Tables

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# Kelp Timeseries Model

| term | df | 𝛘2 | p |
| --- | --- | --- | --- |
| year | 1 | 111.837 | 3.880e-26 |
| region | 5 | 367.980 | 2.351e-77 |
| year:region | 5 | 14.210 | 1.433e-02 |

Table 1. likelihood ratio tests for trend analysis of kelp over time.

# Urchin Timseries Model

|  | term | 𝛘2 | df | p |
| --- | --- | --- | --- | --- |
| A) Non-Zero Urchins | year | 1.661 | 1 | 1.975e-01 |
|  | region | 84.139 | 5 | 1.141e-16 |
|  | year:region | 9.052 | 5 | 1.070e-01 |
| B) Zero Inflation | year | 27.272 | 1 | 1.768e-07 |
|  | region | 68.927 | 5 | 1.714e-13 |
|  | year:region | 22.464 | 5 | 4.272e-04 |

Table 2. likelihood ratio tests for trend analysis of kelp over time. A) Trend analysis if urchins are not zero. B) Tests of predictors of zero inflation.

# Kelp Drivers Model

| term | 𝛘2 | df | p |
| --- | --- | --- | --- |
| urchin anomaly | 54.149 | 1 | 1.859e-13 |
| spring temperature anomaly | 4.588 | 1 | 3.219e-02 |
| lag summer temperature anomaly | 5.349 | 1 | 2.074e-02 |
| average urchins in subregion | 44.439 | 1 | 2.624e-11 |
| average spring temperature in subregion | 51.701 | 1 | 6.463e-13 |
| average lag summer temperature in subregion | 1.169 | 1 | 2.795e-01 |

Table 3. likelihood ratio tests of drivers of kelp abundance in the northern Gulf of Maine.

| term | estimate | SE | z | p |
| --- | --- | --- | --- | --- |
| Intercept | 7.678 | 0.863 | 8.897 | 5.745e-19 |
| urchin anomaly | -0.051 | 0.007 | -7.359 | 1.859e-13 |
| spring temperature anomaly | -0.216 | 0.101 | -2.142 | 3.219e-02 |
| lag summer temperature anomaly | -0.204 | 0.088 | -2.313 | 2.074e-02 |
| average urchins in subregion | 0.322 | 0.048 | 6.666 | 2.624e-11 |
| average spring temperature in subregion | -1.771 | 0.246 | -7.190 | 6.463e-13 |
| average lag summer temperature in subregion | 0.057 | 0.053 | 1.081 | 2.795e-01 |
| year sd | 0.405 |  |  |  |
| region sd | 0.000 |  |  |  |

Table 4. Coefficient estimates, SE, and z tests for the kelp drivers model.

# Kelp Composition Model

| term | 𝛘2 | df | p |
| --- | --- | --- | --- |
| year | 33.748 | 4 | 8.392e-07 |
| region | 130.831 | 20 | 0.000e+00 |
| year:region | 52.283 | 20 | 1.035e-04 |

Table 5. likelihood ratio tests for trend analysis of kelp species composition over time.

| species | term | 𝛘2 | df | p |
| --- | --- | --- | --- | --- |
| agar | region | 400.594 | 5 | 0.000e+00 |
| agar | year | 20.458 | 1 | 6.094e-06 |
| agar | year:region | 237.241 | 5 | 0.000e+00 |
| alar | region | 461.068 | 5 | 0.000e+00 |
| alar | year | 57.274 | 1 | 1.519e-13 |
| alar | year:region | 673.939 | 5 | 0.000e+00 |
| ldig | region | 504.662 | 5 | 0.000e+00 |
| ldig | year | 24.849 | 1 | 8.268e-07 |
| ldig | year:region | 687.397 | 5 | 0.000e+00 |
| sac | region | 434.305 | 5 | 0.000e+00 |
| sac | year | 27.916 | 1 | 2.534e-07 |
| sac | year:region | 1,176.377 | 5 | 0.000e+00 |

Table 6. likelihood ratio tests for changes in individual kelp species over time with p-values corrected for false discovery rate.

| Species | Region | Mean Differerence from 2004 to 2018 | Lower 95% CI | Upper 95%CI |
| --- | --- | --- | --- | --- |
| agar | York | 0.048 | -2.223 | 2.734 |
| agar | Casco Bay | -2.562 | -5.780 | 0.598 |
| agar | Midcoast | -1.078 | -2.966 | 1.310 |
| agar | Penobscot Bay | -2.643 | -5.765 | 0.806 |
| agar | MDI | -7.278 | -14.083 | -1.902 |
| agar | Downeast | -2.609 | -8.933 | 2.345 |
| alar | York | -0.029 | -1.361 | 1.511 |
| alar | Casco Bay | -1.190 | -3.136 | 0.875 |
| alar | Midcoast | -0.277 | -1.681 | 1.526 |
| alar | Penobscot Bay | -3.547 | -5.849 | -1.220 |
| alar | MDI | -4.850 | -10.319 | 0.232 |
| alar | Downeast | -4.703 | -9.912 | -0.865 |
| ldig | York | -1.850 | -4.879 | 1.288 |
| ldig | Casco Bay | 2.190 | -2.549 | 9.109 |
| ldig | Midcoast | 12.895 | 2.241 | 28.644 |
| ldig | Penobscot Bay | 4.363 | -13.365 | 24.182 |
| ldig | MDI | 27.509 | -4.577 | 57.042 |
| ldig | Downeast | 51.973 | 27.044 | 72.443 |
| sac | York | 12.963 | -3.441 | 34.977 |
| sac | Casco Bay | -22.912 | -41.049 | -8.350 |
| sac | Midcoast | -10.114 | -25.661 | 10.093 |
| sac | Penobscot Bay | -0.360 | -9.717 | 12.178 |
| sac | MDI | 4.511 | -24.980 | 40.860 |
| sac | Downeast | -9.238 | -31.035 | 4.323 |

Table 7. Posthoc comparisons of differences in kelp species within each subregion between 2004 and 2018. Differences derived via simulation, and as such we include the 95% CI for each.

# Understory Composition Model

| term | 𝛘2 | df | p |
| --- | --- | --- | --- |
| year | 16.732 | 13 | 2.118e-01 |
| region | 161.868 | 65 | 3.162e-10 |
| year:region | 127.609 | 65 | 5.766e-06 |

Table 8. likelihood ratio tests for trend analysis of understory species composition over time.

| species | term | 𝛘2 | df | p |
| --- | --- | --- | --- | --- |
| ccrisp | region | 14.278 | 5 | 2.265e-02 |
| ccrisp | year | 19.233 | 1 | 3.008e-05 |
| ccrisp | year:region | 29.487 | 5 | 1.261e-04 |
| chaet | region | 10.114 | 5 | 7.807e-02 |
| chaet | year | 20.357 | 1 | 2.088e-05 |
| chaet | year:region | 28.655 | 5 | 1.261e-04 |
| codm | region | 10.240 | 5 | 7.807e-02 |
| codm | year | 9.813 | 1 | 2.503e-03 |
| codm | year:region | 3.965 | 5 | 8.009e-01 |
| coral | region | 29.974 | 5 | 4.850e-05 |
| coral | year | 2.160 | 1 | 1.417e-01 |
| coral | year:region | 28.497 | 5 | 1.261e-04 |
| desm | region | 11.781 | 5 | 5.476e-02 |
| desm | year | 4.462 | 1 | 3.755e-02 |
| desm | year:region | 13.566 | 5 | 6.049e-02 |
| palm | region | 2.897 | 5 | 7.159e-01 |
| palm | year | 7.920 | 1 | 6.356e-03 |
| palm | year:region | 11.681 | 5 | 9.358e-02 |
| phyc | region | 54.975 | 5 | 8.585e-10 |
| phyc | year | 27.592 | 1 | 6.492e-07 |
| phyc | year:region | 11.376 | 5 | 9.358e-02 |
| poly | region | 34.671 | 5 | 7.584e-06 |
| poly | year | 12.782 | 1 | 5.687e-04 |
| poly | year:region | 10.546 | 5 | 9.938e-02 |
| porph | region | 56.244 | 5 | 8.585e-10 |
| porph | year | 29.177 | 1 | 4.294e-07 |
| porph | year:region | 11.051 | 5 | 9.358e-02 |
| ptilo | region | 11.078 | 5 | 6.481e-02 |
| ptilo | year | 45.713 | 1 | 1.779e-10 |
| ptilo | year:region | 0.993 | 5 | 9.671e-01 |
| rhod | region | 27.732 | 5 | 1.068e-04 |
| rhod | year | 17.396 | 1 | 6.575e-05 |
| rhod | year:region | 2.768 | 5 | 9.564e-01 |
| sder | region | 19.816 | 5 | 2.931e-03 |
| sder | year | 13.007 | 1 | 5.687e-04 |
| sder | year:region | 0.942 | 5 | 9.671e-01 |
| ulva | region | 16.573 | 5 | 1.000e-02 |
| ulva | year | 7.688 | 1 | 6.568e-03 |
| ulva | year:region | 1.719 | 5 | 9.671e-01 |

Table 9. likelihood ratio tests for changes in individual understory species over time with p-values corrected for false discovery rate.

| Species | Region | Mean Differerence from 2004 to 2018 | Lower 95% CI | Upper 95%CI |
| --- | --- | --- | --- | --- |
| ccrisp | York | -2.913 | -2.945 | -2.880 |
| ccrisp | Casco Bay | 8.013 | 7.939 | 8.086 |
| ccrisp | Midcoast | 11.182 | 11.090 | 11.275 |
| ccrisp | Penobscot Bay | 14.876 | 14.760 | 14.993 |
| ccrisp | MDI | 1.250 | 1.232 | 1.268 |
| ccrisp | Downeast | -0.054 | -0.062 | -0.046 |
| chaet | York | 2.213 | 1.860 | 2.582 |
| chaet | Casco Bay | 1.214 | 0.826 | 1.643 |
| chaet | Midcoast | 0.127 | -0.151 | 0.426 |
| chaet | Penobscot Bay | 0.164 | -0.142 | 0.493 |
| chaet | MDI | 0.472 | 0.178 | 0.808 |
| chaet | Downeast | 0.182 | -0.093 | 0.492 |
| codm | York | -0.198 | -0.409 | 0.019 |
| codm | Casco Bay | -0.726 | -0.990 | -0.454 |
| codm | Midcoast | -0.354 | -0.616 | -0.075 |
| codm | Penobscot Bay | 0.003 | -0.269 | 0.291 |
| codm | MDI | 0.004 | -0.234 | 0.271 |
| codm | Downeast | 0.005 | -0.238 | 0.278 |
| coral | York | 8.360 | 7.423 | 9.364 |
| coral | Casco Bay | 4.291 | 3.658 | 4.986 |
| coral | Midcoast | 2.417 | 1.997 | 2.888 |
| coral | Penobscot Bay | 0.503 | 0.318 | 0.719 |
| coral | MDI | 1.500 | 1.239 | 1.792 |
| coral | Downeast | 5.253 | 4.517 | 6.052 |
| desm | York | 1.943 | 1.681 | 2.228 |
| desm | Casco Bay | -1.972 | -2.036 | -1.902 |
| desm | Midcoast | -0.240 | -0.386 | -0.067 |
| desm | Penobscot Bay | 3.906 | 3.351 | 4.518 |
| desm | MDI | -0.576 | -0.641 | -0.498 |
| desm | Downeast | -1.225 | -1.240 | -1.205 |
| palm | York | 0.115 | -0.131 | 0.369 |
| palm | Casco Bay | -0.782 | -1.090 | -0.464 |
| palm | Midcoast | 0.647 | 0.286 | 1.042 |
| palm | Penobscot Bay | -0.516 | -0.881 | -0.133 |
| palm | MDI | 0.789 | 0.429 | 1.180 |
| palm | Downeast | 0.504 | 0.172 | 0.877 |
| phyc | York | -5.079 | -5.401 | -4.769 |
| phyc | Casco Bay | -4.549 | -4.861 | -4.249 |
| phyc | Midcoast | -0.247 | -0.324 | -0.159 |
| phyc | Penobscot Bay | -1.001 | -1.063 | -0.941 |
| phyc | MDI | -0.231 | -0.299 | -0.153 |
| phyc | Downeast | 1.997 | 1.642 | 2.389 |
| poly | York | 37.393 | 37.289 | 37.496 |
| poly | Casco Bay | 3.217 | 3.166 | 3.267 |
| poly | Midcoast | 10.580 | 10.498 | 10.663 |
| poly | Penobscot Bay | 3.732 | 3.678 | 3.785 |
| poly | MDI | -5.050 | -5.066 | -5.035 |
| poly | Downeast | 11.586 | 11.504 | 11.668 |
| porph | York | -0.723 | -0.857 | -0.586 |
| porph | Casco Bay | -0.468 | -0.625 | -0.303 |
| porph | Midcoast | 0.613 | 0.436 | 0.797 |
| porph | Penobscot Bay | 1.757 | 1.273 | 2.316 |
| porph | MDI | -0.929 | -1.114 | -0.738 |
| porph | Downeast | 0.890 | 0.662 | 1.136 |
| ptilo | York | -0.921 | -1.189 | -0.643 |
| ptilo | Casco Bay | -3.477 | -3.836 | -3.118 |
| ptilo | Midcoast | -0.142 | -0.434 | 0.155 |
| ptilo | Penobscot Bay | -0.735 | -1.066 | -0.406 |
| ptilo | MDI | -0.457 | -0.737 | -0.160 |
| ptilo | Downeast | -0.659 | -0.966 | -0.321 |
| rhod | York | 0.265 | 0.014 | 0.525 |
| rhod | Casco Bay | 0.979 | 0.590 | 1.406 |
| rhod | Midcoast | 4.531 | 3.707 | 5.439 |
| rhod | Penobscot Bay | 2.134 | 1.595 | 2.719 |
| rhod | MDI | 1.005 | 0.642 | 1.391 |
| rhod | Downeast | 1.437 | 1.005 | 1.908 |
| ulva | York | -0.136 | -0.397 | 0.134 |
| ulva | Casco Bay | -0.064 | -0.351 | 0.237 |
| ulva | Midcoast | -0.087 | -0.419 | 0.265 |
| ulva | Penobscot Bay | 0.902 | 0.433 | 1.414 |
| ulva | MDI | -0.595 | -0.904 | -0.275 |
| ulva | Downeast | 0.146 | -0.177 | 0.498 |

Table 10. Posthoc comparisons of differences in understory species within each subregion between 2004 and 2018. Differences derived via simulation, and as such we include the 95% CI for each.

## Supplementary Tables

# Kelp Timeseries Model at 10m

| term | df | 𝛘2 | p |
| --- | --- | --- | --- |
| year | 1 | 7.123 | 7.609e-03 |
| region | 5 | 25.784 | 9.828e-05 |
| year:region | 5 | 10.038 | 7.417e-02 |

Supplementary Table 1. likelihood ratio tests for trend analysis of kelp over time in model with an interaction. Note the interaction is not well supported. The logit coefficient of the relationship across all of Maine is -0.023.

# Sample Sizes

## # A tibble: 97 × 3  
## Year Region `Sample Size`  
## <int> <fct> <int>  
## 1 2001 Downeast 22  
## 2 2002 Downeast 20  
## 3 2003 Downeast 26  
## 4 2004 Downeast 20  
## 5 2005 Downeast 26  
## 6 2006 Downeast 20  
## 7 2007 Downeast 18  
## 8 2008 Downeast 20  
## 9 2009 Downeast 18  
## 10 2010 Downeast 20  
## # … with 87 more rows  
## # ℹ Use `print(n = ...)` to see more rows

Supplementary Table S2. Sample size per region per year for use in the 5m kelp timeseries and driver models.

## # A tibble: 12 × 3  
## Year Region `Sample Size`  
## <fct> <fct> <int>  
## 1 2018 York 7  
## 2 2004 York 16  
## 3 2018 Casco Bay 5  
## 4 2004 Casco Bay 11  
## 5 2018 Midcoast 5  
## 6 2004 Midcoast 24  
## 7 2018 Penobscot Bay 7  
## 8 2004 Penobscot Bay 21  
## 9 2018 MDI 3  
## 10 2004 MDI 6  
## 11 2018 Downeast 5  
## 12 2004 Downeast 4

Supplementary Table S3. Sample size per region per year for use in the 5m understory community composition.

# Temperature

| term | sumsq | df | f | p |
| --- | --- | --- | --- | --- |
| year | 11.7991777 | 1 | 15.800 | 1.439e-04 |
| region | 21.6122126 | 5 | 5.788 | 1.148e-04 |
| year:region | 0.5504499 | 5 | 0.147 | 9.803e-01 |
| Residuals | 65.7155498 | 88 |  | NA |

Supplementary Table S5. F Table results from summer temperature trend linear regression model.

| term | estimate | std. error | t | p |
| --- | --- | --- | --- | --- |
| (Intercept) | -164.46565746 | 88.92233454 | -1.850 | 6.774e-02 |
| year | 0.08436646 | 0.04424672 | 1.907 | 5.982e-02 |
| regionMDI | -28.12441167 | 125.75517150 | -0.224 | 8.236e-01 |
| regionPenobscot Bay | 56.24394148 | 123.70073620 | 0.455 | 6.505e-01 |
| regionMidcoast | 47.97334937 | 123.70073620 | 0.388 | 6.991e-01 |
| regionCasco Bay | 50.54886816 | 123.67099947 | 0.409 | 6.837e-01 |
| regionYork | 40.65779301 | 123.70073620 | 0.329 | 7.432e-01 |
| year:regionMDI | 0.01388899 | 0.06257431 | 0.222 | 8.249e-01 |
| year:regionPenobscot Bay | -0.02797927 | 0.06154742 | -0.455 | 6.505e-01 |
| year:regionMidcoast | -0.02375071 | 0.06154742 | -0.386 | 7.005e-01 |
| year:regionCasco Bay | -0.02477701 | 0.06154742 | -0.403 | 6.882e-01 |
| year:regionYork | -0.01968189 | 0.06154742 | -0.320 | 7.499e-01 |

Supplementary Table S6. Coefficient Table results from summer temperature trend linear regression model.

| term | sumsq | df | f | p |
| --- | --- | --- | --- | --- |
| year | 11.7991777 | 1 | 15.800 | 1.439e-04 |
| region | 21.6122126 | 5 | 5.788 | 1.148e-04 |
| year:region | 0.5504499 | 5 | 0.147 | 9.803e-01 |
| Residuals | 65.7155498 | 88 |  | NA |

Supplementary Table S7. F Table results from spring temperature trend linear regression model.

| term | estimate | std. error | t | p |
| --- | --- | --- | --- | --- |
| (Intercept) | -164.46565746 | 88.92233454 | -1.850 | 6.774e-02 |
| year | 0.08436646 | 0.04424672 | 1.907 | 5.982e-02 |
| regionMDI | -28.12441167 | 125.75517150 | -0.224 | 8.236e-01 |
| regionPenobscot Bay | 56.24394148 | 123.70073620 | 0.455 | 6.505e-01 |
| regionMidcoast | 47.97334937 | 123.70073620 | 0.388 | 6.991e-01 |
| regionCasco Bay | 50.54886816 | 123.67099947 | 0.409 | 6.837e-01 |
| regionYork | 40.65779301 | 123.70073620 | 0.329 | 7.432e-01 |
| year:regionMDI | 0.01388899 | 0.06257431 | 0.222 | 8.249e-01 |
| year:regionPenobscot Bay | -0.02797927 | 0.06154742 | -0.455 | 6.505e-01 |
| year:regionMidcoast | -0.02375071 | 0.06154742 | -0.386 | 7.005e-01 |
| year:regionCasco Bay | -0.02477701 | 0.06154742 | -0.403 | 6.882e-01 |
| year:regionYork | -0.01968189 | 0.06154742 | -0.320 | 7.499e-01 |

Supplementary Table S8. Coefficient Table results from spring temperature trend linear regression model.