

Small Creatures Signal Big Changes: The Role of Invertebrates in Understanding Restoration  
Effectiveness in the Stillaguamish River Delta

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**Abstract**

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Estuarine and river delta habitats contribute a vast array of ecosystem services that support coastal economies, livelihoods, cultural traditions and wellbeing. Human development has driven losses of these important ecosystems on a global scale, and restoration is being prioritized to address the environmental impacts of these losses. In the Pacific Northwest region of the United States, river delta restoration is often performed to support recovery of Pacific salmon (*Oncorhynchus* spp.) that inhabit these ecosystems as juveniles during their outmigration from natal streams to the Pacific Ocean. For Puget Sound Chinook salmon (*O. tshawytscha*), the period of marine entry is a critical life stage in which access to abundant and high-quality invertebrate prey can determine marine survival. Successful restoration returns dynamic ecosystem processes to delta landscapes that enable establishment of macroinvertebrate

communities, and in turn, produce favorable foraging conditions for juvenile salmon as well as other estuary-dependent consumers. We investigated spatial and temporal variation in terrestrial and benthic macroinvertebrate community structure in restoration and reference areas of the Stillaguamish River delta, Puget Sound, Washington State, USA. We found that high-quality invertebrate prey, including adult dipterans and other insects, polychaetes, and amphipods were abundant in restoration areas, suggesting that restoration efforts are effectively producing energy-rich prey for juvenile Chinook salmon. The largest increase in terrestrial invertebrate abundance occurred between April and May, and benthic invertebrate abundance peaked in May. We found similar terrestrial invertebrate abundance and diversity across the delta. Restoration areas had higher benthic invertebrate abundance and greater diversity of marine-associated taxa than reference areas. Our results will provide a useful comparison as current restoration sites age and as new restoration projects are completed in the future.

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## ABSTRACT

Estuarine and river delta habitats contribute a vast array of ecosystem services that support coastal economies, livelihoods, cultural traditions and wellbeing. Human development has driven losses of these important ecosystems on a global scale, and restoration is being prioritized to address the environmental impacts of these losses. In the Pacific Northwest region of the United States, river delta restoration is often performed to support recovery of Pacific salmon (*Oncorhynchus* spp.) that inhabit these ecosystems as juveniles during their outmigration from natal streams to the Pacific Ocean. For Puget Sound Chinook salmon (*O. tshawytscha*), the period of marine entry is a critical life stage in which access to abundant and high-quality invertebrate prey can determine marine survival. Successful restoration returns dynamic ecosystem processes to delta landscapes that enable establishment of macroinvertebrate communities, and in turn, produce favorable foraging conditions for juvenile salmon as well as other estuary-dependent consumers. We investigated spatial and temporal variation in terrestrial and benthic macroinvertebrate community structure in restoration and reference areas of the Stillaguamish River delta, Puget Sound, Washington State, USA. We found that high-quality invertebrate prey, including adult dipterans and other insects, polychaetes, and amphipods were abundant in restoration areas, suggesting that restoration efforts are effectively producing energy-rich prey for juvenile Chinook salmon. The largest increase in terrestrial invertebrate abundance occurred between April and May, and benthic invertebrate abundance peaked in May. We found similar terrestrial invertebrate abundance and diversity across the delta. Restoration

areas had higher benthic invertebrate abundance and greater diversity of marine-associated taxa than reference areas. Our results will provide a useful comparison as current restoration sites age and as new restoration projects are completed in the future.

## **INTRODUCTION**

River deltas and connected intertidal wetland habitats are positioned at the interface of land and sea, where freshwater and saltwater combine. Estuary ecosystems are culturally significant for many communities and support coastal economies through a variety of ecosystem services (Bassett et al., 2013; Huppert et al., 2003; Thrush et al., 2013). The diverse array of ecological benefits they provide includes carbon sequestration (Chmura et al., 2003), storm buffering (Fairchild et al., 2021; Sheaves et al., 2015), enhancement of coastal fisheries (Jänes et al., 2020), and filtration and uptake of land-based nutrient runoff (Jickells, Andrews, and Parkes 2016). Habitat degradation and loss driven by coastal development are serious threats to estuarine ecosystems globally (Defeo and Elliott, 2021; Halpern et al., 2008; Lotze et al., 2006). For river deltas specifically, agricultural land-conversion is the primary anthropogenic driver of habitat loss on a global scale (Murray et al., 2022). Restoration has been prioritized as a strategy to address loss, fragmentation, and degradation of these ecologically important systems (Kennish, 2022; Lotze et al., 2006; Murray et al., 2022). A guiding goal for restoration in river delta and intertidal wetland habitats is to return to dynamic ecosystem processes that have been modified by development and other anthropogenic impacts. For instance, agricultural dikes are often built when delta habitats are converted to farmland, which blocks tidal inundation and fluvial flooding processes important for water and sediment transport throughout deltas (Syvitski and Saito, 2007). Return of dynamic processes is necessary to restore ecological function for

target species and create conditions for self-sustaining ecosystems (Simenstad, Reid, and Ford 2006). The return and long-term persistence of dynamic processes brought about through restoration creates a shifting habitat mosaic of structural complexity and biological heterogeneity important to ecological function (Bellmore et al., 2013; Stanford, Lurang, and Heaur 2017).

Restoration effectiveness is commonly evaluated by monitoring abiotic and biotic factors following the return of dynamic ecosystem processes (Roni et al., 2019). Common biotic metrics include the productivity and biodiversity of invertebrate communities (Borges et al., 2021; Castella et al., 2015; Kerans and Karr, 1994). Invertebrates are often first to respond to the environmental changes that accompany restoration; therefore, comparing invertebrate community structure among areas of different restoration status can be informative. The return of tidal inundation, freshwater transport, and sediment deposition following river delta restoration can change salinity, sediment texture and accretion rates, and vegetation (Barrett and Niering, 1993; Hood, 2004; Jongepier et al., 2015). These changes in habitat conditions can drive changes in invertebrate community structure; for instance, arthropods, annelids, and mollusks can quickly colonize new habitats created during restoration due to their small body sizes, quick generation times, and occupation of a variety of niches (Barton and Moir, 2015). Research has demonstrated that immediately following dike breaching and channel excavation, invertebrate productivity, density, biomass, and biodiversity have increased in restored estuarine river deltas (Cordell et al., 1998, Ellings et al., 2016; Rubin et al., 2024; Woo et al., 2017). Monitoring invertebrate community composition and dynamics can help researchers understand how successfully a restoration site returns dynamic processes to an ecosystem. Further, these understandings provide insights on the base of the food web that species of conservation concern depend on for prey.

Over the past century, 85% of vegetated tidal wetlands along the west coast of the United States have been lost, and this rate of loss is even greater in the Salish Sea, where estuaries and river deltas have decreased in area by approximately 95% (Brophy et al., 2019). The Puget Sound is located within the Salish Sea, and conversion of delta habitats for agricultural purposes is among the top three land development activities contributing to the loss of Puget Sound river deltas (Simenstad et al., 2011). Loss of tidal wetland habitat negatively impacts a diverse group of consumers that use river deltas as foraging habitat. Native bat populations feed on nocturnal flying insects at land-water edge habitats (Hayes and Wiles, 2013) and migrating waterfowl and resident shorebirds depend on deltas for adequate prey resources, including aquatic insects and invertebrates (Michel et al., 2021). Juvenile Pacific salmon (*Oncorhynchus* spp.) use estuaries as nursery habitat on their out-migration from natal streams to the ocean (Simenstad, Fresh, and Salo 1982; Quinn, 2018). For Chinook salmon (*O. tshawytscha*), the marine entry period is considered a critical life stage where growth in estuaries can determine overwinter survival during the first year of life and marine survival overall (Beamish and Mahnken, 2001; Beamish, Mahnken, and Neville 2004; Duffy and Beauchamp, 2011). Access to abundant, high-quality prey, including macroinvertebrates, terrestrial insects, and marine-derived invertebrates is crucial for optimal nutrition and growth during the marine entry period (Chamberlin et al., 2022; Cordell et al. 2011; Woo et al., 2019). The significance of Puget Sound river deltas for Pacific salmon, and for juvenile ocean-type Chinook specifically, is a key motivator behind restoration efforts in the region (Fresh, 2006).

Eight species of salmonids use the Stillaguamish River, the focal watershed of this study, including Puget Sound Chinook salmon, which are listed as threatened under the Endangered Species Act (Cereghino et al., 2012; SIRC, 2005; Krosby et al., 2016; 50 CFR §223-224, 1999).

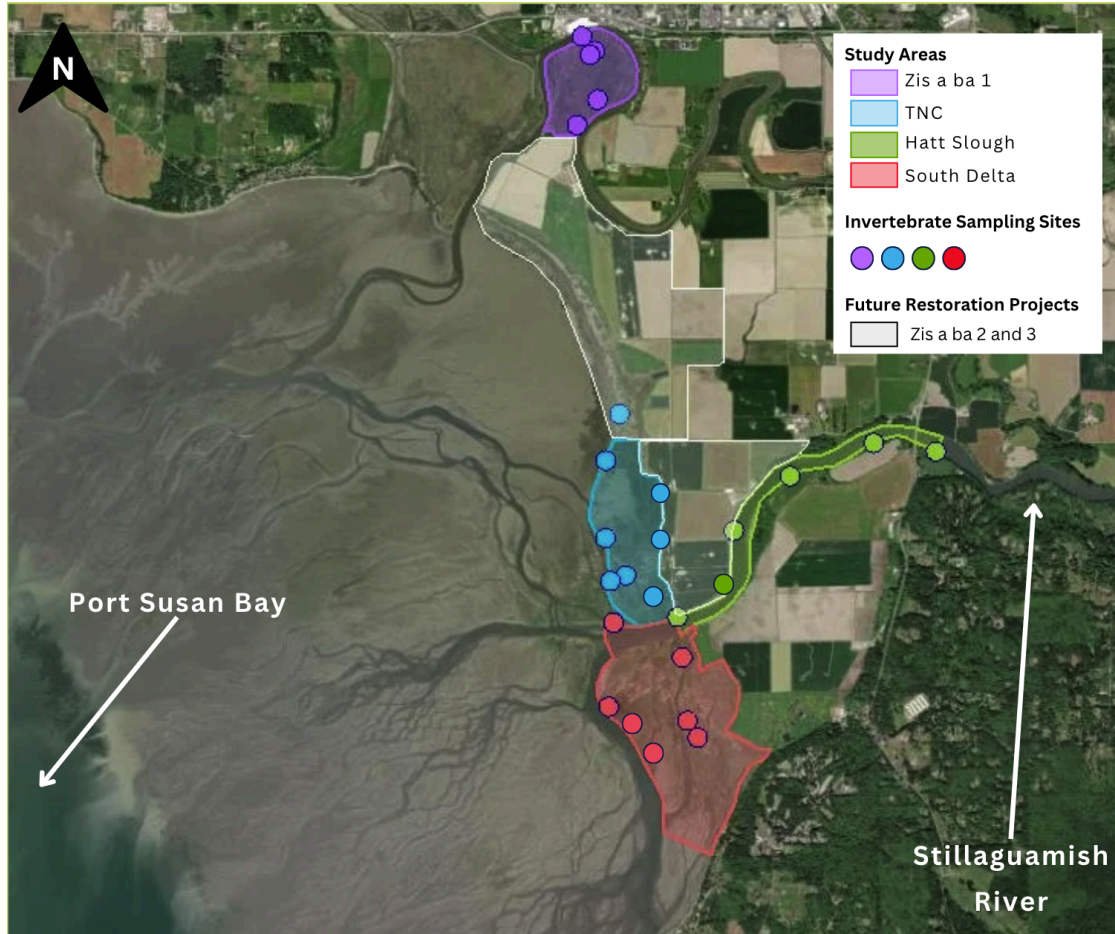
Stillaguamish Chinook are one of the most imperiled populations of Puget Sound Chinook and low populations levels have led to closures of subsistence and commercial harvest for the Stillaguamish Tribe (Stillaguamish Tribe, 2025; Puget Sound Indian Tribes and WDFW, 2022). Loss and degradation of rearing habitat is recognized in the Stillaguamish Watershed Recovery Plan as a factor affecting Chinook salmon populations (SIRC, 2005). The Stillaguamish River delta is also an important stop for migrating birds along the Pacific Flyway and was designated as a site of regional importance in 2012 by the Western Hemisphere Shorebird Reserve Network (Michel et al., 2021).

In this study, we investigated terrestrial and benthic invertebrate community structure in the Stillaguamish River delta, an intertidal wetland in the Puget Sound portion of the Salish Sea, Washington State, USA, that has been undergoing large-scale active restoration since 2012 (Nowacki and Grossman, 2020). A central motivation of the study was to characterize the invertebrate community that comprises potential prey for juvenile Chinook salmon during their early marine entry period. Our research objective was to evaluate spatial and temporal variation in invertebrate abundance, diversity, and community composition. Specifically, we tested for differences in these ecological metrics across sampling months and among areas that differ in restoration status. We interpreted results in the context of spatial and temporal patterns in environmental conditions throughout the delta. Measuring environmental factors associated with bottom-up ecological processes that drive invertebrate community dynamics is crucial to understanding restoration effects on realized function for species of conservation concern, such as juvenile Chinook salmon (Lynam et al., 2017; Pearsall et al. 2021; Rodgers et al., 2024; Simenstad and Cordell, 2000).

## **METHODS**

### *Study System*

The Stillaguamish River delta is within the traditional and contemporary homeland of the *stuləgʷábš* (People of the River), who have stewarded the lands and waters since time immemorial (Stillaguamish Tribe of Indians, 2025). The river is undammed and flow is unregulated, but due to climate change the system is shifting from snow-melt dominated to rain dominated (Mauger, 2018). Estimates place the historic vegetated extent of the Stillaguamish River delta between 2,181 and 3,124 hectares (Brophy et al., 2019; Ramirez, 2019; Simenstad et al., 2011). Today, the Stillaguamish River delta is the third largest of 16 large river deltas in Puget Sound at 911 hectares (Simenstad et al., 2011; Brophy et al., 2019), but the impacts of Euro-American settlement and on-going land conversion on habitat quantity and quality are stark. Land-use demand for agriculture and residential development is high in the Whidbey Basin where the delta is located, and these pressures have driven extensive habitat loss (Cereghino et al., 2012). Historically, the Stillaguamish, Skagit, and Snohomish sub-basins of the Whidbey Basin accounted for 70% of tidal delta habitat in Puget Sound (Cereghino et al., 2012). Today, an estimated 69% of vegetated tidal wetland area has been lost in the Stillaguamish sub-basin (Simenstad et al., 2011).



**Figure 1.** Map of the Stillaguamish River delta and study areas represented by different colored polygons (purple = zis a ba 1; blue = TNC; green = Hatt Slough; red = South Delta). Invertebrate sampling sites are marked by circles that are color coded by area. White outlined polygons represent the location of restoration projects planned for construction beginning summer 2025.

To identify landscape-scale patterns in invertebrate communities across the delta, four areas of varying restoration status, position along the estuary’s salinity gradient, and connectivity to the freshwater source of the Stillaguamish River delta were included in this study: the Stillaguamish Tribe’s zis a ba 1 restoration area (zis a ba 1), The Nature Conservancy’s Port Susan Bay restoration area (TNC), Hatt Slough (currently the mainstem outlet of the

Stillaguamish river), and South Delta (Figure 1). Both zis a ba 1 and TNC are restoration projects working to restore ecosystem processes in areas that were converted for agriculture development.

The zis a ba 1 area, bordered by the Old Stillaguamish mainstem and Port Susan Bay, was restored in 2018 and includes 35 hectares of intertidal habitat located at the northern reach of the delta (Washington State Recreation and Conservation Office, 2025a). The restoration project's namesake is Chief zis a ba of the sp-la-tum village originally located near present-day Warm Beach, Snohomish County (Stillaguamish Tribe of Indians, 2025). Tidal inundation was returned to the former farmland with the removal of a perimeter dike and excavation of an interior blind tidal channel network. The site's vegetation is characterized by native emergent marsh species in the interior, and expanding shrub communities on remaining exterior dikes.

The TNC area is 60 hectares and is located in the central delta, positioned directly north of the Stillaguamish River mouth (i.e. Hatt Slough; Washington State Recreation and Conservation Office, 2025b). The farmland once present at the TNC area has undergone a two-phase restoration process: in 2012 a perimeter dike was removed to the level of the marshplain and breached in two seaward-facing locations to recover tidal exchange. A new setback dike was constructed to protect farmland eastward of the site. Between 2012 and 2023, the TNC restoration site did not have direct hydrological connection to the Stillaguamish River. In 2023, an interior pilot channel system and a distributary channel network were excavated to improve hydrologic connectivity within the restoration area and to recover direct connectivity to the Stillaguamish River (Shaw, 2020). The area is characterized by dense, native emergent marsh vegetation, as well as an expanding native-non-native hybrid cattail (*Typha angustifolia*-*Typha latifolia*) community.

The Hatt Slough area comprises the tidally influenced reach of the Stillaguamish River's mainstem and outflow into the estuary. Due to the configuration of the dike and levee system, discharge from Hatt Slough currently flows southwestward into Port Susan Bay, away from tidal marshes in the northern margins of the bay (Yang et al., 2010). The riverbanks along Hatt Slough are characterized by an older rip-rap levee system, a narrow band of intermittent native and non-native riparian trees and shrubs, but a lack of riparian floodplain.

The South Delta area includes a large, intact reference marsh area consisting of a complex of intertidal channels and marsh islands vegetated with native emergent marsh species located south of the Stillaguamish River mouth. Tidal inundation and freshwater distribution processes have remained unconstrained over time in this area, as it has never undergone land conversion.

### *Field Sampling*

We sampled terrestrial and benthic invertebrates at five sites within each of the four delta areas (n = 20 sites) on a monthly basis from March through June of 2023 and 2024 (Figure 1). Sampling sites were selected to represent a range of environmental conditions (channel morphology, vegetation) within each area. A total of 160 fallout trap samples and 160 benthic core samples were collected over the study period, with 20 samples of each type collected per area each year. Between 2023 and 2024, one site was relocated in Hatt Slough and two sites were relocated in South Delta due to challenging sampling conditions with high water levels. Three sites were relocated at TNC following the 2023 channel excavations. Sites locations did not change for this area across both years. To ensure sampling conditions remained comparable across both years, all relocated 2024 sites were placed in locations as near as possible to 2023

sites with similar channel morphology and vegetation cover.

We used fallout traps to catch land-based invertebrates as they fell from overhanging vegetation onto the water's surface. Traps were deployed for 24 hours using a 40 cm × 25 cm plastic bin containing a small amount of soapy water. Each bin was placed on a level stand secured in the marsh bed and attached to four 1-inch PVC poles using metal rings. The top rim of each bin was wrapped in foam to ensure level flotation during high tide. After the 24-hour period, bin contents were poured through a 106 µm sieve and preserved in 70% isopropanol to be returned to the laboratory for processing. We used benthic cores to collect epi-benthic and benthic invertebrates from the surface and top layer of sediment. Cores were taken at the marsh side of channel-edges in areas submerged during high tide using a 2-inch diameter PVC plastic-corer taken to a depth of approximately 10 cm. Contents were preserved in 10% buffered formalin and returned to the laboratory for processing.

For the purposes of this study, 'benthic invertebrates' refers to organisms collected using benthic cores and includes aquatic taxa living within and on the surface of sediment submerged in estuary waters during high tide. Benthic taxa included insects with aquatic larval, pupal, and nymphal life stages, worms, amphipods, isopods, copepods, bivalves, and gastropods.

'Terrestrial invertebrates' refers to organisms collected using fallout traps and includes invertebrates that live on land and enter estuary waters by falling off overhanging vegetation. Terrestrial taxa included insects with terrestrial adult life stages, arachnids, and collembolans (springtails). Some estuarine invertebrates have life histories with aquatic and terrestrial life stages. These taxa were found in fallout traps as mature adults and benthic cores as immature larvae, pupae, and nymphs.

We recorded water temperature and salinity for each area, and channel morphology,

sediment texture, and dominant vegetation type at each site. Water temperature (°C) and salinity (ppt) data were taken on a continuous basis at 15-minute intervals using HOBO and CTD Van Essen loggers stationed at fixed long-term locations throughout the delta, and data from loggers nearest to each sample site was used. Channel morphology was classified as one of three types (mainstem, distributary, blind tidal) and determined from restoration plans and ground-truthed during field sampling. Dominant vegetation type was qualitatively assessed during field sampling at each site.

### *Sample Processing*

Fallout trap sample contents were rinsed through a 160 µm sieve and benthic core sample contents were rinsed through a 500 µm sieve to remove sediment and isopropanol and formalin. Invertebrate organisms were enumerated and identified under a dissecting microscope to the lowest possible taxonomic level and life stage using taxonomic keys (Merritt and Cummins, 1996; Stimpson, 1857; Triplehorn and Johnson, 2005; Wetzer, Wall and Bruce 2021). A subsampling method was used for two benthic core samples that contained large numbers of Oligochaeta and annelids of the genus *Manayunkia* sp. When subsampling, sample contents were rinsed through a 500 µm sieve and remaining contents were suspended in 300 mL of tap water. An aerator was used to consistently suspend sample contents in the water while 10 mL aliquots were consecutively removed with a pipet for processing under the microscope. Once a count of 200 individuals was reached for a single taxonomic group (e.g., Oligochaeta), the total volume of 10 mL aliquots containing the 200 count was recorded (e.g., 3 aliquots totaled 30 mL). The concentration (n / mL) was used to extrapolate the count of subsampled taxon for the total sample volume of 300 mL. All taxa in the sample with counts under 200 were identified and

enumerated. Sediment texture was categorized as fine/silt, coarse/sand, or cobble and recorded during benthic core sample processing.

### *Data Preparation, Visualization, and Analysis*

To prepare invertebrate data for analysis, we checked for errors and consistency in taxonomic identification. We identified most invertebrates to family level. For analysis, all taxa identified to genus or species were reclassified to the family level. For some non-insect taxa such as worms, mollusks, arachnids, and small marine crustaceans it was only possible to identify to higher taxonomic levels or phylum, class, subclass, or order. For insects with damaged bodies or early instar larva it was only possible to identify order or suborder.

Relative abundance of terrestrial and benthic invertebrates was determined as the total number of organisms per sample, which was averaged across sites for each month and area combination. We created bar plots to visualize spatial and temporal patterns in mean relative abundance. We tested for differences in the average abundance of terrestrial and benthic invertebrates between sample areas and months using a 2-way analysis of variance (ANOVA) that simultaneously tested for the effects of month and area, followed by Tukey's Honestly Significantly Difference (HSD) post-hoc test. Abundance data were normalized using a log transformation prior to statistical analysis and significance was assessed at a p-value of 0.05 (Fisher, 1992).

Taxonomic richness was used as a proxy for diversity. Taxon accumulation curves were created to visualize differences in taxonomic richness among months and areas. Sample order was randomized and resampled ( $n = 1000$  permutations) to generate a smooth curve showing

mean taxonomic richness and a 95% confidence interval around the mean. We tested for spatial and seasonal differences in the mean taxonomic richness of terrestrial and benthic invertebrates per sample using a 2-way analysis of variance (ANOVA) that simultaneously tested for the effects of month and area, followed by Tukey's Honestly Significantly Difference (HSD) post-hoc test. Richness data were normalized using a log transformation prior to performing statistical analyses and significance was assessed at a p-value of 0.05 (Fisher, 1992).

Nonmetric multidimensional scaling (NMDS) ordination plots were created to visualize differences in invertebrate community composition among areas and months. A Bray-Curtis similarity matrix generated from fourth-root transformed data was used. The NMDS was run in as many dimensions as needed to reduce stress below 20% (achieved in 3 dimensions for terrestrial and benthic invertebrates) (Clarke et al., 2014). Samples with fewer than five individual organisms were omitted from the NMDS to improve the fit of the ordination. This resulted in sample sizes of 129 benthic cores and 126 fallout traps. A permutational multivariate analysis of variance (PERMANOVA) was performed to test for pairwise differences in community composition among areas and months, using a p-value of 0.05 to assess significance (Fisher, 1992). To understand which taxa most explained differences in community composition, we overlaid vectors showing taxa with moderate to strong correlations ( $R^2 > 0.4$ ) with the NMDS scores. Stacked bar plots were created to visualize patterns in community composition and differences in proportional abundance of taxa among areas (averaged over months and years) and months (averaged over areas and years).

We calculated a monthly average for measurements of salinity and water temperature across sites and year for zis a ba 1, South Delta and Hatt Slough. To account for landscape

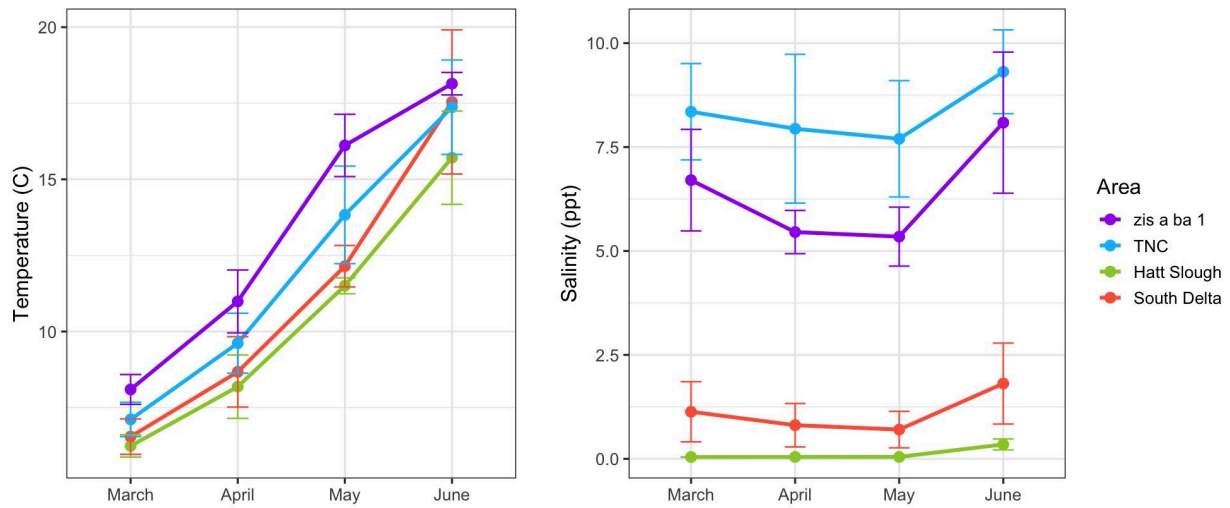
changes that occurred between sample years at TNC, water temperature and salinity averages were calculated across sites and separately for 2023 and 2024.

## **RESULTS**

### *Overview of Environmental Conditions*

Average water temperature increased from March to June in all areas. During all months, temperatures were highest at zis a ba 1, intermediate at TNC and South Delta, and lowest at Hatt Slough (Figure 2). During June, average water temperature was highest at TNC (2024), at similar intermediate levels at zis a ba 1 and South Delta, and at similar low levels at Hatt Slough and TNC (2023). Average salinity levels were higher at TNC and zis a ba 1 than at South Delta and Hatt Slough, and peaked during June in all four areas (Figure 2).

Channel morphology types associated with sampling sites varied among the four delta areas, with zis a ba 1 and TNC sites located on majority blind tidal channels, Hatt Slough sites along the river mainstem, and South Delta sites on majority distributary channels (Table 1). The dominant vegetation type associated with sites varied between the four delta areas (Table 1). Mixohaline (brackish) emergent grasses, sedges, and bulrushes occurred at all sites in zis a ba 1. Mixohaline (brackish) emergent grasses, and sedges occurred at all sites in TNC. Five species groups of woody riparian trees and shrubs occurred at all sites in Hatt Slough. Mixohaline (brackish) emergent sedges, bulrushes, and cattails occurred at four of the sites at South Delta and woody riparian shrubs with invasive species understory occurred at the one remaining site. Sediment at zis a ba 1 and TNC was characterized as fine silt. South Delta sediment was characterized as coarse sand. Hatt Slough sediment was characterized as a combination of coarse sand and cobble.



**Figure 2.** Monthly mean water temperature (degrees Celsius; left) and salinity (parts per thousand; right) averaged across all sample sites and years. Different colors correspond to area (green = Hatt Slough, red = South Delta, blue = TNC, purple = zis a ba 1), points represent the monthly average across all sites, and error bars represent 1 standard error.

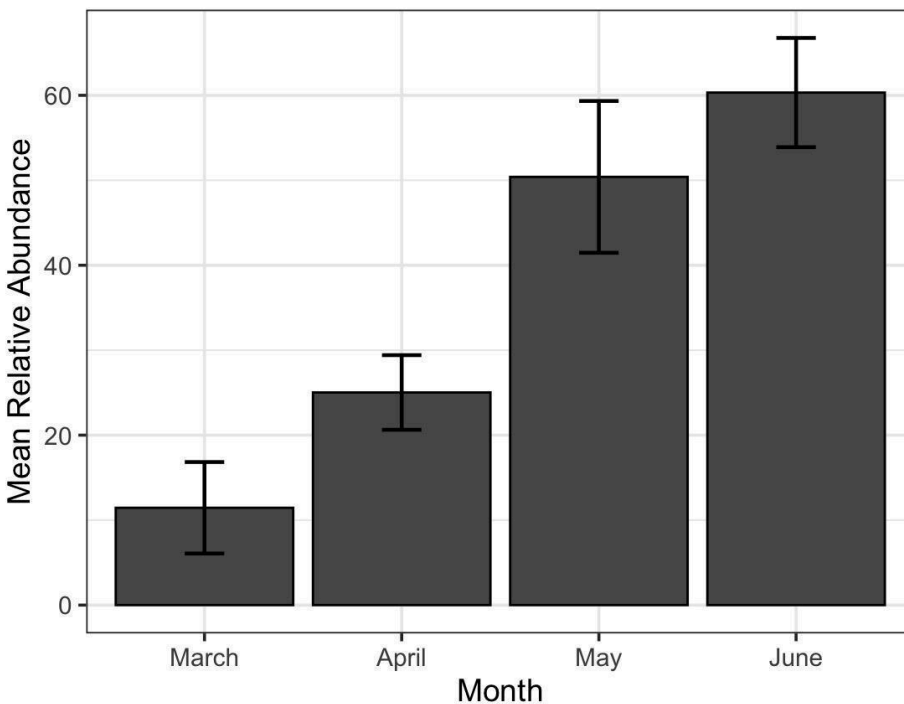
**Table 1.** Description of environmental conditions associated with sample sites in each delta area.

Delta Area	Sediment Texture	Channel Morphology (n sites)	Vegetation Cover (n sites)
zis a ba 1	Fine silt	blind-tidal (4); distributary (1)	mixohaline (brackish) emergent (5)
TNC	Fine silt	blind-tidal (5)	mixohaline (brackish) emergent (5)
South Delta	Coarse sand	distributary (4); blind-tidal (1)	mixohaline (brackish) emergent (4); riparian (1)
Hatt Slough	Coarse sand; Cobble	mainstem (5)	riparian (5)

*Spatiotemporal patterns of relative abundance*

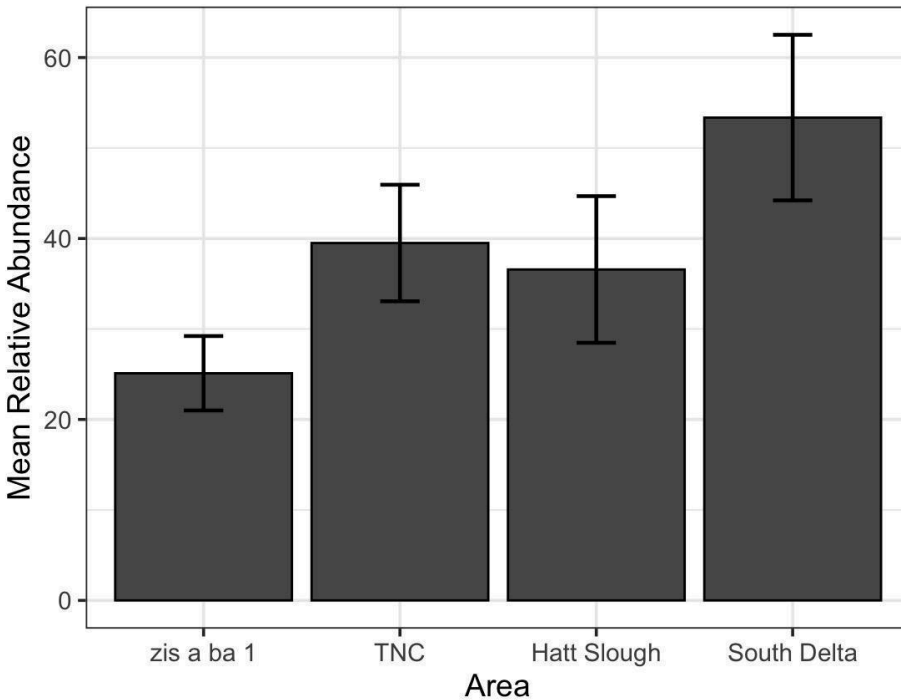
## Terrestrial invertebrates

The mean abundance of terrestrial invertebrates increased from March (Mean  $\pm$  SE:  $11 \pm 5 \text{ trap}^{-1}\text{day}^{-1}$ ) to June ( $60 \pm 6 \text{ trap}^{-1}\text{day}^{-1}$ ). The largest increase in mean relative abundance occurred between April and May (Figure 3). Mean relative abundance of terrestrial invertebrates varied between the four delta areas, from lowest at zis a ba 1 ( $25 \pm 4 \text{ trap}^{-1}\text{day}^{-1}$ ), intermediate at Hatt Slough ( $36 \pm 8 \text{ trap}^{-1}\text{day}^{-1}$ ) and TNC ( $40 \pm 6 \text{ trap}^{-1}\text{day}^{-1}$ ), and highest at South Delta ( $53 \pm 9 \text{ trap}^{-1}\text{day}^{-1}$ ) (Figure 4). Mean relative abundance of terrestrial invertebrates differed significantly among months (ANOVA:  $df = 3$ ,  $F = 38.5$ ,  $p\text{-value} = < 2e^{-16}$ ). Mean relative abundance of terrestrial invertebrates was significantly different between all month-pairs except between May and June (Tukey's HSD:  $p\text{-value} = 0.272$ ). Mean relative abundance of terrestrial invertebrates did not differ among areas ( $df = 3$ ,  $F = 2.04$ ,  $p\text{-value} = 0.111$ ).



**Figure 3.** Mean relative abundance of terrestrial invertebrates by month, averaged across

sites, areas, and years. Error bars show 1 standard error.

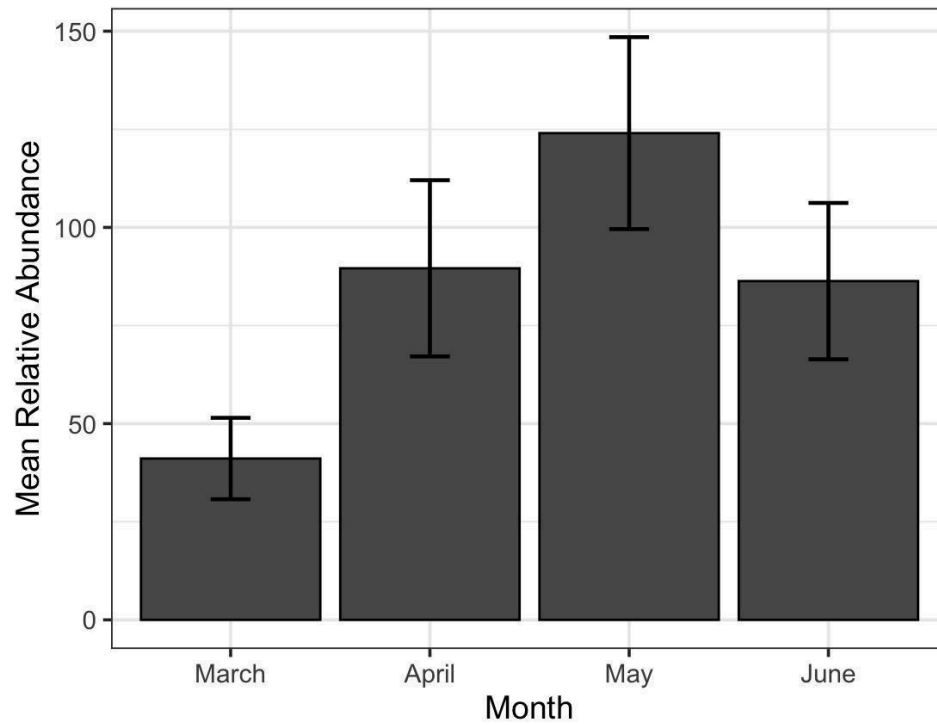


**Figure 4.** Mean relative abundance of terrestrial invertebrates by area, averaged across sites, months, and years. Error bars show 1 standard error.

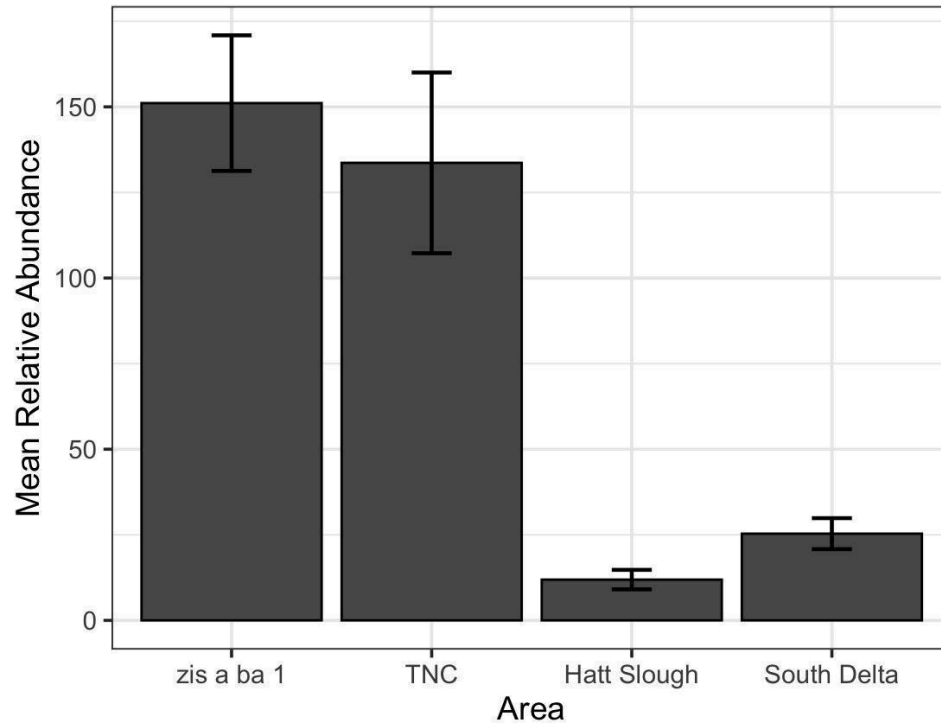
### Benthic Invertebrates

The mean relative abundance of benthic invertebrates increased from March (Mean  $\pm$  SE:  $41 \pm 10$  core<sup>-1</sup>day<sup>-1</sup>) to May ( $124 \pm 24$  core<sup>-1</sup>day<sup>-1</sup>) before decreasing in June ( $86 \pm 20$  core<sup>-1</sup>day<sup>-1</sup>) (Figure 5). Mean relative abundances were highest at restoration areas (zis a ba 1:  $151 \pm 20$  core<sup>-1</sup>day<sup>-1</sup>, TNC:  $134 \pm 26$  core<sup>-1</sup>day<sup>-1</sup>) and lower at South Delta ( $25 \pm 5$  core<sup>-1</sup>day<sup>-1</sup>) and Hatt Slough ( $12 \pm 3$  core<sup>-1</sup>day<sup>-1</sup>) (Figure 6). Mean relative abundance of benthic invertebrates differed significantly among months (ANOVA: df = 3, F = 5.07, p-value = 0.002). Mean relative abundance of benthic invertebrates differed significantly between March and May (Tukey's HSD: p-value = 0.013), and between March and June (p-value =

0.002). Mean relative abundance of benthic invertebrates differed among areas (ANOVA:  $df = 3$ ,  $F = 44.507$ ,  $p\text{-value} = < 0.0001$ ). Mean relative abundance of benthic invertebrates differed significantly among all areas except between zis a ba 1 and TNC.



**Figure 5.** Mean relative abundance of benthic invertebrates by month, averaged across sites, areas, and years. Error bars show 1 standard error.



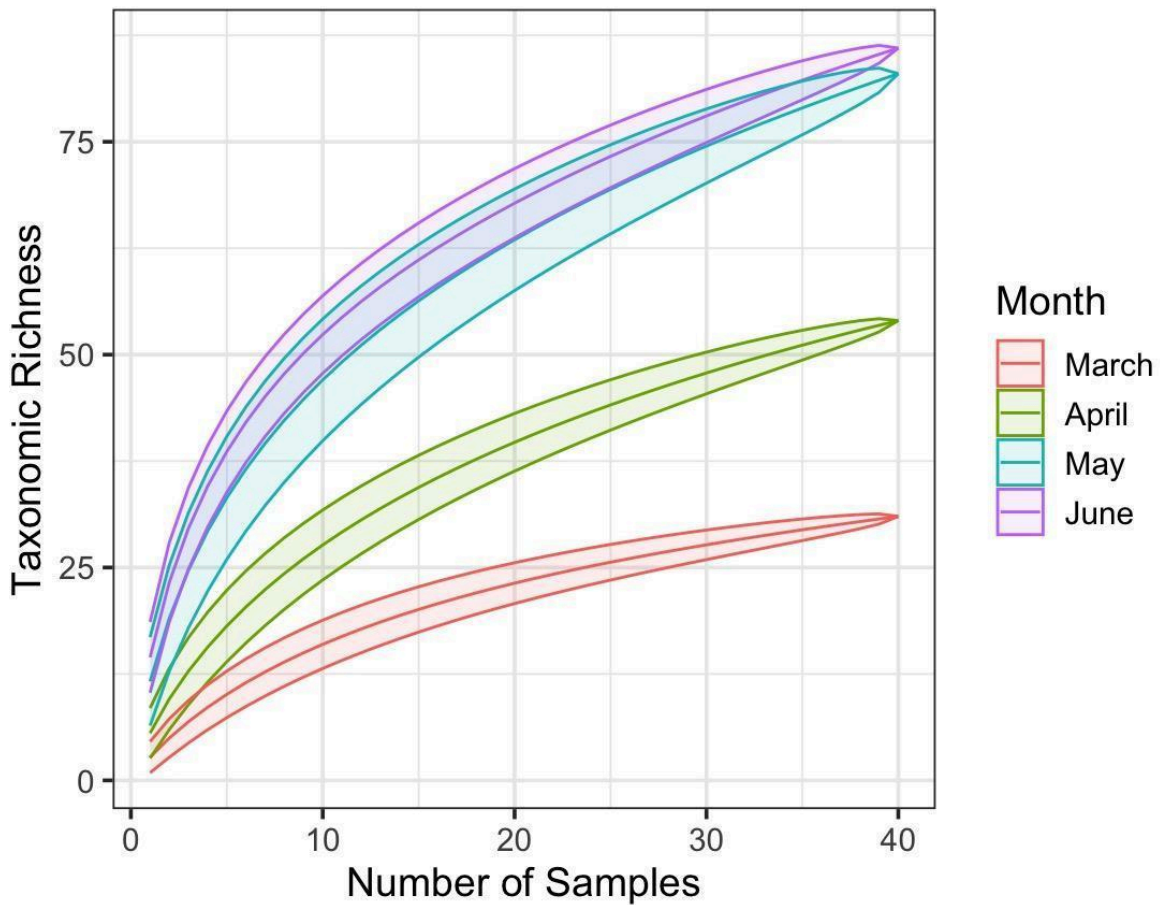
**Figure 6.** Mean relative abundance of benthic invertebrates by area, averaged across sites, months, and years. Error bars show 1 standard error.

### *Spatiotemporal patterns of taxonomic richness*

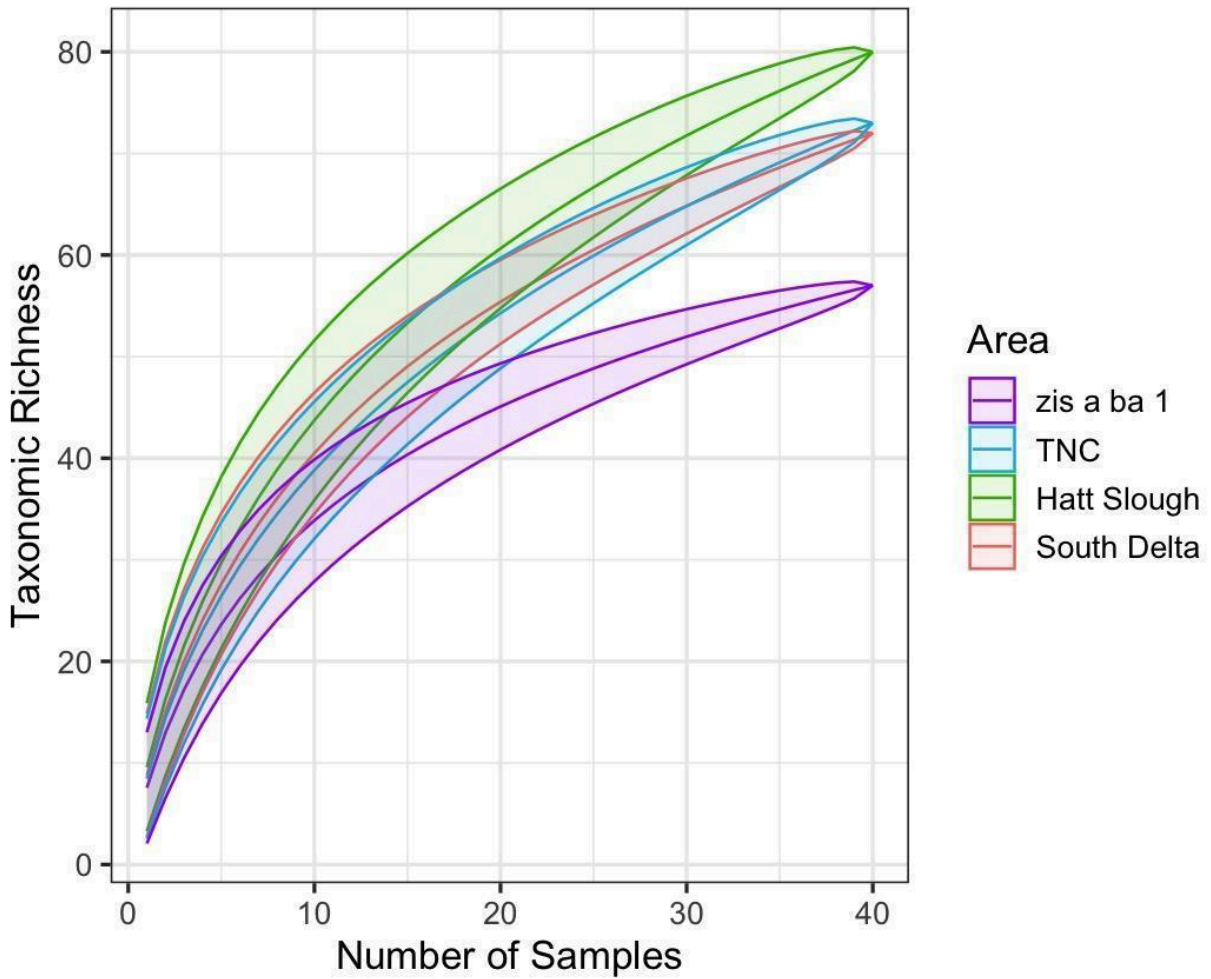
#### Terrestrial Invertebrates

A total of 113 taxa were identified in fallout trap samples collected during the study period. The taxon accumulation curves show that taxonomic richness increased with sample size (Figure 7; Figure 8). Taxonomic richness was low during March, intermediate during April, and similarly high during May and June (Figure 7). Mean richness of terrestrial invertebrates per sample differed among months (ANOVA:  $df = 3$ ,  $F = 71.836$ ,  $p\text{-value} < 0.0001$ ). Mean richness of terrestrial invertebrates per sample differed significantly among all months except between May and June, based on Tukey's HSD. Taxonomic richness was low at zis a ba 1, intermediate at TNC and South Delta, and high at Hatt Slough (Figure 8). Mean

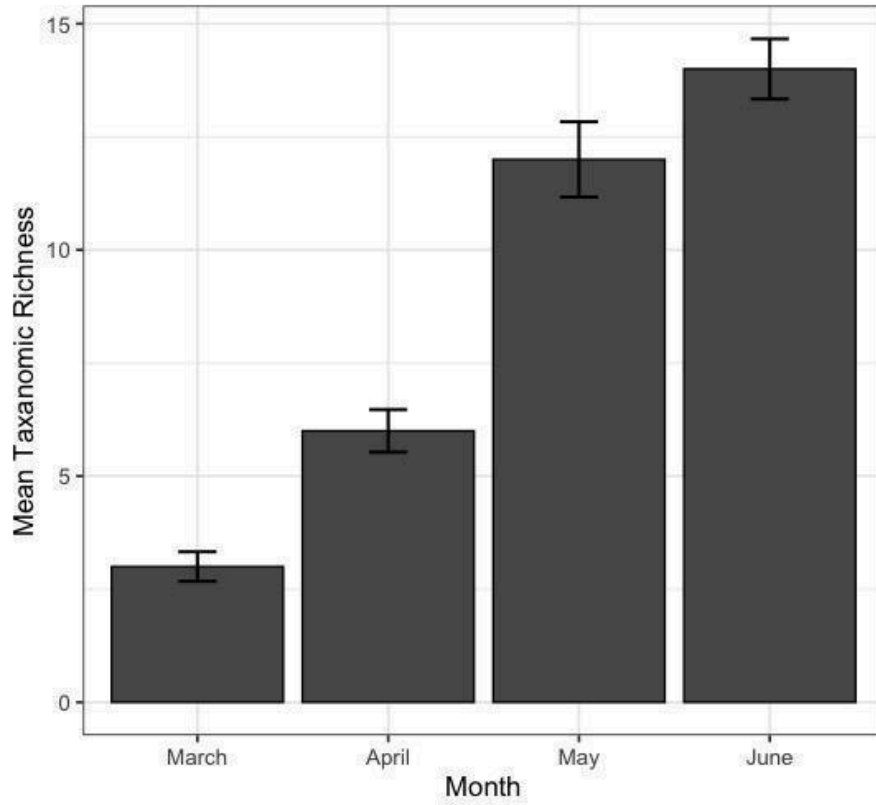
richness of terrestrial invertebrates per sample did not differ among areas ( $df = 3, F = 2.006, p\text{-value} = 0.116$ ). No taxon accumulation curves reached an asymptote, suggesting a larger sample size would be required to exhaustively sample all benthic taxa present in the Stillaguamish River delta during spring months.



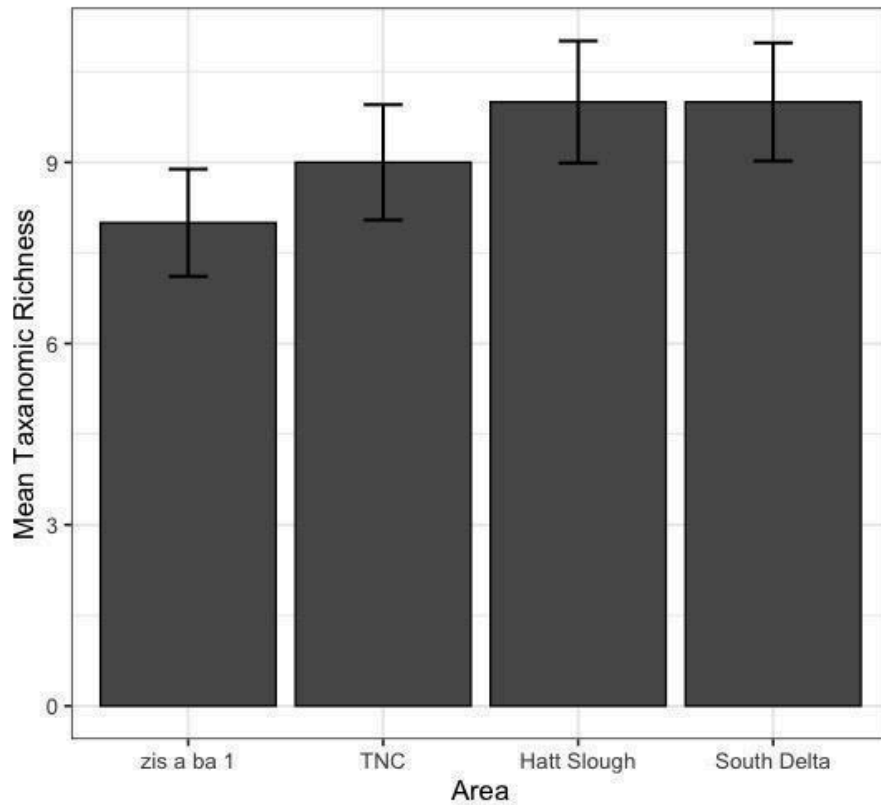
**Figure 7.** Taxon accumulation curves showing the cumulative number of terrestrial taxa identified for each additional sample processed. Sample order was randomized and resampled to generate a smooth curve; the solid line is the mean taxonomic richness per sample size and the shaded band is the 95% confidence interval of 1000 permutations. Colors represent different months.



**Figure 8.** Taxon accumulation curves showing the cumulative number of terrestrial taxa identified for each additional fallout trap sample processed. Sample order was randomized and resampled to generate a smooth curve; the solid line is the mean taxonomic richness per sample size and the shaded band is the 95% confidence interval of 1000 permutations. Colors represent different delta areas.



**Figure 9.** Monthly mean taxonomic richness of terrestrial invertebrates per fallout trap sample, averaged across site, area, and year. Error bars show 1 standard error.

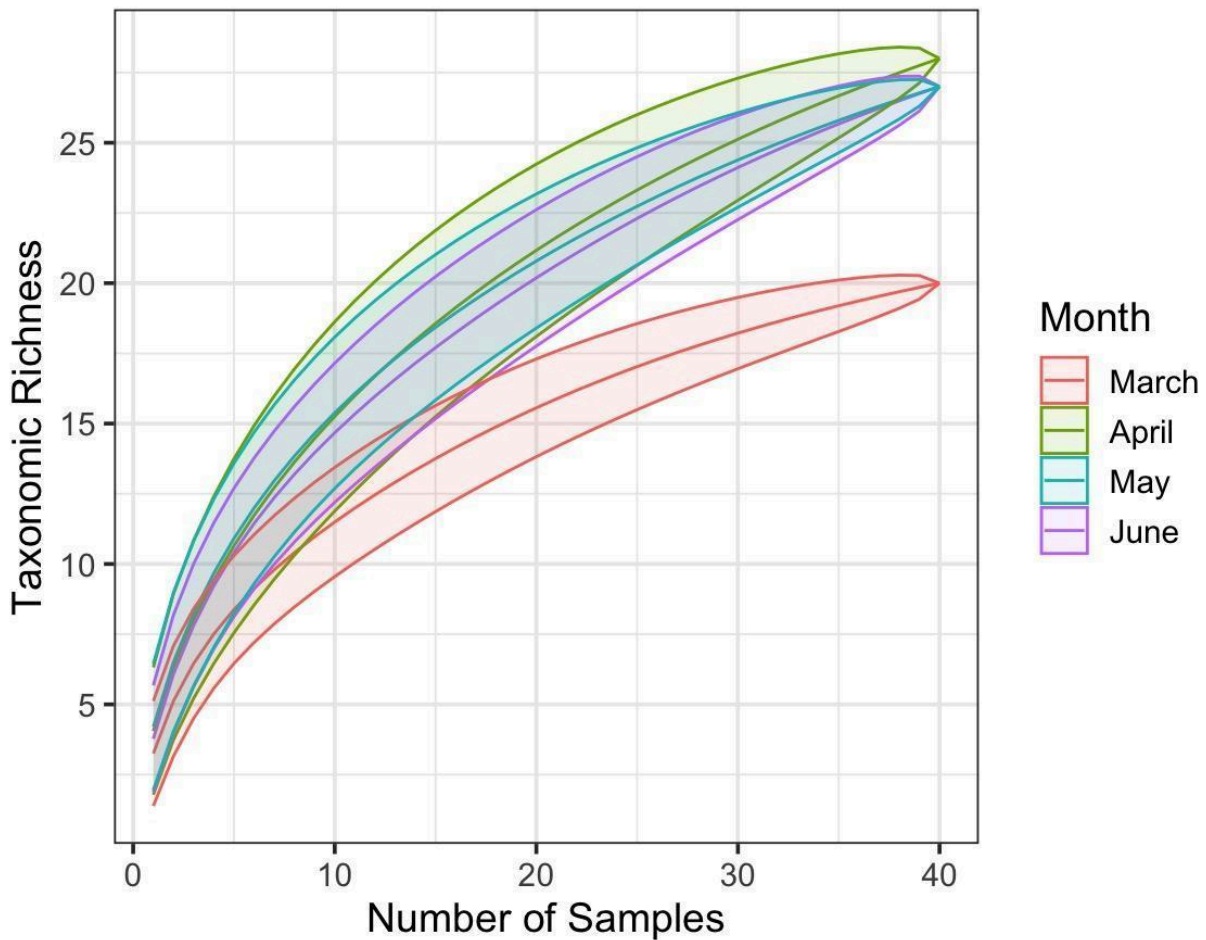


**Figure 10.** Mean taxonomic richness of terrestrial invertebrates per fallout trap sample for each area, averaged across site, month, and year. Error bars show 1 standard error.

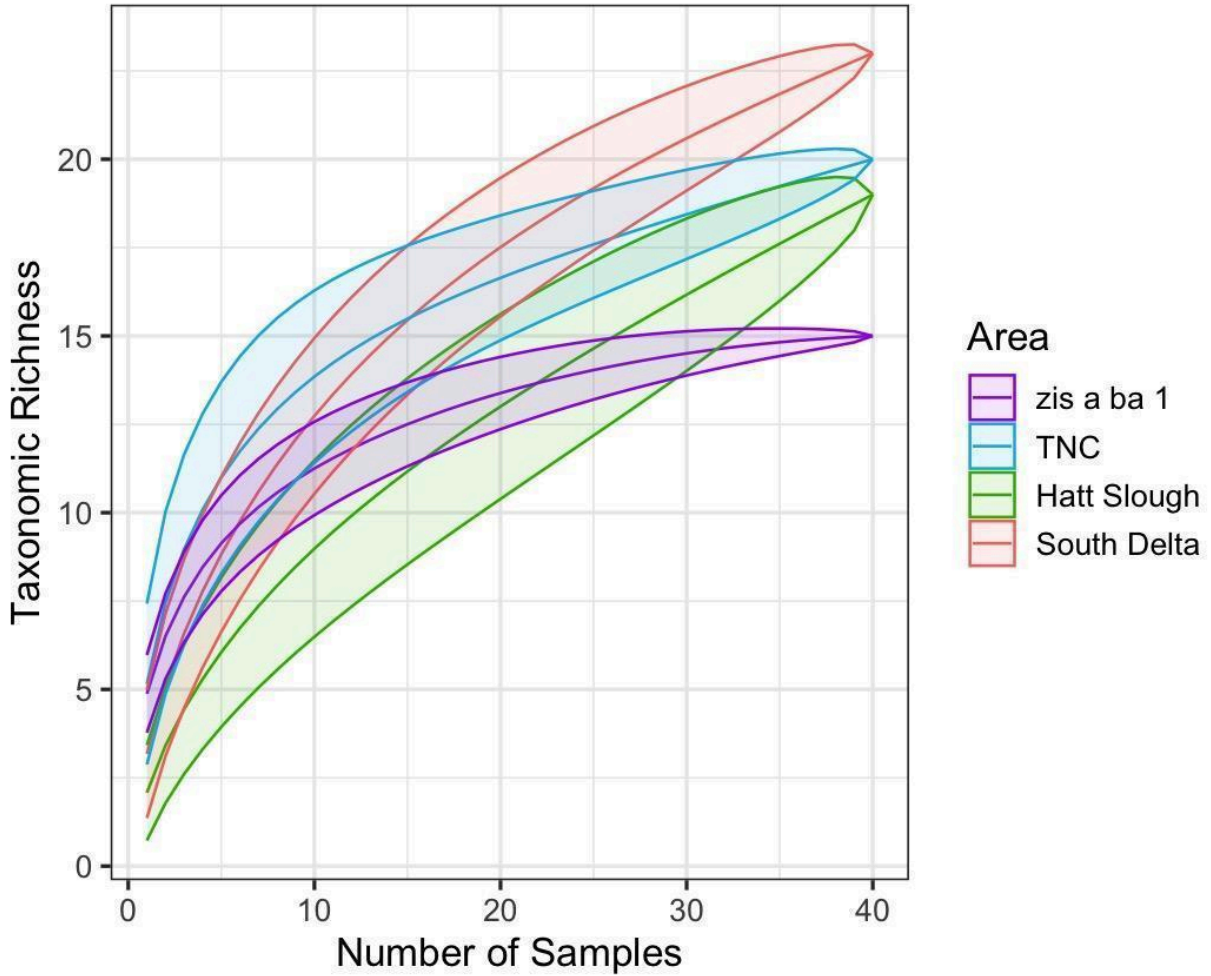
### Benthic Invertebrates

A total of 33 taxa were identified in all benthic core samples collected during the study period. The taxon accumulation taxa curves show that benthic taxonomic richness increased with sample size (Figure 11; Figure 12). Taxonomic richness was low during March and similarly high during April, May, and June (Figure 11). Mean richness of benthic invertebrates per sample differed among months ( $df = 3$ ,  $F = 2.51$ ,  $p\text{-value} = 0.033$ ). Mean richness of benthic invertebrates per sample differed significantly between March and May (Tukey's HSD:  $p\text{-value} = 0.047$ ) but no other month pairs. Taxonomic richness was low at zis a ba 1, intermediate at Hatt Slough and TNC, and high at South Delta (Figure 12). Mean

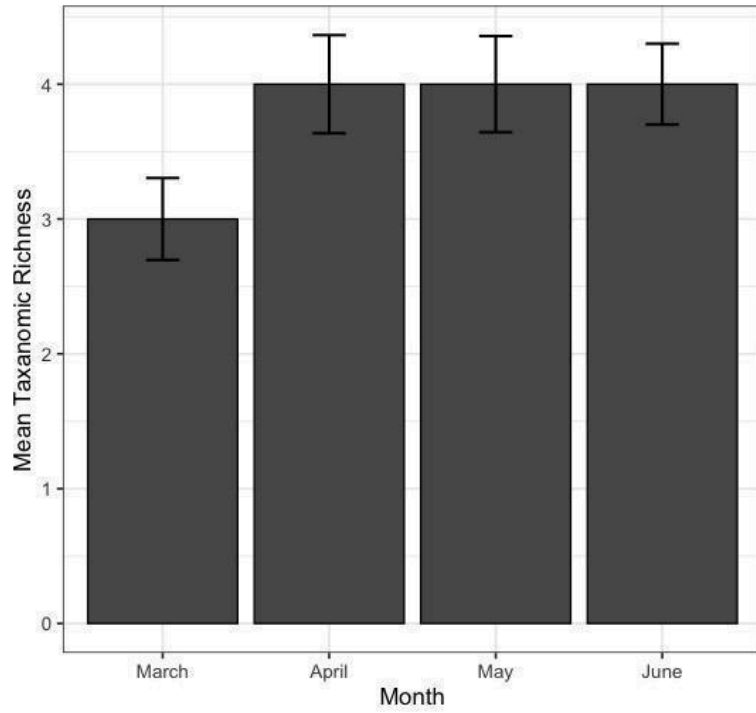
richness of benthic invertebrates per sample differed among areas (ANOVA:  $df = 3$ ,  $F = 27.71$ ,  $p\text{-value} < 0.0001$ ). All areas differed significantly except between zis a ba 1 and TNC (Tukey's HSD:  $p\text{-value} = 0.999$ ). All taxon accumulation curves do not reach an asymptote suggesting a larger sample size would be required to exhaustively sample all benthic taxa present in the Stillaguamish River delta during spring months.



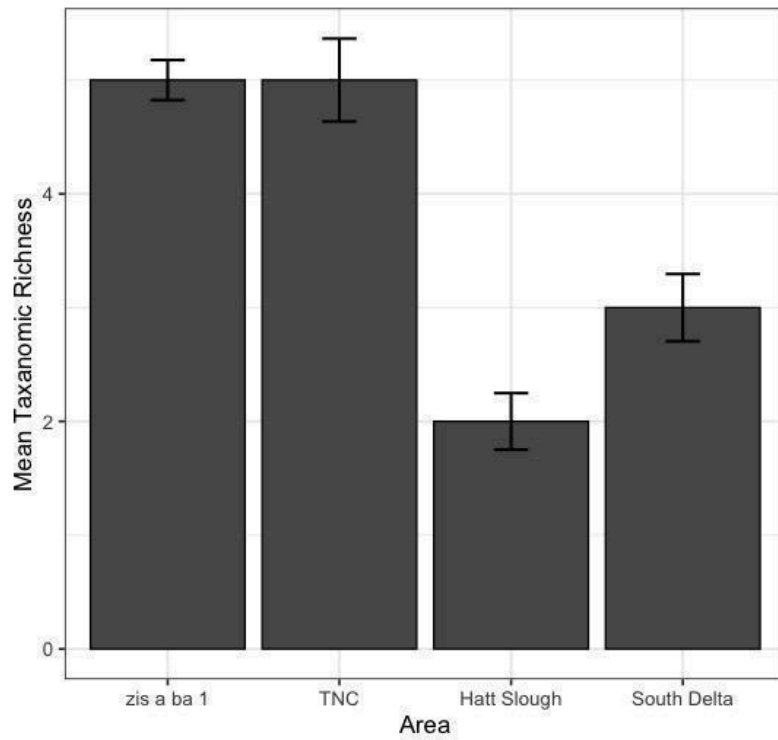
**Figure 11.** Taxon accumulation curves showing the cumulative number of benthic taxa identified for each additional sample processed. Sample order was randomized and resampled to generate a smooth curve; the solid line is the mean taxonomic richness per sample size and the shaded band is the 95% confidence interval of 1000 permutations. Colors represent different months.



**Figure 12.** Taxon accumulation curves showing the cumulative number of benthic taxa identified for each additional sample processed. Sample order was randomized and resampled to generate a smooth curve; the solid line is the mean taxonomic richness per sample size and the shaded band is the 95% confidence interval of 1000 permutations. Colors represent different areas.



**Figure 13.** Monthly mean taxonomic richness of benthic invertebrates per benthic core sample, averaged across site, area, and year. Error bars show 1 standard error.



**Figure 14.** Mean taxonomic richness of benthic invertebrates per benthic core sample for each area, averaged across site, month, and year. Error bars show 1 standard error.

*Spatiotemporal patterns of community composition*

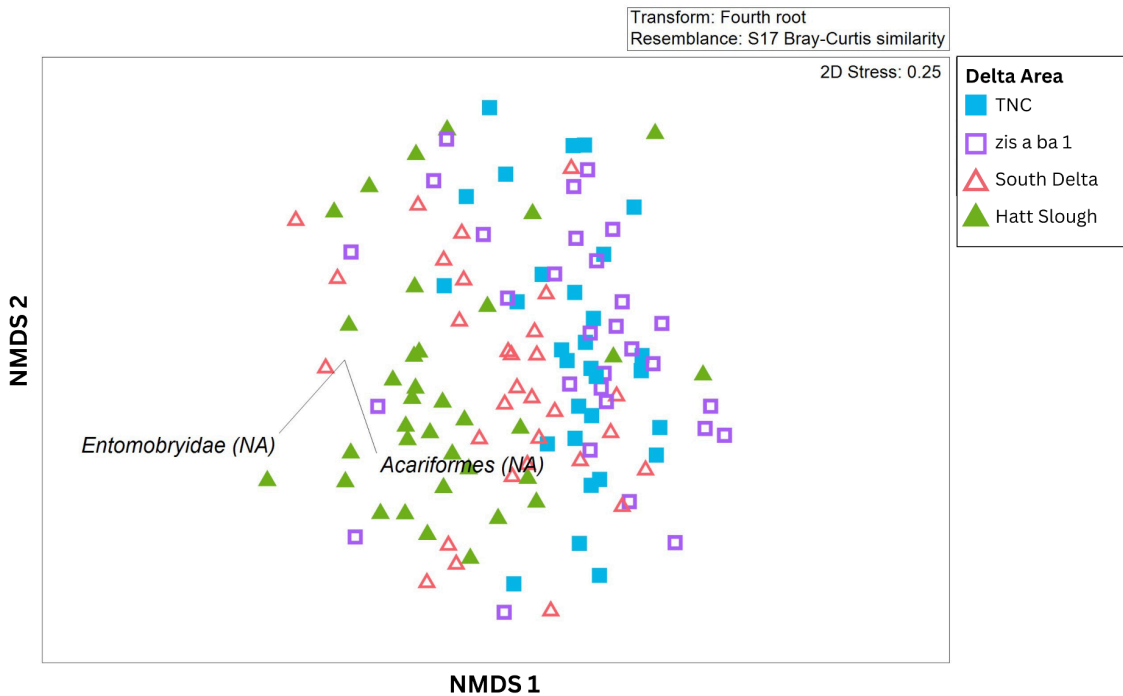
Terrestrial Invertebrates

The NMDS provided a good representation of terrestrial invertebrate community structure in three dimensions based on a stress value of 0.19 (Figure 15). The 2D ordination plots indicated some differentiation among areas overall (Figure 15) and areas within months (Figure A1). The results of the PERMANOVA indicate that during March, community composition did not differ significantly among areas (Table 2). During April, Hatt Slough community composition differed significantly from all other delta areas (p-value < 0.05) and zis a ba 1 and South Delta had significantly different community composition (p-value = 0.04; Table 2). During May and June, community composition was significantly different among areas except between zis a ba 1 and TNC (Table 2).

**Table 2.** PERMANOVA results for terrestrial invertebrates. P-values indicating a significant difference are shaded.

Area Pairs	March		April		May		June	
	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value
Hatt Slough - TNC	1.188	0.227	1.903	0.002	2.169	0.001	1.974	0.001
Hatt Slough - South Delta	0.903	0.849	1.544	0.009	1.638	0.002	1.583	0.009

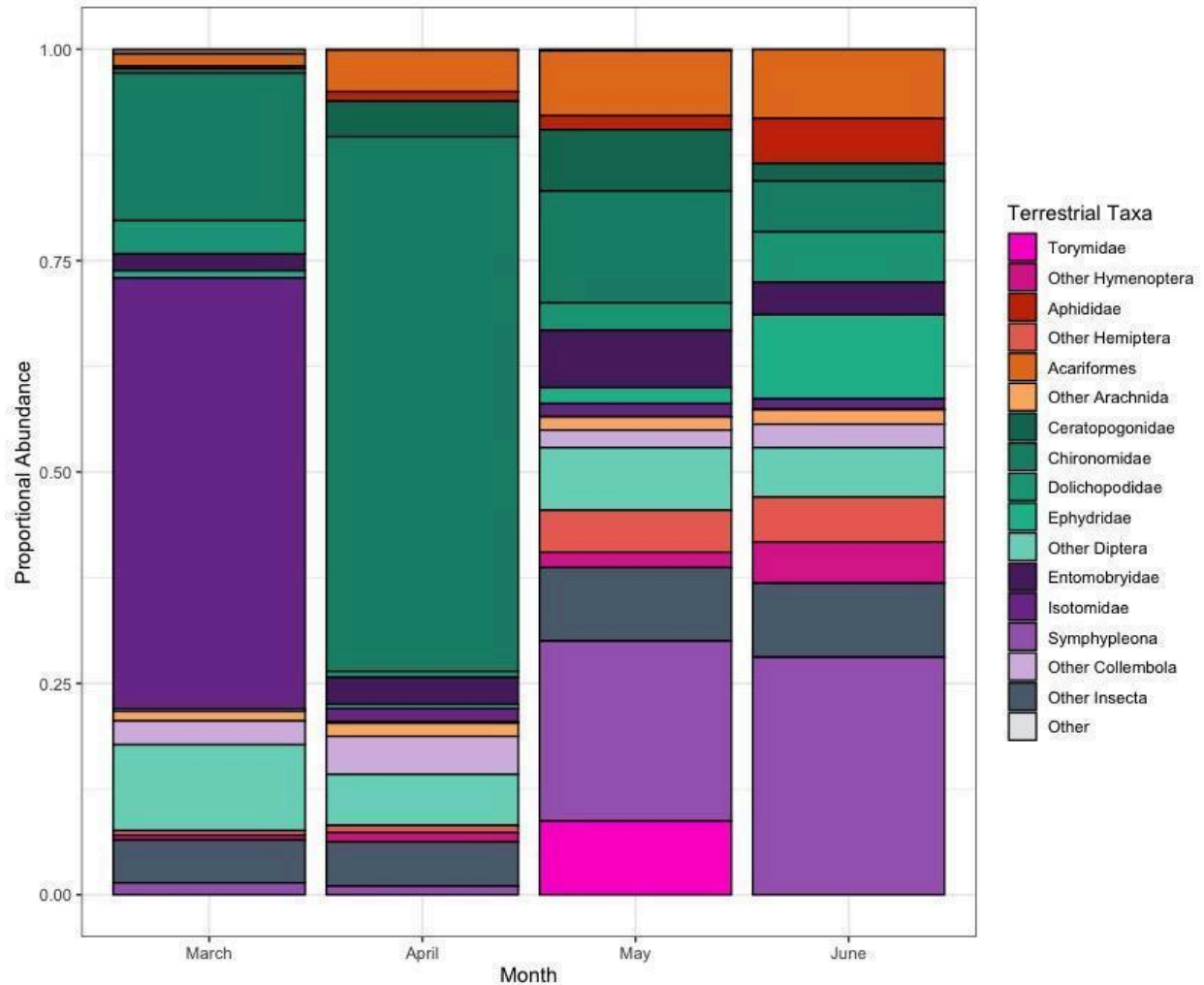
Hatt Slough - zis a ba 1	0.876	0.705	2.045	0.002	1.973	0.002	1.899	0.001
TNC - South Delta	1.509	0.204	1.212	0.129	1.423	0.020	2.035	0.001
TNC - zis a ba 1	1.105	0.285	0.958	0.524	0.904	0.636	1.186	0.144
zis a ba 1 - South Delta	1.074	0.500	1.376	0.044	1.518	0.020	1.877	0.001



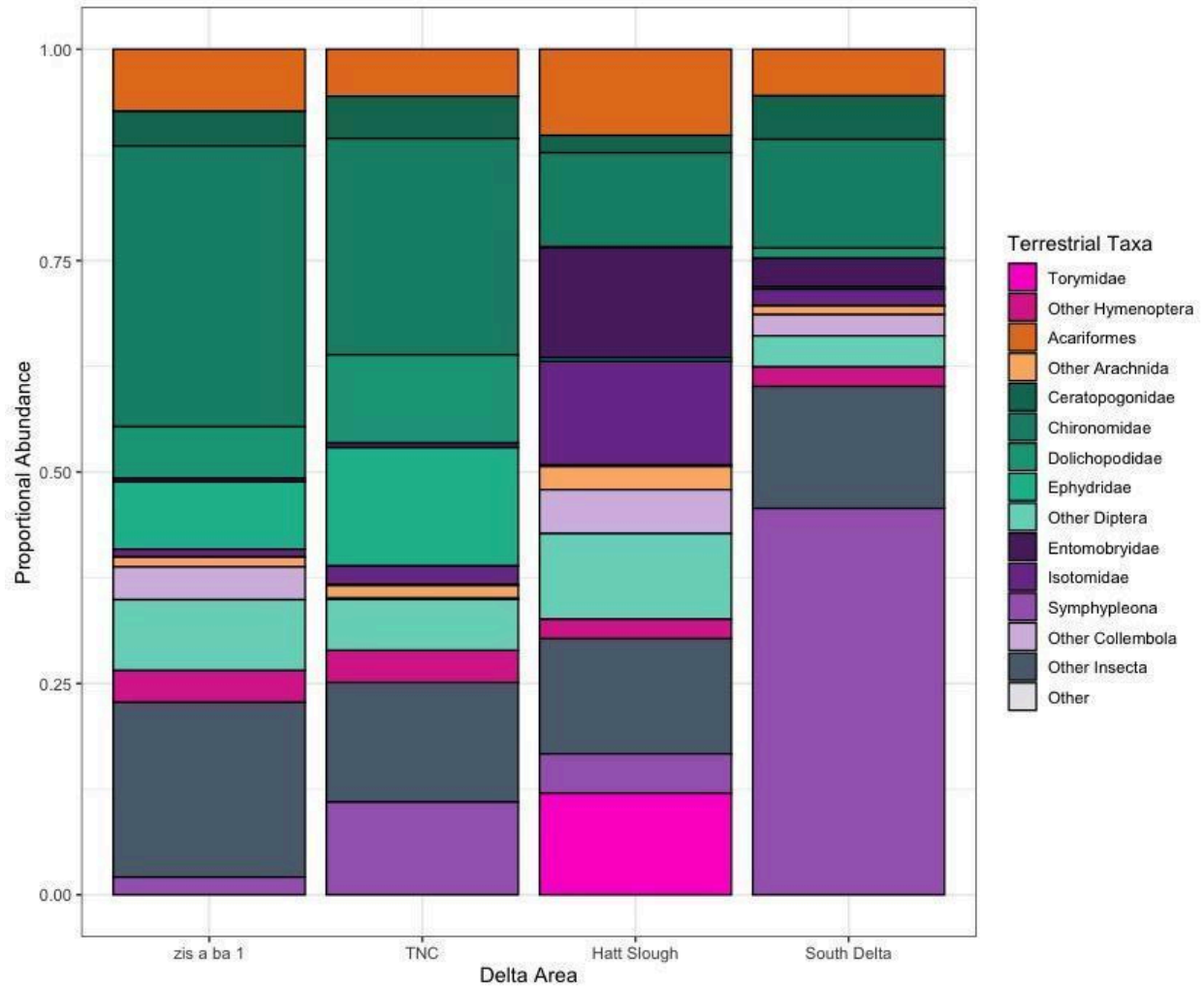
**Figure 15.** Non-metric multidimensional scaling (NMDS) ordination plot of terrestrial invertebrate community composition for all sampling events. Each point represents the invertebrate community identified during each sampling event ( $n = 126$  fallout trap samples). Symbol color and shape correspond to delta area (green: Hatt Slough, red: South Delta, purple:

zis a ba 1, blue: TNC). Vectors show the directional influence of the invertebrate taxa (only correlations with  $R^2 \geq 0.4$  are shown).

Overall, most terrestrial taxa had low correlations ( $R^2 < 0.4$ ) with NMDS scores. A vector analysis indicated that Entomobryidae (springtails) and Acariformes (immature mites) were moderately correlated ( $R^2 > 0.4$ ) with the scores on the NMDS 2 axis (Figure 15). Highest relative abundances of these taxa were observed at Hatt Slough (Table 3). When looking across the delta as whole, terrestrial invertebrate community composition varied temporally, with shifts in the taxonomic composition from March to June (Figure 17). The taxa with highest relative abundance were Isotomidae (springtails) during March (51%), adult Chironomidae (flies) during April (63%), and Symphypleona (springtails) during May (21%) and June (29%) (Appendix Table A1). When summarized across all months and years, terrestrial invertebrate community composition varied among delta areas (Figure 18). Adult Chironomidae contributed the highest relative abundance at zis a ba 1 (33%) and TNC (26%). Entomobryidae contributed the highest relative abundance at Hatt Slough (13%). Symphypleona contributed the highest relative abundance at South Delta (46%) (Table 3).



**Figure 17.** Community composition of terrestrial invertebrates by month. Proportions were calculated as the abundance of each taxon divided by the total abundance across all samples in a given area. Different colors represent broader taxonomic groups [pink = Hymenoptera, red = Hemiptera, orange = Arachnia, green = Diptera, purple = Collembola, dark gray = Insecta, light gray = other]. Taxa with proportions below 0.05 are combined in broader class, subclass, and order categories (Other Hymenoptera, Other Hemiptera, Other Arachnida, Other Diptera, Other Collembola, Other Insecta) or an Other category (Pulmonata, Oligochaeta, Amphipods).



**Figure 18.** Community composition of terrestrial invertebrates by delta area. Proportions were calculated as the abundance of each taxon divided by the total abundance across all samples in a given area. Different colors represent broader taxonomic groups [pink = Hymenoptera, orange = Arachnia, green = Diptera, purple = Collembola, dark gray = Insecta, light gray = other]. Taxa with proportions below 0.05 are combined in broader class, subclass, and order categories (Other Hymenoptera, Other Arachnida, Other Diptera, Other Collembola, Other Insecta) or an Other category (Pulmonata, Oligochaeta, Amphipods).

**Table 3.** Relative abundances and proportional abundances (in parentheses) of terrestrial

invertebrate taxa in fallout trap samples collected from the four delta areas. Life stage is indicated for taxa with aquatic and terrestrial life stages, where ‘A’ is adult. The taxa contributing the highest relative abundance at each area are shaded.

<b>Order/ Subclass</b>	<b>Taxon</b>	<b>Hatt Slough</b>	<b>South Delta</b>	<b>zis a ba 1</b>	<b>TNC</b>
Arachnida	Acariformes	149 (0.10)	106 (0.06)	70 (0.07)	79 (0.06)
Diptera	Ceratopogonidae (A)	30 (0.021)	99 (0.052)	39 (0.04)	71 (0.05)
Diptera	Chironomidae (A)	163 (0.11)	247 (0.13)	317 (0.33)	364 (0.26)
Diptera	Dolichopodidae (A)	1 (0.0007)	23 (0.01)	58 (0.06)	148 (0.10)
Collembola	Entomobryidae	191 (0.13)	65 (0.03)	4 (0.004)	8 (0.006)
Diptera	Ephydriidae (A)	6 (0.004)	5 (0.002)	76 (0.08)	199 (0.14)
Collembola	Isotomidae	179 (0.12)	37 (0.02)	9 (0.01)	31 (0.02)
Collembola	Symphyleona	68 (0.05)	878 (0.46)	20 (0.02)	156 (0.11)
Hymenoptera	Torymidae (A)	176 (0.12)	NA	NA	NA
NA	Other Arachnida	40 (0.03)	20 (0.01)	11 (0.01)	21 (0.02)
NA	Other Collembola	76 (0.05)	48 (0.02)	37 (0.04)	2 (0.001)
NA	Other Diptera	148 (0.1)	71 (0.04)	80 (0.08)	86 (0.06)
NA	Other Hymenoptera	34 (0.02)	44 (0.02)	36 (0.04)	54 (0.04)

NA	Other Insecta	199 (0.14)	277 (0.14)	197 (0.21)	201 (0.14)
NA	Other	3 (0.002)	1 (0.0005)	NA	2 (0.001)

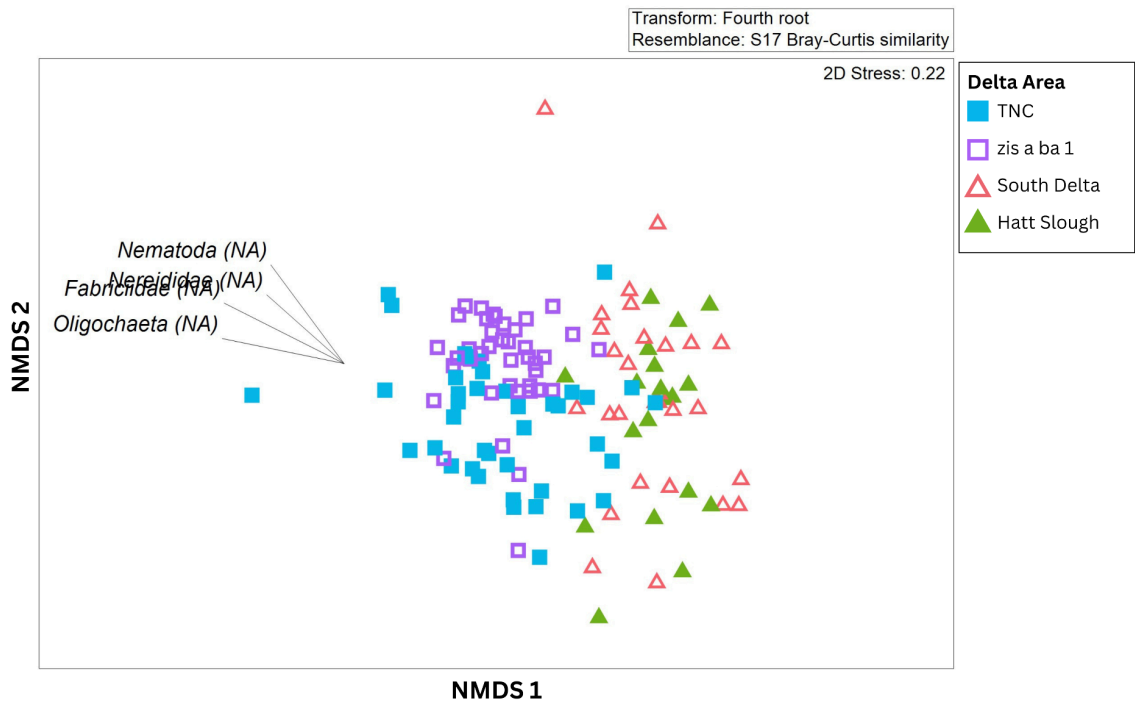
### Benthic Invertebrates

The NMDS provided a good representation of benthic invertebrate community structure in three dimensions based on a stress value of 0.15 (Figure 19). The 2D ordination plots indicated some differentiation among areas overall (Figure 19) and areas within months (Figure A2). The results of the PERMANOVA indicate that during March, community composition differed significantly among areas (p-value < 0.05) except between TNC and South Delta (p-value = 0.06). During April, zis a ba 1 and TNC community composition differed significantly from Hatt Slough and South Delta. During May and June, community composition differed significantly among all areas except between Hatt Slough and South Delta (p-value = May: 0.067; June: 0.242) (Table 4).

**Table 4.** PERMANOVA results for benthic invertebrates. P-values indicating a significant difference are shaded.

Area Pairs	March		April		May		June	
	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value
Hatt Slough - TNC	2.3845	0.006	1.9278	0.008	2.8062	0.004	2.1277	0.002
Hatt Slough -	3.7205	0.002	2.6832	0.001	3.4984	0.001	2.8049	0.001

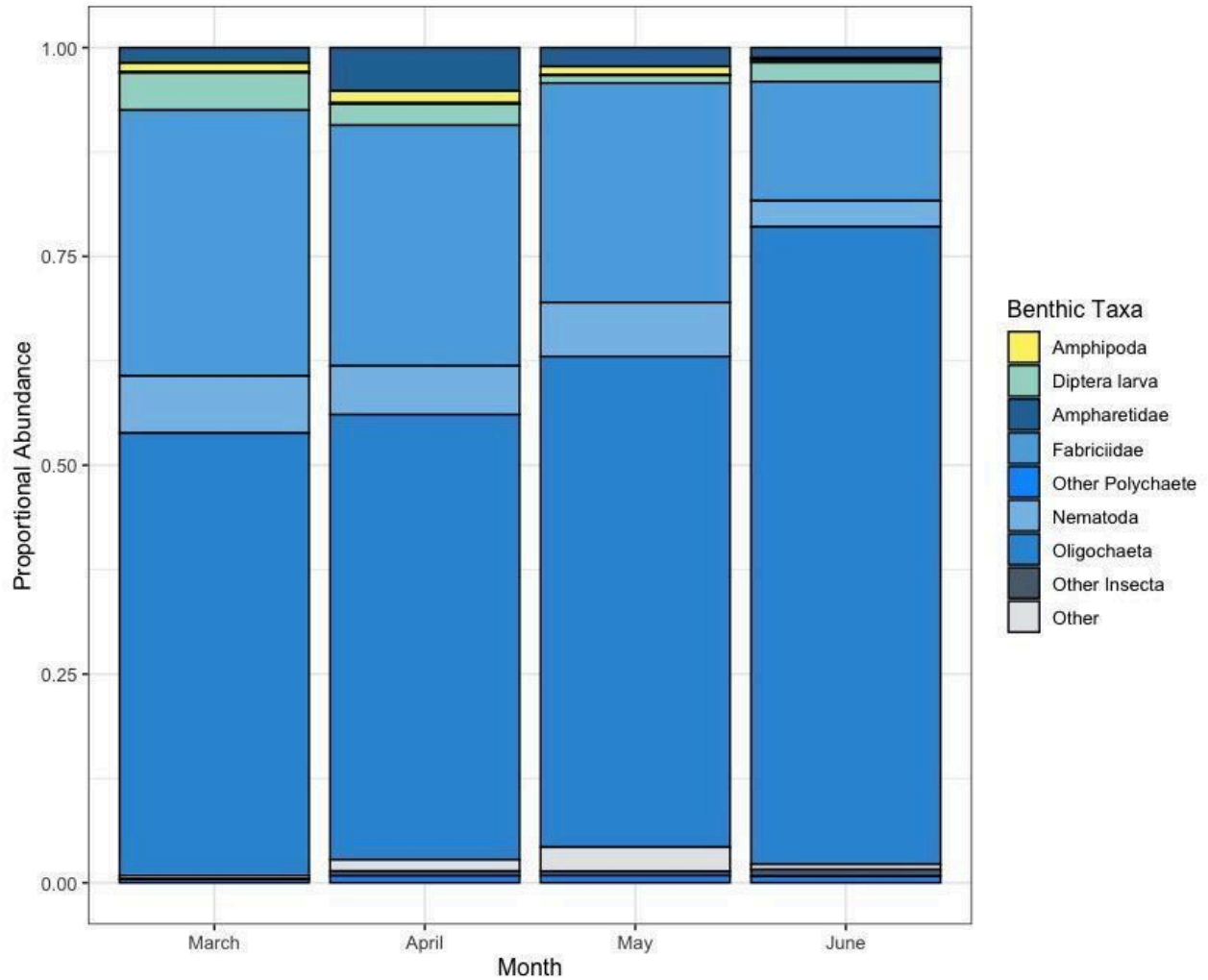
zis a ba 1								
Hatt Slough - South Delta	1.7028	0.017	1.0482	0.356	1.4144	0.067	1.141	0.242
TNC - zis a ba 1	1.6541	0.022	1.984	0.188	1.6946	0.007	2.7302	0.001
TNC - South Delta	1.5218	0.06	2.347	0.002	2.5637	0.001	1.9157	0.002
zis a ba 1 - South Delta	2.1654	0.002	3.0128	0.001	3.1875	0.001	3.1835	0.001



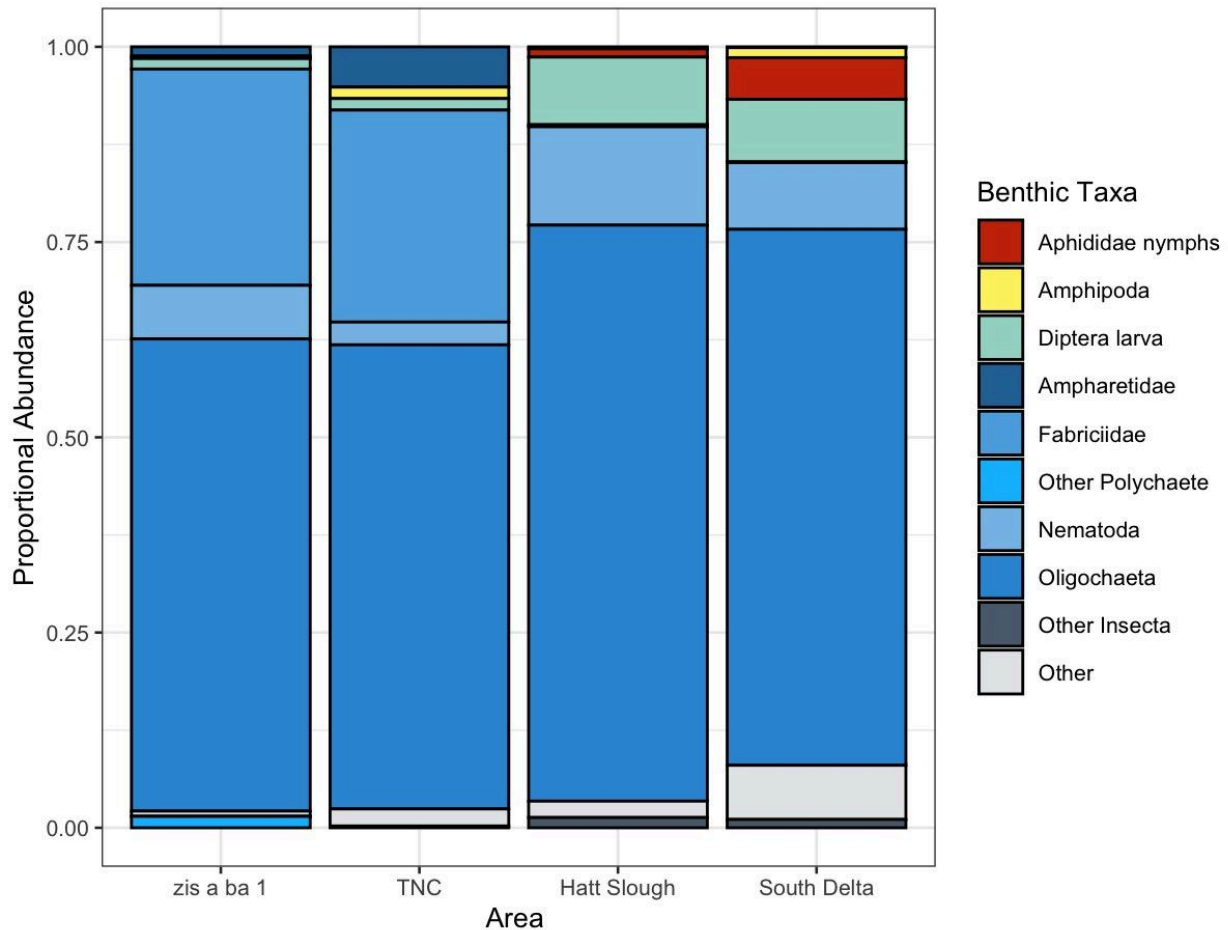
**Figure 19.** Non-metric multidimensional scaling (NMDS) ordination plot of benthic invertebrate community composition for all sampling events. Each point represents the invertebrate community identified during each sampling event ( $n = 129$  benthic core samples). Symbol color and shape correspond to delta area (green: Hatt Slough, red: South Delta, purple: zis a ba 1, blue:

TNC). Vectors show the directional influence of the invertebrate taxa (only correlations with  $R^2 \geq 0.4$  are shown).

Overall, most benthic taxa had low correlations ( $R^2 < 0.4$ ) with NMDS scores. A vector analysis indicated that Nematoda (nematodes), Nerididae (burrowing marine polychaetes), Fabridacidae (small tube-dwelling marine polychaetes), and Oligochaeta (small segmented marine worms), were correlated ( $R^2 > 0.4$ ) with scores on the NMDS 1 and 2 axis (Figure 19). When looking across the delta as a whole, benthic invertebrate community composition did not vary much from March through June (Figure 21). Oligochaeta contributed the highest relative abundance during all sample months, followed by Fabriciidae, and nematoda (Table A2). Combined, Oligochaeta and Fabriciidae accounted for over 80% of all benthic invertebrates collected during the entire sampling period (Table A2). When summarized across all months, benthic community composition showed little variation across the delta (Figure 22). Oligochaeta contributed the highest relative abundance among all areas (Hatt Slough = 74%, South Delta = 69%, zis a ba 1 = 61%, TNC = 59%). Fabriciidae contributed the second highest relative abundance at zis a ba 1 (28%) and TNC (27%) and Nematoda contributed the second highest relative abundances at Hatt Slough (13%) and South Delta (9%) (Table 5).



**Figure 21.** Community composition of benthic invertebrates by month. Proportions were calculated as the abundance of each taxon divided by the total abundance across all samples in a given area. Different colors represent broader taxonomic groups [yellow = Amphipoda, green = Diptera, blue = worms (Annelida including Polychaetes and Oligochaeta, and Nematoda), dark gray = Insecta, light gray = other]. Taxa with proportions below 0.05 are combined in broader class categories (Other Polychaete, Other Insecta) or an Other category (Arachnida, Bivalvia, Collembola, Cumacea, Gastropoda, Harpacticoida, Isopoda, Ostracoda, Turbellaria).



**Figure 22.** Community composition of benthic invertebrates by delta area. Proportions were calculated as the abundance of each taxon divided by the total abundance across all samples in a given area. Different colors represent broader taxonomic groups [red = Hemiptera (Aphididae nymphs), yellow = Amphipoda, green = Diptera, blue = worms (Annelida including Polychaetes and Oligochaeta, and Nematoda), dark gray = Insecta, light gray = other]. Taxa with proportions below 0.05 are combined in broader class categories (Other Polychaete, Other Insecta) or an Other category (Arachnida, Bivalvia, Collembola, Cumacea, Gastropoda, Harpacticoida, Isopoda, Ostracoda, Turbellaria).

**Table 5.** Relative abundances and proportional abundances (in parentheses) of terrestrial

invertebrate taxa in fallout trap samples collected from the four delta areas. Life stage is indicated for taxa with aquatic and terrestrial life stages, where ‘A’ is adult. The taxa contributing the highest relative abundance at each area are shaded.

<b>Order/ Class</b>	<b>Taxon</b>	<b>Hatt Slough</b>	<b>South Delta</b>	<b>zis a ba 1</b>	<b>TNC</b>
Polychaeta	Ampharetidae	NA	1 (0.001)	71 (0.01)	276 (0.05)
NA	Amphipoda	1 (0.003)	12 (0.01)	20 (0.003)	78 (0.01)
Hemiptera	Aphididae (n)	4 (0.010)	50 (0.05)	NA	NA
Diptera	Diptera larva	33 (0.09)	75 (0.08)	81 (0.01)	79 (0.01)
Polychaeta	Fabridiidae	1 (0.003)	1 (0.001)	1,674 (0.28)	1,451 (0.27)
NA	Nematoda	48 (0.13)	80 (0.09)	415 (0.07)	156 (0.03)
NA	Oligochaeta	281 (0.74)	643 (0.69)	3,654 (0.61)	3,177 (0.59)
NA	Other Insecta	5 (0.01)	10 (0.01)	1 (0.0002)	NA
NA	Other Polychaeta	NA	NA	88 (0.01)	12 (0.002)
NA	Other	8 (0.02)	65 (0.07)	40 (0.0002)	117 (0.02)

## **DISCUSSION**

Since 2012, restoration actions have excavated channel networks and returned tidal exchange to former marshes in the Stillaguamish River delta. As a result, new habitats have

opened for macroinvertebrates, potentially increasing prey availability for juvenile Chinook salmon and other estuarine-dependent consumers such as bats and shorebirds. This study is the first to document the terrestrial invertebrate community in the Stillaguamish River delta and builds on prior benthic invertebrate monitoring conducted in 2012, 2013, and 2015 (Fuller, 2018). Our data indicate that the return of tidal inundation at zis a ba 1 and TNC has supported the development of abundant and diverse terrestrial invertebrate communities and enabled colonization by marine benthic organisms. High-quality terrestrial and benthic prey (insects, amphipods, and polychaetes) for juvenile Chinook salmon occur in restored areas (zis a ba 1 and TNC) at comparable or higher levels than at natural marsh areas and the river's mainstem. However, the high abundance of benthic invertebrates associated with fine sediments, salinity, and high temperatures at the zis a ba 1 and TNC locations indicate that connectivity to the delta's source of freshwater (Hatt Slough mainstem) and coarse fluvial sediments may not yet be fully restored, or is still actively restoring. We were unable to document the invertebrate communities present at zis a ba 1 and TNC prior to restoration, and as a result could not capture changes before and after dike breaching and channel excavation. However, our results provide a useful benchmark for comparison over time as these restoration sites develop. To overlap with peak Chinook salmon outmigration in the Stillaguamish River delta, our sampling included only spring months. As a result, we did not investigate invertebrate community dynamics over the entire year that could be relevant for other estuarine consumers. The TNC area underwent adaptive management between sample years and our analysis of invertebrate data did not account for interannual differences. Future study of the benthic invertebrate community at TNC will be insightful as the restoration matures and dynamic processes return.

We found similar mean abundance and taxonomic richness of terrestrial invertebrates at zis a ba 1, TNC, and undisturbed delta areas. Mixohaline emergent vegetation was present at restored areas and the association between vegetation cover and terrestrial invertebrates in estuarine deltas has been well documented (David et al., 2016; Gratton and Denno, 2005; Romanuk and Levings, 2003; Schaffers et al., 2008; Toft et al., 2003). Marine invertebrates have been recorded colonizing new tidal channels created by restoration in Puget Sound deltas (Woo et al., 2017) and our results align with these observations. We found higher abundances and greater diversity of marine-associated benthic invertebrates at restored areas (zis a ba 1 and TNC) compared to South Delta and Hatt Slough. Salinity levels were higher at zis a ba 1 and TNC compared to South Delta and Hatt Slough as well. We found higher mean abundances of benthic invertebrates at restored areas (zis a ba 1 and TNC) compared to reference areas (South Delta and Hatt Slough), which aligns with findings from similar studies in Puget Sound deltas (Rubin et al., 2024; Woo et al., 2017). The taxa with highest abundances were marine Oligochaeta and Fabriciidae and these benthic organisms are known to be associated with fine sediments (Seys, Vincx and Meire 1999; Phillips et al., 2019), and are tolerant to high salinity (Piscart, Moreteau and Beisel 2005; Rubin et al., 2014) and warm temperatures (Chapman, Farrell and Brinkhurst 1982; Rubin et al., 2024). The excavation of distributary channels that reestablished direct fresh water connection between TNC and the river's mouth in 2024 may explain why benthic community composition differed between zis a ba 1 and TNC despite similarities in sediment texture and temperature. The short time elapsed between our 2024 sampling efforts and 2023 channel additions may have not allowed sufficient time for the invertebrate communities to respond to salinity changes. As the transport of fresh water continues to decrease salinity at TNC, we would expect to see

changes in benthic community composition, similar to other studies (Yang, 2019).

Food limitation during estuary residency can be a factor preventing the recovery of Chinook salmon in Puget Sound (Pershall et al., 2021). Capacity metrics, such as the availability of invertebrate prey, is a useful measure in evaluating the effectiveness of restoration projects in providing foraging benefits for juvenile salmonids (Simenstand and Cordell, 2000). We found that the mean abundance and taxonomic richness of terrestrial invertebrates was not different between restoration areas and undeveloped parts of the delta. This suggests that the zis a ba 1 and TNC restoration areas provide habitat conditions that enable terrestrial invertebrate productivity at comparable levels to more natural reference areas. Insects, and adult dipterans in particular, are an important terrestrial prey resource for rearing juvenile Chinook in Puget Sound deltas (Davis et al., 2017; Davis et al., 2020; Duffy et al., 2010). We found that adult dipterans were most available as prey during April and reached highest abundances at zis a ba 1 and TNC. Restored areas had significantly higher mean abundance of benthic invertebrates, dominated by Oligochaeta and Fabriciidae. While these taxa have not been recorded in the diets of Whidbey Basin juvenile Chinook (Duffy et al., 2010), they are an important prey resource for other consumers like waterfowl and shorebirds (Fuller, 2018; Hamer et al., 2006; Coelho et al., 2024). Polychaetes and amphipods have been found in the diets of juvenile Chinook in the Whidbey Basin (Duffy et al., 2010; Howe, 2022; Bidwell, 2024), and we found higher abundances of these taxa in restored areas during April and May. Adult dipterans and other insects, polychaetes, and amphipods are considered high quality prey for juvenile Chinook due to their high energy densities (Duffy et al., 2010). Aquatic dipteran larvae and pupae represent substantial fractions of the benthic prey in Stillaguamish Chinook diets (Howe, 2022; Bidwell, 2024). We found higher abundances of these taxa in undisturbed delta areas, suggesting that restored areas are not

currently providing aquatic dipteran larva and pupae prey resources at comparable levels.

This study provides insights into how invertebrate communities can change over space and time when subjected to restoration activities and how position within the delta landscape can influence restoration trajectories. Future restoration in the Stillaguamish River delta is expected to return dynamic ecosystem processes to large portions of delta habitat formerly converted to agriculture and increase connectivity between existing restoration areas. The Stillaguamish Tribe is initiating zis a ba 2 (~348 acres) and zis a ba 3 (~500 acres) projects to restore hydrologic connection between the river's mouth and Port Susan Bay, and to create continuous intertidal wetland habitat across the delta's bayfront between Hatt Slough's outflow and the Old Stillaguamish mainstem. As these projects develop and riverine flows and sediment transport are returned north-westward across the delta, we might expect the benthic invertebrate communities at zis a ba 1 and TNC to become more similar to the South Delta communities observed during our study. To investigate opportunity metrics in the restoring delta, such as the ability of salmon to access increased prey resources, it will be informative to compare invertebrate communities described in this study with juvenile Chinook salmon diets from the Stillaguamish delta to see whether differences exist between the potential prey community available and invertebrates found in stomach contents (Simenstand and Cordell, 2000).

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## APPENDIX

**Table A1.** Relative abundances and proportional abundances (in parentheses) of terrestrial invertebrate taxa in fallout trap samples from March-June. Life stage is indicated for some taxa, where ‘A’ is adult, and ‘n’ is immature nymph. The taxa contributing the highest relative abundance during each month are shaded.

Order/ Subclass	Taxon	March	April	May	June
Arachnida	Acariformes	5 (0.01)	48 (0.05)	155 (0.08)	196 (0.08)
Hemiptera	Aphididae (A)(n)	1 (0.003)	11 (0.01)	33 (0.02)	129 (0.05)
Diptera	Ceratopogonidae (A)	2 (0.006)	41 (0.04)	146 (0.07)	50 (0.02)
Diptera	Chironomidae (A)	62 (0.17)	617 (0.63)	267 (0.13)	145 (0.06)
Diptera	Dolichopodidae (A)	14 (0.04)	7 (0.007)	65 (0.03)	144 (0.06)
Collembola	Entomobryidae	7 (0.02)	31 (0.03)	137 (0.07)	93 (0.04)
Diptera	Ephydriidae (A)	3 (0.008)	5 (0.005)	38 (0.02)	240 (0.10)
Collembola	Isotomidae	181 (0.51)	15 (0.02)	31 (0.02)	29 (0.01)
Collembola	Symphyleona	5 (0.01)	10 (0.01)	429 (0.21)	678 (0.28)
Hymenoptera	Torymidae (A)	NA	NA	176 (0.09)	NA
NA	Other Arachnida	4 (0.01)	15 (0.02)	31 (0.02)	41 (0.02)
NA	Other Collembola	10 (0.03)	44 (0.05)	42 (0.02)	67 (0.03)

NA	Other Diptera	36 (0.1)	59 (0.06)	149 (0.07)	141 (0.06)
NA	Other Hemiptera	2 (0.006)	8 (0.008)	100 (0.05)	128 (0.05)
NA	Other Hymenoptera	2 (0.006)	11 (0.01)	37 (0.02)	118 (0.05)
NA	Other Insecta	18 (0.05)	51 (0.05)	175 (0.09)	211 (0.09)
NA	Other	1 (0.002)	2 (0.002)	1 (0.0004)	2 (0.0008)

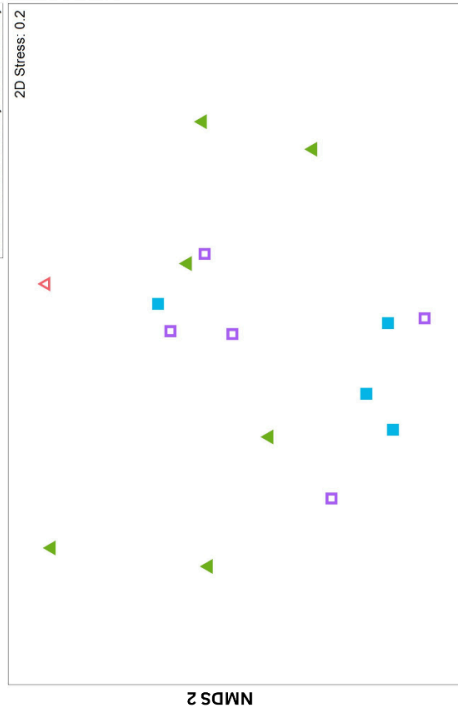
**Table A2.** Relative and proportional abundances (in parentheses) of benthic invertebrate taxa in benthic core samples from all areas. Life stage is indicated for some taxa, where ‘n’ is nymph and ‘lp’ is larva or pupa. The taxa contributing the highest relative abundance during each month are shaded.

<b>Order/ Class</b>	<b>Taxon</b>	<b>March</b>	<b>April</b>	<b>May</b>	<b>June</b>
Polychaeta	Ampharetidae	28 (0.02)	177 (0.05)	104 (0.02)	39 (0.01)
NA	Amphipoda	16 (0.01)	48 (0.01)	46 (0.01)	1 (0.0003)
Diptera	Diptera larva	68 (0.04)	86 (0.03)	41 (0.009)	73 (0.02)
Polychaeta	Fabridiidae	484 (0.32)	981 (0.29)	1,206 (0.26)	456 (0.14)
NA	Nematoda	104 (0.07)	199 (0.06)	297 (0.06)	99 (0.03)
NA	Oligochaeta	806 (0.053)	1,814 (0.053)	2,697 (0.59)	2,438 (0.76)
NA	Other Insecta	1	19	24	26

		(0.0007)	(0.006)	(0.005)	(0.008)
NA	Other Polychaete	6 (0.004)	29 (0.009)	24 (0.005)	25 (0.008)
NA	Other	8 (0.005)	51 (0.01)	134 (0.03)	37 (0.01)

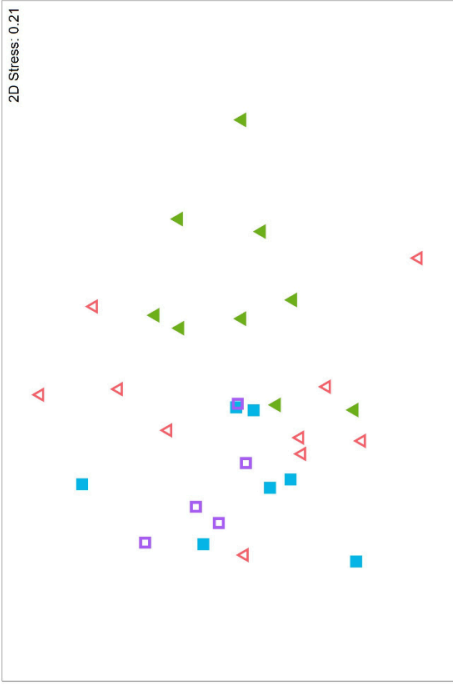
March

Transform: Fourth root  
Resemblance: S17 Bray-Curtis similarity



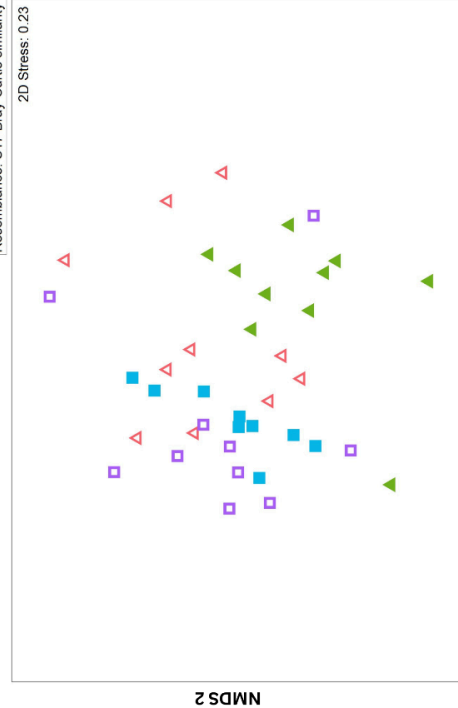
April

Transform: Fourth root  
Resemblance: S17 Bray-Curtis similarity



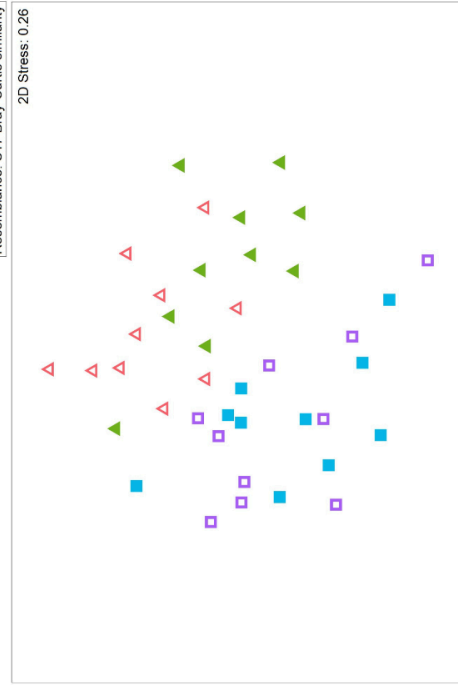
May

Transform: Fourth root  
Resemblance: S17 Bray-Curtis similarity



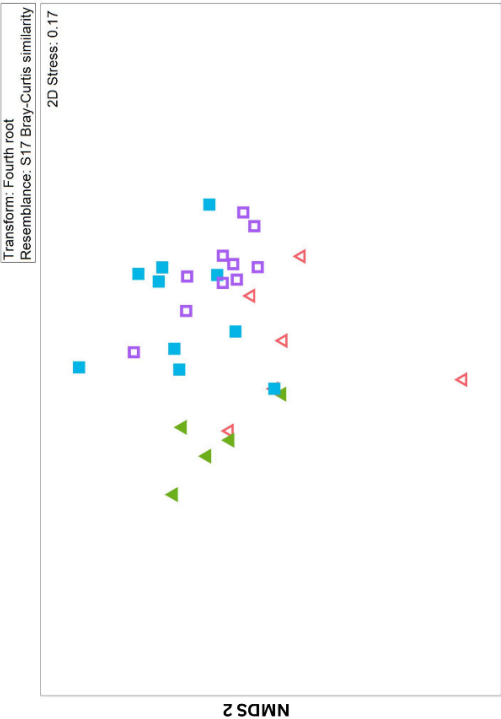
June

Transform: Fourth root  
Resemblance: S17 Bray-Curtis similarity

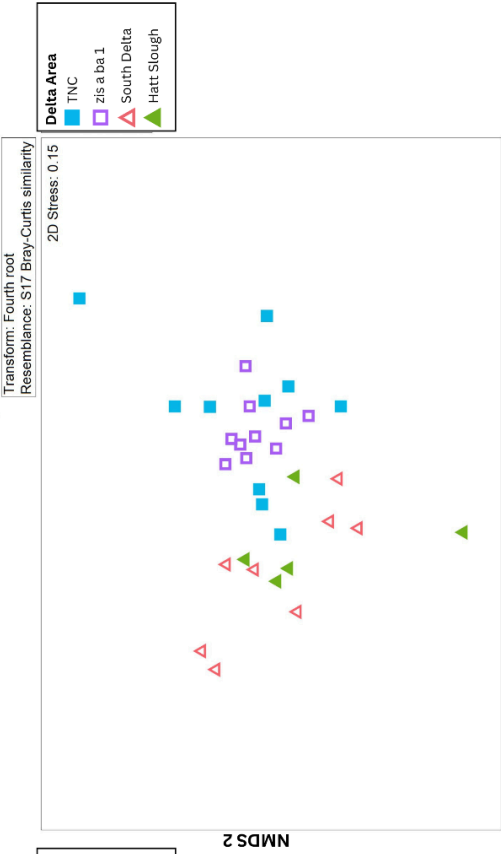


**Figure A1.** Non-metric multidimensional scaling (NMDS) ordination plot of terrestrial invertebrate community composition separated by month (March: top left, April: top right, May: bottom left, June: bottom right). Each point represents the invertebrate community identified during each month's sampling event summed across both sample years (notes on sample size). Colors correspond to delta area (green: Hatt Slough, red: South Delta, purple: zis a ba 1, blue: TNC).

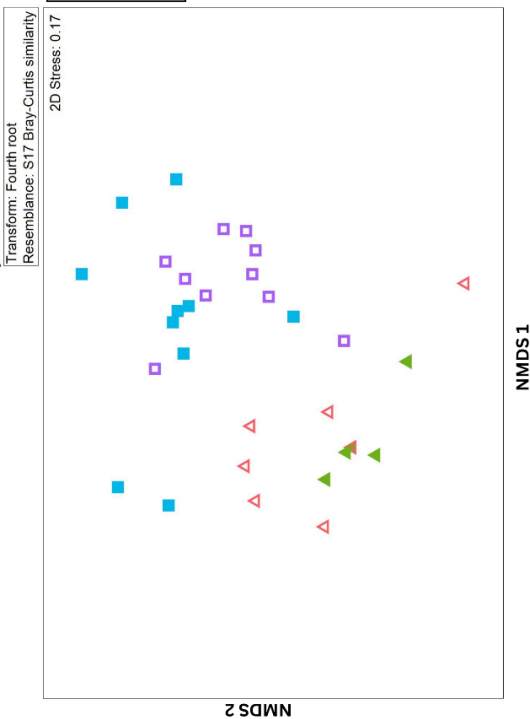
March



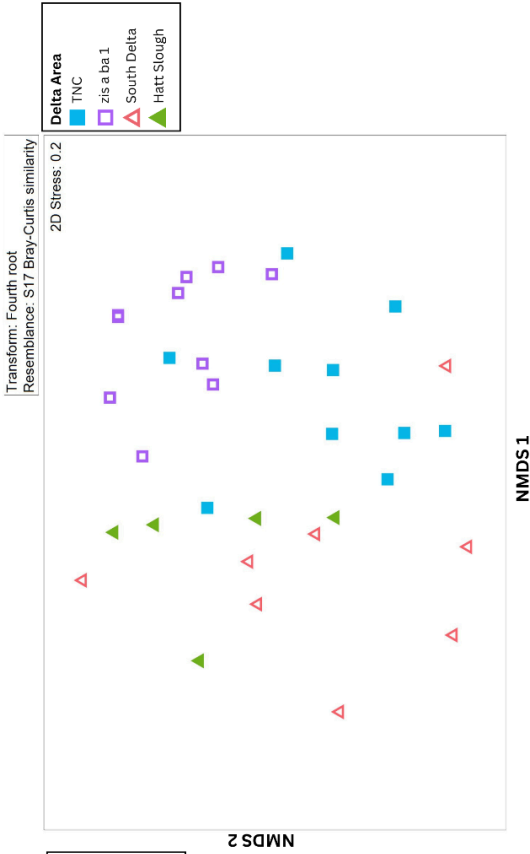
April



May



June



**Figure A2.** Non-metric multidimensional scaling (NMDS) ordination plot of benthic invertebrate community composition separated by month (March: top left, April: top right, May: bottom left, June: bottom right). Each point represents the invertebrate community identified during each month's sampling event summed across both sample years (notes on sample size). Colors correspond to delta area (green: Hatt Slough, red: South Delta, purple: zis a ba 1, blue: TNC).