106876
## 4 1 SGR 1-SGR coastal San Gabriel River 106877
## 5 1 SGR 1-SGR coastal San Gabriel River 108450
## 6 1 SGR 1-SGR coastal San Gabriel River 108451
## Collect_Date Run_Date Percent_N Percent_C d15N d13C COLOR SCL CCL
## 1 2010-06-18 <NA> 15.9 45.6 15.4 -16.8 44.0 46.9
## 2 2011-07-14 2014-02-09 15.7 45.5 15.8 -15.1 57.6 62.6
## 3 2011-07-14 2014-02-09 15.2 47.0 15.6 -15.6 54.3 59.3
## 4 2011-08-18 2014-02-09 15.5 45.4 16.0 -14.4 63.2 67.2
## 5 2012-06-19 2014-02-09 14.7 47.0 18.1 -13.3 96.8 101.0
## 6 2012-06-19 2014-02-09 15.2 46.5 15.3 -18.9 71.1 76.8
```

```
tail(data) #got rid of some NAs at end, now should be good
```

```
## SITE_No SITE_CODE Ordered_SITE Habitat_Type
## 713 24 PPE 24-PPE oceanic
```

##	714	24	PPE	24-PPE	oceanic		
##	715	24	PPE	24-PPE	oceanic		
##	716	24	PPE	24-PPE	oceanic		
##	717	24	PPE	24-PPE	oceanic		
##	718	24	PPE	24-PPE	oceanic		
##				Location	LABID	Collect_Date	Run_Date Percent_N
##	713	Oceanic Waters, Peru (Longline)	87310	2009-02-09	<NA>		14.5
##	714	Oceanic Waters, Peru (Longline)	87312	2009-02-12	<NA>		11.6
##	715	Oceanic Waters, Peru (Longline)	87313	2009-02-13	<NA>		12.0
##	716	Oceanic Waters, Peru (Longline)	87316	2009-02-06	<NA>		10.0
##	717	Oceanic Waters, Peru (Longline)	87317	2009-02-06	<NA>		14.4
##	718	Oceanic Waters, Peru (Longline)	87319	2009-02-16	<NA>		14.2
##		Percent_C d15N d13C COLOR SCL CCL Alt.ID Notes					
##	713	42.4 11.4 -15.9	NA	NA			
##	714	36.3 12.3 -16.2	NA	NA			
##	715	34.9 12.6 -17.0	NA	NA			
##	716	27.4 13.0 -15.5	NA	NA			
##	717	41.1 12.9 -15.4	NA	NA			
##	718	44.3 11.5 -15.6	NA	NA			

summary(data)

##	SITE_No	SITE_CODE	Ordered_SITE	Habitat_Type
##	Min. : 1.00	SDB : 90	3-SDB : 90	coastal:366
##	1st Qu.: 9.00	GOR : 76	18-GOR : 76	insular:277
##	Median :15.00	PPE : 75	24-PPE : 75	oceanic: 75
##	Mean :13.81	DUL : 74	13-DUL : 74	
##	3rd Qu.:19.00	COC : 67	17-COC : 67	
##	Max. :24.00	BLA : 53	9-BLA : 53	
##		(Other):283	(Other):283	
##			Location	LABID
##	San Diego Bay, United States	: 90	101	: 1
##	Isla Gorgona, Colombia	: 76	102	: 1
##	Oceanic Waters, Peru (Longline)	: 75	103	: 1
##	Golfo Dulce, Costa Rica	: 74	104	: 1
##	Cocos Island, Costa Rica	: 67	105087	: 1
##	Bahia de los Angeles, Gulf of California, Mexico	: 53	105088	: 1
##	(Other)	:283	(Other):712	
##	Collect_Date		Run_Date	
##	Min. :1990-03-31 00:00:00	Min. :2003-01-17 00:00:00		
##	1st Qu.:2004-08-30 00:00:00	1st Qu.:2005-02-01 00:00:00		

```
## Median :2006-12-05 00:00:00 Median :2007-06-12 00:00:00
## Mean   :2007-09-13 16:14:06 Mean   :2007-09-17 17:31:54
## 3rd Qu.:2010-10-12 00:00:00 3rd Qu.:2007-08-09 00:00:00
## Max.    :2014-08-06 00:00:00 Max.    :2014-02-10 00:00:00
## NA's    :33 NA's    :404
## Percent_N Percent_C d15N d13C
## Min.      : 0.00 Min.      : 0.00 Min.      : 4.50 Min.      : -25.50
## 1st Qu.:11.45 1st Qu.:37.60 1st Qu.:11.72 1st Qu.: -16.80
## Median :13.10 Median :42.10 Median :13.50 Median : -15.90
## Mean    :12.66 Mean    :40.53 Mean    :13.60 Mean    : -15.84
## 3rd Qu.:14.70 3rd Qu.:45.10 3rd Qu.:15.38 3rd Qu.: -14.90
## Max.    :21.00 Max.    :65.70 Max.    :21.20 Max.    : -8.10
## NA's    :87 NA's    :87
## COLOR SCL CCL Alt.ID
## :642 Min.      : 39.70 Min.      : 38.30 :589
## BLACK : 29 1st Qu.: 55.85 1st Qu.: 64.00 Alt ID : 24
## YELLOW: 47 Median : 64.60 Median : 74.90 : 4
## Mean    : 68.18 Mean    : 74.76 100 : 1
## 3rd Qu.: 75.90 3rd Qu.: 82.00 105 : 1
## Max.    :110.40 Max.    :116.50 106 : 1
## NA's    :387 NA's    :310 (Other): 98
```

table(data\$SITE_CODE,data\$Habitat_Type) *#frequency table, note some sites have few samples*

```
## coastal insular oceanic
## BLA 53 0 0
## BMA 30 0 0
## CIN 28 0 0
## COC 0 67 0
## DUL 74 0 0
## ESC 10 0 0
## GOR 0 76 0
## IGD 0 37 0
## IGE 0 37 0
## IGN 0 3 0
## IGP 0 42 0
## IGZ 0 6 0
## IPD 1 0 0
## ISL 0 9 0
## LOR 1 0 0
## LSI 12 0 0
## MEJ 21 0 0
```

```
##    PAR      21      0      0
##    PPE       0      0     75
##    SBN       6      0      0
##    SDB      90      0      0
##    SGR      19      0      0
```

#found/fixed formatting issues, all good to move forward

N.B. 87 entries are missing percent N or C, but have the delta N and C-follow up with Jeff/Joel if this is an issue given that these are variables to check sample quality (see metadata above)

SI data specific QC checks

#Are all the samples unique/any issues of duplicates?

```
length(unique(data$LABID))
```

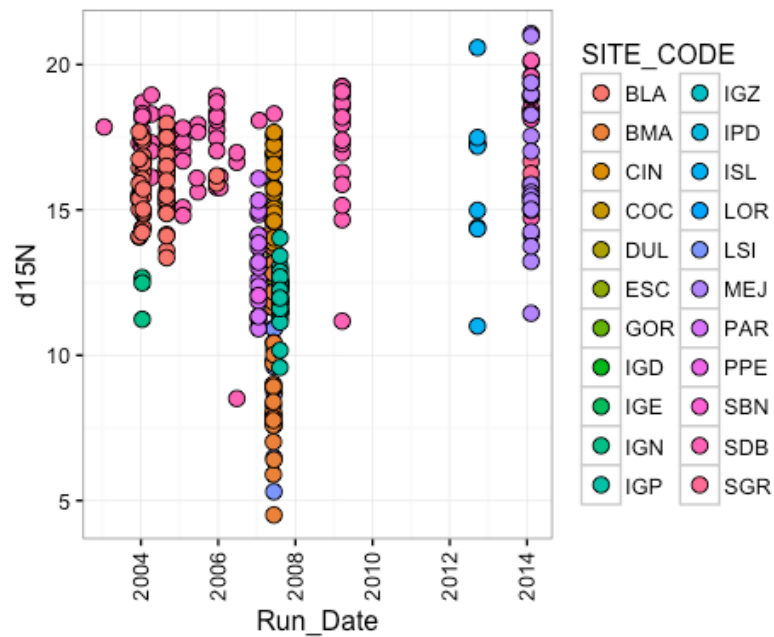
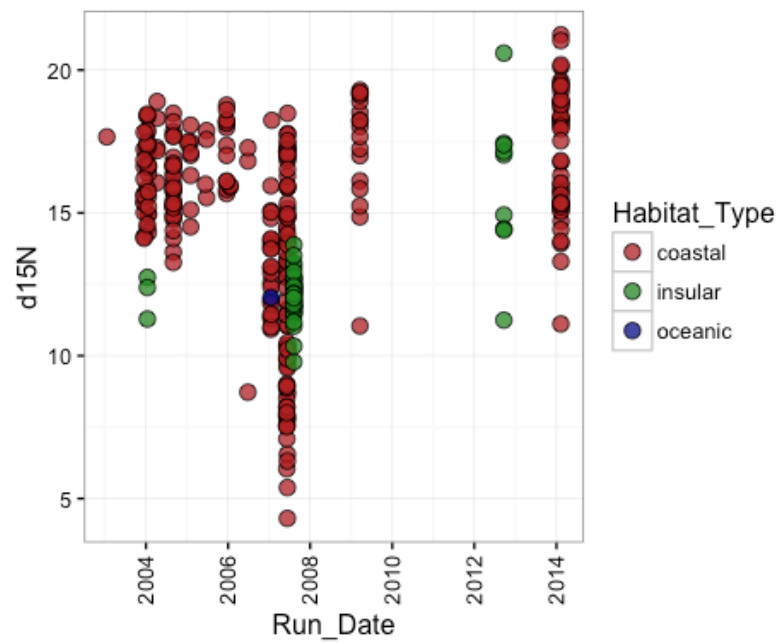
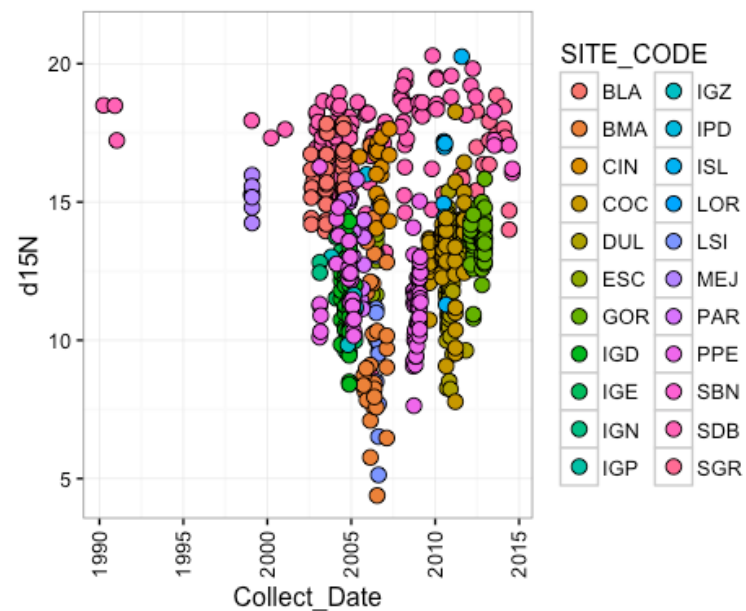
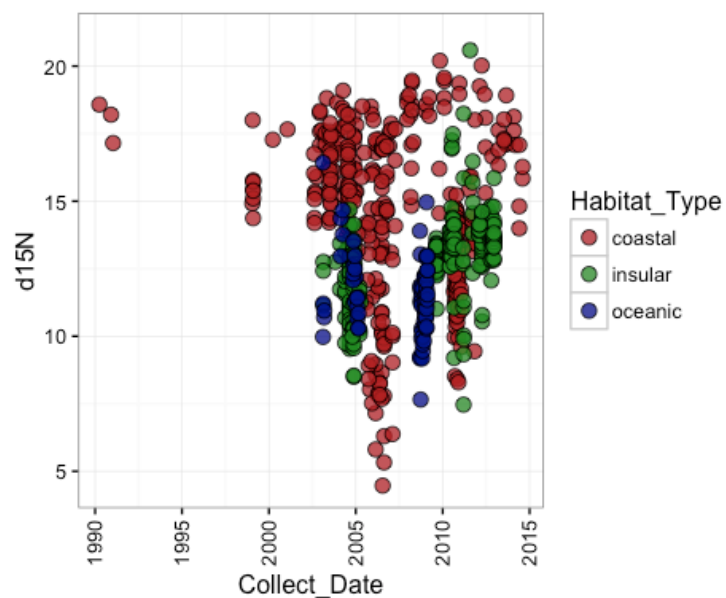
```
## [1] 718
```

```
length(data$LABID)
```

```
## [1] 718
```

#all good

#Any issues with confounding dates of collection or run?

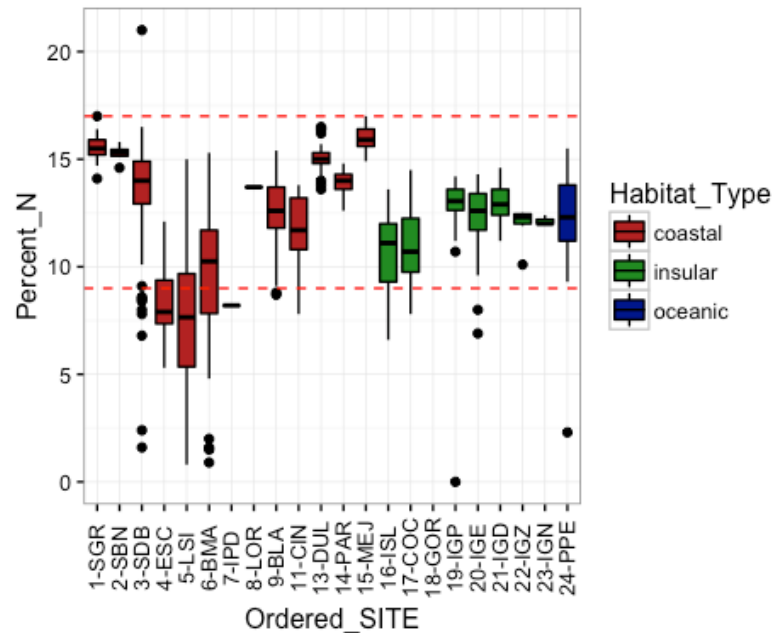
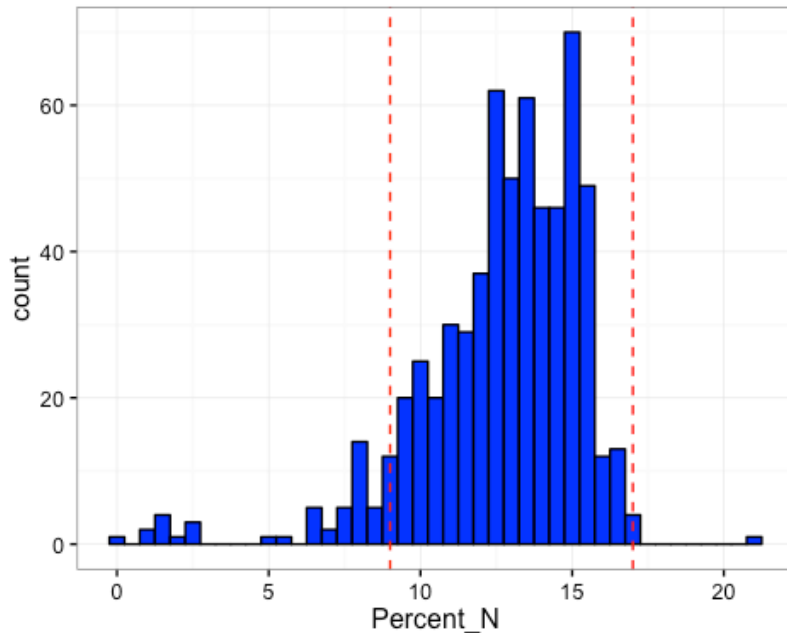


##Are any samples of suspect quality?

####Percent N: anything outside of ~9-17% N raises a red flag

```
summary(data$Percent_N)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.     NA's
##      0.00   11.45   13.10   12.66   14.70   21.00      87
```



```
length(which(data_noNAs$Percent_N<9))
```

```
## [1] 48
```

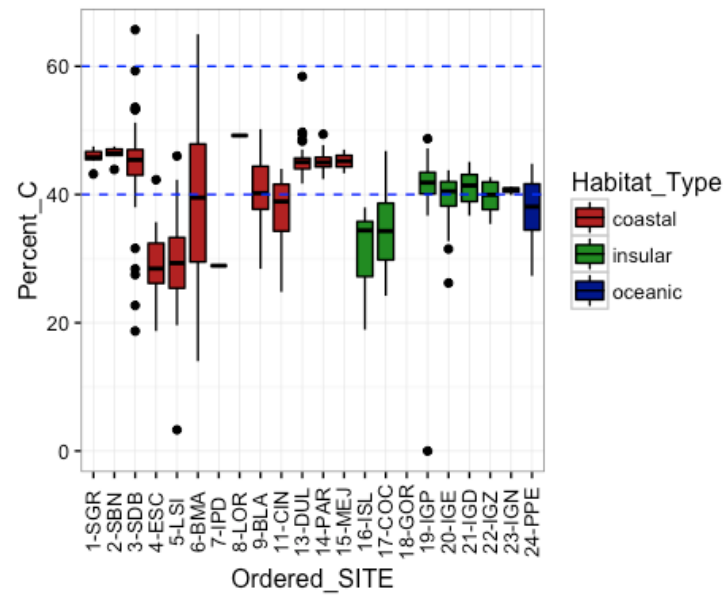
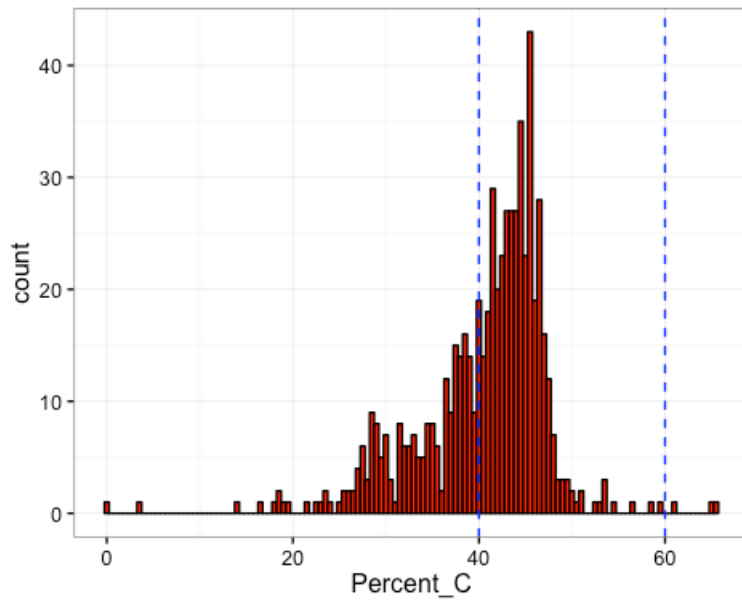
```
length(which(data_noNAs$Percent_N>17))
```

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

Percent C: anything outside of ~40-60% C raises a red flag

```
summary(data$Percent_C)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.     NA's
##      0.00   37.60   42.10   40.53   45.10   65.70      87
```



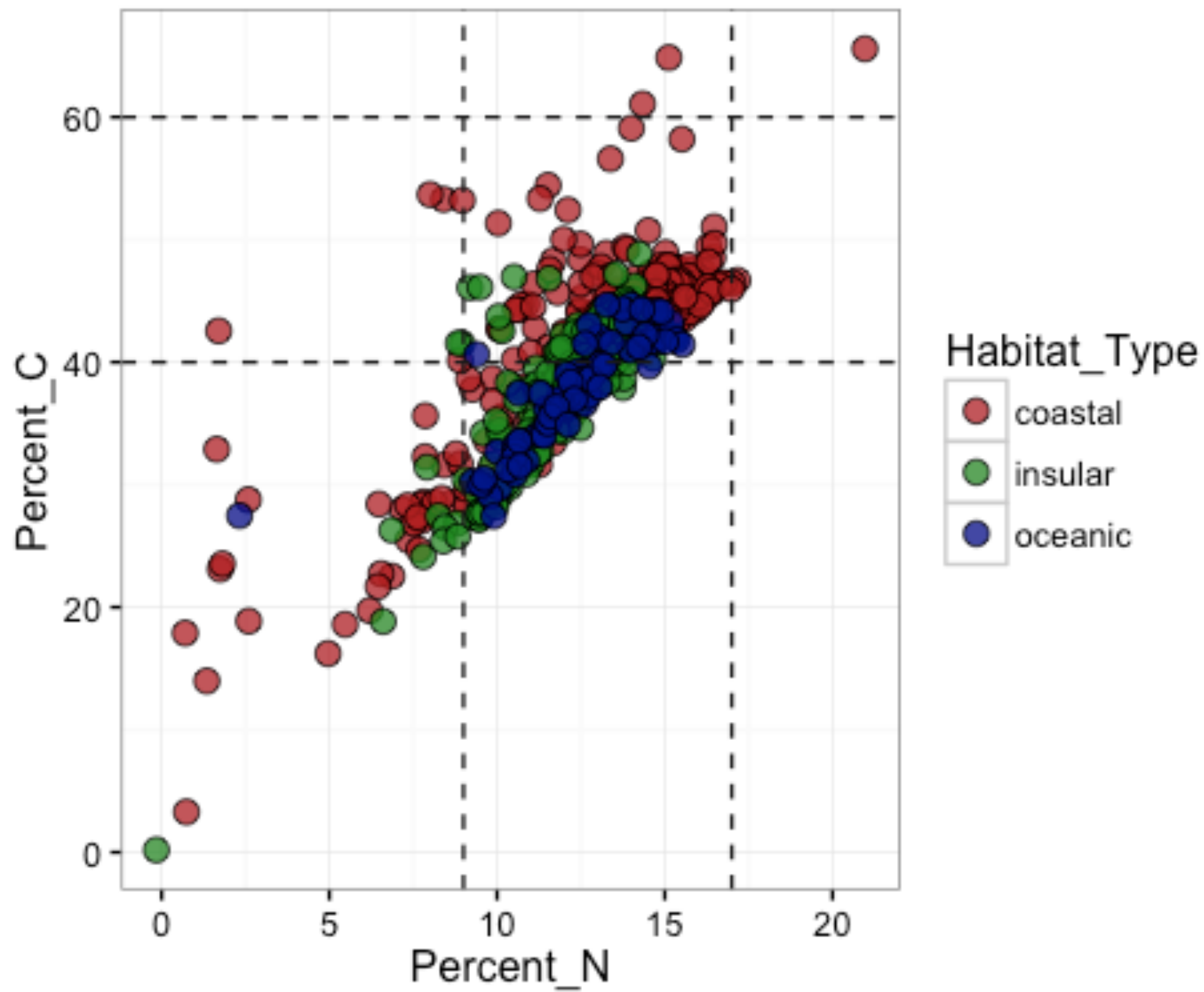
```
length(which(data_noNAs$Percent_C<39))
```

```
## [1] 202
```

```
length(which(data_noNAs$Percent_C>61))
```

```
## [1] 2
```

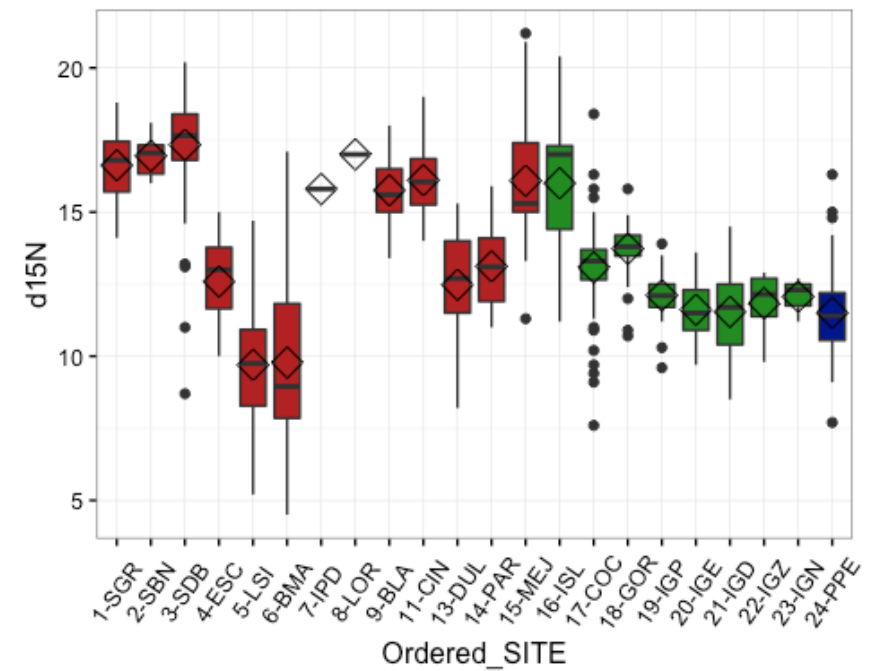
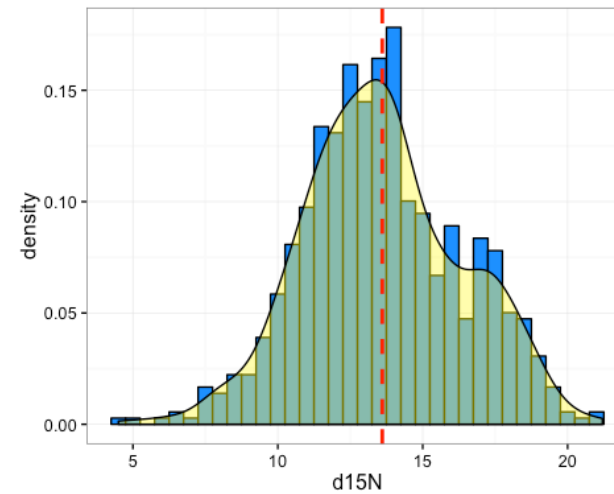
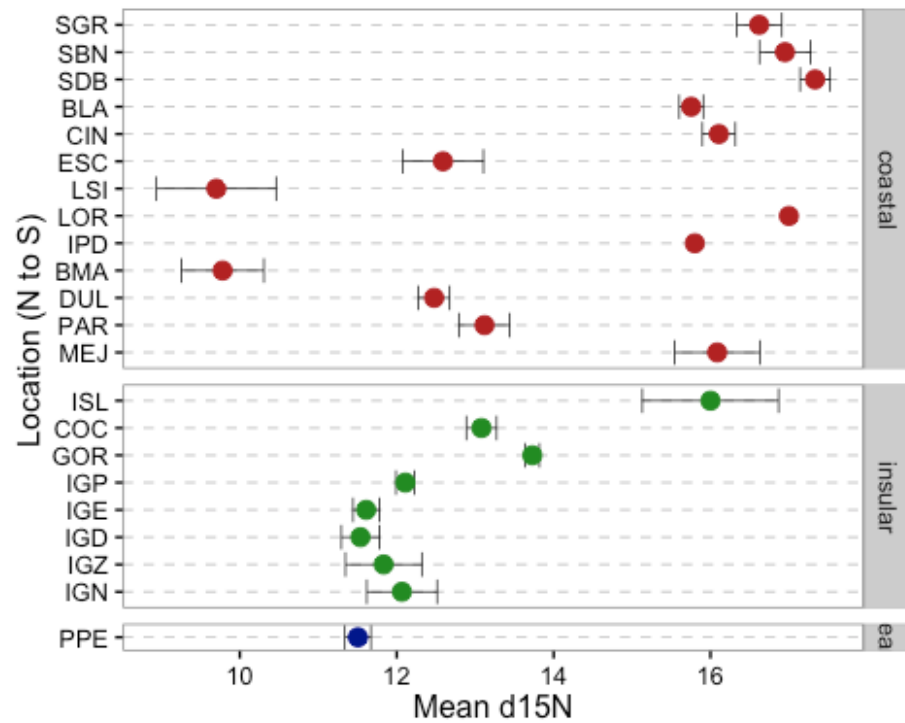

Percent C vs. Percent N: are the samples 'bad' values for both?

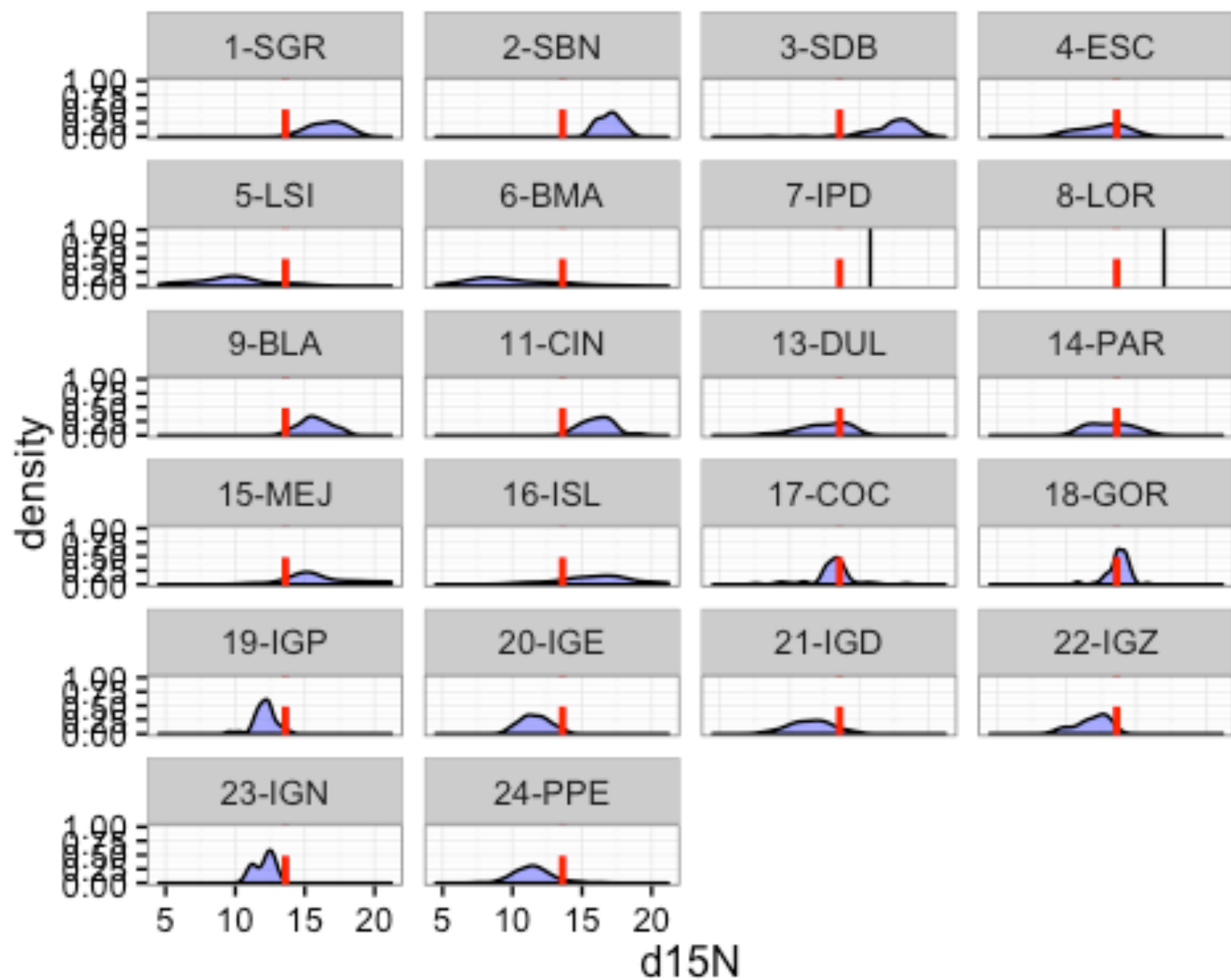


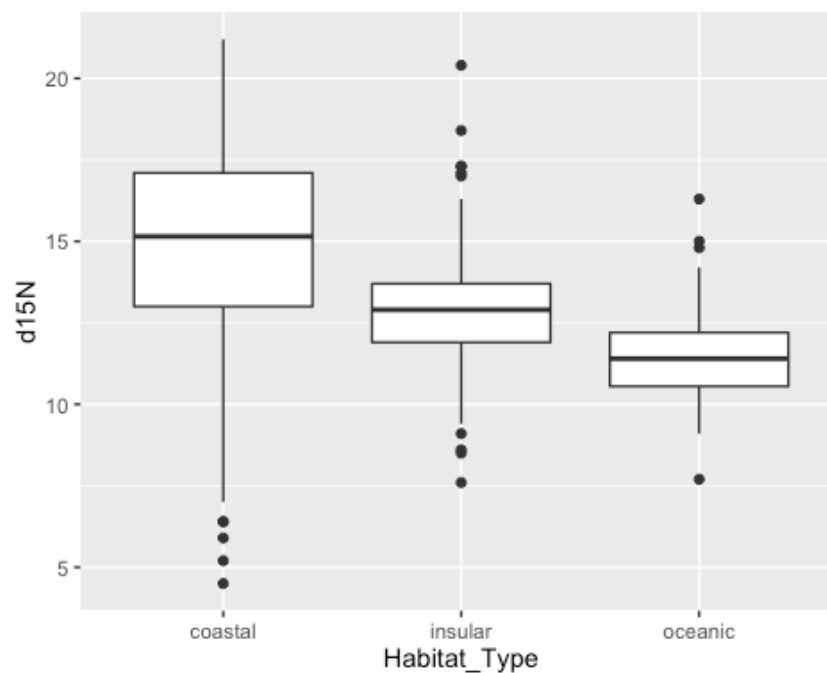
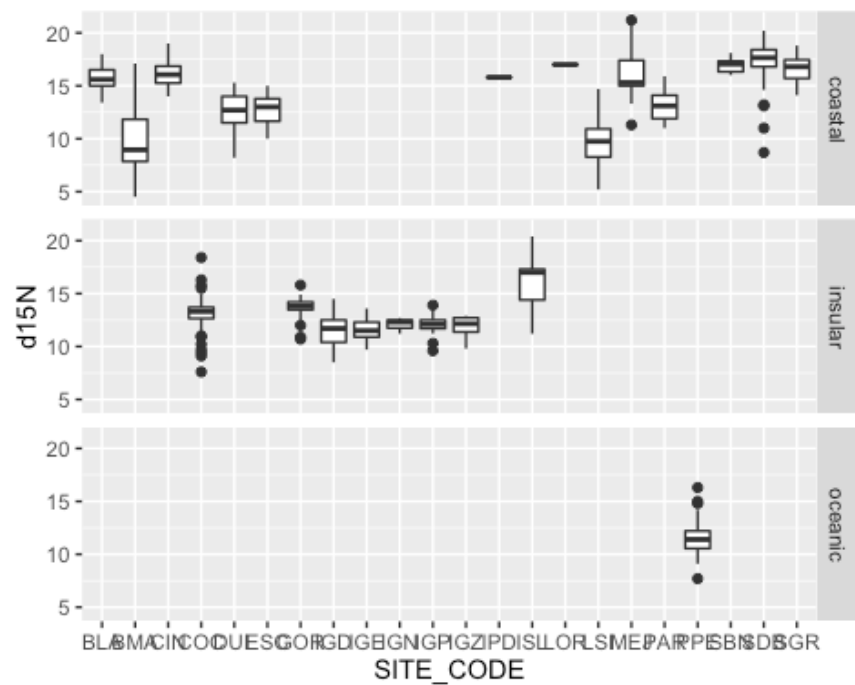
need to follow up with Jeff to determine what to do about samples that don't pass the QC criteria?

Initial Data exploration for delta C and N Ggplot univariate & bivariate graphic scans etc

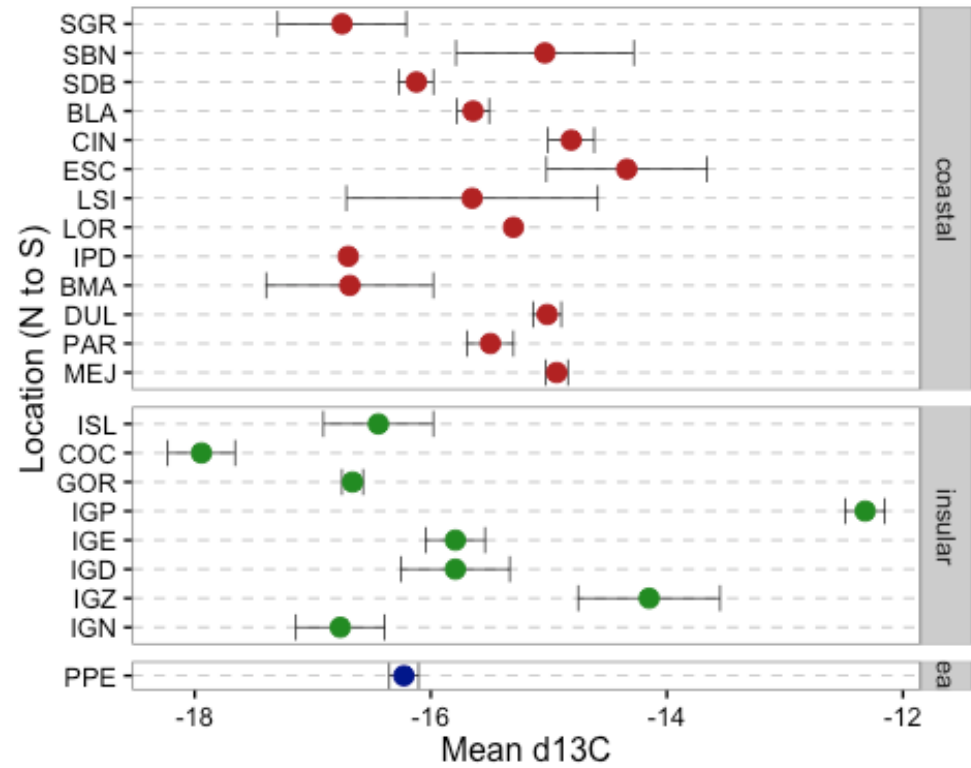
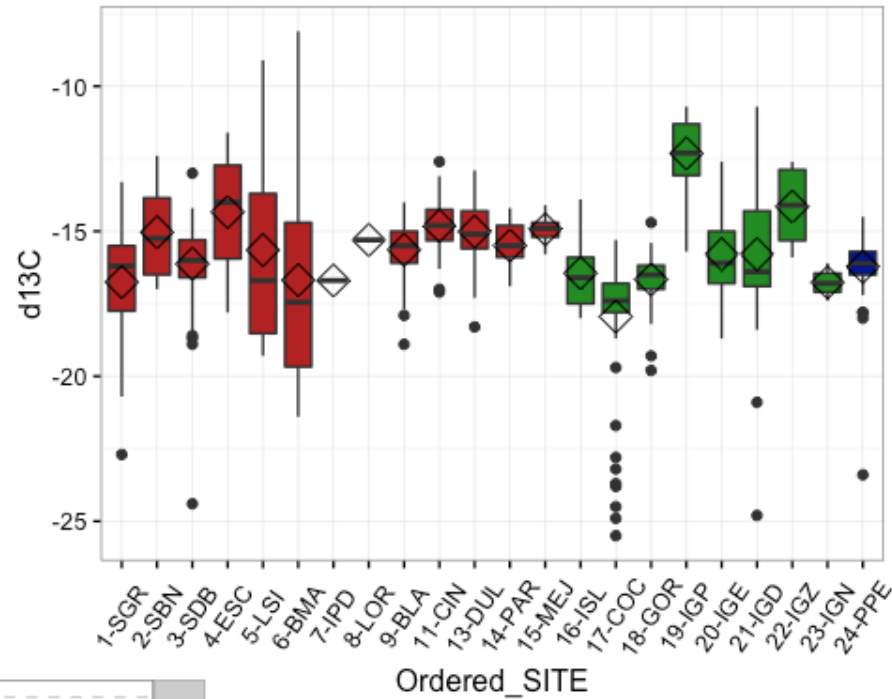
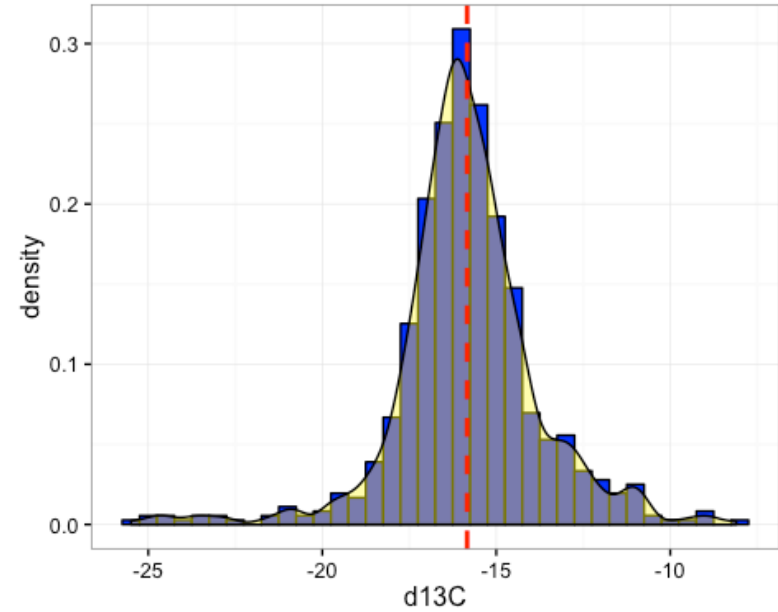
1. Nitrogen

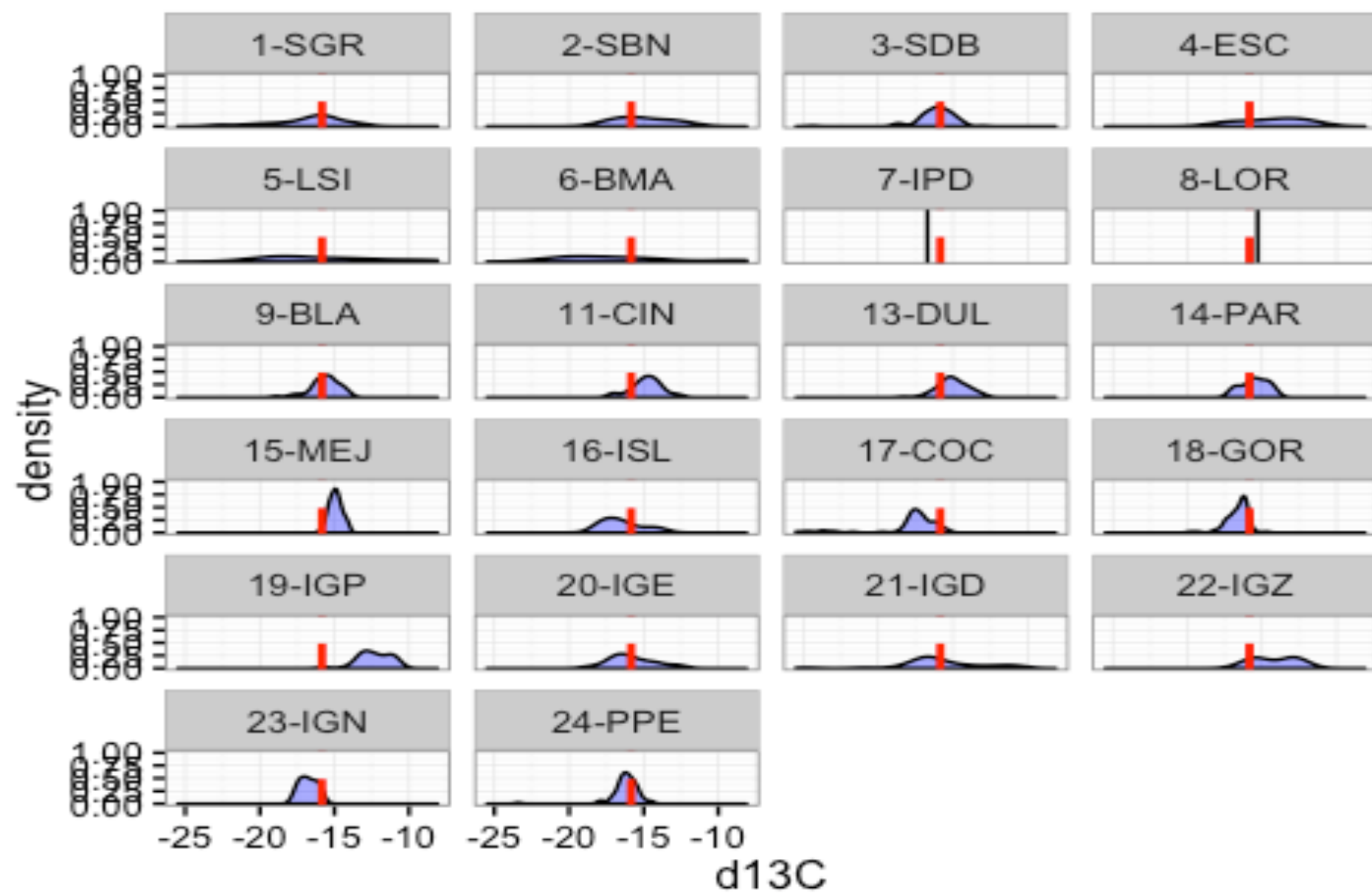


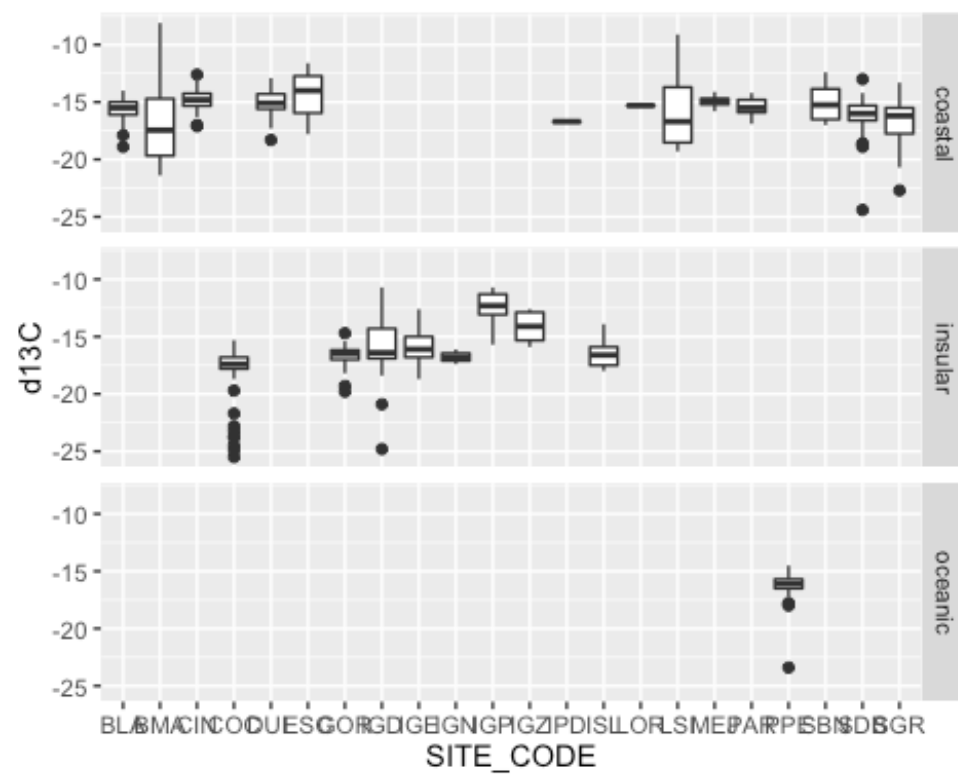
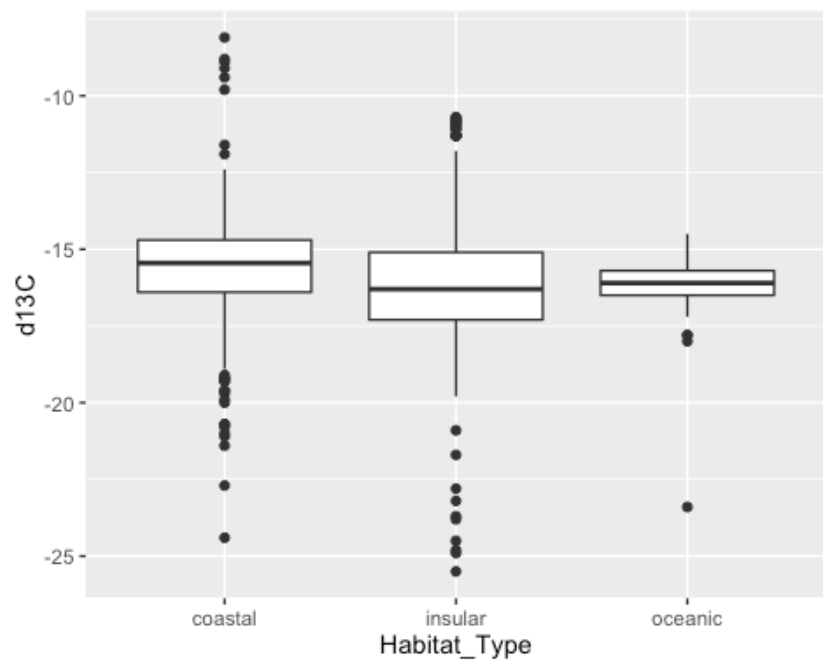




Carbon

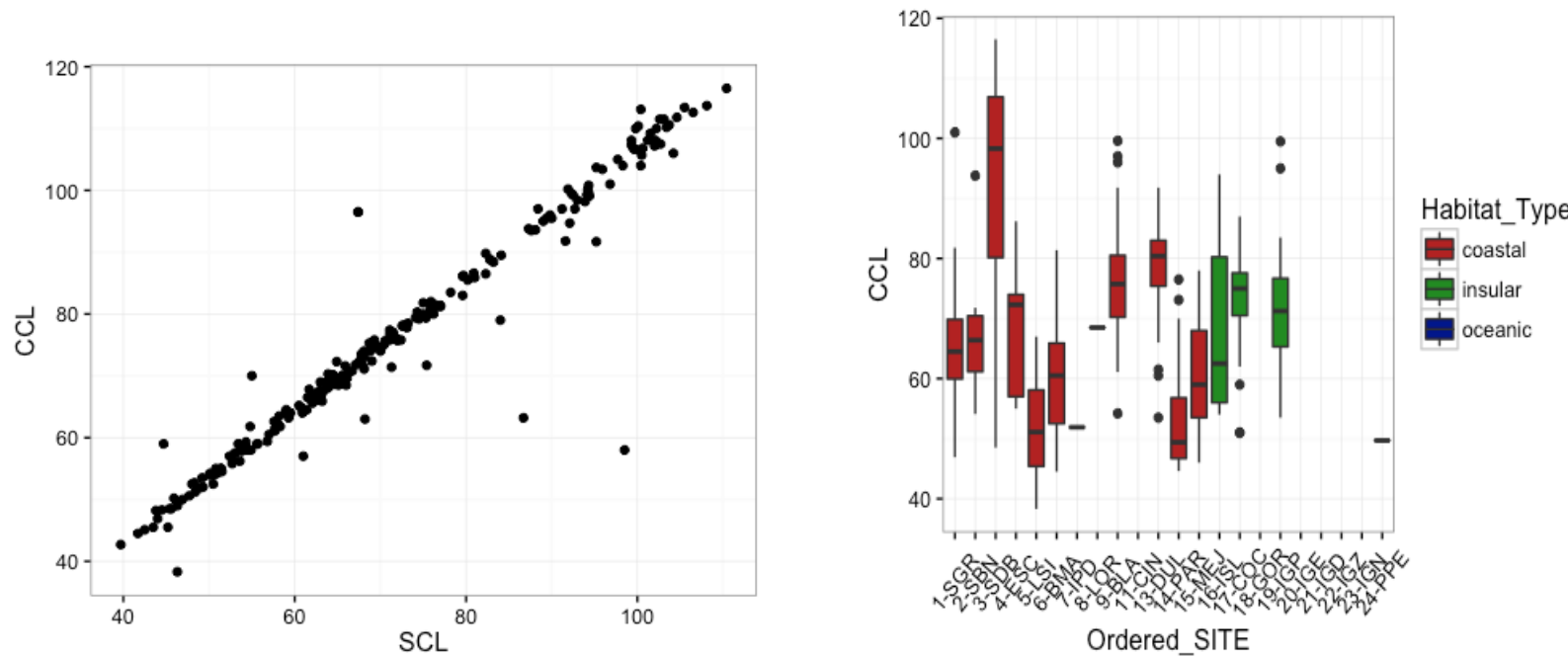






Any relationships/confounding issues with Turtle Size?

duh-but maybe double check the few that are way out there off the line?



```
sum(!is.na(data$SCL))
```

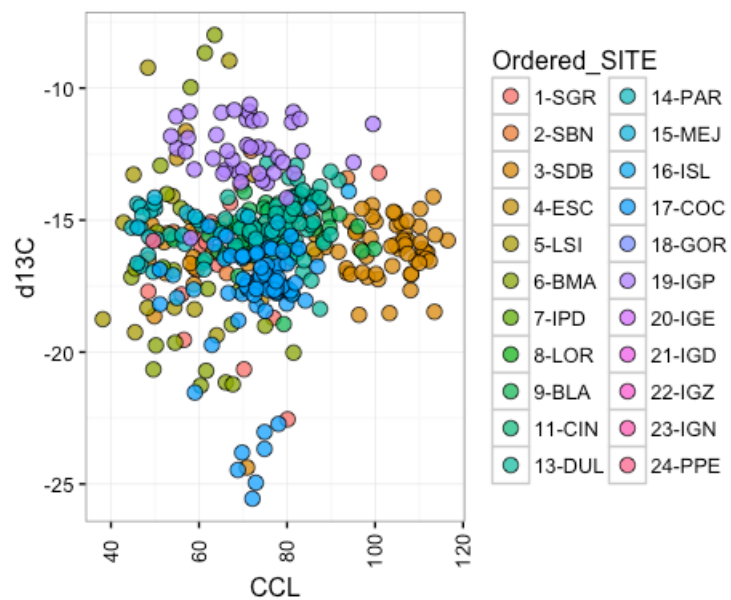
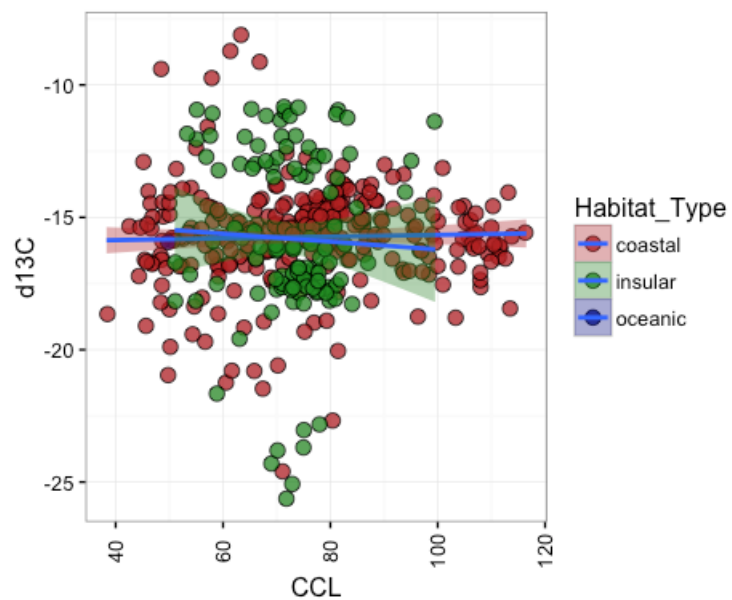
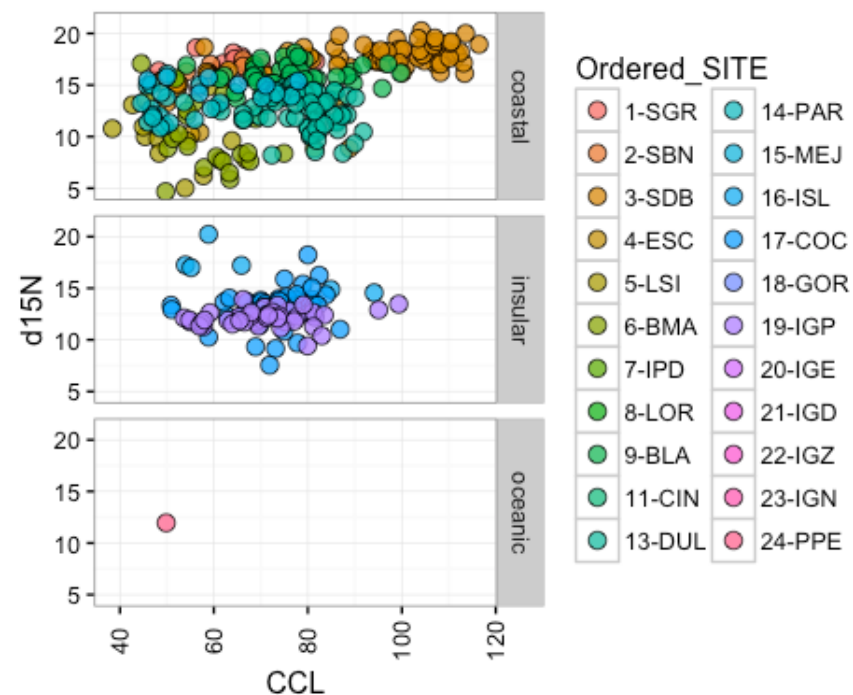
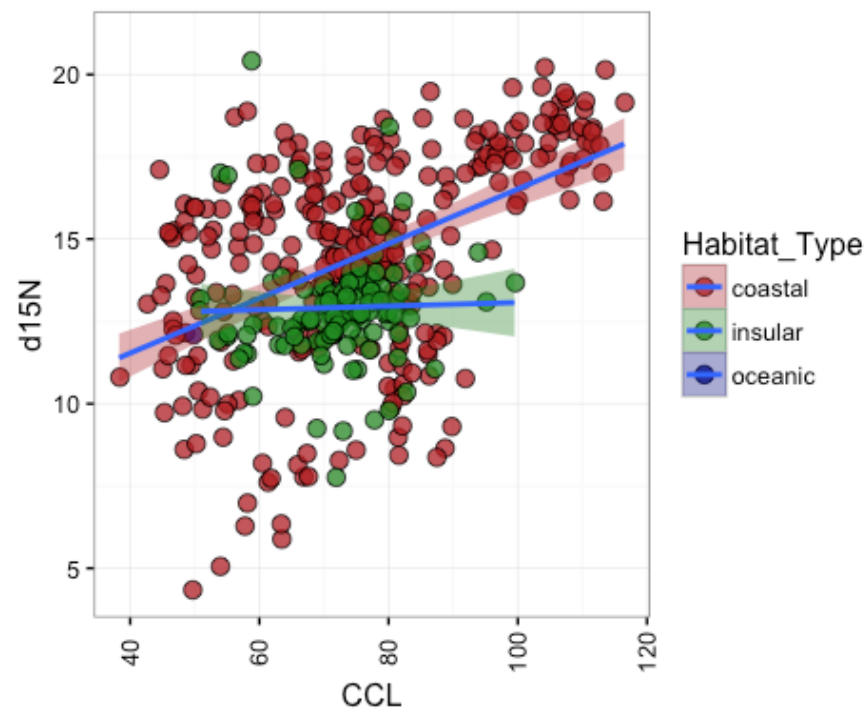
```
## [1] 331
```

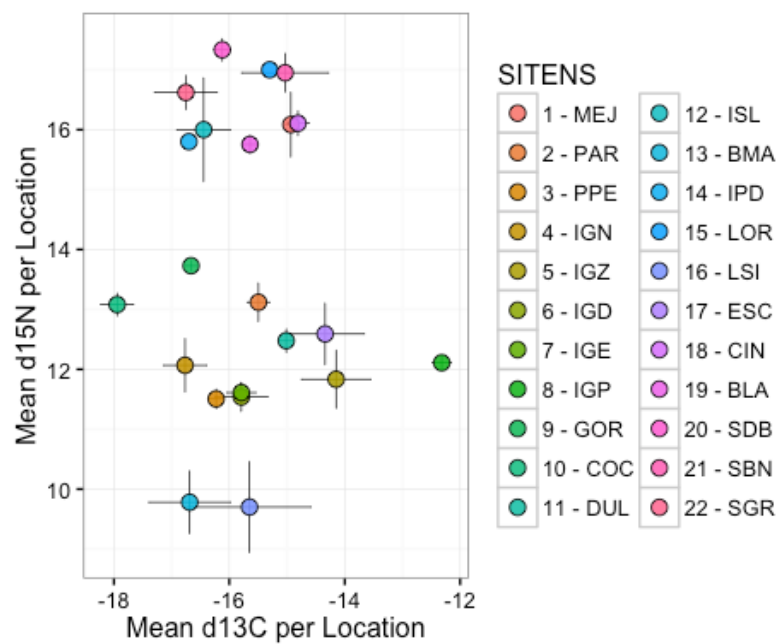
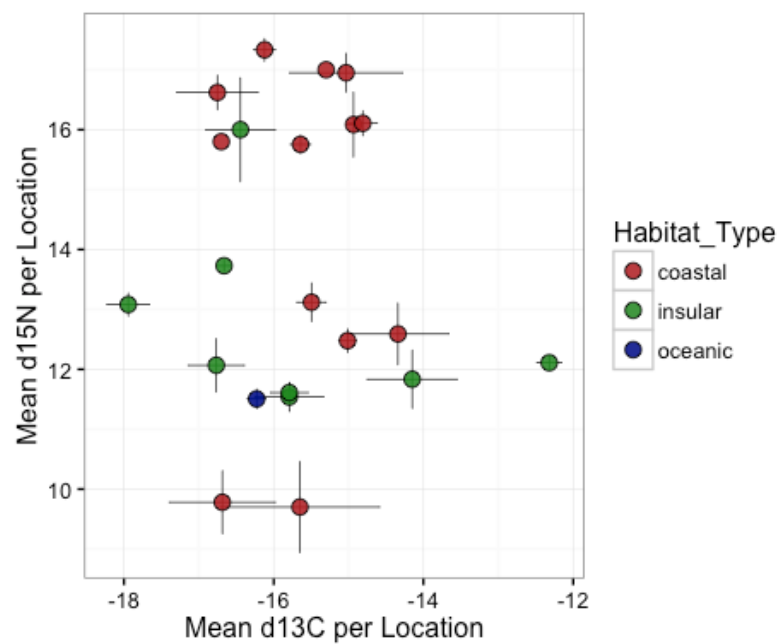
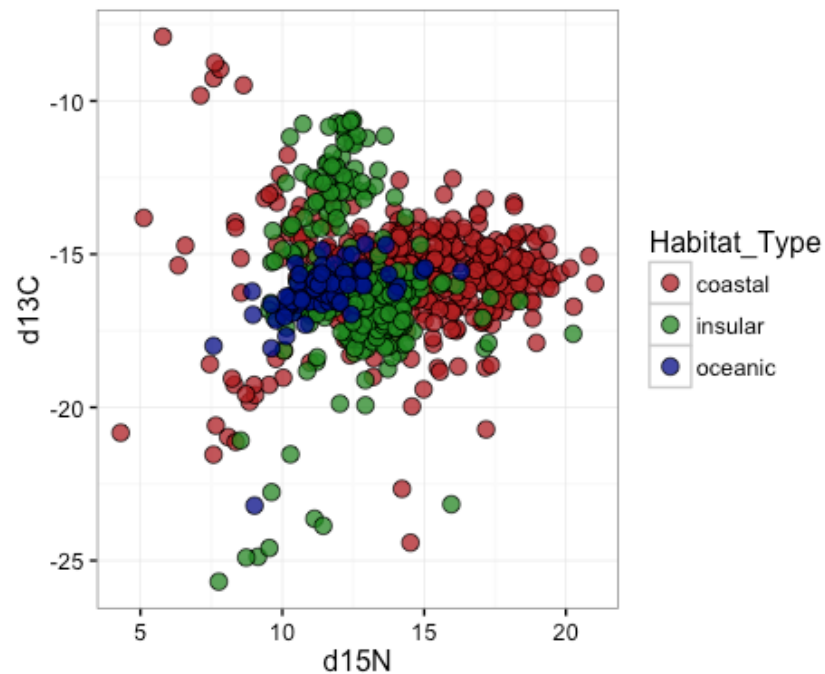
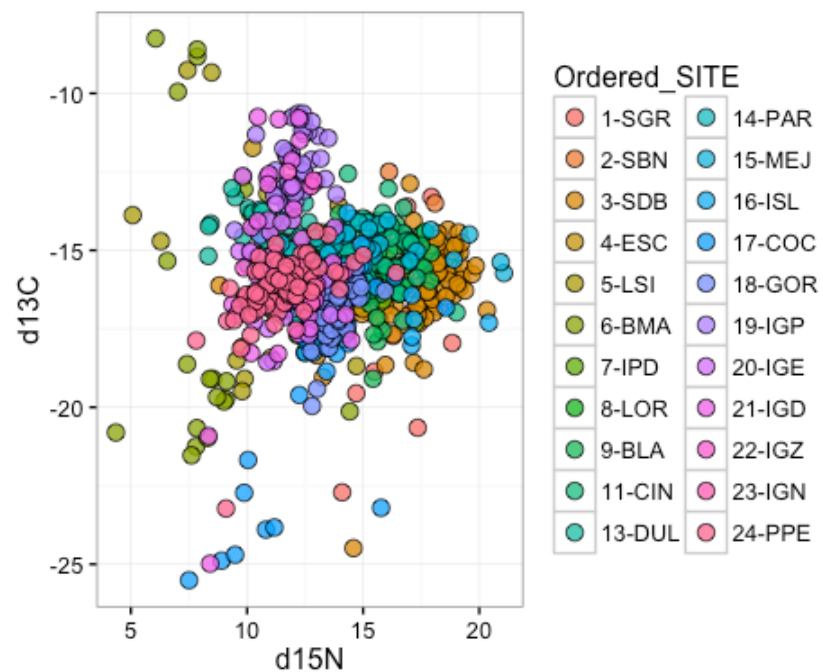
```
sum(!is.na(data$CCL))#CCL has fewer missing/NA's, so use this for now
```

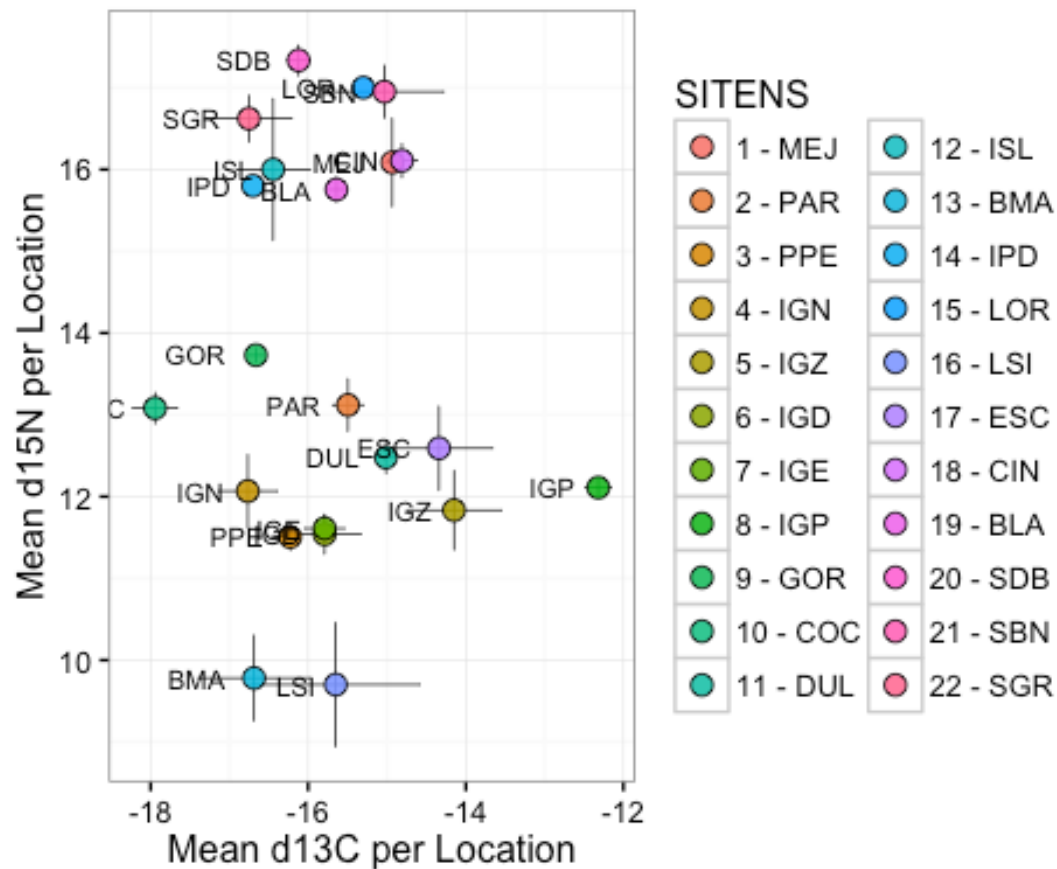
```
## [1] 408
```

#bunch of missing carapace data, for insular sites, only have 3 sites with carapace data but there are 5 sites according to frequency table below

#issue of big turtles at certain sites?







#analysis (don't read into results because some carapace data is missing)
#random effect of site nested within habitat type

#Nitrogen:

```
mN1<-lmer(data=data2, d15N~Habitat_Type+(1|Habitat_Type/SITE_CODE)) #single Habitat model
mN2<-lmer(data=data2, d15N~CCL+(1|Habitat_Type/SITE_CODE)) #single CCL model
mN3<-lmer(data=data2, d15N~Habitat_Type+CCL+(1|Habitat_Type/SITE_CODE)) #additive model
mN4<-lmer(data=data2, d15N~Habitat_Type*CCL+(1|Habitat_Type/SITE_CODE)) #interactive model
summary(mN1)
```

```
## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: d15N ~ Habitat_Type + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 2488.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -5.4398 -0.4849  0.0487  0.5187  4.5741
##
## Random effects:
##      Groups                Name         Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept)  5.277      2.297
## Habitat_Type           (Intercept)  1.445      1.202
## Residual                  2.510      1.584
## Number of obs: 643, groups:  SITE_CODE:Habitat_Type, 21; Habitat_Type, 2
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)    14.4718764   1.3718541  0.0001221   10.55    0.999
## Habitat_Typeinsular -1.7226543   2.0033180  0.0001388    -0.86    0.999
##
## Correlation of Fixed Effects:
##              (Intr)
## Hbtt_Typnsl -0.685
```

summary(mN2)

```
## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: d15N ~ CCL + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 1612.6
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -5.2857 -0.4106  0.0683  0.4803  4.6734
##
## Random effects:
```

```

## Groups Name Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 6.202e+00 2.490e+00
## Habitat_Type (Intercept) 4.455e-14 2.111e-07
## Residual 2.669e+00 1.634e+00
## Number of obs: 407, groups: SITE_CODE:Habitat_Type, 15; Habitat_Type, 2
##
## Fixed effects:
## Estimate Std. Error df t value Pr(>|t|)
## (Intercept) 1.257e+01 8.138e-01 3.090e+01 15.449 4.44e-16 ***
## CCL 2.382e-02 6.907e-03 3.992e+02 3.449 0.000622 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
## (Intr)
## CCL -0.575

summary(mN3)

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: dl5N ~ Habitat_Type + CCL + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 1609.7
##
## Scaled residuals:
## Min 1Q Median 3Q Max
## -5.2868 -0.4107 0.0699 0.4796 4.6754
##
## Random effects:
## Groups Name Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 6.694 2.587
## Habitat_Type (Intercept) 2.128 1.459
## Residual 2.669 1.634
## Number of obs: 407, groups: SITE_CODE:Habitat_Type, 15; Habitat_Type, 2
##
## Fixed effects:
## Estimate Std. Error df t value Pr(>|t|)
## (Intercept) 12.662282 1.715426 0.000000 7.381 0.99973
## Habitat_Typeinsular -0.394562 2.673730 0.000000 -0.148 0.99981

```

```

## CCL                0.023783    0.006911 398.500000    3.441  0.00064 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##      (Intr) Hbtt_T
## Hbtt_Typnsl -0.592
## CCL        -0.269 -0.011

summary(mN4)

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: dl5N ~ Habitat_Type * CCL + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 1614.8
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -5.2796 -0.4002  0.0693  0.4819  4.7001
##
## Random effects:
## Groups              Name                Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept)  6.609      2.571
## Habitat_Type           (Intercept)  2.143      1.464
## Residual                2.670      1.634
## Number of obs: 407, groups:  SITE_CODE:Habitat_Type, 15; Habitat_Type, 2
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)  12.470104   1.728769    0.000000   7.213 0.999472
## Habitat_Typeinsular  0.919076   2.996176    0.000000   0.307 0.999379
## CCL           0.026643   0.007511 398.500000   3.547 0.000435
## Habitat_Typeinsular:CCL -0.018622   0.019205 392.200000  -0.970 0.332842
##
## (Intercept)
## Habitat_Typeinsular
## CCL ***
## Habitat_Typeinsular:CCL
## ---

```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr) Hbtt_T CCL
## Hbtt_Typnsl -0.577
## CCL          -0.290  0.168
## Hbtt_Ty:CCL  0.114 -0.452 -0.391

#just simple LM-some sites are different? follow up checking df's, etc.
m5<-lm(data=data2, d15N~SITE_CODE)
summary(m5)

##
## Call:
## lm(formula = d15N ~ SITE_CODE, data = data2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8.6333 -0.7785  0.0711  0.8341  7.3200
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  15.75472    0.21767   72.379 < 2e-16 ***
## SITE_CODEBMA -5.97472    0.36206  -16.502 < 2e-16 ***
## SITE_CODECIN  0.35243    0.37022   0.952  0.3415
## SITE_CODECOC -2.67412    0.29131  -9.180 < 2e-16 ***
## SITE_CODEDUL -3.27769    0.28516 -11.494 < 2e-16 ***
## SITE_CODEESC -3.16472    0.54635  -5.792 1.10e-08 ***
## SITE_CODEGOR -2.02577    0.28359  -7.143 2.56e-12 ***
## SITE_CODEIGD -4.21688    0.33948 -12.421 < 2e-16 ***
## SITE_CODEIGE -4.14391    0.33948 -12.206 < 2e-16 ***
## SITE_CODEIGN -3.68805    0.94044  -3.922 9.77e-05 ***
## SITE_CODEIGP -3.64519    0.32737 -11.135 < 2e-16 ***
## SITE_CODEIGZ -3.92138    0.68257  -5.745 1.44e-08 ***
## SITE_CODEIPD  0.04528    1.59954   0.028  0.9774
## SITE_CODEISL  0.24528    0.57131   0.429  0.6678
## SITE_CODELOR  1.24528    1.59954   0.779  0.4366
## SITE_CODELSI -6.05472    0.50660 -11.952 < 2e-16 ***
## SITE_CODEMEJ  0.33100    0.40861   0.810  0.4182
## SITE_CODEPAR -2.63567    0.40861  -6.450 2.24e-10 ***
## SITE_CODESBN  1.19528    0.68257   1.751  0.0804 .
```



```

## SITE_CODESDB 1.57862 0.27438 5.753 1.37e-08 ***
## SITE_CODESGR 0.86634 0.42373 2.045 0.0413 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.585 on 622 degrees of freedom
## Multiple R-squared: 0.6752, Adjusted R-squared: 0.6647
## F-statistic: 64.64 on 20 and 622 DF, p-value: < 2.2e-16

#Carbon:
mC1<-lmer(data=data2, dl3C~Habitat_Type+(1|Habitat_Type/SITE_CODE)) #single Habitat model

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : unable to evaluate scaled gradient

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Hessian is numerically singular: parameters are not uniquely
## determined

mC2<-lmer(data=data2, dl3C~CCL+(1|Habitat_Type/SITE_CODE)) #single CCL model
mC3<-lmer(data=data2, dl3C~Habitat_Type+CCL+(1|Habitat_Type/SITE_CODE)) #additive model

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, : Model is nearly u
nidentifiable: large eigenvalue ratio
## - Rescale variables?

mC4<-lmer(data=data2, dl3C~Habitat_Type*CCL+(1|Habitat_Type/SITE_CODE)) #interactive model

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, : Model is nearly u
nidentifiable: large eigenvalue ratio
## - Rescale variables?

summary(mC1)

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : unable to evaluate scaled gradient

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Hessian is numerically singular: parameters are not uniquely
## determined

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]

```

```

## Formula: dl3C ~ Habitat_Type + (1 | Habitat_Type/SITE_CODE)
##   Data: data2
##
## REML criterion at convergence: 2600.1
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -5.1130 -0.3811  0.0618  0.4476  4.8290
##
## Random effects:
##   Groups                Name                Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 1.46484   1.2103
## Habitat_Type            (Intercept) 0.02906   0.1705
## Residual                  3.10659   1.7626
## Number of obs: 643, groups:  SITE_CODE:Habitat_Type, 21; Habitat_Type, 2
##
## Fixed effects:
##              Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)    -1.555e+01  4.098e-01  7.107e-06 -37.933      1
## Habitat_Typeinsular -1.748e-01  6.393e-01  1.052e-05  -0.273      1
##
## Correlation of Fixed Effects:
##              (Intr)
## Hbtt_Typnsl -0.641
## convergence code: 0
## unable to evaluate scaled gradient
## Hessian is numerically singular: parameters are not uniquely determined

summary(mC2)

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
##   to degrees of freedom [lmerMod]
## Formula: dl3C ~ CCL + (1 | Habitat_Type/SITE_CODE)
##   Data: data2
##
## REML criterion at convergence: 1692.2
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.3541 -0.3011  0.0892  0.5241  4.6383
##

```

```

## Random effects:
##   Groups                Name          Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 1.764      1.328
## Habitat_Type           (Intercept) 0.000      0.000
## Residual                3.399      1.844
## Number of obs: 407, groups:  SITE_CODE:Habitat_Type, 15; Habitat_Type, 2
##
## Fixed effects:
##               Estimate Std. Error      df t value Pr(>|t|)
## (Intercept) -16.371468   0.647733 101.900000 -25.275   <2e-16 ***
## CCL          0.011188   0.007657 402.100000   1.461     0.145
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##      (Intr)
## CCL -0.809

summary(mC3)

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, : Model is nearly u
nidentifiable: large eigenvalue ratio
## - Rescale variables?

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: dl3C ~ Habitat_Type + CCL + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 1690.5
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.3522 -0.3008  0.0901  0.5246  4.6413
##
## Random effects:
##   Groups                Name          Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 1.9072      1.3810
## Habitat_Type           (Intercept) 0.1119      0.3345
## Residual                3.4003      1.8440
## Number of obs: 407, groups:  SITE_CODE:Habitat_Type, 15; Habitat_Type, 2

```

```

##
## Fixed effects:
##
##      Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   -16.398440    0.761285    0.000000  -21.540    1.000
## Habitat_Typeinsular    0.124908    1.062536    0.000000    0.118    1.000
## CCL              0.011196    0.007674  401.500000    1.459    0.145
##
## Correlation of Fixed Effects:
##      (Intr) Hbtt_T
## Hbtt_Typnsl -0.366
## CCL         -0.681 -0.027
## convergence code: 0
## Model is nearly unidentifiable: large eigenvalue ratio
## - Rescale variables?

summary(mC4)

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, : Model is nearly u
nidentifiable: large eigenvalue ratio
## - Rescale variables?

## Linear mixed model fit by REML t-tests use Satterthwaite approximations
## to degrees of freedom [lmerMod]
## Formula: dl3C ~ Habitat_Type * CCL + (1 | Habitat_Type/SITE_CODE)
## Data: data2
##
## REML criterion at convergence: 1695.6
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.3804 -0.2961  0.0867  0.5167  4.6450
##
## Random effects:
##      Groups              Name      Variance Std.Dev.
## SITE_CODE:Habitat_Type (Intercept) 1.91874   1.3852
## Habitat_Type           (Intercept) 0.09866   0.3141
## Residual                  3.40241   1.8446
## Number of obs: 407, groups:  SITE_CODE:Habitat_Type, 15; Habitat_Type, 2
##
## Fixed effects:
##
##      Estimate Std. Error      df t value Pr(>|t|)

```

```
## (Intercept)          -16.218514    0.783808    0.000000   -20.692    1.000
## Habitat_Typeinsular   -1.147154    1.855852    0.000000    -0.618    0.999
## CCL                   0.008533    0.008319   397.500000    1.026    0.306
## Habitat_Typeinsular:CCL 0.017973    0.021603   398.100000    0.832    0.406
##
## Correlation of Fixed Effects:
##              (Intr) Hbtt_T CCL
## Hbtt_Typnsl -0.422
## CCL         -0.717  0.303
## Hbtt_Ty:CCL  0.276 -0.824 -0.385
## convergence code: 0
## Model is nearly unidentifiable: large eigenvalue ratio
## - Rescale variables?
```

#just simple LM-some sites are different? follow up checking df's, etc.

```
m5<-lm(data=data2, d13C~SITE_CODE)
```

```
summary(m5)
```

```
##
## Call:
## lm(formula = d13C ~ SITE_CODE, data = data2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -9.0081  -0.6837   0.1135   0.7936   8.5867
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -15.641509    0.242429  -64.520 < 2e-16 ***
## SITE_CODEBMA  -1.045157    0.403239   -2.592  0.00977 **
## SITE_CODECIN   0.830795    0.412333    2.015  0.04435 *
## SITE_CODECOC  -2.301774    0.324442   -7.095 3.55e-12 ***
## SITE_CODEDUL   0.627996    0.317592    1.977  0.04844 *
## SITE_CODEESC   1.301509    0.608491    2.139  0.03283 *
## SITE_CODEGOR  -1.021648    0.315844   -3.235  0.00128 **
## SITE_CODEIGD  -0.150382    0.378098   -0.398  0.69096
## SITE_CODEIGE  -0.150382    0.378098   -0.398  0.69096
## SITE_CODEIGN  -1.125157    1.047412   -1.074  0.28314
## SITE_CODEIGP   3.322462    0.364604    9.113 < 2e-16 ***
## SITE_CODEIGZ   1.491509    0.760212    1.962  0.05021 .
## SITE_CODEIPD  -1.058491    1.781480   -0.594  0.55262
```

```

## SITE_CODEISL  -0.802935    0.636295   -1.262    0.20746
## SITE_CODELOR   0.341509    1.781480    0.192    0.84804
## SITE_CODELSI  -0.008491    0.564222   -0.015    0.98800
## SITE_CODEMEJ   0.708176    0.455083    1.556    0.12018
## SITE_CODEPAR   0.146271    0.455083    0.321    0.74800
## SITE_CODESDN   0.608176    0.760212    0.800    0.42401
## SITE_CODESDB  -0.480713    0.305584   -1.573    0.11621
## SITE_CODESGR  -1.111122    0.471926   -2.354    0.01886 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.765 on 622 degrees of freedom
## Multiple R-squared:  0.3547, Adjusted R-squared:  0.3339
## F-statistic: 17.09 on 20 and 622 DF,  p-value: < 2.2e-16

```