reg_AIC

April 24, 2024

```
[1]: # Kristina Fauss
     # April 19, 2024
     # model selection by AIC testing all 1st order interactions

     import warnings
     warnings.filterwarnings("ignore")

     import pandas as pd
     import statsmodels.formula.api as smf

     from ols_mixedef_custom import *
```

```
[2]: fp = '/Users/kristinafauss/BackupToBox/Git/lab-flammability-testing-2022/data/
      ↪processed-data/main_dataset.csv'

     flamog = pd.read_csv(fp)

     # drop na's for flam metrics
     print(len(flamog))
     for col in ['fh', 'fd', 'pfg', 'temp_change', 'heat_flux_change']:
         flamog.dropna(subset=col, inplace=True)
     print(len(flamog))

     flamog['plant_id']=[str(a)+'_'+str(b) for a,b in zip(flamog['plant'],␣
      ↪flamog['species'])]

     # report
     print(flamog.columns)
     flamog.head()
```

```
172
171
Index(['Unnamed: 0', 'species', 'plant', 'date', 'total_branch_mass',
       'total_leaf_mass', 'stem_mass_ratio', 'leaf_mass_ratio', 'leaf_lfm',
       'thickness', 'leaf_wet_mass', 'leaf_dry_mass', 'stem_lfm', 'stem_width',
       'stem_wet_mass', 'stem_dry_mass', 'stem_sav', 'lfm', 'leaf_dmc',
       'stem_dmc', 'dmc', 'leaf_area', 'leaf_sav', 'LMA', 'SLA', 'rep',
       'branch_length', 'branch_width', 'branch_height', 'sample_wt',
```

```
          'no_branches', 'mpa', 'notes_on_plant_char', 'start_time',
          'ambient_temp', 'ambient_humidity', 'pre_ignition_glow',
          'first_glow_time', 'ignition', 'primary_ignition',
          'primary_time_of_flame_end', 'secondary_ignition',
          'secondary_time_of_flame_end', 'third_ignition',
          'third_time_of_ignition_flame_end', 'time_fh', 'fh', 'time_of_glow_end',
          'end_time', 'thermocoupler_height', 'hotplate_height',
          'notes_on_flam_data', 'fd', 'tti', 'pfg', 'max_temp',
          'time_at_max_temp', 'max_temp_sensor', 'start_temp',
          'start_temp_sensor', 'stable_avg_temp', 'temp_change', 'avg_temp_ch3',
          'max_heat_flux_loessCH7', 'time_at_max_heat_flux_loessCH7',
          'max_heat_flux_loessCH8', 'time_at_max_heat_flux_loessCH8',
          'avg_heat_flux_stableCH7', 'avg_heat_flux_stableCH8',
          'heat_flux_change', 'prop_ig', 'wet_mass', 'dry_mass', 'gdw_gfw',
          'dw_flam_sample', 'ww_flam_sample', 'branch_volume', 'branching',
          'sample_density', 'dw_sppdev', 'plant_id'],
         dtype='object')
```

[2]:   Unnamed: 0 species plant   date total_branch_mass total_leaf_mass \
     0   1 ARCDEN   1 2022-08-10   20.347   19.505
     1   2 ARCDEN   1 2022-08-10   20.347   19.505
     2   3 ARCDEN   1 2022-08-10   20.347   19.505
     3   4 ARCDEN   1 2022-08-10   20.347   19.505
     4   5 ARCDEN   1 2022-08-10   20.347   19.505

        stem_mass_ratio leaf_mass_ratio   leaf_lfm thickness … wet_mass \
     0   0.510564   0.489436 251.06912   0.514 …   1.151
     1   0.510564   0.489436 251.06912   0.514 …   1.151
     2   0.510564   0.489436 251.06912   0.514 …   1.151
     3   0.510564   0.489436 251.06912   0.514 …   1.151
     4   0.510564   0.489436 251.06912   0.514 …   1.151

        dry_mass   gdw_gfw dw_flam_sample ww_flam_sample branch_volume \
     0   0.3683 0.242414   1.291195   4.035205   1082.04
     1   0.3683 0.242414   1.429372   4.467028   1370.20
     2   0.3683 0.242414   1.283923   4.012477   682.04
     3   0.3683 0.242414   1.283923   4.012477   1262.25
     4   0.3683 0.242414   0.811215   2.535185   819.00

        branching sample_density dw_sppdev plant_id
     0   0.416667   0.004923   0.923122 1_ARCDEN
     1   0.322581   0.004303   1.348152 1_ARCDEN
     2   0.294118   0.007766   0.900752 1_ARCDEN
     3   0.466667   0.004196   0.900752 1_ARCDEN
     4   0.500000   0.004086 -0.553297 1_ARCDEN

     [5 rows x 81 columns]

	Coef.	Std.Err.	z	P> |z|	[0.025	0.975]
Model:	MixedLM	Dependent Variable:	fh			
No. Observations:	171	Method:	ML			
No. Groups:	58	Scale:	51.4006			
Min. group size:	1	Log-Likelihood:	-610.5181			
Max. group size:	11	Converged:	Yes			
Mean group size:	2.9					

	Coef.	Std.Err.	z	P> |z|	[0.025	0.975]
Intercept	1.807	8.316	0.217	0.828	-14.492	18.106
species[T.ARTCAL]	-1.429	5.410	-0.264	0.792	-12.032	9.174
species[T.CEAGRI]	6.016	5.222	1.152	0.249	-4.219	16.250
species[T.ERIKAR]	-12.658	5.016	-2.524	0.012	-22.489	-2.828
species[T.HETARB]	11.932	5.969	1.999	0.046	0.234	23.630
species[T.MALLAU]	-2.647	5.945	-0.445	0.656	-14.299	9.006
species[T.SALAPI]	0.198	5.375	0.037	0.971	-10.336	10.732
species[T.SALLEU]	-2.810	5.085	-0.553	0.581	-12.777	7.157
total_branch_mass	1.146	0.360	3.181	0.001	0.440	1.852
Group Var	38.508	2.421				

```
[3]: model = smf.mixedlm("fh ~ total_branch_mass + species", data=flamog,
      ↪groups=flamog["plant_id"])
     results = model.fit(reml=False)
     results.summary()
```
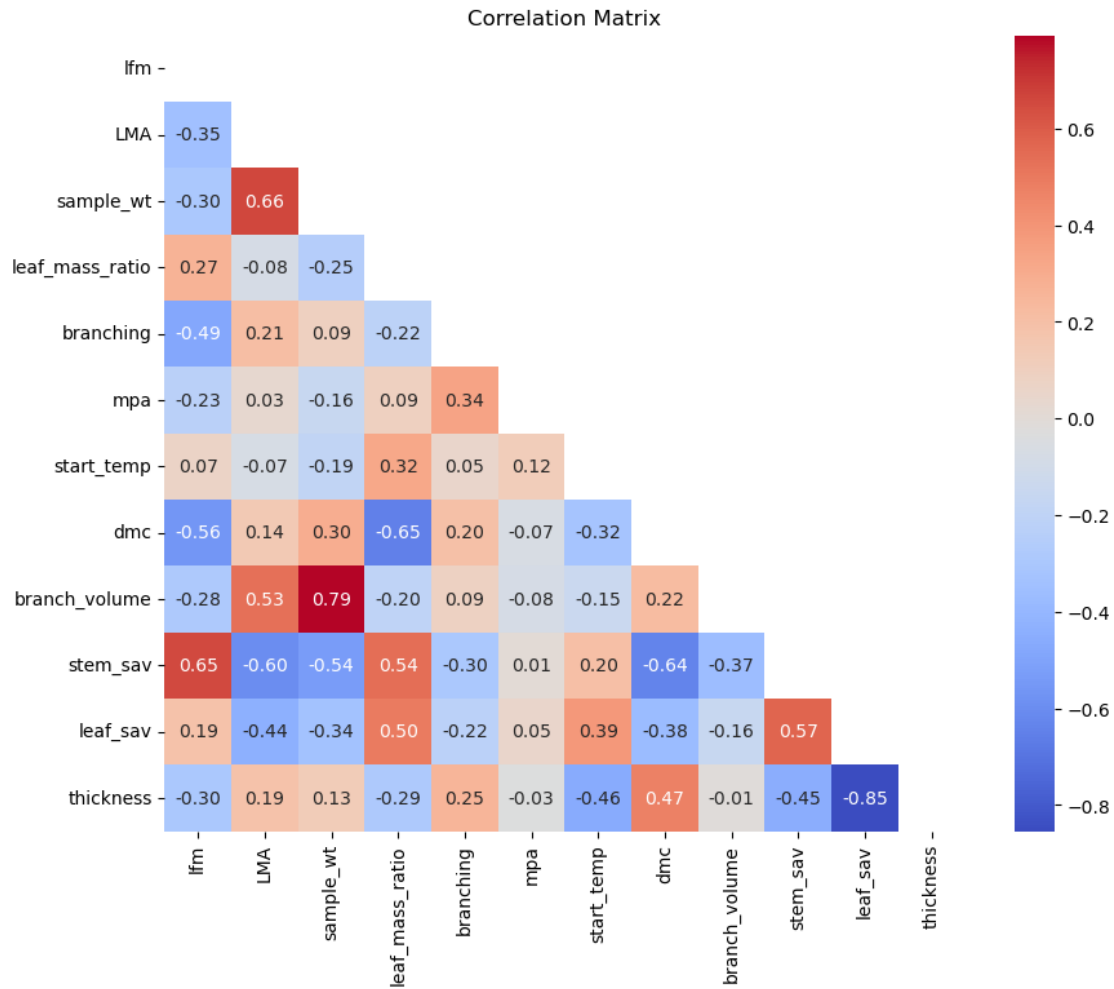
[3]:

```
[4]: results.aic
```

[4]: 1243.0361180203022

1 Examine Correlation & Structure in Num. Var's

```
[5]: cols_num_use = ['lfm', 'LMA', 'sample_wt', 'leaf_mass_ratio', 'branching',
      ↪'mpa', 'start_temp', 'dmc', 'branch_volume', 'stem_sav', 'leaf_sav',
      ↪'thickness']

     corrplot(flamog, cols_num_use)
```

Correlation Matrix

	lfm	LMA	sample_wt	leaf_mass_ratio	branching	mpa	start_temp	dmc	branch_volume	stem_sav	leaf_sav	thickness
lfm												
LMA	-0.35											
sample_wt	-0.30	0.66										
leaf_mass_ratio	0.27	-0.08	-0.25									
branching	-0.49	0.21	0.09	-0.22								
mpa	-0.23	0.03	-0.16	0.09	0.34							
start_temp	0.07	-0.07	-0.19	0.32	0.05	0.12						
dmc	-0.56	0.14	0.30	-0.65	0.20	-0.07	-0.32					
branch_volume	-0.28	0.53	0.79	-0.20	0.09	-0.08	-0.15	0.22				
stem_sav	0.65	-0.60	-0.54	0.54	-0.30	0.01	0.20	-0.64	-0.37			
leaf_sav	0.19	-0.44	-0.34	0.50	-0.22	0.05	0.39	-0.38	-0.16	0.57		
thickness	-0.30	0.19	0.13	-0.29	0.25	-0.03	-0.46	0.47	-0.01	-0.45	-0.85	

```
[6]:  # PCAplot(flamog, cols_num_use)
```

2 Modeling Preprocessing

```
[7]:  # scale and center
      cols_all = ['fh', 'fd', 'temp_change', 'heat_flux_change'] + cols_num_use
      flam = scale_and_center(flamog, cols_all, cols_no_change=['plant_id',␣
       ↪'species', 'ignition'])

      # declare as factors
      flam['species'] = pd.Categorical(flam['species'])
      flam['plant_id'] = pd.Categorical(flam['plant_id'])
      flam['ignition'] = pd.Categorical(flam['ignition'])

      # drop na's
```

```
print(len(flam))
cols_all_dpna = cols_all + ['plant_id', 'species', 'ignition']
flam.dropna(subset=cols_all_dpna, inplace=True)
print(len(flam))

# declare all possible IV cols to model
cols_use = cols_num_use + ['species']
print(cols_use)
```

```
171
166
['lfm', 'LMA', 'sample_wt', 'leaf_mass_ratio', 'branching', 'mpa', 'start_temp',
 'dmc', 'branch_volume', 'stem_sav', 'leaf_sav', 'thickness', 'species']
```

3 Run Model Selector

3.0.1 NOTE: Random effect is simply `plant_id`

- NO nested effects
- NO 'species'

It was not possible to test all combinations. Therefore, only combinations of significnt interaction terms and all singletons will be tested.

```
[8]: maxnumsingle = 5
     minnumsingle = 1
```

4 Flame Height

```
[9]: # REDUCE INTERACTIONS TO TEST

     Y_VAR = 'fh'

     # singletons: y = b + mx
     compare_predictors_mixedeff(flam, cols_num_use, yvar=Y_VAR)

     print('\n\n')

     # singleton interactions: y = b + m1x1 + m2x2 + m3x1x2
     sig_interactions = compare_predictors_interaction_singletons(flam,cols_use,
       y=Y_VAR, thresh=0.05, probs = [], printsumm=0)

     print('\n\n')

     # # try all 2-way interactions in 1 model
     # form_all_int = formula_all_2way_interactions(cols_use, y='fh', report=0)
     # model = smf.mixedlm(form_all_int, data=flam, groups=flam["plant_id"])
```

```
# result = model.fit(reml=False)
# # print only significant results
# significant_results = result.summary().tables[1].loc[result.pvalues < 0.05]
# print(significant_results)

print('\n\n')

# generate list of known interactions

sig_interactions_tuples = [tuple(x.split('*')) for x in sig_interactions]
for pair in sig_interactions_tuples:
    print(pair)
```

```
               cols          pvals       coefs  significant
2          sample_wt  2.290442e-17   0.531690         True
9           stem_sav  8.211280e-11  -0.576347         True
1                LMA  1.686945e-06   0.448328         True
8      branch_volume  1.785638e-06   0.328704         True
3    leaf_mass_ratio  1.627335e-05  -0.473655         True
4          branching  2.782677e-05   0.276897         True
0                lfm  1.956642e-04  -0.386256         True
7                dmc  1.914826e-03   0.275048         True
10          leaf_sav  5.369394e-03  -0.305540         True
5                mpa  2.542692e-01   0.088750        False
6         start_temp  3.136141e-01   0.077621        False
11         thickness  3.205268e-01   0.115109        False
```

```
ERROR: Formula model error: fh ~ LMA*species
13 13 {'leaf_sav', 'branching', 'thickness', 'stem_sav', 'LMA', 'mpa',
'sample_wt', 'branch_volume', 'leaf_mass_ratio', 'start_temp', 'species', 'dmc',
'lfm'}
```

```
('lfm', 'sample_wt')
('lfm', 'dmc')
('lfm', 'branch_volume')
('lfm', 'leaf_sav')
('lfm', 'thickness')
('lfm', 'species')
('LMA', 'stem_sav')
('sample_wt', 'species')
```

```
('leaf_mass_ratio', 'dmc')
('leaf_mass_ratio', 'leaf_sav')
('leaf_mass_ratio', 'thickness')
('leaf_mass_ratio', 'species')
('branching', 'leaf_sav')
('branching', 'species')
('mpa', 'branch_volume')
('mpa', 'species')
('start_temp', 'dmc')
('start_temp', 'species')
('dmc', 'stem_sav')
('dmc', 'leaf_sav')
('dmc', 'thickness')
('dmc', 'species')
('branch_volume', 'leaf_sav')
('branch_volume', 'thickness')
('branch_volume', 'species')
('stem_sav', 'species')
('leaf_sav', 'species')
('thickness', 'species')
```

```python
[10]: # generate list of formulas

df = flam
cols = cols_use
int_tuple_list = sig_interactions_tuples
dv = Y_VAR


formulas = []
cols_used = []

# iterate over possible interactions
for int_tup in int_tuple_list:

    # create a copy of singletons list
    cols_wkg = cols.copy()
    # isolate terms in interaction
    x1,x2 = int_tup
    # drop those terms from singletons list
    cols_wkg.remove(x1)
    cols_wkg.remove(x2)

    # add the 1st formula - just the interaction term y ~ x1 * x2
    formulas.append(dv+' ~ '+x1+'*'+x2)
    colsi = [x1,x2]
```

```python
    # generate list of all possible combos of singletons, from 1 to as many as
↪there are
    singles_combos = [list(combinations(cols_wkg, n)) for n in
↪range(minnumsingle, maxnumsingle+1)]

    # iterate over combo set (ie 1 poss singleton, 2 poss singletons, ... etc)
    for comboset in singles_combos:
        # for each combo in the combo set
        for combo in comboset:
            # generate formula
            form = dv+' ~ '+x1+'*'+x2
            for single in combo:
                form+=' + '+single
                colsi.append(single)
            formulas.append(form)
            cols_used.append([colsi])

print(len(formulas))

# AIC ITERATION
resdf_fh, num_top_models = AICscore_from_all_pos_2way_interactions(df,
↪formulas, report=0)

# report
for idx,row in resdf_fh[0:num_top_models].iterrows():
    formula = row.Formula
    print(formula)
for idx,row in resdf_fh[0:num_top_models].iterrows():
    formula = row.Formula
    model = smf.ols(formula, data=df)
    results = model.fit()
    print(results.summary())
    plot_ols_coefficients(results)
    plt.show();
    # if 'species' in cols:
    #     cols.remove('species')
    # plot_resid(df, cols, results)
```

```
28672
28672 28672
fh ~ lfm*branch_volume + sample_wt + branching + mpa + start_temp + stem_sav
                        OLS Regression Results
==============================================================================
Dep. Variable:                     fh   R-squared:                       0.659
Model:                            OLS   Adj. R-squared:                  0.641
Method:                 Least Squares   F-statistic:                     37.88
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           5.68e-33
```

```
Time:                          14:39:10   Log-Likelihood:                    -143.36
No. Observations:                   166   AIC:                                 304.7
Df Residuals:                       157   BIC:                                 332.7
Df Model:                             8
Covariance Type:               nonrobust
================================================================================
=====
                    coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept         0.0937      0.053      1.766      0.079      -0.011
0.199
lfm               0.0817      0.083      0.982      0.328      -0.083
0.246
branch_volume     0.0091      0.089      0.102      0.919      -0.166
0.184
lfm:branch_volume 0.3328      0.099      3.356      0.001       0.137
0.529
sample_wt         0.6555      0.090      7.287      0.000       0.478
0.833
branching         0.1491      0.056      2.664      0.009       0.039
0.260
mpa               0.1639      0.052      3.171      0.002       0.062
0.266
start_temp        0.2074      0.048      4.343      0.000       0.113
0.302
stem_sav         -0.1889      0.074     -2.565      0.011      -0.334
-0.043
================================================================================
Omnibus:                       15.640   Durbin-Watson:                       1.739
Prob(Omnibus):                  0.000   Jarque-Bera (JB):                   37.881
Skew:                           0.325   Prob(JB):                         5.95e-09
Kurtosis:                       5.248   Cond. No.                             4.87
================================================================================
```
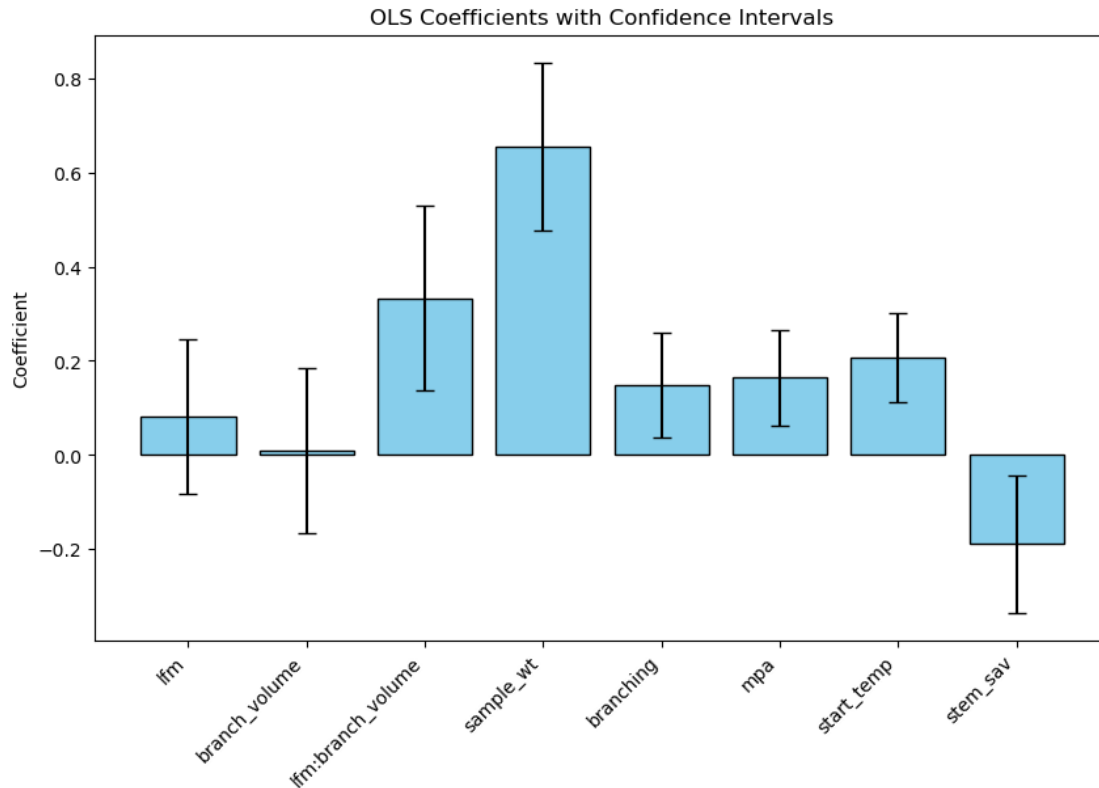
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals

5 Flame Duration

```
[11]:  # REDUCE INTERACTIONS TO TEST

       Y_VAR = 'fd'

       # singletons: y = b + mx
       compare_predictors_mixedeff(flam, cols_num_use, yvar=Y_VAR)

       print('\n\n')

       # singleton interactions: y = b + m1x1 + m2x2 + m3x1x2
       sig_interactions = compare_predictors_interaction_singletons(flam,cols_use,␣
        ↪y=Y_VAR, thresh=0.05, probs = [], printsumm=0)

       print('\n\n')

       # # try all 2-way interactions in 1 model
       # form_all_int = formula_all_2way_interactions(cols_use, y='fh', report=0)
       # model = smf.mixedlm(form_all_int, data=flam, groups=flam["plant_id"])
       # result = model.fit(reml=False)
```

```python
# # print only significant results
# significant_results = result.summary().tables[1].loc[result.pvalues < 0.05]
# print(significant_results)

print('\n\n')

# generate list of known interactions

sig_interactions_tuples = [tuple(x.split('*')) for x in sig_interactions]
for pair in sig_interactions_tuples:
    print(pair)
```

	cols	pvals	coefs	significant
2	sample_wt	2.181882e-11	0.499795	True
8	branch_volume	1.223520e-06	0.372319	True
7	dmc	2.344202e-06	0.390794	True
9	stem_sav	2.513616e-06	-0.385912	True
0	lfm	6.575573e-05	-0.348868	True
1	LMA	7.605417e-05	0.362449	True
3	leaf_mass_ratio	4.525313e-04	-0.380075	True
10	leaf_sav	7.496719e-03	-0.272524	True
4	branching	1.364565e-02	0.206268	True
11	thickness	6.348566e-02	0.204278	False
6	start_temp	3.760549e-01	-0.077204	False
5	mpa	5.031638e-01	-0.064662	False

13 13 {'leaf_sav', 'branching', 'thickness', 'stem_sav', 'LMA', 'mpa', 'sample_wt', 'branch_volume', 'leaf_mass_ratio', 'start_temp', 'species', 'dmc', 'lfm'}

```
('lfm', 'sample_wt')
('lfm', 'stem_sav')
('LMA', 'leaf_sav')
('LMA', 'thickness')
('LMA', 'species')
('sample_wt', 'dmc')
('sample_wt', 'leaf_sav')
('sample_wt', 'species')
('leaf_mass_ratio', 'dmc')
('branching', 'stem_sav')
```

```
('mpa', 'branch_volume')
('start_temp', 'species')
('dmc', 'branch_volume')
('thickness', 'species')
```

[12]:
```python
# generate list of formulas

df = flam
cols = cols_use
int_tuple_list = sig_interactions_tuples
dv = Y_VAR


formulas = []
cols_used = []

# iterate over possible interactions
for int_tup in int_tuple_list:

    # create a copy of singletons list
    cols_wkg = cols.copy()
    # isolate terms in interaction
    x1,x2 = int_tup
    # drop those terms from singletons list
    cols_wkg.remove(x1)
    cols_wkg.remove(x2)

    # add the 1st formula - just the interaction term y ~ x1 * x2
    formulas.append(dv+' ~ '+x1+'*'+x2)
    colsi = [x1,x2]

    # generate list of all possible combos of singletons, from 1 to as many as␣
 ↪there are
    singles_combos = [list(combinations(cols_wkg, n)) for n in␣
 ↪range(minnumsingle, maxnumsingle+1)]

    # iterate over combo set (ie 1 poss singleton, 2 poss singletons, ... etc)
    for comboset in singles_combos:
        # for each combo in the combo set
        for combo in comboset:
            # generate formula
            form = dv+' ~ '+x1+'*'+x2
            for single in combo:
                form+=' + '+single
                colsi.append(single)
            formulas.append(form)
            cols_used.append([colsi])
```

```python
print(len(formulas))

# AIC ITERATION

resdf_fd, num_top_models = AICscore_from_all_pos_2way_interactions(df,␣
 ↪formulas, report=0)

# report
for idx,row in resdf_fd[0:num_top_models].iterrows():
    formula = row.Formula
    print(formula)
for idx,row in resdf_fd[0:num_top_models].iterrows():
    formula = row.Formula
    model = smf.ols(formula, data=df)
    results = model.fit()
    print(results.summary())
    plot_ols_coefficients(results)
    plt.show();
    # if 'species' in cols:
    #     cols.remove('species')
    # plot_resid(df, cols, results)
```

```
14336
ERROR: Formula model error: fd ~ LMA*species + sample_wt + thickness
ERROR: Formula model error: fd ~ LMA*species + branching + thickness
ERROR: Formula model error: fd ~ LMA*species + mpa + start_temp
ERROR: Formula model error: fd ~ LMA*species + sample_wt + leaf_mass_ratio +
thickness
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching +
start_temp
ERROR: Formula model error: fd ~ LMA*species + sample_wt + mpa + start_temp
ERROR: Formula model error: fd ~ LMA*species + sample_wt + dmc + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + mpa + dmc + branch_volume
ERROR: Formula model error: fd ~ LMA*species + start_temp + dmc + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + start_temp + stem_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + dmc + branch_volume + stem_sav
ERROR: Formula model error: fd ~ LMA*species + dmc + branch_volume + thickness
ERROR: Formula model error: fd ~ LMA*species + lfm + leaf_mass_ratio +
start_temp + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + branching + mpa + dmc
ERROR: Formula model error: fd ~ LMA*species + lfm + branching + branch_volume +
stem_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + mpa + dmc + thickness
ERROR: Formula model error: fd ~ LMA*species + lfm + start_temp + branch_volume
+ stem_sav
ERROR: Formula model error: fd ~ LMA*species + sample_wt + leaf_mass_ratio +
```

start_temp + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching + mpa + dmc
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching + mpa +
thickness
ERROR: Formula model error: fd ~ LMA*species + sample_wt + dmc + branch_volume +
stem_sav
ERROR: Formula model error: fd ~ LMA*species + sample_wt + dmc + leaf_sav +
thickness
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + mpa +
start_temp + branch_volume
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + start_temp +
dmc + stem_sav
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + dmc +
branch_volume + stem_sav
ERROR: Formula model error: fd ~ LMA*species + branching + mpa + start_temp +
dmc
ERROR: Formula model error: fd ~ LMA*species + branching + mpa + branch_volume +
leaf_sav
ERROR: Formula model error: fd ~ LMA*species + branching + mpa + leaf_sav +
thickness
ERROR: Formula model error: fd ~ LMA*species + branching + start_temp + dmc +
leaf_sav
ERROR: Formula model error: fd ~ LMA*species + mpa + start_temp + leaf_sav +
thickness
ERROR: Formula model error: fd ~ LMA*species + mpa + dmc + branch_volume +
thickness
ERROR: Formula model error: fd ~ LMA*species + mpa + dmc + leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + mpa + stem_sav + leaf_sav +
thickness
ERROR: Formula model error: fd ~ LMA*species + lfm + sample_wt + leaf_mass_ratio
+ mpa + stem_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + sample_wt + mpa + dmc +
leaf_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + leaf_mass_ratio + branching
+ mpa + stem_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + leaf_mass_ratio + branching
+ start_temp + dmc
ERROR: Formula model error: fd ~ LMA*species + lfm + leaf_mass_ratio + dmc +
branch_volume + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + lfm + branching + dmc + stem_sav
+ leaf_sav
ERROR: Formula model error: fd ~ LMA*species + sample_wt + leaf_mass_ratio +
branching + dmc + leaf_sav
ERROR: Formula model error: fd ~ LMA*species + sample_wt + leaf_mass_ratio + mpa
+ branch_volume + thickness
ERROR: Formula model error: fd ~ LMA*species + sample_wt + leaf_mass_ratio +
start_temp + dmc + branch_volume
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching + mpa +

14

```
start_temp + branch_volume
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching +
start_temp + leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + sample_wt + branching + dmc +
leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + sample_wt + mpa + start_temp +
dmc + stem_sav
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + branching + mpa
+ dmc + stem_sav
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + branching +
start_temp + dmc + thickness
ERROR: Formula model error: fd ~ LMA*species + leaf_mass_ratio + mpa +
branch_volume + leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + branching + start_temp + dmc +
leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + branching + dmc + branch_volume +
leaf_sav + thickness
ERROR: Formula model error: fd ~ LMA*species + mpa + start_temp + dmc +
branch_volume + leaf_sav
14284 14336
fd ~ sample_wt*dmc + leaf_mass_ratio + species
fd ~ sample_wt*species + dmc
fd ~ sample_wt*dmc + species
fd ~ sample_wt*dmc + lfm + leaf_mass_ratio + species
fd ~ sample_wt*species + lfm + dmc
fd ~ sample_wt*species + leaf_mass_ratio + dmc
fd ~ sample_wt*species + lfm + leaf_mass_ratio + dmc
fd ~ sample_wt*dmc + leaf_mass_ratio + branch_volume + species
fd ~ sample_wt*dmc + leaf_mass_ratio + mpa + species
fd ~ sample_wt*species + leaf_mass_ratio + dmc + branch_volume
fd ~ sample_wt*species + branching + dmc
fd ~ sample_wt*dmc + lfm + species
fd ~ sample_wt*species + mpa + dmc
fd ~ sample_wt*species + dmc + branch_volume
fd ~ sample_wt*dmc + leaf_mass_ratio + leaf_sav + species
fd ~ sample_wt*dmc + lfm + leaf_mass_ratio + mpa + species
fd ~ sample_wt*dmc + lfm + leaf_mass_ratio + branch_volume + species
fd ~ sample_wt*species + LMA + dmc
fd ~ sample_wt*species + leaf_mass_ratio + mpa + dmc
fd ~ sample_wt*species + lfm + leaf_mass_ratio + dmc + branch_volume
fd ~ sample_wt*dmc + mpa + species
fd ~ sample_wt*dmc + LMA + leaf_mass_ratio + species
fd ~ sample_wt*dmc + branch_volume + species
fd ~ sample_wt*dmc + leaf_mass_ratio + mpa + branch_volume + species
fd ~ sample_wt*species + dmc + leaf_sav
fd ~ sample_wt*dmc + leaf_mass_ratio + thickness + species
fd ~ sample_wt*dmc + leaf_mass_ratio + start_temp + species
fd ~ sample_wt*species + lfm + leaf_mass_ratio + mpa + dmc
```

```
fd ~ sample_wt*dmc + leaf_mass_ratio + branching + species
fd ~ sample_wt*dmc + leaf_mass_ratio + stem_sav + species
                         OLS Regression Results
================================================================================
=====
Dep. Variable:                    fd   R-squared:                       0.436
Model:                           OLS   Adj. R-squared:                  0.395
Method:                Least Squares   F-statistic:                     10.80
Date:               Wed, 24 Apr 2024   Prob (F-statistic):           1.33e-14
Time:                       16:38:25   Log-Likelihood:                -188.74
No. Observations:                166   AIC:                             401.5
Df Residuals:                    154   BIC:                             438.8
Df Model:                         11
Covariance Type:           nonrobust
================================================================================
=====
                         coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept              -0.0183      0.295     -0.062      0.950      -0.600
0.564
species[T.ARTCAL]      -0.3698      0.364     -1.017      0.311      -1.088
0.349
species[T.CEAGRI]       0.6213      0.329      1.887      0.061      -0.029
1.272
species[T.ERIKAR]      -0.4789      0.337     -1.422      0.157      -1.144
0.186
species[T.HETARB]       0.0153      0.671      0.023      0.982      -1.310
1.340
species[T.MALLAU]      -0.2085      0.394     -0.530      0.597      -0.986
0.569
species[T.SALAPI]      -0.3775      0.378     -0.999      0.319      -1.124
0.369
species[T.SALLEU]       0.1488      0.397      0.375      0.708      -0.635
0.933
sample_wt               0.3953      0.106      3.730      0.000       0.186
0.605
dmc                     0.3614      0.139      2.609      0.010       0.088
0.635
sample_wt:dmc           0.3394      0.105      3.247      0.001       0.133
0.546
leaf_mass_ratio         0.2467      0.166      1.490      0.138      -0.080
0.574
================================================================================
Omnibus:                      113.135   Durbin-Watson:                   2.322
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1088.744
Skew:                           2.378   Prob(JB):                    3.82e-237
Kurtosis:                      14.610   Cond. No.                         20.7
```

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Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
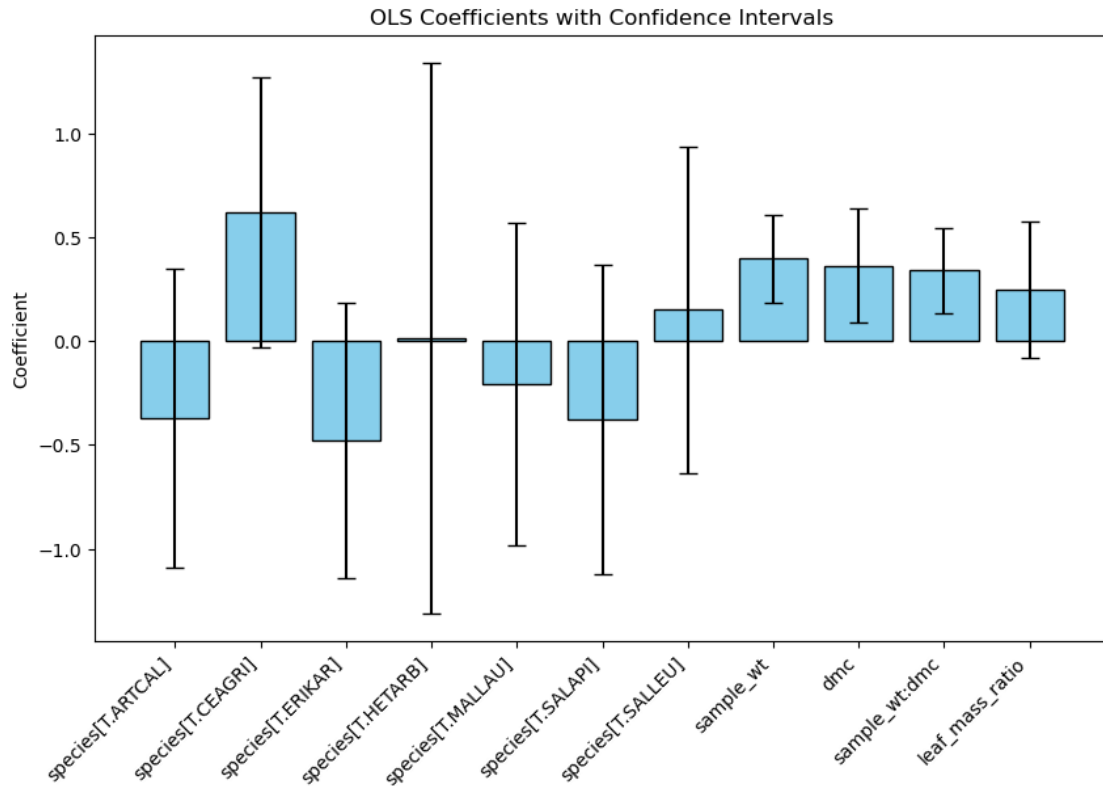
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.467
Model:	OLS	Adj. R-squared:	0.410
Method:	Least Squares	F-statistic:	8.173
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	8.18e-14
Time:	16:38:25	Log-Likelihood:	-183.92
No. Observations:	166	AIC:	401.8
Df Residuals:	149	BIC:	454.7
Df Model:	16		
Covariance Type:	nonrobust		

==
===============

| | coef | std err | t | P>|t| |
| [0.025 | 0.975] | | | |

```
---------------
Intercept                      0.0194      0.382      0.051      0.960
-0.735       0.773
species[T.ARTCAL]             -1.1212      1.324     -0.847      0.399
-3.738       1.495
species[T.CEAGRI]              0.5202      0.406      1.282      0.202
-0.282       1.322
species[T.ERIKAR]              0.6058      2.155      0.281      0.779
-3.652       4.863
species[T.HETARB]             -2.6662      3.028     -0.881      0.380
-8.649       3.317
species[T.MALLAU]             -0.6236      0.489     -1.275      0.204
-1.590       0.343
species[T.SALAPI]             -0.3799      0.436     -0.870      0.385
-1.242       0.482
species[T.SALLEU]              0.3741      0.473      0.791      0.430
-0.561       1.309
sample_wt                      0.3779      1.067      0.354      0.724
-1.730       2.486
sample_wt:species[T.ARTCAL]   -1.2331      1.958     -0.630      0.530
-5.101       2.635
sample_wt:species[T.CEAGRI]   -0.1558      1.090     -0.143      0.887
-2.310       1.999
sample_wt:species[T.ERIKAR]    0.8631      2.633      0.328      0.744
-4.341       6.067
sample_wt:species[T.HETARB]    1.3355      1.792      0.745      0.457
-2.206       4.877
sample_wt:species[T.MALLAU]    0.4097      1.082      0.378      0.706
-1.729       2.549
sample_wt:species[T.SALAPI]   -0.2189      1.079     -0.203      0.840
-2.351       1.913
sample_wt:species[T.SALLEU]    1.1923      1.112      1.072      0.286
-1.006       3.390
dmc                            0.2165      0.112      1.935      0.055
-0.005       0.438
==============================================================================
Omnibus:                      111.946   Durbin-Watson:                   2.379
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1118.888
Skew:                           2.325   Prob(JB):                    1.09e-243
Kurtosis:                      14.838   Cond. No.                         77.5
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
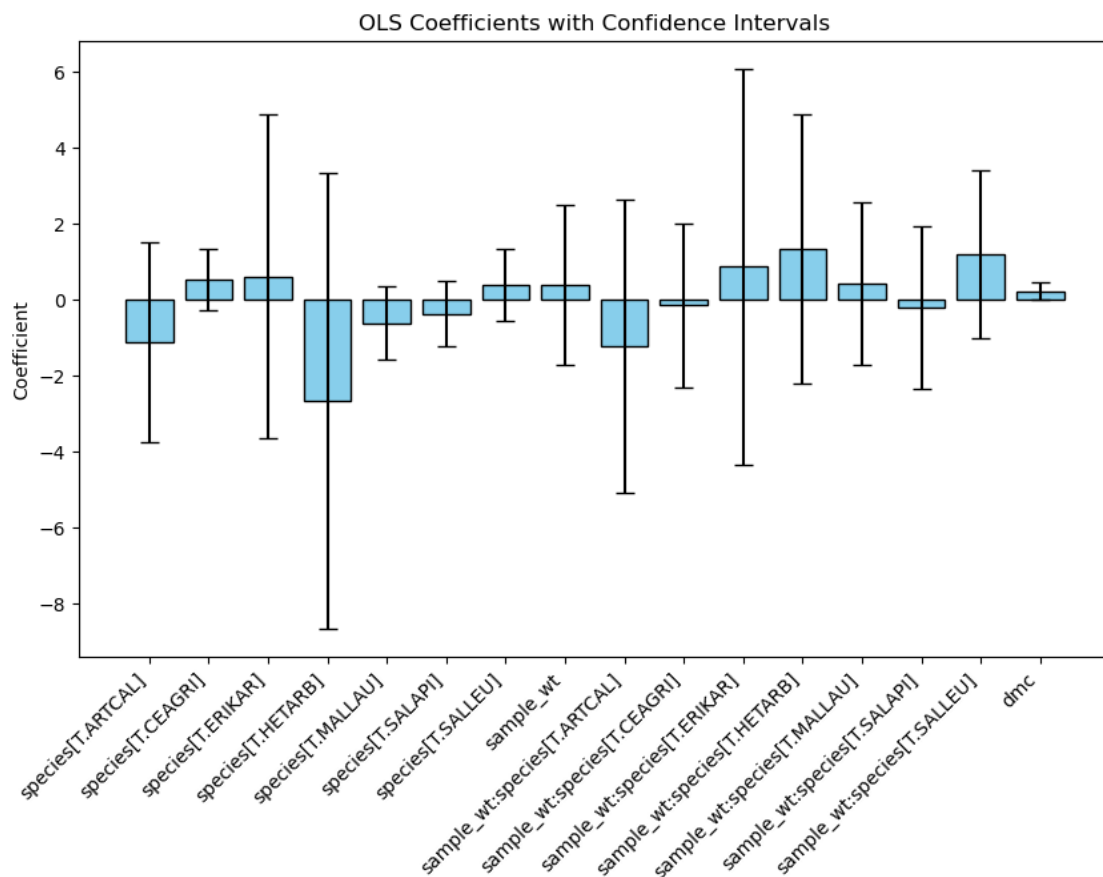
```
                           OLS Regression Results
================================================================================
Dep. Variable:                      fd   R-squared:                       0.427
Model:                             OLS   Adj. R-squared:                  0.390
Method:                  Least Squares   F-statistic:                     11.57
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           1.04e-14
Time:                         16:38:25   Log-Likelihood:                 -189.93
No. Observations:                  166   AIC:                             401.9
Df Residuals:                      155   BIC:                             436.1
Df Model:                           10
Covariance Type:             nonrobust
================================================================================
=====
                     coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept         -0.0164      0.296     -0.055      0.956      -0.601
0.568
species[T.ARTCAL]  -0.3153      0.363     -0.868      0.387      -1.033
```

19

```
0.402
species[T.CEAGRI]      0.5701      0.329      1.735      0.085     -0.079
1.219
species[T.ERIKAR]     -0.3731      0.330     -1.129      0.261     -1.026
0.280
species[T.HETARB]     -0.0130      0.673     -0.019      0.985     -1.343
1.317
species[T.MALLAU]     -0.3258      0.387     -0.841      0.401     -1.091
0.439
species[T.SALAPI]     -0.5591      0.359     -1.558      0.121     -1.268
0.150
species[T.SALLEU]      0.1471      0.399      0.369      0.713     -0.640
0.934
sample_wt              0.4013      0.106      3.775      0.000      0.191
0.611
dmc                    0.2403      0.113      2.134      0.034      0.018
0.463
sample_wt:dmc          0.3273      0.105      3.129      0.002      0.121
0.534
==============================================================================
Omnibus:                      114.177   Durbin-Watson:                   2.314
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1108.834
Skew:                           2.405   Prob(JB):                     1.66e-241
Kurtosis:                      14.712   Cond. No.                         18.1
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
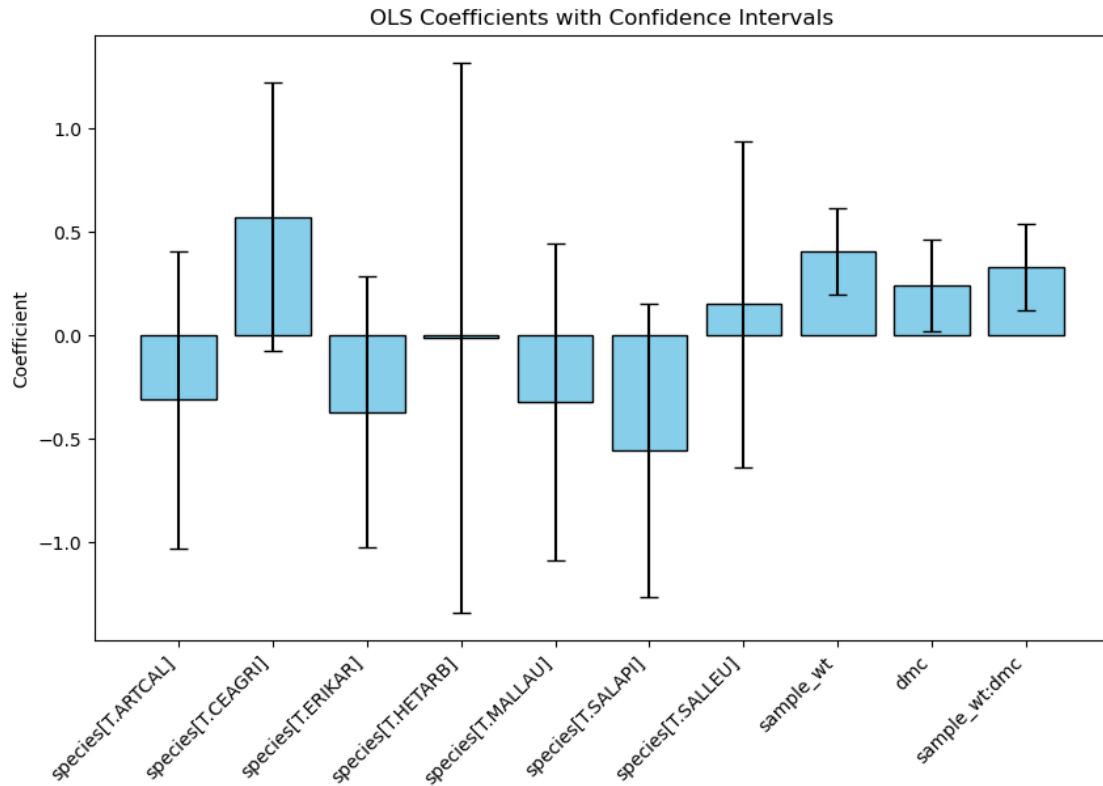
OLS Regression Results

```
==============================================================================
Dep. Variable:                    fd   R-squared:                       0.441
Model:                           OLS   Adj. R-squared:                  0.397
Method:                Least Squares   F-statistic:                     10.04
Date:               Wed, 24 Apr 2024   Prob (F-statistic):           2.41e-14
Time:                       16:38:25   Log-Likelihood:                 -188.00
No. Observations:                166   AIC:                             402.0
Df Residuals:                    153   BIC:                             442.5
Df Model:                         12
Covariance Type:             nonrobust
==============================================================================
=====
                    coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
-----
Intercept        -0.0119      0.294     -0.040      0.968      -0.593
0.569
species[T.ARTCAL] -0.2370     0.380     -0.623      0.534      -0.989
0.515
species[T.CEAGRI]  0.7477      0.346      2.161      0.032       0.064
```

1.431

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.ERIKAR]	-0.7235	0.396	-1.829	0.069	-1.505	0.058
species[T.HETARB]	0.1623	0.681	0.238	0.812	-1.184	1.509
species[T.MALLAU]	-0.1452	0.397	-0.366	0.715	-0.929	0.639
species[T.SALAPI]	-0.4898	0.389	-1.259	0.210	-1.259	0.279
species[T.SALLEU]	0.2348	0.403	0.582	0.561	-0.562	1.031
sample_wt	0.3966	0.106	3.746	0.000	0.187	0.606
dmc	0.4173	0.146	2.852	0.005	0.128	0.706
sample_wt:dmc	0.3397	0.104	3.254	0.001	0.133	0.546
lfm	0.1809	0.154	1.173	0.242	-0.124	0.485
leaf_mass_ratio	0.2778	0.168	1.658	0.099	-0.053	0.609

==

Omnibus:	108.305	Durbin-Watson:	2.341
Prob(Omnibus):	0.000	Jarque-Bera (JB):	987.475
Skew:	2.261	Prob(JB):	3.74e-215
Kurtosis:	14.059	Cond. No.	23.3

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Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
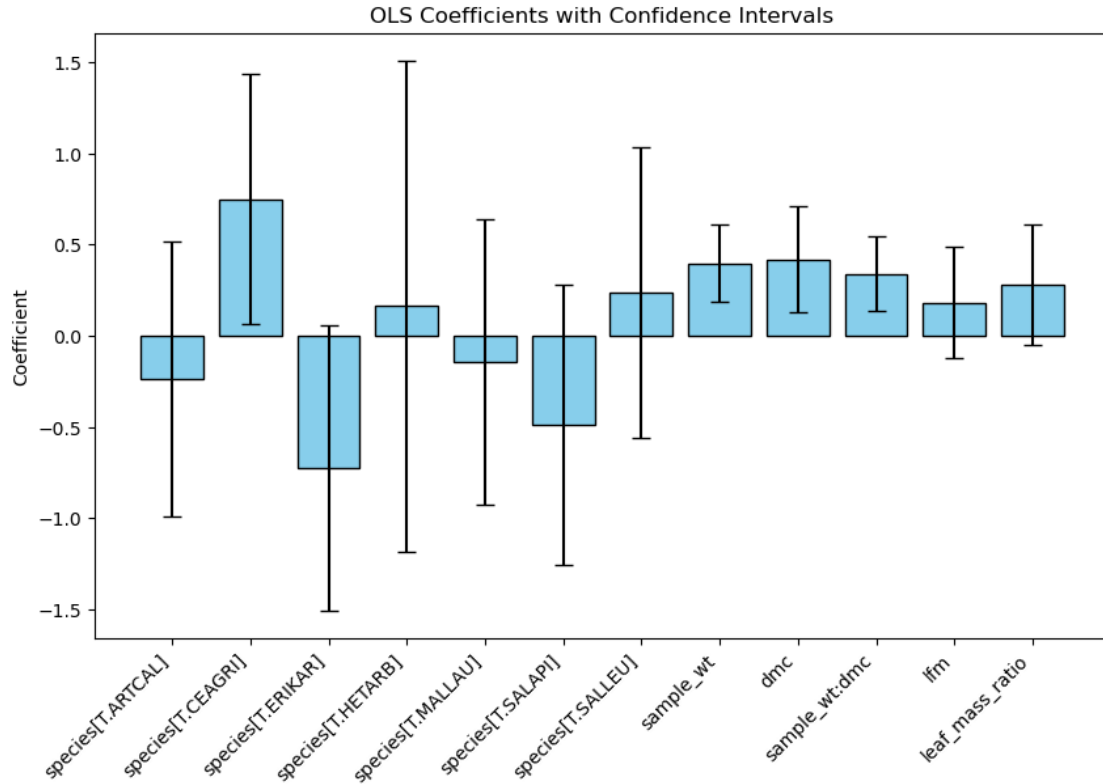
OLS Regression Results

```
==============================================================================
Dep. Variable:                     fd   R-squared:                       0.472
Model:                            OLS   Adj. R-squared:                  0.411
Method:                 Least Squares   F-statistic:                     7.785
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           1.34e-13
Time:                        16:38:26   Log-Likelihood:                -183.19
No. Observations:                 166   AIC:                             402.4
Df Residuals:                     148   BIC:                             458.4
Df Model:                          17
Covariance Type:            nonrobust
==============================================================================

===============
                      coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------

---------------
Intercept          -0.0011      0.382     -0.003      0.998
-0.755      0.753
species[T.ARTCAL]  -0.9953      1.327     -0.750      0.455
-3.618      1.628
species[T.CEAGRI]   0.6657      0.425      1.567      0.119
```

```
                                 -0.174       1.505
species[T.ERIKAR]                 0.5508      2.153     0.256     0.798
                                 -3.704       4.805
species[T.HETARB]                -2.6997      3.025    -0.893     0.374
                                 -8.677       3.278
species[T.MALLAU]                -0.5626      0.491    -1.145     0.254
                                 -1.534       0.409
species[T.SALAPI]                -0.4900      0.446    -1.098     0.274
                                 -1.372       0.392
species[T.SALLEU]                 0.4868      0.483     1.009     0.315
                                 -0.467       1.441
sample_wt                         0.2737      1.070     0.256     0.798
                                 -1.840       2.387
sample_wt:species[T.ARTCAL]      -1.1709      1.956    -0.599     0.550
                                 -5.037       2.695
sample_wt:species[T.CEAGRI]      -0.0828      1.091    -0.076     0.940
                                 -2.239       2.073
sample_wt:species[T.ERIKAR]       1.1352      2.641     0.430     0.668
                                 -4.085       6.355
sample_wt:species[T.HETARB]       1.5389      1.799     0.855     0.394
                                 -2.016       5.094
sample_wt:species[T.MALLAU]       0.5248      1.086     0.483     0.630
                                 -1.621       2.671
sample_wt:species[T.SALAPI]      -0.1019      1.083    -0.094     0.925
                                 -2.241       2.037
sample_wt:species[T.SALLEU]       1.2955      1.115     1.162     0.247
                                 -0.908       3.499
lfm                               0.1753      0.153     1.145     0.254
                                 -0.127       0.478
dmc                               0.2535      0.116     2.179     0.031
                                  0.024       0.483
==============================================================================
Omnibus:                        106.386   Durbin-Watson:                   2.405
Prob(Omnibus):                    0.000   Jarque-Bera (JB):             1003.681
Skew:                             2.190   Prob(JB):                     1.13e-218
Kurtosis:                        14.222   Cond. No.                         89.1
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
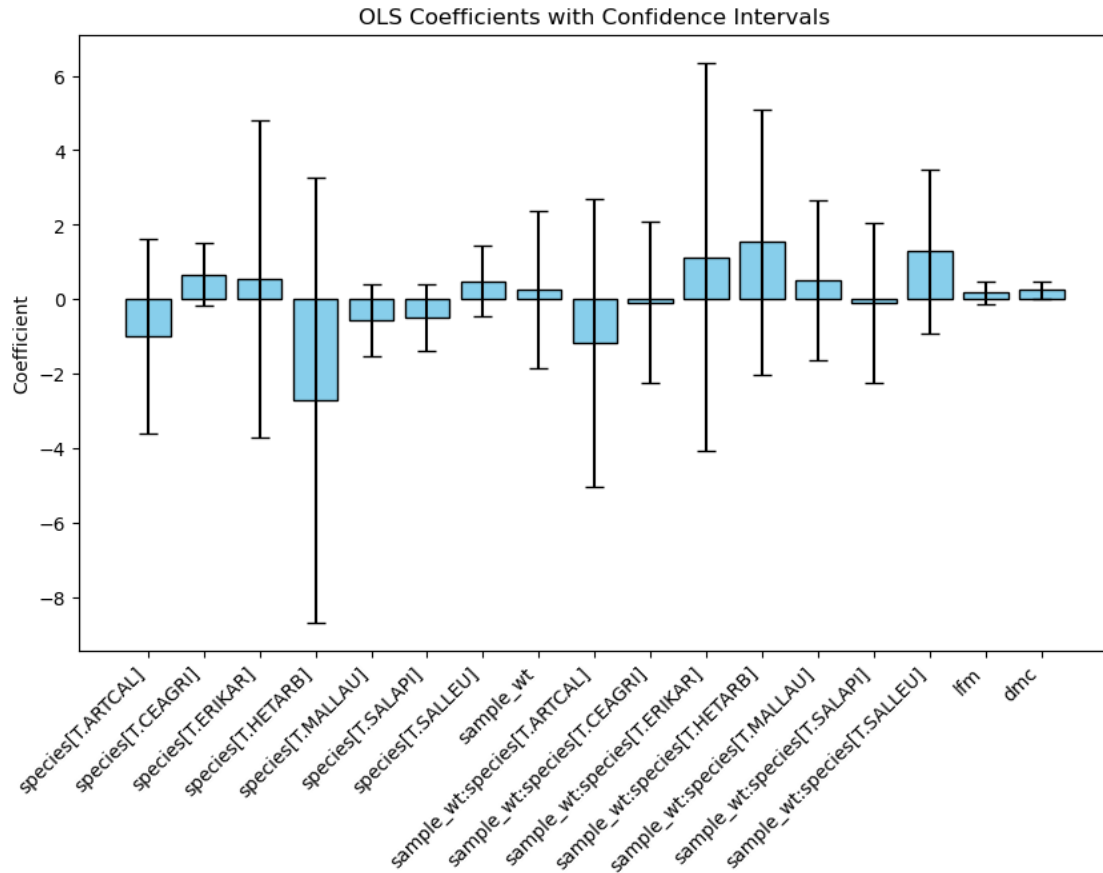
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.472
Model:	OLS	Adj. R-squared:	0.411
Method:	Least Squares	F-statistic:	7.780
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	1.37e-13
Time:	16:38:26	Log-Likelihood:	-183.21
No. Observations:	166	AIC:	402.4
Df Residuals:	148	BIC:	458.4
Df Model:	17		
Covariance Type:	nonrobust		

===
==============

	coef	std err	t	P>|t|
			[0.025	0.975]

----

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0378	0.382	0.099	0.921	-0.716	0.792
species[T.ARTCAL]	-1.1550	1.323	-0.873	0.384		

```
                                                  -3.770       1.460
species[T.CEAGRI]                  0.5363    0.406    1.322    0.188
                                                  -0.265       1.338
species[T.ERIKAR]                  0.7035    2.154    0.327    0.744
                                                  -3.554       4.961
species[T.HETARB]                 -2.4873    3.029   -0.821    0.413
                                                  -8.473       3.499
species[T.MALLAU]                 -0.5444    0.494   -1.103    0.272
                                                  -1.520       0.431
species[T.SALAPI]                 -0.2576    0.449   -0.573    0.567
                                                  -1.146       0.630
species[T.SALLEU]                  0.3460    0.473    0.731    0.466
                                                  -0.589       1.281
sample_wt                          0.4363    1.067    0.409    0.683
                                                  -1.673       2.545
sample_wt:species[T.ARTCAL]       -1.2727    1.956   -0.651    0.516
                                                  -5.138       2.593
sample_wt:species[T.CEAGRI]       -0.1856    1.090   -0.170    0.865
                                                  -2.339       1.968
sample_wt:species[T.ERIKAR]        1.0100    2.634    0.383    0.702
                                                  -4.196       6.216
sample_wt:species[T.HETARB]        1.1869    1.795    0.661    0.510
                                                  -2.361       4.735
sample_wt:species[T.MALLAU]        0.3437    1.083    0.317    0.751
                                                  -1.797       2.484
sample_wt:species[T.SALAPI]       -0.2897    1.080   -0.268    0.789
                                                  -2.423       1.844
sample_wt:species[T.SALLEU]        1.1259    1.113    1.012    0.313
                                                  -1.074       3.325
leaf_mass_ratio                    0.1860    0.165    1.125    0.262
                                                  -0.141       0.513
dmc                                0.3120    0.140    2.223    0.028
 0.035       0.589
==============================================================================
Omnibus:                         111.031   Durbin-Watson:                   2.377
Prob(Omnibus):                     0.000   Jarque-Bera (JB):             1105.626
Skew:                              2.300   Prob(JB):                     8.25e-241
Kurtosis:                         14.777   Cond. No.                         88.1
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
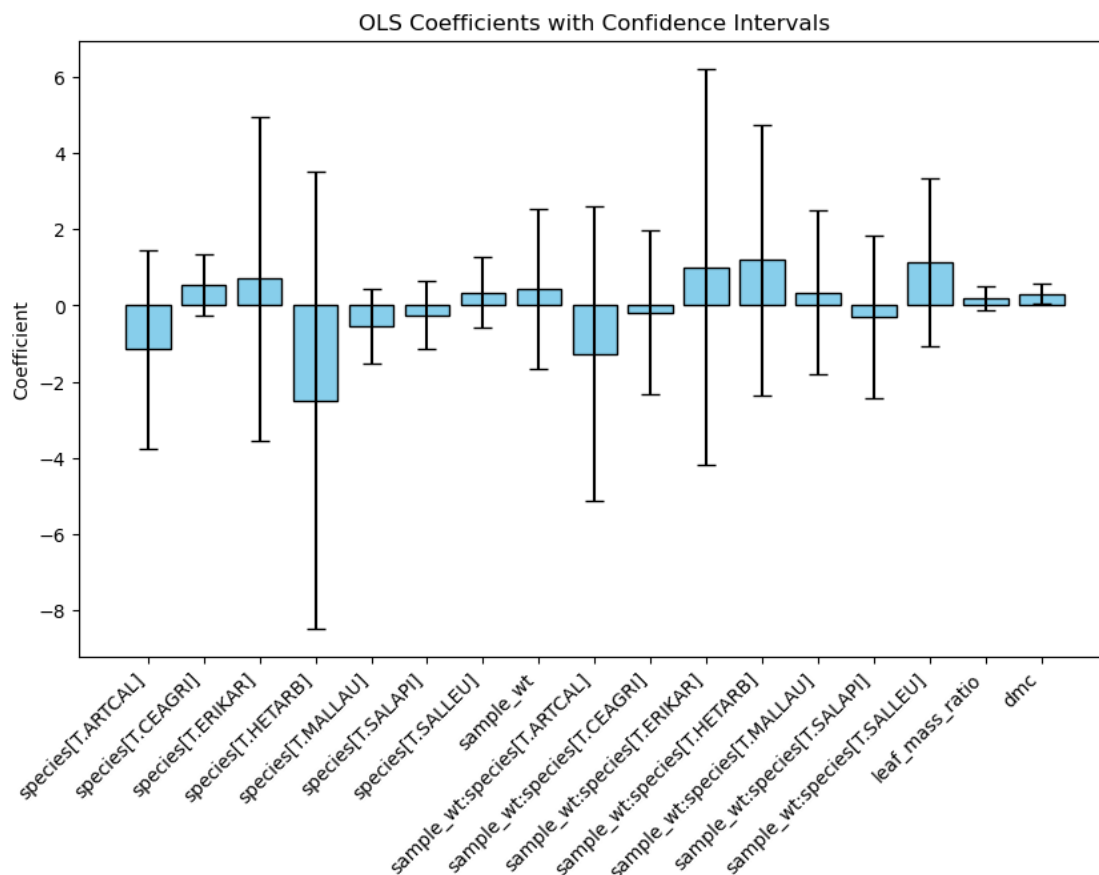
OLS Regression Results

```
==============================================================================
Dep. Variable:                     fd   R-squared:                       0.478
Model:                            OLS   Adj. R-squared:                  0.414
Method:                 Least Squares   F-statistic:                     7.482
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           1.82e-13
Time:                        16:38:26   Log-Likelihood:                -182.23
No. Observations:                 166   AIC:                             402.5
Df Residuals:                     147   BIC:                             461.6
Df Model:                          18
Covariance Type:            nonrobust
==============================================================================
==============
                      coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
---------------
Intercept           0.0171      0.381      0.045      0.964
-0.736      0.770
species[T.ARTCAL]  -1.0144      1.324     -0.766      0.445
```

	coef	std err	t	P>|t|	[0.025	0.975]
					-3.632	1.603
species[T.CEAGRI]	0.7080	0.425	1.665	0.098	-0.132	1.548
species[T.ERIKAR]	0.6559	2.149	0.305	0.761	-3.592	4.903
species[T.HETARB]	-2.4965	3.022	-0.826	0.410	-8.468	3.475
species[T.MALLAU]	-0.4604	0.497	-0.927	0.355	-1.442	0.521
species[T.SALAPI]	-0.3653	0.456	-0.802	0.424	-1.266	0.535
species[T.SALLEU]	0.4722	0.482	0.980	0.329	-0.480	1.424
sample_wt	0.3250	1.068	0.304	0.761	-1.785	2.435
sample_wt:species[T.ARTCAL]	-1.2072	1.952	-0.618	0.537	-5.065	2.650
sample_wt:species[T.CEAGRI]	-0.1058	1.089	-0.097	0.923	-2.257	2.046
sample_wt:species[T.ERIKAR]	1.3504	2.640	0.511	0.610	-3.868	6.569
sample_wt:species[T.HETARB]	1.3984	1.798	0.778	0.438	-2.155	4.952
sample_wt:species[T.MALLAU]	0.4664	1.084	0.430	0.668	-1.677	2.609
sample_wt:species[T.SALAPI]	-0.1657	1.081	-0.153	0.878	-2.302	1.971
sample_wt:species[T.SALLEU]	1.2346	1.113	1.109	0.269	-0.965	3.435
lfm	0.2036	0.154	1.320	0.189	-0.101	0.509
leaf_mass_ratio	0.2170	0.167	1.303	0.195	-0.112	0.546
dmc	0.3710	0.147	2.524	0.013	0.080	0.661

```
==============================================================================
Omnibus:                      104.367   Durbin-Watson:                   2.404
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              971.207
Skew:                           2.138   Prob(JB):                     1.27e-211
Kurtosis:                      14.051   Cond. No.                         97.5
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
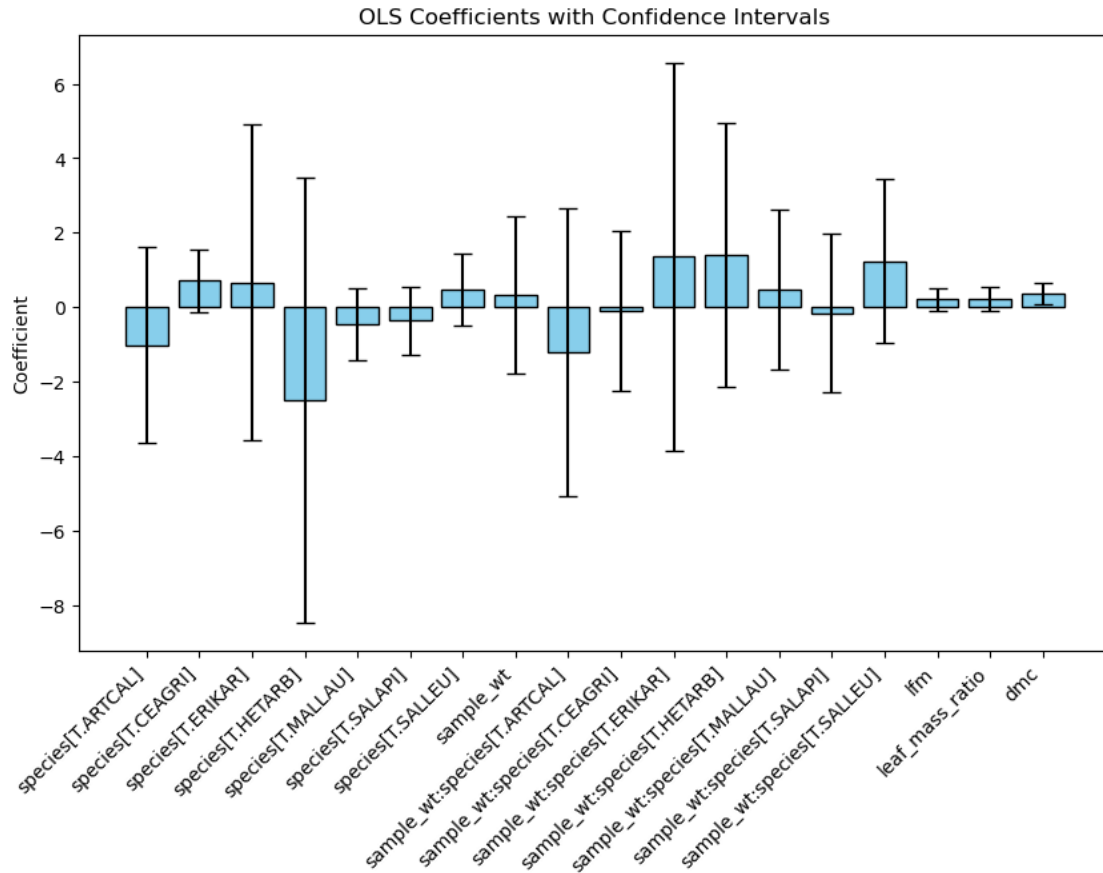
```
                          OLS Regression Results
================================================================================
=====
Dep. Variable:                      fd   R-squared:                       0.439
Model:                             OLS   Adj. R-squared:                  0.395
Method:                  Least Squares   F-statistic:                     9.987
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           2.85e-14
Time:                         16:38:26   Log-Likelihood:                 -188.20
No. Observations:                  166   AIC:                             402.4
Df Residuals:                      153   BIC:                             442.9
Df Model:                           12
Covariance Type:               nonrobust
================================================================================
=====
                      coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept           -0.0639      0.298     -0.214      0.831      -0.653
0.525
species[T.ARTCAL]   -0.3617      0.364     -0.994      0.322      -1.080
```

0.357

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.CEAGRI]	0.6851	0.335	2.044	0.043	0.023	1.347
species[T.ERIKAR]	-0.4719	0.337	-1.401	0.163	-1.137	0.193
species[T.HETARB]	0.0882	0.675	0.131	0.896	-1.245	1.421
species[T.MALLAU]	-0.0496	0.424	-0.117	0.907	-0.888	0.788
species[T.SALAPI]	-0.3422	0.379	-0.902	0.368	-1.092	0.407
species[T.SALLEU]	0.1868	0.399	0.469	0.640	-0.601	0.975
sample_wt	0.4682	0.128	3.646	0.000	0.214	0.722
dmc	0.3769	0.139	2.704	0.008	0.102	0.652
sample_wt:dmc	0.3529	0.105	3.349	0.001	0.145	0.561
leaf_mass_ratio	0.2834	0.170	1.671	0.097	-0.052	0.618
branch_volume	-0.1182	0.118	-1.005	0.316	-0.351	0.114

```
==============================================================================
Omnibus:                      108.807   Durbin-Watson:                   2.307
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              965.965
Skew:                           2.289   Prob(JB):                     1.75e-210
Kurtosis:                      13.895   Cond. No.                         23.0
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
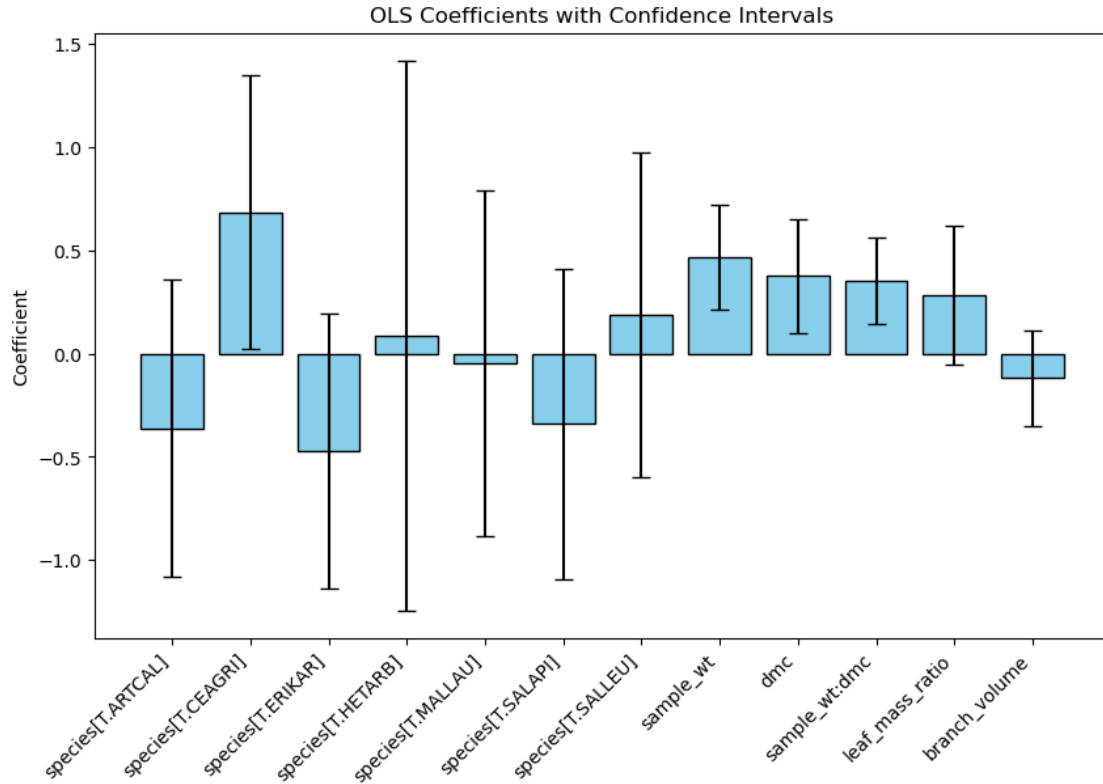
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.439
Model:	OLS	Adj. R-squared:	0.394
Method:	Least Squares	F-statistic:	9.958
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	3.11e-14
Time:	16:38:27	Log-Likelihood:	-188.30
No. Observations:	166	AIC:	402.6
Df Residuals:	153	BIC:	443.1
Df Model:	12		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0520	0.297	-0.175	0.861	-0.639	0.535
species[T.ARTCAL]	-0.3419	0.365	-0.936	0.351	-1.063	0.380
species[T.CEAGRI]	0.7592	0.363	2.092	0.038	0.042	

```
1.476
species[T.ERIKAR]    -0.4693     0.337     -1.392     0.166     -1.135
0.197
species[T.HETARB]     0.0293     0.671      0.044     0.965     -1.297
1.355
species[T.MALLAU]    -0.1863     0.395     -0.472     0.638     -0.966
0.593
species[T.SALAPI]    -0.3745     0.378     -0.991     0.323     -1.121
0.372
species[T.SALLEU]     0.1541     0.397      0.388     0.699     -0.631
0.939
sample_wt             0.3822     0.107      3.570     0.000      0.171
0.594
dmc                   0.3810     0.140      2.716     0.007      0.104
0.658
sample_wt:dmc         0.3460     0.105      3.300     0.001      0.139
0.553
leaf_mass_ratio       0.2702     0.168      1.611     0.109     -0.061
0.602
mpa                  -0.0737     0.081     -0.905     0.367     -0.235
0.087
==============================================================================
Omnibus:                      112.130   Durbin-Watson:                   2.264
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1054.897
Skew:                           2.359   Prob(JB):                     8.55e-230
Kurtosis:                      14.413   Cond. No.                         21.0
==============================================================================
```
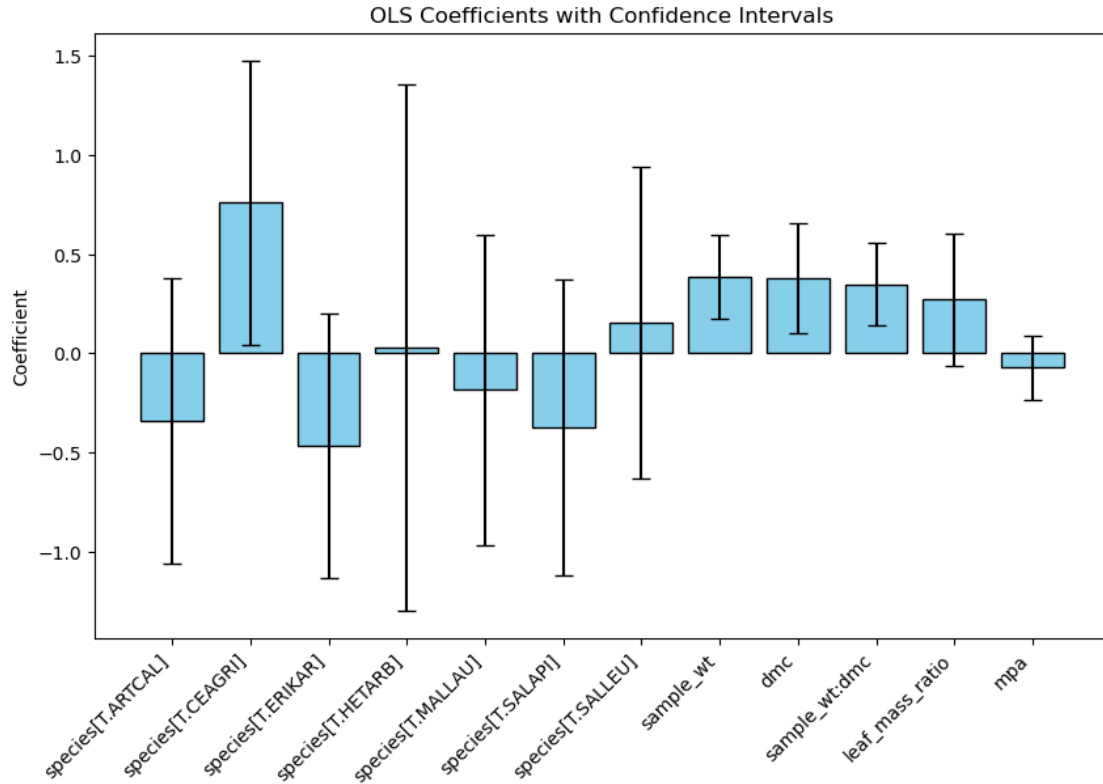
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

OLS Regression Results

Dep. Variable:	fd	R-squared:	0.477
Model:	OLS	Adj. R-squared:	0.413
Method:	Least Squares	F-statistic:	7.456
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	2.03e-13
Time:	16:38:27	Log-Likelihood:	-182.37
No. Observations:	166	AIC:	402.7
Df Residuals:	147	BIC:	461.9
Df Model:	18		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0195	0.384	-0.051	0.960	-0.778	0.739
species[T.ARTCAL]	-1.0845	1.322	-0.820	0.413	-3.698	1.529
species[T.CEAGRI]	0.6122	0.410	1.494	0.137		

```
                                   -0.198       1.422
species[T.ERIKAR]                   1.1131       2.177      0.511      0.610
                                   -3.188       5.415
species[T.HETARB]                  -2.0071       3.049     -0.658      0.511
                                   -8.034       4.019
species[T.MALLAU]                  -0.3241       0.525     -0.618      0.538
                                   -1.361       0.713
species[T.SALAPI]                  -0.1650       0.455     -0.363      0.717
                                   -1.064       0.734
species[T.SALLEU]                   0.3869       0.474      0.817      0.415
                                   -0.549       1.323
sample_wt                           0.5175       1.067      0.485      0.629
                                   -1.592       2.627
sample_wt:species[T.ARTCAL]        -1.1895       1.954     -0.609      0.544
                                   -5.051       2.672
sample_wt:species[T.CEAGRI]        -0.0468       1.094     -0.043      0.966
                                   -2.208       2.115
sample_wt:species[T.ERIKAR]         1.4673       2.656      0.552      0.582
                                   -3.782       6.717
sample_wt:species[T.HETARB]         1.0201       1.797      0.568      0.571
                                   -2.532       4.572
sample_wt:species[T.MALLAU]         0.3710       1.082      0.343      0.732
                                   -1.766       2.508
sample_wt:species[T.SALAPI]        -0.3328       1.079     -0.309      0.758
                                   -2.464       1.799
sample_wt:species[T.SALLEU]         1.1771       1.112      1.059      0.292
                                   -1.020       3.374
leaf_mass_ratio                     0.2507       0.173      1.447      0.150
                                   -0.092       0.593
dmc                                 0.3476       0.143      2.428      0.016
 0.065       0.630
branch_volume                      -0.1619       0.132     -1.225      0.223
                                   -0.423       0.099
==============================================================================
Omnibus:                          105.172   Durbin-Watson:                   2.349
Prob(Omnibus):                      0.000   Jarque-Bera (JB):              939.504
Skew:                               2.180   Prob(JB):                     9.75e-205
Kurtosis:                          13.808   Cond. No.                         98.2
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
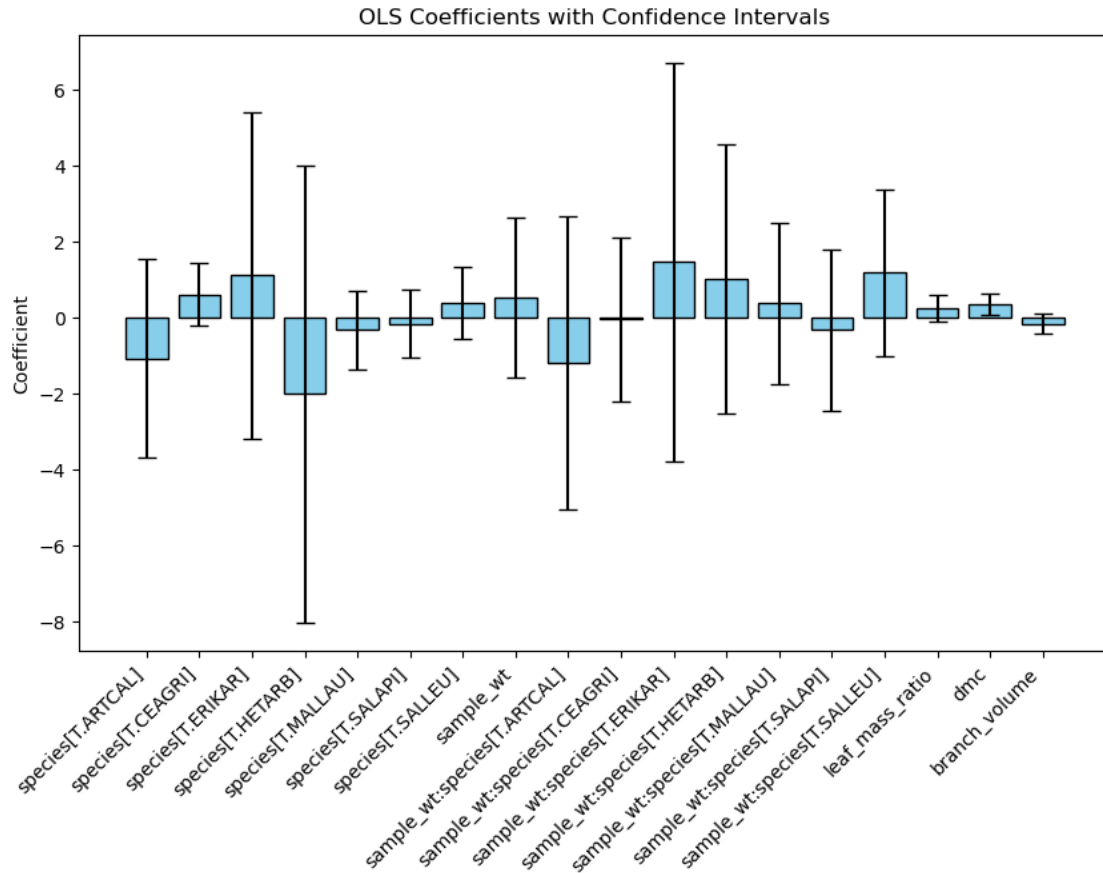
OLS Regression Results

Dep. Variable:	fd	R-squared:		0.470
Model:	OLS	Adj. R-squared:		0.409
Method:	Least Squares	F-statistic:		7.726
Date:	Wed, 24 Apr 2024	Prob (F-statistic):		1.70e-13
Time:	16:38:27	Log-Likelihood:		-183.48
No. Observations:	166	AIC:		403.0
Df Residuals:	148	BIC:		459.0
Df Model:	17			
Covariance Type:	nonrobust			

===

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.1287	0.401	0.321	0.749	-0.665	0.922
species[T.ARTCAL]	-0.7748	1.382	-0.561	0.576		

```
-3.506       1.957
species[T.CEAGRI]               0.4973      0.407      1.222      0.224
-0.307       1.302
species[T.ERIKAR]               0.6963      2.159      0.323      0.747
-3.569       4.962
species[T.HETARB]              -2.5924      3.031     -0.855      0.394
-8.582       3.398
species[T.MALLAU]              -0.7806      0.521     -1.499      0.136
-1.810       0.249
species[T.SALAPI]              -0.5440      0.475     -1.146      0.254
-1.482       0.394
species[T.SALLEU]               0.3164      0.478      0.662      0.509
-0.628       1.261
sample_wt                       0.4477      1.071      0.418      0.676
-1.668       2.563
sample_wt:species[T.ARTCAL]    -0.7167      2.045     -0.351      0.726
-4.757       3.324
sample_wt:species[T.CEAGRI]    -0.2006      1.092     -0.184      0.855
-2.359       1.958
sample_wt:species[T.ERIKAR]     1.0823      2.647      0.409      0.683
-4.149       6.313
sample_wt:species[T.HETARB]     1.1762      1.802      0.653      0.515
-2.386       4.738
sample_wt:species[T.MALLAU]     0.3562      1.085      0.328      0.743
-1.788       2.500
sample_wt:species[T.SALAPI]    -0.2942      1.083     -0.272      0.786
-2.434       1.846
sample_wt:species[T.SALLEU]     1.2376      1.114      1.111      0.269
-0.965       3.440
branching                      -0.0838      0.095     -0.882      0.379
-0.272       0.104
dmc                             0.2227      0.112      1.985      0.049
0.001       0.444
==============================================================================
Omnibus:                      109.820   Durbin-Watson:                   2.365
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1079.055
Skew:                           2.271   Prob(JB):                     4.86e-235
Kurtosis:                      14.636   Cond. No.                         80.1
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```

OLS Coefficients with Confidence Intervals
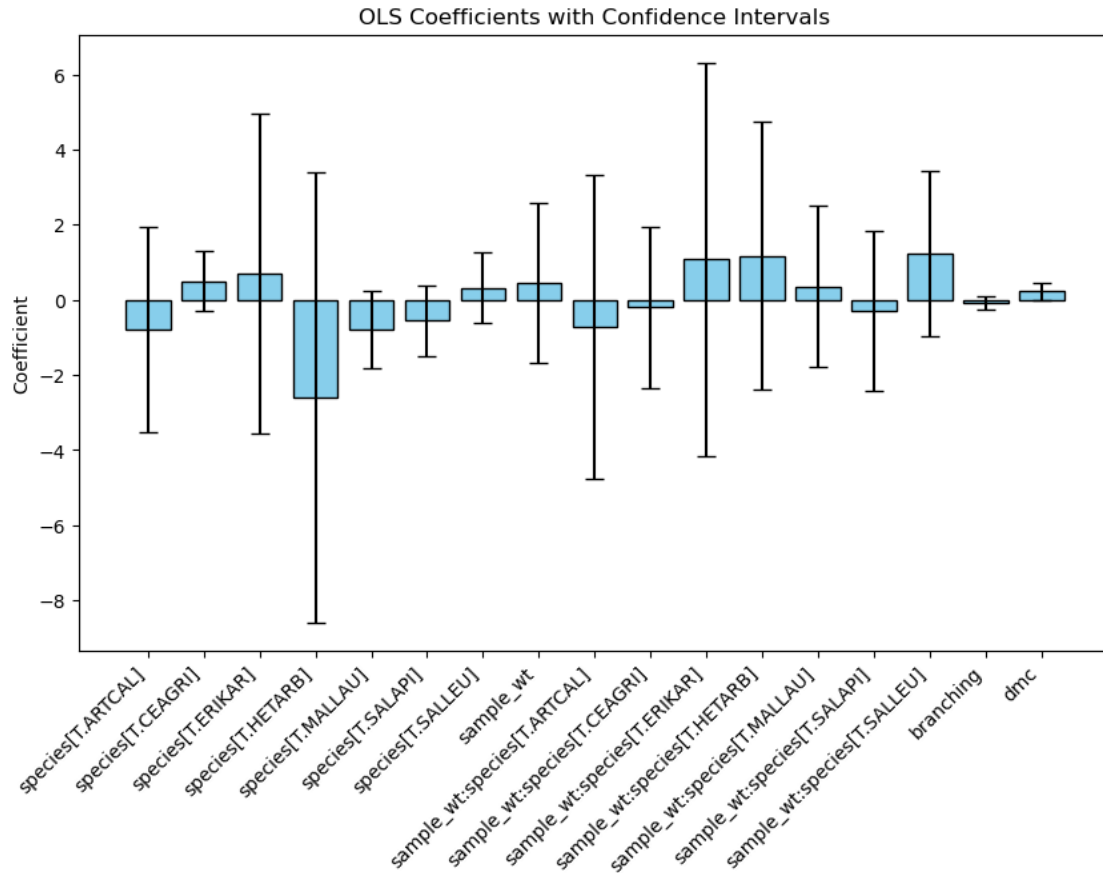
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.431
Model:	OLS	Adj. R-squared:	0.390
Method:	Least Squares	F-statistic:	10.58
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	2.50e-14
Time:	16:38:27	Log-Likelihood:	-189.48
No. Observations:	166	AIC:	403.0
Df Residuals:	154	BIC:	440.3
Df Model:	11		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0112	0.296	-0.038	0.970	-0.596	0.573
species[T.ARTCAL]	-0.2068	0.382	-0.541	0.589	-0.962	

```
0.548
species[T.CEAGRI]      0.6632     0.344      1.927      0.056     -0.017
1.343
species[T.ERIKAR]     -0.5527     0.384     -1.439      0.152     -1.312
0.206
species[T.HETARB]      0.0983     0.684      0.144      0.886     -1.253
1.450
species[T.MALLAU]     -0.2881     0.390     -0.740      0.461     -1.058
0.482
species[T.SALAPI]     -0.6641     0.377     -1.762      0.080     -1.409
0.080
species[T.SALLEU]      0.2137     0.405      0.527      0.599     -0.587
1.014
sample_wt              0.4029     0.106      3.787      0.000      0.193
0.613
dmc                    0.2719     0.118      2.308      0.022      0.039
0.505
sample_wt:dmc          0.3263     0.105      3.118      0.002      0.120
0.533
lfm                    0.1405     0.153      0.918      0.360     -0.162
0.443
==============================================================================
Omnibus:                      110.620   Durbin-Watson:                   2.330
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1031.279
Skew:                           2.319   Prob(JB):                     1.15e-224
Kurtosis:                      14.296   Cond. No.                         21.3
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
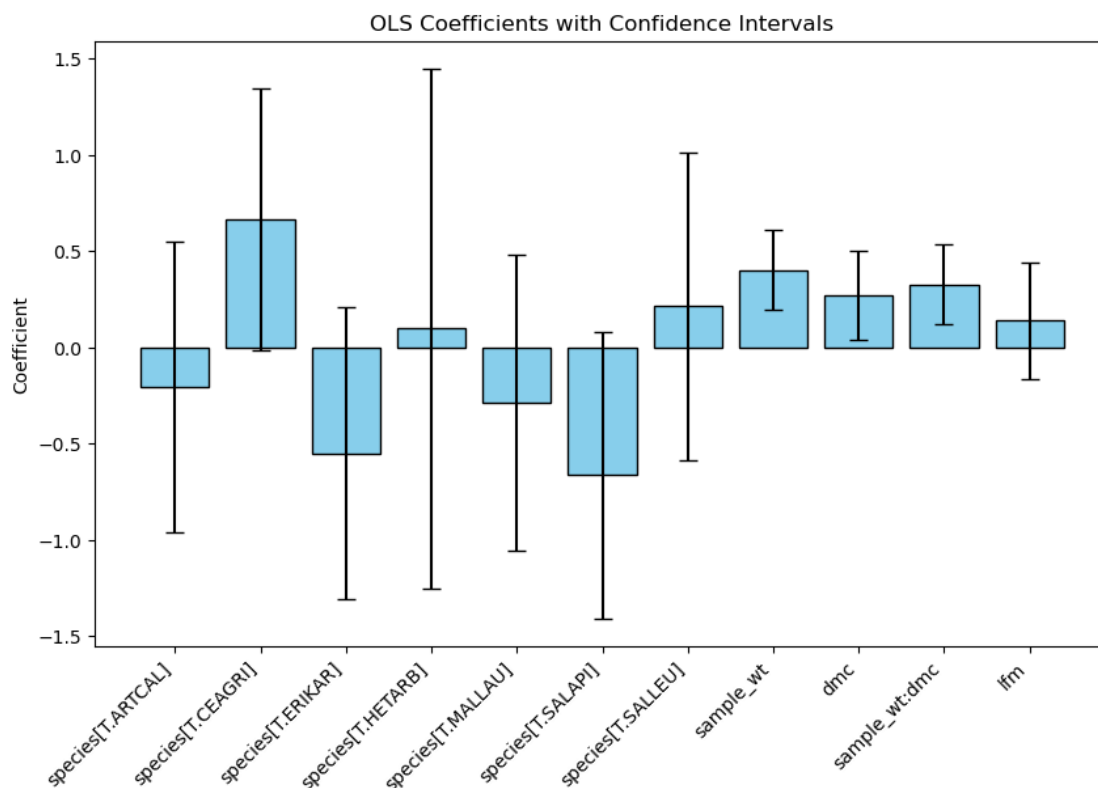
```
                        OLS Regression Results
================================================================================
Dep. Variable:                      fd   R-squared:                       0.470
Model:                             OLS   Adj. R-squared:                  0.409
Method:                  Least Squares   F-statistic:                     7.716
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           1.77e-13
Time:                         16:38:27   Log-Likelihood:                 -183.53
No. Observations:                  166   AIC:                             403.1
Df Residuals:                      148   BIC:                             459.1
Df Model:                           17
Covariance Type:             nonrobust
================================================================================
===============
                        coef    std err          t      P>|t|
[0.025      0.975]
--------------------------------------------------------------------------------
---------------
Intercept             -0.0181      0.385     -0.047      0.962
-0.778       0.742
species[T.ARTCAL]     -1.1876      1.328     -0.894      0.373
-3.812       1.437
species[T.CEAGRI]      0.6502      0.435      1.493      0.138
```

39

	coef	std err	t	P>|t|	[0.025	0.975]
					-0.210	1.511
species[T.ERIKAR]	0.3586	2.177	0.165	0.869	-3.944	4.661
species[T.HETARB]	-2.8388	3.038	-0.934	0.352	-8.842	3.165
species[T.MALLAU]	-0.6254	0.490	-1.277	0.203	-1.593	0.342
species[T.SALAPI]	-0.3868	0.437	-0.885	0.377	-1.250	0.477
species[T.SALLEU]	0.3867	0.474	0.816	0.416	-0.550	1.323
sample_wt	0.3413	1.069	0.319	0.750	-1.771	2.454
sample_wt:species[T.ARTCAL]	-1.3454	1.964	-0.685	0.494	-5.227	2.536
sample_wt:species[T.CEAGRI]	-0.1499	1.092	-0.137	0.891	-2.307	2.007
sample_wt:species[T.ERIKAR]	0.5763	2.659	0.217	0.829	-4.678	5.831
sample_wt:species[T.HETARB]	1.4536	1.800	0.808	0.421	-2.103	5.010
sample_wt:species[T.MALLAU]	0.4512	1.085	0.416	0.678	-1.692	2.595
sample_wt:species[T.SALAPI]	-0.1905	1.081	-0.176	0.860	-2.326	1.945
sample_wt:species[T.SALLEU]	1.2169	1.114	1.092	0.276	-0.984	3.418
mpa	-0.0679	0.082	-0.829	0.408	-0.230	0.094
dmc	0.2218	0.112	1.977	0.050	9.04e-05	0.444

```
==============================================================================
Omnibus:                      110.707   Durbin-Watson:                   2.328
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1082.805
Skew:                           2.299   Prob(JB):                     7.45e-236
Kurtosis:                      14.637   Cond. No.                         79.0
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
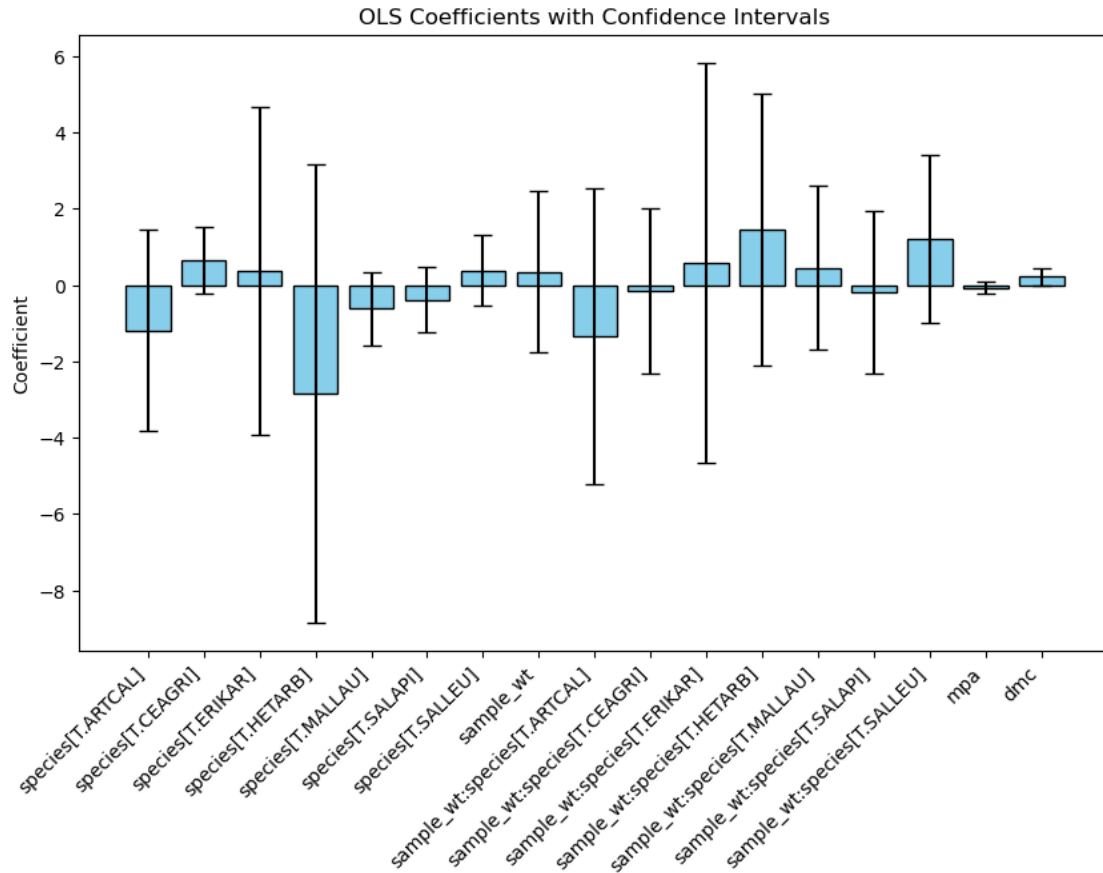
```
                          OLS Regression Results
================================================================================
==============
Dep. Variable:                      fd   R-squared:                       0.470
Model:                             OLS   Adj. R-squared:                  0.409
Method:                  Least Squares   F-statistic:                     7.715
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           1.78e-13
Time:                         16:38:28   Log-Likelihood:                -183.54
No. Observations:                  166   AIC:                             403.1
Df Residuals:                      148   BIC:                             459.1
Df Model:                           17
Covariance Type:              nonrobust
================================================================================
==============
                          coef    std err          t      P>|t|
[0.025      0.975]
--------------------------------------------------------------------------------
---------------
Intercept              -0.0214      0.385     -0.056      0.956
-0.783       0.740
species[T.ARTCAL]      -1.0686      1.327     -0.805      0.422
```

	coef	std err	t	P>|t|	[0.025	0.975]
					-3.691	1.554
species[T.CEAGRI]	0.5652	0.410	1.379	0.170	-0.245	1.375
species[T.ERIKAR]	0.8461	2.177	0.389	0.698	-3.455	5.148
species[T.HETARB]	-2.3987	3.049	-0.787	0.433	-8.423	3.626
species[T.MALLAU]	-0.5002	0.512	-0.977	0.330	-1.512	0.512
species[T.SALAPI]	-0.3478	0.439	-0.793	0.429	-1.215	0.519
species[T.SALLEU]	0.4065	0.475	0.855	0.394	-0.533	1.346
sample_wt	0.4168	1.069	0.390	0.697	-1.696	2.530
sample_wt:species[T.ARTCAL]	-1.1710	1.961	-0.597	0.551	-5.047	2.705
sample_wt:species[T.CEAGRI]	-0.0603	1.098	-0.055	0.956	-2.230	2.109
sample_wt:species[T.ERIKAR]	1.1232	2.655	0.423	0.673	-4.124	6.371
sample_wt:species[T.HETARB]	1.2618	1.796	0.702	0.483	-2.288	4.811
sample_wt:species[T.MALLAU]	0.4418	1.084	0.407	0.684	-1.701	2.585
sample_wt:species[T.SALAPI]	-0.2307	1.080	-0.214	0.831	-2.365	1.904
sample_wt:species[T.SALLEU]	1.2399	1.115	1.112	0.268	-0.964	3.444
dmc	0.2180	0.112	1.946	0.054	-0.003	0.439
branch_volume	-0.1036	0.126	-0.820	0.414	-0.353	0.146

```
==============================================================================
Omnibus:                      108.364   Durbin-Watson:                   2.360
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1014.615
Skew:                           2.251   Prob(JB):                    4.78e-221
Kurtosis:                      14.244   Cond. No.                         92.2
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
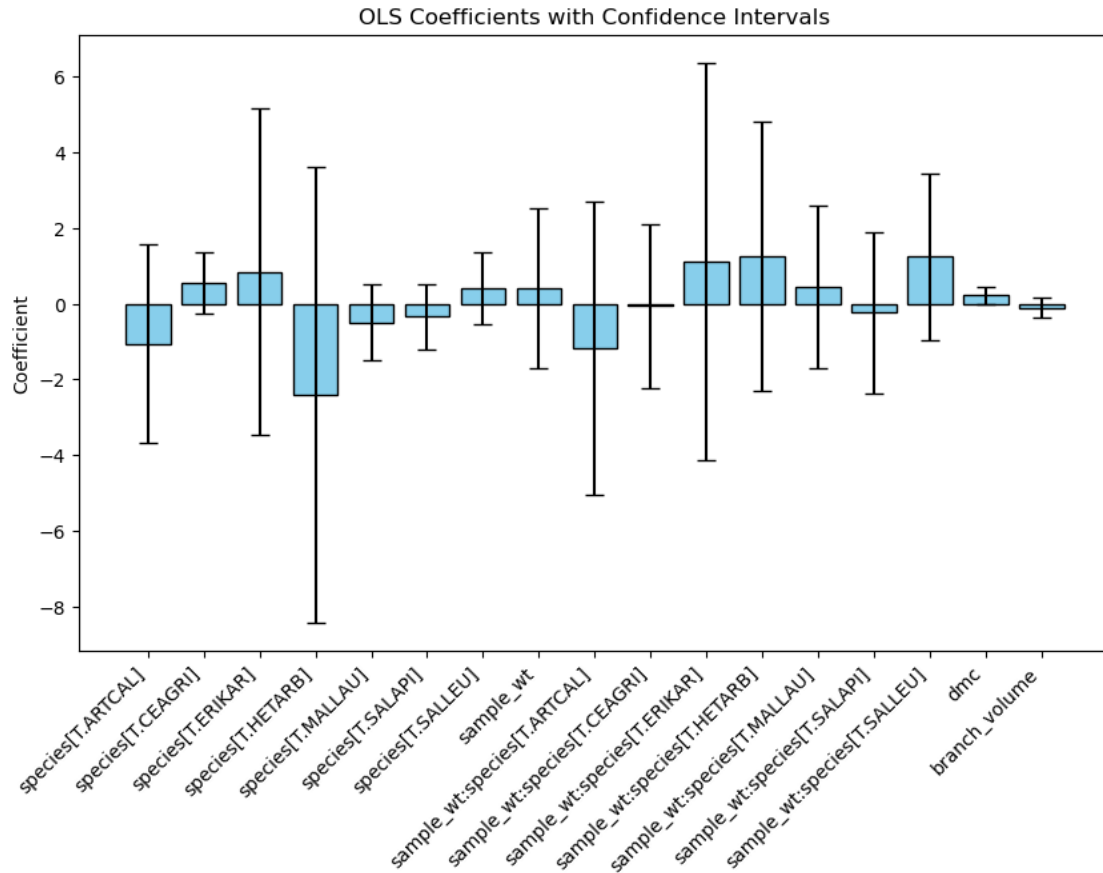
```
                        OLS Regression Results
==================================================================================
Dep. Variable:                     fd   R-squared:                       0.437
Model:                            OLS   Adj. R-squared:                  0.393
Method:                 Least Squares   F-statistic:                     9.884
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           3.91e-14
Time:                        16:38:28   Log-Likelihood:                -188.57
No. Observations:                 166   AIC:                             403.1
Df Residuals:                     153   BIC:                             443.6
Df Model:                          12
Covariance Type:            nonrobust
==================================================================================
=====
                       coef    std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------------------
-----
Intercept           -0.0672      0.308     -0.218      0.828      -0.675
0.541
species[T.ARTCAL]   -0.2779      0.399     -0.696      0.488      -1.067
```

```
                      0.511
species[T.CEAGRI]     0.6663      0.339      1.963      0.051     -0.004
                      1.337
species[T.ERIKAR]    -0.4046      0.362     -1.117      0.266     -1.120
                      0.311
species[T.HETARB]     0.0508      0.675      0.075      0.940     -1.283
                      1.385
species[T.MALLAU]    -0.1507      0.408     -0.370      0.712     -0.956
                      0.655
species[T.SALAPI]    -0.3408      0.384     -0.887      0.376     -1.100
                      0.418
species[T.SALLEU]     0.1780      0.401      0.444      0.658     -0.615
                      0.971
sample_wt             0.3899      0.107      3.656      0.000      0.179
                      0.601
dmc                   0.3700      0.140      2.649      0.009      0.094
                      0.646
sample_wt:dmc         0.3411      0.105      3.254      0.001      0.134
                      0.548
leaf_mass_ratio       0.2653      0.169      1.568      0.119     -0.069
                      0.600
leaf_sav             -0.0458      0.081     -0.563      0.574     -0.207
                      0.115
==============================================================================
Omnibus:                      112.199   Durbin-Watson:                   2.331
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1068.286
Skew:                           2.355   Prob(JB):                     1.06e-232
Kurtosis:                      14.500   Cond. No.                         23.4
==============================================================================
```
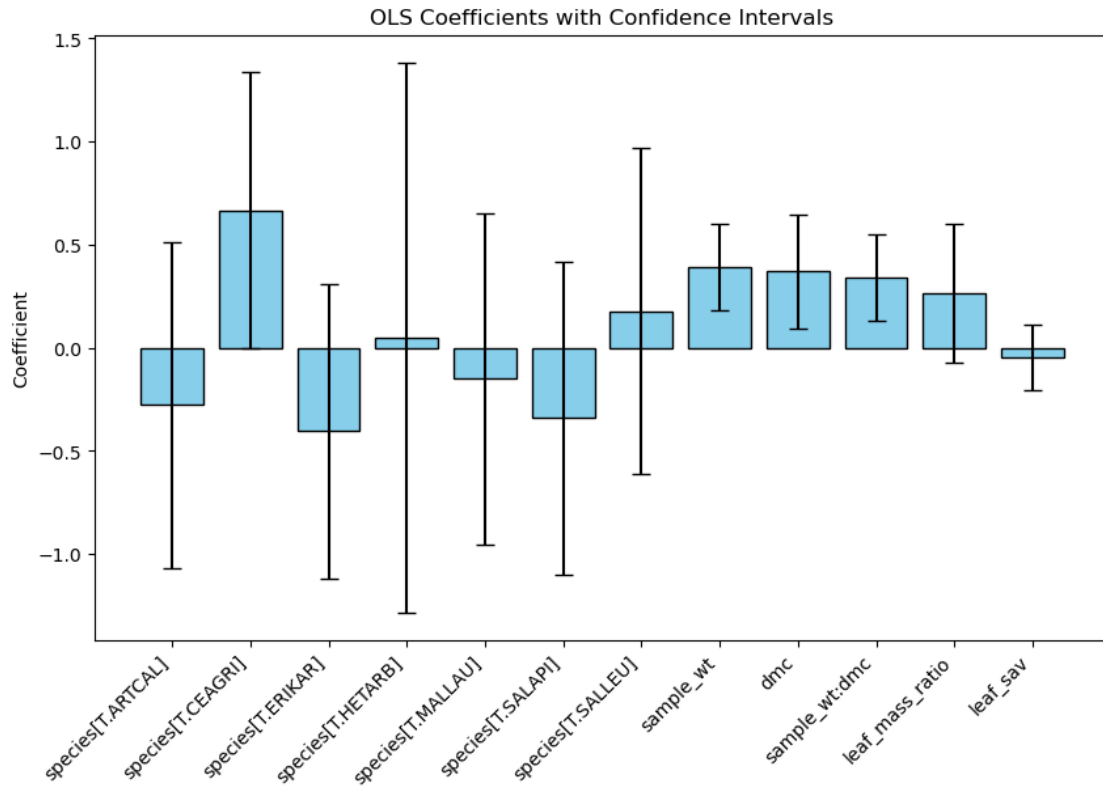
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

```
                      OLS Regression Results
================================================================================
=====
Dep. Variable:                       fd   R-squared:                       0.443
Model:                              OLS   Adj. R-squared:                  0.395
Method:                   Least Squares   F-statistic:                     9.297
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           5.86e-14
Time:                         16:38:28   Log-Likelihood:                 -187.65
No. Observations:                   166   AIC:                             403.3
Df Residuals:                       152   BIC:                             446.9
Df Model:                            13
Covariance Type:               nonrobust
================================================================================
=====
                       coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept            -0.0424      0.297     -0.143      0.887      -0.629
0.544
species[T.ARTCAL]    -0.2200      0.381     -0.577      0.565      -0.974
0.534
species[T.CEAGRI]     0.8637      0.375      2.303      0.023       0.123
```

1.604

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.ERIKAR]	-0.7004	0.397	-1.764	0.080	-1.485	0.084
species[T.HETARB]	0.1661	0.682	0.243	0.808	-1.182	1.514
species[T.MALLAU]	-0.1292	0.398	-0.325	0.746	-0.915	0.657
species[T.SALAPI]	-0.4804	0.390	-1.232	0.220	-1.251	0.290
species[T.SALLEU]	0.2345	0.404	0.581	0.562	-0.563	1.032
sample_wt	0.3848	0.107	3.596	0.000	0.173	0.596
dmc	0.4315	0.148	2.925	0.004	0.140	0.723
sample_wt:dmc	0.3455	0.105	3.298	0.001	0.139	0.553
lfm	0.1701	0.155	1.098	0.274	-0.136	0.476
leaf_mass_ratio	0.2969	0.169	1.753	0.082	-0.038	0.632
mpa	-0.0660	0.082	-0.807	0.421	-0.227	0.095

```
==============================================================================
Omnibus:                      107.521   Durbin-Watson:                   2.285
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              959.396
Skew:                           2.249   Prob(JB):                     4.68e-209
Kurtosis:                      13.885   Cond. No.                         23.4
==============================================================================
```
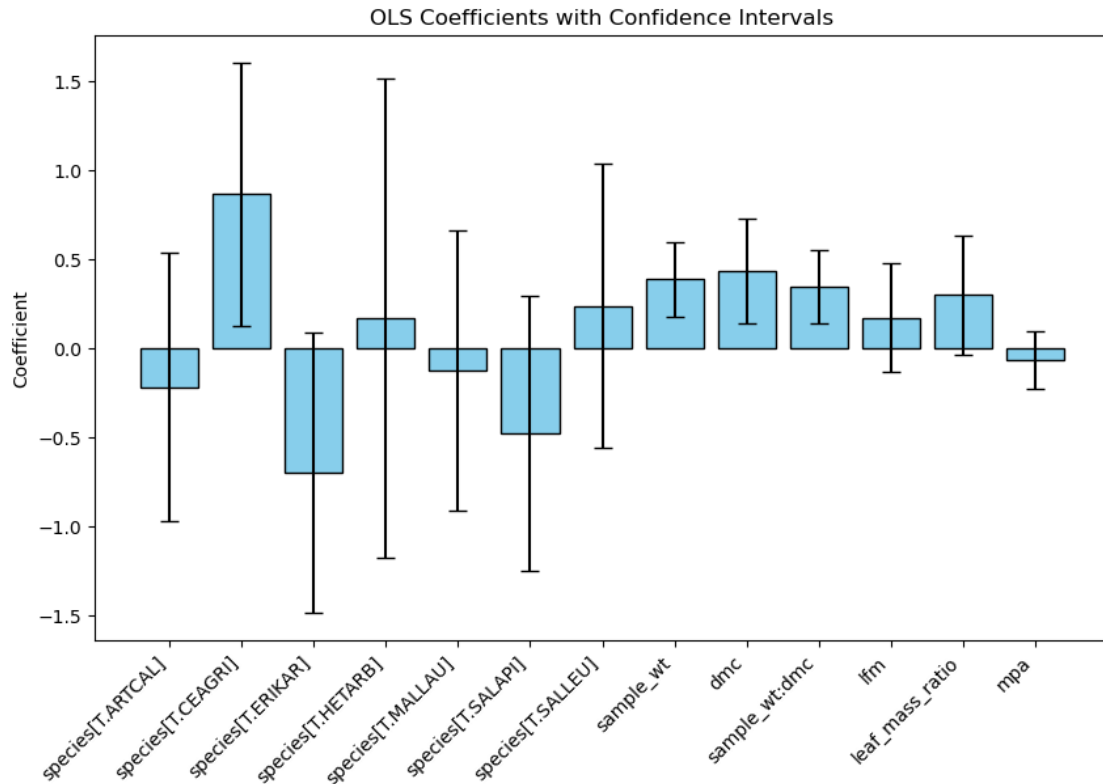
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

OLS Regression Results

Dep. Variable:	fd	R-squared:	0.443
Model:	OLS	Adj. R-squared:	0.396
Method:	Least Squares	F-statistic:	9.312
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	5.58e-14
Time:	16:38:28	Log-Likelihood:	-187.59
No. Observations:	166	AIC:	403.2
Df Residuals:	152	BIC:	446.7
Df Model:	13		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0522	0.298	-0.175	0.861	-0.641	0.537
species[T.ARTCAL]	-0.2419	0.381	-0.635	0.526	-0.994	0.510
species[T.CEAGRI]	0.7920	0.350	2.263	0.025	0.101	

47

```
1.483
species[T.ERIKAR]      -0.6954      0.397      -1.750      0.082      -1.480
0.090
species[T.HETARB]       0.2126      0.684       0.311      0.757      -1.140
1.565
species[T.MALLAU]      -0.0124      0.426      -0.029      0.977      -0.853
0.828
species[T.SALAPI]      -0.4489      0.392      -1.144      0.254      -1.224
0.326
species[T.SALLEU]       0.2603      0.405       0.643      0.521      -0.539
1.060
sample_wt               0.4601      0.129       3.577      0.000       0.206
0.714
dmc                     0.4258      0.147       2.901      0.004       0.136
0.716
sample_wt:dmc           0.3514      0.105       3.336      0.001       0.143
0.560
lfm                     0.1646      0.155       1.059      0.291      -0.142
0.472
leaf_mass_ratio         0.3070      0.171       1.796      0.075      -0.031
0.645
branch_volume          -0.1031      0.118      -0.870      0.385      -0.337
0.131
==============================================================================
Omnibus:                      104.826   Durbin-Watson:                   2.325
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              891.665
Skew:                           2.193   Prob(JB):                     2.38e-194
Kurtosis:                      13.473   Cond. No.                         25.0
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```

OLS Coefficients with Confidence Intervals
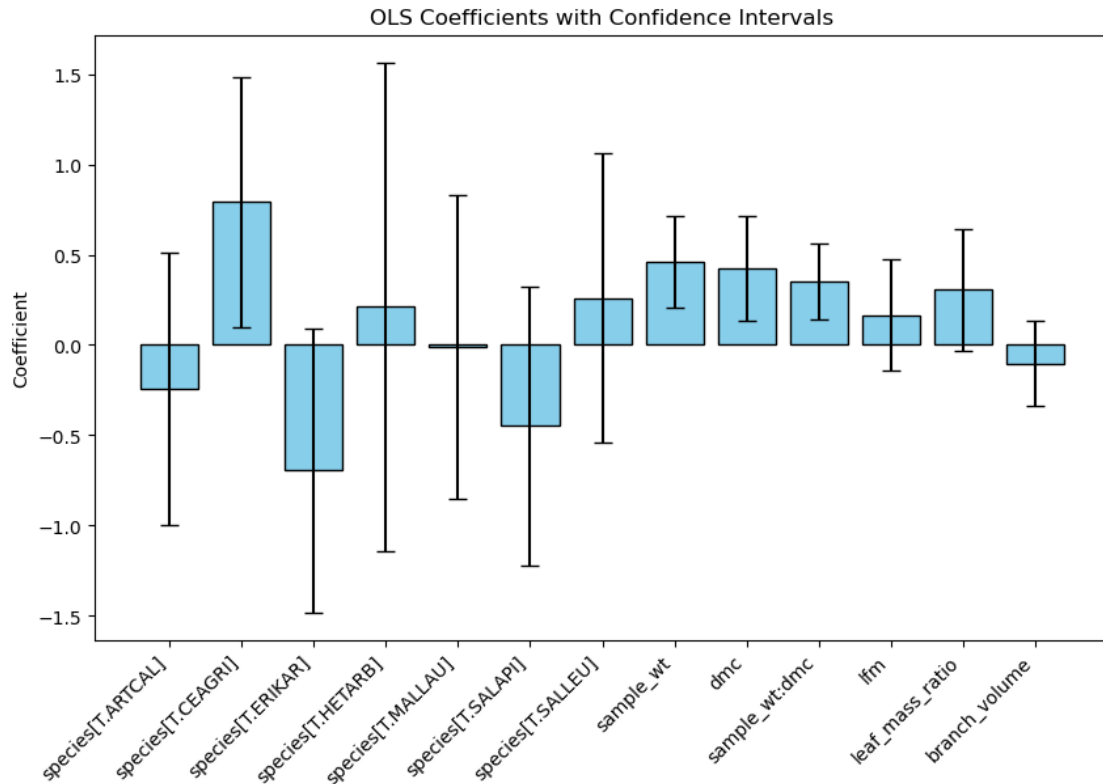
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.469
Model:	OLS	Adj. R-squared:	0.408
Method:	Least Squares	F-statistic:	7.688
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	1.98e-13
Time:	16:38:29	Log-Likelihood:	-183.68
No. Observations:	166	AIC:	403.4
Df Residuals:	148	BIC:	459.4
Df Model:	17		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.2490	0.518	0.481	0.631	-0.774	1.272
species[T.ARTCAL]	-1.5175	1.457	-1.042	0.299	-4.397	1.362
species[T.CEAGRI]	0.3633	0.471	0.771	0.442		

	coef	std err	t	P>|t|	[0.025	0.975]
					-0.568	1.295
species[T.ERIKAR]	0.2739	2.217	0.124	0.902	-4.107	4.655
species[T.HETARB]	-2.9750	3.070	-0.969	0.334	-9.041	3.091
species[T.MALLAU]	-0.7340	0.518	-1.417	0.159	-1.757	0.289
species[T.SALAPI]	-0.5595	0.515	-1.086	0.279	-1.578	0.459
species[T.SALLEU]	0.0596	0.673	0.089	0.930	-1.270	1.390
sample_wt	0.3801	1.069	0.356	0.723	-1.732	2.492
sample_wt:species[T.ARTCAL]	-1.2361	1.961	-0.630	0.529	-5.112	2.640
sample_wt:species[T.CEAGRI]	-0.1516	1.093	-0.139	0.890	-2.311	2.007
sample_wt:species[T.ERIKAR]	0.9087	2.639	0.344	0.731	-4.307	6.125
sample_wt:species[T.HETARB]	1.5389	1.822	0.845	0.400	-2.061	5.139
sample_wt:species[T.MALLAU]	0.4342	1.085	0.400	0.690	-1.710	2.579
sample_wt:species[T.SALAPI]	-0.2211	1.081	-0.205	0.838	-2.357	1.915
sample_wt:species[T.SALLEU]	1.2029	1.115	1.079	0.282	-1.000	3.406
LMA	-0.1460	0.222	-0.658	0.511	-0.584	0.292
dmc	0.2196	0.112	1.957	0.052	-0.002	0.441

```
==============================================================================
Omnibus:                      109.863   Durbin-Watson:                   2.372
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1077.726
Skew:                           2.273   Prob(JB):                     9.44e-235
Kurtosis:                      14.626   Cond. No.                         87.0
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
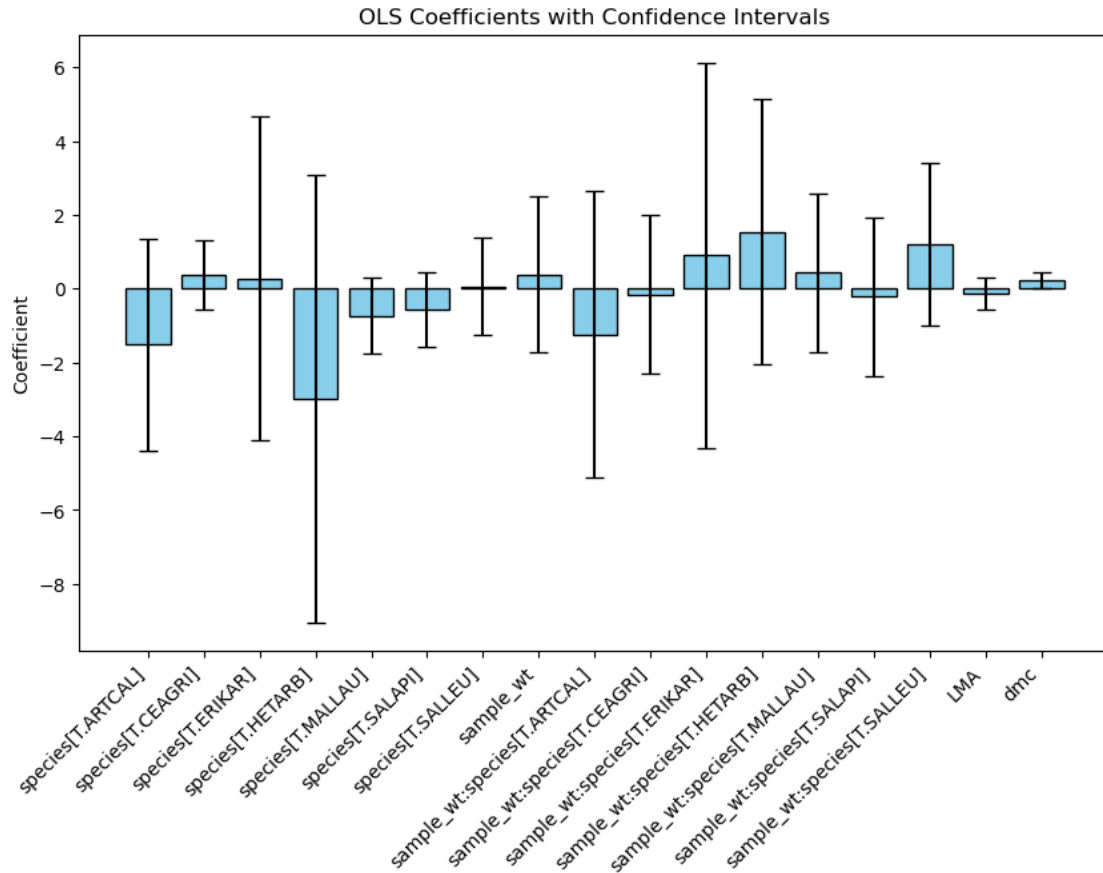
```
                           OLS Regression Results
==============================================================================
Dep. Variable:                     fd   R-squared:                       0.475
Model:                            OLS   Adj. R-squared:                  0.411
Method:                 Least Squares   F-statistic:                     7.398
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           2.58e-13
Time:                        16:38:29   Log-Likelihood:                -182.68
No. Observations:                 166   AIC:                             403.4
Df Residuals:                     147   BIC:                             462.5
Df Model:                          18
Covariance Type:            nonrobust
==============================================================================
==============
                     coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
---------------
Intercept          -0.0046      0.384     -0.012      0.990
-0.764       0.754
species[T.ARTCAL]  -1.2371      1.326     -0.933      0.352
```

	coef	std err	t	P>|t|	[0.025	0.975]
					-3.858	1.384
species[T.CEAGRI]	0.6918	0.436	1.586	0.115	-0.170	1.553
species[T.ERIKAR]	0.4216	2.174	0.194	0.846	-3.875	4.718
species[T.HETARB]	-2.6723	3.036	-0.880	0.380	-8.672	3.327
species[T.MALLAU]	-0.5382	0.494	-1.090	0.278	-1.514	0.438
species[T.SALAPI]	-0.2529	0.449	-0.563	0.574	-1.141	0.635
species[T.SALLEU]	0.3578	0.474	0.756	0.451	-0.578	1.294
sample_wt	0.3992	1.068	0.374	0.709	-1.712	2.510
sample_wt:species[T.ARTCAL]	-1.4098	1.962	-0.719	0.473	-5.286	2.467
sample_wt:species[T.CEAGRI]	-0.1818	1.090	-0.167	0.868	-2.336	1.972
sample_wt:species[T.ERIKAR]	0.6865	2.656	0.258	0.796	-4.562	5.935
sample_wt:species[T.HETARB]	1.3108	1.800	0.728	0.468	-2.247	4.868
sample_wt:species[T.MALLAU]	0.3858	1.084	0.356	0.722	-1.757	2.528
sample_wt:species[T.SALAPI]	-0.2636	1.080	-0.244	0.808	-2.398	1.871
sample_wt:species[T.SALLEU]	1.1479	1.113	1.031	0.304	-1.052	3.348
leaf_mass_ratio	0.2058	0.167	1.235	0.219	-0.123	0.535
mpa	-0.0802	0.082	-0.975	0.331	-0.243	0.082
dmc	0.3285	0.141	2.323	0.022	0.049	0.608

```
==============================================================================
Omnibus:                      109.453   Durbin-Watson:                   2.316
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1061.784
Skew:                           2.266   Prob(JB):                    2.73e-231
Kurtosis:                      14.532   Cond. No.                         89.2
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
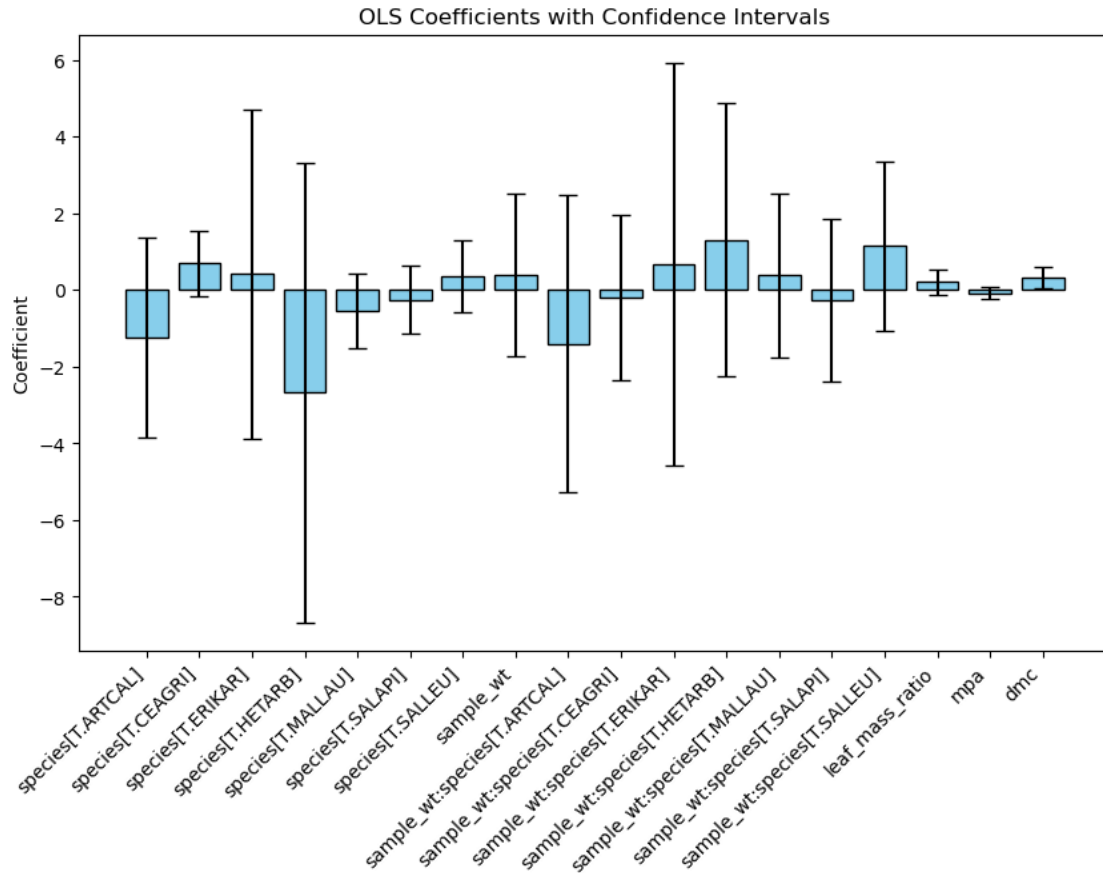
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.482
Model:	OLS	Adj. R-squared:	0.414
Method:	Least Squares	F-statistic:	7.137
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	3.35e-13
Time:	16:38:29	Log-Likelihood:	-181.69
No. Observations:	166	AIC:	403.4
Df Residuals:	146	BIC:	465.6
Df Model:	19		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0268	0.384	-0.070	0.944	-0.785	0.731
species[T.ARTCAL]	-0.9777	1.325	-0.738	0.462		

	coef	std err	t	P>|t|	[0.025	0.975]
					-3.596	1.641
species[T.CEAGRI]	0.7445	0.427	1.744	0.083	-0.099	1.588
species[T.ERIKAR]	0.9987	2.178	0.459	0.647	-3.305	5.302
species[T.HETARB]	-2.1015	3.049	-0.689	0.492	-8.126	3.923
species[T.MALLAU]	-0.2925	0.525	-0.557	0.578	-1.330	0.745
species[T.SALAPI]	-0.2732	0.465	-0.587	0.558	-1.192	0.646
species[T.SALLEU]	0.4868	0.482	1.010	0.314	-0.466	1.439
sample_wt	0.4082	1.071	0.381	0.704	-1.709	2.526
sample_wt:species[T.ARTCAL]	-1.1488	1.953	-0.588	0.557	-5.009	2.711
sample_wt:species[T.CEAGRI]	-0.0039	1.094	-0.004	0.997	-2.166	2.158
sample_wt:species[T.ERIKAR]	1.6742	2.661	0.629	0.530	-3.585	6.933
sample_wt:species[T.HETARB]	1.2299	1.806	0.681	0.497	-2.340	4.800
sample_wt:species[T.MALLAU]	0.4704	1.085	0.434	0.665	-1.673	2.614
sample_wt:species[T.SALAPI]	-0.2196	1.083	-0.203	0.840	-2.359	1.920
sample_wt:species[T.SALLEU]	1.2603	1.114	1.132	0.260	-0.941	3.461
lfm	0.1731	0.157	1.100	0.273	-0.138	0.484
leaf_mass_ratio	0.2654	0.174	1.528	0.129	-0.078	0.609
dmc	0.3913	0.148	2.636	0.009	0.098	0.685
branch_volume	-0.1327	0.135	-0.985	0.326	-0.399	0.134

```
==============================================================================
Omnibus:                      100.324   Durbin-Watson:                 2.375
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            857.640
Skew:                           2.063   Prob(JB):                  5.83e-187
Kurtosis:                      13.343   Cond. No.                       105.
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
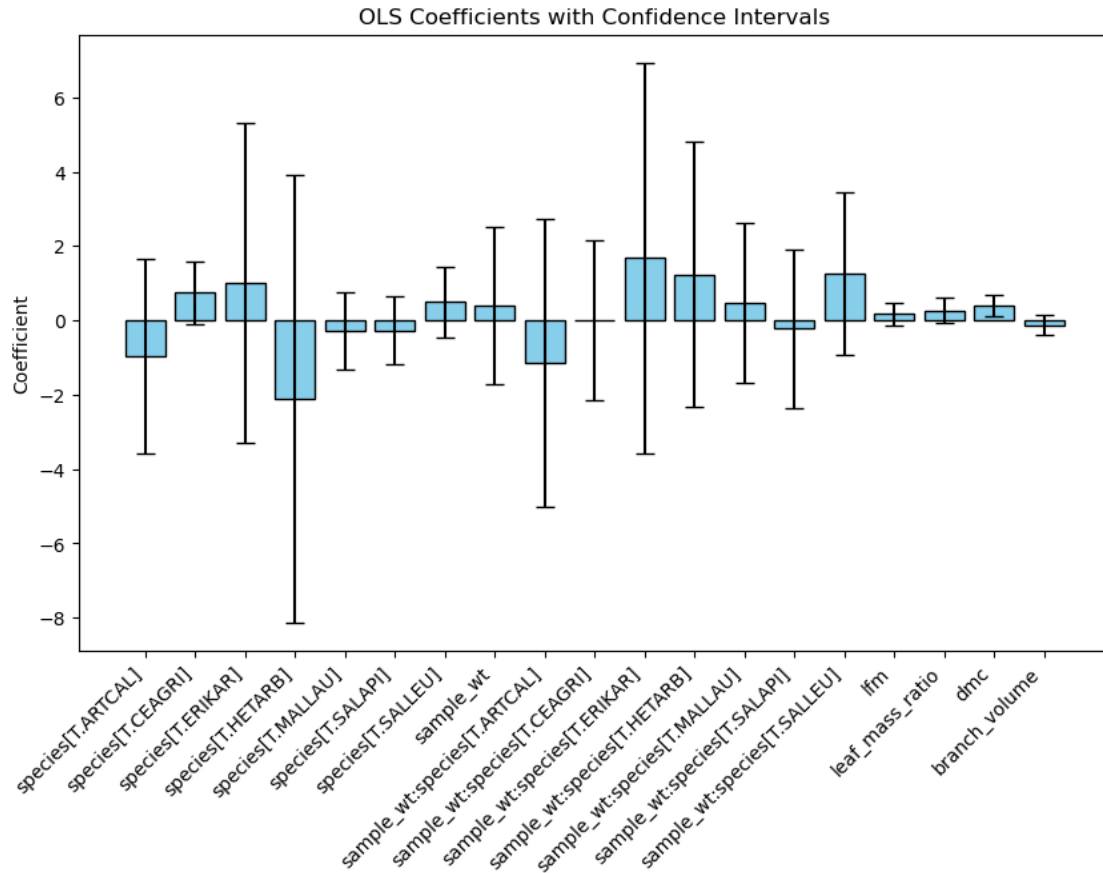
```
                          OLS Regression Results
================================================================================
=====
Dep. Variable:                      fd   R-squared:                       0.429
Model:                             OLS   Adj. R-squared:                  0.388
Method:                  Least Squares   F-statistic:                     10.52
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           3.01e-14
Time:                         16:38:29   Log-Likelihood:                -189.70
No. Observations:                  166   AIC:                             403.4
Df Residuals:                      154   BIC:                             440.7
Df Model:                           11
Covariance Type:             nonrobust
================================================================================
=====
                     coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept          -0.0407      0.299     -0.136      0.892      -0.630
0.549
species[T.ARTCAL]  -0.2913      0.366     -0.797      0.427      -1.014
```

0.431
	coef	std err	t	P>|t|	[0.025	0.975]
species[T.CEAGRI]	0.6665	0.360	1.850	0.066	-0.045	1.378
species[T.ERIKAR]	-0.3589	0.332	-1.082	0.281	-1.014	0.296
species[T.HETARB]	-0.0048	0.674	-0.007	0.994	-1.337	1.327
species[T.MALLAU]	-0.3178	0.388	-0.819	0.414	-1.085	0.449
species[T.SALAPI]	-0.5695	0.360	-1.583	0.116	-1.280	0.141
species[T.SALLEU]	0.1509	0.399	0.378	0.706	-0.638	0.940
sample_wt	0.3922	0.107	3.652	0.000	0.180	0.604
dmc	0.2462	0.113	2.176	0.031	0.023	0.470
sample_wt:dmc	0.3312	0.105	3.155	0.002	0.124	0.539
mpa	-0.0534	0.081	-0.660	0.510	-0.213	0.106

```
==============================================================================
Omnibus:                      113.535   Durbin-Watson:                   2.271
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1085.183
Skew:                           2.393   Prob(JB):                     2.27e-236
Kurtosis:                      14.575   Cond. No.                         18.3
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
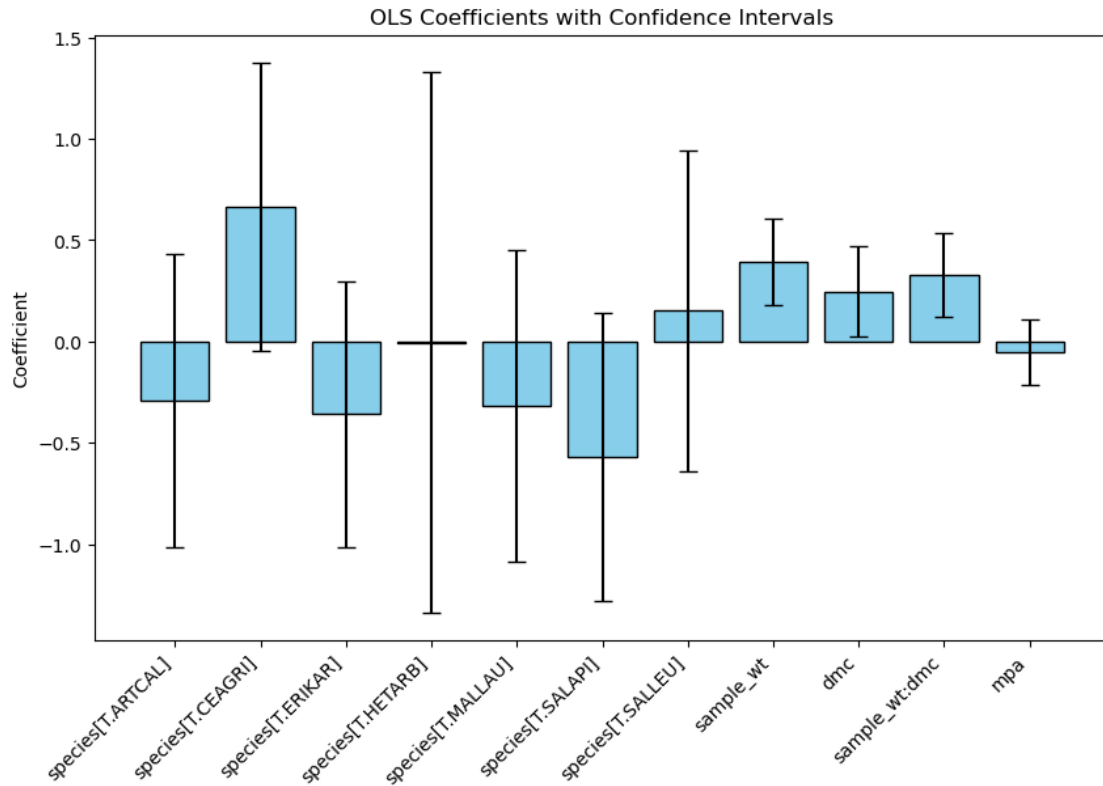
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.436
Model:	OLS	Adj. R-squared:	0.392
Method:	Least Squares	F-statistic:	9.852
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	4.32e-14
Time:	16:38:30	Log-Likelihood:	-188.69
No. Observations:	166	AIC:	403.4
Df Residuals:	153	BIC:	443.8
Df Model:	12		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0910	0.454	0.200	0.842	-0.807	0.989
species[T.ARTCAL]	-0.5562	0.693	-0.803	0.423	-1.924	0.812
species[T.CEAGRI]	0.5466	0.406	1.348	0.180	-0.255	

57

	coef	std err	t	P>|t|	[0.025	0.975]
						1.348
species[T.ERIKAR]	-0.6553	0.652	-1.006	0.316	-1.942	0.632
species[T.HETARB]	0.0585	0.686	0.085	0.932	-1.298	1.415
species[T.MALLAU]	-0.2526	0.419	-0.603	0.547	-1.080	0.575
species[T.SALAPI]	-0.4666	0.472	-0.989	0.324	-1.399	0.466
species[T.SALLEU]	-0.0007	0.618	-0.001	0.999	-1.221	1.219
sample_wt	0.3997	0.107	3.729	0.000	0.188	0.611
dmc	0.3633	0.139	2.613	0.010	0.089	0.638
sample_wt:dmc	0.3429	0.105	3.253	0.001	0.135	0.551
LMA	-0.0692	0.218	-0.317	0.752	-0.501	0.362
leaf_mass_ratio	0.2466	0.166	1.484	0.140	-0.082	0.575

```
==============================================================================
Omnibus:                      112.283   Durbin-Watson:                   2.316
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1069.315
Skew:                           2.358   Prob(JB):                     6.33e-233
Kurtosis:                      14.505   Cond. No.                         32.5
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
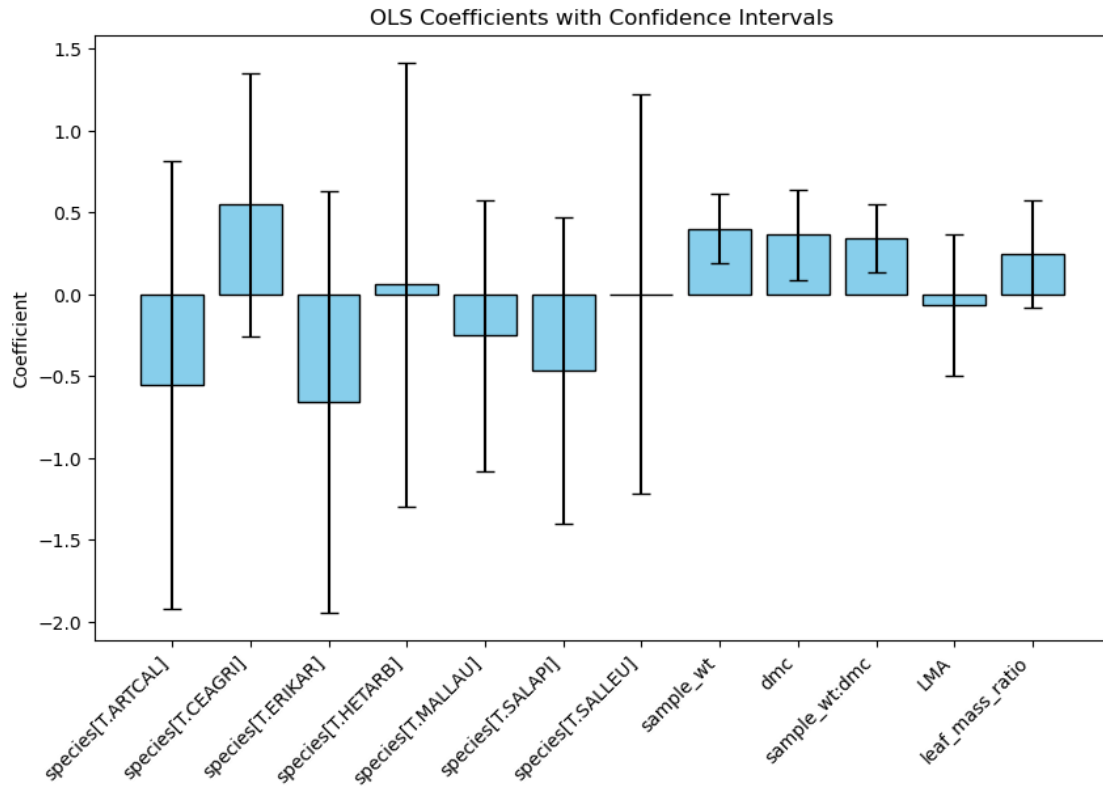
```
                          OLS Regression Results
================================================================================
=====
Dep. Variable:                      fd   R-squared:                       0.429
Model:                             OLS   Adj. R-squared:                  0.388
Method:                  Least Squares   F-statistic:                     10.52
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           3.02e-14
Time:                         16:38:30   Log-Likelihood:                -189.70
No. Observations:                  166   AIC:                             403.4
Df Residuals:                      154   BIC:                             440.7
Df Model:                           11
Covariance Type:             nonrobust
================================================================================
=====
                      coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept          -0.0454      0.300     -0.152      0.880      -0.637
0.546
species[T.ARTCAL]  -0.3049      0.364     -0.837      0.404      -1.024
0.415
species[T.CEAGRI]   0.6061      0.334      1.816      0.071      -0.053
```

59

```
                                                                      1.265
species[T.ERIKAR]     -0.3585      0.332     -1.081      0.282     -1.014
0.297
species[T.HETARB]      0.0310      0.678      0.046      0.964     -1.308
1.370
species[T.MALLAU]     -0.2351      0.412     -0.571      0.569     -1.049
0.578
species[T.SALAPI]     -0.5538      0.360     -1.540      0.126     -1.264
0.157
species[T.SALLEU]      0.1713      0.401      0.427      0.670     -0.621
0.963
sample_wt              0.4487      0.129      3.488      0.001      0.195
0.703
dmc                    0.2387      0.113      2.116      0.036      0.016
0.462
sample_wt:dmc          0.3348      0.105      3.176      0.002      0.127
0.543
branch_volume         -0.0758      0.116     -0.656      0.512     -0.304
0.152
==============================================================================
Omnibus:                      111.467   Durbin-Watson:                   2.303
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1031.196
Skew:                           2.348   Prob(JB):                     1.20e-224
Kurtosis:                      14.271   Cond. No.                         21.3
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
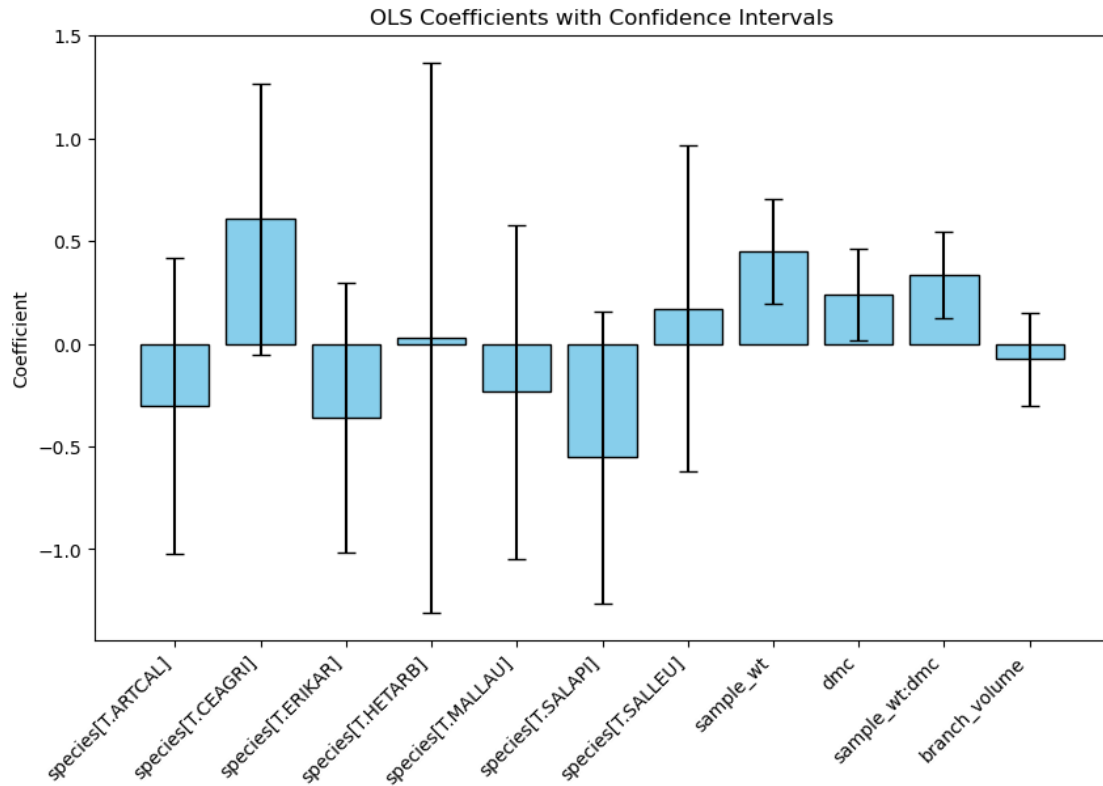
OLS Regression Results

```
==============================================================================
Dep. Variable:                      fd   R-squared:                       0.442
Model:                             OLS   Adj. R-squared:                  0.395
Method:                  Least Squares   F-statistic:                     9.273
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           6.34e-14
Time:                         16:38:30   Log-Likelihood:                 -187.74
No. Observations:                  166   AIC:                             403.5
Df Residuals:                      152   BIC:                             447.0
Df Model:                           13
Covariance Type:             nonrobust
==============================================================================
=====
                     coef     std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
-----
Intercept          -0.0985      0.301     -0.328      0.744      -0.692
0.495
species[T.ARTCAL]  -0.3334      0.365     -0.913      0.363      -1.055
0.388
species[T.CEAGRI]   0.8255      0.369      2.239      0.027       0.097
```

1.554

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.ERIKAR]	-0.4621	0.337	-1.371	0.172	-1.128	0.204
species[T.HETARB]	0.1032	0.675	0.153	0.879	-1.231	1.437
species[T.MALLAU]	-0.0255	0.425	-0.060	0.952	-0.866	0.815
species[T.SALAPI]	-0.3388	0.380	-0.893	0.374	-1.089	0.411
species[T.SALLEU]	0.1927	0.399	0.483	0.630	-0.596	0.981
sample_wt	0.4557	0.129	3.526	0.001	0.200	0.711
dmc	0.3970	0.141	2.812	0.006	0.118	0.676
sample_wt:dmc	0.3597	0.106	3.403	0.001	0.151	0.569
leaf_mass_ratio	0.3076	0.172	1.791	0.075	-0.032	0.647
mpa	-0.0746	0.081	-0.916	0.361	-0.236	0.086
branch_volume	-0.1194	0.118	-1.015	0.312	-0.352	0.113

```
==============================================================================
Omnibus:                      107.860   Durbin-Watson:                   2.249
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              936.311
Skew:                           2.272   Prob(JB):                     4.81e-204
Kurtosis:                      13.711   Cond. No.                         23.3
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
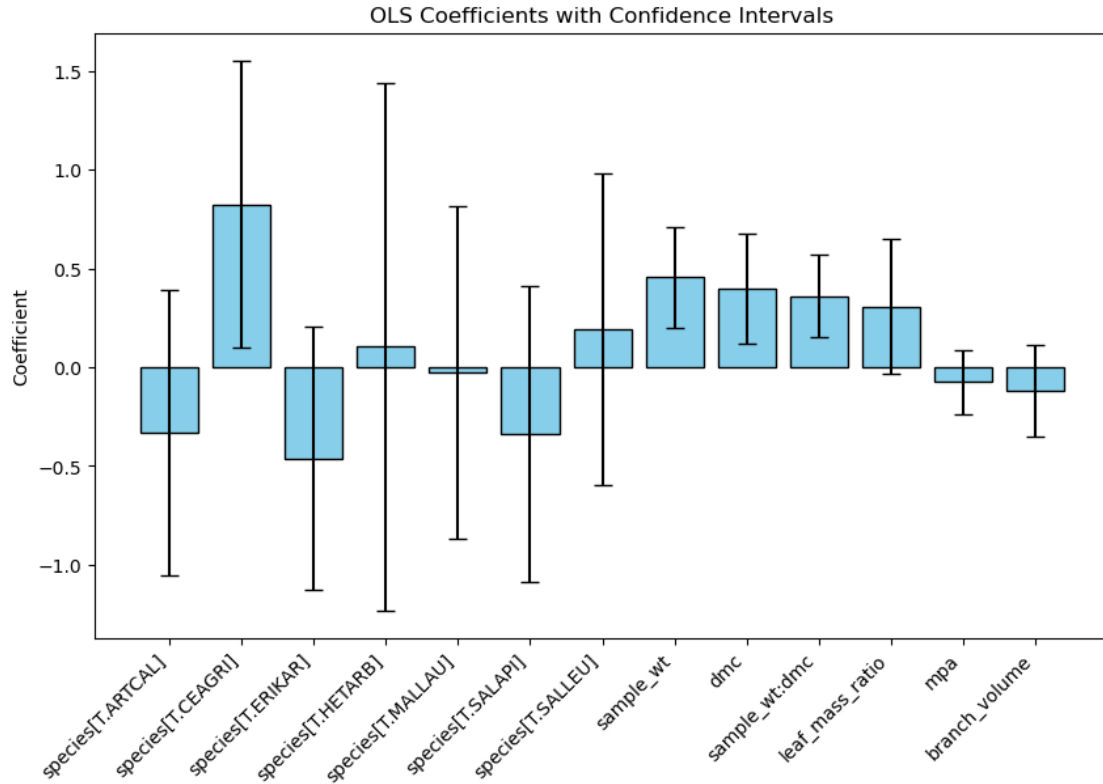
OLS Regression Results

Dep. Variable:	fd	R-squared:	0.469
Model:	OLS	Adj. R-squared:	0.408
Method:	Least Squares	F-statistic:	7.676
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	2.08e-13
Time:	16:38:30	Log-Likelihood:	-183.74
No. Observations:	166	AIC:	403.5
Df Residuals:	148	BIC:	459.5
Df Model:	17		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0318	0.393	-0.081	0.936	-0.808	0.744
species[T.ARTCAL]	-1.1068	1.327	-0.834	0.406	-3.730	1.516
species[T.CEAGRI]	0.5645	0.414	1.363	0.175		

63

```
                                 -0.254       1.383
species[T.ERIKAR]                 0.5875       2.160      0.272      0.786
                                 -3.680       4.855
species[T.HETARB]                -2.5706       3.039     -0.846      0.399
                                 -8.577       3.435
species[T.MALLAU]                -0.5733       0.498     -1.151      0.252
                                 -1.558       0.411
species[T.SALAPI]                -0.3559       0.439     -0.810      0.419
                                 -1.224       0.512
species[T.SALLEU]                 0.4107       0.478      0.858      0.392
                                 -0.535       1.356
sample_wt                         0.3644       1.070      0.341      0.734
                                 -1.749       2.478
sample_wt:species[T.ARTCAL]      -1.3341       1.970     -0.677      0.499
                                 -5.227       2.559
sample_wt:species[T.CEAGRI]      -0.1571       1.093     -0.144      0.886
                                 -2.317       2.003
sample_wt:species[T.ERIKAR]       0.7549       2.646      0.285      0.776
                                 -4.475       5.984
sample_wt:species[T.HETARB]       1.3151       1.796      0.732      0.465
                                 -2.235       4.865
sample_wt:species[T.MALLAU]       0.4197       1.085      0.387      0.699
                                 -1.725       2.564
sample_wt:species[T.SALAPI]      -0.2072       1.082     -0.192      0.848
                                 -2.344       1.930
sample_wt:species[T.SALLEU]       1.2148       1.116      1.089      0.278
                                 -0.990       3.419
dmc                               0.2151       0.112      1.917      0.057
                                 -0.007       0.437
leaf_sav                         -0.0457       0.080     -0.569      0.570
                                 -0.204       0.113
==============================================================================
Omnibus:                        110.547   Durbin-Watson:                   2.389
Prob(Omnibus):                    0.000   Jarque-Bera (JB):             1096.159
Skew:                             2.287   Prob(JB):                     9.38e-239
Kurtosis:                        14.728   Cond. No.                         85.5
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```

OLS Coefficients with Confidence Intervals
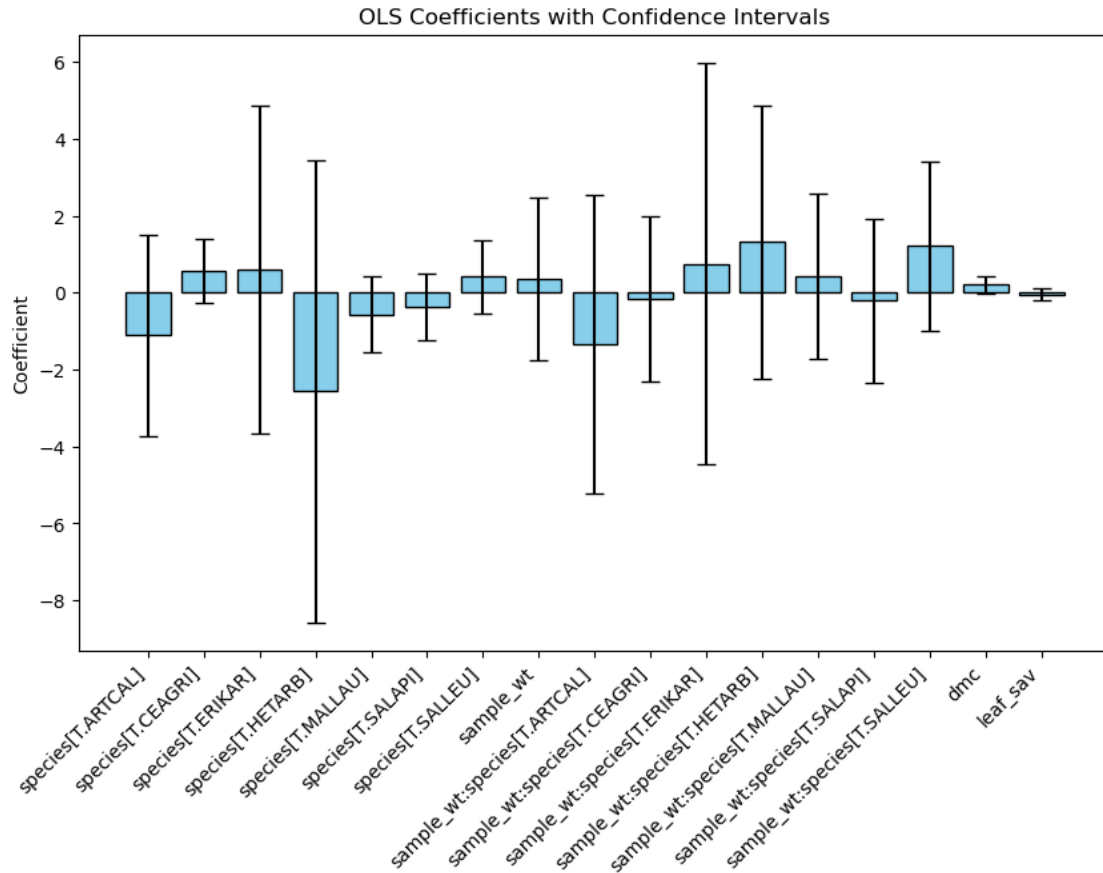
```
                          OLS Regression Results
================================================================================
=====
Dep. Variable:                      fd   R-squared:                       0.436
Model:                             OLS   Adj. R-squared:                  0.392
Method:                  Least Squares   F-statistic:                     9.848
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           4.38e-14
Time:                         16:38:30   Log-Likelihood:                -188.71
No. Observations:                  166   AIC:                             403.4
Df Residuals:                      153   BIC:                             443.9
Df Model:                           12
Covariance Type:             nonrobust
================================================================================
=====
                     coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
-----
Intercept         -0.0423      0.309     -0.137      0.891      -0.652
0.568
species[T.ARTCAL]  -0.3341      0.389     -0.860      0.391      -1.102
```

65

```
0.434
species[T.CEAGRI]      0.6495      0.347      1.873      0.063     -0.036
1.335
species[T.ERIKAR]     -0.4475      0.358     -1.251      0.213     -1.154
0.259
species[T.HETARB]      0.0398      0.679      0.059      0.953     -1.302
1.381
species[T.MALLAU]     -0.1723      0.418     -0.413      0.680     -0.997
0.653
species[T.SALAPI]     -0.3516      0.391     -0.899      0.370     -1.124
0.421
species[T.SALLEU]      0.1571      0.399      0.393      0.695     -0.632
0.946
sample_wt              0.3942      0.106      3.705      0.000      0.184
0.604
dmc                    0.3615      0.139      2.602      0.010      0.087
0.636
sample_wt:dmc          0.3407      0.105      3.246      0.001      0.133
0.548
leaf_mass_ratio        0.2540      0.168      1.509      0.133     -0.079
0.587
thickness              0.0215      0.081      0.266      0.791     -0.138
0.181
==============================================================================
Omnibus:                      113.038   Durbin-Watson:                  2.324
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            1086.767
Skew:                           2.376   Prob(JB):                   1.03e-236
Kurtosis:                      14.599   Cond. No.                        23.5
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals

OLS Regression Results

Dep. Variable:	fd	R-squared:	0.436
Model:	OLS	Adj. R-squared:	0.391
Method:	Least Squares	F-statistic:	9.839
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	4.50e-14
Time:	16:38:31	Log-Likelihood:	-188.74
No. Observations:	166	AIC:	403.5
Df Residuals:	153	BIC:	443.9
Df Model:	12		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0191	0.296	-0.065	0.949	-0.603	0.565
species[T.ARTCAL]	-0.3749	0.369	-1.017	0.311	-1.103	0.354
species[T.CEAGRI]	0.6163	0.334	1.844	0.067	-0.044	

67

```
1.277
species[T.ERIKAR]      -0.4794      0.338      -1.419      0.158      -1.147
0.188
species[T.HETARB]       0.0172      0.673       0.026      0.980      -1.313
1.347
species[T.MALLAU]      -0.2025      0.400      -0.506      0.613      -0.992
0.588
species[T.SALAPI]      -0.3762      0.379      -0.992      0.323      -1.125
0.373
species[T.SALLEU]       0.1544      0.403       0.384      0.702      -0.641
0.950
sample_wt               0.3952      0.106       3.717      0.000       0.185
0.605
dmc                     0.3600      0.140       2.576      0.011       0.084
0.636
sample_wt:dmc           0.3391      0.105       3.232      0.002       0.132
0.546
leaf_mass_ratio         0.2446      0.168       1.460      0.146      -0.086
0.576
start_temp              0.0071      0.075       0.096      0.924      -0.140
0.154
==============================================================================
Omnibus:                      113.145   Durbin-Watson:                  2.322
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            1090.296
Skew:                           2.378   Prob(JB):                    1.76e-237
Kurtosis:                      14.620   Cond. No.                        21.9
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
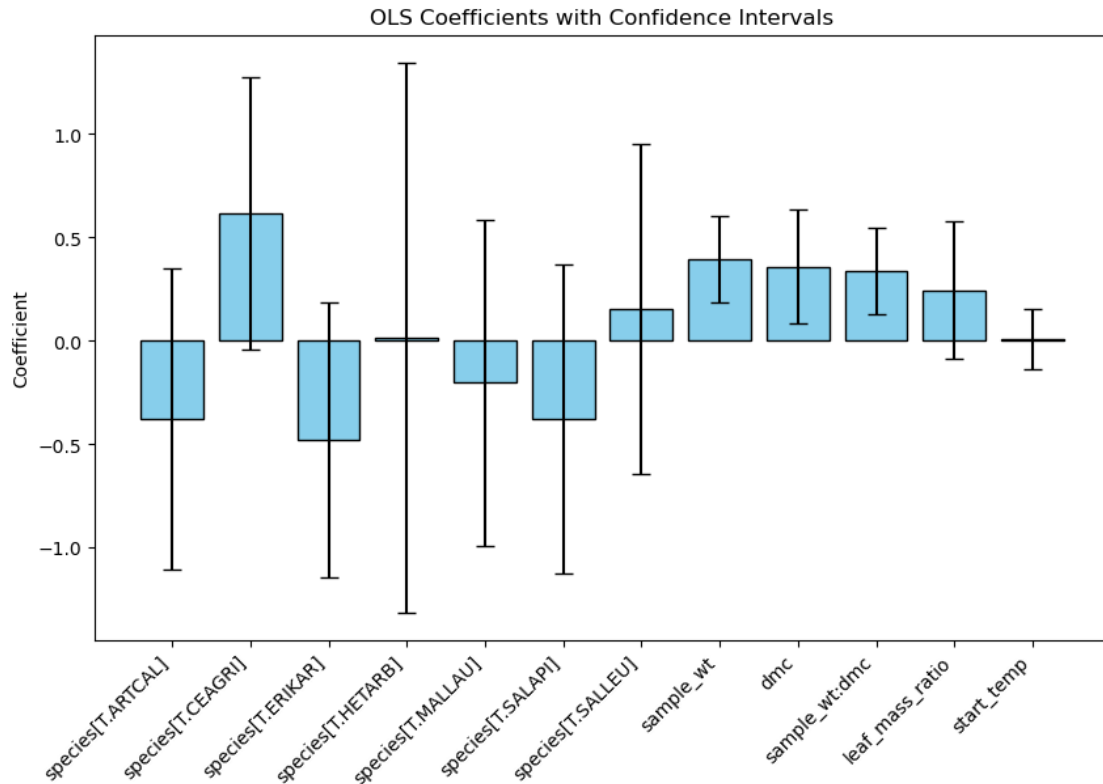
```
                          OLS Regression Results
================================================================================
Dep. Variable:                      fd   R-squared:                       0.481
Model:                             OLS   Adj. R-squared:                  0.413
Method:                  Least Squares   F-statistic:                     7.117
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           3.66e-13
Time:                         16:38:31   Log-Likelihood:                 -181.80
No. Observations:                  166   AIC:                             403.6
Df Residuals:                      146   BIC:                             465.8
Df Model:                           19
Covariance Type:             nonrobust
================================================================================
===============
                        coef    std err          t      P>|t|
[0.025      0.975]
--------------------------------------------------------------------------------
---------------
Intercept             -0.0199      0.384     -0.052      0.959
-0.778       0.738
species[T.ARTCAL]     -1.0956      1.329     -0.825      0.411
-3.722       1.530
species[T.CEAGRI]      0.8388      0.451      1.860      0.065
```

	coef	std err	t	P>|t|	[0.025	0.975]
					-0.052	1.730
species[T.ERIKAR]	0.4048	2.170	0.187	0.852	-3.884	4.694
species[T.HETARB]	-2.6624	3.030	-0.879	0.381	-8.651	3.326
species[T.MALLAU]	-0.4592	0.497	-0.924	0.357	-1.441	0.523
species[T.SALAPI]	-0.3554	0.456	-0.779	0.437	-1.257	0.546
species[T.SALLEU]	0.4763	0.482	0.988	0.325	-0.476	1.429
sample_wt	0.2974	1.069	0.278	0.781	-1.816	2.411
sample_wt:species[T.ARTCAL]	-1.3339	1.959	-0.681	0.497	-5.205	2.537
sample_wt:species[T.CEAGRI]	-0.1065	1.090	-0.098	0.922	-2.260	2.047
sample_wt:species[T.ERIKAR]	1.0416	2.666	0.391	0.697	-4.227	6.310
sample_wt:species[T.HETARB]	1.4987	1.803	0.831	0.407	-2.065	5.062
sample_wt:species[T.MALLAU]	0.4979	1.086	0.459	0.647	-1.648	2.644
sample_wt:species[T.SALAPI]	-0.1487	1.082	-0.137	0.891	-2.287	1.990
sample_wt:species[T.SALLEU]	1.2488	1.114	1.121	0.264	-0.953	3.451
lfm	0.1930	0.155	1.246	0.215	-0.113	0.499
leaf_mass_ratio	0.2332	0.168	1.390	0.167	-0.098	0.565
mpa	-0.0722	0.082	-0.876	0.383	-0.235	0.091
dmc	0.3827	0.148	2.591	0.011	0.091	0.675

```
==============================================================================
Omnibus:                      103.069   Durbin-Watson:                   2.346
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              934.178
Skew:                           2.114   Prob(JB):                     1.40e-203
Kurtosis:                      13.826   Cond. No.                         98.0
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals
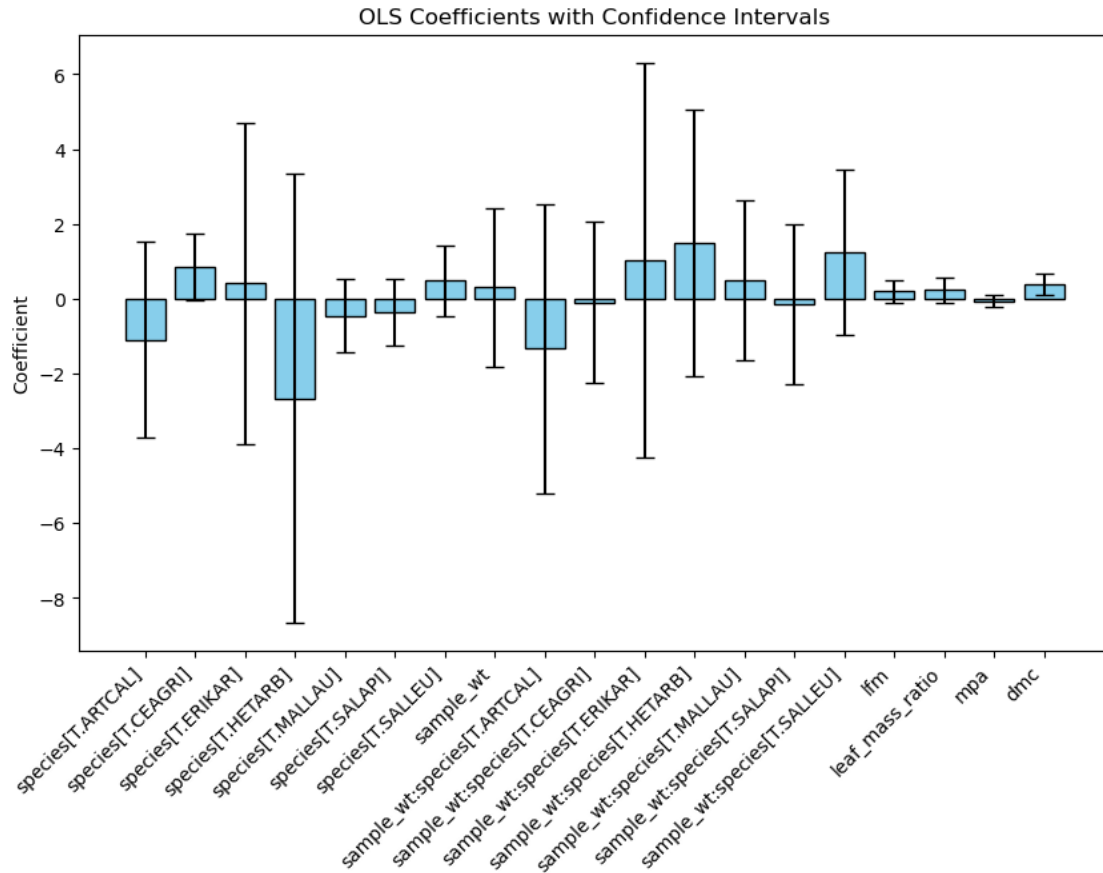
```
                        OLS Regression Results
=================================================================================
=====
Dep. Variable:                      fd   R-squared:                       0.436
Model:                             OLS   Adj. R-squared:                  0.391
Method:                  Least Squares   F-statistic:                     9.838
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           4.52e-14
Time:                         16:38:31   Log-Likelihood:                -188.74
No. Observations:                  166   AIC:                             403.5
Df Residuals:                      153   BIC:                             443.9
Df Model:                           12
Covariance Type:               nonrobust
=================================================================================
=====
                     coef    std err          t      P>|t|      [0.025
0.975]
---------------------------------------------------------------------------------
-----
Intercept          -0.0207      0.311     -0.067      0.947      -0.635
0.594
species[T.ARTCAL]  -0.3679      0.373     -0.986      0.325      -1.105
```

```
                                0.369
species[T.CEAGRI]      0.6216      0.330      1.881      0.062     -0.031
                                1.274
species[T.ERIKAR]     -0.4755      0.365     -1.304      0.194     -1.196
                                0.245
species[T.HETARB]      0.0187      0.687      0.027      0.978     -1.339
                                1.376
species[T.MALLAU]     -0.2044      0.429     -0.477      0.634     -1.051
                                0.642
species[T.SALAPI]     -0.3730      0.421     -0.887      0.377     -1.204
                                0.458
species[T.SALLEU]      0.1505      0.404      0.372      0.710     -0.648
                                0.949
sample_wt              0.3949      0.108      3.656      0.000      0.182
                                0.608
dmc                    0.3614      0.139      2.601      0.010      0.087
                                0.636
sample_wt:dmc          0.3392      0.105      3.219      0.002      0.131
                                0.547
leaf_mass_ratio        0.2471      0.167      1.478      0.141     -0.083
                                0.577
branching              0.0021      0.085      0.025      0.980     -0.165
                                0.169
==============================================================================
Omnibus:                      113.205   Durbin-Watson:                   2.323
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1090.268
Skew:                           2.380   Prob(JB):                     1.78e-237
Kurtosis:                      14.618   Cond. No.                         22.5
==============================================================================
```
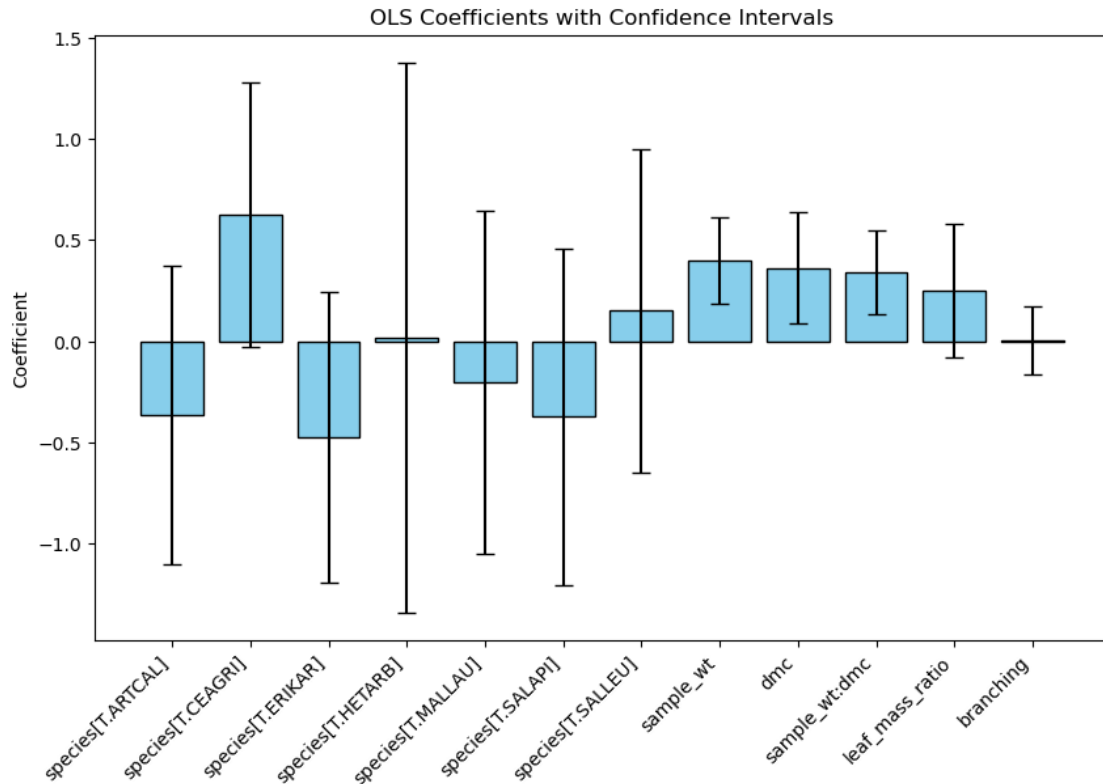
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

```
                     OLS Regression Results
================================================================================
Dep. Variable:                      fd   R-squared:                       0.436
Model:                             OLS   Adj. R-squared:                  0.391
Method:                  Least Squares   F-statistic:                     9.839
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):           4.50e-14
Time:                         16:38:31   Log-Likelihood:                -188.74
No. Observations:                  166   AIC:                             403.5
Df Residuals:                      153   BIC:                             443.9
Df Model:                           12
Covariance Type:             nonrobust
=================================================================================
=====
                    coef    std err          t      P>|t|      [0.025
0.975]
---------------------------------------------------------------------------------
-----
Intercept          -0.0311      0.324     -0.096      0.924      -0.672
0.610
species[T.ARTCAL]  -0.3513      0.413     -0.851      0.396      -1.167
0.464
species[T.CEAGRI]   0.6231      0.331      1.884      0.061      -0.030
```

73

	coef	std err	t	P>|t|	[0.025	0.975]
						1.277
species[T.ERIKAR]	-0.4281	0.629	-0.680	0.497	-1.671	0.815
species[T.HETARB]	0.0155	0.673	0.023	0.982	-1.314	1.345
species[T.MALLAU]	-0.2081	0.395	-0.527	0.599	-0.988	0.572
species[T.SALAPI]	-0.3815	0.381	-1.001	0.319	-1.135	0.372
species[T.SALLEU]	0.1523	0.400	0.381	0.704	-0.638	0.942
sample_wt	0.3950	0.106	3.712	0.000	0.185	0.605
dmc	0.3594	0.141	2.557	0.012	0.082	0.637
sample_wt:dmc	0.3397	0.105	3.238	0.001	0.132	0.547
leaf_mass_ratio	0.2486	0.167	1.486	0.139	-0.082	0.579
stem_sav	-0.0239	0.250	-0.096	0.924	-0.518	0.470

```
==============================================================================
Omnibus:                      113.209   Durbin-Watson:                   2.323
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             1090.578
Skew:                           2.380   Prob(JB):                    1.53e-237
Kurtosis:                      14.620   Cond. No.                         25.7
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

74

OLS Coefficients with Confidence Intervals
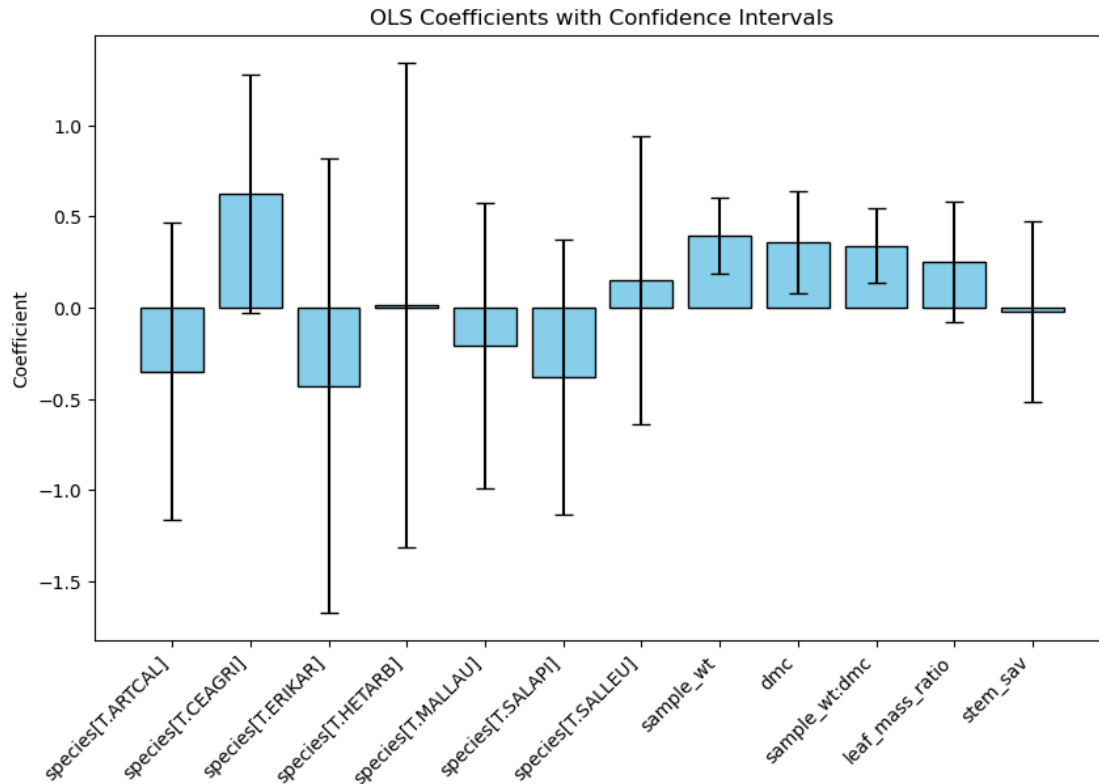
6 Temp Change

```
[13]: # REDUCE INTERACTIONS TO TEST

Y_VAR = 'temp_change'

# singletons: y = b + mx
compare_predictors_mixedeff(flam, cols_num_use, yvar=Y_VAR)

print('\n\n')

# singleton interactions: y = b + m1x1 + m2x2 + m3x1x2
sig_interactions = compare_predictors_interaction_singletons(flam,cols_use,
 ↪y=Y_VAR, thresh=0.05,
                                                         probs =
 ↪['temp_change ~ leaf_sav*thickness'], printsumm=0)

print('\n\n')

# # try all 2-way interactions in 1 model
# form_all_int = formula_all_2way_interactions(cols_use, y='fh', report=0)
```

```python
# model = smf.mixedlm(form_all_int, data=flam, groups=flam["plant_id"])
# result = model.fit(reml=False)
# # print only significant results
# significant_results = result.summary().tables[1].loc[result.pvalues < 0.05]
# print(significant_results)

print('\n\n')


# generate list of known interactions

sig_interactions_tuples = [tuple(x.split('*')) for x in sig_interactions]
for pair in sig_interactions_tuples:
    print(pair)
```

```
             cols      pvals      coefs  significant
6        start_temp   0.000017  -0.320890         True
1               LMA   0.000019   0.534923         True
2         sample_wt   0.000258   0.282132         True
4         branching   0.002838   0.196010         True
0               lfm   0.010824  -0.382844         True
10         leaf_sav   0.020611  -0.333811         True
9          stem_sav   0.022272  -0.380000         True
5               mpa   0.036702   0.162373         True
7               dmc   0.049687   0.193818         True
8     branch_volume   0.050270   0.146199        False
11        thickness   0.115967   0.208315        False
3   leaf_mass_ratio   0.138911  -0.208767        False




13 13 {'leaf_sav', 'branching', 'thickness', 'stem_sav', 'LMA', 'mpa',
'sample_wt', 'branch_volume', 'start_temp', 'leaf_mass_ratio', 'species', 'dmc',
'lfm'}




('lfm', 'LMA')
('lfm', 'sample_wt')
('lfm', 'start_temp')
('lfm', 'leaf_sav')
('lfm', 'species')
('LMA', 'species')
('sample_wt', 'start_temp')
('sample_wt', 'branch_volume')
```

```
('sample_wt', 'species')
('leaf_mass_ratio', 'species')
('branching', 'start_temp')
('branching', 'species')
('mpa', 'start_temp')
('mpa', 'species')
('start_temp', 'branch_volume')
('start_temp', 'leaf_sav')
('start_temp', 'thickness')
('start_temp', 'species')
('dmc', 'species')
('branch_volume', 'leaf_sav')
('branch_volume', 'thickness')
('branch_volume', 'species')
('stem_sav', 'species')
('leaf_sav', 'species')
('thickness', 'species')
```

```
[14]: # generate list of formulas

      df = flam
      cols = cols_use
      int_tuple_list = sig_interactions_tuples
      dv = Y_VAR


      formulas = []
      cols_used = []

      # iterate over possible interactions
      for int_tup in int_tuple_list:

          # create a copy of singletons list
          cols_wkg = cols.copy()
          # isolate terms in interaction
          x1,x2 = int_tup
          # drop those terms from singletons list
          cols_wkg.remove(x1)
          cols_wkg.remove(x2)

          # add the 1st formula - just the interaction term y ~ x1 * x2
          formulas.append(dv+' ~ '+x1+'*'+x2)
          colsi = [x1,x2]

          # generate list of all possible combos of singletons, from 1 to as many as␣
      ↪there are
```

```python
    singles_combos = [list(combinations(cols_wkg, n)) for n in
 ↪range(minnumsingle, maxnumsingle+1)]

    # iterate over combo set (ie 1 poss singleton, 2 poss singletons, ... etc)
    for comboset in singles_combos:
        # for each combo in the combo set
        for combo in comboset:
            # generate formula
            form = dv+' ~ '+x1+'*'+x2
            for single in combo:
                form+=' + '+single
                colsi.append(single)
            formulas.append(form)
            cols_used.append([colsi])

print(len(formulas))

# AIC ITERATION
probs = ['temp_change ~ LMA*species + leaf_mass_ratio + dmc',
        'temp_change ~ LMA*species + leaf_mass_ratio + start_temp + thickness',
        'temp_change ~ LMA*species + branching + dmc + leaf_sav',
        'temp_change ~ LMA*species + start_temp + branch_volume + stem_sav',
        'temp_change ~ LMA*species + start_temp + stem_sav + leaf_sav',
        'temp_change ~ LMA*species + lfm + sample_wt + leaf_mass_ratio + mpa']

for prob in probs:
    formulas.remove(prob)

resdf_tc, num_top_models = AICscore_from_all_pos_2way_interactions(df,
 ↪formulas, report=0)

# report
for idx,row in resdf_tc[0:num_top_models].iterrows():
    formula = row.Formula
    print(formula)
for idx,row in resdf_tc[0:num_top_models].iterrows():
    formula = row.Formula
    model = smf.ols(formula, data=df)
    results = model.fit()
    print(results.summary())
    plot_ols_coefficients(results)
    plt.show();
    # if 'species' in cols:
    #     cols.remove('species')
    # plot_resid(df, cols, results)
```

25600

```
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt + mpa +
start_temp
ERROR: Formula model error: temp_change ~ LMA*species + lfm + leaf_mass_ratio +
mpa + dmc
ERROR: Formula model error: temp_change ~ LMA*species + lfm + start_temp +
branch_volume + stem_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + branch_volume +
leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + mpa + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + start_temp + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
start_temp + dmc
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
start_temp + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio +
branching + mpa + thickness
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio +
branching + start_temp + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio +
start_temp + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + branching + mpa +
start_temp + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + branching + start_temp +
branch_volume + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + mpa + start_temp +
branch_volume + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + start_temp + dmc +
branch_volume + stem_sav
ERROR: Formula model error: temp_change ~ LMA*species + start_temp + dmc +
leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
leaf_mass_ratio + start_temp + stem_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
leaf_mass_ratio + stem_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
branching + mpa + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
branching + start_temp + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
branching + dmc + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt + mpa +
start_temp + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt +
start_temp + dmc + stem_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + sample_wt + dmc +
branch_volume + leaf_sav
```

```
ERROR: Formula model error: temp_change ~ LMA*species + lfm + leaf_mass_ratio +
branching + mpa + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + leaf_mass_ratio +
mpa + start_temp + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + branching +
start_temp + dmc + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + lfm + branching +
start_temp + stem_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + branching + dmc +
leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + lfm + start_temp + dmc +
branch_volume + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + branching + start_temp + dmc
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + start_temp + dmc + branch_volume
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + start_temp + branch_volume + stem_sav
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + start_temp + branch_volume + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt +
leaf_mass_ratio + dmc + branch_volume + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
mpa + start_temp + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
mpa + dmc + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
start_temp + dmc + branch_volume
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + branching +
start_temp + stem_sav + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + mpa +
start_temp + dmc + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + mpa +
start_temp + stem_sav + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + mpa +
start_temp + stem_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + sample_wt + start_temp +
dmc + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio + mpa +
dmc + branch_volume + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio + mpa +
branch_volume + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + leaf_mass_ratio + dmc +
branch_volume + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + branching + mpa +
start_temp + dmc + thickness
ERROR: Formula model error: temp_change ~ LMA*species + branching + mpa +
start_temp + branch_volume + leaf_sav
```

```
ERROR: Formula model error: temp_change ~ LMA*species + branching + mpa + dmc +
branch_volume + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + branching + start_temp +
branch_volume + stem_sav + leaf_sav
ERROR: Formula model error: temp_change ~ LMA*species + mpa + start_temp +
branch_volume + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + mpa + dmc +
branch_volume + leaf_sav + thickness
ERROR: Formula model error: temp_change ~ LMA*species + start_temp + dmc +
stem_sav + leaf_sav + thickness
25541 25594
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp
temp_change ~ stem_sav*species + lfm + LMA + sample_wt + branching + start_temp
temp_change ~ mpa*species + lfm + LMA + sample_wt + branching + start_temp
temp_change ~ mpa*species + LMA + sample_wt + leaf_mass_ratio + branching +
start_temp
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp + thickness
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp +
branch_volume
temp_change ~ stem_sav*species + LMA + sample_wt + branching + start_temp + dmc
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp + stem_sav
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp + dmc
temp_change ~ mpa*species + LMA + sample_wt + branching + start_temp + leaf_sav
                        OLS Regression Results
================================================================================
Dep. Variable:            temp_change   R-squared:                       0.781
Model:                            OLS   Adj. R-squared:                  0.752
Method:                 Least Squares   F-statistic:                     27.35
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           9.87e-39
Time:                        17:27:08   Log-Likelihood:                -110.63
No. Observations:                 166   AIC:                             261.3
Df Residuals:                     146   BIC:                             323.5
Df Model:                          19
Covariance Type:            nonrobust
================================================================================
=========
                      coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
---------
Intercept            0.4603      0.370      1.244      0.215      -0.271
1.191
species[T.ARTCAL]   -0.8897      0.502     -1.774      0.078      -1.881
0.102
species[T.CEAGRI]   -0.6863      0.374     -1.837      0.068      -1.425
0.052
species[T.ERIKAR]   -1.0992      0.469     -2.343      0.020      -2.026
-0.172
```

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.HETARB]	11.6599	0.746	15.631	0.000	10.186	13.134
species[T.MALLAU]	0.1301	0.369	0.352	0.725	-0.599	0.859
species[T.SALAPI]	-0.6809	0.394	-1.729	0.086	-1.459	0.098
species[T.SALLEU]	-0.7214	0.431	-1.673	0.096	-1.574	0.131
mpa	-0.2413	0.510	-0.473	0.637	-1.250	0.768
mpa:species[T.ARTCAL]	-0.1178	0.560	-0.210	0.834	-1.225	0.989
mpa:species[T.CEAGRI]	0.5351	0.520	1.030	0.305	-0.492	1.562
mpa:species[T.ERIKAR]	0.2282	0.520	0.439	0.662	-0.800	1.256
mpa:species[T.HETARB]	10.6066	0.955	11.112	0.000	8.720	12.493
mpa:species[T.MALLAU]	0.3681	0.535	0.688	0.492	-0.689	1.425
mpa:species[T.SALAPI]	-0.1010	0.540	-0.187	0.852	-1.168	0.966
mpa:species[T.SALLEU]	0.2319	0.537	0.432	0.667	-0.830	1.293
LMA	-0.4258	0.146	-2.923	0.004	-0.714	-0.138
sample_wt	0.1534	0.068	2.243	0.026	0.018	0.289
branching	0.1287	0.058	2.207	0.029	0.013	0.244
start_temp	-0.3738	0.052	-7.137	0.000	-0.477	-0.270

```
==============================================================================
Omnibus:                       23.348   Durbin-Watson:                   1.988
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               61.198
Skew:                           0.538   Prob(JB):                     5.14e-14
Kurtosis:                       5.773   Cond. No.                         59.2
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
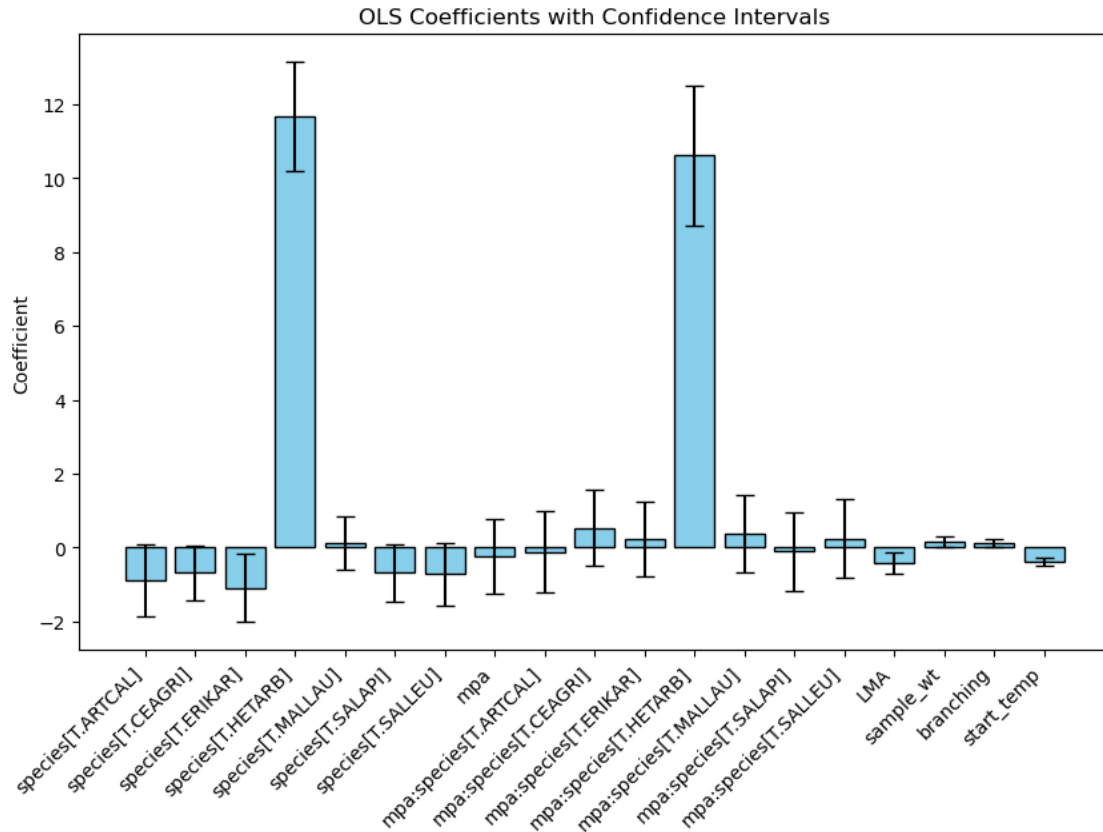
```
                                      OLS Regression Results
===============================================================================
Dep. Variable:            temp_change   R-squared:                       0.784
Model:                            OLS   Adj. R-squared:                  0.754
Method:                 Least Squares   F-statistic:                     26.30
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           1.83e-38
Time:                        17:27:08   Log-Likelihood:                 -109.38
No. Observations:                 166   AIC:                             260.8
Df Residuals:                     145   BIC:                             326.1
Df Model:                          20
Covariance Type:            nonrobust
===============================================================================
=============
                            coef    std err          t      P>|t|
[0.025      0.975]
-------------------------------------------------------------------------------
--------------
Intercept                 0.1063      1.270      0.084      0.933
-2.403       2.616
species[T.ARTCAL]        -0.4660      1.288     -0.362      0.718
-3.011       2.079
```

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.CEAGRI]	1.7587	1.582	1.111	0.268	-1.369	4.886
species[T.ERIKAR]	-0.3465	1.331	-0.260	0.795	-2.976	2.283
species[T.HETARB]	-8.8426	1.706	-5.183	0.000	-12.215	-5.471
species[T.MALLAU]	0.3035	1.435	0.212	0.833	-2.533	3.140
species[T.SALAPI]	-1.6733	1.558	-1.074	0.284	-4.752	1.405
species[T.SALLEU]	0.4486	1.364	0.329	0.743	-2.247	3.144
stem_sav	-1.1400	3.020	-0.377	0.706	-7.109	4.829
stem_sav:species[T.ARTCAL]	0.4566	3.038	0.150	0.881	-5.548	6.461
stem_sav:species[T.CEAGRI]	5.1934	3.619	1.435	0.153	-1.959	12.346
stem_sav:species[T.ERIKAR]	1.1265	3.030	0.372	0.711	-4.862	7.115
stem_sav:species[T.HETARB]	-23.8721	3.490	-6.839	0.000	-30.771	-16.974
stem_sav:species[T.MALLAU]	1.0536	3.195	0.330	0.742	-5.262	7.369
stem_sav:species[T.SALAPI]	-1.0676	3.180	-0.336	0.738	-7.353	5.218
stem_sav:species[T.SALLEU]	3.0932	3.157	0.980	0.329	-3.146	9.332
lfm	-0.2438	0.104	-2.337	0.021	-0.450	-0.038
LMA	-0.4461	0.152	-2.928	0.004	-0.747	-0.145
sample_wt	0.1382	0.069	2.013	0.046	0.003	0.274
branching	0.1755	0.056	3.149	0.002	0.065	0.286
start_temp	-0.4101	0.054	-7.607	0.000	-0.517	-0.304

```
==============================================================================
Omnibus:                       18.009   Durbin-Watson:                   2.098
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               68.105
Skew:                           0.135   Prob(JB):                     1.63e-15
Kurtosis:                       6.126   Cond. No.                         442.
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
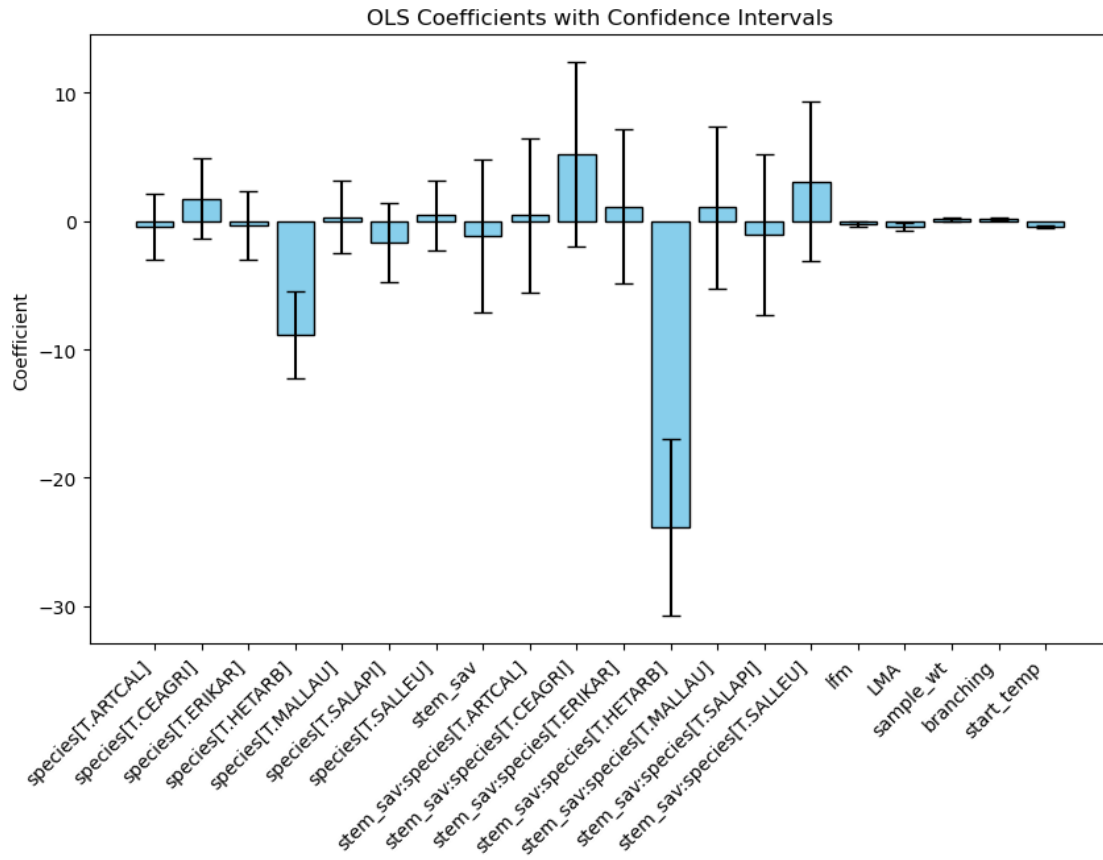
```
                          OLS Regression Results
==================================================================================
Dep. Variable:           temp_change   R-squared:                        0.783
Model:                            OLS   Adj. R-squared:                   0.753
Method:                 Least Squares   F-statistic:                      26.19
Date:                Wed, 24 Apr 2024   Prob (F-statistic):            2.34e-38
Time:                        17:27:08   Log-Likelihood:                 -109.68
No. Observations:                 166   AIC:                              261.4
Df Residuals:                     145   BIC:                              326.7
Df Model:                          20
Covariance Type:            nonrobust
==================================================================================
=========
                          coef     std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------------------
---------
Intercept               0.4903       0.370      1.326      0.187      -0.241
1.221
species[T.ARTCAL]      -1.0021       0.508     -1.973      0.050      -2.006
```

	coef	std err	t	P>|t|	[0.025	0.975]
						0.002
species[T.CEAGRI]	-0.7546	0.376	-2.004	0.047	-1.499	-0.010
species[T.ERIKAR]	-0.9507	0.482	-1.973	0.050	-1.903	0.002
species[T.HETARB]	11.4977	0.755	15.236	0.000	10.006	12.989
species[T.MALLAU]	0.0424	0.374	0.113	0.910	-0.697	0.782
species[T.SALAPI]	-0.6181	0.396	-1.561	0.121	-1.401	0.165
species[T.SALLEU]	-0.8591	0.443	-1.939	0.054	-1.735	0.017
mpa	-0.2660	0.510	-0.522	0.603	-1.273	0.741
mpa:species[T.ARTCAL]	-0.1017	0.559	-0.182	0.856	-1.206	1.003
mpa:species[T.CEAGRI]	0.5364	0.518	1.034	0.303	-0.488	1.561
mpa:species[T.ERIKAR]	0.2644	0.520	0.509	0.612	-0.763	1.292
mpa:species[T.HETARB]	10.5738	0.953	11.099	0.000	8.691	12.457
mpa:species[T.MALLAU]	0.3750	0.534	0.703	0.483	-0.680	1.430
mpa:species[T.SALAPI]	-0.0516	0.540	-0.096	0.924	-1.119	1.016
mpa:species[T.SALLEU]	0.2464	0.536	0.460	0.646	-0.813	1.306
lfm	-0.1287	0.099	-1.297	0.197	-0.325	0.067
LMA	-0.4324	0.145	-2.973	0.003	-0.720	-0.145
sample_wt	0.1530	0.068	2.242	0.026	0.018	0.288
branching	0.1169	0.059	1.986	0.049	0.001	0.233
start_temp	-0.3771	0.052	-7.209	0.000	-0.481	-0.274

```
==============================================================================
Omnibus:                       24.137   Durbin-Watson:                   2.004
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               72.619
Skew:                           0.505   Prob(JB):                     1.70e-16
Kurtosis:                       6.079   Cond. No.                         65.6
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly

specified.

OLS Coefficients with Confidence Intervals
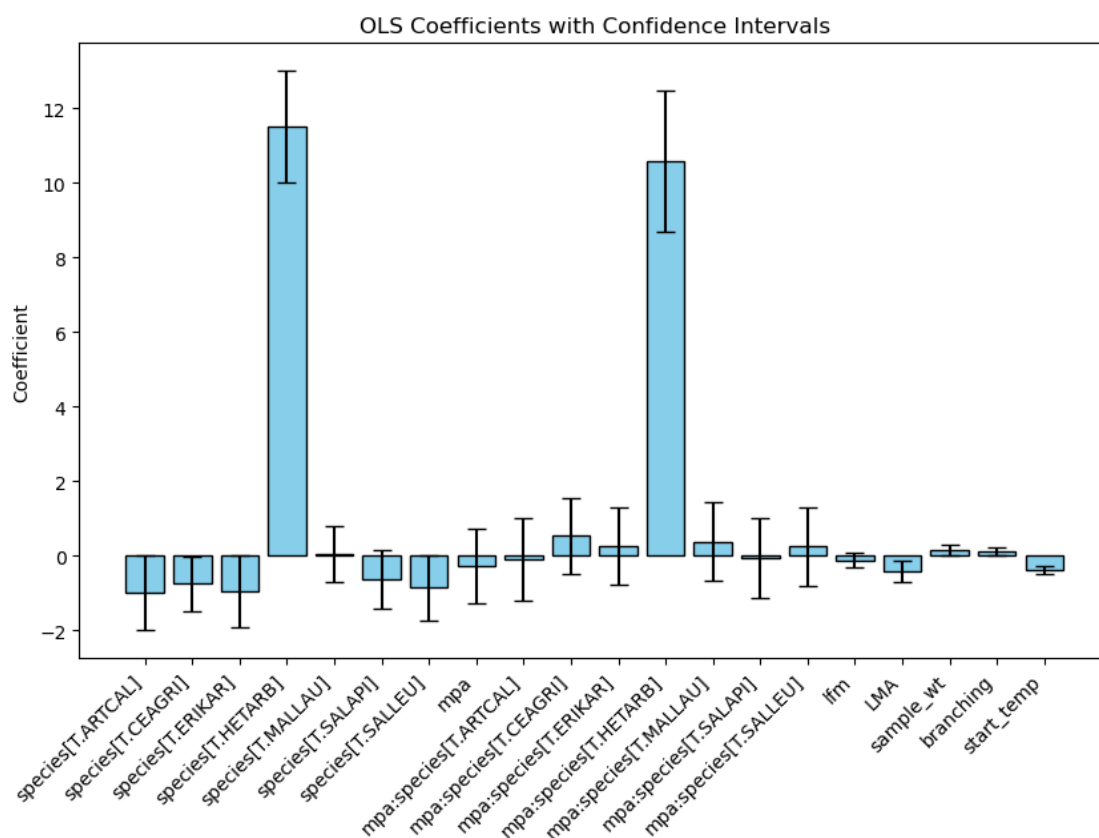
OLS Regression Results

Dep. Variable:	temp_change	R-squared:	0.782
Model:	OLS	Adj. R-squared:	0.752
Method:	Least Squares	F-statistic:	26.03
Date:	Wed, 24 Apr 2024	Prob (F-statistic):	3.25e-38
Time:	17:27:08	Log-Likelihood:	-110.06
No. Observations:	166	AIC:	262.1
Df Residuals:	145	BIC:	327.5
Df Model:	20		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.5173	0.374	1.382	0.169	-0.223	1.257

	coef	std err	t	P>|t|	[0.025	0.975]
species[T.ARTCAL]	-0.9068	0.502	-1.807	0.073	-1.899	0.085
species[T.CEAGRI]	-0.7645	0.382	-2.003	0.047	-1.519	-0.010
species[T.ERIKAR]	-1.0915	0.469	-2.326	0.021	-2.019	-0.164
species[T.HETARB]	11.6173	0.747	15.548	0.000	10.141	13.094
species[T.MALLAU]	0.0231	0.384	0.060	0.952	-0.736	0.783
species[T.SALAPI]	-0.8084	0.414	-1.952	0.053	-1.627	0.010
species[T.SALLEU]	-0.8371	0.446	-1.875	0.063	-1.720	0.045
mpa	-0.2358	0.511	-0.462	0.645	-1.245	0.773
mpa:species[T.ARTCAL]	-0.1043	0.560	-0.186	0.853	-1.212	1.003
mpa:species[T.CEAGRI]	0.5429	0.520	1.045	0.298	-0.484	1.570
mpa:species[T.ERIKAR]	0.2226	0.520	0.428	0.669	-0.806	1.251
mpa:species[T.HETARB]	10.6155	0.955	11.120	0.000	8.729	12.502
mpa:species[T.MALLAU]	0.3659	0.535	0.684	0.495	-0.691	1.423
mpa:species[T.SALAPI]	-0.0927	0.540	-0.172	0.864	-1.160	0.975
mpa:species[T.SALLEU]	0.2052	0.538	0.382	0.703	-0.858	1.268
LMA	-0.4328	0.146	-2.967	0.004	-0.721	-0.145
sample_wt	0.1542	0.068	2.254	0.026	0.019	0.289
leaf_mass_ratio	-0.0884	0.088	-1.000	0.319	-0.263	0.086
branching	0.1204	0.059	2.043	0.043	0.004	0.237
start_temp	-0.3699	0.053	-7.043	0.000	-0.474	-0.266

```
==============================================================================
Omnibus:                       23.159   Durbin-Watson:                   1.997
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               60.405
Skew:                           0.535   Prob(JB):                     7.64e-14
Kurtosis:                       5.755   Cond. No.                         61.7
==============================================================================
```

Notes:

[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
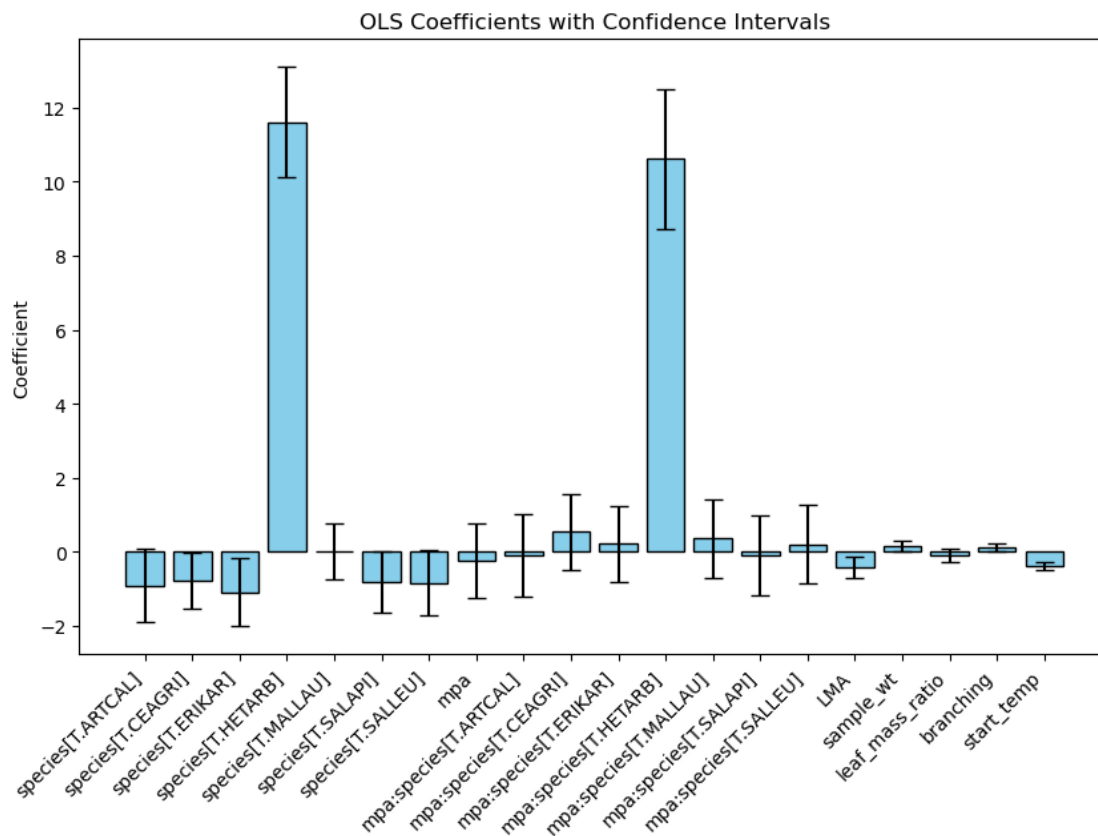
OLS Regression Results

```
==============================================================================
Dep. Variable:          temp_change   R-squared:                      0.781
Model:                          OLS   Adj. R-squared:                 0.751
Method:               Least Squares   F-statistic:                    25.91
Date:              Wed, 24 Apr 2024   Prob (F-statistic):          4.16e-38
Time:                      17:27:09   Log-Likelihood:               -110.36
No. Observations:               166   AIC:                            262.7
Df Residuals:                   145   BIC:                            328.1
Df Model:                        20
Covariance Type:          nonrobust
==============================================================================
=========
                     coef     std err           t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
---------
Intercept          0.5035       0.376       1.340      0.182      -0.239
```

```
1.246
species[T.ARTCAL]        -0.9647       0.514      -1.877       0.062      -1.980
0.051
species[T.CEAGRI]        -0.7147       0.377      -1.898       0.060      -1.459
0.029
species[T.ERIKAR]        -1.1758       0.483      -2.436       0.016      -2.130
-0.222
species[T.HETARB]        11.6978       0.749      15.612       0.000      10.217
13.179
species[T.MALLAU]         0.0691       0.380       0.182       0.856      -0.682
0.820
species[T.SALAPI]        -0.7208       0.399      -1.808       0.073      -1.509
0.067
species[T.SALLEU]        -0.7268       0.432      -1.682       0.095      -1.581
0.127
mpa                      -0.2575       0.512      -0.503       0.616      -1.269
0.754
mpa:species[T.ARTCAL]    -0.1194       0.561      -0.213       0.832      -1.228
0.989
mpa:species[T.CEAGRI]     0.5427       0.521       1.042       0.299      -0.487
1.572
mpa:species[T.ERIKAR]     0.2452       0.522       0.470       0.639      -0.786
1.276
mpa:species[T.HETARB]    10.7194       0.970      11.052       0.000       8.802
12.636
mpa:species[T.MALLAU]     0.3840       0.536       0.716       0.475      -0.676
1.444
mpa:species[T.SALAPI]    -0.0985       0.541      -0.182       0.856      -1.168
0.971
mpa:species[T.SALLEU]     0.3045       0.548       0.556       0.579      -0.779
1.388
LMA                      -0.4341       0.146      -2.964       0.004      -0.723
-0.145
sample_wt                 0.1537       0.069       2.243       0.026       0.018
0.289
branching                 0.1348       0.059       2.282       0.024       0.018
0.252
start_temp               -0.3902       0.058      -6.784       0.000      -0.504
-0.277
thickness                -0.0457       0.066      -0.696       0.487      -0.175
0.084
==============================================================================
Omnibus:                       21.504   Durbin-Watson:                   1.993
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               57.363
Skew:                           0.477   Prob(JB):                     3.50e-13
Kurtosis:                       5.717   Cond. No.                         60.8
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

```
                         OLS Regression Results
==============================================================================
Dep. Variable:            temp_change   R-squared:                       0.781
Model:                            OLS   Adj. R-squared:                  0.751
Method:                 Least Squares   F-statistic:                     25.90
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           4.30e-38
Time:                        17:27:09   Log-Likelihood:                -110.40
No. Observations:                 166   AIC:                             262.8
Df Residuals:                     145   BIC:                             328.1
Df Model:                          20
Covariance Type:            nonrobust
==============================================================================
========
                 coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
---------
```
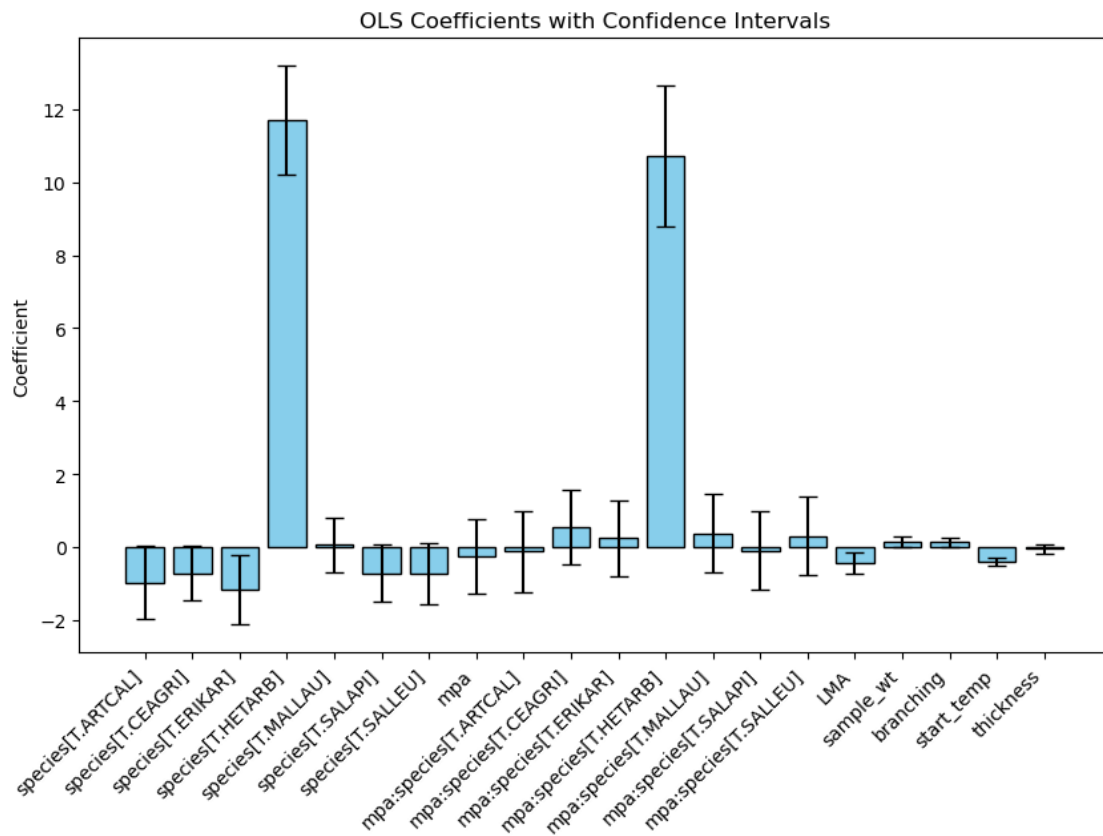
```
Intercept                 0.4360      0.373      1.170      0.244     -0.300
1.172
species[T.ARTCAL]        -0.8720      0.503     -1.732      0.085     -1.867
0.123
species[T.CEAGRI]        -0.6650      0.376     -1.769      0.079     -1.408
0.078
species[T.ERIKAR]        -1.0743      0.472     -2.277      0.024     -2.007
-0.142
species[T.HETARB]        11.6499      0.748     15.583      0.000     10.172
13.128
species[T.MALLAU]         0.2061      0.388      0.531      0.596     -0.561
0.973
species[T.SALAPI]        -0.6675      0.395     -1.689      0.093     -1.449
0.114
species[T.SALLEU]        -0.6990      0.433     -1.613      0.109     -1.556
0.158
mpa                      -0.2383      0.512     -0.466      0.642     -1.249
0.773
mpa:species[T.ARTCAL]    -0.1136      0.561     -0.202      0.840     -1.223
0.996
mpa:species[T.CEAGRI]     0.5325      0.521      1.023      0.308     -0.497
1.562
mpa:species[T.ERIKAR]     0.2191      0.522      0.420      0.675     -0.812
1.250
mpa:species[T.HETARB]    10.5489      0.961     10.981      0.000      8.650
12.448
mpa:species[T.MALLAU]     0.3871      0.537      0.721      0.472     -0.674
1.448
mpa:species[T.SALAPI]    -0.0984      0.541     -0.182      0.856     -1.168
0.971
mpa:species[T.SALLEU]     0.2262      0.538      0.420      0.675     -0.838
1.290
LMA                      -0.4214      0.146     -2.884      0.005     -0.710
-0.133
sample_wt                 0.1849      0.084      2.197      0.030      0.019
0.351
branching                 0.1302      0.058      2.226      0.028      0.015
0.246
start_temp               -0.3698      0.053     -6.998      0.000     -0.474
-0.265
branch_volume            -0.0494      0.077     -0.644      0.521     -0.201
0.102
==============================================================================
Omnibus:                      24.021   Durbin-Watson:                   2.002
Prob(Omnibus):                 0.000   Jarque-Bera (JB):               58.622
Skew:                          0.586   Prob(JB):                     1.86e-13
Kurtosis:                      5.665   Cond. No.                         67.2
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
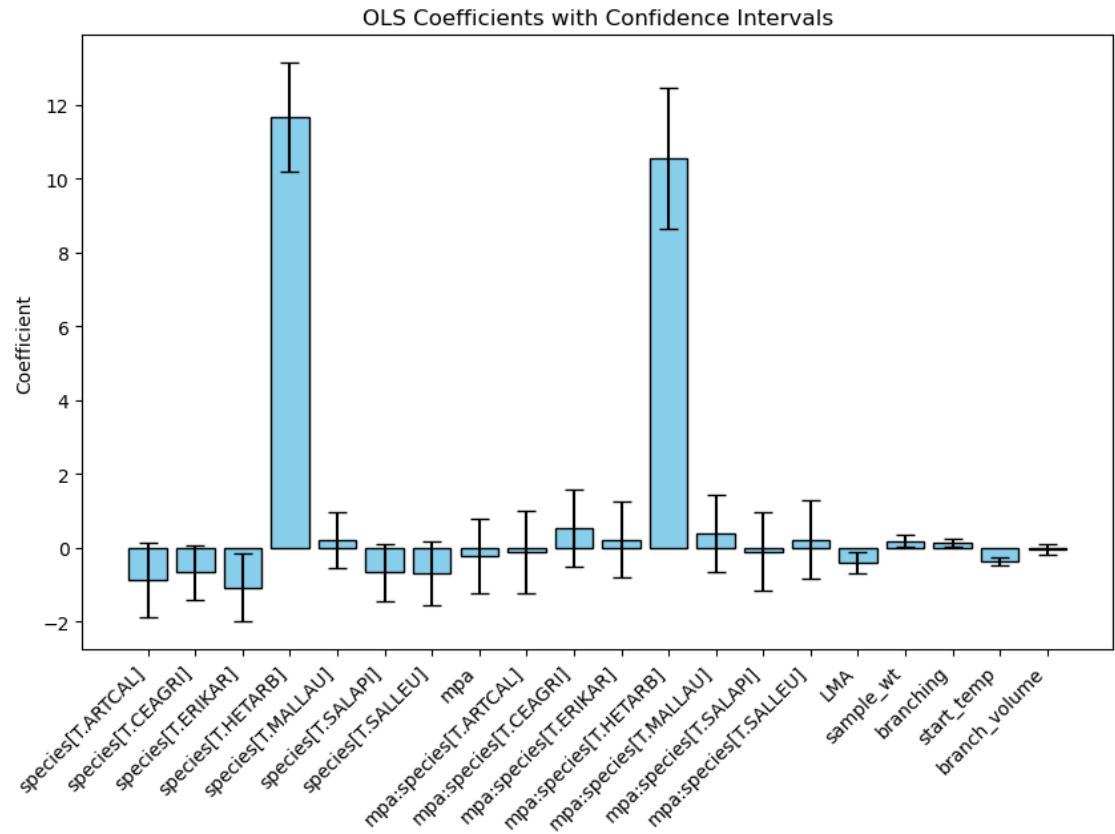
OLS Regression Results

```
==============================================================================
Dep. Variable:            temp_change   R-squared:                       0.782
Model:                            OLS   Adj. R-squared:                  0.751
Method:                 Least Squares   F-statistic:                     25.94
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           3.90e-38
Time:                        17:27:09   Log-Likelihood:                 -110.28
No. Observations:                 166   AIC:                             262.6
Df Residuals:                     145   BIC:                             327.9
Df Model:                          20
Covariance Type:            nonrobust
==============================================================================
=============
                     coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
```

```
--------------
Intercept                          0.1663      1.278      0.130      0.897
  -2.359       2.691
species[T.ARTCAL]                 -0.1807      1.292     -0.140      0.889
  -2.735       2.374
species[T.CEAGRI]                  2.3246      1.583      1.468      0.144
  -0.805       5.454
species[T.ERIKAR]                 -0.8677      1.315     -0.660      0.511
  -3.468       1.732
species[T.HETARB]                 -8.8811      1.716     -5.176      0.000
 -12.273      -5.490
species[T.MALLAU]                  0.7183      1.443      0.498      0.619
  -2.133       3.570
species[T.SALAPI]                 -1.1662      1.582     -0.737      0.462
  -4.294       1.961
species[T.SALLEU]                  1.2616      1.431      0.881      0.380
  -1.567       4.091
stem_sav                          -1.3276      3.040     -0.437      0.663
  -7.336       4.681
stem_sav:species[T.ARTCAL]         0.6859      3.059      0.224      0.823
  -5.360       6.731
stem_sav:species[T.CEAGRI]         6.3203      3.653      1.730      0.086
  -0.900      13.540
stem_sav:species[T.ERIKAR]         1.5151      3.051      0.497      0.620
  -4.515       7.546
stem_sav:species[T.HETARB]       -23.9601      3.509     -6.829      0.000
 -30.895     -17.026
stem_sav:species[T.MALLAU]         2.0247      3.246      0.624      0.534
  -4.390       8.440
stem_sav:species[T.SALAPI]         0.1071      3.243      0.033      0.974
  -6.303       6.517
stem_sav:species[T.SALLEU]         5.0991      3.421      1.491      0.138
  -1.661      11.860
LMA                               -0.4401      0.153     -2.875      0.005
  -0.743      -0.138
sample_wt                          0.1364      0.069      1.977      0.050
 8.07e-06      0.273
branching                          0.1812      0.056      3.244      0.001
   0.071       0.292
start_temp                        -0.4240      0.055     -7.716      0.000
  -0.533      -0.315
dmc                                0.2350      0.120      1.961      0.052
  -0.002       0.472
==============================================================================
Omnibus:                          16.223   Durbin-Watson:                   2.093
Prob(Omnibus):                     0.000   Jarque-Bera (JB):               57.810
Skew:                              0.009   Prob(JB):                     2.80e-13
Kurtosis:                          5.891   Cond. No.                         438.
```
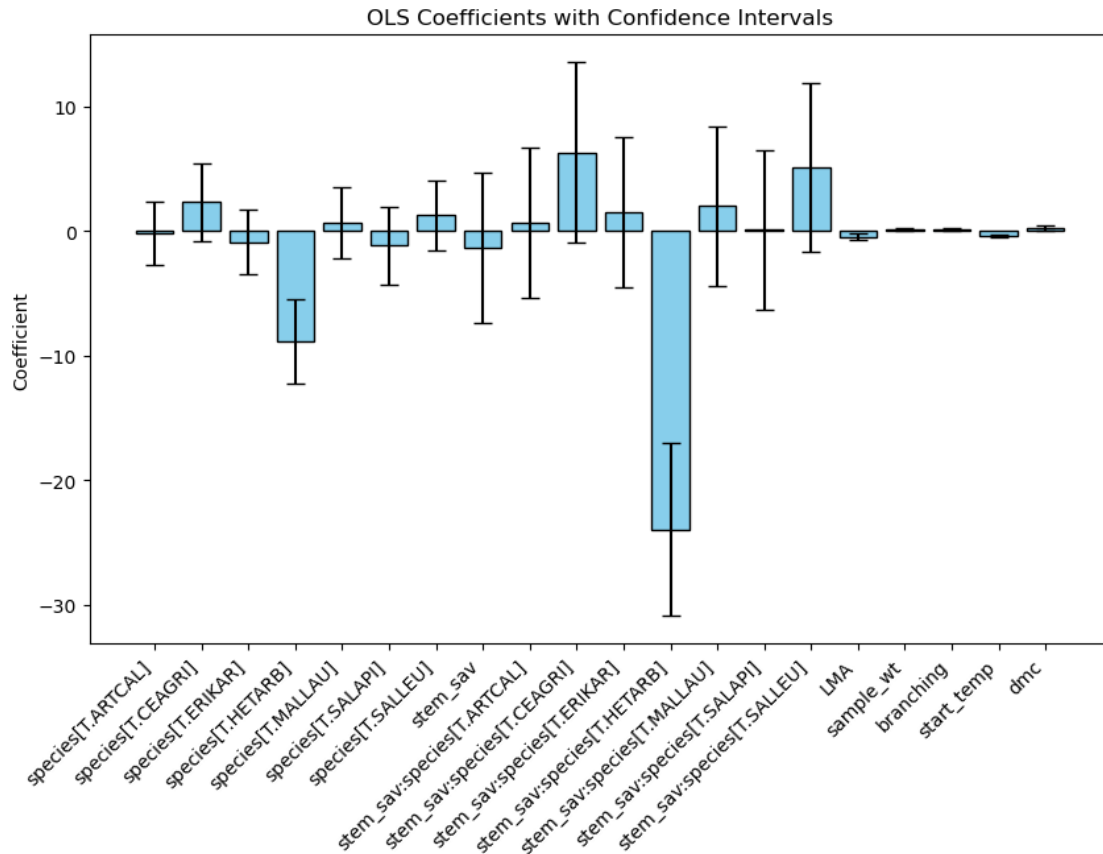
94

==

Notes:

[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

OLS Regression Results

==
========

Dep. Variable:	temp_change	R-squared:			0.781
Model:	OLS	Adj. R-squared:			0.751
Method:	Least Squares	F-statistic:			25.84
Date:	Wed, 24 Apr 2024	Prob (F-statistic):			4.90e-38
Time:	17:27:09	Log-Likelihood:			-110.55
No. Observations:	166	AIC:			263.1
Df Residuals:	145	BIC:			328.5
Df Model:	20				
Covariance Type:	nonrobust				

==
========

	coef	std err	t	P>|t|	[0.025

95

0.975]
```
------------------------------------------------------------------------------------------
---------
Intercept                   0.4875      0.378      1.290      0.199      -0.259
1.234
species[T.ARTCAL]          -0.9360      0.518     -1.809      0.073      -1.959
0.087
species[T.CEAGRI]          -0.6802      0.375     -1.813      0.072      -1.422
0.061
species[T.ERIKAR]          -1.2377      0.594     -2.083      0.039      -2.412
-0.063
species[T.HETARB]          11.6798      0.750     15.574      0.000      10.198
13.162
species[T.MALLAU]           0.1370      0.371      0.370      0.712      -0.595
0.869
species[T.SALAPI]          -0.6619      0.398     -1.662      0.099      -1.449
0.125
species[T.SALLEU]          -0.7123      0.433     -1.644      0.102      -1.568
0.144
mpa                        -0.2499      0.512     -0.488      0.627      -1.263
0.763
mpa:species[T.ARTCAL]      -0.1374      0.564     -0.244      0.808      -1.252
0.977
mpa:species[T.CEAGRI]       0.5435      0.522      1.042      0.299      -0.488
1.575
mpa:species[T.ERIKAR]       0.2428      0.523      0.464      0.643      -0.791
1.277
mpa:species[T.HETARB]      10.6391      0.961     11.069      0.000       8.739
12.539
mpa:species[T.MALLAU]       0.3758      0.537      0.700      0.485      -0.685
1.437
mpa:species[T.SALAPI]      -0.0936      0.542     -0.173      0.863      -1.165
0.977
mpa:species[T.SALLEU]       0.2458      0.540      0.455      0.650      -0.821
1.313
LMA                        -0.4261      0.146     -2.916      0.004      -0.715
-0.137
sample_wt                   0.1554      0.069      2.259      0.025       0.019
0.291
branching                   0.1254      0.059      2.120      0.036       0.008
0.242
start_temp                 -0.3744      0.053     -7.124      0.000      -0.478
-0.271
stem_sav                    0.0627      0.165      0.381      0.703      -0.262
0.388
==========================================================================
Omnibus:                       23.025   Durbin-Watson:                   1.992
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               60.621
```
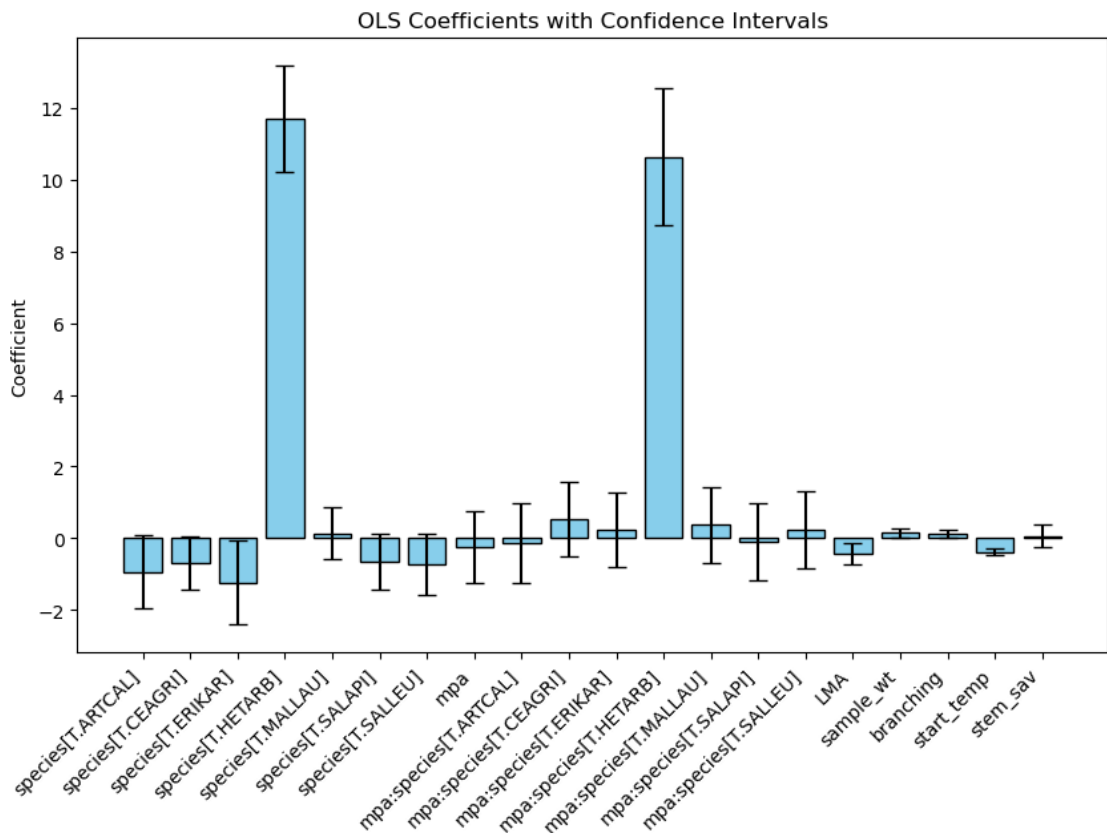
```
Skew:                           0.527   Prob(JB):                      6.86e-14
Kurtosis:                       5.766   Cond. No.                          67.2
================================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

```
                         OLS Regression Results
================================================================================
Dep. Variable:            temp_change   R-squared:                       0.781
Model:                            OLS   Adj. R-squared:                  0.750
Method:                 Least Squares   F-statistic:                     25.81
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           5.16e-38
Time:                        17:27:10   Log-Likelihood:                 -110.61
No. Observations:                 166   AIC:                             263.2
Df Residuals:                     145   BIC:                             328.6
Df Model:                          20
Covariance Type:            nonrobust
================================================================================
=========
```

```
                              coef    std err          t     P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
---------
Intercept                   0.4744     0.379      1.253     0.212      -0.274
1.223
species[T.ARTCAL]          -0.8943     0.504     -1.775     0.078      -1.890
0.101
species[T.CEAGRI]          -0.6963     0.379     -1.839     0.068      -1.445
0.052
species[T.ERIKAR]          -1.1019     0.471     -2.340     0.021      -2.033
-0.171
species[T.HETARB]          11.6524     0.749     15.548     0.000      10.171
13.134
species[T.MALLAU]           0.1137     0.380      0.299     0.765      -0.638
0.865
species[T.SALAPI]          -0.6987     0.406     -1.720     0.087      -1.501
0.104
species[T.SALLEU]          -0.7571     0.472     -1.606     0.111      -1.689
0.175
mpa                        -0.2428     0.512     -0.474     0.636      -1.255
0.770
mpa:species[T.ARTCAL]      -0.1161     0.562     -0.207     0.837      -1.227
0.995
mpa:species[T.CEAGRI]       0.5364     0.521      1.029     0.305      -0.494
1.567
mpa:species[T.ERIKAR]       0.2285     0.522      0.438     0.662      -0.803
1.260
mpa:species[T.HETARB]      10.6104     0.958     11.076     0.000       8.717
12.504
mpa:species[T.MALLAU]       0.3708     0.537      0.691     0.491      -0.690
1.432
mpa:species[T.SALAPI]      -0.0993     0.542     -0.183     0.855      -1.170
0.972
mpa:species[T.SALLEU]       0.2259     0.540      0.419     0.676      -0.841
1.293
LMA                        -0.4276     0.146     -2.919     0.004      -0.717
-0.138
sample_wt                   0.1523     0.069      2.210     0.029       0.016
0.288
branching                   0.1280     0.059      2.182     0.031       0.012
0.244
start_temp                 -0.3747     0.053     -7.099     0.000      -0.479
-0.270
dmc                         0.0140     0.074      0.190     0.849      -0.132
0.160
================================================================================
Omnibus:                            23.662   Durbin-Watson:                1.986
```
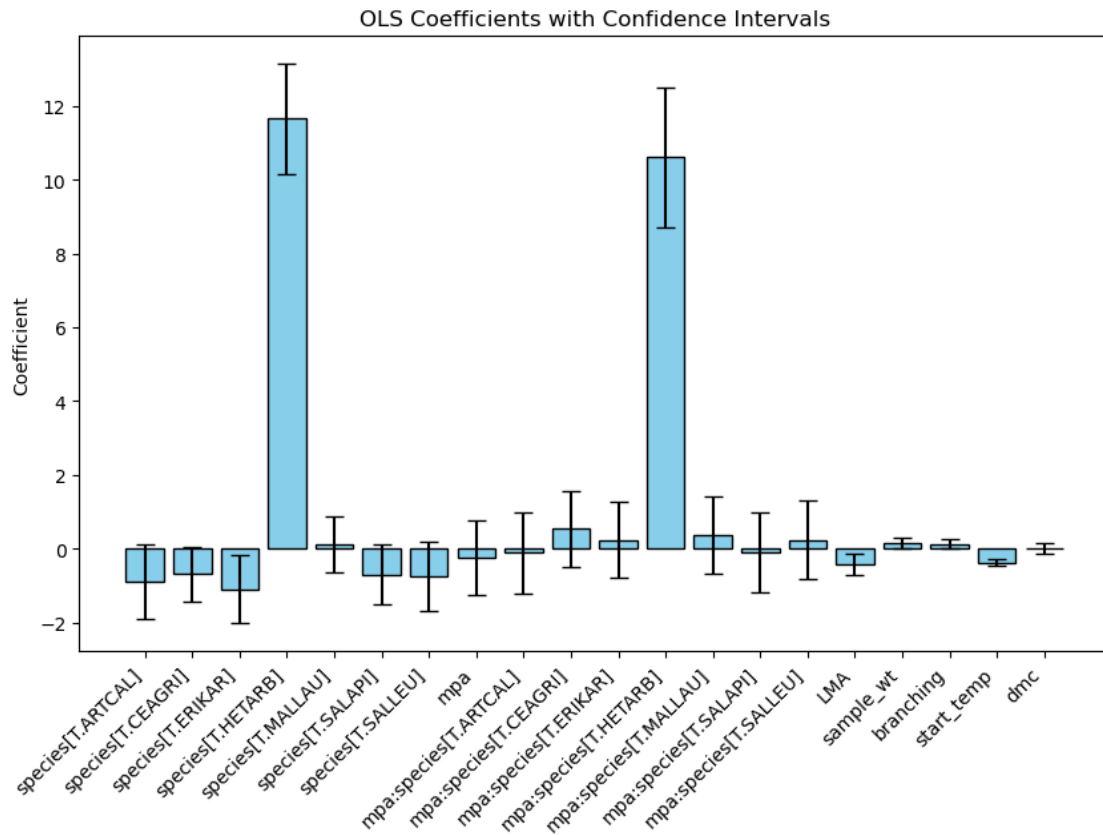
98

```
Prob(Omnibus):                    0.000   Jarque-Bera (JB):              63.088
Skew:                             0.541   Prob(JB):                     2.00e-14
Kurtosis:                         5.820   Cond. No.                        61.7
==============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

OLS Coefficients with Confidence Intervals

```
                        OLS Regression Results
==============================================================================
Dep. Variable:            temp_change   R-squared:                       0.781
Model:                            OLS   Adj. R-squared:                  0.750
Method:                 Least Squares   F-statistic:                     25.80
Date:                Wed, 24 Apr 2024   Prob (F-statistic):           5.25e-38
Time:                        17:27:10   Log-Likelihood:                 -110.63
No. Observations:                 166   AIC:                             263.3
Df Residuals:                     145   BIC:                             328.6
Df Model:                          20
Covariance Type:            nonrobust
==============================================================================
```

```
=========
                             coef    std err          t      P>|t|      [0.025
0.975]
--------------------------------------------------------------------------------
---------
Intercept                  0.4593     0.376      1.223      0.223      -0.283
1.201
species[T.ARTCAL]         -0.8879     0.513     -1.729      0.086      -1.903
0.127
species[T.CEAGRI]         -0.6859     0.375     -1.827      0.070      -1.428
0.056
species[T.ERIKAR]         -1.0975     0.481     -2.282      0.024      -2.048
-0.147
species[T.HETARB]         11.6596     0.749     15.573      0.000      10.180
13.139
species[T.MALLAU]          0.1313     0.377      0.348      0.728      -0.614
0.876
species[T.SALAPI]         -0.6802     0.397     -1.714      0.089      -1.465
0.104
species[T.SALLEU]         -0.7209     0.434     -1.662      0.099      -1.578
0.136
mpa                       -0.2411     0.512     -0.470      0.639      -1.254
0.772
mpa:species[T.ARTCAL]     -0.1172     0.563     -0.208      0.835      -1.230
0.996
mpa:species[T.CEAGRI]      0.5351     0.521      1.026      0.307      -0.496
1.566
mpa:species[T.ERIKAR]      0.2281     0.522      0.437      0.663      -0.804
1.260
mpa:species[T.HETARB]     10.6049     0.963     11.017      0.000       8.702
12.507
mpa:species[T.MALLAU]      0.3679     0.537      0.685      0.494      -0.693
1.429
mpa:species[T.SALAPI]     -0.1009     0.542     -0.186      0.852      -1.172
0.970
mpa:species[T.SALLEU]      0.2307     0.543      0.425      0.672      -0.843
1.304
LMA                       -0.4258     0.146     -2.913      0.004      -0.715
-0.137
sample_wt                  0.1533     0.069      2.229      0.027       0.017
0.289
branching                  0.1287     0.059      2.199      0.029       0.013
0.244
start_temp                -0.3735     0.055     -6.744      0.000      -0.483
-0.264
leaf_sav                  -0.0011     0.060     -0.018      0.986      -0.119
0.117
================================================================================
```
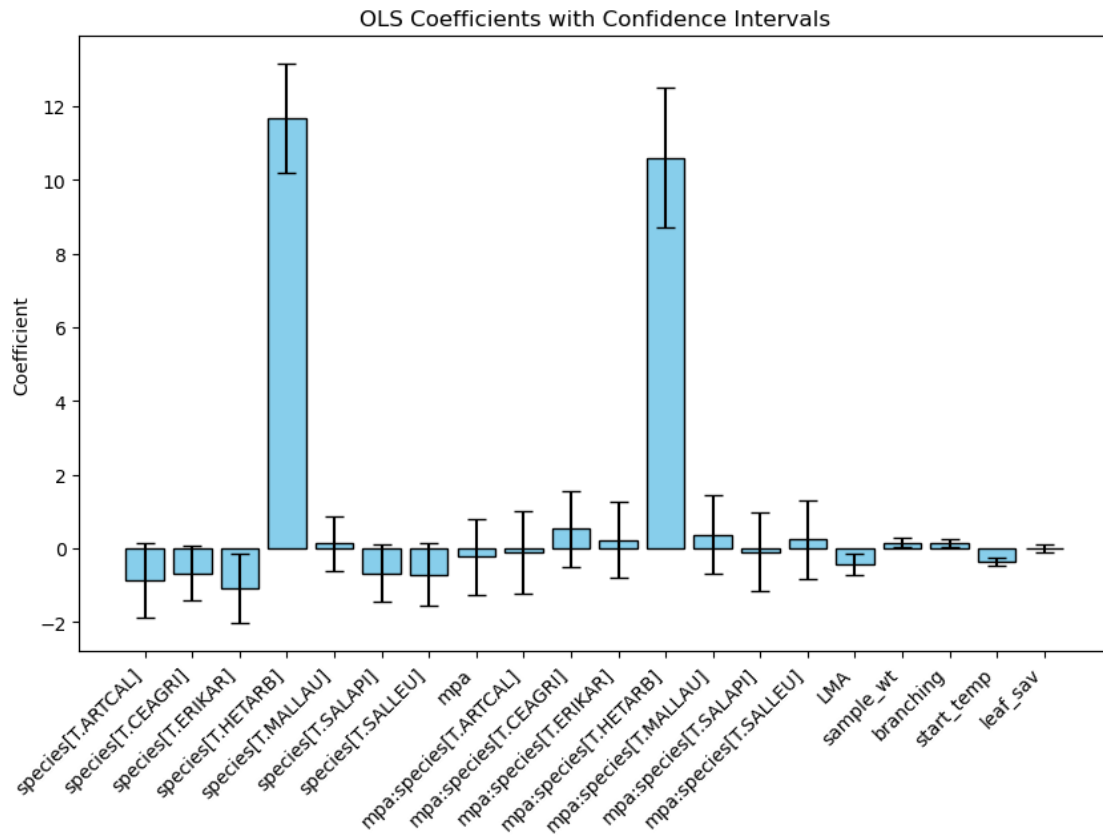
```
Omnibus:                         23.392    Durbin-Watson:                  1.988
Prob(Omnibus):                    0.000    Jarque-Bera (JB):              61.256
Skew:                             0.540    Prob(JB):                    4.99e-14
Kurtosis:                         5.773    Cond. No.                        63.6
===============================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals

7 Heat Flux Change

```
[15]: # REDUCE INTERACTIONS TO TEST

Y_VAR = 'heat_flux_change'

# singletons: y = b + mx
compare_predictors_mixedeff(flam, cols_num_use, yvar=Y_VAR)

print('\n\n')
```

```python
# singleton interactions: y = b + m1x1 + m2x2 + m3x1x2
sig_interactions = compare_predictors_interaction_singletons(flam,cols_use,␣
 ↪y=Y_VAR, thresh=0.05, probs = [], printsumm=0)

print('\n\n')

# # try all 2-way interactions in 1 model
# form_all_int = formula_all_2way_interactions(cols_use, y='fh', report=0)
# model = smf.mixedlm(form_all_int, data=flam, groups=flam["plant_id"])
# result = model.fit(reml=False)
# # print only significant results
# significant_results = result.summary().tables[1].loc[result.pvalues < 0.05]
# print(significant_results)

print('\n\n')

# generate list of known interactions

sig_interactions_tuples = [tuple(x.split('*')) for x in sig_interactions]
for pair in sig_interactions_tuples:
    print(pair)
```

	cols	pvals	coefs	significant
2	sample_wt	4.833183e-25	0.670656	True
8	branch_volume	2.758968e-09	0.438674	True
1	LMA	2.433891e-08	0.481080	True
9	stem_sav	8.420917e-05	-0.378518	True
3	leaf_mass_ratio	3.820173e-04	-0.404141	True
10	leaf_sav	8.635177e-04	-0.335408	True
0	lfm	5.211122e-03	-0.285119	True
7	dmc	1.135685e-02	0.240699	True
4	branching	1.403803e-02	0.194726	True
11	thickness	1.707630e-01	0.154728	False
6	start_temp	2.560324e-01	0.101154	False
5	mpa	8.944642e-01	-0.011634	False

```
13 10 {'thickness', 'stem_sav', 'LMA', 'sample_wt', 'branch_volume',
'leaf_mass_ratio', 'start_temp', 'species', 'dmc', 'lfm'}
```

```
('lfm', 'dmc')
('LMA', 'branch_volume')
('sample_wt', 'leaf_mass_ratio')
('sample_wt', 'dmc')
('sample_wt', 'stem_sav')
('leaf_mass_ratio', 'branch_volume')
('leaf_mass_ratio', 'stem_sav')
('leaf_mass_ratio', 'thickness')
('start_temp', 'species')
('dmc', 'branch_volume')
('dmc', 'stem_sav')
('dmc', 'thickness')
('dmc', 'species')
```

[16]:
```python
# generate list of formulas

df = flam
cols = cols_use
int_tuple_list = sig_interactions_tuples
dv = Y_VAR


formulas = []
cols_used = []

# iterate over possible interactions
for int_tup in int_tuple_list:

    # create a copy of singletons list
    cols_wkg = cols.copy()
    # isolate terms in interaction
    x1,x2 = int_tup
    # drop those terms from singletons list
    cols_wkg.remove(x1)
    cols_wkg.remove(x2)

    # add the 1st formula - just the interaction term y ~ x1 * x2
    formulas.append(dv+' ~ '+x1+'*'+x2)
    colsi = [x1,x2]

    # generate list of all possible combos of singletons, from 1 to as many as
 ↪there are
    singles_combos = [list(combinations(cols_wkg, n)) for n in
 ↪range(minnumsingle, maxnumsingle+1)]

    # iterate over combo set (ie 1 poss singleton, 2 poss singletons, ... etc)
    for comboset in singles_combos:
```

```python
        # for each combo in the combo set
        for combo in comboset:
            # generate formula
            form = dv+' ~ '+x1+'*'+x2
            for single in combo:
                form+=' + '+single
                colsi.append(single)
            formulas.append(form)
            cols_used.append([colsi])

print(len(formulas))

# AIC ITERATION
resdf_hx, num_top_models = AICscore_from_all_pos_2way_interactions(df,␣
 ↪formulas, report=0)

# report
for idx,row in resdf_hx[0:num_top_models].iterrows():
    formula = row.Formula
    print(formula)
for idx,row in resdf_hx[0:num_top_models].iterrows():
    formula = row.Formula
    model = smf.ols(formula, data=df)
    results = model.fit()
    print(results.summary())
    plot_ols_coefficients(results)
    plt.show();
    # if 'species' in cols:
    #     cols.remove('species')
    # plot_resid(df, cols, results)
```

```
13312
13312 13312
heat_flux_change ~ sample_wt*leaf_mass_ratio + lfm + LMA + start_temp + leaf_sav
+ species
heat_flux_change ~ sample_wt*leaf_mass_ratio + lfm + LMA + start_temp + species
                        OLS Regression Results
==============================================================================
Dep. Variable:        heat_flux_change   R-squared:                     0.604
Model:                             OLS   Adj. R-squared:                0.567
Method:                  Least Squares   F-statistic:                   16.42
Date:                 Wed, 24 Apr 2024   Prob (F-statistic):         7.97e-24
Time:                         17:52:36   Log-Likelihood:              -159.27
No. Observations:                  166   AIC:                           348.5
Df Residuals:                      151   BIC:                           395.2
Df Model:                           14
Covariance Type:             nonrobust
```

```
========================================================================
============
                          coef    std err         t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------
-------------
Intercept                0.5232    0.388      1.349      0.179
-0.243       1.289
species[T.ARTCAL]       -0.8719    0.602     -1.449      0.149
-2.061       0.317
species[T.CEAGRI]       -0.3177    0.367     -0.865      0.389
-1.043       0.408
species[T.ERIKAR]       -0.7364    0.573     -1.286      0.200
-1.868       0.395
species[T.HETARB]       -0.7716    0.589     -1.311      0.192
-1.935       0.392
species[T.MALLAU]       -1.2976    0.371     -3.500      0.001
-2.030      -0.565
species[T.SALAPI]       -0.8244    0.409     -2.018      0.045
-1.632      -0.017
species[T.SALLEU]       -0.6029    0.517     -1.165      0.246
-1.625       0.419
sample_wt                0.6766    0.093      7.311      0.000
0.494       0.859
leaf_mass_ratio          0.0387    0.120      0.322      0.748
-0.199       0.276
sample_wt:leaf_mass_ratio  -0.4677  0.103    -4.545      0.000
-0.671      -0.264
lfm                     -0.1687    0.131     -1.286      0.200
-0.428       0.090
LMA                     -0.0677    0.184     -0.367      0.714
-0.432       0.297
start_temp               0.1735    0.066      2.629      0.009
0.043       0.304
leaf_sav                -0.1656    0.076     -2.181      0.031
-0.316      -0.016
========================================================================
Omnibus:                 18.209    Durbin-Watson:                  1.607
Prob(Omnibus):            0.000    Jarque-Bera (JB):              62.322
Skew:                    -0.233    Prob(JB):                    2.93e-14
Kurtosis:                 5.965    Cond. No.                        35.4
========================================================================
```

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

OLS Coefficients with Confidence Intervals
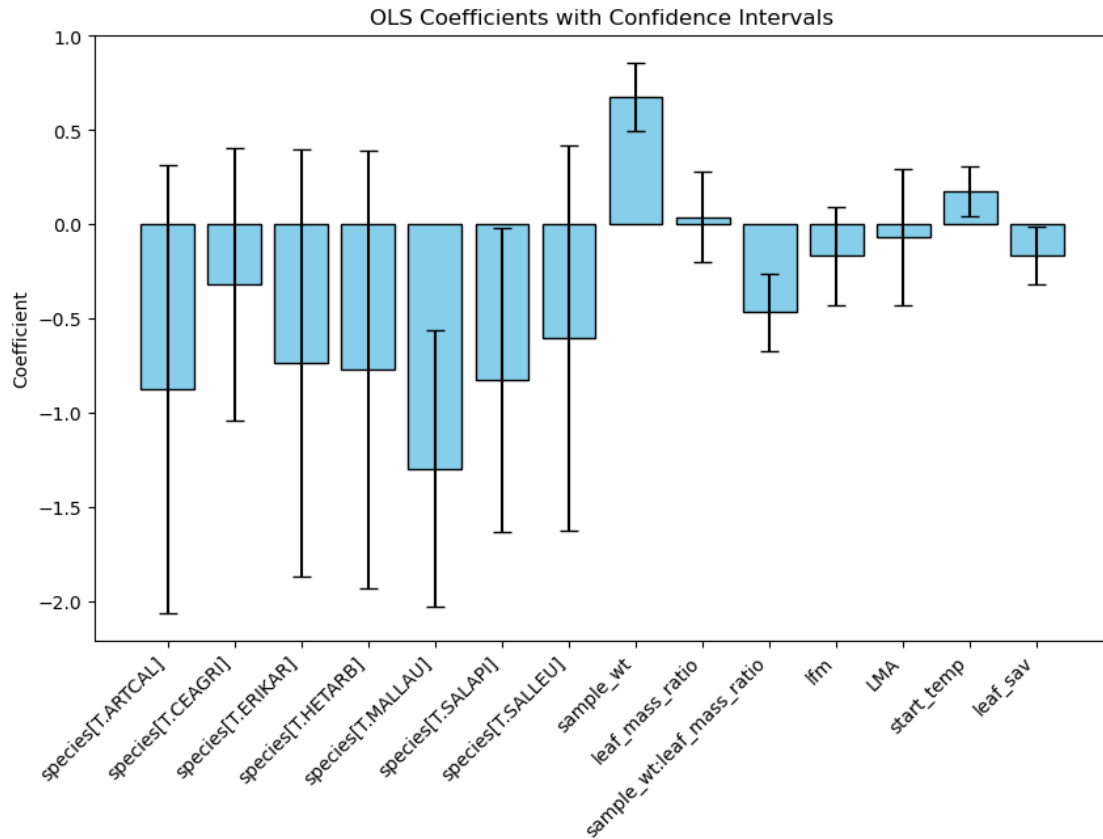
OLS Regression Results

```
==============================================================================
Dep. Variable:        heat_flux_change   R-squared:                  0.591
Model:                            OLS    Adj. R-squared:             0.556
Method:                 Least Squares    F-statistic:                16.90
Date:                Wed, 24 Apr 2024    Prob (F-statistic):      1.74e-23
Time:                        17:52:36    Log-Likelihood:           -161.85
No. Observations:                 166    AIC:                        351.7
Df Residuals:                     152    BIC:                        395.3
Df Model:                          13
Covariance Type:            nonrobust
==============================================================================
=============
                        coef     std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
-------------
Intercept             0.6795       0.386      1.761      0.080
-0.083       1.442
species[T.ARTCAL]    -1.0466       0.604     -1.734      0.085
-2.239       0.146
```
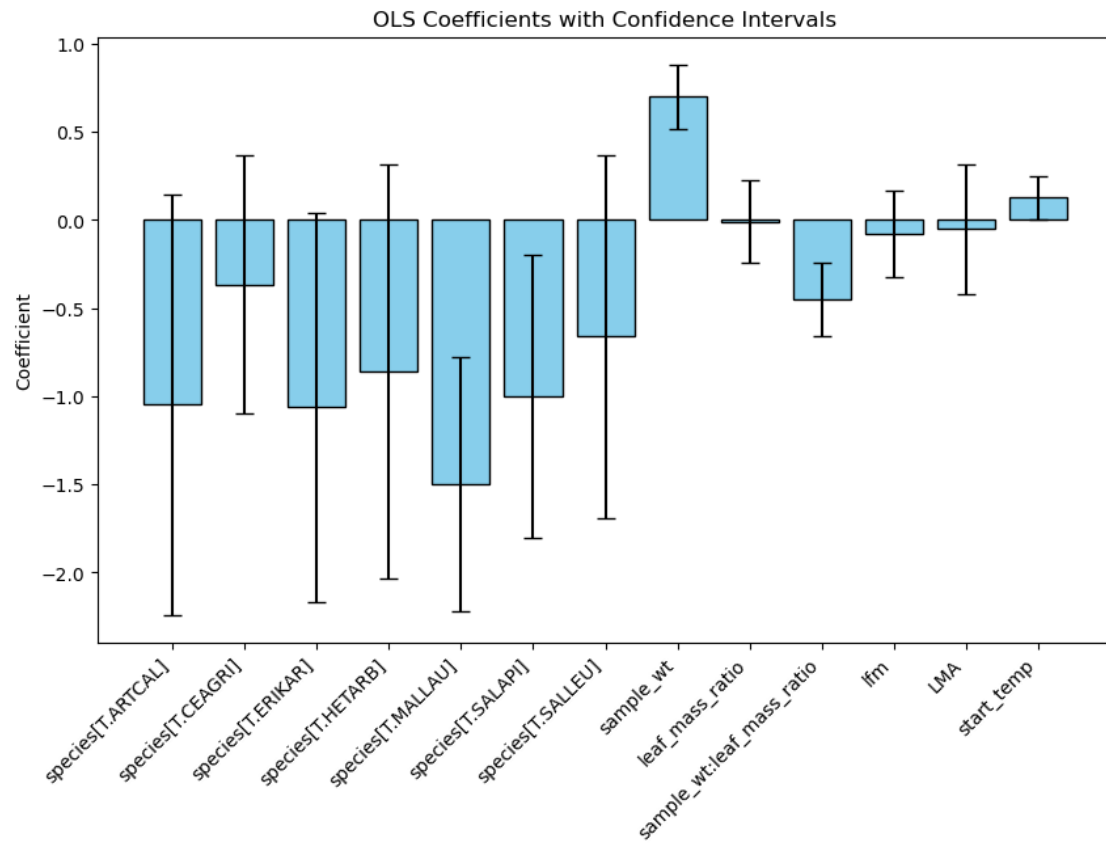
```
species[T.CEAGRI]               -0.3674      0.371     -0.990      0.324
-1.101         0.366
species[T.ERIKAR]               -1.0622      0.560     -1.898      0.060
-2.168         0.044
species[T.HETARB]               -0.8596      0.594     -1.446      0.150
-2.034         0.315
species[T.MALLAU]               -1.4980      0.364     -4.120      0.000
-2.216        -0.780
species[T.SALAPI]               -1.0004      0.405     -2.467      0.015
-1.801        -0.199
species[T.SALLEU]               -0.6615      0.523     -1.265      0.208
-1.695         0.372
sample_wt                        0.7004      0.093      7.529      0.000
0.517         0.884
leaf_mass_ratio                 -0.0088      0.120     -0.073      0.942
-0.245         0.228
sample_wt:leaf_mass_ratio       -0.4501      0.104     -4.334      0.000
-0.655        -0.245
lfm                             -0.0780      0.126     -0.620      0.536
-0.327         0.171
LMA                             -0.0489      0.187     -0.262      0.793
-0.417         0.320
start_temp                       0.1275      0.063      2.014      0.046
0.002         0.253
==============================================================================
Omnibus:                        23.720   Durbin-Watson:                   1.589
Prob(Omnibus):                   0.000   Jarque-Bera (JB):               87.433
Skew:                           -0.402   Prob(JB):                     1.03e-19
Kurtosis:                        6.463   Cond. No.                         32.3
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```

OLS Coefficients with Confidence Intervals

[ ]:

[ ]: