Muss_PCA_GLM_DMX_Benthic

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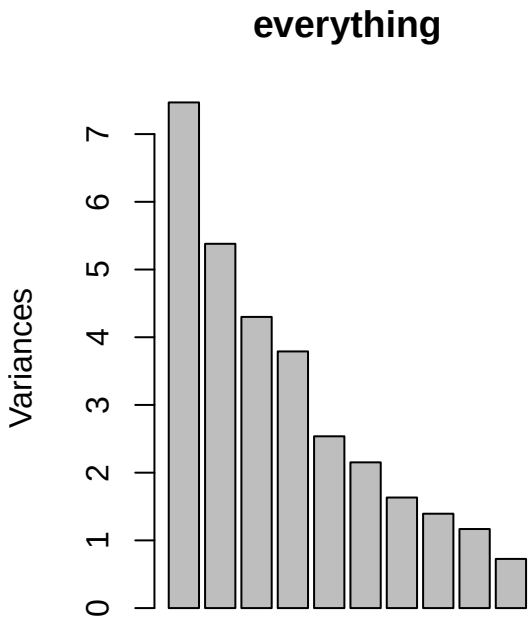
Regional Scale Analyses

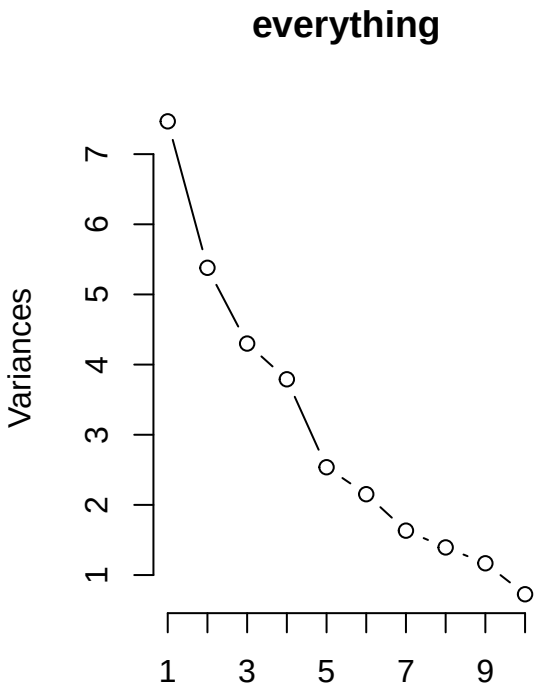
H1: Mussel recruitment (via abundance) is associated with strong wind stress periods (monthly average - and some metric of oscillations? freq?).

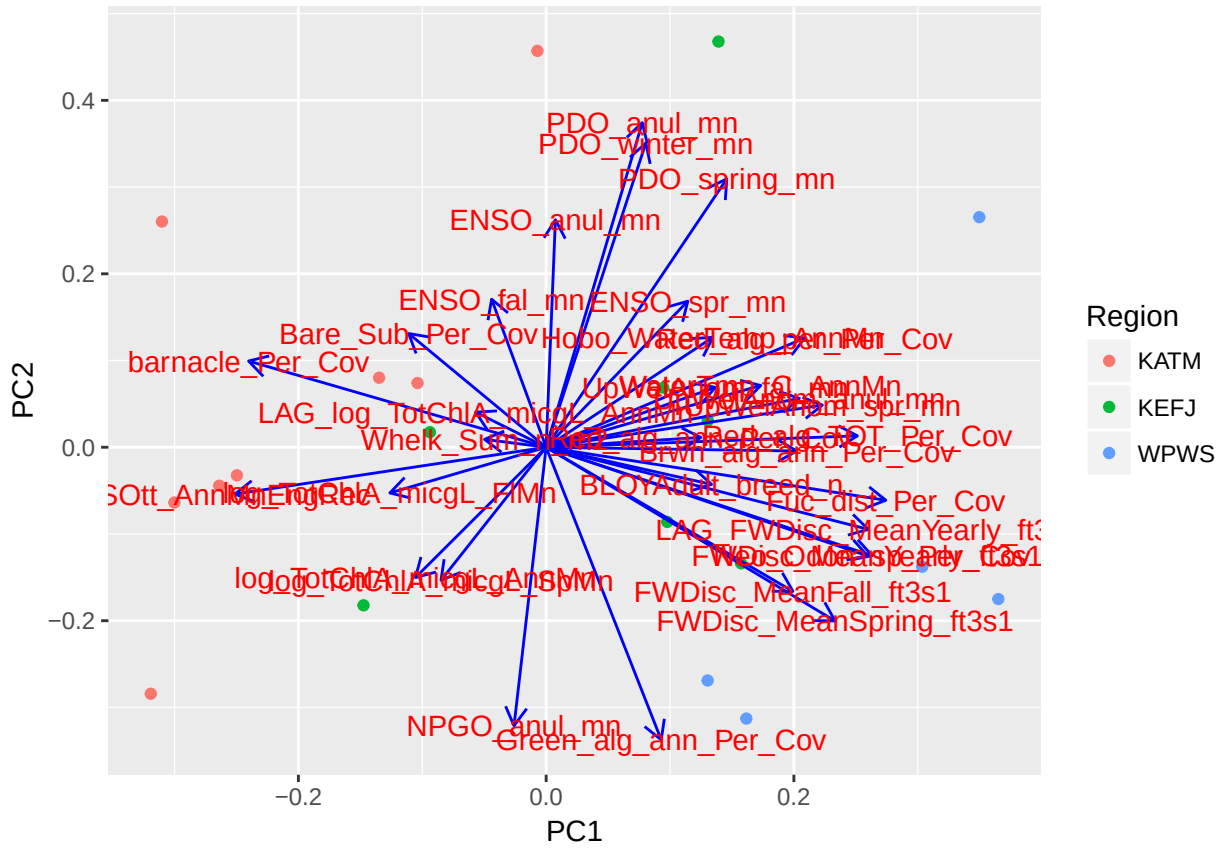
H2: Mussel recruitment (via abundance) is associated with high Chl years - specifically the spring bloom.

H3: Mussel recruitment (via abundance) is driven by extreme air temperatures – meaning degree heating days type of threshold plus time (needs to include tidal threshold).

```
## Importance of components:
##                           PC1    PC2    PC3    PC4     PC5     PC6     PC7
## Standard deviation     2.7327 2.3194 2.0736 1.9469 1.59273 1.46708 1.27783
## Proportion of Variance 0.2334 0.1681 0.1344 0.1185 0.07927 0.06726 0.05103
## Cumulative Proportion  0.2334 0.4015 0.5359 0.6543 0.73358 0.80084 0.85187
##                            PC8     PC9   PC10    PC11    PC12    PC13
## Standard deviation     1.18060 1.08053 0.8522 0.60267 0.53210 0.49927
## Proportion of Variance 0.04356 0.03649 0.0227 0.01135 0.00885 0.00779
## Cumulative Proportion  0.89542 0.93191 0.9546 0.96595 0.97480 0.98259
##                           PC14    PC15    PC16    PC17    PC18    PC19
## Standard deviation     0.43735 0.37629 0.31139 0.24469 0.21320 0.14793
## Proportion of Variance 0.00598 0.00442 0.00303 0.00187 0.00142 0.00068
## Cumulative Proportion  0.98857 0.99299 0.99602 0.99790 0.99932 1.00000
##                            PC20
## Standard deviation     7.173e-16
## Proportion of Variance 0.000e+00
## Cumulative Proportion  1.000e+00
```


everything
Variances
0
1
2
3
4
5
6
7


everything
Variances
1
2
3
4
5
6
7
1
3
5
7
9



Scenario 1 - Region

NOTE:

chose to retain Spring Freshwater over LAG Annual Freshwater
chose to retain PDO over ENSO
chose to retain log Chla spring over PDO Winter
chose to retain Freshwater Yearly over Neo-Odon algae
chose to retain Upwelling Annual over Water Temp (buoys)
chose to retain Fucus over BLOY Adults, Upwelling spring, Red algae perennial, and Red algae TOTAL

Then had to reduce to 17 variables, since we have only 17 observations at the Region level.

Scenario 2 - Region

Scenario 3 - Region

Scenario 4 - Region

Scenario 5 - Region

Scenario 6 - Region

Scenario 7 - Region

Scenario 8 - Region

Scenario 9 - Region

Scenario 10 - Region

Scenario 11 - Region

Scenario 12 - Region

Scenario 13 - Region

Scenario 14 - Region

Scenario 15 - Region

Scenario 16 - Region

Scenario 17 - Region

AIC values for all Regional models

```
##     Model      AIC
## 1   Sce_1 12.73974
## 2   Sce_2 17.49823
## 3   Sce_4 18.66444
## 4   Sce_3 19.92759
## 5  Sce_11 21.79969
## 6  Sce_12 27.03126
## 7  Sce_15 28.14169
## 8   Sce_8 28.32941
## 9  Sce_16 28.33078
## 10 Sce_13 29.82170
## 11  Sce_9 30.21160
## 12 Sce_10 30.46359
## 13 Sce_17 31.69290
## 14 Sce_14 35.38108
## 15  Sce_5 36.72592
## 16  Sce_6 36.89552
## 17  Sce_7 38.25016
```

Coefficients for model(s) with lowest AIC scores

```
##
## Call:
## glm(formula = mussel_Anom ~ ., family = gaussian, data = BN_reg_sub_df)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -0.38770  -0.12356  -0.02197   0.09667   0.38746
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)             -0.854474   2.243988  -0.381   0.7165
## log_TotChlA_micgL_AnnMn -0.181825   0.403219  -0.451   0.6679
## FWDisc_MeanYearly_ft3s1  0.064660   0.030736   2.104   0.0801 .
## ENSO_anul_mn            -0.182650   0.218052  -0.838   0.4343
## NPGO_anul_mn            -0.217868   0.206864  -1.053   0.3328
## UpWelAnom_anul_mn       -0.041340   0.011627  -3.556   0.0120 *
## Hobo_WaterTemp_AnnMn    -0.310575   0.095513  -3.252   0.0174 *
## Bare_Sub_Per_Cov         0.083535   0.038280   2.182   0.0718 .
## Whelk_Sum_n_m2          -0.004505   0.010913  -0.413   0.6941
## SOtt_AnnMnEngRec        -0.036920   0.076440  -0.483   0.6462
## barnacle_Per_Cov         0.030680   0.018014   1.703   0.1394
## Fuc_dist_Per_Cov         0.049022   0.019578   2.504   0.0463 *
## Brwn_alg_ann_Per_Cov     0.011173   0.027539   0.406   0.6990
## Green_alg_ann_Per_Cov   -0.032878   0.021563  -1.525   0.1782
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.1107276)
##
##     Null deviance: 3.97494  on 19  degrees of freedom
## Residual deviance: 0.66437  on  6  degrees of freedom
## AIC: 18.664
##
## Number of Fisher Scoring iterations: 2
```

NOTE: If other scales come up with other "best" models, test it all all scale levels.

Also, test scenario 13 at other scales.

Test model performance of the "best" model at each level on all levels.

Test all scenarios from Region data at lower scales.

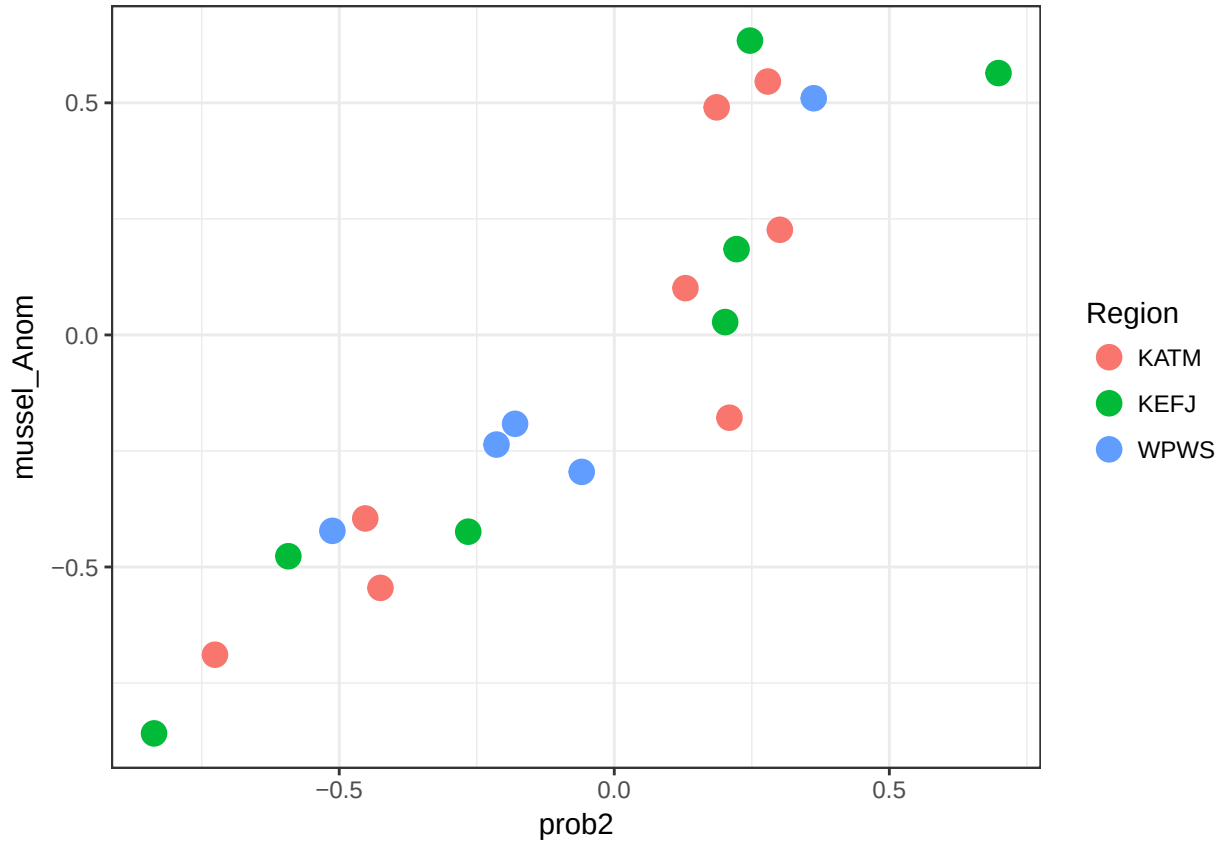
Scenario WINNER of the Site-level analysis

```
## [1] 28.17394
```

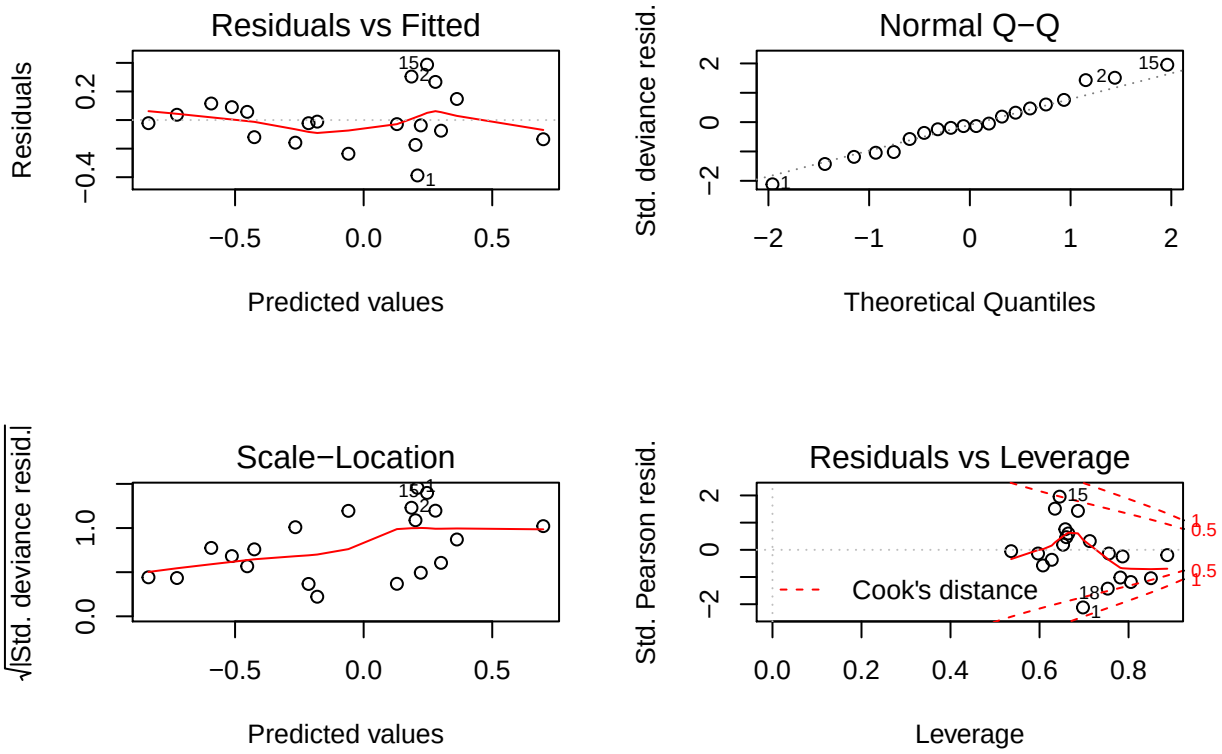
Scenario WINNER from the Transect-level analysis

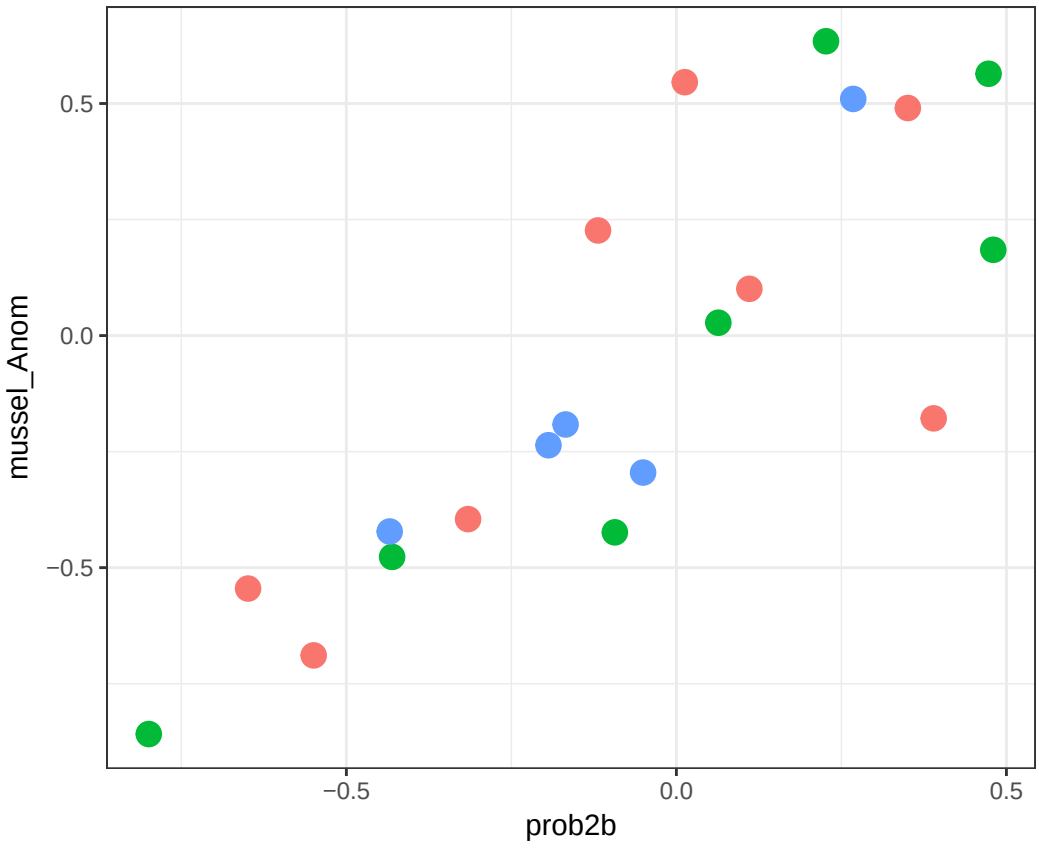
```
## [1] 31.85651
```

Scenario 4 - Region best model




```
##      mussel_Anom
## [1,]   0.9126125
```

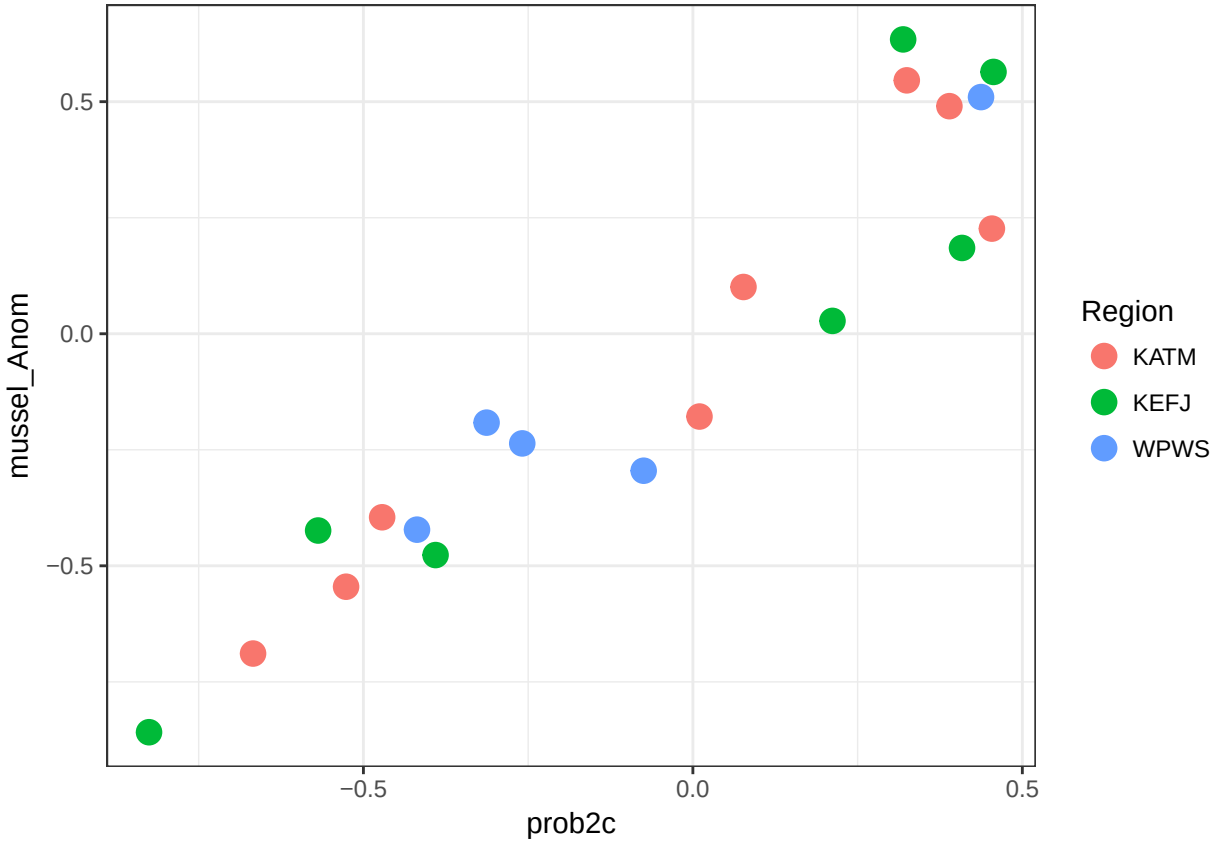

Residuals vs Fitted
Residuals
Predicted values
Normal Q−Q
Std. deviance resid.
Theoretical Quantiles
Scale−Location
√|Std. deviance resid.|
Predicted values
Residuals vs Leverage
Std. Pearson resid.
Cook's distance
Leverage



Scenario 11

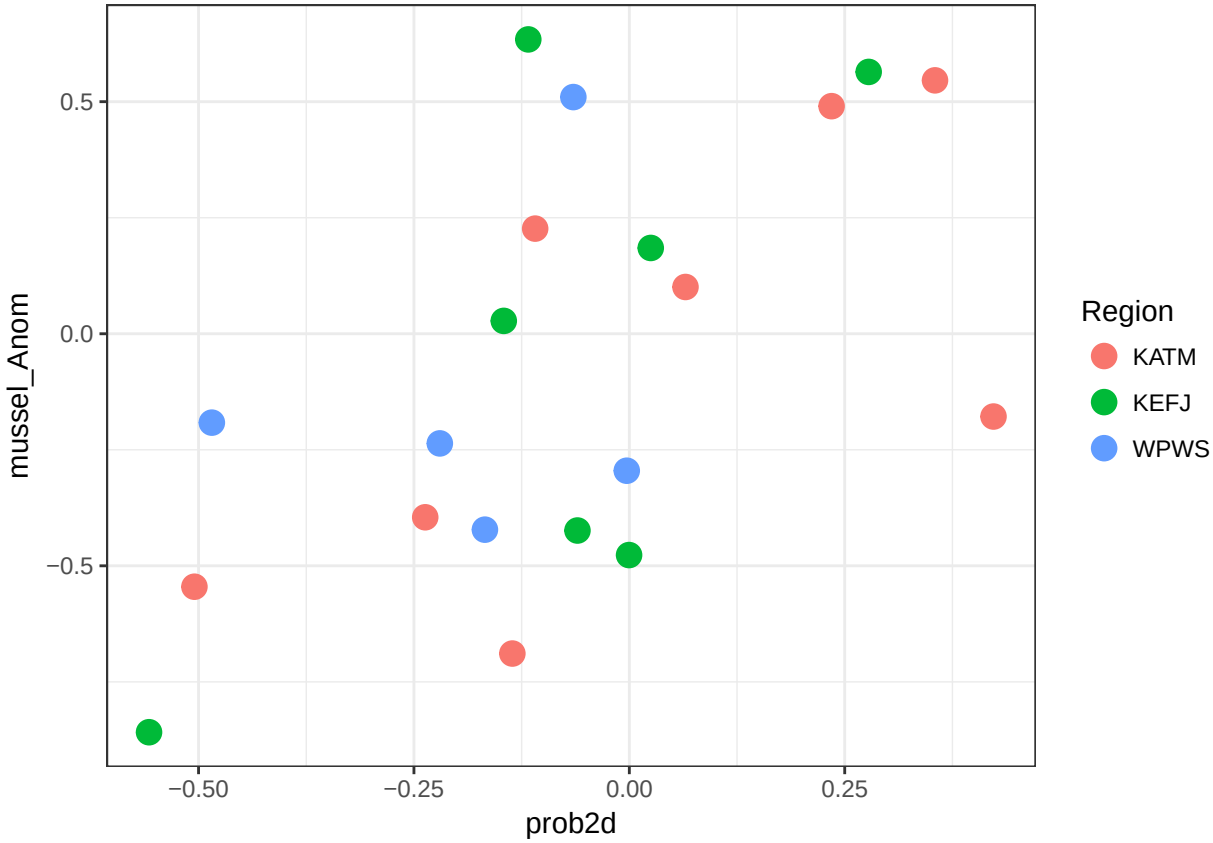
```
##      mussel_Anom
## [1,]   0.8232055
```

Scenario 1



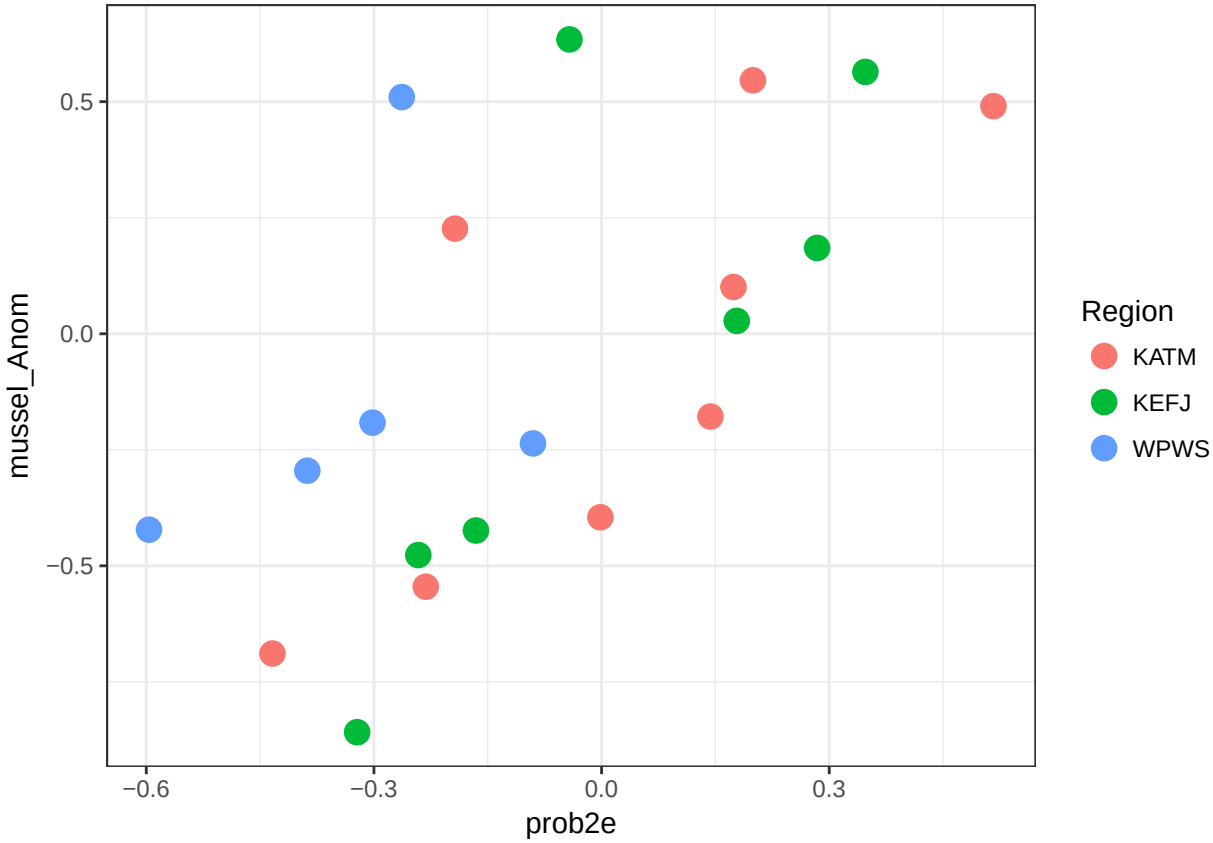

```
##      mussel_Anom
## [1,]   0.9420941
```

Site winner

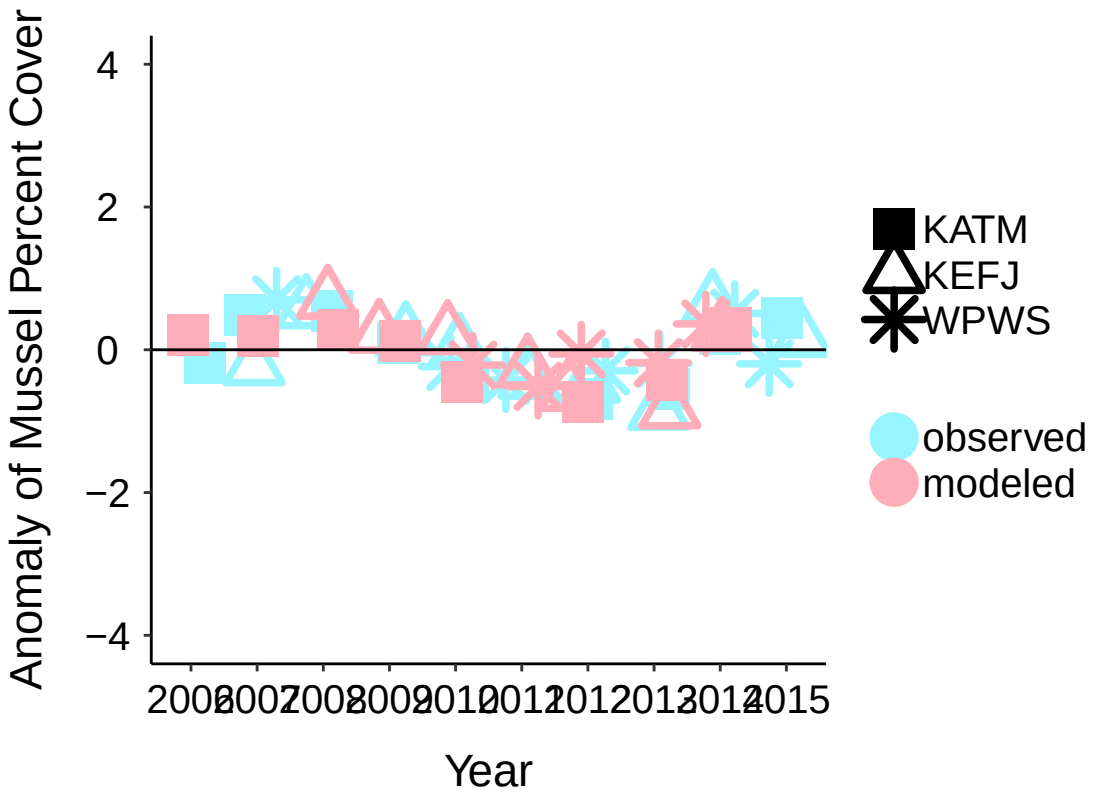


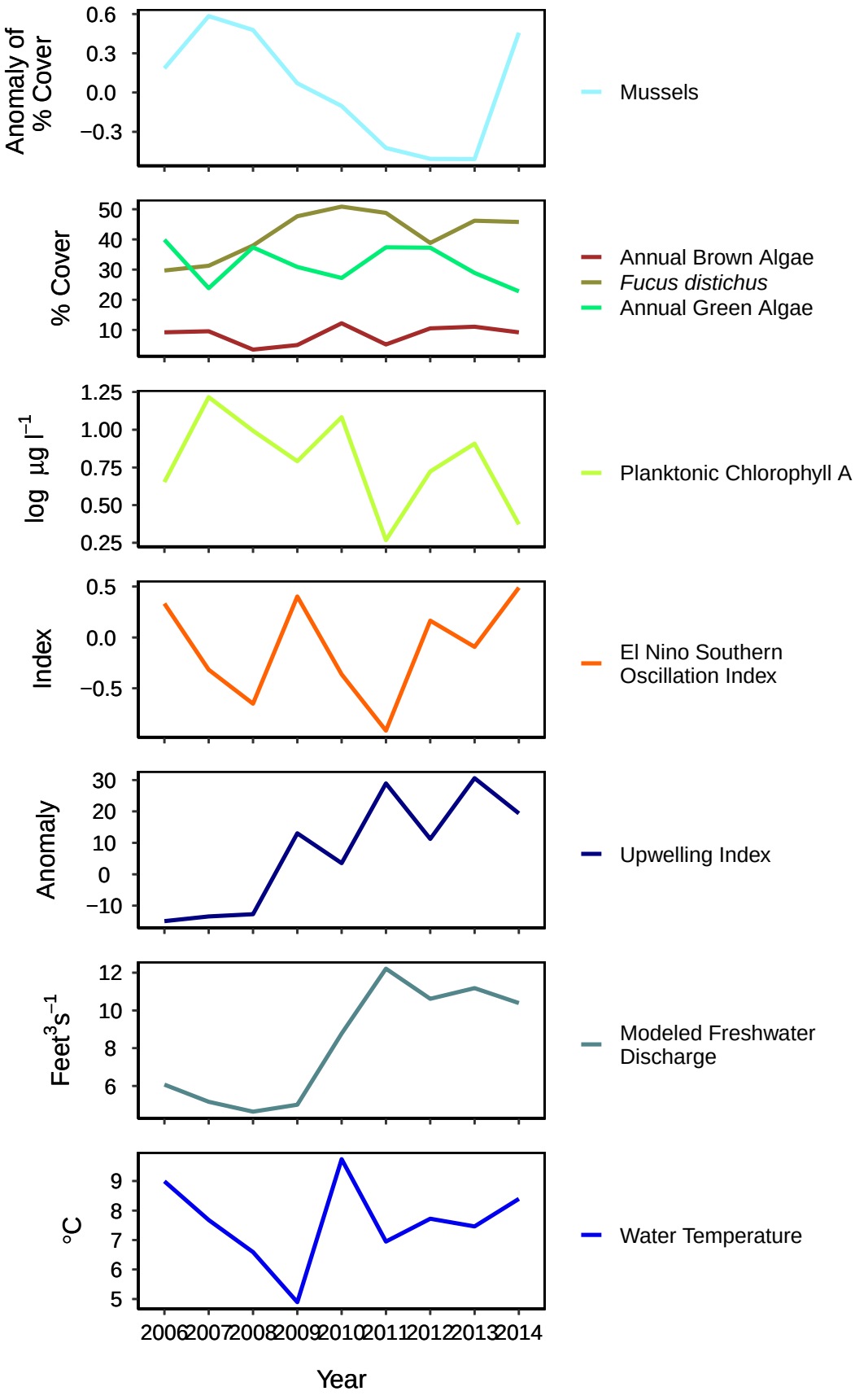

```
##      mussel_Anom
## [1,]   0.5819286
```

Transect winner



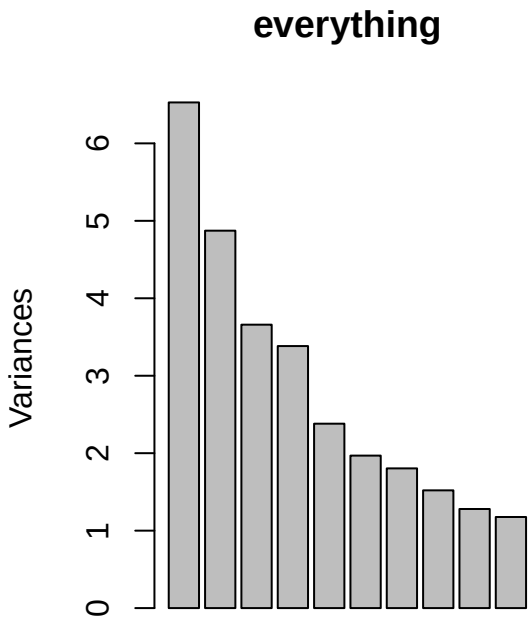

```
##      mussel_Anom
## [1,]   0.6410931
```

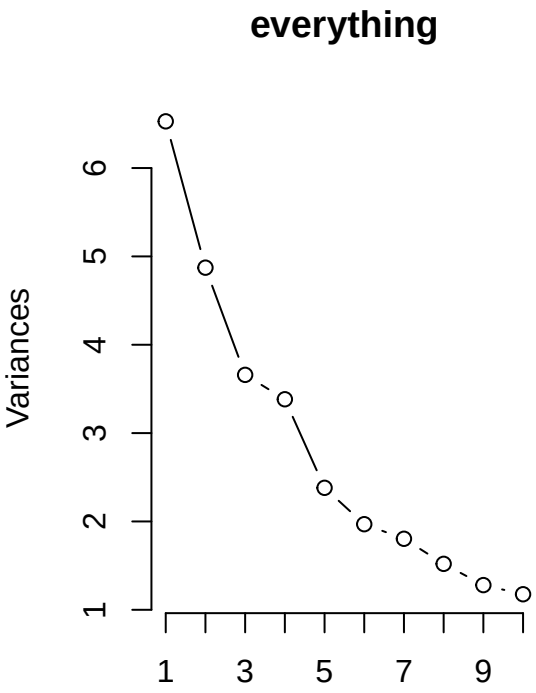

Anomaly of Mussel Percent Cover
4
2
0
−2
−4
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year
KATM
KEFJ
WPWS
observed
modeled

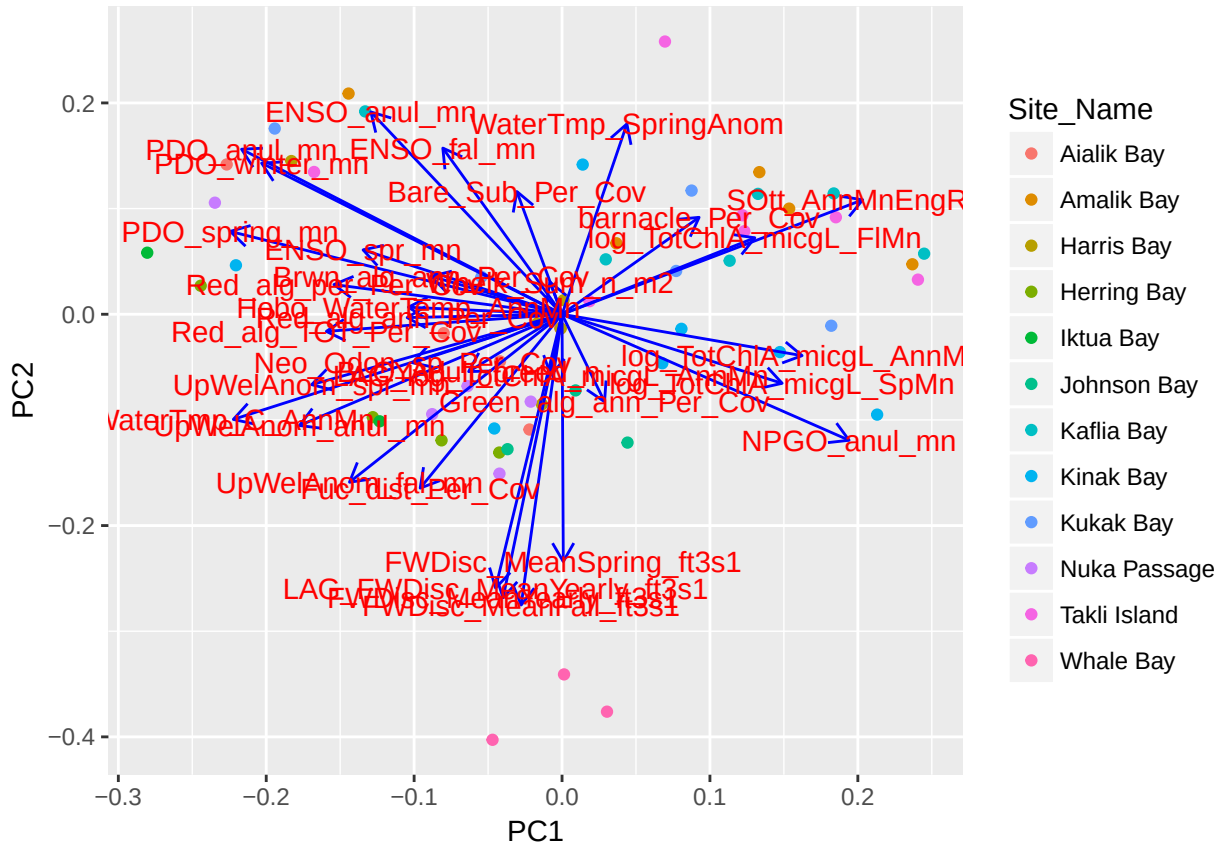

Anomaly of % Cover
0.6
0.3
0.0
−0.3
Mussels
% Cover
50
40
30
20
10
Annual Brown Algae
Fucus distichus
Annual Green Algae
log µg l−1
1.25
1.00
0.75
0.50
0.25
Planktonic Chlorophyll A
Index
0.5
0.0
−0.5
El Nino Southern Oscillation Index
Anomaly
30
20
10
0
−10
Upwelling Index
Feet3s−1
12
10
8
6
Modeled Freshwater Discharge
°C
9
8
7
6
5
Water Temperature
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year

Site-level Analysis

```
## Importance of components:
##                            PC1    PC2    PC3    PC4     PC5     PC6     PC7
## Standard deviation     2.5551 2.2074 1.9129 1.8393 1.54292 1.40313 1.34309
## Proportion of Variance 0.1978 0.1477 0.1109 0.1025 0.07214 0.05966 0.05466
## Cumulative Proportion  0.1978 0.3455 0.4564 0.5589 0.63102 0.69068 0.74534
##                            PC8     PC9    PC10    PC11    PC12    PC13
## Standard deviation     1.23286 1.13113 1.08445 0.92238 0.86071 0.81966
## Proportion of Variance 0.04606 0.03877 0.03564 0.02578 0.02245 0.02036
## Cumulative Proportion  0.79140 0.83017 0.86581 0.89159 0.91404 0.93440
##                           PC14    PC15    PC16   PC17    PC18    PC19
## Standard deviation     0.74590 0.56923 0.55666 0.5233 0.47581 0.36270
## Proportion of Variance 0.01686 0.00982 0.00939 0.0083 0.00686 0.00399
## Cumulative Proportion  0.95126 0.96108 0.97047 0.9788 0.98563 0.98961
##                           PC20    PC21    PC22    PC23    PC24    PC25
## Standard deviation     0.32455 0.28778 0.22602 0.21320 0.18602 0.11999
## Proportion of Variance 0.00319 0.00251 0.00155 0.00138 0.00105 0.00044
## Cumulative Proportion  0.99281 0.99532 0.99686 0.99824 0.99929 0.99973
##                           PC26    PC27      PC28      PC29      PC30
## Standard deviation     0.08727 0.03757 4.809e-16 3.775e-16 2.828e-16
## Proportion of Variance 0.00023 0.00004 0.000e+00 0.000e+00 0.000e+00
## Cumulative Proportion  0.99996 1.00000 1.000e+00 1.000e+00 1.000e+00
##                             PC31      PC32      PC33
## Standard deviation     2.439e-16 2.022e-16 1.806e-16
## Proportion of Variance 0.000e+00 0.000e+00 0.000e+00
## Cumulative Proportion  1.000e+00 1.000e+00 1.000e+00
```


everything
Variances
0
1
2
3
4
5
6


everything
Variances
1
2
3
4
5
6
1
3
5
7
9



Scenario 1 - Site

*NOTE:

chose Sea Otter eng rec over barnacles and bare substrate
chose NPGO annual over ENSO fall
chose Water temp buoys over Neo-Odon algae and Red annual algae
chose Freshwater Yearly over LAG Freshwater Yearly
chose Fucus over Red algae TOTAL and Upwelling fall and Freshwater Fall
chose HOBO Water temp over Brown algae
chose PDO annual over PDO Winter

Also removed ENSO Spring, ENSO Annual, PDO Annual and PDO Spring due to singularities

Scenario 2 - Site

Scenario 3 - Site

Scenario 4 - Site

Scenario 5 - Site

Scenario 6 - Site

Scenario 7 - Site

Scenario 8 - Site

Scenario 9 - Site

Scenario 10 - Site

Scenario 11 - Site

Scenario 12 - Site

Scenario 13

Scenario 14 - Site

Scenario 15 - Site

Scenario 16 - Site

Scenario 17 - Site

Scenario 18 - Site

Scenario 19 - Site

Scenario 20 - Site

Scenario 21 - Site

Scenario 22 - Site

Scenario 23 - Site

Scenario 24 - Site

Scenario 25 - Site

Scenario 26 - Site

Scenario 27 - Site

Scenario 28 - Site

AIC values for all Site models

```
##       Model      AIC
## 1  Sce_17_s 110.1608
## 2  Sce_15_s 110.4956
## 3  Sce_21_s 111.1814
## 4  Sce_28_s 111.8523
## 5  Sce_12_s 111.9124
## 6  Sce_22_s 111.9190
## 7   Sce_9_s 111.9771
## 8  Sce_23_s 111.9782
## 9  Sce_11_s 112.4865
## 10 Sce_16_s 112.4874
## 11 Sce_10_s 112.5424
## 12 Sce_13_s 112.7998
## 13 Sce_24_s 112.9316
## 14  Sce_8_s 114.0989
## 15 Sce_14_s 114.1299
## 16 Sce_26_s 114.4535
## 17 Sce_18_s 114.7024
## 18  Sce_7_s 114.9759
## 19 Sce_25_s 116.6769
## 20 Sce_27_s 118.3180
## 21 Sce_19_s 118.9211
## 22  Sce_2_s 119.4998
## 23  Sce_1_s 122.4615
## 24  Sce_3_s 123.5843
## 25  Sce_6_s 124.9759
## 26  Sce_5_s 124.9815
## 27 Sce_20_s 126.8808
## 28  Sce_4_s 127.5227
```

Coefficients for model(s) with lowest AIC scores

```
##
## Call:
## glm(formula = mussel_Anom ~ ., family = gaussian, data = BN_reg_sub_df)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.00786  -0.39235  -0.07737   0.42005   1.96501
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)             -3.313622   1.114557  -2.973 0.004460 **
## log_TotChlA_micgL_AnnMn  0.060729   0.310040   0.196 0.845471
## WaterTmp_C_AnnMn         0.276108   0.109656   2.518 0.014922 *
## SOtt_AnnMnEngRec         0.164913   0.043626   3.780 0.000406 ***
## Brwn_alg_ann_Per_Cov    -0.005609   0.013173  -0.426 0.672025
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.369992)
##
##     Null deviance: 25.055  on 56  degrees of freedom
## Residual deviance: 19.240  on 52  degrees of freedom
## AIC: 111.85
##
## Number of Fisher Scoring iterations: 2
```

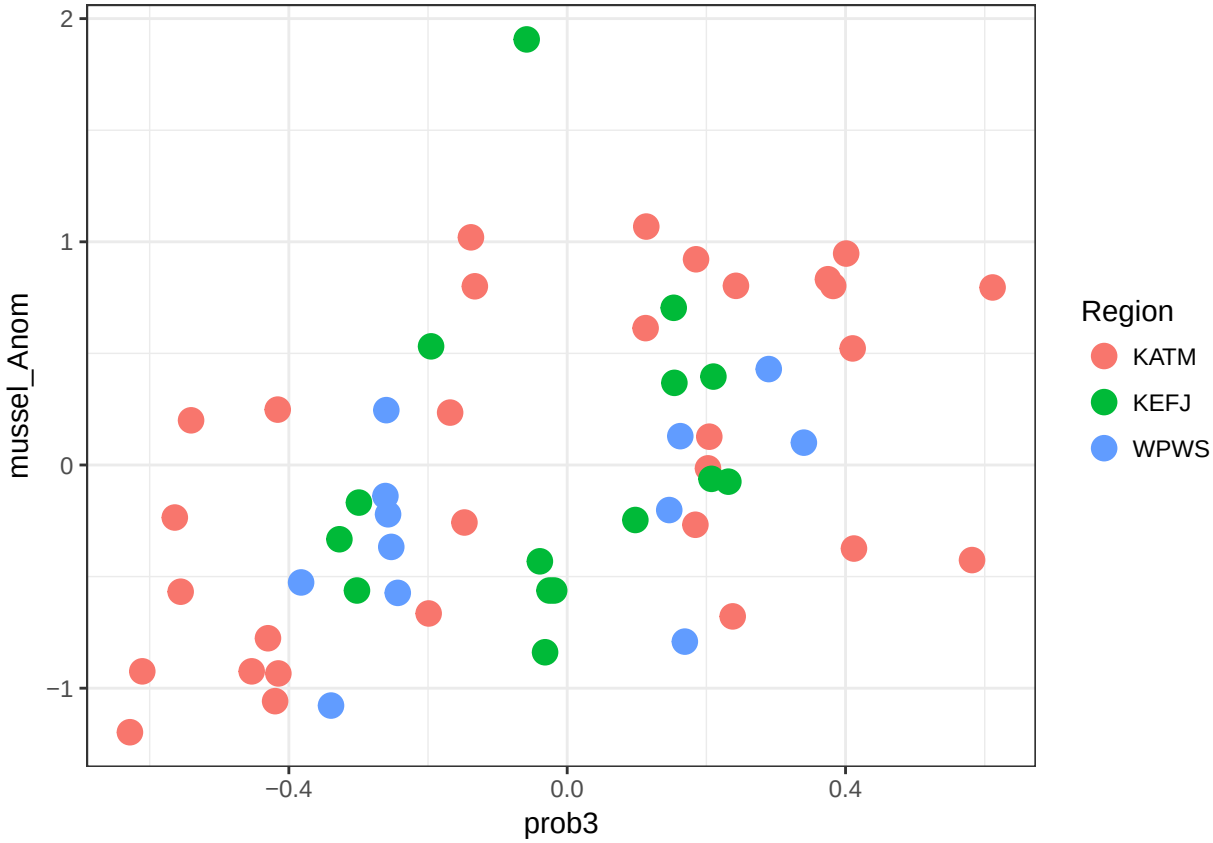
Scenario WINNER from Region-level analysis

```
## [1] 115.4106
```

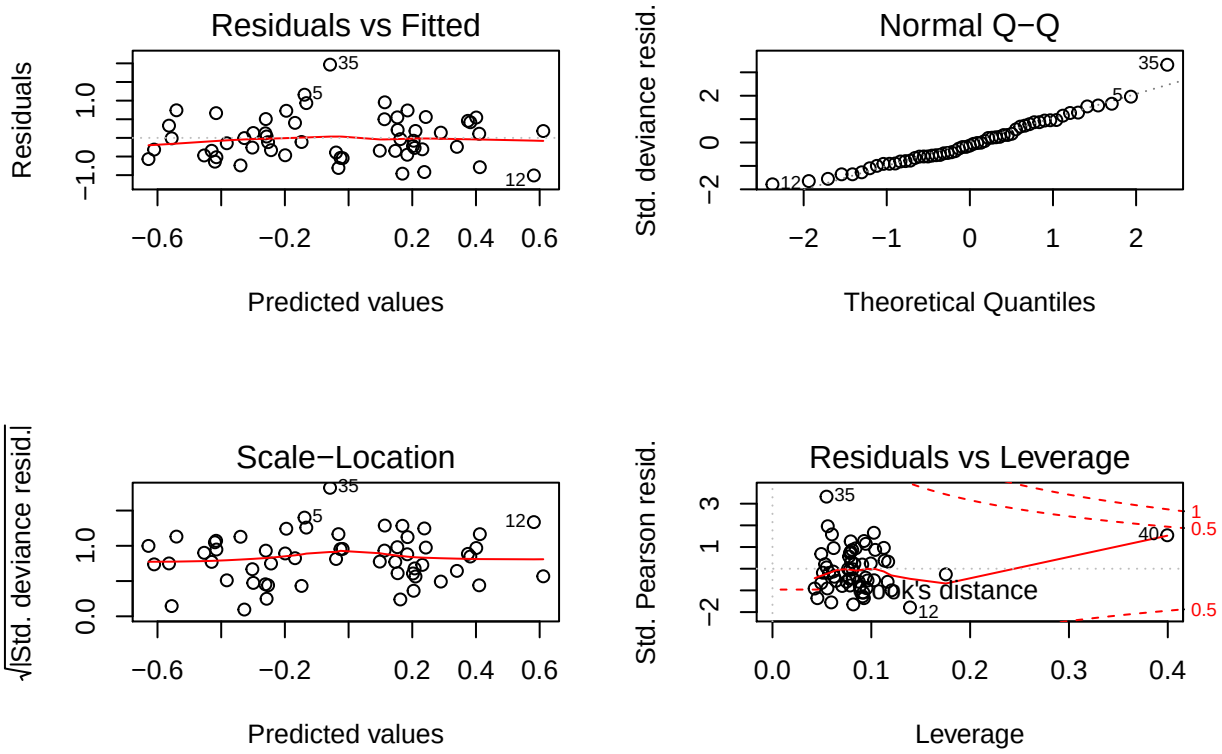
Scenario WINNER from the Transect-level analysis

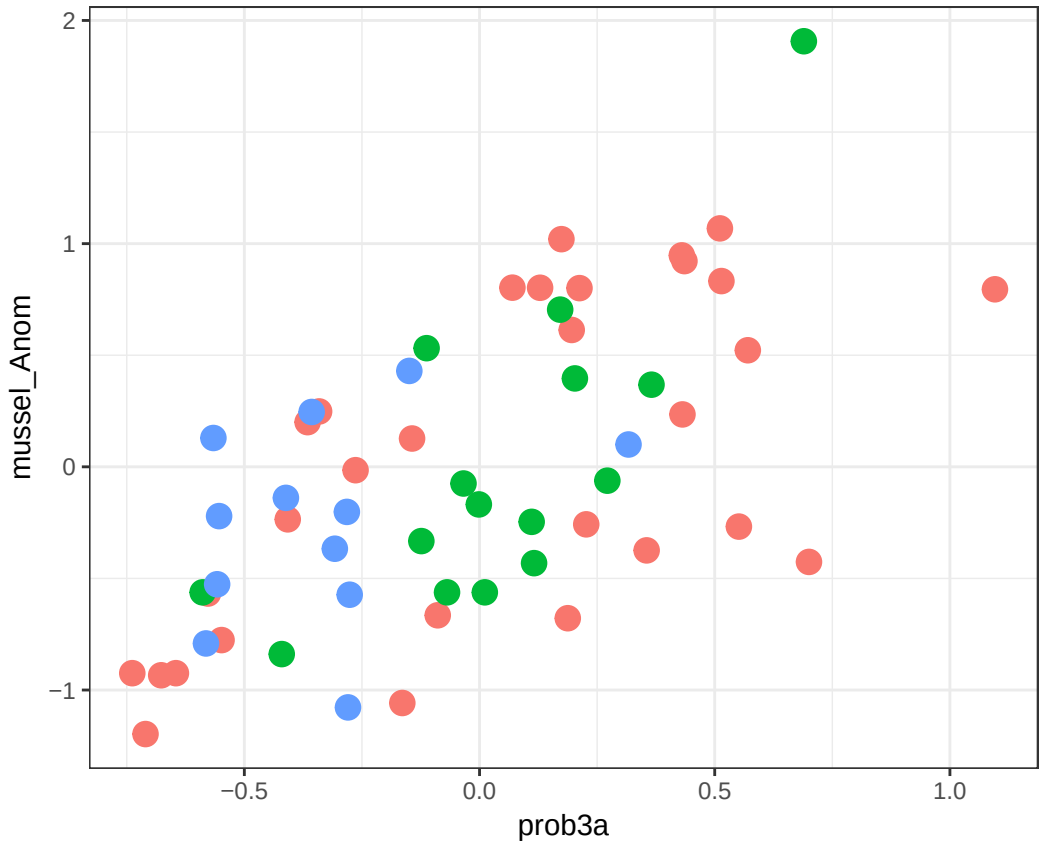
```
## [1] 117.9339
```

Scenario 28 - Site best model




```
##      mussel_Anom
## [1,]   0.4817733
```

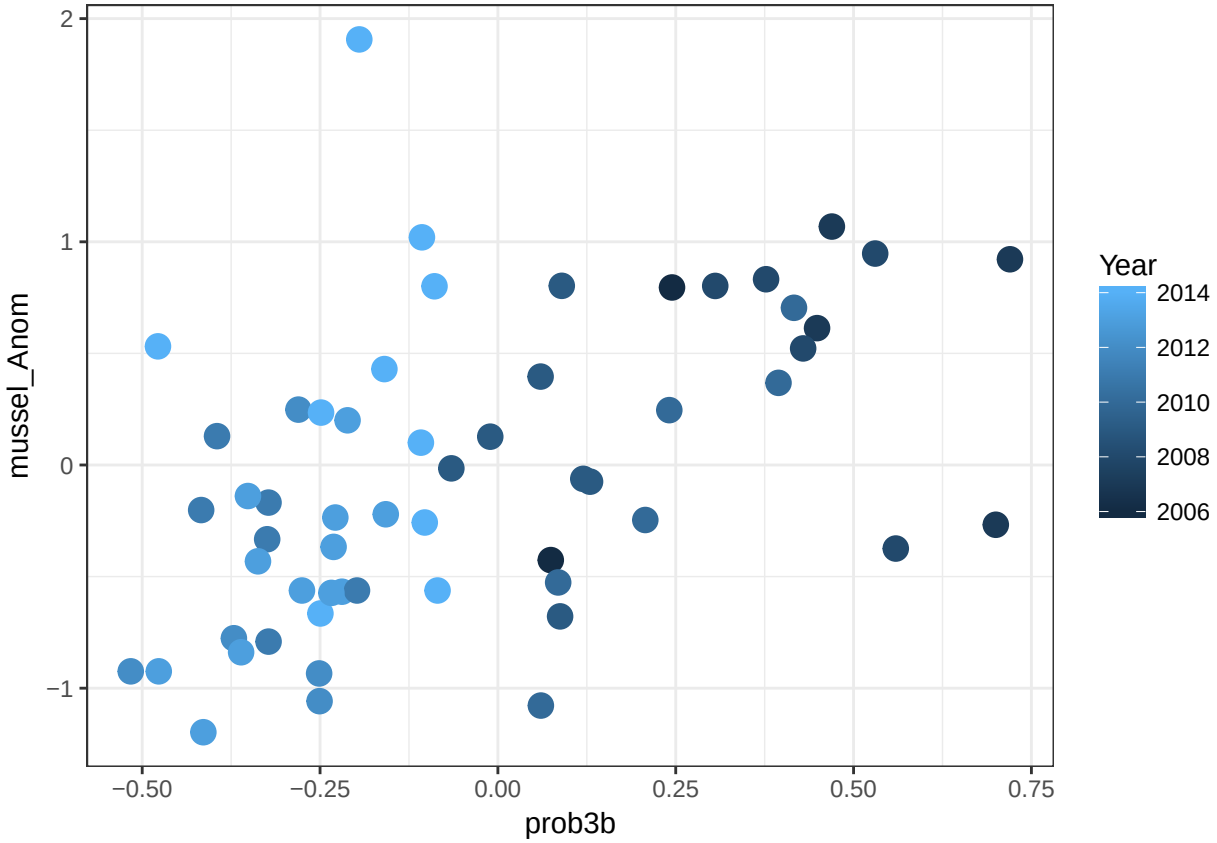

Residuals vs Fitted
Residuals
Predicted values
Normal Q−Q
Std. deviance resid.
Theoretical Quantiles
Scale−Location
√|Std. deviance resid.|
Predicted values
Residuals vs Leverage
Std. Pearson resid.
Cook's distance
Leverage



Region Winner

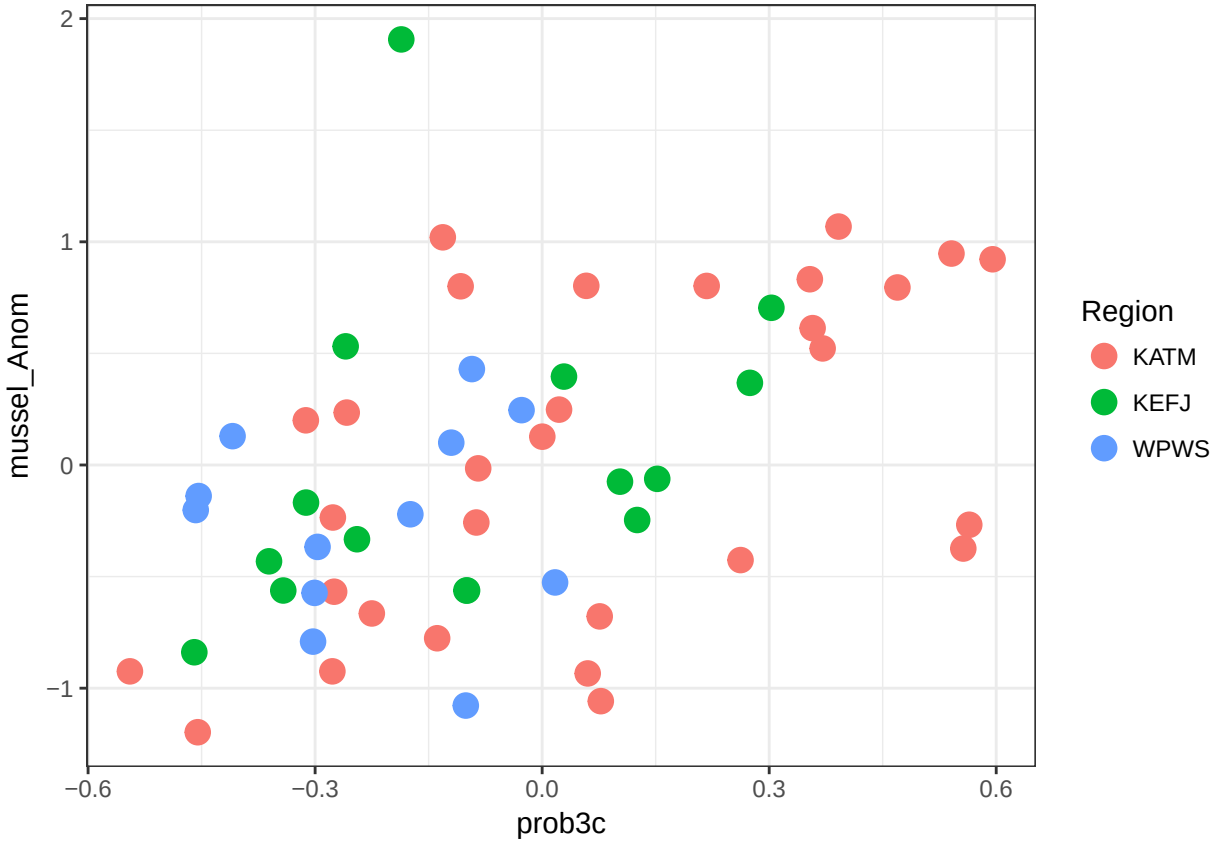
```
##      mussel_Anom
## [1,]   0.6355879
```

Transect Winner



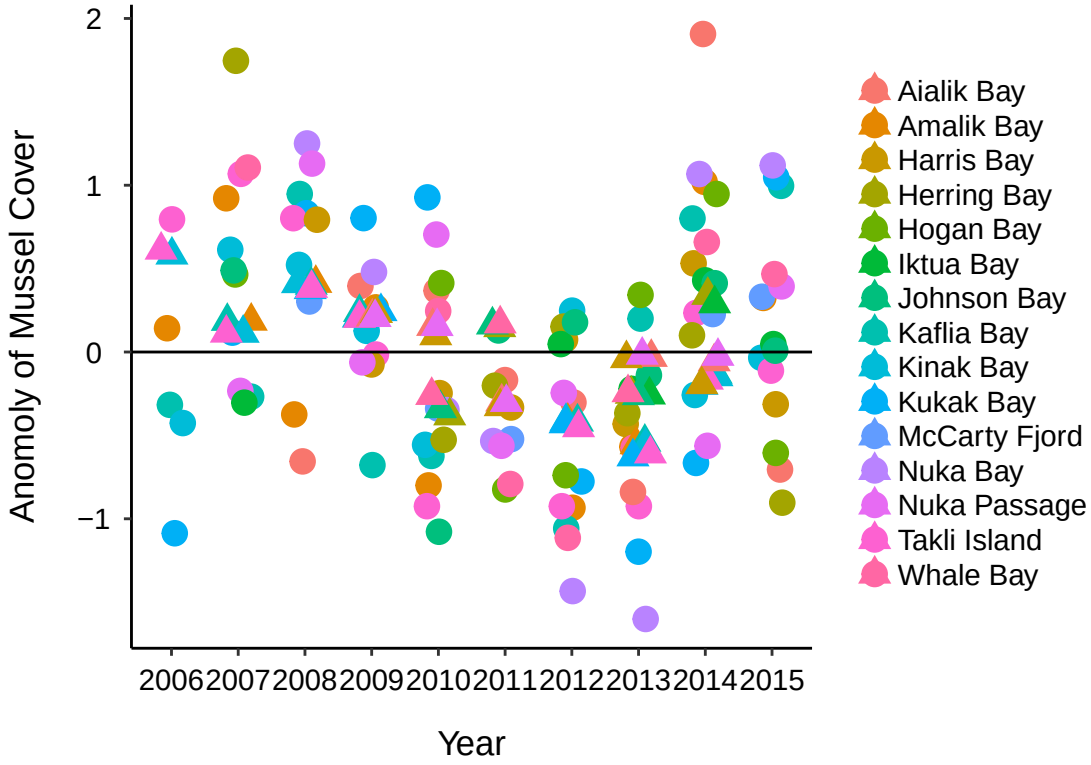

```
##      mussel_Anom
## [1,]   0.4806303
```

Scenario 27



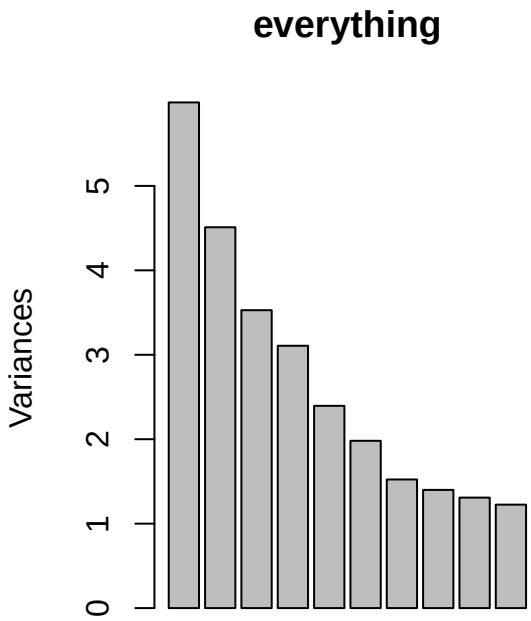

```
##      mussel_Anom
## [1,]   0.4451506
```

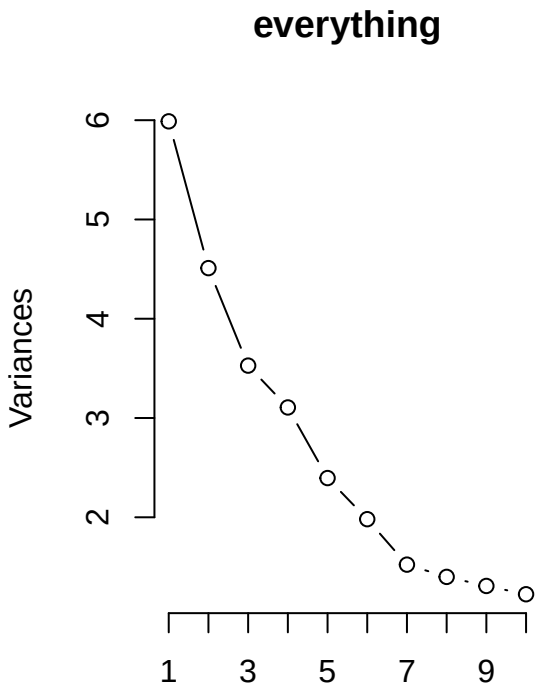
```
## Warning: Removed 49 rows containing missing values (geom_point).
```

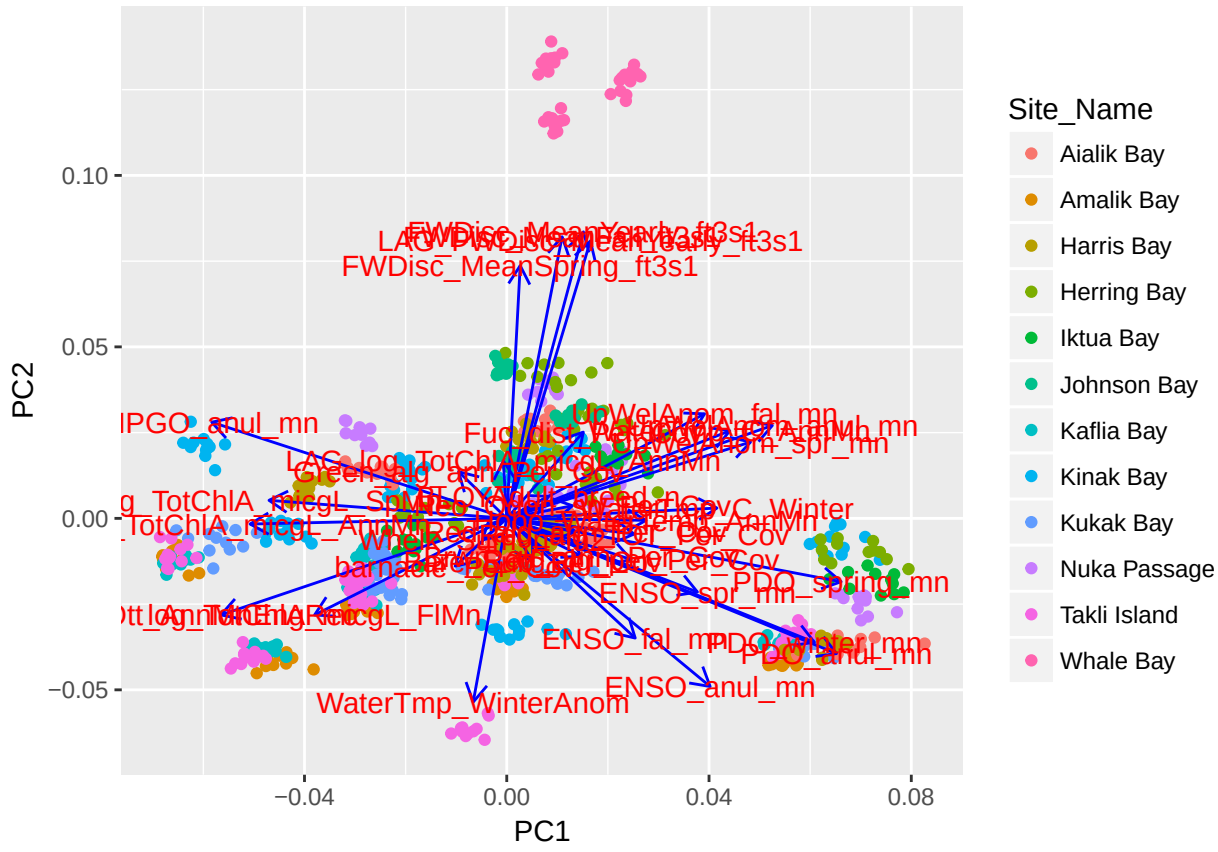


Transect-level Analyses (Within-Site)

```
## Importance of components:
##                           PC1    PC2    PC3     PC4     PC5     PC6    PC7
## Standard deviation     2.4471 2.1236 1.8782 1.76251 1.54759 1.40750 1.2342
## Proportion of Variance 0.1761 0.1326 0.1038 0.09137 0.07044 0.05827 0.0448
## Cumulative Proportion  0.1761 0.3088 0.4125 0.50389 0.57434 0.63260 0.6774
##                            PC8     PC9    PC10   PC11    PC12    PC13
## Standard deviation     1.18310 1.14377 1.10675 1.0014 0.94724 0.91526
## Proportion of Variance 0.04117 0.03848 0.03603 0.0295 0.02639 0.02464
## Cumulative Proportion  0.71857 0.75705 0.79307 0.8226 0.84896 0.87360
##                           PC14    PC15    PC16    PC17    PC18    PC19
## Standard deviation     0.89422 0.80272 0.78556 0.75479 0.72944 0.55967
## Proportion of Variance 0.02352 0.01895 0.01815 0.01676 0.01565 0.00921
## Cumulative Proportion  0.89712 0.91607 0.93422 0.95097 0.96662 0.97584
##                           PC20    PC21    PC22    PC23    PC24    PC25
## Standard deviation     0.54049 0.41618 0.36565 0.29427 0.25926 0.22451
## Proportion of Variance 0.00859 0.00509 0.00393 0.00255 0.00198 0.00148
## Cumulative Proportion  0.98443 0.98952 0.99346 0.99600 0.99798 0.99946
##                           PC26    PC27     PC28      PC29      PC30
## Standard deviation     0.12476 0.05237 7.81e-15 6.219e-15 5.026e-15
## Proportion of Variance 0.00046 0.00008 0.00e+00 0.000e+00 0.000e+00
## Cumulative Proportion  0.99992 1.00000 1.00e+00 1.000e+00 1.000e+00
##                             PC31      PC32      PC33      PC34
## Standard deviation     4.028e-15 2.007e-15 1.768e-15 7.656e-16
## Proportion of Variance 0.000e+00 0.000e+00 0.000e+00 0.000e+00
## Cumulative Proportion  1.000e+00 1.000e+00 1.000e+00 1.000e+00
```


everything
Variances
0
1
2
3
4
5


everything
Variances
2
3
4
5
6
1
3
5
7
9



Scenario 1 - Transect PCA-informed model

*NOTE:

chose NPGO annual over ENSO fall
chose Green algae over LAG annual Chla
chose Bare Substrate over Barnacles and Sea Otter eng rec
chose PDO Annual over PDO Winter
chose Brown algae over ENSO Spring
chose HOBO Water Temp over PDO Spring
chose Water Temp Annual Buoys over Upwelling Spring and Neo-Odon algae
chose Freshwater Yearly over Fucus and LAG Freshwater Yearly
chose Water Temp Winter over Freshwater Spring and Red algae TOTAL

Also removed Upwelling Fall and Upwelling Winter Anomaly due to singularities

Scenario 2 - Transect

Scenario 3 - Transect

Scenario 4 - Transect

Scenario 5 - Transect

Scenario 6 - Transect

Scenario 7 - Transect

Scenario 8 - Transect

Scenario 9 - Transect

Scenario 10 - Transect

Scenario 11 - Transect

Scenario 12 - Transect

Scenario 13 - Transect

Scenario 14 - Transect

Scenario 15 - Transect

Scenario 16 - Transect

Scenario 17 - Transect

Scenario 18 - Transect

Scenario 19 - Transect

Scenario 20 - Transect

Scenario 21 - Transect

Scenario 22 - Transect

Scenario 23 - Transect

Scenario 24 - Transect

Scenario 25 - Transect

Scenario 26 - Transect

Scenario 27 - Transect

Scenario 28 - Transect

Scenario 29 - Transect

```
##       Model      AIC
## 1   Sce_1_t 2317.748
## 2   Sce_4_t 2320.049
## 3   Sce_3_t 2321.929
## 4  Sce_25_t 2335.087
## 5  Sce_24_t 2336.681
## 6   Sce_2_t 2336.926
## 7  Sce_22_t 2342.168
## 8  Sce_10_t 2345.807
## 9  Sce_21_t 2354.189
## 10 Sce_23_t 2355.210
## 11 Sce_20_t 2359.774
## 12 Sce_18_t 2365.453
## 13 Sce_29_t 2367.655
## 14 Sce_19_t 2368.414
## 15 Sce_14_t 2368.703
## 16 Sce_16_t 2374.168
## 17 Sce_13_t 2374.849
## 18  Sce_9_t 2384.972
## 19  Sce_7_t 2385.909
## 20  Sce_5_t 2387.012
## 21 Sce_17_t 2387.012
## 22 Sce_12_t 2389.011
## 23 Sce_15_t 2392.237
## 24 Sce_27_t 2392.681
## 25 Sce_11_t 2395.704
## 26 Sce_28_t 2399.603
## 27 Sce_26_t 2401.129
## 28  Sce_6_t 2403.503
## 29  Sce_8_t 2405.227
```

Coefficients for model(s) with lowest AIC scores

```
##
## Call:
## glm(formula = mussel_Anom ~ ., family = gaussian, data = BN_reg_sub_df)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.9756  -0.8267   0.0122   0.7160   3.2197
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)             0.7925374  0.2045420   3.875 0.000116 ***
## UpWelAnom_fal_mn        0.0063900  0.0024337   2.626 0.008819 **
## UpWelAnom_anul_mn      -0.0231883  0.0031727  -7.309 6.74e-13 ***
## Hobo_WaterTemp_AnnMn   -0.0255188  0.0254342  -1.003 0.316018
## Bare_Sub_Per_Cov       -0.0069407  0.0022450  -3.092 0.002062 **
## Red_alg_TOT_Per_Cov     0.0009937  0.0011550   0.860 0.389849
## Brwn_alg_ann_Per_Cov   -0.0142785  0.0038267  -3.731 0.000204 ***
## Green_alg_ann_Per_Cov -0.0055845  0.0016654  -3.353 0.000838 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 1.164318)
##
##     Null deviance: 1009.33  on 779  degrees of freedom
## Residual deviance:  898.85  on 772  degrees of freedom
## AIC: 2342.2
##
## Number of Fisher Scoring iterations: 2
```

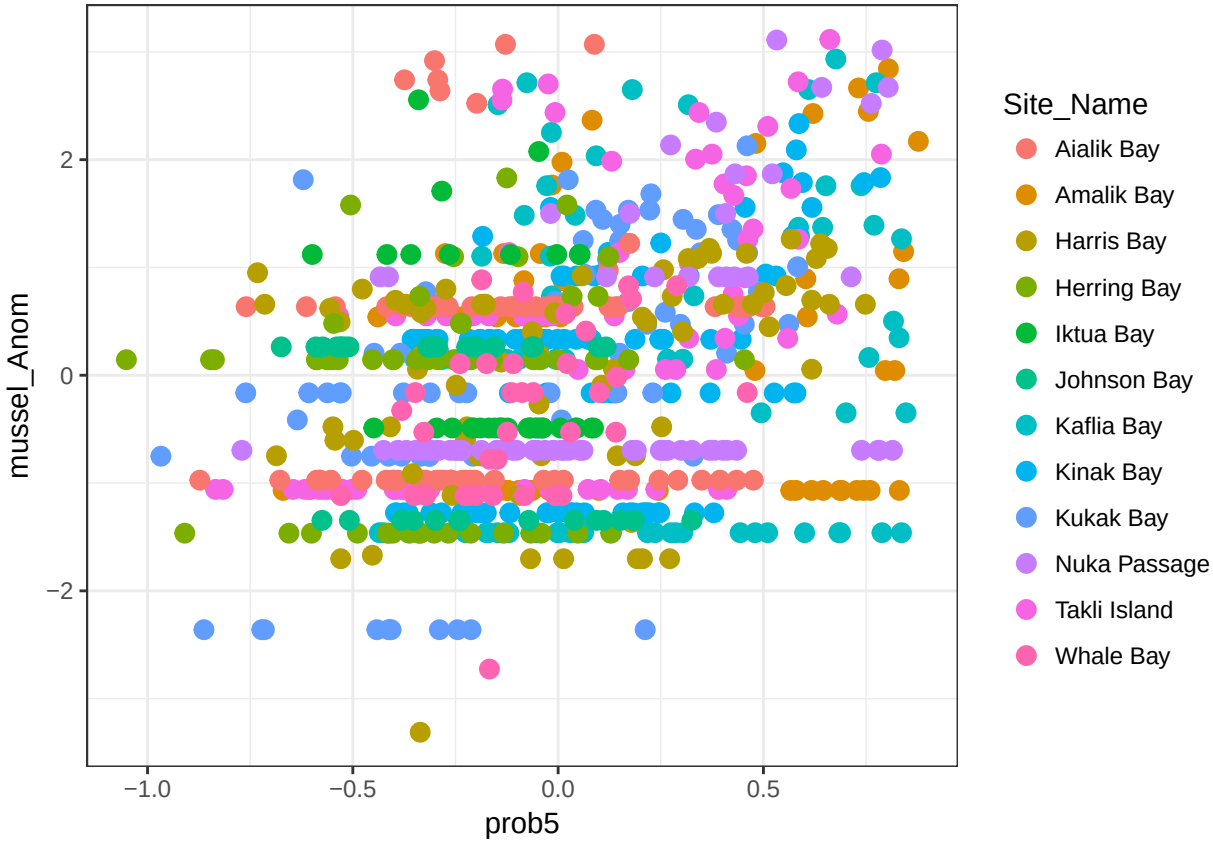
Scenario Winner from Region-level analysis above

```
## [1] 2332.37
```

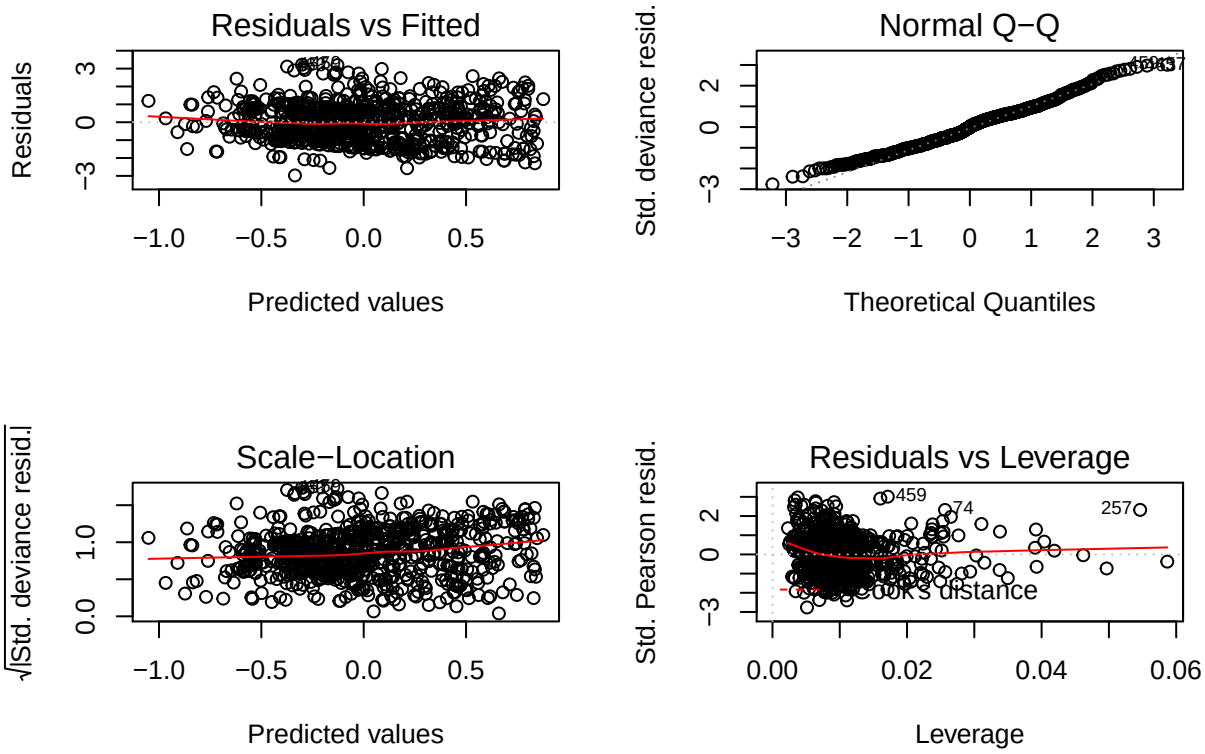
Scenario Winner from Site-level analysis above

```
## [1] 2355.109
```

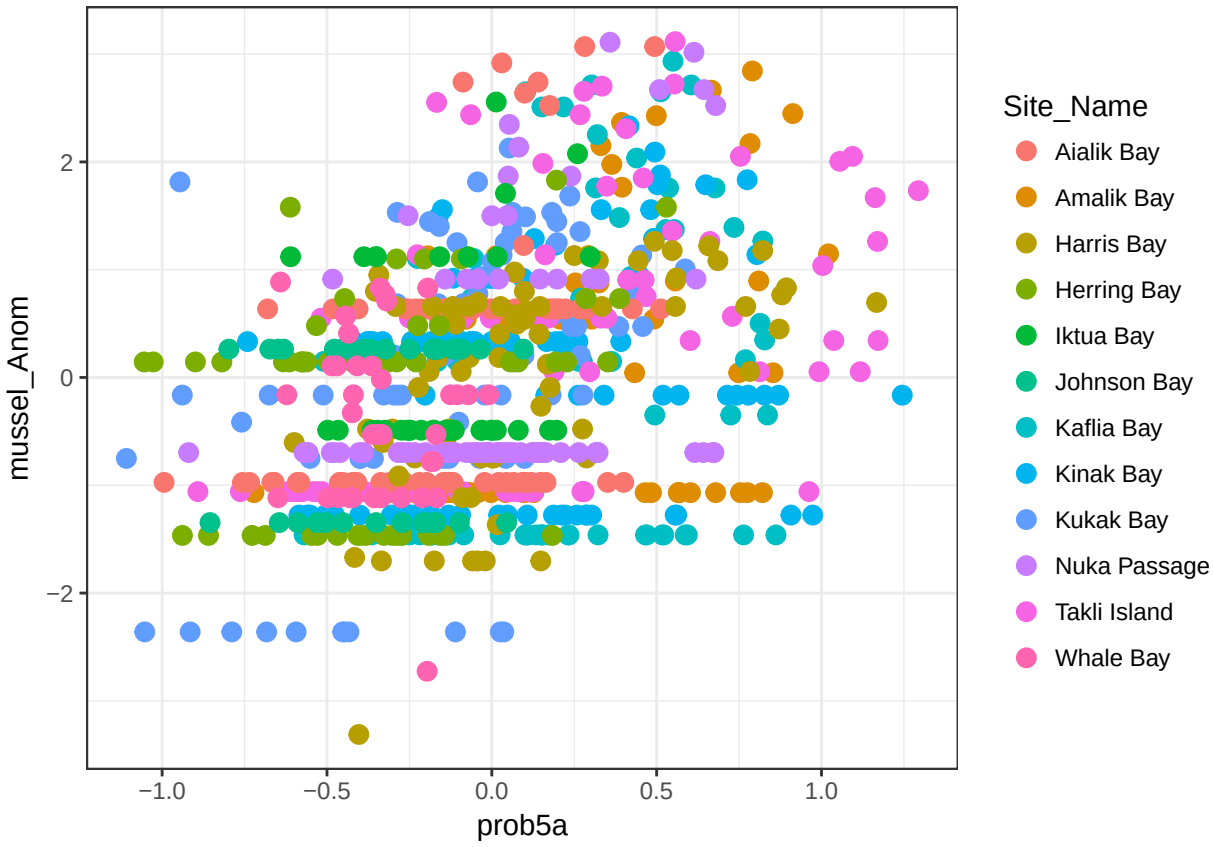
Scenario 22 - Best Model




```
##      mussel_Anom
## [1,]   0.3308445
```

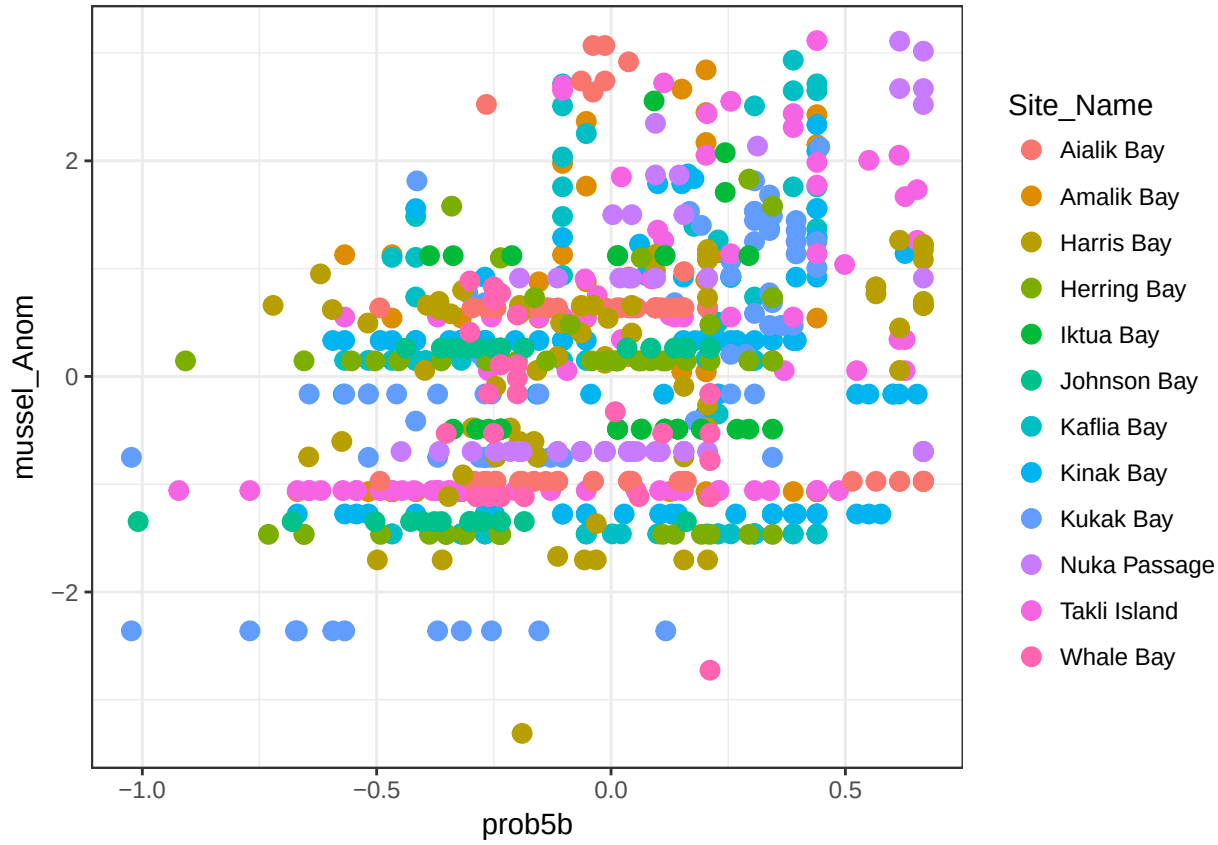

Residuals vs Fitted
Residuals
Predicted values
Normal Q−Q
Std. deviance resid.
Theoretical Quantiles
Scale−Location
√|Std. deviance resid.|
Predicted values
Residuals vs Leverage
Std. Pearson resid.
459
74
257
Cook's distance
Leverage

Region winning scenario



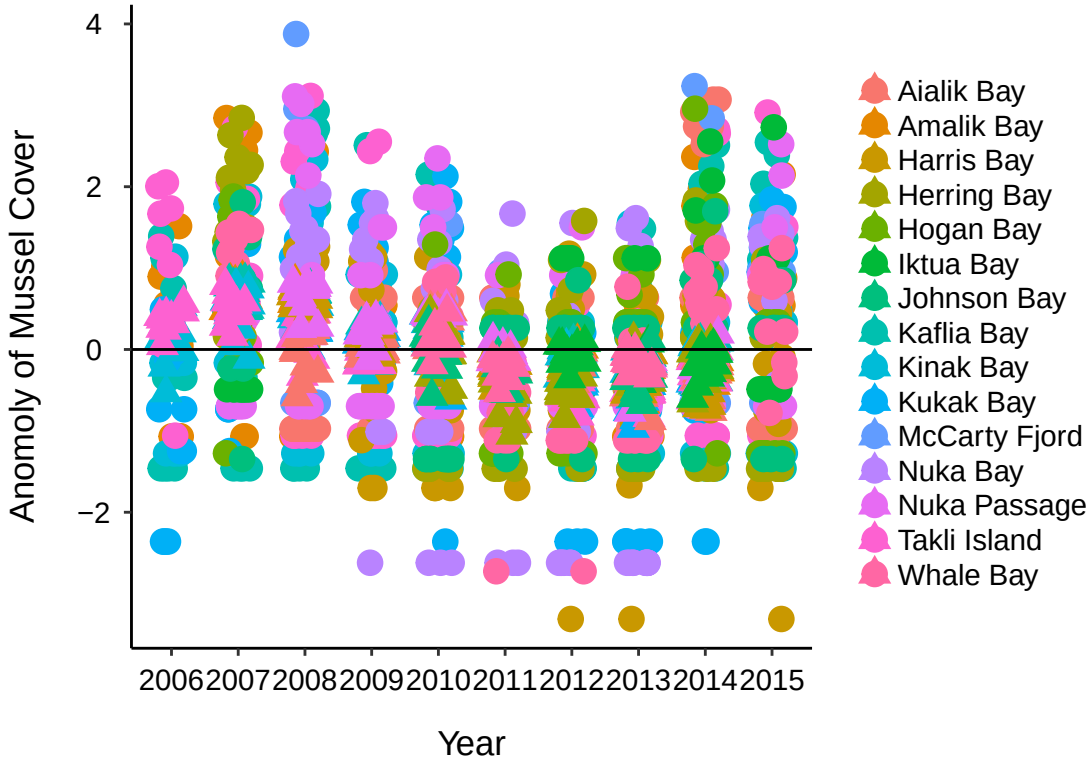

```
##      mussel_Anom
## [1,]   0.3660622
```

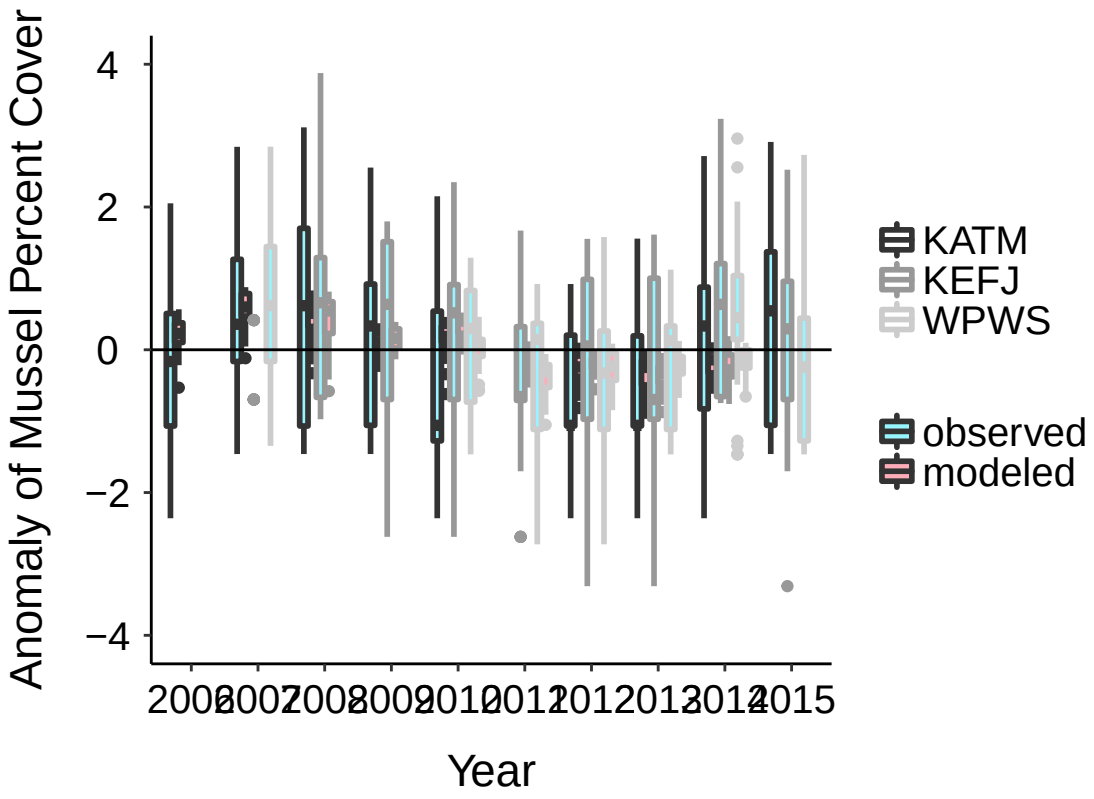
Site winning scenario




```
##      mussel_Anom
## [1,]   0.2959186
```

```
## Warning: Removed 588 rows containing missing values (geom_point).
```




Anomaly of Mussel Percent Cover
4
2
0
−2
−4
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year
KATM
KEFJ
WPWS
observed
modeled