Biomass-Weighted Community Estuarine Assimilation Estimates

Sean Kinard

2024-05-30

Contents

1 Report Summary

1.1 Background:

This research project aims to quantify the contributions of estuarine-derived nutrients to coastal streams across a natural precipitation gradient in South-Central Texas. It investigates estuarine assimilation in both inconspicuous migrants and freshwater taxa while examining its relationships with climate, geography, and anthropogenic factors.

1.2 Project Overview:

In this script, I merge two biological datasets—estuarine assimilation (EA) and biomass—to calculate a species-biomass-weighted estimate for the overall community estuarine assimilation across nine streams. Subsequently, I examine the relationships between EA and annual rainfall using regression analysis at various scales of comparison.

1.3 Key Findings:

These results confirm the increased assimilation of estuarine-derived nutrients in regions with arid climates. Furthermore, they demonstrate that this relationship holds true for both freshwater and euryhaline species. Notably, the findings reveal a counterintuitive pattern: freshwater taxa exhibit greater consumption of estuarine materials in arid environments, while euryhaline species show reduced assimilation in humid environments. It's important to note that these results do not imply the mechanisms of consumption. For instance, freshwater fish in arid environments may either consume euryhaline wanderers or make periodic trips to nearby estuaries to directly consume estuarine materials before returning to their freshwater habitat.

1.4 Relevance:

Our research sheds light on the intricate dynamics of estuarine assimilation in coastal stream ecosystems, spanning a natural precipitation gradient. By quantifying the contributions of estuarine-derived nutrients and their relationships with climatic factors, our findings challenge conventional assumptions. We reveal a nuanced pattern where freshwater taxa exhibit unexpected reliance on estuarine materials in arid environments, while euryhaline species display reduced assimilation in humid regions. These insights not only deepen our understanding of ecosystem dynamics but also have practical implications for managing and conserving coastal ecosystems, highlighting the importance of considering species-specific responses to environmental variability.

2 Estuarine Assimilation Versus Annual Rainfall

This code chunk contains a set of functions designed to analyze the relationship between Estuarine Assimilation (EA) and annual rainfall across various taxonomic groups. The functions facilitate data preparation, linear regression analysis, and visualization of the EA versus Rainfall relationship. Specifically, the functions compute linear regression statistics, generate base plots, and perform analysis for each taxonomic group of interest. Overall, this code chunk streamlines the process of exploring and understanding the impact of rainfall on estuarine assimilation within different ecological communities.

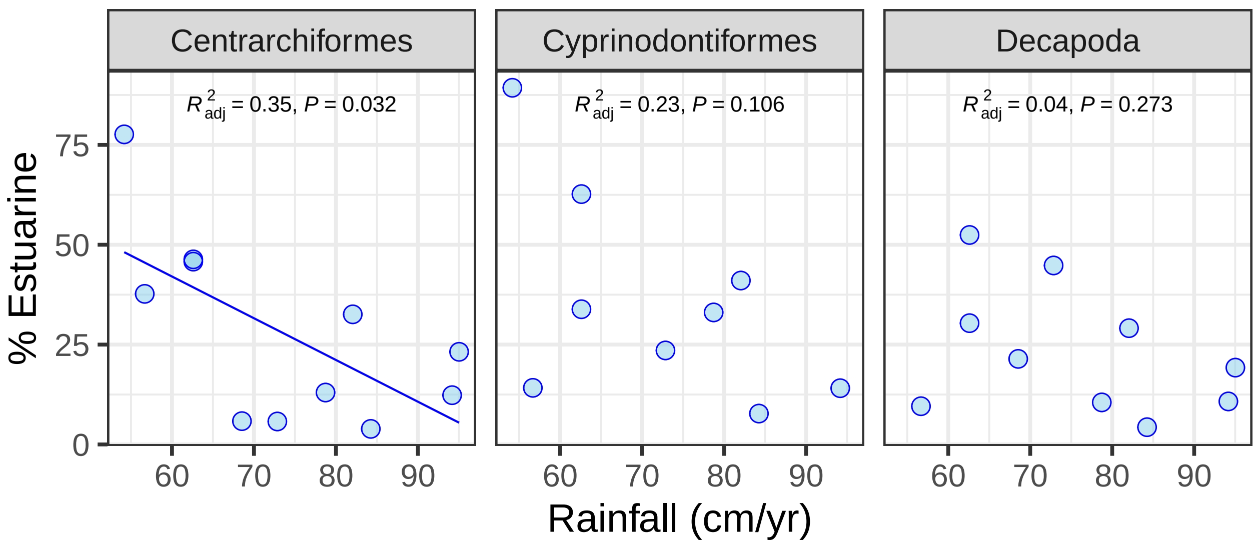
```
#------------------------------------------------------------------------------
# Setup: EA Versus Rainfall (Taxonomic Groups)
#------------------------------------------------------------------------------

# table function: EA versus Rainfall
table_lm_stats <- function(x) {

  lm(formula = EA_XX_mu ~ annualrain,
     data = x %>% add_rain()) %>%
    summary()  %>%
    broom::tidy()
}

# base plot: EA versus Rainfall
plot_ea_v_rain <- function(x) {

  x %>%
    ggplot(aes(x=annualrain, y=EA_XX_mu)) +
    stat_poly_eq(label.x=.5, label.y=.95, formula=y~x,
                 color='black', use_label(c("adj.R2","p")), size=4) +
    geom_point(size=4, color='blue', fill='skyblue', shape=21, alpha=.5) +
    geom_point(size=4, color='blue', fill=NA, shape=21) +
    labs(x='Rainfall (cm/yr)', y='% Estuarine') +
    theme_bw(base_size=20) +
    geom_smooth(data = . %>% filter(p.value < 0.1 & p.value >= 0.05),
                method = "lm", se = FALSE,
                color = "blue", lwd=.5, lty=2)  +
    geom_smooth(data = . %>% filter(p.value < 0.05),
                method = "lm", se = FALSE,
                color = "blue", lwd=.5, lty=1)
}

# Generate table and plot for x_group of comparison
ea_vs_rain <-function(x_data, x_group, n_sites=1) {
  temp_data <- x_data
  colnames(temp_data) <- str_replace_all(colnames(temp_data), x_group, 'XX')

  # list widespread groups
  widespread <- temp_data %>%
    group_by(XX) %>%
    summarize(n_samples = length(EA_XX_mu)) %>%
    filter(n_samples>n_sites) %>%
    pull(XX)

  # Table: Regression Statistics
```

```r
  t_EA_vs_rain <- temp_data %>%
    filter(XX %in% widespread) %>%
    group_by(XX) %>%
    nest() %>%
    mutate(lm = map(data, table_lm_stats)) %>%
    unnest(lm) %>%
    filter(term == 'annualrain') %>%
    select(-term, -data) %>%
    ungroup()

  colnames(t_EA_vs_rain) <- str_replace_all(colnames(t_EA_vs_rain), x_group, 'XX')

  # visualize
  p_EA_vs_rain <- temp_data %>%
    filter(XX %in% widespread) %>%
    left_join(t_EA_vs_rain) %>%
    plot_ea_v_rain() +
    facet_wrap(~XX)

  colnames(t_EA_vs_rain) <- str_replace_all(colnames(t_EA_vs_rain), 'XX', x_group)

  output <- list(figure = p_EA_vs_rain,
      table = t_EA_vs_rain)

  return(output)
}
```

2.1 Widespread Taxonomic Order

Linear regression of average estuarine assimilation (EA) within widespread taxonomic orders versus annual rainfall. EA is estimated for each order using bayesian mixing models with d13C and d34S stable isotope data in pre-requisite analyses.

```
#---------------------------------------------------------------------------
# EA Versus Rainfall: Within Widespread Orders
#---------------------------------------------------------------------------
widespread_orders <- ea_vs_rain(x_data = iso_order,
                                x_group= 'order',
                                n_sites = 8)
widespread_orders$figure
```




```
widespread_orders$table %>%
  ungroup() %>%
  gt() %>%
  fmt_number(columns = where(is.numeric), decimals = 3)
```

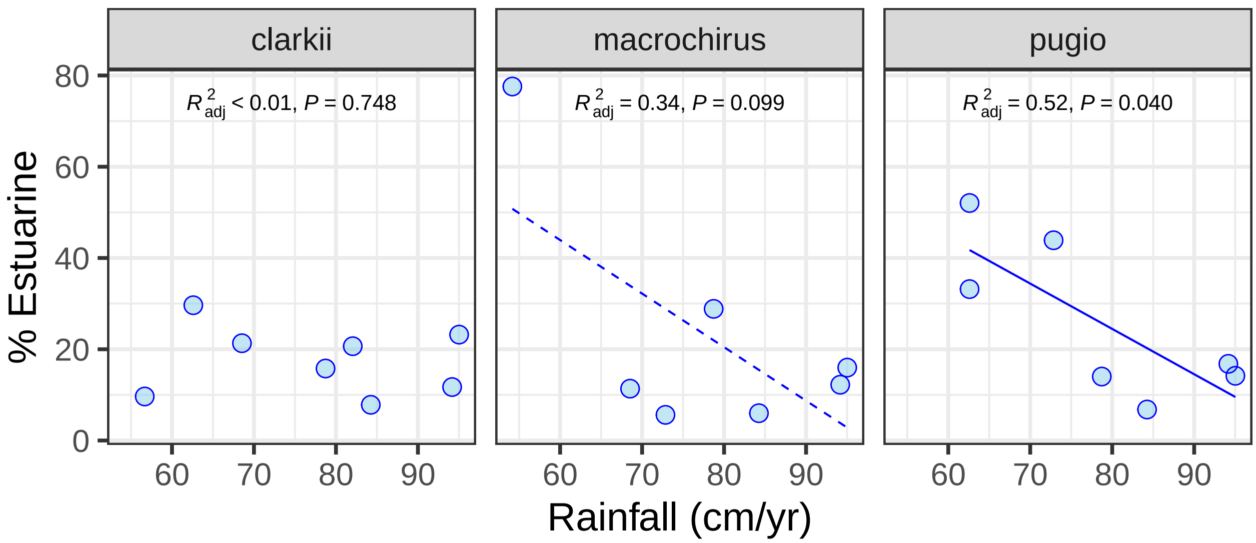
order	estimate	std.error	statistic	p.value
Centrarchiformes	−1.045	0.411	−2.543	0.032
Cyprinodontiformes	−1.092	0.589	−1.854	0.106
Decapoda	−0.459	0.390	−1.177	0.273

2.1.1 Interpretation

The analysis indicates a significant negative correlation between estuarine assimilation (EA) and annual rainfall within the taxonomic order Centrarchiformes. Additionally, while Cyprinidontiformes exhibit a similar relationship, it falls just short of statistical significance (p = 0.106). Notably, Decapoda also demonstrates a pattern resembling other orders, but data from the most arid site were missing, potentially affecting the analysis. These findings suggest that, within widespread taxonomic orders, centrarchiformes display a clear linear decline in EA with increasing annual rainfall, indicating species-specific responses to environmental variables. However, further investigation is warranted to account for missing data and confirm the observed trends across all taxa.

2.2 Widespread Taxonomic Species

```
#------------------------------------------------------------------------------
# EA versus rainfall within widespread species
#------------------------------------------------------------------------------
widespread_species <- ea_vs_rain(x_data = iso_species,
                                 x_group= 'species',
                                 n_sites = 6)

widespread_species$figure
```



Linear regression of average estuarine assimilation (EA) within widespread taxonomic species versus annual rainfall. EA is estimated for each order using bayesian mixing models with d13C and d34S stable isotope data in pre-requisite analyses.

```
widespread_species$table %>%
  ungroup() %>%
  gt() %>%
  fmt_number(columns = where(is.numeric), decimals = 3)
```

species	estimate	std.error	statistic	p.value
clarkii	−0.073	0.216	−0.337	0.748
macrochirus	−1.174	0.581	−2.022	0.099
pugio	−0.993	0.362	−2.747	0.040

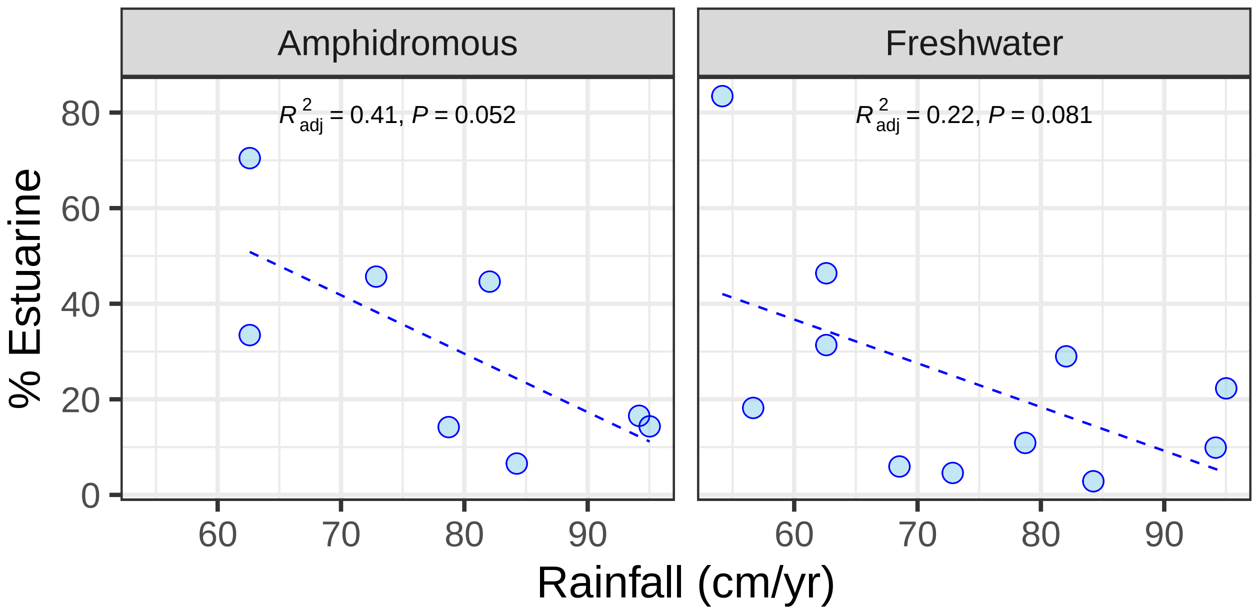
2.2.1 Interpretation

The analysis reveals a significant negative correlation between estuarine assimilation (EA) and annual rainfall for two widespread species: Lepomis macrochirus (bluegill sunfish) with a p-value below 0.1 threshold and Palaemonetes pugio (daggerblade grass shrimp) with a p-value below 0.05 threshold. In contrast, EA in other species like Procambarus clarkii did not exhibit a linear correlation with annual rainfall. These findings suggest that estuarine exploitation varies among species, with Pugio and macrochirus showing a decreased reliance on estuarine-derived materials in regions with higher rainfall. This indicates that estuarine foraging behavior is species-specific and not universally inherent within the community.

2.3 Widespread Transient Categories

Linear regression of average estuarine assimilation (EA) within widespread taxonomic species versus annual rainfall. EA is estimated for each order using bayesian mixing models with d13C and d34S stable isotope data in pre-requisite analyses.

```
#------------------------------------------------------------------------------
# EA versus rainfall within Transient Type
#------------------------------------------------------------------------------
widespread_transient <- ea_vs_rain(x_data = iso_transient,
                                   x_group= 'transient',
                                   n_sites = 5)
widespread_transient$figure
```




```
widespread_transient$table %>%
  ungroup() %>%
  gt() %>%
  fmt_number(columns = where(is.numeric), decimals = 3)
```

transient	estimate	std.error	statistic	p.value
Freshwater	−0.916	0.467	−1.962	0.081
Amphidromous	−1.224	0.505	−2.423	0.052

2.3.1 Interpretation:

The analysis reveals a significant negative correlation between estuarine assimilation (EA) and rainfall for both Amphidromous and Freshwater organisms. This suggests that these organisms tend to consume more estuarine-derived materials in regions with lower rainfall, possibly due to increased concentration of nutrients and salinity during dry periods. In contrast, transient and catadromous organisms show no linear relationship with annual rainfall, indicating a consistent consumption of estuarine-derived materials irrespective of rainfall patterns.

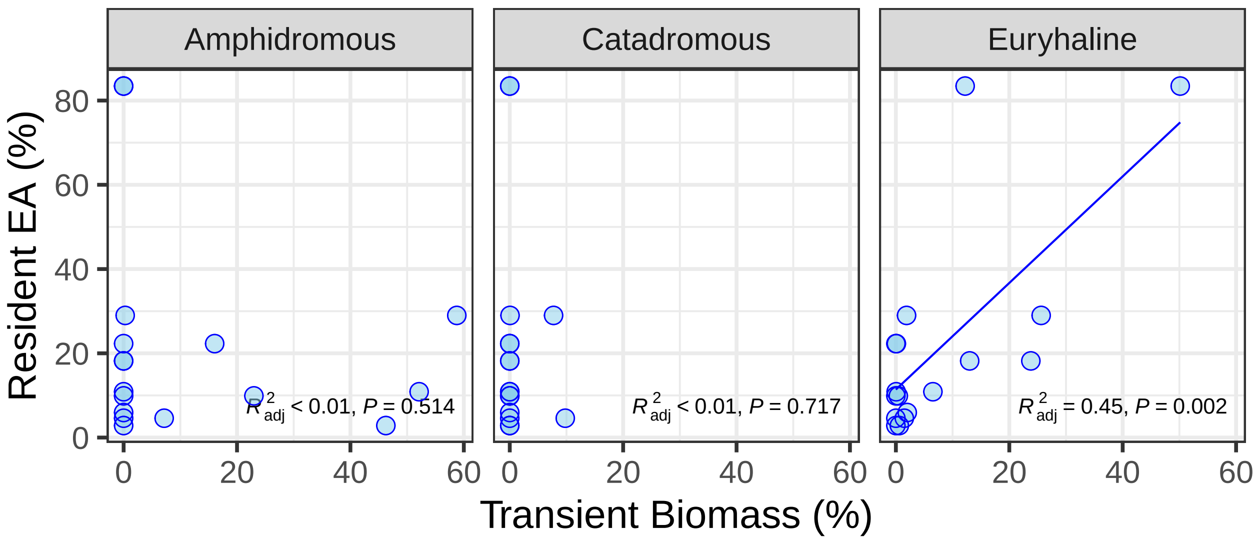
2.4 Widespread Transient Categories

Linear regression of average estuarine assimilation (EA) within widespread taxonomic species versus annual rainfall. EA is estimated for each order using bayesian mixing models with d13C and d34S stable isotope data in pre-requisite analyses.

```
#-----------------------------------------------------------------------------
# resident EA versus % biomass transient
#-----------------------------------------------------------------------------

# table function: EA versus Rainfall
table_lm_stats2 <- function(x) {

  lm(formula = EA_fresh ~ biomass_percent, data = x) %>%
    summary()  %>%
    broom::tidy()
}

plot_ea_v_tb <-function(X) {
  X %>%
    ggplot(aes(x=biomass_percent, y=EA_fresh)) +
    stat_poly_eq(label.y = "bottom", label.x = "right", formula=y~x,
                 color='black', use_label(c("adj.R2","p")), size=4) +
    geom_point(size=4, color='blue', fill='skyblue', shape=21, alpha=.5) +
    geom_point(size=4, color='blue', fill=NA, shape=21) +
    labs(x='Transient Biomass (%)', y="Resident EA (%)") +
    theme_bw(base_size=20) +
    geom_smooth(data = . %>% filter(p.value < 0.1 & p.value >= 0.05),
                method = "lm", se = FALSE,
                color = "blue", lwd=.5, lty=2)  +
    geom_smooth(data = . %>% filter(p.value < 0.05),
                method = "lm", se = FALSE,
                color = "blue", lwd=.5, lty=1) }

# data prep:
d_ea_v_tb <- dc %>%
  filter(collection_period %in% c('2019-Q4', '2020-Q1')) %>%
  group_by(site_code, collection_period, transient_type) %>%
  summarize(biomass_percent = sum(biomass_percent, na.rm=T)) %>%
  ungroup() %>%
  mutate(present = ifelse(near(biomass_percent, 0), 0, 1)) %>%
  group_by(transient_type, collection_period) %>%
  mutate(n_sites = sum(present)) %>%
  ungroup() %>%
  select(-present) %>%
  add_rain() %>%
  left_join(iso_transient %>%
              filter(transient == 'Freshwater') %>%
              rename(EA_fresh = EA_transient_mu) %>%
              select(site_code, EA_fresh) )

# Table: Regression Statistics
t_EA_vs_tb <- d_ea_v_tb %>%
  group_by(transient_type) %>%
  nest() %>%
```

```
  mutate(lm = map(data, table_lm_stats2)) %>%
  unnest(lm) %>%
  filter(term == 'biomass_percent') %>%
  select(-term, -data)



# figure: Resident EA Versus % Transient Biomass
p_ea_v_tb <- d_ea_v_tb %>%
  left_join(t_EA_vs_tb) %>%
  filter(transient_type != 'Freshwater') %>%
  plot_ea_v_tb() +
  facet_wrap(~transient_type)
```

```
p_ea_v_tb
```




```
t_EA_vs_tb %>%
  ungroup() %>%
  gt() %>%
  fmt_number(columns = where(is.numeric), decimals = 3)
```

transient_type	estimate	std.error	statistic	p.value
Amphidromous	−0.206	0.308	−0.669	0.514
Catadromous	−0.801	2.172	−0.369	0.717
Euryhaline	1.265	0.335	3.777	0.002
Freshwater	−0.309	0.286	−1.080	0.297

2.4.1 Interpretation:

The analysis reveals a significant negative correlation between estuarine assimilation (EA) and rainfall for both Amphidromous and Freshwater organisms. This suggests that these organisms tend to consume more estuarine-derived materials in regions with lower rainfall, possibly due to increased concentration of nutrients and salinity during dry periods. In contrast, transient and catadromous organisms show no linear relationship with annual rainfall, indicating a consistent consumption of estuarine-derived materials irrespective of rainfall patterns.