Ecology Article

Evaluating top-down, bottom-up, and environmental drivers of pelagic food web dynamics along an estuarine gradient

Authors: Tanya L. Rogers*[1], Samuel M. Bashevkin*[2], Christina E. Burdi[3], Denise D. Colombano[4], Peter N. Dudley[1,5], Brian Mahardja[6], Lara Mitchell[7], Sarah Perry[8], Parsa Saffarinia[9]

Affiliations:

[1]Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, [2]Delta Science Program, Delta Stewardship Council, [3]California Department of Fish and Wildlife, [4]Department of Environmental Science, Policy, and Management, University of California, Berkeley, [5]Fisheries Collaborative Program, Institute of Marine Sciences, University of California, Santa Cruz, [6]Bureau of Reclamation, [7]Lodi Fish and Wildlife Office, United States Fish and Wildlife Service, [8]California Department of Water Resources, [9]Department of Wildlife, Fish and Conservation Biology, University of California, Davis

*Equal contribution, corresponding authors: tanya.rogers@noaa.gov and sam.bashevkin@waterboards.ca.gov

Open research statement: Data are available on EDI (placeholder link) and code is available at https://github.com/Delta-Stewardship-Council/swg-21-foodwebs

Key words (12): bottom-up; estuaries; fish; food webs; invasive species; long term monitoring; phytoplankton; structural equation model; top-down; zooplankton

Abstract

Identification of the key biotic and abiotic drivers within food webs is important for understanding species abundance changes in ecosystems, particularly across ecotones where there may be strong variation in interaction strengths. Using structural equation models and four decades of integrated data from the San Francisco Estuary, we investigated the relative effects of top-down, bottom-up, and environmental drivers on multiple trophic levels of the pelagic food web along an estuarine salinity gradient and at both annual and monthly temporal resolutions. For zooplankton and estuarine fishes, bottom-up effects appeared to be stronger in the freshwater upstream regions, while top-down effects were stronger in the brackish downstream regions. Interestingly, this contrasts with hypotheses that freshwater systems have stronger top-down effects than marine systems due to the more limited spatial range of their predators. The net effect of environmental drivers was similar to or greater than bottom-up and top-down effects for all food web components. Some relationships (e.g., bottom-up effects of phytoplankton on zooplankton) were seen primarily at annual timescales, whereas others (e.g., temperature effects) were only observed at monthly timescales. Overall, our results provide strong evidence that environmental gradients can structure the relative strengths of bottom-up, top-down, and environmental drivers within food webs. This advances our understanding of the influence of environmental drivers on species interactions, as well as the mechanisms behind variability in the relative strengths of bottom-up and top-down drivers among habitats and ecosystems. Furthermore, these findings can help identify which trophic levels or environmental factors could be targeted by management actions to have the greatest impact on estuarine forage fishes. This approach of leveraging long-term datasets to identify trophic interactions is applicable to a wide range of systems, including complex, dynamic systems along environmental gradients.

Introduction

Understanding the effect of biotic and abiotic drivers on species distribution and abundance is a central challenge in ecology (Power 1992). Empirical studies of trophic interactions and environmental effects have been conducted in a variety of terrestrial, freshwater, and marine systems across the globe (e.g., forests: Dyer and Letourneau 1999, deserts: Meserve et al. 2003, lakes: Carpenter et al. 1985, oceans: Lynam et al. 2017). Overall, there is a growing appreciation for the complexity of datasets and models required to quantify the influence of top-down, bottom-up, and environmental forces within food webs (Hampton et al. 2006). Data availability in space or time often limits studies, and as a result, inferences based on such studies may also be limited, especially in highly variable systems (Miller-Rushing et al. 2010). Recent advances in ecological synthesis—namely the ‘big data revolution’ and the adoption of ‘open science’ practices (Hampton et al. 2013)—are now allowing ecologists to address long-standing questions about food web dynamics using long-term, spatially replicated observational data. By examining effects at different levels of spatial, temporal, and taxonomic resolution, it is possible to determine the scales at which these interactions manifest and at which management interventions may (or may not) be detectable.

Pelagic food webs are a model system for studying the relative influences of top-down, bottom-up, and environmental drivers on ecological communities (Hampton et al. 2006, Lynam et al. 2017). Primary producers and consumers (e.g., phytoplankton, zooplankton) support secondary consumers (e.g., predatory zooplankton and forage fishes), which in turn are prey for tertiary or higher consumers (e.g., predatory fishes, birds, mammals). Interactions with lower and higher trophic levels, and with fluctuating environmental conditions, can lead to changes in species abundance, distribution, and/or phenology to track better conditions for foraging, growth, or spawning (Cushing 1990). For example, in well-studied pelagic marine systems such as the North Sea, the commercial harvest of pelagic forage fishes alters plankton abundance (via top-down effects) and sea surface temperatures drive plankton, fish, and seabird abundances (via bottom-up and environmental effects; Lynam et al. 2017). Depending on the direction and magnitude of responses, restructuring of pelagic food webs and species interactions may occur, which could affect population, community, and ecosystem dynamics (Arimitsu et al. 2021).

Estuaries are spatially and temporally variable transition zones between freshwater and marine environments that support diverse assemblages of pelagic fishes and invertebrates (Nelson et al. 2015). Species often respond to changes in hydroclimatic conditions (e.g., temperature, salinity), which can shift spatially across the ecotone and temporally over different timescales (Lauchlan and Nagelkerken 2020). The prevalence of human impacts in estuaries (e.g., habitat and hydrologic alteration, introduced species, climate change) further complicates the ability to disentangle food web drivers, since these impacts can materialize as both bottom-up (McClelland et al. 1997) and top-down (Grimaldo et al. 2012) drivers. Although studies in estuarine ecosystems have examined top-down, bottom-up, and environmental drivers of benthic (e.g., Leonard et al. 1998) and select trophic levels of the pelagic food web (e.g., Hoover et al. 2006), relatively few studies have examined the full estuarine pelagic food web from phytoplankton to fishes, and how it varies across space and time.

Here we examine pelagic food web dynamics in the San Francisco Estuary, California, USA (hereafter, SF Estuary). Flow regulation (Monsen et al. 2007), loss of historical habitat (Nichols et al. 1986), and species introductions (Cohen and Carlton 1998) have altered the SF Estuary. The ecological impacts of these stressors have been monitored for decades (Tempel et al. 2021). Specifically, the introduction and proliferation of a small filter-feeding clam

(*Potamocorbula amurensis*) has been implicated as one driver of the collapse of the pelagic food web, including phytoplankton (Jassby 2008), native zooplankton (Kimmerer and Orsi 1996) and forage fishes (e.g., Delta Smelt, *Hypomesus transpacificus*; Longfin Smelt, *Spirinchus thaleichthys*; Mac Nally et al. 2010). Studies using multivariate models have investigated biological and environmental drivers of this food web and found that the primary proximate drivers were salinity and water clarity (Mac Nally et al. 2010, Feyrer et al. 2015). We expand on these prior studies by examining drivers of multiple trophic levels across more and finer spatial, temporal, and taxonomic scales. Using a single modeling framework and more than a decade's worth of additional data, we integrate multiple data sources, sampling gear types, and species interactions.

We asked two overarching questions: (1) what are the relative (net) effects of top-down, bottom-up, and environmental drivers on pelagic food web dynamics in the SF Estuary, and (2) how do these effects vary over spatial and temporal scales? To address these questions, we first developed a conceptual model of hypothesized pelagic food web interactions (among phytoplankton, clams, zooplankton, and forage fishes) and environmental drivers (flow/salinity, temperature, water clarity, nutrients) based on previous studies in this system. We then quantified support for these interactions using structural equation models (SEMs) fit to publicly available long-term monitoring data (**Table 1**) collected along the estuarine salinity gradient over four decades (1980-2020). We compared results from models at different biological, spatial, and temporal resolutions to assess interactions within and among trophic levels. Finally, we summarized the net effects of different interaction types in the high temporal resolution models.

Methods

Study area

The SF Estuary is California's largest estuary, stretching from San Francisco Bay to the tidal freshwater Sacramento-San Joaquin Delta. Large pumping facilities in the southern Delta export freshwater towards southern California, while the rest flows downstream towards Suisun Bay, San Pablo Bay, and eventually the Pacific Ocean. The Delta is managed to remain fresh year-round and only experiences salinity intrusion during extreme drought years, whereas San Pablo and Suisun Bays have more variable salinities. The SF Estuary has a Mediterranean climate with a wet winter-spring and a dry summer-fall, resulting in considerable intra-annual variability in inflow, salinity, and temperature. California also experiences high interannual variability in precipitation, leading to swings between droughts to floods. Due to the system's complexity and its central role in water supply, there are over 20 long-term monitoring programs conducted by government agencies and universities, mostly started between the 1950s and 1990s (https://iep.ca.gov/Data/IEP-Survey-Data).

Data processing

We compiled data from 8 long-term monitoring programs that sample different components of the food web (**Table 1**). We obtained data on chlorophyll-a (a proxy for phytoplankton), six aggregate categories of zooplankton (cladocerans, herbivorous copepods, predatory copepods, mysids, amphipods, and rotifers; specific species given in **Appendix S1: Table S1**), two clam species (*Potamocorbula amurensis* and *Corbicula fluminea*, hereafter *Potamocorbula* and *Corbicula*), and an aggregate of estuarine fishes from each of three different surveys (Fall Midwater Trawl, FMWT; Summer Townet, STN; San Francisco Bay Study Midwater Trawl, BSMT). The fishes included in this aggregation were five commonly caught, planktivorous, freshwater-brackish fish species of high management interest: Delta Smelt, Longfin Smelt, Threadfin Shad (*Dorosoma petenense*), juvenile American Shad (*Alosa sapidissima*), and age-0 Striped Bass (*Morone saxatilis*). We also assembled data on potential competitors and predators of the estuarine forage fishes, specifically planktivorous marine fishes (aggregate of Northern Anchovy [*Engraulis mordax*] and Pacific Herring [*Clupea pallasii*], competitors), Mississippi Silverside (*Menidia audens*, competitor), age-1+ Striped Bass (predator), and fishes from the centrarchid family (predators, **Appendix S1: Table S1**). We used biomass per unit effort (BPUE) for all biological variables except the clams, for which only count per unit effort was available for the full timeseries. We also obtained data on dissolved inorganic nitrogen (DIN) and three environmental drivers: temperature, flow, and turbidity. Phosphorous was considered but excluded because it is not limiting in the system (Cloern et al. 2020), and salinity was considered but excluded as it is highly correlated with flow in this system. Further details on the processing of each variable are provided in **Appendix S1**.

Each variable in each source dataset was summarized into annual, annual-regional, and monthly-regional averages (**Appendix S1: Figs S1-6, Appendix S2: Table S1**), allowing for models with different spatial and temporal resolutions. Both annual and annual-regional datasets spanned 40 years (1980-2020). The monthly-regional dataset spanned 24 years (1997-2020), as monthly resolution data were only available over this time period. We only calculated averages from continuously monitored sampling stations (**Appendix S2: Table S2)**. For both annual- and monthly-regional datasets, the SF Estuary was divided into four regions: San Pablo (San Pablo Bay), Suisun (Suisun Bay), Sacramento (lower Sacramento River), and San Joaquin (lower San Joaquin River) representing different salinity and hydrodynamic habitat types within the SF Estuary (**Fig. 1**). Due to limited sampling in San Pablo before the mid-1990s, this region was only included for the monthly-regional dataset.

Analysis

We evaluated relationships among the food web components and environmental drivers using structural equation models (SEMs), a common tool for investigating dominant pathways in ecological networks including food webs (Grace et al. 2010). We first developed a conceptual model of the hypothesized direct relationships between all variables for which we had data (**Fig. 2**). These relationships reflected known ecological interactions and were based on existing literature and our knowledge of the system (**Appendix S1: Table S2**). From the conceptual model, we developed simplified models for each level of spatiotemporal resolution (annual, annual-regional, and monthly-regional) that had a corresponding dataset (**Appendix S1: Table S3**). Regional models at both time scales were fit separately to each region. Species were omitted from models of particular regions if they were rare or not sampled in that region.

The annual and annual-regional models had the same structure and focused on the relative importance of environmental drivers and food supply for estuarine fishes. For these models, we simplified the zooplankton food web by computing two aggregate zooplankton variables representing two trophic levels: herbivorous zooplankton (cladocerans + herbivorous copepods + rotifers) and predatory zooplankton (predatory copepods + mysids). Amphipods were not included in these aggregates because the units of BPUE were not equivalent. Estuarine fishes were modeled as a latent variable manifested by three survey datasets (BSMT, FMWT, STN). Environmental drivers and clams were included as exogenous predictors. We fit two versions of each annual/annual-regional model: one using the original time series and one using detrended time series from which linear trends had been removed. Contemporaneous values were used for all relationships.

For the monthly-regional data, we employed three submodels with different sets of focal (endogenous) response variables, which allowed us to explore more detailed interactions between adjacent trophic levels. We had an ‘upper trophic level,’ (response variables: estuarine fishes from BSMT, herbivorous zooplankton, predatory zooplankton), a ‘lower trophic level’ model (DIN, phytoplankton, clams), and a model of individual zooplankton groups. All models used 1-month lagged values for the biological predictors: a response variable was influenced by lower trophic levels, higher trophic levels, and itself at a 1-month lag, thus allowing us to account for autocorrelation/self-regulation, bottom-up effects, and top-down effects while maintaining a recursive model structure. For the upper and lower trophic level models, we computed the total effect size of each interaction type (self-regulation, bottom-up, top-down, environmental, nutrient cycling) for each response variable as the square root of the sum of squared path coefficients corresponding to each interaction type. Since the monthly data displayed high seasonality, we removed the seasonal trend from each variable by subtracting the mean monthly value from each timepoint. Models were fit to the resulting seasonal anomalies.

All variables were log transformed (except temperature, turbidity, and clam densities) and scaled to mean 0 and unit variance. We ensured that all final models were plausible given the data (chi-squared p>0.05) and our understanding of the system. SEM models were fit using the lavaan package (Rosseel 2012) in R version 4.0.2 (R Core Team 2020). Further analytical details can be found in **Appendix S1**.

Results

Annual and annual-regional models

Standardized path coefficients in the annual model results exhibited regional variability, as well as some differences between original and detrended data.

Original data

In the original units (**Fig. 3, Appendix S2: Table S3**), we found consistent positive effects of zooplankton food supply (either herbivorous or predatory zooplankton) on estuarine fishes in all regions (standardized path coefficient range: 0.26 to 0.61). Significant trophic links between the herbivorous and predatory zooplankton were found in every region except Sacramento (0.28 to 0.61). The full bottom-up pathway from phytoplankton to fishes was reconstructed in the whole estuary and San Joaquin. *Potamocorbula* clams had negative effects on estuarine fishes and herbivorous zooplankton in the whole estuary (-0.32 and -0.31 respectively) and Suisun (-0.33 and -0.35). In contrast, *Corbicula* clams showed a positive relationship with zooplankton and phytoplankton in Sacramento and San Joaquin (0.28 to 0.45).

Turbidity had consistent positive effects on estuarine fishes in all regions (0.26 to 0.79), on herbivorous zooplankton in Sacramento (0.45), and on phytoplankton in San Joaquin (0.37), but a negative effect on herbivorous zooplankton in Suisun (-0.28). Flow had a negative effect on predatory zooplankton in all regions (-0.20 to -0.38) except San Joaquin. Temperature had no significant effects on any variables.

Detrended data

When the linear trend was removed from the data, a few notable differences appeared (**Appendix S1: Fig. S7, Appendix S2: Table S3**). The effect of food supply on estuarine fishes became nonsignificant in Suisun and San Joaquin. In the whole estuary, predatory zooplankton, rather than herbivorous zooplankton, now positively affected fishes (0.40). The effects of *Potamocorbula* clams became nonsignificant in the whole estuary and Suisun and the effect of turbidity on fishes remained significant only in San Joaquin (0.39; and only for the FMWT dataset – other survey datasets did not show significant relationships with any of the predictors).

Phytoplankton now had a positive effect on herbivorous zooplankton in all regions (0.39 to 0.63), and flow had a positive effect on estuarine fishes in all regions except San Joaquin (0.54 to 0.79). Lastly, temperature had a significant negative effect on phytoplankton in Suisun (-0.32).

Monthly-regional models

In the monthly models, most variables had relatively low R^2 values, with predictors explaining less than half of the variation in the response (endogenous) variables, and with significant regional variability. All response variables except estuarine fishes and herbivorous copepods in Sacramento and rotifers in San Joaquin showed a significant positive relationship with past (1-month lagged) abundance.

Upper trophic level model

Bottom-up effects were more common in Sacramento and San Joaquin while top-down effects were more common in San Pablo and Suisun. Positive bottom-up effects of zooplankton on fishes were significant in all regions except Suisun (range 0.13 to 0.14), and total top-down effects on fishes were only significant in Suisun and Sacramento, although the effect of Striped Bass was positive in Suisun (**Figs. 4, 5a; Appendix S2: Table S4**). For predatory zooplankton, total top-down effects were not significant in any region, whereas bottom-up effects were significant in all regions except San Pablo. For herbivorous zooplankton, top-down effects were only significant in San Pablo and Suisun, while bottom-up effects were only significant in San Joaquin. *Potamocorbula* clams had negative effects on herbivorous zooplankton in Suisun (-0.22) and San Pablo (-0.21) while *Corbicula* clams had no significant effects. The full bottom-up pathway from phytoplankton to fishes was reconstructed in Sacramento and San Joaquin.

Environmental drivers were significant for nearly all response variables. The net effect of environmental drivers was typically on par with or greater than bottom-up and top-down effects

(**Fig. 5a**). Consistent with the annual models, turbidity had a positive effect on fishes in all regions except Sacramento (0.21 to 0.23; **Fig. 4, Appendix S2: Table S4**). In contrast to the annual models, flow had a negative effect on fishes in Suisun (-0.21) and Sacramento (-0.44). The effect of flow on zooplankton varied by trophic level, with negative effects on predatory zooplankton in Sacramento (-0.44) and San Joaquin (-0.13) and positive effects on herbivorous zooplankton in Suisun (0.18), Sacramento (0.24), and San Joaquin (0.19).

Lower trophic level model

Bottom-up effects on clams and phytoplankton were largely absent, and the only observed effects of lower trophic levels on higher trophic levels were negative (DIN on phytoplankton in Sacramento [-0.13] and predatory zooplankton on clams in San Pablo [-0.16], **Fig. 4e-h, Appendix S2: Table S4**). Total top-down effects on phytoplankton were only significant in Sacramento. R^2 values for phytoplankton were very low in all regions. For DIN, top-down effects of phytoplankton were significant and negative in all regions (-0.13 to -0.20). This effect was not lagged because a lag was not supported by the data.

Total environmental drivers were significant for all variables except phytoplankton in Suisun and San Joaquin. Total environmental effects exceeded total top-down effects for DIN in all regions (**Fig. 5b**). Flow had a negative effect on DIN in all regions except San Joaquin (-0.18 to -0.46). One case of nutrient cycling was detected in San Joaquin, where upper trophic levels (predatory zooplankton) had a positive effect on DIN (0.12).

Zooplankton model

Estuarine fishes had negative top-down effects on individual zooplankton groups in Suisun and San Joaquin (-0.18 to -0.19), but a positive effect on rotifers in San Joaquin (0.17; **Fig. 6, Appendix S2: Table S4**). *Potamocorbula* clams had negative top-down effects on herbivorous copepods in San Pablo (-0.16) and Suisun (-0.17), while *Corbicula* clams had a positive effect on herbivorous copepods in Sacramento (0.13) and San Joaquin (0.12). Interactions among zooplankton groups were most common in Suisun (-0.13 to 0.19), present in Sacramento (-0.13), but absent from San Pablo and San Joaquin. Phytoplankton had positive bottom-up effects in all regions except San Pablo (0.12 to 0.20), most prominently in San Joaquin. The bottom-up effects in each of these regions included 'skipped' trophic levels in which phytoplankton had significant effects on predatory taxa.

Environmental effects were regionally and taxonomically variable with mixed positive and negative effects of flow and turbidity but predominantly positive temperature effects (**Fig. 6, Appendix S2: Table S4**). Flow had the largest effects in Sacramento and the most consistent effects on rotifers in all regions except San Pablo (0.22 to 0.38). Temperature positively affected copepods in all regions (0.13 to 0.23). Turbidity had no effect in San Pablo, similar effects in Suisun and Sacramento, and limited influence in San Joaquin.

Discussion

In this study, we used four decades of integrated biological and environmental data to investigate the relative effects of top-down, bottom-up, and environmental drivers on pelagic food web dynamics in the SF Estuary and how these effects vary over spatial and temporal scales. Our models captured annual and monthly variation in food web interactions along the estuarine gradient and fine-scale relationships within and among trophic levels. Overall, the results provide strong evidence for bottom-up drivers of food web dynamics, supporting food supply as a critical management objective in the SF Estuary. Notably, the results support specific hypotheses, such as the positive bottom-up effects of zooplankton on forage fishes, which are corroborated by previous studies in this system and others (Supplemental discussion, **Appendix**

S1). In addition, our results provide new insights, such as the positive bottom-up effects of chlorophyll-a on zooplankton, which address long-standing questions in this highly studied estuary.

Relative effects of top-down, bottom-up, and environmental drivers

Broadly speaking, aquatic food webs are more likely to be top-down dominated than terrestrial systems (Shurin et al. 2006, Gruner et al. 2008). However, we found stronger bottom-up than top-down effects in our estuarine food web. Bottom-up effects were apparent for many (but not all) trophic linkages. For example, although we did not find evidence for a bottom-up effect of nutrients (DIN) on phytoplankton, we did find a robust bottom-up pathway from phytoplankton to estuarine fishes, most apparent at the level of the whole estuary and in the freshwater (Sacramento and San Joaquin) regions. Our study is the first to document a direct impact of chlorophyll on zooplankton biomass in the SF Estuary following the clam invasion (Kimmerer and Orsi 1996) (Supplemental Discussion, **Appendix S1)**. Additionally, unlagged negative top-down effects of phytoplankton on DIN across the estuary are consistent with prior studies suggesting rapid nutrient uptake during phytoplankton blooms (Peterson et al. 1985).

The net effect of environmental drivers was typically on par with or greater than bottom-up and top-down effects for all components of the food web (**Fig. 5**). Consistent with other estuaries, we found that flow and turbidity, defining features of an estuarine mixing zone, were important influences in the food web (Nelson et al. 2015, Wang et al. 2021). The importance of environmental factors in estuarine food webs is advantageous from a management standpoint in the sense that these factors can often be manipulated directly (Sommer et al. 2020) and can be easier to implement than biotic interventions such as predator removal. Furthermore, they can be used for indirect management of the lower food web (e.g. through freshwater flow manipulation)

(Hemraj et al. 2017).

Our analysis incorporates 12 more years of data than the last multivariate food web analysis in the SF Estuary (Mac Nally et al. 2010), allowing us to update the state of the science. While our models are not directly comparable due to different spatiotemporal scales, we were able to identify some food web relationships not present in Mac Nally et al. (2010): the bottom-up regulation from chlorophyll through zooplankton to estuarine fish biomass, trophic relationships among zooplankton guilds, and regionally-dependent effects of flow on all levels from nutrients to fishes. **Appendix S1** contains more discussion of the model pathways in relation to prior research in the SF Estuary.

Regional-scale variation

Many ecological studies have found the relative importance of different species interactions to vary across environmental gradients (e.g. stress gradient hypothesis: Bertness and Callaway 1994), and thus we also expected variation across the estuarine gradient. For zooplankton and estuarine fishes, bottom-up effects appeared to be stronger in the freshwater upstream regions (Sacramento and San Joaquin) while top-down effects were stronger in the brackish downstream regions (Suisun and San Pablo; **Fig. 5**). Although brackish regions are not truly ‘marine’, this result contrasts with the expectation that freshwater environments have stronger top-down effects than marine environments because marine predators have wider spatial ranges (McCann et al. 2005, Shurin et al. 2006). However, the freshwater regions of estuaries are subject to tidal mixing and do not limit predator movement in the same way as lakes. Greater top-down effects in brackish regions may reflect a greater abundance and diversity of predators at the mixing zone between marine and freshwater environments. This mixing zone is often located in Suisun, where we found the greatest number of interactions in the individual zooplankton model, along with higher zooplankton diversity and abundance (**Appendix S1: Fig. S6**).

The invasive clam *Potamocorbula*, found in brackish regions of the SF Estuary, always exhibited negative top-down effects on zooplankton, whereas relationships with *Corbicula*, found in the freshwater regions, were either positive or neutral. This is a reasonable result given that *Potamocorbula* can have a much higher grazing rate than *Corbicula* (Foe and Knight 1986, Cole et al. 1992) and has been implicated by other studies in plankton declines (Kimmerer 2002a). We do not have a good explanation for the positive relationships with *Corbicula*, which were only seen in the annual and individual zooplankton models but speculate on some possibilities in the supplemental discussion (**Appendix S1**).

Effects of environmental drivers were also regionally variable. Flow effects and total environmental effects were almost always greatest in Sacramento (**Figs. 4, 5a, 6**), likely because the Sacramento River contributes 85% of estuarine inflow (Kimmerer 2002b) and higher flows can often transport plankton downstream (Kimmerer et al. 2018). Flow had negative effects on DIN in all regions except San Joaquin, with effect strength declining downstream. This spatial pattern in flow-DIN impacts potentially reflects nutrient export processes and flow-related dilution of wastewater discharge, which is a major source of nitrogen (Jassby 2008) upstream of the Sacramento region. Further studies would be needed to disentangle the effects of different nutrients on phytoplankton, which we were unable to decouple due to collinearity.

Temporal-scale variation

While the annual and monthly model results were largely consistent, the detectability of some interactions changed with temporal resolution. For instance, bottom-up effects were resolvable primarily at coarser (annual) temporal scales. Temperature effects, in contrast, were resolvable primarily at fine (monthly) temporal scales. There were few relationships with mean annual temperature, but results at the monthly scale likely reflect positive effects of temperature on growth/development rates and the subtropical origin of most zooplankton species (Orsi and Ohtsuka 1999). Results in the annual models also suggest that the effects of *Potamocorbula* clams and turbidity on fishes were primarily due to linear trends rather than year-to-year variability.

Perhaps the largest discrepancy between the annual and monthly models relates to flow, which had a positive effect on estuarine fishes in the annual models but negative effects in the monthly upper trophic model. One explanation is that the annual data largely reflect interannual changes in population size, whereas the monthly data also reflect fish movement and distributional shifts within the estuary. We observed a negative correlation between flow and estuarine fishes in the Sacramento region in the monthly data, which became less prominent in Suisun, and changed to a positive correlation in San Pablo (**Appendix S1: Fig. S3**). This suggests that center of distribution of estuarine fishes tends to stay within the low salinity zone of the system, which moves with freshwater flow. The flow-fish relationship in San Pablo was not significant in the model results likely because it was superseded by turbidity, which is collinear with flow and also correlated with fish abundance (**Appendix S1: Fig. S3**).

Data limitations

Our study was limited by lack of long-term monitoring data on several important food web components. For instance, we used chlorophyll as a coarse proxy for phytoplankton abundance since high-quality, long-term phytoplankton data are lacking from this system. Although chlorophyll was often a significant driver of zooplankton abundance, chlorophyll itself was poorly explained by the predictors in our models ($R^2 \leq 0.3$ in annual models, and even lower in the monthly models). This highlights a gap in our ability to explain variation in overall primary productivity. Factors not included in our study such as residence time or light availability may be important (Kimmerer 2002a), or finer taxonomic resolution is needed. Other components for which we are lacking regular, long-term data are large-bodied piscivorous fishes, which can exert strong top-down effects (Carpenter et al. 1985); microplankton (e.g., ciliates and bacteria), which are often consumed by ‘herbivorous’ zooplankton (Gifford et al. 2007); submersed and emergent aquatic vegetation, which can contribute substantially to the pelagic trophic pathway (Young et al. 2020); contaminants (e.g., herbicides, pesticides), which can have considerable impacts on food webs and are a known issue in the SF Estuary (Fong et al. 2016), and entrainment of phytoplankton, zooplankton, and fishes in the water export pumps. These data gaps highlight potential priorities for future monitoring.

In some cases, the models suggested paths that were unexpected, given our conceptual model. For instance, some of the paths added during the model evaluation and modification phase to properly reflect covariance in the data appeared to jump trophic levels (e.g., phytoplankton having a positive effect on predatory zooplankton). Other paths had opposite signs as expected from a priori knowledge (e.g., positive effects of *Corbicula* on herbivorous zooplankton, **Fig. 6**). Two possible explanations are missing variables or indirect effects. Indirect effects can appear as direct effects if they are integrated over a long enough timestep (i.e., interactions on the monthly timestep reflect integrated effects over the course of that month rather than ‘instantaneous’ interactions). This could explain both the phenomenon of ‘skipped’ trophic levels and the unexpected signs of some interactions. We also note that our analyses had a large number of parameters relative to data (Wolf et al. 2013). Thus, a non-significant result does not mean the relationship is absent or unimportant, but simply that we did not find support for it in this analysis.

Model limitations

The linear additive structure of SEMs poses some limitations to our ability to resolve food web interactions. Our model structure did not allow for interactions among predictors, thus we could not detect how biotic interactions vary with environmental conditions within a region. For example, turbidity can help estuarine forage fishes find prey as well as hide from predators (Baskerville-Bridges et al. 2004, Ferrari et al. 2014). SEM also does not allow for nonlinear or time-varying effects, which may be important. Some of the inconsistent linear effects we observed may also indicate higher-order predator-prey interactions such as prey-switching behavior, which SEMs would not be able to account for. For instance, we found effects of fish on zooplankton in some regions, and which regions contain this relationship varied depending on whether trophic level aggregates or individual zooplankton groups were used (**Figs. 4, 6**).

The use of time lags in the monthly models revealed that self-regulation (autocorrelation) was important in the dynamics of nearly all food web components, and thus is important to consider. However, the intra- and inter-specific time lags used were the same for all components, even though intrinsic timescales of movement, growth, and reproduction may vary among species. Further investigation and a different modeling approach would be needed to tailor time lags to each component.

Conclusion

Estuarine food webs can exhibit substantial variation in structure even when they share a common geographic location (Sheaves et al. 2017). Our study provides a broad picture of the SF Estuary food web, where environmental factors drive large parts of the ecosystem dynamics but productivity may be limited by the lower trophic levels, especially within the freshwater regions.

These findings identify the trophic levels or environmental factors that management actions could target to have the greatest impact on estuarine forage fishes. Our integrated dataset (**citation**) and food web model can further serve as the groundwork for the development of predictive models that can directly inform management (Adams et al. 2020, Munch et al. in press). These results can also serve as a baseline for further hypothesis-driven analyses, such as those related to climate change projections. Our approach of leveraging long-term datasets to identify trophic interactions is applicable to a wide range of systems, including complex, dynamic systems along environmental gradients.

Acknowledgements

This project was supported by an agreement with the Delta Science Program, Delta Stewardship Council (DSC contract 19167). Funding was provided by the Delta Science Program and activities were supported by the National Center for Ecological Analysis and Synthesis (NCEAS) Learning Hub. The findings and conclusions of this study are those of the authors and do not necessarily represent the views of their respective organizations.

Tables

Table 1. Variables and data sources

Variables	Data source	Citation
Zooplankton (cladocerans, herbivorous copepods, mysids, predatory copepods, rotifers)	Environmental Monitoring Program (EMP Zooplankton)	(Barros 2021)
Benthic invertebrates (clams, amphipods)	Environmental Monitoring Program (EMP Benthic)	(Wells and Interagency Ecological Program 2021)
Fish (estuarine fishes, marine fishes, age 1+ striped bass)	San Francisco Bay Study Midwater Trawl (BSMT)	https://wildlife.ca.gov/Conservation/Delta/Bay-Study
Fish (estuarine fishes)	Fall Midwater Trawl Survey (FMWT)	https://dfg.ca.gov/delta/projects.asp?ProjectID=FMWT
	Summer Townet Survey (STN)	https://wildlife.ca.gov/Conservation/Delta/Townet-Survey
Fish (Mississippi Silverside, centrarchid species)	Delta Juvenile Fish Monitoring Program (DJFMP)	(Interagency Ecological Program et al. 2021b)
Chlorophyll-*a*, Temperature, Secchi depth, Nutrients	Environmental Monitoring Program (EMP Water Quality)	(Interagency Ecological Program et al. 2021a)
Flow	Dayflow, California Department of Water Resources	https://data.cnra.ca.gov/dataset/dayflow

Figure captions

Fig. 1. Map of the SF Estuary, California, USA with region (San Pablo, Suisun, Sacramento, San Joaquin) boundaries and survey stations used in (a) annual and annual-regional analyses and (b) monthly-regional analyses. Cities are shown for reference in gray text. The Sacramento and San Joaquin regions are contained within the primarily freshwater Sacramento-San Joaquin Delta, while Suisun and San Pablo are more dynamic in salinity and remain largely brackish to marine. For survey acronyms, see Table 1.

Fig. 2. Conceptual model of hypothesized relationships between all variables. Direct consumption arrows point in the direction of energy flow.

Fig. 3. Path diagrams for annual and annual-regional SEMs. Arrows point from predictor variables to response variables. Blue arrows indicate positive path coefficients and red arrows indicate negative path coefficients. Arrow thickness is proportional to the magnitude of the standardized path coefficient (**Appendix S2: Table S3**).

Fig. 4. Path diagrams for monthly-regional SEMs using (a-d) upper trophic level aggregates and (e-h) lower trophic level aggregates. Arrows point from predictor variables to response variables. Blue arrows indicate positive path coefficients and red arrows indicate negative path coefficients. Arrow thickness is proportional to the magnitude of the standardized path coefficient (**Appendix S2: Table S4**).

Fig. 5. Total effect sizes for different interaction types in monthly-regional SEMs using (a) upper trophic level aggregates and (b) lower trophic level aggregates. * = total effect significant ($p<0.05$)

Fig. 6. Path diagrams for monthly-regional SEMs using individual zooplankton groups. Arrows

point from predictor variables to response variables. Blue arrows indicate positive path coefficients and red arrows indicate negative path coefficients. Arrow thickness is proportional to the magnitude of the standardized path coefficient (**Appendix S2: Table S4**).

Figures

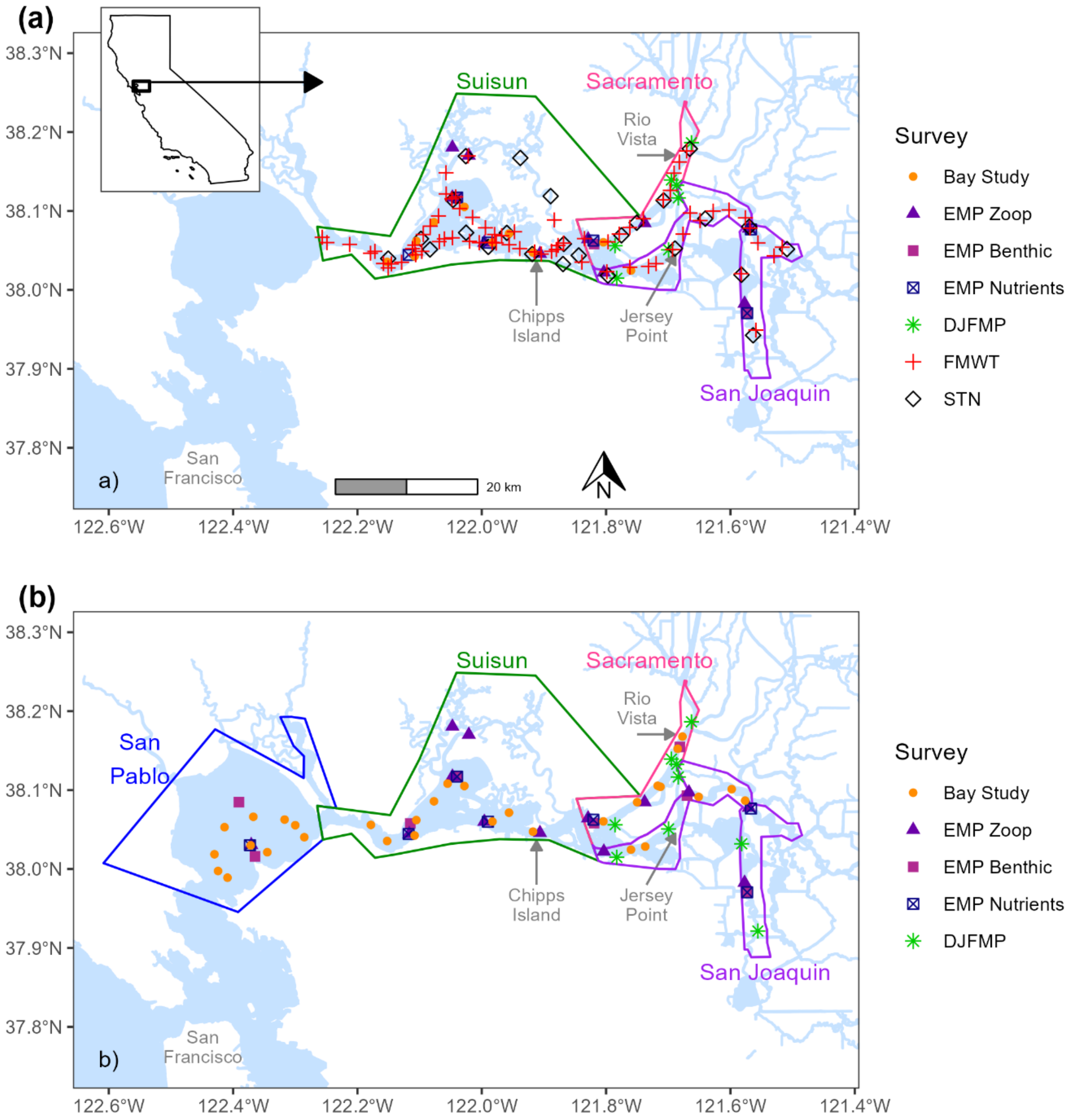


Figure 1

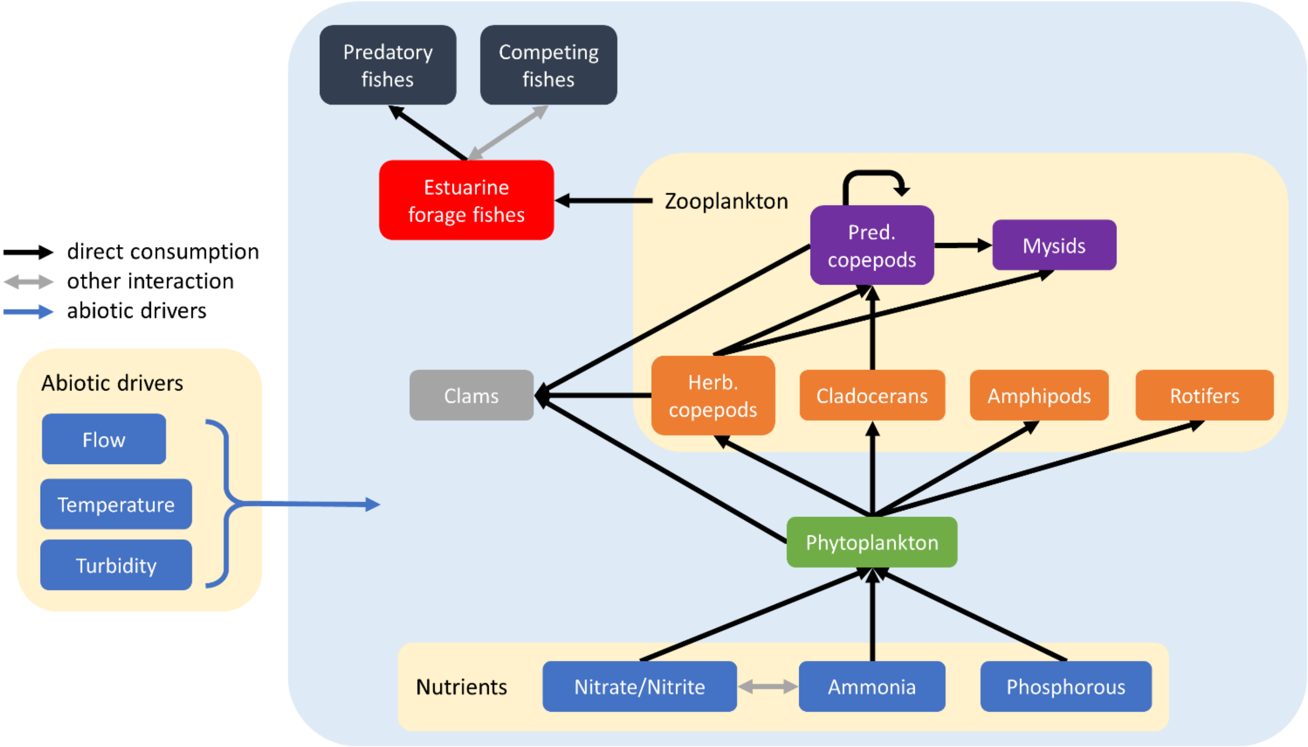

Predatory fishes
Competing fishes
Estuarine forage fishes
Zooplankton
Pred. copepods
Mysids
direct consumption
other interaction
abiotic drivers
Abiotic drivers
Flow
Temperature
Turbidity
Clams
Herb. copepods
Cladocerans
Amphipods
Rotifers
Phytoplankton
Nutrients
Nitrate/Nitrite
Ammonia
Phosphorous

Figure 2.

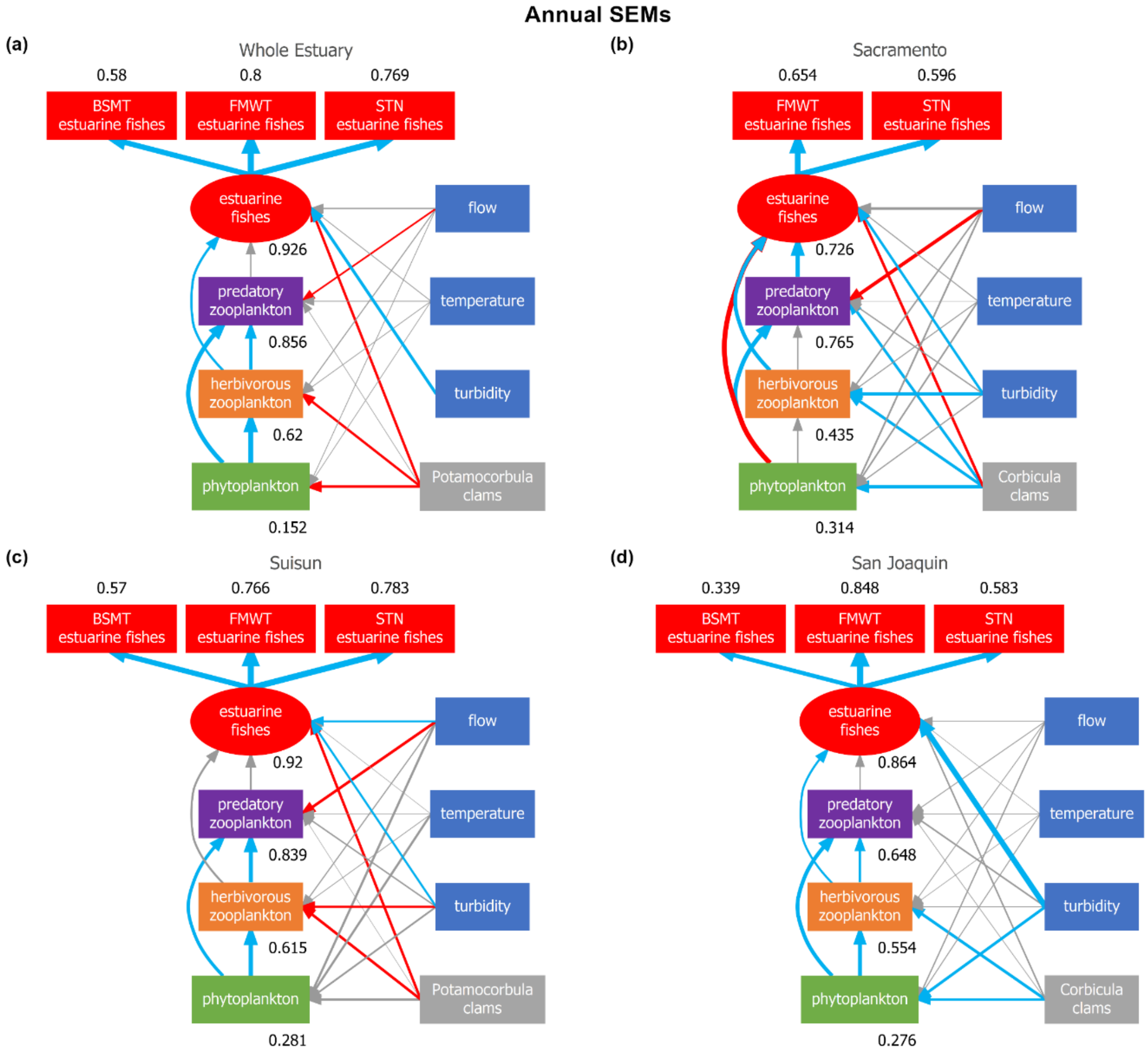
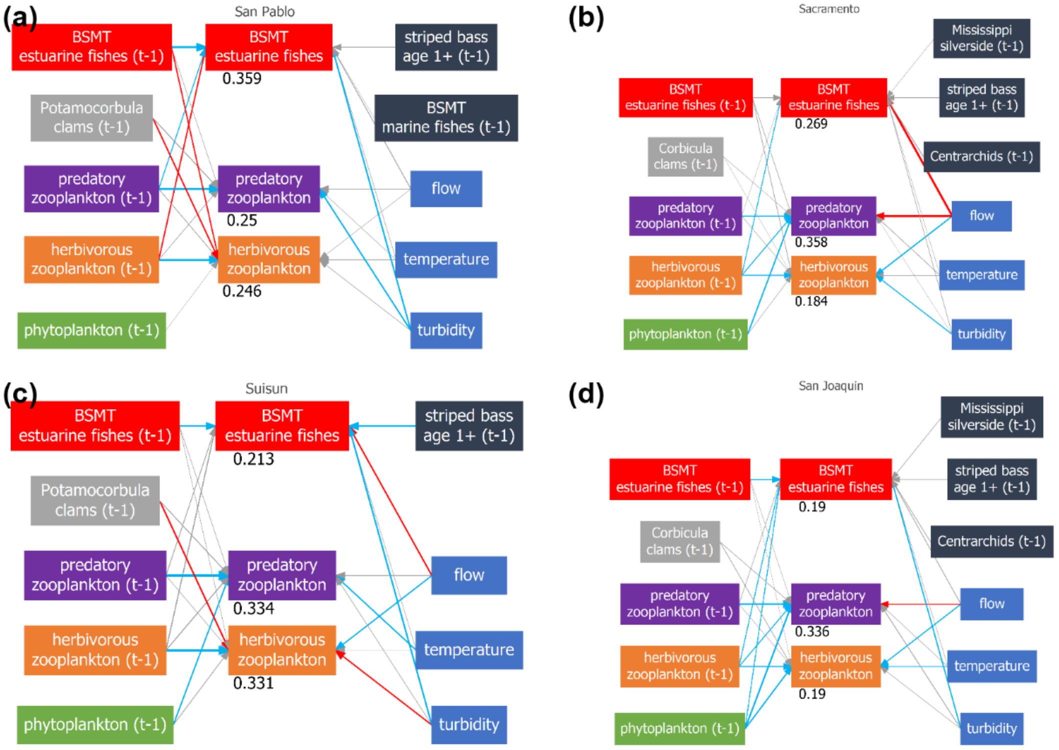

Annual SEMs
(a)
Whole Estuary
0.58
0.8
0.769
BSMT estuarine fishes
FMWT estuarine fishes
STN estuarine fishes
estuarine fishes
flow
0.926
predatory zooplankton
temperature
0.856
herbivorous zooplankton
turbidity
0.62
phytoplankton
Potamocorbula clams
0.152
(b)
Sacramento
0.654
0.596
FMWT estuarine fishes
STN estuarine fishes
estuarine fishes
flow
0.726
predatory zooplankton
temperature
0.765
herbivorous zooplankton
turbidity
0.435
phytoplankton
Corbicula clams
0.314
(c)
Suisun
0.57
0.766
0.783
BSMT estuarine fishes
FMWT estuarine fishes
STN estuarine fishes
estuarine fishes
flow
0.92
predatory zooplankton
temperature
0.839
herbivorous zooplankton
turbidity
0.615
phytoplankton
Potamocorbula clams
0.281
(d)
San Joaquin
0.339
0.848
0.583
BSMT estuarine fishes
FMWT estuarine fishes
STN estuarine fishes
estuarine fishes
flow
0.864
predatory zooplankton
temperature
0.648
herbivorous zooplankton
turbidity
0.554
phytoplankton
Corbicula clams
0.276

Figure 3.

Monthly regional models: upper trophic level



Monthly regional models: lower trophic level

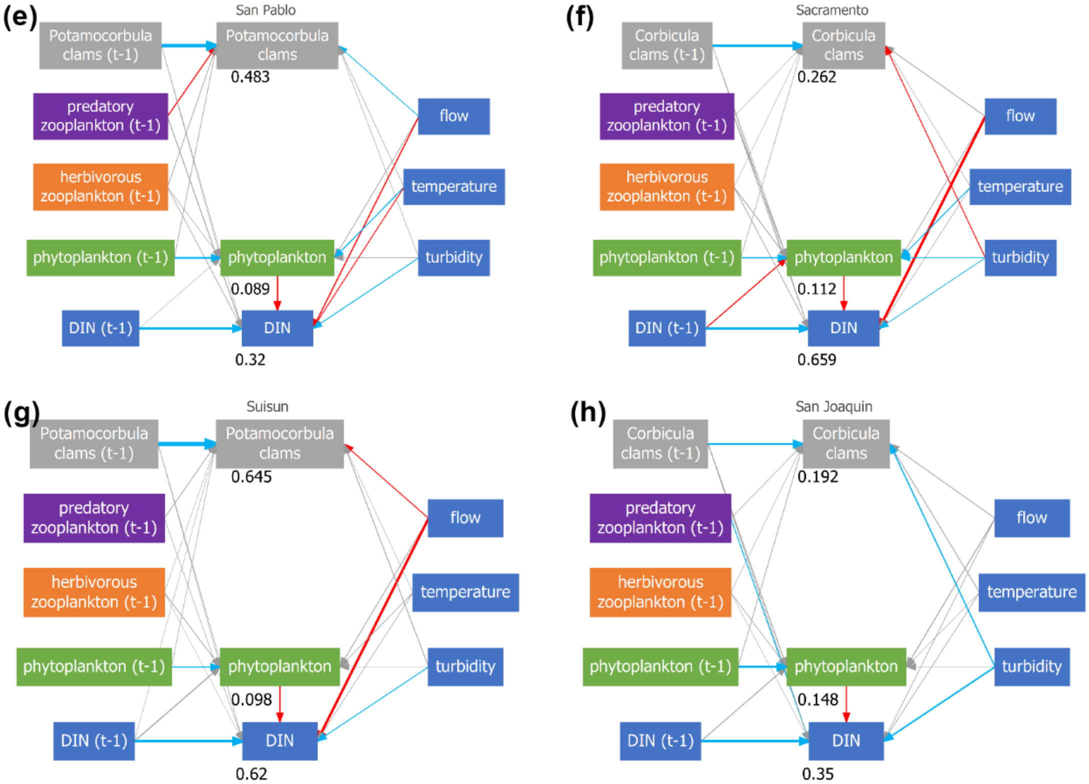


Figure 4.

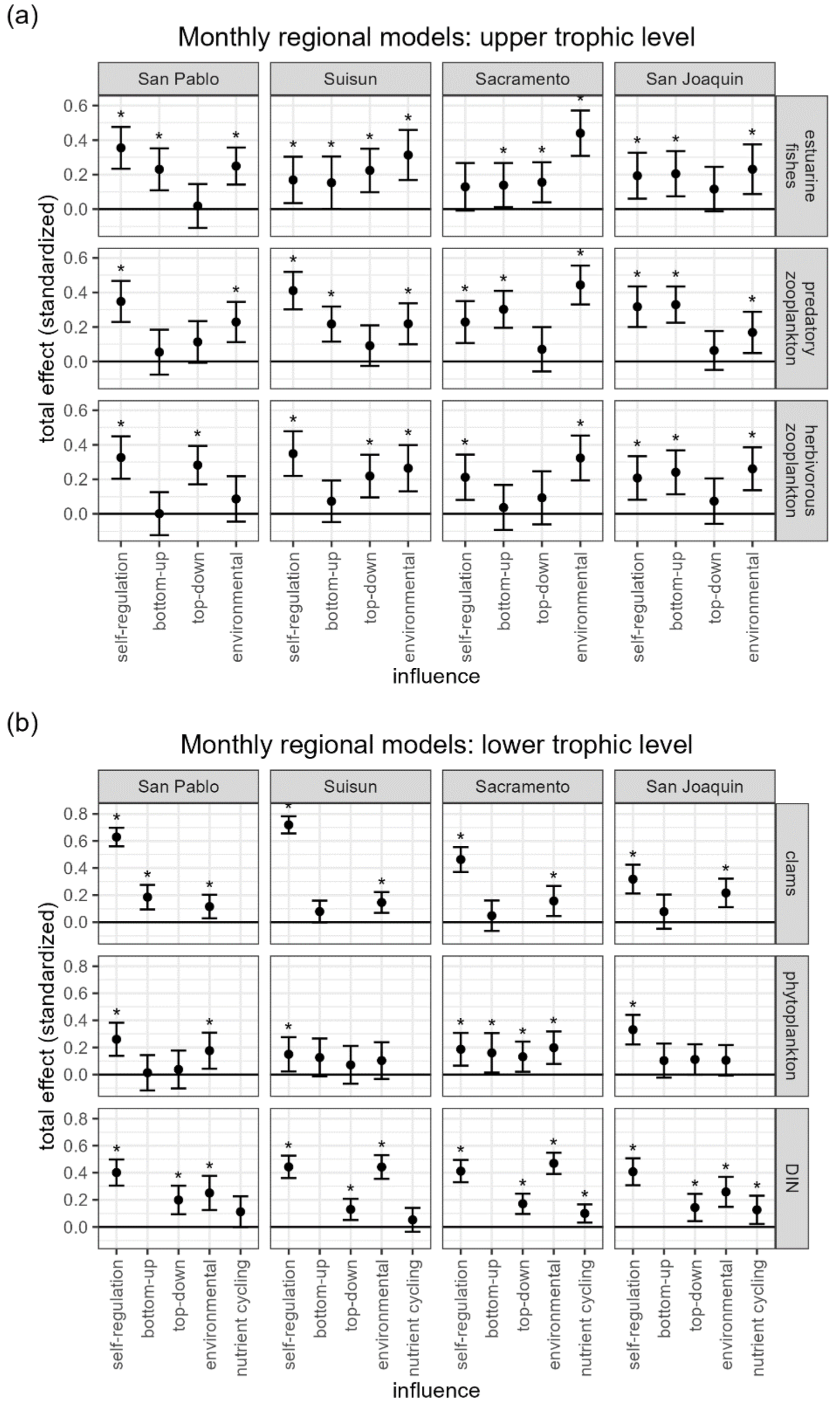

(a)
Monthly regional models: upper trophic level
San Pablo
Suisun
Sacramento
San Joaquin
estuarine fishes
predatory zooplankton
herbivorous zooplankton
total effect (standardized)
0.6
0.4
0.2
0.0
self-regulation
bottom-up
top-down
environmental
influence
(b)
Monthly regional models: lower trophic level
San Pablo
Suisun
Sacramento
San Joaquin
clams
phytoplankton
DIN
total effect (standardized)
0.8
0.6
0.4
0.2
0.0
self-regulation
bottom-up
top-down
environmental
nutrient cycling
influence

Figure 5.

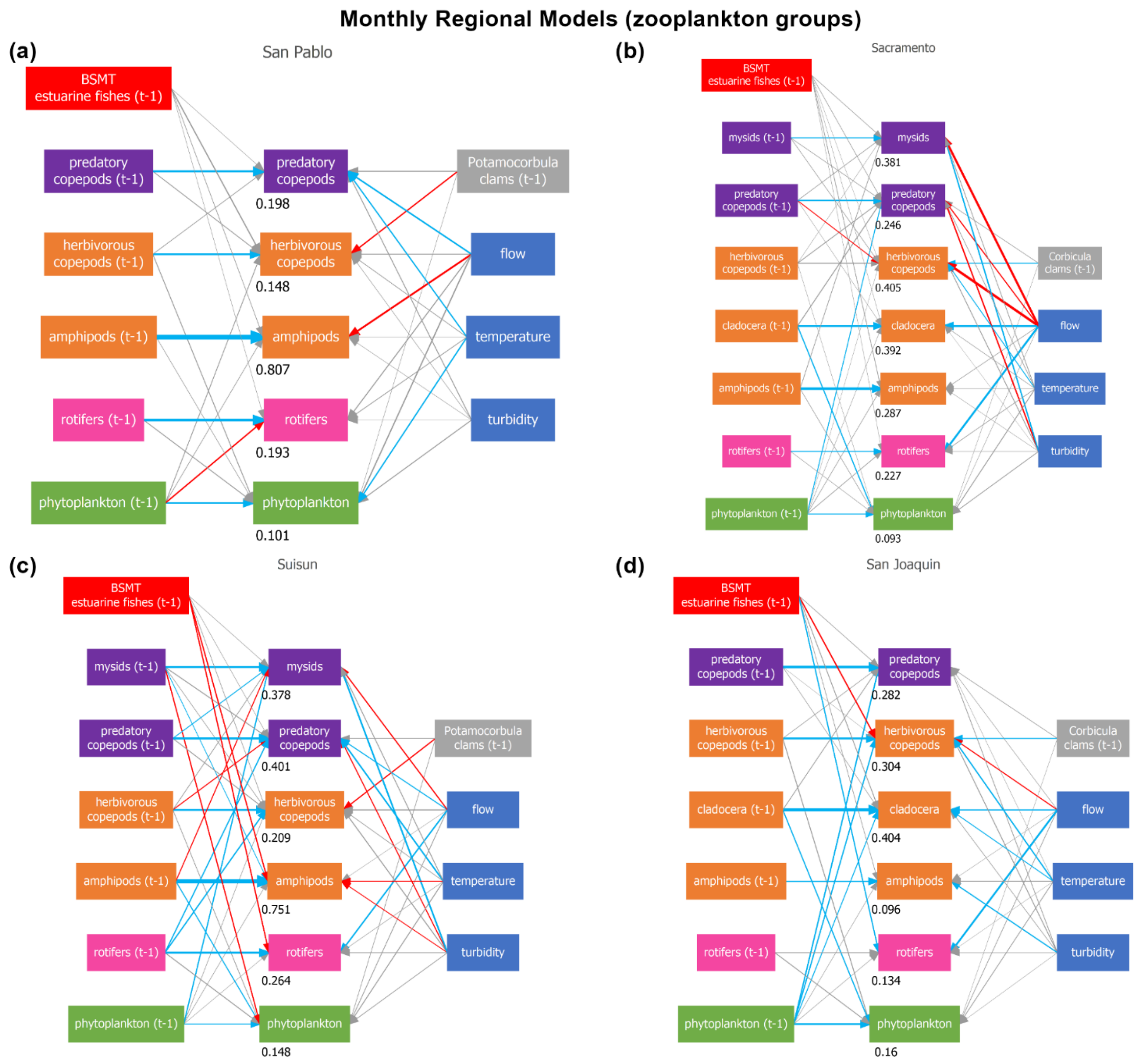

Monthly Regional Models (zooplankton groups)
(a)
San Pablo
BSMT estuarine fishes (t-1)
predatory copepods (t-1)
herbivorous copepods (t-1)
amphipods (t-1)
rotifers (t-1)
phytoplankton (t-1)
predatory copepods
0.198
herbivorous copepods
0.148
amphipods
0.807
rotifers
0.193
phytoplankton
0.101
Potamocorbula clams (t-1)
flow
temperature
turbidity
(b)
Sacramento
BSMT estuarine fishes (t-1)
mysids (t-1)
predatory copepods (t-1)
herbivorous copepods (t-1)
cladocera (t-1)
amphipods (t-1)
rotifers (t-1)
phytoplankton (t-1)
mysids
0.381
predatory copepods
0.246
herbivorous copepods
0.405
cladocera
0.392
amphipods
0.287
rotifers
0.227
phytoplankton
0.093
Corbicula clams (t-1)
flow
temperature
turbidity
(c)
Suisun
BSMT estuarine fishes (t-1)
mysids (t-1)
predatory copepods (t-1)
herbivorous copepods (t-1)
amphipods (t-1)
rotifers (t-1)
phytoplankton (t-1)
mysids
0.378
predatory copepods
0.401
herbivorous copepods
0.209
amphipods
0.751
rotifers
0.264
phytoplankton
0.148
Potamocorbula clams (t-1)
flow
temperature
turbidity
(d)
San Joaquin
BSMT estuarine fishes (t-1)
predatory copepods (t-1)
herbivorous copepods (t-1)
cladocera (t-1)
amphipods (t-1)
rotifers (t-1)
phytoplankton (t-1)
predatory copepods
0.282
herbivorous copepods
0.304
cladocera
0.404
amphipods
0.096
rotifers
0.134
phytoplankton
0.16
Corbicula clams (t-1)
flow
temperature
turbidity

Figure 6.

Literature cited

Adams, M. P., S. A. Sisson, K. J. Helmstedt, C. M. Baker, M. H. Holden, M. Plein, J. Holloway, K. L. Mengersen, and E. McDonald-Madden. 2020. Informing management decisions for ecological networks, using dynamic models calibrated to noisy time-series data. Ecology Letters 23:607–619.

Arimitsu, M. L., J. F. Piatt, S. Hatch, R. M. Suryan, S. Batten, M. A. Bishop, R. W. Campbell, H. Coletti, D. Cushing, K. Gorman, R. R. Hopcroft, K. J. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, S. Pegau, A. Schaefer, S. Schoen, J. Straley, and V. R. von Biela. 2021. Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Global Change Biology 27:1859–1878.

Barros, A. E. 2021. Interagency Ecological Program Zooplankton Study. ver 9. Environmental Data Initiative.

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 219–227 *in* F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society Symposium, Bethesda, MD, USA.

Bertness, M. D., and R. Callaway. 1994. Positive interactions in communities. Trends in Ecology & Evolution 9:191–193.

Carpenter, S. R., J. F. Kitchell, and J. R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity: Fish predation and herbivory can regulate lake ecosystems. BioScience 35:634–639.

Cloern, J. E., T. S. Schraga, E. Nejad, and C. Martin. 2020. Nutrient Status of San Francisco Bay and Its Management Implications. Estuaries and Coasts.

Cohen, A. N., and J. T. Carlton. 1998. Accelerating Invasion Rate in a Highly Invaded Estuary. Science 279:555–558.

Cole, B. E., J. K. Thompson, and J. E. Cloern. 1992. Measurement of filtration rates by infaunal bivalves in a recirculating flume. Marine Biology 113:219–225.

Cushing, D. H. 1990. Plankton Production and Year-class Strength in Fish Populations: an Update of the Match/Mismatch Hypothesis. Pages 249–293 *in* J. H. S. Blaxter and A. J. Southward, editors. Advances in Marine Biology. Academic Press.

Dyer, L. A., and D. K. Letourneau. 1999. Relative strengths of top-down and bottom-up forces in a tropical forest community. Oecologia 119:265–274.

Ferrari, M. C. O., L. Ranåker, K. L. Weinersmith, M. J. Young, A. Sih, and J. L. Conrad. 2014. Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. Environmental Biology of Fishes 97:79–90.

Feyrer, F., J. E. Cloern, L. R. Brown, M. A. Fish, K. A. Hieb, and R. D. Baxter. 2015. Estuarine fish communities respond to climate variability over both river and ocean basins. Global Change Biology 21:3608–3619.

Foe, C., and A. Knight. 1986. Growth of *Corbicula fluminea* (bivalvia) fed artificial and algal diets. Hydrobiologia 133:155–164.

Fong, S., S. Louie, I. Werner, J. Davis, and R. E. Connon. 2016. Contaminant Effects on California Bay–Delta Species and Human Health. San Francisco Estuary and Watershed Science 14.

Gifford, S. M., G. Rollwagen-Bollens, and S. M. Bollens. 2007. Mesozooplankton omnivory in the upper San Francisco Estuary. Marine Ecology Progress Series 348:33–46.

Grace, J. B., T. M. Anderson, H. Olff, and S. M. Scheiner. 2010. On the specification of structural equation models for ecological systems. Ecological Monographs 80:67–87.

Grimaldo, L., R. E. Miller, C. M. Peregrin, and Z. Hymanson. 2012. Fish Assemblages in Reference and Restored Tidal Freshwater Marshes of the San Francisco Estuary. San Francisco Estuary and Watershed Science 10.

Gruner, D. S., J. E. Smith, E. W. Seabloom, S. A. Sandin, J. T. Ngai, H. Hillebrand, W. S. Harpole, J. J. Elser, E. E. Cleland, M. E. S. Bracken, E. T. Borer, and B. M. Bolker. 2008. A cross-system synthesis of consumer and nutrient resource control on producer biomass. Ecology Letters 11:740–755.

Hampton, S. E., M. D. Scheuerell, and D. E. Schindler. 2006. Coalescence in the Lake Washington story: Interaction strengths in a planktonic food web. Limnology and Oceanography 51:2042–2051.

Hampton, S. E., C. A. Strasser, J. J. Tewksbury, W. K. Gram, A. E. Budden, A. L. Batcheller, C. S. Duke, and J. H. Porter. 2013. Big data and the future of ecology. Frontiers in Ecology and the Environment 11:156–162.

Hemraj, D. A., A. Hossain, Q. Ye, J. G. Qin, and S. C. Leterme. 2017. Anthropogenic shift of planktonic food web structure in a coastal lagoon by freshwater flow regulation. Scientific Reports 7:44441.

Hoover, R. S., D. Hoover, M. Miller, M. R. Landry, E. H. DeCarlo, and F. T. Mackenzie. 2006. Zooplankton response to storm runoff in a tropical estuary: bottom-up and top-down controls. Marine Ecology Progress Series 318:187–201.

Interagency Ecological Program, M. Martinez, and S. Perry. 2021a. Interagency Ecological Program: Discrete water quality monitoring in the Sacramento-San Joaquin Bay-Delta, collected by the Environmental Monitoring Program, 1975-2020. ver 4. Environmental Data Initiative.

Interagency Ecological Program, R. McKenzie, J. Speegle, A. Nanninga, J. R. Cook, J. Hagen, B. Mahardja, A. Arrambide, and L. Smith. 2021b. Over four decades of juvenile fish monitoring data from the San Francisco Estuary, collected by the Delta Juvenile Fish Monitoring Program, 1976-2019 ver 5. Environmental Data Initiative.

Jassby, A. 2008. Phytoplankton in the Upper San Francisco Estuary: Recent Biomass Trends, Their Causes, and Their Trophic Significance. San Francisco Estuary and Watershed Science 6.

Kimmerer, W. J. 2002a. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39–55.

Kimmerer, W. J. 2002b. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25:1275–1290.

Kimmerer, W. J., T. R. Ignoffo, K. R. Kayfetz, and A. M. Slaughter. 2018. Effects of freshwater flow and phytoplankton biomass on growth, reproduction, and spatial subsidies of the estuarine copepod *Pseudodiaptomus forbesi*. Hydrobiologia 807:113–130.

Kimmerer, W. J., and J. J. Orsi. 1996. Changes in the zooplankton of the San Francisco Bay Estuary since the introduction of the clam *Potamocorbula amurensis*. Pages 403–424 *in* J. T. Hollibaugh, editor. San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.

Lauchlan, S. S., and I. Nagelkerken. 2020. Species range shifts along multistressor mosaics in estuarine environments under future climate. Fish and Fisheries 21:32–46.

Leonard, G. H., J. M. Levine, P. R. Schmidt, and M. D. Bertness. 1998. Flow-Driven Variation in Intertidal Community Structure in a Maine Estuary. Ecology 79:1395–1411.

Lynam, C. P., M. Llope, C. Möllmann, P. Helaouët, G. A. Bayliss-Brown, and N. C. Stenseth. 2017. Interaction between top-down and bottom-up control in marine food webs. Proceedings of the National Academy of Sciences 114:1952–1957.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, and S. D. Culberson. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417–1430.

McCann, K. S., J. B. Rasmussen, and J. Umbanhowar. 2005. The dynamics of spatially coupled food webs. Ecology Letters 8:513–523.

McClelland, J. W., I. Valiela, and R. H. Michener. 1997. Nitrogen-stable isotope signatures in estuarine food webs: A record of increasing urbanization in coastal watersheds. Limnology and Oceanography 42:930–937.

Meserve, P. L., D. A. Kelt, W. B. Milstead, and J. R. GutiÉrrez. 2003. Thirteen Years of Shifting Top-Down and Bottom-Up Control. BioScience 53:633–646.

Miller-Rushing, A. J., T. T. Høye, D. W. Inouye, and E. Post. 2010. The effects of phenological mismatches on demography. Philosophical Transactions of the Royal Society B: Biological Sciences 365:3177–3186.

Monsen, N. E., J. E. Cloern, and J. R. Burau. 2007. Effects of Flow Diversions on Water and Habitat Quality: Examples from California’s Highly Manipulated Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science 5.

Munch, S. B., T. L. Rogers, and G. Sugihara. in press. Recent developments in empirical dynamic modeling. Methods in Ecology and Evolution.

Nelson, J. A., L. Deegan, and R. Garritt. 2015. Drivers of spatial and temporal variability in estuarine food webs. Marine Ecology Progress Series 533:67–77.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The Modification of an Estuary. Science 231:567–573.

Orsi, J. J., and S. Ohtsuka. 1999. Introduction of the Asian copepods *Acartiella sinensis*, *Tortanus dextrilobatus* (Copepoda: Calanoida), and *Limnoithona tetraspina* (Copepoda: Cyclopoida) to the San Francisco Estuary, California, USA. Plankton Biology and Ecology 46:128–131.

Peterson, D. H., R. E. Smith, S. W. Hager, D. D. Harmon, R. E. Herndon, and L. E. Schemel. 1985. Interannual variability in dissolved inorganic nutrients in Northern San Francisco Bay Estuary. Pages 37–58 *in* J. E. Cloern and F. H. Nichols, editors. Temporal Dynamics of an Estuary: San Francisco Bay. Springer Netherlands, Dordrecht.

Power, M. E. 1992. Top-Down and Bottom-Up Forces in Food Webs: Do Plants Have Primacy. Ecology 73:733–746.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Rosseel, Y. 2012. lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software 48:1–36.

Sheaves, M., R. Baker, K. G. Abrantes, and R. M. Connolly. 2017. Fish Biomass in Tropical Estuaries: Substantial Variation in Food Web Structure, Sources of Nutrition and Ecosystem-Supporting Processes. Estuaries and Coasts 40:580–593.

Shurin, J. B., D. S. Gruner, and H. Hillebrand. 2006. All wet or dried up? Real differences between aquatic and terrestrial food webs. Proceedings of the Royal Society B:

Biological Sciences 273:1–9.

Sommer, T., R. Hartman, M. Koller, M. Koohafkan, J. L. Conrad, M. MacWilliams, A. Bever, C. Burdi, A. Hennessy, and M. Beakes. 2020. Evaluation of a large-scale flow manipulation to the upper San Francisco Estuary: Response of habitat conditions for an endangered native fish. PLOS ONE 15:e0234673.

Tempel, T. L., T. D. Malinich, J. Burns, A. Barros, C. E. Burdi, and J. A. Hobbs. 2021. The value of long-term monitoring of the San Francisco Estuary for Delta Smelt and Longfin Smelt. California Fish and Wildlife:148–171.

Wang, H., F. Chen, C. Zhang, M. Wang, and J. Kan. 2021. Estuarine gradients dictate spatiotemporal variations of microbiome networks in the Chesapeake Bay. Environmental Microbiome 16:22.

Wells, E., and Interagency Ecological Program. 2021. Interagency Ecological Program: Benthic invertebrate monitoring in the Sacramento-San Joaquin Bay-Delta, collected by the Environmental Monitoring Program, 1975-2020.

Wolf, E. J., K. M. Harrington, S. L. Clark, and M. W. Miller. 2013. Sample Size Requirements for Structural Equation Models: An Evaluation of Power, Bias, and Solution Propriety. Educational and Psychological Measurement 73:913–934.

Young, M., E. Howe, T. O’Rear, K. Berridge, and P. Moyle. 2020. Food Web Fuel Differs Across Habitats and Seasons of a Tidal Freshwater Estuary. Estuaries and Coasts.

Evaluating top-down, bottom-up, and environmental drivers of pelagic food web dynamics along an estuarine gradient

Authors: Tanya L. Rogers, Samuel M. Bashevkin, Christina E. Burdi, Denise D. Colombano, Peter N. Dudley, Brian Mahardja, Lara Mitchell, Sarah Perry, Parsa Saffarinia

Appendix S1: Supplemental text, tables, and figures

Supplemental methods

Data processing

Many of the variables were obtained from the Environmental Monitoring Program (EMP), a long-running year-round monitoring program in the SF Estuary with three distinct studies: Zooplankton, Benthic Invertebrates, and Water Quality.

Invertebrates

Zooplankton abundance data were obtained from the EMP Zooplankton Study (Barros 2021) and Benthic Study (Wells and Interagency Ecological Program 2021), the longest-running and only year-round invertebrate surveys in the SF Estuary. Zooplankton Study data were accessed through the R package ‘zooper’ v2.4.1 (Bashevkin et al. 2022b). Zooplankton were grouped into 6 categories for analysis: cladocerans, herbivorous copepods, predatory copepods, mysids, amphipods, and rotifers (**Appendix S1: Table S1**). The herbivorous copepod category included some taxa that are occasionally predatory (e.g., *Limnoithona sinensis*) but only predate on taxa not included in our model (e.g., ciliates). Amphipods were obtained from the Benthic Study because the Zooplankton Study did not record amphipods until 1996 and did not identify them to genus until 2014. Only amphipods routinely found in fish diets (Slater et al. 2019; unpublished data) and in areas sampled by the fish monitoring surveys were included (**Appendix**

S1: Table S1). Biomass per unit effort (BPUE; µg carbon mass m^{-3} [m^{-2} for amphipods]) was calculated from count data using conversions compiled from the literature by Bashevkin et al. (2022c, 2022b) and Burdi et al. (2021). Since length data were only available for mysids and amphipods, length-mass conversions were used for those taxa while average mass values were used for the other groups. However, since the Benthic Study lacked amphipod length measurements, amphipod BPUE was estimated using the average biomass for each species from the Zooplankton Study (using the genus-level data from 2014 – present), calculated via the length-mass equations.

For each zooplankton group, we additionally calculated energy per unit effort (EPUE, J m^{-3} [m^{-2} for amphipods]) using energy density measurements (J g^{-1} dry mass) from the literature. From eight sources (Cummins 1967, Schindler et al. 1971, Vijverberg and Th. Frank 1976, Johnson and Hopkins 1978, Theilacker and Kimball 1984, Yúfera and Pascual 1989, Hanson et al. 1997, Forster 1999), we gathered 36 records of energy density for various types of zooplankton. Of these records, 29 were identified at the species level, two at the genus level, two at the family level, two at the order level, and one at the superorder level. In total, there were 28 unique categories of zooplankton energy density. We matched each of the 28 categories to one of the six categories of zooplankton used in this analysis. This matching gave us two values for amphipods, 12 for cladocerans, 14 for herbivorous copepods, three for predatory copepods, two for mysids, and three for rotifers. We then took averages (**Appendix S1: Fig. S8**) to get a value for each category (Dudley et al. 2022). We ultimately did not use EPUE in our analysis as it was highly correlated with BPUE (Pearson $r > 0.99$) and gave very similar results.

The EMP Benthic study was also used to calculate density metrics (count m^{-2}) for each of the two invasive clam species (*Potamocorbula amurensis* and *Corbicula fluminea*).

From the Zooplankton Study, annual averages were calculated from 10 stations, while monthly averages were calculated from 15 stations (**Fig. 1, Appendix S2: Table S2**). From the Benthic Study, annual averages were calculated from 3 stations while the monthly averages were calculated from 8 stations (**Fig. 1, Appendix S2: Table S2**).

Fish

Fish data were accessed through the R package ‘deltafish’ v2.2.0 (Bashevkin et al. 2022a, Clark and Bashevkin 2022), which integrates fish monitoring data from the SF Estuary. Most fish monitoring programs in the SF Estuary sample small pelagic fish species or young-of-year fishes in the open water (Tempel et al. 2021). We selected three of the longest-running pelagic fish surveys (Fall Midwater Trawl, FMWT; Summer Townet, STN; San Francisco Bay Study Midwater Trawl, BSMT) and assembled an aggregate biomass index for estuarine forage fishes. The species included in this aggregation were five commonly caught, planktivorous, freshwater-brackish fish species of high management interest: Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), Threadfin Shad (*Dorosoma petenense*), juvenile American Shad (*Alosa sapidissima*), and age-0 Striped Bass (*Morone saxatilis*) (**Appendix S1: Table S1**).

We also assembled data on potential predators and competitors of the estuarine forage fishes. From the BSMT dataset, we produced an aggregate index for planktivorous marine fishes, represented by Northern Anchovy (*Engraulis mordax*) and Pacific Herring (*Clupea pallasii*), which are common in saline waters. We also obtained data for age-1+ Striped Bass from the same dataset as a proxy for piscivorous fishes. From the Delta Juvenile Fish Monitoring Program (DJFMP) beach seine survey, which monitors the littoral fish assemblage, we obtained data for Mississippi Silverside (*Menidia audens*) and fishes from the centrarchid family (**Appendix S1:**

Table S1). Mississippi Silversides are known to overlap in diet with the pelagic forage fish species and to potentially consume larval fishes (Schreier et al. 2016). Centrarchid fishes are potential predators known to associate with submerged aquatic vegetation, and they have rapidly increased in abundance in the past two decades within the SF Estuary (Brown and Michniuk 2007, Mahardja et al. 2017). Data from the DJFMP beach seine survey were only included in the shorter-term monthly dataset, as year-round sampling only began in 1995, and prior sampling was inconsistent.

To calculate fish BPUE for each species (or species assemblage) in each survey, fork length (mm) of each fish was first converted to biomass in grams using length-weight regression equations from Kimmerer et al. (2005) for the pelagic surveys, and Perry (2020) for the beach seine survey. These biomass measurements were then summed for each sampling occasion (i.e., tow). For the annual dataset, BPUE values were averaged across stations for each region and sampling interval (either month or two-week period), and then averaged again to obtain the annual value. Note that for the BSMT data, only April-October sampling was used to calculate annual values as per Feyrer et al. (2015). For the monthly dataset, only the BSMT and beach seine data were used because the two remaining surveys (STN and FMWT) are seasonal (summer and fall only). BPUE was averaged for each month and station combination, then averaged across stations to obtain monthly BPUE. Alternate stations meant to replace another sampling station in the DJFMP beach seine survey dataset were treated as a single station for the purpose of our analysis (SR012E and SR012W, SJ058E and SJ058W). Beach seine data were only available for the Sacramento and San Joaquin regions, as sampling does not extend to other regions. Annual averages were calculated from 71 stations for the FMWT dataset, 25 stations for the STN dataset, and 10 stations for the BSMT dataset (**Fig. 1, Appendix S2: Table S2**).

Monthly averages were calculated from 31 stations for the BSMT dataset and nine stations for the DJFMP beach seine survey dataset (**Appendix S2: Table S2)**.

Chlorophyll-a, Nutrients, and Environmental Drivers

Temperature, Secchi depth, chlorophyll-a, and nutrient data were obtained from the EMP Water Quality Study and accessed from an integrated database of discrete water quality monitoring data (Bashevkin et al. 2022d). Data were collected monthly, and stations were selected to ensure consistent coverage over the selected timespan. Chlorophyll-a was used as a proxy for phytoplankton abundance. Nitrogen compounds, specifically ammonia and nitrate, have been proposed as a potential influence in the Delta ecosystem (e.g., Cloern 2001, Richey et al. 2018). However, the nutrients (ammonium, nitrate/nitrite, and phosphorous) were correlated with one another (**Appendix S1: Fig. S3)**. Due to the complex relationship between different nitrogen forms, we chose to aggregate ammonium and nitrate/nitrite as dissolved inorganic nitrogen (DIN), which represents biologically available nitrogen. We then decided to exclude phosphorous because it is not limiting in the system (Cloern et al. 2020).

Water temperatures were corrected for time-of-day effects by adjusting all measurements to noon using a monthly smooth function of temperature by time-of-day. This smooth function was derived from a generalized additive model fit with the R package mgcv (Wood 2011, Wood et al. 2016) to temperature data from the integrated water quality dataset (Bashevkin et al. 2022d). The model was fit with the code: bam(Temperature ~ Year + te(Longitude, Latitude, day_of_year, d=c(2,1), bs=c('cr', 'cc'), k=c(25, 13), by=Year) + te(Time, day_of_year, bs=c('cr', 'cc'), k=c(5, 13)), data = Data, method='fREML', discrete=T). As a measure of turbidity, we used negative secchi depth, so that higher values would mean higher turbidities and aid in interpretation. Salinity was considered but excluded as a driver because it was highly correlated with flow (**Appendix S1: Fig. S3)**. Flow is also more directly controlled by management.

For nutrient data values below reporting limits (RL), we substituted the values below the RL with simulated values drawn from a uniform distribution U(0.001, RL) (Helsel 2011). One simulation was run for each parameter and a seed was set prior to running the simulation to ensure reproducibility. When historic reporting limits were not always reported, we used the most common historical RL (0.01) for the nutrient parameters.

Prior to computing regional and temporal averages, we imputed missing values for each variable at each station by fitting autoregressive integrated moving average (ARIMA) models. ARIMA models are time series models that account for dependence on prior values and longer-term values. We specified ARIMA models that explicitly account for seasonality and allow drift (non-stationarity), and then identified the best fit model using Akaike Information Criterion (AIC). Using the best fit model, we applied a Kalman filter to impute missing values in the time series. Then we evaluated performance by checking the residuals, autocorrelation, and accuracy. These functions were performed using the R package 'forecast' (Hyndman and Khandakar 2008, Hyndman et al. 2022).

We obtained flow data from the Dayflow dataset made available by the California Department of Water Resources (DWR) (https://data.cnra.ca.gov/dataset/dayflow). This dataset provides modeled daily flows, calibrated by several USGS gaging stations, for upstream reaches which flow into the SF Estuary as well as estimates of net inflows and outflows. For the annual dataset, total outflow (QTOT) was used. For the regional datasets, outflow at Rio Vista (QRIO) was used for the Sacramento region, San Joaquin River flow past Jersey point (QWEST) for the San Joaquin region, and total outflow for both the Suisun and San Pablo regions. For the annual datasets, daily flows were averaged by water year (1 October – 30 September), while for the monthly dataset, daily flows were averaged by month.

Analysis

Converting the conceptual model into SEMs required simplification to facilitate implementation and interpretation. For instance, were we to fit the complete conceptual model to the annual dataset, the number of free parameters would vastly exceed the number of data points.

Thus, each SEM model employed only a subset of variables and (in many cases) species aggregates rather than finer taxonomic groups.

The annual models employed a latent variable for estuarine fishes. Since latent variables require that the manifest variables be correlated in order to extract a common trend, the BSMT dataset was dropped from the Sacramento region because it was not correlated with the other two fish surveys (FMWT and STN; **Appendix S1: Fig. S1)**. In the San Joaquin region using detrended data, none of the survey indices were correlated (**Appendix S1: Fig. S2)**, so all indices were tried in separate models. Only the BSMT dataset was used in the monthly models because it was the only survey with year-round monthly sampling.

To compute the total effect size of each interaction type in the monthly models, the lagged effect of a species on itself was considered 'self-regulation,' the effect of all lower trophic levels (including nutrients on phytoplankton) was considered 'bottom-up,' the effect of all higher trophic levels was considered 'top-down,' the effect of all abiotic drivers (flow, temperature, turbidity) was considered 'environmental,' and the effect of all consumers (zooplankton, clams) on nutrients was considered 'nutrient cycling.' The structure of the monthly SEMs was very similar to a vector autoregressive model, but where food web structure places constraints on the predictor variables used.

If a time series contained zeros, the minimum nonzero value was added to all values prior to log transformation. For flow values in the regional datasets, which were sometimes negative, the largest negative value was subtracted prior to this procedure. Removal of trends or seasonality was done after log transformation, but before scaling. Zeros were excluded from the regression used to remove the linear trend, and always remained zeros (this was relevant mainly for the *Potamocorbula* clam data, which were not log transformed and contained long runs of zeros at the beginning of the time series). For both regional datasets (annual and monthly), all data transformations were done within each region.

We assessed model fit using a chi-squared test, which tests the hypothesis that the predicted and observed covariance matrices are equal. If this test was statistically significant ($p<0.05$), indicating lack of model fit, we examined the residual covariance among variables, and modified the original model (added additional paths or covariances) to better account for these residual relationships. We only added paths that improved model fit, and that were biologically reasonable and consistent with our knowledge of the natural history of the system.

Supplemental discussion on SF Estuary-specific findings

Top-down effects of predatory zooplankton on herbivorous zooplankton were not observed in the model of upper trophic level aggregates, and among individual zooplankton groups, negative top-down effects were only detected in Sacramento (between predatory and herbivorous copepods). Thus, we did not find strong support for top-down trophic control among plankton functional groups, although variation in zooplankton community composition and complex interactions within and among functional groups may limit our ability to resolve this.

For instance, several of the species we considered herbivorous (since they do not predate on other taxa in our model) are actually omnivorous (e.g. *Limnoithona* spp., *P. forbesi*) and predate on smaller microzooplankton (e.g. ciliates) (Bouley and Kimmerer 2006, York et al. 2014) which are not monitored well in the SF Estuary.

We detected top-down effects of fishes on herbivorous (but not predatory) zooplankton, consistent with findings that fishes in the SF Estuary (e.g., Striped Bass, Delta Smelt, Longfin Smelt) positively select for herbivorous copepods over other available zooplankton prey (Bryant and Arnold 2007, Slater and Baxter 2014, Barros et al. 2022, Lojkovic Burris et al. 2022). This could be partially due to predatory copepods having a lower nutritional value than herbivorous copepods (Kratina and Winder 2015). At the top of the food web, we did not detect any negative effects of other fish groups on estuarine fishes, although this may reflect deficiencies in the monitoring data (see *Data limitations* in the main text). We did detect a positive effect of age 1+ striped bass on estuarine fishes in Suisun, but this could be partially explained by self-regulation since younger striped bass were included in the estuarine fishes metric.

The positive relationships of *Corbicula* with zooplankton in the individual zooplankton and annual models were unexpected. One possible explanation for this pattern in the annual model is that the direction of causality may be reversed. The annual models did not incorporate time-lags, so we were unable to use them to investigate specific directions of the causality in each relationship as we did in the monthly models. It is possible that annual zooplankton abundance is positively related to *Corbicula* abundance since zooplankton are a food source for *Corbicula*. A second possible explanation is that the count data we obtained for *Corbicula* biomass may not be fully representative of their feeding impact since clearance rates are strongly related to clam size (Lauritsen 1986), which was not represented in our data. Lastly, *Corbicula* tend to be found in higher abundance in constructed canals (Eng 1979) and shallow water (Benson and Williams 2021) whereas our data were mostly collected in deeper channels. Thus, the counts we used may not be entirely reflective of their true population size and top-down impact on zooplankton.

Our study is the first to find strong evidence for a bottom-up relationship between chlorophyll and zooplankton biomass in the current regime. However, past studies have found this link before the clam and zooplankton invasions induced a regime shift (Orsi and Mecum 1986), or have weakly linked chlorophyll to zooplankton growth rates (Kimmerer et al. 2018, Gearty et al. 2021, yet see Kimmerer et al. 2014). Furthermore, Mac Nally et al. (2010) found weak evidence for spring chlorophyll as a driver of spring calanoid and summer mysid biomass.

Flow had predominantly positive effects on herbivorous zooplankton but negative effects on predatory zooplankton. This could be due to salinity-driven biotic interactions, as certain predatory zooplankton (e.g., *Acartiella sinensis*), along with *Potamocorbula,* limit the distribution of herbivorous zooplankton via predation (Slaughter et al. 2016, Kayfetz and Kimmerer 2017); however, most predatory species occur in more saline waters and shift downstream with high flows.

Turbidity had largely positive effects on DIN, zooplankton, and fish, except in Suisun where effects on zooplankton were more negative. The SF Estuary was historically turbid, and turbidity is a key habitat requirement for native species such as Delta Smelt (Thomson et al. 2010, Feyrer et al. 2011) so species are expected to benefit from more turbid conditions. Furthermore, turbidity could be associated with abundance of detrital plant material that can serve as an important, selected-for food source for zooplankton (Harfmann et al. 2019, Jeffres et al. 2020).

Supplemental Tables

Table S1. List of taxonomic groups used in our analysis, their dominant feeding strategies, and their constituent taxa.

Category	Feeding Strategy	Taxon name
Cladocerans	Herbivorous	*Bosmina longirostris* *Daphnia* spp. *Diaphanosoma* spp. Other Cladocera
Herbivorous Copepods	Herbivorous	*Acartia* spp. Diaptomidae *Eurytemora affinis* *Pseudodiaptomus* spp. *Pseudodiaptomus forbesi* *Pseudodiaptomus marinus* *Sinocalanus doerrii* Cirripedia larvae Copepod larvae Harpacticoida
	Omnivorous	*Limnoithona* spp. *Limnoithona sinensis* *Limnoithona tetraspina*
Mysids	Predatory	*Hyperacanthomysis longirostris* *Neomysis mercedis* *Orientomysis aspera*

		Alienacanthomysis macropsis *Deltamysis holmquistae* *Neomysis kadiakensis*
Predatory Copepods	Predatory	*Acartiella sinensis* *Tortanus* spp. *Acanthocyclops* spp. *Oithona* spp. *Oithona davisae* *Oithona similis*
Rotifers	Predatory	*Asplanchna* spp.
	Herbivorous	*Keratella* spp. *Polyarthra* spp. *Synchaeta* spp. *Trichocerca* spp.
Amphipods	Herbivorous	*Ampelisca* spp. *Monocorophium* spp. *Sinocorophium* spp. *Gammarus* spp. *Americorophium* spp. *Crangonyx* spp. *Hyalella* spp.
Estuarine fishes	Planktivorous	Delta Smelt (*Hypomesus transpacificus*) Longfin Smelt (*Spirinchus thaleichthys*)

		Threadfin Shad (*Dorosoma petenense*) American Shad, juvenile (*Alosa sapidissima*) Striped Bass, age 0 (*Morone saxatilis*)
Marine fishes	Planktivorous	Northern Anchovy (*Engraulis mordax*) Pacific Herring (*Clupea pallasii*)
Mississippi Silverside	Planktivorous	*Menidia audens*
Striped Bass	Piscivorous	*Morone saxatilis* (age 1+)
Centrarchid fishes	Piscivorous	Largemouth Bass (*Micropterus salmoides*) Smallmouth Bass (*Micropterus dolomieu*) Bluegill (*Lepomis macrochirus*) Redear sunfish (*Lepomis microlophus*)

Table S2. Empirical support and justification for paths in conceptual model.

Arrow start	Arrow end	Explanation
Estuarine forage fishes	Predatory fishes	The introduced Striped Bass and Largemouth Bass are potentially important predators of the estuarine forage fish species. Striped Bass may have exerted top-down control on smaller-sized fishes for decades (Nobriga and Smith 2020) and consumption by sub-adults partly sampled by the surveys in this study may be quite significant (Loboschefsky et al. 2012). Largemouth Bass is a highly prolific piscivore in the

		freshwater portion of the SF Estuary and associated with the rapidly expanding invasive submersed aquatic vegetation (Conrad et al. 2016, Mahardja et al. 2017).
Estuarine forage fishes	Competing fishes	When zooplankton levels declined after the clam *Potamocorbula* was introduced in the 1980s, distribution of the planktivorous and marine-oriented Northern Anchovy (*Engraulis mordax*) shifted towards higher salinity in the SF Estuary, indicating some overlap in diet with estuarine forage fishes (Kimmerer 2006). The highly abundant and widely distributed Mississippi Silverside (*Menidia audens*) has been considered as both competitor and intraguild predator of the endangered Delta Smelt, a species included in the estuarine forage fish group (Baerwald et al. 2012, Mahardja et al. 2016).
Zooplankton	Estuarine forage fishes	The estuarine forage fishes in these models eat zooplankton at all life stages included within this category (Feyrer et al. 2003, Kimmerer 2006, Slater et al. 2019).
Pred. copepods	Pred. copepods	Predatory copepods feed on other predator copepods in this dataset (Kerfoot 1978, Li and Li 1979)
Pred. copepods	Mysids	Mysids (including native species) feed on copepods (Wilson 1951, Knutson and Orsi 1983)

Herb. copepods	Pred. copepods	Predatory copepods consume herbivorous copepods: (Kayfetz and Kimmerer 2017)
Herb. copepods	Mysids	Mysids (including native species) feed on copepods (Wilson 1951, Knutson and Orsi 1983)
Cladocerans	Pred. copepods	Predatory copepods such as *Acanthocyclops* feed on cladocerans (Gliwicz and Stibor 1993)
Pred. copepods	Clams	*Potamocorbula* consumes copepod nauplii (Kimmerer et al. 1994).
Herb. copepods	Clams	*Potamocorbula* consumes copepod nauplii (Kimmerer et al. 1994).
Phytoplankton	Clams	The invasive clams consume phytoplankton (Alpine and Cloern 1992).
Phytoplankton	Herb. copepods	Herbivorous copepods consume phytoplankton (Orsi 1995)
Phytoplankton	Cladocerans	Cladocerans consume phytoplankton (Orsi 1995).
Phytoplankton	Amphipods	Amphipods consume phytoplankton such as diatoms (Durand 2015)
Phytoplankton	Rotifers	Rotifers consume phytoplankton (Walz 1995)
Nitrate/Nitrite	Phytoplankton	Phytoplankton have some control over nitrate concentrations (Peterson et al. 1985).

Ammonia	Phytoplankton	Phytoplankton have some control over ammonia concentrations (Peterson et al. 1985).
Phosphorous	Phytoplankton	Phytoplankton have some control over phosphorous concentrations (Peterson et al. 1985).
All biotic variables	Flow	Flow is a strong driver of species abundance and distribution in the SF Estuary (Kimmerer 2002)
All biotic variables	Temperature	Temperature impacts food webs from sub-cellular to community scales (Petchey et al. 1999, Clarke 2006, Herbold et al. 2022)
All biotic variables	Turbidity	Turbidity is an important indicator of habitat in the SF Estuary (Feyrer et al. 2007)

Table S3. Overview of endogenous (response) and exogenous variable for each SEM.

Spatiotemporal resolution (submodel)	Endogenous variables	Exogenous variables
Annual	Phytoplankton Herbivorous zooplankton Predatory zooplankton Estuarine fishes	Clams Flow Temperature Turbidity
Annual-regional	Phytoplankton Herbivorous zooplankton Predatory zooplankton	Clams Flow Temperature

	Estuarine fishes	Turbidity
Monthly-regional (upper trophic level)	Herbivorous zooplankton Predatory zooplankton Estuarine fishes	Clams Phytoplankton Age 1+ Striped Bass Mississippi Silversides Centrarchid fishes Flow Temperature Turbidity Lagged endogenous variables
Monthly-regional (lower trophic level)	Phytoplankton Clams DIN	Herbivorous zooplankton Predatory zooplankton Flow Temperature Turbidity Lagged endogenous variables
Monthly-regional (zooplankton groups)	Phytoplankton Rotifers Amphipods Cladocerans Herbivorous copepods Predatory copepods	Clams Flow Temperature Turbidity Lagged endogenous variables

	Mysids	

Table S4. Summary of total effect sizes for upper trophic level and lower trophic level monthly-regional SEMs. * = total effect significant (p<0.05), o = total effect not significant, blank = not tested

Model	Endogenous variable	Region	Self-regulation	Bottom-up	Top-down	Environmental	Nutrient cycling
Upper trophic level	Estuarine fishes	San Pablo	*	*	o	*	
		Suisun	*	*	*	*	
		Sacramento	o	*	*	*	
		San Joaquin	*	*	o	*	
	Predatory zooplankton	San Pablo	*	o	o	*	
		Suisun	*	*	o	*	
		Sacramento	*	*	o	*	
		San Joaquin	*	*	o	*	
	Herbivorous zooplankton	San Pablo	*	o	*	o	
		Suisun	*	o	*	*	
		Sacramento	*	o	o	*	
		San Joaquin	*	*	o	*	
Lower trophic level	Clams (*Potamocorbula*)	San Pablo	*	*		*	
		Suisun	*	o		*	

	Clams (*Corbicula*)	Sacramento	*	o		*	
		San Joaquin	*	o		*	
	Phytoplankton	San Pablo	*	o	o	*	
		Suisun	*	o	o	o	
		Sacramento	*	*	*	*	
		San Joaquin	*	o	o	o	
	DIN	San Pablo	*		*	*	o
		Suisun	*		*	*	o
		Sacramento	*		*	*	*
		San Joaquin	*		*	*	*

Supplemental Figures

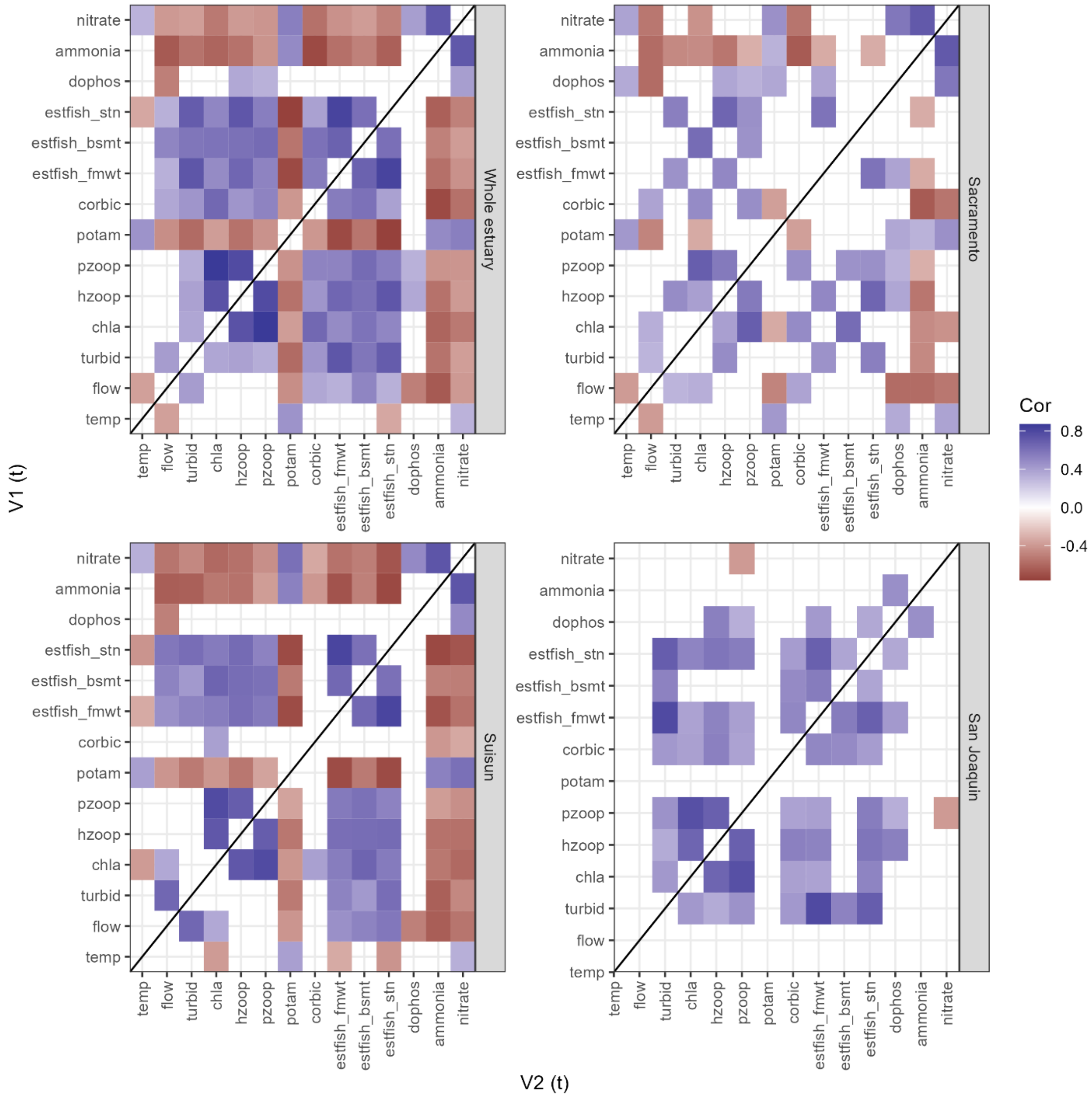


Figure S1. Cross-correlation matrices for the annual, original-units dataset with no lag. V1 and V2 refer to the different variables for which the correlation is calculated, while t refers to the timepoint at which their correlation is calculated. Abbreviated variable names are as follows: dophos = dissolved orthophosphate, estfish_stn = estuarine fishes from the Summer Townet survey, estfish_bsmt = estuarine fishes from the Bay Study Midwater Trawl, estfish_fmwt =

estuarine fishes from the Fall Midwater Trawl, corbic = *Corbicula*, potam = *Potamocorbula*, pzoop = predatory zooplankton, hzoop = herbivorous zooplankton, chla = chlorophyll a, turbid = turbidity, temp = temperature.

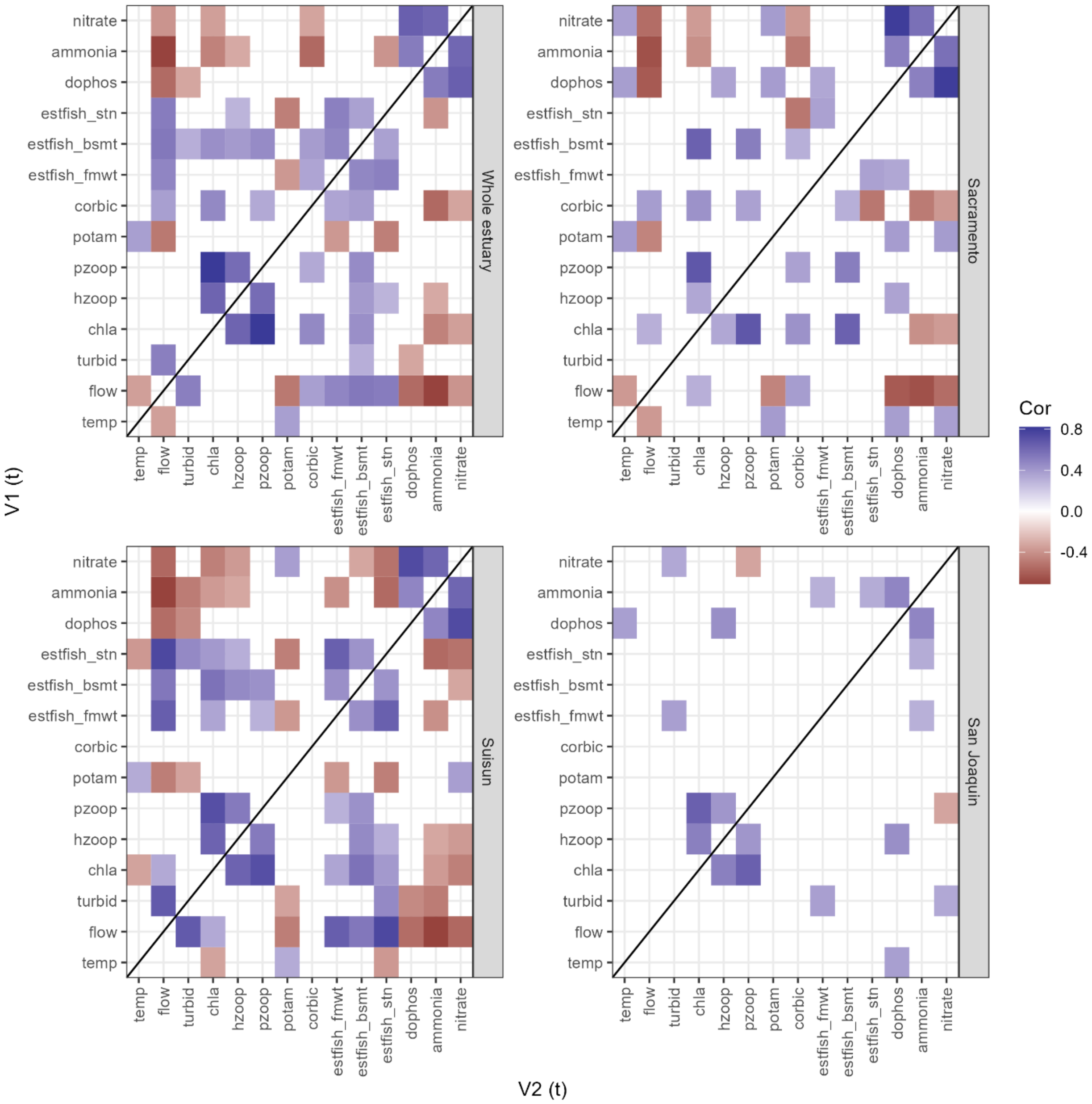


Figure S2. Cross-correlation matrices for the annual detrended dataset with no lag. See **Fig. S1** for the abbreviated variable name definitions.

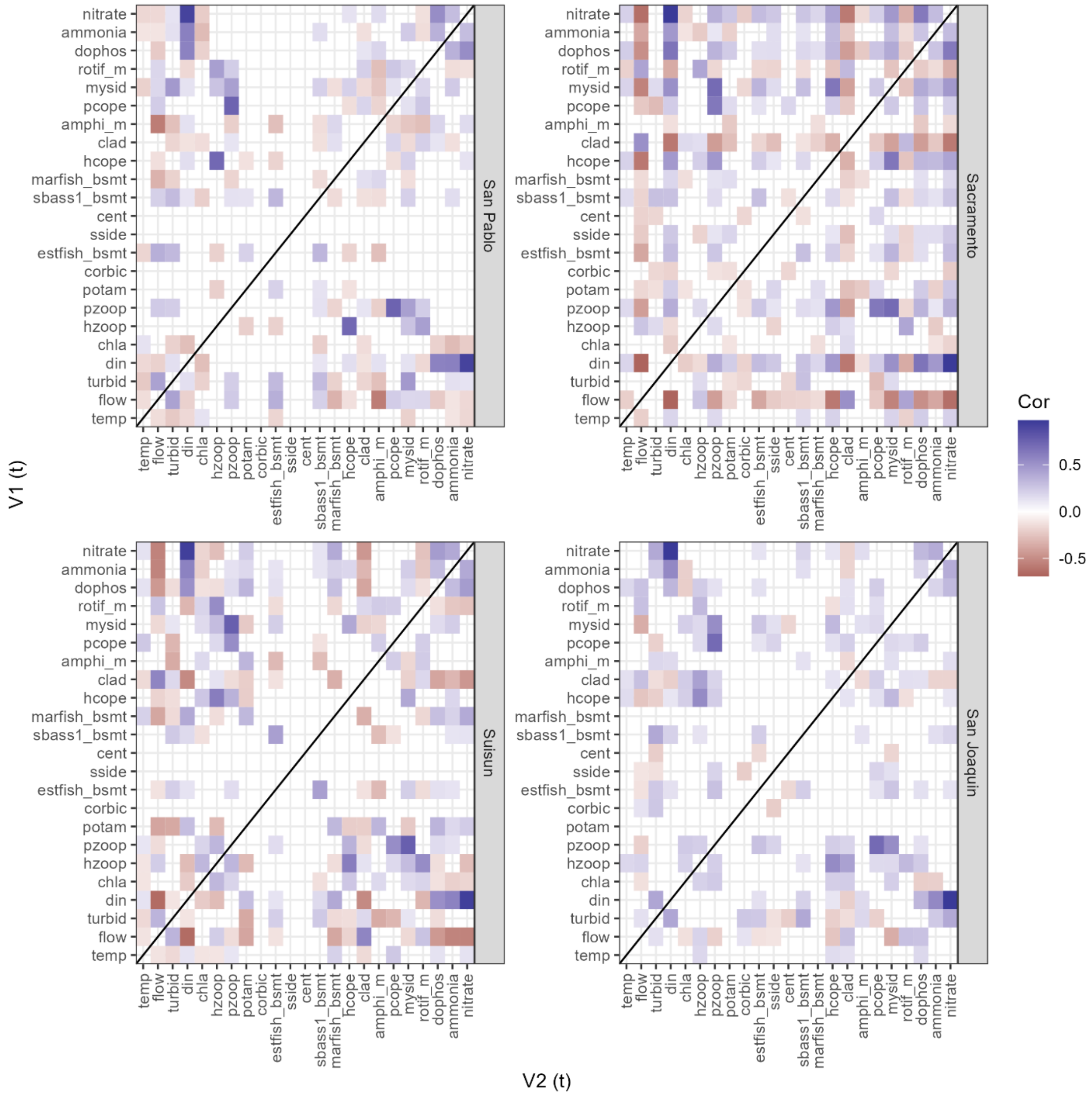


Figure S3. Cross-correlation matrices for the monthly dataset with no lag. Abbreviated variable names are as follows: dophos = dissolved orthophosphate, rotif_m = rotifers, pcope = predatory copepods, amphi_m = amphipods, clad = cladocerans, hcope = herbivorous copepods, marfish_bsmt = marine fishes from the Bay Study Midwater Trawl, sbass1_bsmt = Striped Bass age 1+ from the Bay Study Midwater Trawl, cent = Centrarchids, sside = Mississippi Silversides, estfish_bsmt = estuarine fishes from the Bay Study Midwater Trawl, corbic = *Corbicula*, potam = *Potamocorbula*, pzoop = predatory zooplankton, hzoop = herbivorous zooplankton, chla = chlorophyll a, din = dissolved inorganic nitrogen, turbid = turbidity, temp = temperature.

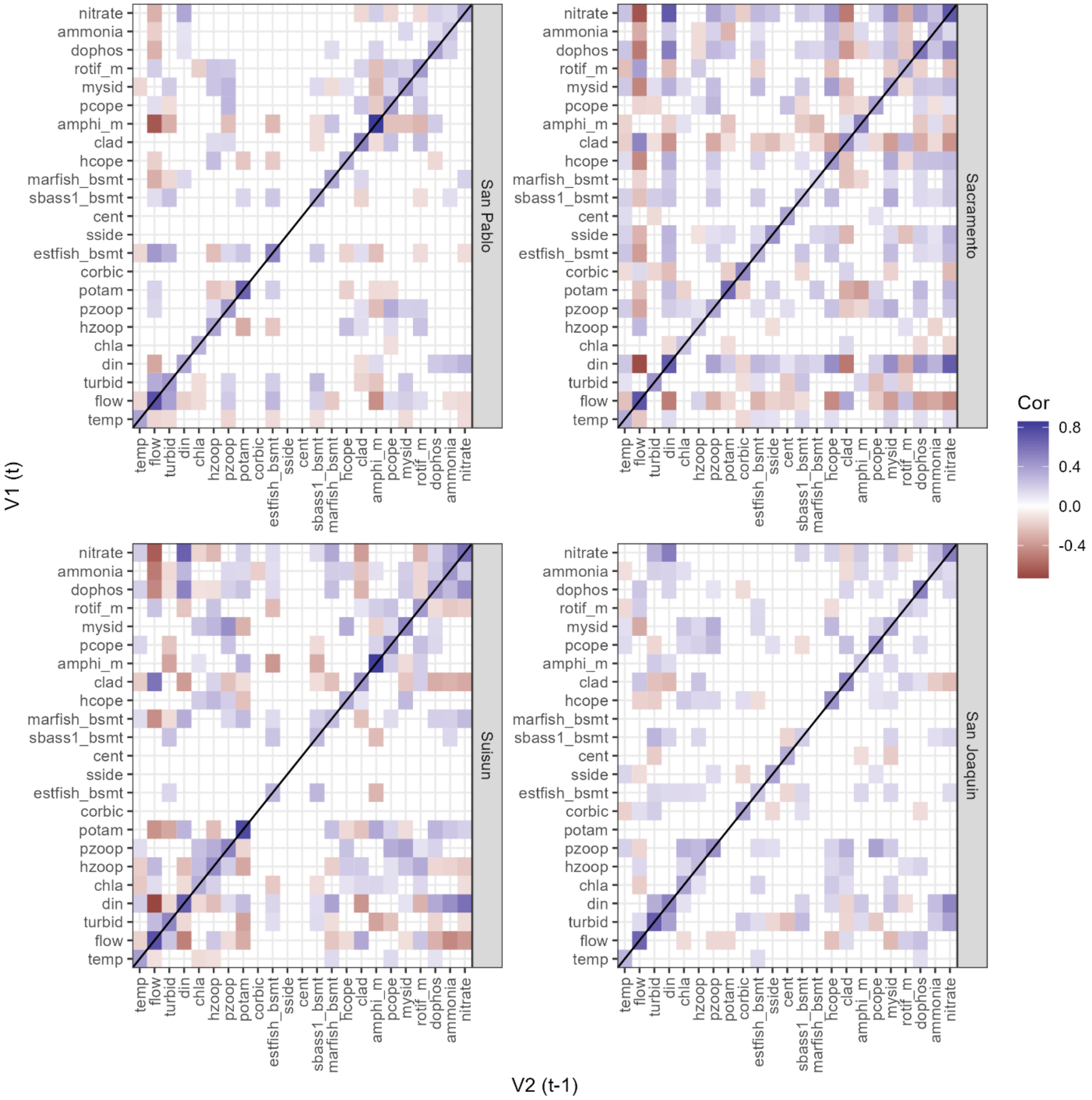


Figure S4. Cross-correlation matrices for the monthly dataset with a lag of 1 month. See **Fig. S3** for abbreviated variable name definitions.

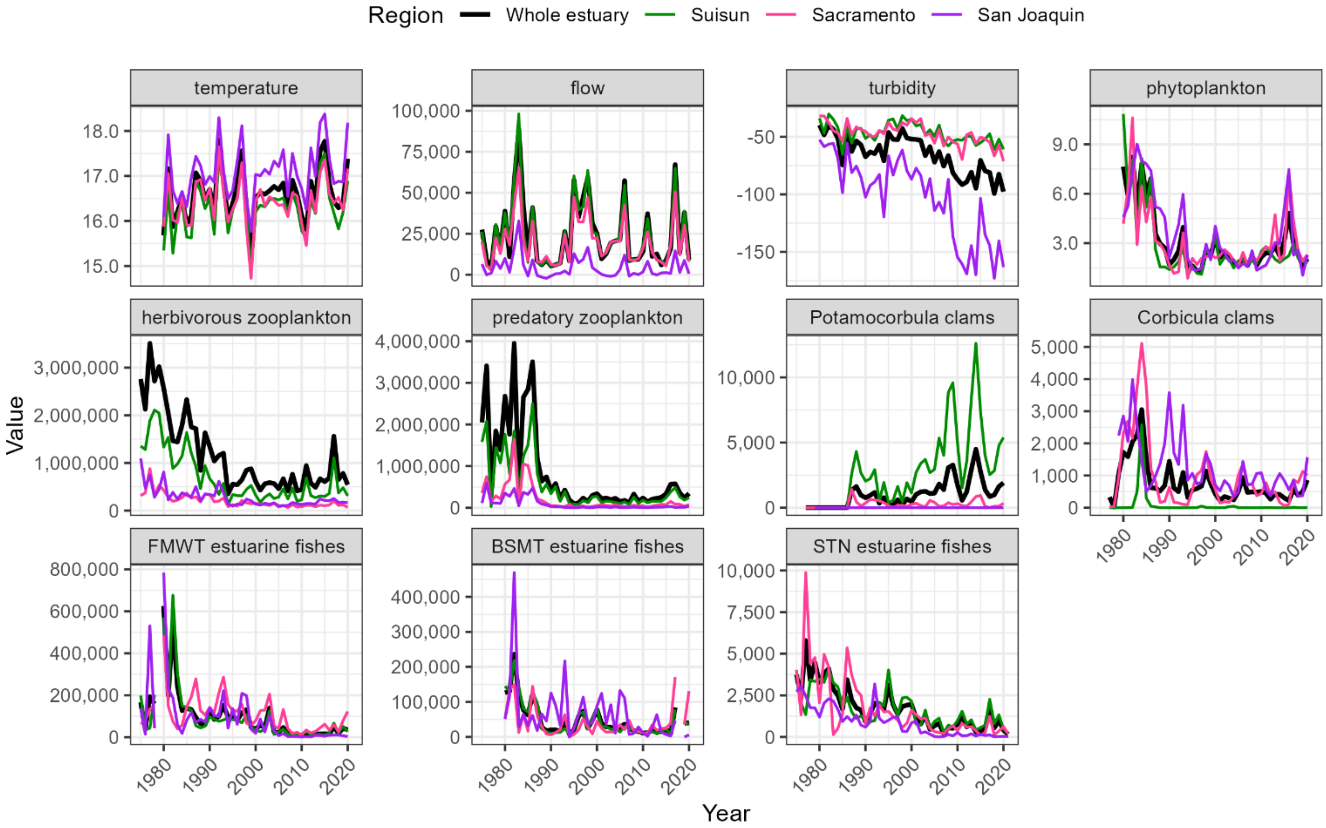


Figure S5. Annual time series. FMWT = Fall Midwater Trawl, BSMT = Bay Study Midwater Trawl, STN = Summer Townet.

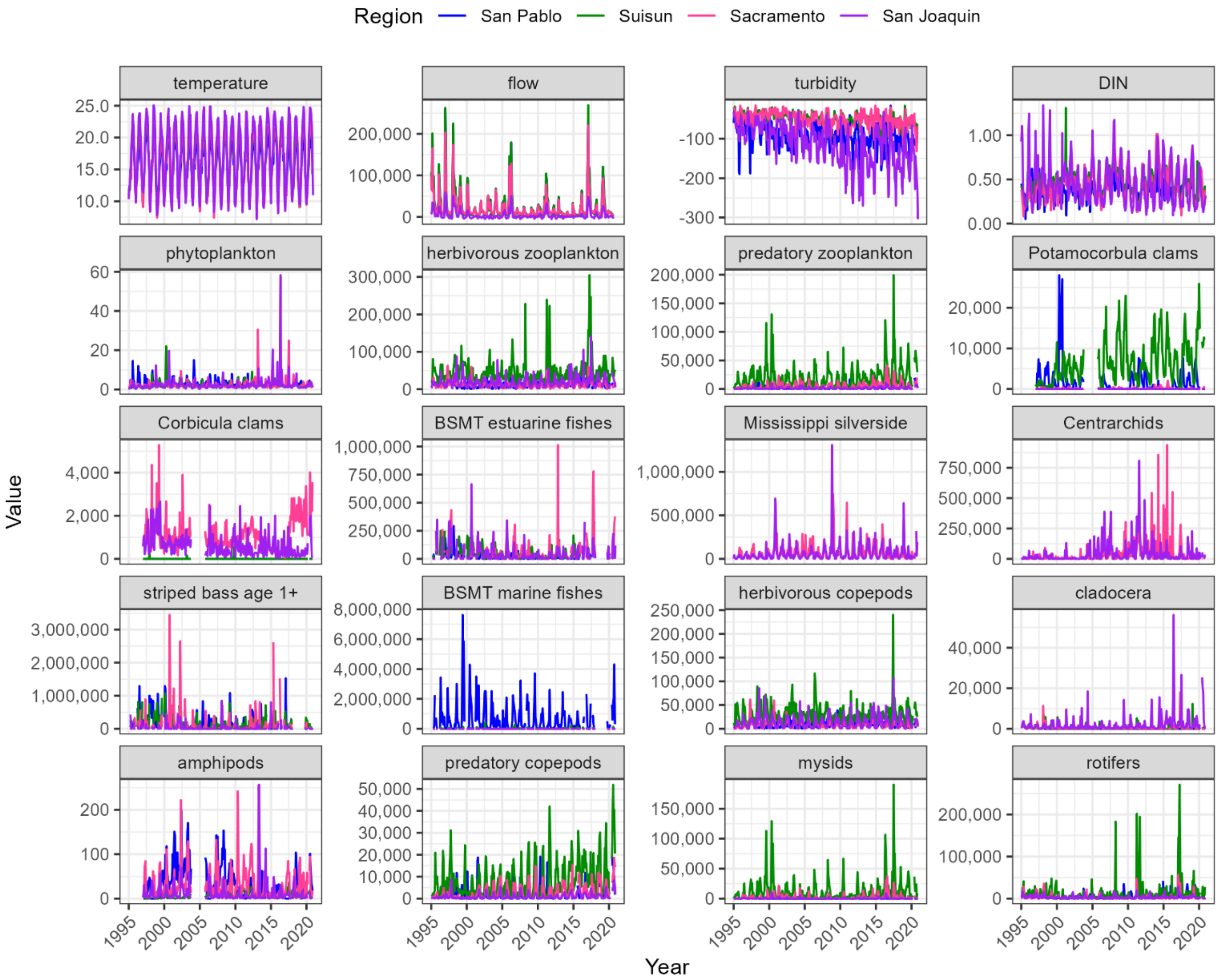


Figure S6. Monthly time series. DIN = dissolved inorganic nitrogen, BSMT = Bay Study Midwater Trawl.

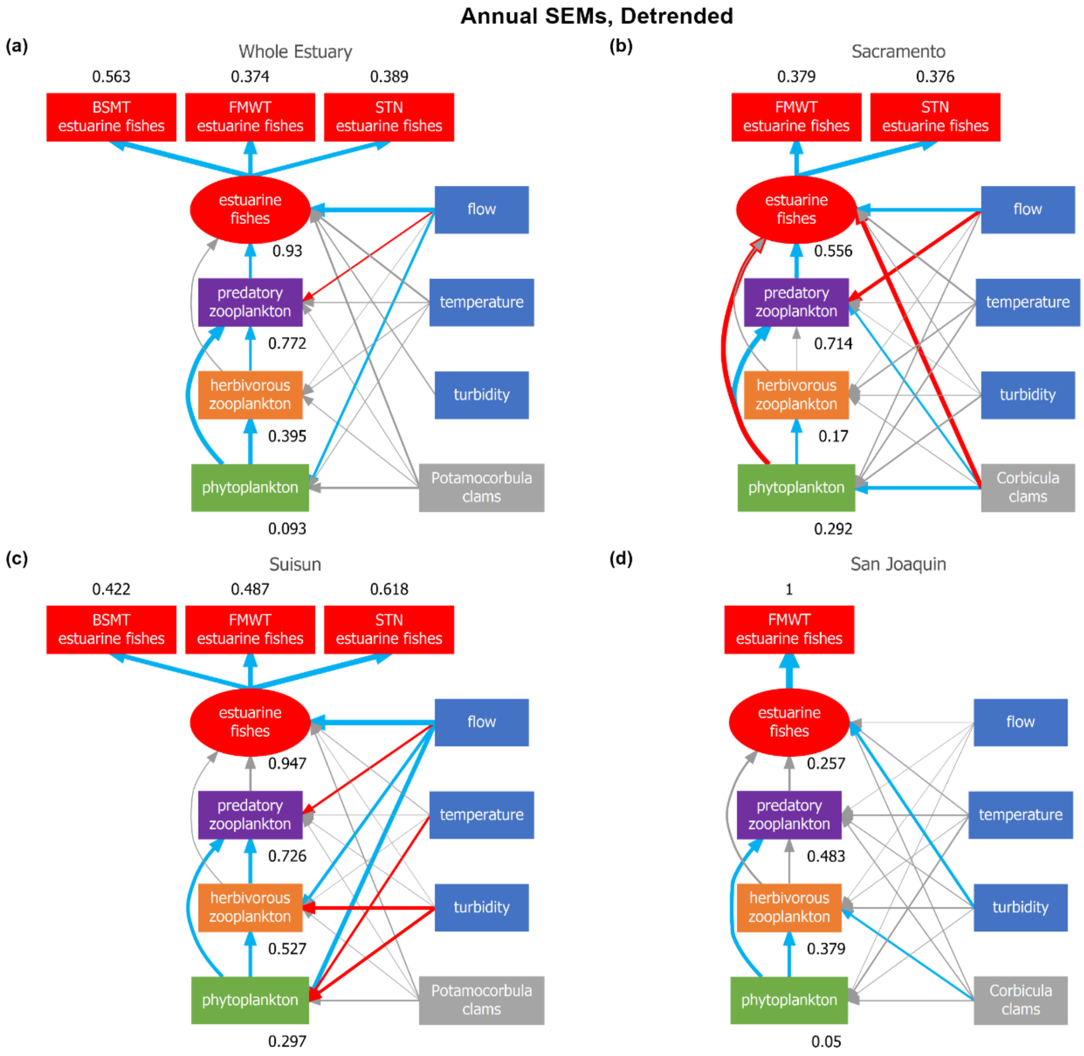


Fig. S7. Path diagrams for annual and annual-regional SEMs using detrended data. Blue arrows indicate positive path coefficients and red arrows indicate negative path coefficients. Arrow thickness is proportional to the magnitude of the standardized path coefficient (**Appendix S2: Table S3**).

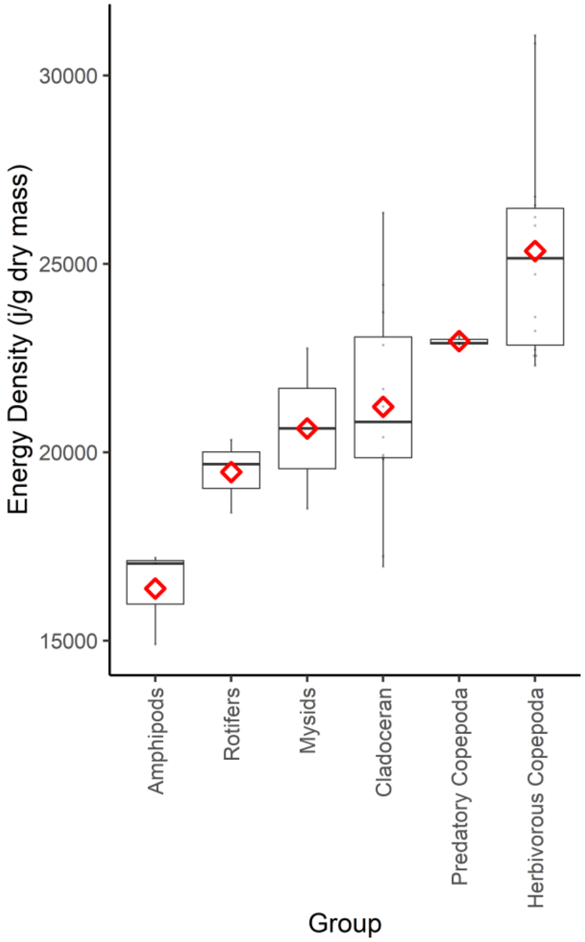


Fig. S8. Box plot of the energy densities for the six categories of zooplankton used in this analysis. Red diamonds represent the mean values.

Literature cited

Alpine, A. E., and J. E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37:946–955.

Baerwald, M. R., B. M. Schreier, G. Schumer, and B. May. 2012. Detection of Threatened Delta Smelt in the Gut Contents of the Invasive Mississippi Silverside in the San Francisco Estuary Using TaqMan Assays. Transactions of the American Fisheries Society 141:1600–1607.

Barros, A. E. 2021. Interagency Ecological Program Zooplankton Study. ver 9. Environmental Data Initiative. https://doi.org/10.6073/pasta/f5ab8671727e2481b57384ba70124e41

Barros, A., J. A. Hobbs, M. Willmes, C. M. Parker, M. Bisson, N. A. Fangue, A. L. Rypel, and L. S. Lewis. 2022. Spatial Heterogeneity in Prey Availability, Feeding Success, and Dietary Selectivity for the Threatened Longfin Smelt. Estuaries and Coasts.

Bashevkin, S. M., J. W. Gaeta, T. X. Nguyen, L. Mitchell, and S. Khanna. 2022a. Fish abundance in the San Francisco Estuary (1959-2021), an integration of 9 monitoring surveys. Environmental Data Initiative. https://doi.org/10.6073/PASTA/0CDF7E5E954BE1798AB9BF4F23816E83

Bashevkin, S. M., R. Hartman, M. Thomas, A. Barros, C. E. Burdi, A. Hennessy, T. Tempel, and K. Kayfetz. 2022b. Five decades (1972–2020) of zooplankton monitoring in the upper San Francisco Estuary. PLOS ONE 17:e0265402.

Bashevkin, S. M., R. Hartman, M. Thomas, A. Barros, C. Burdi, A. Hennessy, T. Tempel, and K. Kayfetz. 2022c. Interagency Ecological Program: Zooplankton abundance in the Upper San Francisco Estuary from 1972-2020, an integration of 5 long-term monitoring programs. ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/89dbadd9d9dbdfc804b160c81633db0d

Bashevkin, S. M., S. E. Perry, and E. B. Stumpner. 2022d. Six decades (1959-2020) of water quality in the upper San Francisco Estuary: an integrated database of 11 discrete monitoring surveys in the Sacramento San Joaquin Delta, Suisun Bay, and Suisun Marsh. Environmental Data Initiative. ver 5. https://doi.org/10.6073/pasta/c9b3da65a8c89cbfa6fc28d26f938c22

Benson, A. J., and J. D. Williams. 2021. Review of the invasive Asian clam Corbicula spp. (Bivalvia: Cyrenidae) distribution in North America, 1924–2019. Page 79 Review of the invasive Asian clam Corbicula spp. (Bivalvia: Cyrenidae) distribution in North America, 1924–2019. USGS Numbered Series, U.S. Geological Survey, Reston, VA.

Bouley, P., and W. J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324:219–228.

Brown, L. R., and D. Michniuk. 2007. Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980–1983 and 2001–2003. Estuaries and Coasts 30:186–200.

Bryant, M. E., and J. D. Arnold. 2007. Diets of age-0 striped bass in the San Francisco Estuary, 1973-2002. California Fish and Game 93:1–22.

Burdi, C. E., S. B. Slater, T. L. Bippus, and J. A. Jimenez. 2021. Mysid and Amphipod Length-Weight Relationships in the San Francisco Estuary. IEP Newsletter 40:15–25.

Clark, J., and S. M. Bashevkin. 2022. Delta-Stewardship-Council/deltafish: deltafish v0.1.0. Zenodo.

Clarke, A. 2006. Temperature and the metabolic theory of ecology. Functional Ecology 20:405–412.

Cloern, J. E., T. S. Schraga, E. Nejad, and C. Martin. 2020. Nutrient Status of San Francisco Bay and Its Management Implications. Estuaries and Coasts.

Conrad, J. L., A. J. Bibian, K. L. Weinersmith, D. De Carion, M. J. Young, P. Crain, E. L. Hestir, M. J. Santos, and A. Sih. 2016. Novel Species Interactions in a Highly Modified Estuary: Association of Largemouth Bass with Brazilian Waterweed Egeria densa. Transactions of the American Fisheries Society 145:249–263.

Cummins, K. W. 1967. Calorific equivalents for studies in ecological energetics. University of Pittsburgh Pennsylvania.

Dudley, P. N., S. M. Bashevkin, and C. E. Burdi. 2022. Zooplankton energy densities from literature. Environmental Data Initiative. https://doi.org/10.6073/PASTA/44683470FBB40014F370BC5E5E7E9D44

Durand, J. R. 2015. A Conceptual Model of the Aquatic Food Web of the Upper San Francisco Estuary. San Francisco Estuary and Watershed Science 13.

Eng, L. L. 1979. Population dynamics of the Asiatic clam, Corbicula fluminea (MUller), in the concrete lined Delta-Mendota Canal of central California, Pp. 40â€” 68in Proceedings. Pages 39–67 *in* J. C. Britton, editor. Proceedings, First International Corbicula Symposium. Texas Christian University, Fort Worth, TX.

Feyrer, F., J. E. Cloern, L. R. Brown, M. A. Fish, K. A. Hieb, and R. D. Baxter. 2015. Estuarine fish communities respond to climate variability over both river and ocean basins. Global Change Biology 21:3608–3619.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277–288.

Feyrer, F., K. Newman, M. Nobriga, and T. Sommer. 2011. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. Estuaries and Coasts 34:120–128.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723–734.

Forster, I. 1999. note on the method of calculating digestibility coefficients of nutrients provided by single ingredients to feeds of aquatic animals. Aquaculture nutrition 5:143–145.

Gearty, A. J., T. R. Ignoffo, A. M. Slaughter, and W. J. Kimmerer. 2021. Growth and reproductive rates of the dominant copepod *Pseudodiaptomus forbesi* in response to environmental factors and habitat type in the northern San Francisco Estuary. Aquatic Ecology.

Gliwicz, Z. M., and H. Stibor. 1993. Egg predation by copepods in *Daphnia* brood cavities. Oecologia 95:295–298.

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish Bioenergetics 3.0. University of Wisconsin Sea Grant Institute, Madison, Wisconsin.

Harfmann, J., T. Kurobe, B. Bergamaschi, S. Teh, and P. Hernes. 2019. Plant detritus is selectively consumed by estuarine copepods and can augment their survival. Scientific Reports 9:9076.

Helsel, D. R. 2011. Statistics for Censored Environmental Data Using Minitab and R. John Wiley & Sons.

Herbold, B., E. Bush, G. Castillo, D. Colombano, R. Hartman, P. Lehman, B. Mahardja, and T. Sommer. 2022. Climate Change Impacts on San Francisco Estuary Aquatic Ecosystems: A Review. San Francisco Estuary and Watershed Science 20.

Hyndman, R., G. Athanasopoulos, C. Bergmeir, G. Caceres, L. Chhay, M. O'Hara-Wild, F. Petropoulos, S. Razbash, E. Wang, and F. Yasmeen. 2022. forecast: Forecasting functions for time series and linear models.

Hyndman, R. J., and Y. Khandakar. 2008. Automatic Time Series Forecasting: The forecast Package for R. Journal of Statistical Software 27:1–22.

Jeffres, C. A., E. J. Holmes, T. R. Sommer, and J. V. E. Katz. 2020. Detrital food web contributes to aquatic ecosystem productivity and rapid salmon growth in a managed floodplain. PLOS ONE 15:e0216019.

Johnson, J. T., and T. L. Hopkins. 1978. Biochemical components of the mysid shrimp *Taphromysis bowmani* Bacescu. Journal of Experimental Marine Biology and Ecology 31:1–9.

Kayfetz, K., and W. Kimmerer. 2017. Abiotic and biotic controls on the copepod *Pseudodiaptomus forbesi* in the upper San Francisco Estuary. Marine Ecology Progress Series 581:85–101.

Kerfoot, W. C. 1978. Combat between predatory copepods and their prey: *Cyclops*, *Epischura*, and *Bosmina*. Limnology and Oceanography 23:1089–1102.

Kimmerer, W., S. R. Avent, S. M. Bollens, F. Feyrer, L. F. Grimaldo, P. B. Moyle, M. Nobriga, and T. Visintainer. 2005. Variability in Length–Weight Relationships Used to Estimate Biomass of Estuarine Fish from Survey Data. Transactions of the American Fisheries Society 134:481–495.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39–55.

Kimmerer, W. J. 2006. Response of anchovies dampens effects of the invasive bivalve Corbula amurensis on the San Francisco Estuary foodweb. Marine Ecology Progress Series 324:207–218.

Kimmerer, W. J., E. Gartside, and J. J. Orsi. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Marine Ecology Progress Series 113:81–93.

Kimmerer, W. J., T. R. Ignoffo, K. R. Kayfetz, and A. M. Slaughter. 2018. Effects of freshwater flow and phytoplankton biomass on growth, reproduction, and spatial subsidies of the estuarine copepod *Pseudodiaptomus forbesi*. Hydrobiologia 807:113–130.

Kimmerer, W. J., T. R. Ignoffo, A. M. Slaughter, and A. L. Gould. 2014. Food-limited reproduction and growth of three copepod species in the low-salinity zone of the San Francisco Estuary. Journal of Plankton Research 36:722–735.

Knutson, A. C., and J. J. Orsi. 1983. Factors Regulating Abundance and Distribution of the Shrimp Neomysis mercedis in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 112:476–485.

Kratina, P., and M. Winder. 2015. Biotic invasions can alter nutritional composition of zooplankton communities. Oikos 124:1337–1345.

Lauritsen, D. D. 1986. Filter-Feeding in Corbicula fluminea and Its Effect on Seston Removal. Journal of the North American Benthological Society 5:165–172.

Li, J. L., and H. W. Li. 1979. Species-specific factors affecting predator-prey interactions of the copepod Acanthocyclops vernalis with its natural prey. Limnology and Oceanography 24:613–626.

Loboschefsky, E., G. Benigno, T. Sommer, K. Rose, T. Ginn, A. Massoudieh, and F. Loge. 2012. Individual-level and Population-level Historical Prey Demand of San Francisco Estuary Striped Bass Using a Bioenergetics Model. San Francisco Estuary and Watershed Science 10.

Lojkovic Burris, Z. P., R. D. Baxter, and C. E. Burdi. 2022. Larval and juvenile Longfin Smelt diets as a function of fish size and prey density in the San Francisco Estuary. California Fish and Wildlife Journal 108.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, and S. D. Culberson. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417–1430.

Mahardja, B., J. L. Conrad, L. Lusher, and B. Schreier. 2016. Abundance Trends, Distribution, and Habitat Associations of the Invasive Mississippi Silverside (Menidia audens) in the Sacramento–San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science 14.

Mahardja, B., M. J. Farruggia, B. Schreier, and T. Sommer. 2017. Evidence of a Shift in the Littoral Fish Community of the Sacramento-San Joaquin Delta. PLOS ONE 12:e0170683.

Nobriga, M. L., and W. E. Smith. 2020. Did a Shifting Ecological Baseline Mask the Predatory Effect of Striped Bass on Delta Smelt? San Francisco Estuary and Watershed Science 18.

Orsi, J. J. 1995. Food Habits of Several Abundant Zooplankton Species in the Sacramento-San Joaquin Estuary. Interagency Ecological Program Technical Reports 41.

Orsi, J. J., and W. L. Mecum. 1986. Zooplankton distribution and abundance in the Sacramento-San Joaquin delta in relation to certain environmental factors. Estuaries 9:326–339.

Perry, S. E. 2020. Synthesized Dataset of Length-Weight Regression Coefficients for Delta Fish. Environmental Data Initiative. https://doi.org/10.6073/PASTA/895D04734AF8380B486087D26D56D95B

Petchey, O. L., P. T. McPhearson, T. M. Casey, and P. J. Morin. 1999. Environmental warming alters food-web structure and ecosystem function. Nature 402:69–72.

Peterson, D. H., R. E. Smith, S. W. Hager, D. D. Harmon, R. E. Herndon, and L. E. Schemel. 1985. Interannual variability in dissolved inorganic nutrients in Northern San Francisco Bay Estuary. Pages 37–58 *in* J. E. Cloern and F. H. Nichols, editors. Temporal Dynamics of an Estuary: San Francisco Bay. Springer Netherlands, Dordrecht.

Schindler, D. W., A. S. Clark, and J. R. Gray. 1971. Seasonal Calorific Values of Freshwater Zooplankton, as Determined with a Phillipson Bomb Calorimeter Modified for Small Samples. Journal of the Fisheries Research Board of Canada 28:559–564.

Schreier, B. M., M. R. Baerwald, J. L. Conrad, G. Schumer, and B. May. 2016. Examination of Predation on Early Life Stage Delta Smelt in the San Francisco Estuary Using DNA Diet Analysis. Transactions of the American Fisheries Society 145:723–733.

Slater, S. B., and R. D. Baxter. 2014. Diet, prey selection, and body condition of age-0 Delta Smelt, *Hypomesus transpacificus*, in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 12.

Slater, S. B., A. Schultz, B. G. Hammock, A. Hennessy, and C. Burdi. 2019. Patterns of Zooplankton Consumption by Juvenile and Adult Delta Smelt (*Hypomesus transpacifus*). Page *in* A. Schultz, editor. Directed Outflow Project Technical Report 1. U. S. Bureau of Reclamation,Bay-Delta Office, Mid-Pacific Region, Sacramento, CA.

Slaughter, A. M., T. R. Ignoffo, and W. Kimmerer. 2016. Predation impact of *Acartiella sinensis*, an introduced predatory copepod in the San Francisco Estuary, USA. Marine Ecology Progress Series 547:47–60.

Tempel, T. L., T. D. Malinich, J. Burns, A. Barros, C. E. Burdi, and J. A. Hobbs. 2021. The value of long-term monitoring of the San Francisco Estuary for Delta Smelt and Longfin Smelt. California Fish and Wildlife:148–171.

Theilacker, G. H., and A. S. Kimball. 1984. Comparative quality of rotifers and copepods as foods for larval fishes. CalCOFI Rep 25:80–86.

Thomson, J. R., W. J. Kimmerer, L. R. Brown, K. B. Newman, R. M. Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431–1448.

Vijverberg, J., and H. Th. Frank. 1976. The chemical composition and energy contents of copepods and cladocerans in relation to their size. Freshwater Biology 6:333–345.

Walz, N. 1995. Rotifer populations in plankton communities: Energetics and life history strategies. Experientia 51:437–453.

Wells, E., and Interagency Ecological Program. 2021. Interagency Ecological Program: Benthic invertebrate monitoring in the Sacramento-San Joaquin Bay-Delta, collected by the Environmental Monitoring Program, 1975-2020.

Wilson, R. R. 1951. Distribution, growth, feedgin habits, abundancve, thermal, and salinity relations of *Neomysis mercedis* (Holmes) from the NIcomekl and Serpentine Rivers, British Columbia. Master of Arts in Zoology, The University of British Columbia.

Wood, S. N. 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society: Series B (Statistical Methodology) 73:3–36.

Wood, S. N., N. Pya, and B. Säfken. 2016. Smoothing Parameter and Model Selection for General Smooth Models. Journal of the American Statistical Association 111:1548–1563.

York, J. K., G. B. McManus, W. J. Kimmerer, A. M. Slaughter, and T. R. Ignoffo. 2014. Trophic Links in the Plankton in the Low Salinity Zone of a Large Temperate Estuary: Top-down Effects of Introduced Copepods. Estuaries and Coasts 37:576–588.

Yúfera, M., and E. Pascual. 1989. Biomass and elemental composition (C.H.N.) of the rotifer *Brachionus plicatilis* cultured as larval food. Hydrobiologia 186:371–374.

Appendix S2: Supplemental data and model tables

Table S1. Variable definitions and temporal extent for the monthly and annual datasets.

Variable	Monthly years (missing months)	Annual years (missing years)	Definition
Ammonia	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Amphipods catch	1997–2020 (18)	1975–2020 (1)	from 5 different sources - year-round - see Bashevkin et al. 2022
Amphipods mass	1997–2020 (18)	1975–2020 (1)	from 5 different sources - year-round - see Bashevkin et al. 2022
Centrarchids DJFMP	1995–2020 (3)		year-round - beach seines - biomass
Cladocera	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Cladocera catch	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Cladocera energy	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Corbicula	1997–2020 (18)	1975–2020 (1)	from the Environmental Monitoring Program (EMP) Benthic Survey at DWR - year-round
Delta smelt BSMT	1995–2020 (38)	1980–2020 (1)	year-round - midwater trawl - biomass
Delta smelt BSOT	1995–2020 (18)	1980–2020 (0)	year-round - otter trawl - biomass
Delta smelt FMWT		1975–2020 (1)	fall (September - December) - midwater trawl - biomass
Delta smelt STN		1975–2021 (0)	summer (June - August) - townet - biomass
Dissolved Inorganic Nitrogen	1995–2020 (0)		from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Dissolved Orthophos	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Estuarine fishes BSMT	1995–2020 (38)	1980–2020 (1)	year-round - midwater trawl - biomass of estuarine pelagic forage fishes
Estuarine fishes BSOT	1995–2020 (18)	1980–2020 (0)	year-round - otter trawl - biomass of estuarine pelagic forage fishes
Estuarine fishes FMWT		1975–2020 (1)	fall (September - December) - midwater trawl - biomass of estuarine pelagic forage fishes
Estuarine fishes STN		1975–2021 (0)	summer (June - August) - townet - biomass of estuarine pelagic forage fishes
Flow	1995–2020 (0)	1975–2020 (0)	year-round - mean Delta outflow (water leaving the Delta to the Bay)
Herbivorous copepods	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Herbivorous copepods catch	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Herbivorous copepods energy	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Herbivorous zooplankton biomass	1995–2020 (2)	1975–2020 (0)	summed herbivorous zooplankton biomass
Herbivorous zooplankton energy	1995–2020 (2)	1975–2020 (0)	summed herbivorous zooplankton energy
Longfin smelt BSMT	1995–2020 (38)	1980–2020 (1)	year-round - midwater trawl - biomass

Variable	Monthly years (missing months)	Annual years (missing years)	Definition
Longfin smelt BSOT	1995–2020 (18)	1980–2020 (0)	year-round - otter trawl - biomass
Longfin smelt FMWT		1975–2020 (1)	fall (September - December) - midwater trawl - biomass
Longfin smelt STN		1975–2021 (0)	summer (June - August) - townet - biomass
Marine fishes BSMT	1995–2020 (38)	1980–2020 (1)	year-round - midwater trawl - biomass
Marine fishes BSOT	1995–2020 (18)	1980–2020 (0)	year-round - otter trawl - biomass
Marine fishes FMWT		1975–2020 (1)	fall (September - December) - midwater trawl - biomass
Marine fishes STN		1975–2021 (0)	summer (June - August) - townet - biomass
Mississippi silverside DJFMP	1995–2020 (3)	1976–2020 (0)	year-round - beach seines - biomass
Mysids	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Mysids catch	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Mysids energy	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Nitrate and Nitrite	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Phytoplankton	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Potamocorbula	1997–2020 (18)	1975–2020 (1)	from the Environmental Monitoring Program (EMP) Benthic Survey at DWR - year-round
Predatory copepods	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Predatory copepods catch	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Predatory copepods energy	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Predatory zooplankton biomass	1995–2020 (2)	1975–2020 (0)	summed predatory zooplankton biomass
Predatory zooplankton energy	1995–2020 (2)	1975–2020 (0)	summed predatory zooplankton energy
Rotifers catch	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Rotifers energy	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Rotifers mass	1995–2020 (2)	1975–2020 (0)	from 5 different sources - year-round - see Bashevkin et al. 2022
Secchi	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round
Striped bass age 1+ BSMT	1995–2020 (38)		year-round - midwater trawl - biomass of age 1+ individuals
Striped bass age 1+ BSOT	1995–2020 (18)		year-round - otter trawl - biomass of age 1+ individuals
Striped bass BSMT	1995–2020 (38)	1980–2020 (1)	year-round - midwater trawl - biomass of age 0 individuals
Striped bass BSOT	1995–2020 (18)	1980–2020 (0)	year-round - otter trawl - biomass of age 0 individuals
Striped bass FMWT		1975–2020 (1)	fall (September - December) - midwater trawl - biomass of age 0 individuals
Striped bass STN		1975–2021 (0)	summer (June - August) - townet - biomass of age 0 individuals
Temperature	1995–2020 (0)	1980–2020 (0)	from the Discrete Environmental Monitoring Program (EMP) at DWR - year-round

Variable	Monthly years (missing months)	Annual years (missing years)	Definition
Total zooplankton biomass	1995–2020 (2)	1975–2020 (0)	summed zooplankton biomass
Total zooplankton energy	1995–2020 (2)	1975–2020 (0)	summed zooplankton energy
Turbidity	1995–2020 (0)	1980–2020 (0)	negative secchi depth

Table S2. Stations used to calculate input data for annual and monthly models.

Survey	Temporal resolution	Stations
Bay Study	Annual	427, 428, 429, 431, 432, 433, 534, 535, 736, 837
DJFMP	Annual	MS001N, SJ001S, SJ005N, SR012E, SR012E, SR014W, TM001N
EMP Benthic	Annual	D4-L, D7-C, D28A-L
EMP Nutrients	Annual	D26, D28A, D4, D6, D7, D8
EMP Zoop	Annual	NZD28, NZ054, NZ074, NZ048, NZ086, NZ064, NZ060, NZ028, NZS42, NZ032
FMWT	Annual	338, 339, 401, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 501, 502, 503, 504, 505, 507, 508, 509, 510, 511, 512, 513, 515, 516, 517, 518, 519, 601, 602, 603, 604, 605, 606, 608, 701, 703, 704, 705, 706, 707, 708, 709, 710, 711, 802, 804, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 902, 904, 905, 906, 908, 915
STN	Annual	405, 411, 418, 501, 504, 508, 513, 519, 520, 602, 606, 609, 610, 704, 706, 707, 711, 801, 804, 809, 812, 815, 902, 906, 915
Bay Study	Monthly	317, 318, 319, 320, 321, 322, 323, 325, 427, 428, 429, 430, 431, 432, 433, 534, 535, 736, 837, 345, 346, 447, 750, 751, 752, 853, 760, 761, 863, 864, 865
DJFMP	Monthly	SR014W, SR012E, MS001N, TM001N, SJ005N, SJ001S, OR003W, OR014W, SR012E
EMP Benthic	Monthly	D4-L, D6-R, D7-C, D16-L, D28A-L, D24-L, D41-C, D41A-C
EMP Nutrients	Monthly	D26, D28A, D4, D41, D6, D7, D8
EMP Zoop	Monthly	NZD28, NZ054, NZ074, NZ048, NZD16, NZ086, NZ064, NZ060, NZ028, NZS42, NZ032, NZD41, NZD06

Table S3. Path coefficients for annual and annual-regional SEMS. The 'op' column defines the operation between the predictor and response where ~ refers to regression, ~~ refers to covariances, and ~= refers to latent variable manifestations. Covariances between exogenous variables do not have standard errors or p-values.

Model	Region	Response	op	Predictor	Effect	se	pvalue
Detrended	Sacramento	chla	~	corbic	0.4860	0.1312	0.0002
Detrended	Sacramento	chla	~	flow	0.1432	0.1506	0.3415
Detrended	Sacramento	chla	~	temp	0.1667	0.1276	0.1913
Detrended	Sacramento	chla	~	turbid	0.1926	0.1341	0.1508
Detrended	Sacramento	hzoop	~	chla	0.3931	0.1594	0.0136
Detrended	Sacramento	hzoop	~	corbic	-0.0633	0.1880	0.7365
Detrended	Sacramento	hzoop	~	flow	0.0270	0.1829	0.8826
Detrended	Sacramento	hzoop	~	temp	0.1665	0.1542	0.2803
Detrended	Sacramento	hzoop	~	turbid	-0.0721	0.1671	0.6660
Detrended	Sacramento	pzoop	~	chla	0.7302	0.0955	0.0000
Detrended	Sacramento	pzoop	~	corbic	0.2671	0.1096	0.0148
Detrended	Sacramento	pzoop	~	flow	-0.4966	0.1034	0.0000
Detrended	Sacramento	pzoop	~	temp	0.0184	0.0933	0.8435
Detrended	Sacramento	pzoop	~	turbid	0.0065	0.0986	0.9472
Detrended	Sacramento	pzoop	~	hzoop	0.0177	0.0917	0.8471
Detrended	Sacramento	fish	~	chla	-0.7132	0.3269	0.0291
Detrended	Sacramento	fish	~	hzoop	0.1530	0.1634	0.3492
Detrended	Sacramento	fish	~	pzoop	0.5734	0.2814	0.0416
Detrended	Sacramento	fish	~	corbic	-0.6484	0.2421	0.0074
Detrended	Sacramento	fish	~	flow	0.5380	0.2443	0.0277
Detrended	Sacramento	fish	~	temp	0.2221	0.1837	0.2266
Detrended	Sacramento	fish	~	turbid	0.0846	0.1983	0.6697
Detrended	Sacramento	fish	=~	estfish	0.6155	0.1286	0.0000
Detrended	Sacramento	fish	=~	estfish_stn	0.7256	0.1396	0.0000
Detrended	Sacramento	estfish_stn	~~	chla	0.6757	0.1661	0.0000
Detrended	Sacramento	estfish	~~	estfish	0.6211	0.1583	0.0001
Detrended	Sacramento	estfish_stn	~~	estfish_stn	0.6237	0.2351	0.0080
Detrended	Sacramento	chla	~~	chla	0.7078	0.1038	0.0000
Detrended	Sacramento	hzoop	~~	hzoop	0.8304	0.1058	0.0000
Detrended	Sacramento	pzoop	~~	pzoop	0.2863	0.0718	0.0001
Detrended	Sacramento	fish	~~	fish	0.4444	0.1769	0.0120
Detrended	Sacramento	corbic	~~	corbic	1.0000	0.0000	
Detrended	Sacramento	corbic	~~	flow	0.3769	0.0000	
Detrended	Sacramento	corbic	~~	temp	-0.1741	0.0000	
Detrended	Sacramento	corbic	~~	turbid	-0.2650	0.0000	
Detrended	Sacramento	flow	~~	flow	1.0000	0.0000	
Detrended	Sacramento	flow	~~	temp	-0.3757	0.0000	
Detrended	Sacramento	flow	~~	turbid	0.2872	0.0000	
Detrended	Sacramento	temp	~~	temp	1.0000	0.0000	
Detrended	Sacramento	temp	~~	turbid	-0.0296	0.0000	
Detrended	Sacramento	turbid	~~	turbid	1.0000	0.0000	
Detrended	San Joaquin	chla	~	corbic	0.1201	0.1555	0.4400
Detrended	San Joaquin	chla	~	flow	-0.0340	0.1678	0.8396
Detrended	San Joaquin	chla	~	temp	0.1756	0.1549	0.2568

Model	Region	Response	op	Predictor	Effect	se	pvalue
Detrended	San Joaquin	chla	~	turbid	-0.0475	0.1630	0.7707
Detrended	San Joaquin	hzoop	~	chla	0.4583	0.1154	0.0001
Detrended	San Joaquin	hzoop	~	corbic	0.2814	0.1221	0.0212
Detrended	San Joaquin	hzoop	~	flow	-0.0084	0.1359	0.9509
Detrended	San Joaquin	hzoop	~	temp	0.0368	0.1298	0.7768
Detrended	San Joaquin	hzoop	~	turbid	-0.1838	0.1298	0.1568
Detrended	San Joaquin	pzoop	~	chla	0.5160	0.1209	0.0000
Detrended	San Joaquin	pzoop	~	corbic	-0.1184	0.1226	0.3342
Detrended	San Joaquin	pzoop	~	flow	-0.0125	0.1239	0.9198
Detrended	San Joaquin	pzoop	~	temp	0.1449	0.1174	0.2173
Detrended	San Joaquin	pzoop	~	turbid	-0.0903	0.1229	0.4627
Detrended	San Joaquin	pzoop	~	hzoop	0.2177	0.1413	0.1235
Detrended	San Joaquin	fish	~	hzoop	0.2551	0.1656	0.1234
Detrended	San Joaquin	fish	~	pzoop	-0.3011	0.1561	0.0537
Detrended	San Joaquin	fish	~	corbic	0.1126	0.1485	0.4482
Detrended	San Joaquin	fish	~	flow	0.0051	0.1486	0.9727
Detrended	San Joaquin	fish	~	temp	0.1178	0.1435	0.4117
Detrended	San Joaquin	fish	~	turbid	0.3880	0.1349	0.0040
Detrended	San Joaquin	fish	=~	estfish	1.0000	0.0000	
Detrended	San Joaquin	estfish	~~	estfish	0.0000	0.0000	
Detrended	San Joaquin	chla	~~	chla	0.9500	0.0655	0.0000
Detrended	San Joaquin	hzoop	~~	hzoop	0.6213	0.1169	0.0000
Detrended	San Joaquin	pzoop	~~	pzoop	0.5169	0.1117	0.0000
Detrended	San Joaquin	fish	~~	fish	0.7428	0.1137	0.0000
Detrended	San Joaquin	corbic	~~	corbic	1.0000	0.0000	
Detrended	San Joaquin	corbic	~~	flow	0.1815	0.0000	
Detrended	San Joaquin	corbic	~~	temp	0.0040	0.0000	
Detrended	San Joaquin	corbic	~~	turbid	-0.0951	0.0000	
Detrended	San Joaquin	flow	~~	flow	1.0000	0.0000	
Detrended	San Joaquin	flow	~~	temp	-0.2024	0.0000	
Detrended	San Joaquin	flow	~~	turbid	0.2808	0.0000	
Detrended	San Joaquin	temp	~~	temp	1.0000	0.0000	
Detrended	San Joaquin	temp	~~	turbid	0.1064	0.0000	
Detrended	San Joaquin	turbid	~~	turbid	1.0000	0.0000	
Detrended	Suisun	chla	~	potam	0.1777	0.1564	0.2561
Detrended	Suisun	chla	~	flow	0.6290	0.1690	0.0002
Detrended	Suisun	chla	~	temp	-0.3245	0.1323	0.0142
Detrended	Suisun	chla	~	turbid	-0.4176	0.1692	0.0136
Detrended	Suisun	hzoop	~	chla	0.4931	0.1207	0.0000
Detrended	Suisun	hzoop	~	potam	-0.0356	0.1322	0.7875
Detrended	Suisun	hzoop	~	flow	0.4195	0.1731	0.0153
Detrended	Suisun	hzoop	~	temp	-0.0056	0.1234	0.9637
Detrended	Suisun	hzoop	~	turbid	-0.5108	0.1472	0.0005
Detrended	Suisun	pzoop	~	chla	0.4911	0.1127	0.0000
Detrended	Suisun	pzoop	~	potam	0.0346	0.1008	0.7318
Detrended	Suisun	pzoop	~	flow	-0.3008	0.1451	0.0381
Detrended	Suisun	pzoop	~	temp	-0.0478	0.0939	0.6107
Detrended	Suisun	pzoop	~	turbid	0.0292	0.1351	0.8287
Detrended	Suisun	pzoop	~	hzoop	0.5076	0.1172	0.0000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Detrended	Suisun	fish	~	hzoop	0.0856	0.1648	0.6037
Detrended	Suisun	fish	~	pzoop	0.2782	0.1505	0.0645
Detrended	Suisun	fish	~	potam	-0.1305	0.1140	0.2525
Detrended	Suisun	fish	~	flow	0.7923	0.1555	0.0000
Detrended	Suisun	fish	~	temp	-0.0635	0.1053	0.5465
Detrended	Suisun	fish	~	turbid	-0.0124	0.1540	0.9356
Detrended	Suisun	fish	=~	estfish	0.6981	0.0819	0.0000
Detrended	Suisun	fish	=~	estfish_stn	0.7858	0.0657	0.0000
Detrended	Suisun	fish	=~	estfish_bsmt	0.6496	0.0913	0.0000
Detrended	Suisun	estfish	~~	estfish	0.5127	0.1144	0.0000
Detrended	Suisun	estfish_stn	~~	estfish_stn	0.3825	0.1033	0.0002
Detrended	Suisun	estfish_bsmt	~~	estfish_bsmt	0.5780	0.1186	0.0000
Detrended	Suisun	chla	~~	chla	0.7026	0.1118	0.0000
Detrended	Suisun	hzoop	~~	hzoop	0.4726	0.1018	0.0000
Detrended	Suisun	pzoop	~~	pzoop	0.2740	0.0726	0.0002
Detrended	Suisun	fish	~~	fish	0.0526	0.0912	0.5636
Detrended	Suisun	potam	~~	potam	1.0000	0.0000	
Detrended	Suisun	potam	~~	flow	-0.5268	0.0000	
Detrended	Suisun	potam	~~	temp	0.2990	0.0000	
Detrended	Suisun	potam	~~	turbid	-0.3924	0.0000	
Detrended	Suisun	flow	~~	flow	1.0000	0.0000	
Detrended	Suisun	flow	~~	temp	-0.2786	0.0000	
Detrended	Suisun	flow	~~	turbid	0.6744	0.0000	
Detrended	Suisun	temp	~~	temp	1.0000	0.0000	
Detrended	Suisun	temp	~~	turbid	-0.2766	0.0000	
Detrended	Suisun	turbid	~~	turbid	1.0000	0.0000	
Detrended	Whole Estuary	chla	~	potam	0.2584	0.1789	0.1485
Detrended	Whole Estuary	chla	~	flow	0.3423	0.1745	0.0499
Detrended	Whole Estuary	chla	~	temp	-0.0611	0.1646	0.7105
Detrended	Whole Estuary	hzoop	~	chla	0.6313	0.1034	0.0000
Detrended	Whole Estuary	hzoop	~	potam	-0.0700	0.1544	0.6501
Detrended	Whole Estuary	hzoop	~	flow	0.0074	0.1576	0.9625
Detrended	Whole Estuary	hzoop	~	temp	0.0639	0.1347	0.6351
Detrended	Whole Estuary	pzoop	~	chla	0.6553	0.0929	0.0000
Detrended	Whole Estuary	pzoop	~	potam	0.0539	0.0953	0.5717
Detrended	Whole Estuary	pzoop	~	flow	-0.1941	0.0971	0.0456
Detrended	Whole Estuary	pzoop	~	hzoop	0.3169	0.0979	0.0012
Detrended	Whole Estuary	pzoop	~	temp	-0.0891	0.0833	0.2846
Detrended	Whole Estuary	fish	~	hzoop	0.1170	0.1563	0.4542
Detrended	Whole Estuary	fish	~	pzoop	0.3977	0.1592	0.0125
Detrended	Whole Estuary	fish	~	flow	0.6744	0.1472	0.0000
Detrended	Whole Estuary	fish	~	turbid	0.1344	0.1276	0.2921
Detrended	Whole Estuary	fish	~	temp	0.2302	0.1215	0.0582
Detrended	Whole Estuary	fish	~	potam	-0.2263	0.1356	0.0953
Detrended	Whole Estuary	fish	=~	estfish	0.6112	0.1040	0.0000
Detrended	Whole Estuary	fish	=~	estfish_stn	0.6241	0.1017	0.0000
Detrended	Whole Estuary	fish	=~	estfish_bsmt	0.7500	0.0805	0.0000
Detrended	Whole Estuary	estfish	~~	estfish	0.6265	0.1271	0.0000
Detrended	Whole Estuary	estfish_stn	~~	estfish_stn	0.6105	0.1270	0.0000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Detrended	Whole Estuary	estfish_bsmt	~~	estfish_bsmt	0.4374	0.1208	0.0003
Detrended	Whole Estuary	chla	~~	chla	0.9067	0.0855	0.0000
Detrended	Whole Estuary	hzoop	~~	hzoop	0.6049	0.1201	0.0000
Detrended	Whole Estuary	pzoop	~~	pzoop	0.2285	0.0634	0.0003
Detrended	Whole Estuary	fish	~~	fish	0.0705	0.1185	0.5519
Detrended	Whole Estuary	potam	~~	potam	1.0000	0.0000	
Detrended	Whole Estuary	potam	~~	flow	-0.5556	0.0000	
Detrended	Whole Estuary	potam	~~	temp	0.3586	0.0000	
Detrended	Whole Estuary	potam	~~	turbid	-0.2760	0.0000	
Detrended	Whole Estuary	flow	~~	flow	1.0000	0.0000	
Detrended	Whole Estuary	flow	~~	temp	-0.3633	0.0000	
Detrended	Whole Estuary	flow	~~	turbid	0.5118	0.0000	
Detrended	Whole Estuary	temp	~~	temp	1.0000	0.0000	
Detrended	Whole Estuary	temp	~~	turbid	-0.0441	0.0000	
Detrended	Whole Estuary	turbid	~~	turbid	1.0000	0.0000	
Original	Sacramento	chla	~	corbic	0.4497	0.1121	0.0001
Original	Sacramento	chla	~	flow	0.2008	0.1373	0.1436
Original	Sacramento	chla	~	temp	0.1777	0.1254	0.1565
Original	Sacramento	chla	~	turbid	0.1056	0.1289	0.4126
Original	Sacramento	hzoop	~	chla	0.1676	0.1409	0.2343
Original	Sacramento	hzoop	~	corbic	0.3840	0.1330	0.0039
Original	Sacramento	hzoop	~	flow	-0.1588	0.1415	0.2617
Original	Sacramento	hzoop	~	temp	0.0864	0.1299	0.5060
Original	Sacramento	hzoop	~	turbid	0.4475	0.1095	0.0000
Original	Sacramento	pzoop	~	chla	0.6016	0.0892	0.0000
Original	Sacramento	pzoop	~	corbic	0.3612	0.0978	0.0002
Original	Sacramento	pzoop	~	flow	-0.4792	0.0902	0.0000
Original	Sacramento	pzoop	~	temp	-0.0037	0.0846	0.9652
Original	Sacramento	pzoop	~	turbid	0.1286	0.0918	0.1612
Original	Sacramento	pzoop	~	hzoop	0.1338	0.1011	0.1858
Original	Sacramento	fish	~	chla	-0.6863	0.2162	0.0015
Original	Sacramento	fish	~	hzoop	0.5237	0.1443	0.0003
Original	Sacramento	fish	~	pzoop	0.6097	0.2253	0.0068
Original	Sacramento	fish	~	corbic	-0.3462	0.1765	0.0499
Original	Sacramento	fish	~	flow	0.3203	0.1776	0.0714
Original	Sacramento	fish	~	temp	0.0923	0.1299	0.4774
Original	Sacramento	fish	~	turbid	0.3255	0.1390	0.0192
Original	Sacramento	fish	=~	estfish	0.8084	0.0709	0.0000
Original	Sacramento	fish	=~	estfish_stn	0.8434	0.0804	0.0000
Original	Sacramento	estfish_stn	~~	chla	0.5948	0.1606	0.0002
Original	Sacramento	estfish	~~	estfish	0.3464	0.1146	0.0025
Original	Sacramento	estfish_stn	~~	estfish_stn	0.4039	0.1428	0.0047
Original	Sacramento	chla	~~	chla	0.6859	0.1021	0.0000
Original	Sacramento	hzoop	~~	hzoop	0.5653	0.1041	0.0000
Original	Sacramento	pzoop	~~	pzoop	0.2351	0.0580	0.0001
Original	Sacramento	fish	~~	fish	0.2744	0.1076	0.0107
Original	Sacramento	corbic	~~	corbic	1.0000	0.0000	
Original	Sacramento	corbic	~~	flow	0.3782	0.0000	
Original	Sacramento	corbic	~~	temp	-0.2155	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Original	Sacramento	corbic	~~	turbid	0.1434	0.0000	
Original	Sacramento	flow	~~	flow	1.0000	0.0000	
Original	Sacramento	flow	~~	temp	-0.3905	0.0000	
Original	Sacramento	flow	~~	turbid	0.3100	0.0000	
Original	Sacramento	temp	~~	temp	1.0000	0.0000	
Original	Sacramento	temp	~~	turbid	-0.1037	0.0000	
Original	Sacramento	turbid	~~	turbid	1.0000	0.0000	
Original	San Joaquin	chla	~	corbic	0.2832	0.1417	0.0458
Original	San Joaquin	chla	~	flow	-0.1280	0.1399	0.3600
Original	San Joaquin	chla	~	temp	0.0810	0.1396	0.5615
Original	San Joaquin	chla	~	turbid	0.3726	0.1385	0.0071
Original	San Joaquin	hzoop	~	chla	0.5227	0.1140	0.0000
Original	San Joaquin	hzoop	~	corbic	0.3779	0.1149	0.0010
Original	San Joaquin	hzoop	~	flow	-0.0630	0.1118	0.5735
Original	San Joaquin	hzoop	~	temp	-0.0253	0.1104	0.8186
Original	San Joaquin	hzoop	~	turbid	-0.0231	0.1267	0.8552
Original	San Joaquin	pzoop	~	chla	0.5156	0.1250	0.0000
Original	San Joaquin	pzoop	~	corbic	-0.0389	0.1204	0.7468
Original	San Joaquin	pzoop	~	flow	-0.0710	0.0997	0.4762
Original	San Joaquin	pzoop	~	temp	0.0493	0.0981	0.6150
Original	San Joaquin	pzoop	~	turbid	0.1778	0.1117	0.1116
Original	San Joaquin	pzoop	~	hzoop	0.2793	0.1393	0.0449
Original	San Joaquin	fish	~	hzoop	0.2551	0.1238	0.0393
Original	San Joaquin	fish	~	pzoop	-0.1211	0.1182	0.3055
Original	San Joaquin	fish	~	corbic	0.1746	0.1047	0.0955
Original	San Joaquin	fish	~	flow	-0.0796	0.0878	0.3646
Original	San Joaquin	fish	~	temp	0.0171	0.0861	0.8427
Original	San Joaquin	fish	~	turbid	0.7935	0.0812	0.0000
Original	San Joaquin	fish	=~	estfish	0.9210	0.0386	0.0000
Original	San Joaquin	fish	=~	estfish_stn	0.7637	0.0662	0.0000
Original	San Joaquin	fish	=~	estfish_bsmt	0.5825	0.1044	0.0000
Original	San Joaquin	estfish	~~	estfish	0.1518	0.0710	0.0326
Original	San Joaquin	estfish_stn	~~	estfish_stn	0.4167	0.1012	0.0000
Original	San Joaquin	estfish_bsmt	~~	estfish_bsmt	0.6606	0.1217	0.0000
Original	San Joaquin	chla	~~	chla	0.7242	0.1117	0.0000
Original	San Joaquin	hzoop	~~	hzoop	0.4461	0.0988	0.0000
Original	San Joaquin	pzoop	~~	pzoop	0.3518	0.0865	0.0000
Original	San Joaquin	fish	~~	fish	0.1362	0.0689	0.0481
Original	San Joaquin	corbic	~~	corbic	1.0000	0.0000	
Original	San Joaquin	corbic	~~	flow	0.1955	0.0000	
Original	San Joaquin	corbic	~~	temp	-0.1689	0.0000	
Original	San Joaquin	corbic	~~	turbid	0.4043	0.0000	
Original	San Joaquin	flow	~~	flow	1.0000	0.0000	
Original	San Joaquin	flow	~~	temp	-0.2199	0.0000	
Original	San Joaquin	flow	~~	turbid	0.2303	0.0000	
Original	San Joaquin	temp	~~	temp	1.0000	0.0000	
Original	San Joaquin	temp	~~	turbid	-0.2027	0.0000	
Original	San Joaquin	turbid	~~	turbid	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Original	Suisun	chla	~	potam	-0.2850	0.1629	0.0802
Original	Suisun	chla	~	flow	0.2798	0.1763	0.1125
Original	Suisun	chla	~	temp	-0.2781	0.1422	0.0506
Original	Suisun	chla	~	turbid	-0.2134	0.1890	0.2588
Original	Suisun	hzoop	~	chla	0.6252	0.1015	0.0000
Original	Suisun	hzoop	~	potam	-0.3526	0.1239	0.0044
Original	Suisun	hzoop	~	flow	0.1063	0.1365	0.4361
Original	Suisun	hzoop	~	temp	0.0478	0.1134	0.6733
Original	Suisun	hzoop	~	turbid	-0.2841	0.1402	0.0428
Original	Suisun	pzoop	~	chla	0.4300	0.0993	0.0000
Original	Suisun	pzoop	~	potam	-0.0136	0.0903	0.8802
Original	Suisun	pzoop	~	flow	-0.3641	0.0920	0.0001
Original	Suisun	pzoop	~	temp	-0.0177	0.0736	0.8100
Original	Suisun	pzoop	~	turbid	0.1482	0.0972	0.1273
Original	Suisun	pzoop	~	hzoop	0.6064	0.1002	0.0000
Original	Suisun	fish	~	hzoop	0.2472	0.1572	0.1157
Original	Suisun	fish	~	pzoop	0.2675	0.1463	0.0675
Original	Suisun	fish	~	potam	-0.3273	0.1002	0.0011
Original	Suisun	fish	~	flow	0.2218	0.1098	0.0434
Original	Suisun	fish	~	temp	0.0062	0.0810	0.9394
Original	Suisun	fish	~	turbid	0.2621	0.1107	0.0179
Original	Suisun	fish	=~	estfish	0.8750	0.0398	0.0000
Original	Suisun	fish	=~	estfish_stn	0.8847	0.0378	0.0000
Original	Suisun	fish	=~	estfish_bsmt	0.7548	0.0675	0.0000
Original	Suisun	estfish	~~	estfish	0.2344	0.0697	0.0008
Original	Suisun	estfish_stn	~~	estfish_stn	0.2174	0.0668	0.0011
Original	Suisun	estfish_bsmt	~~	estfish_bsmt	0.4302	0.1019	0.0000
Original	Suisun	chla	~~	chla	0.7190	0.1117	0.0000
Original	Suisun	hzoop	~~	hzoop	0.3850	0.0910	0.0000
Original	Suisun	pzoop	~~	pzoop	0.1612	0.0460	0.0005
Original	Suisun	fish	~~	fish	0.0801	0.0484	0.0979
Original	Suisun	potam	~~	potam	1.0000	0.0000	
Original	Suisun	potam	~~	flow	-0.4816	0.0000	
Original	Suisun	potam	~~	temp	0.4001	0.0000	
Original	Suisun	potam	~~	turbid	-0.5489	0.0000	
Original	Suisun	flow	~~	flow	1.0000	0.0000	
Original	Suisun	flow	~~	temp	-0.2948	0.0000	
Original	Suisun	flow	~~	turbid	0.6585	0.0000	
Original	Suisun	temp	~~	temp	1.0000	0.0000	
Original	Suisun	temp	~~	turbid	-0.3542	0.0000	
Original	Suisun	turbid	~~	turbid	1.0000	0.0000	
Original	Whole Estuary	chla	~	potam	-0.3407	0.1708	0.0461
Original	Whole Estuary	chla	~	flow	0.0546	0.1738	0.7532
Original	Whole Estuary	chla	~	temp	-0.0354	0.1659	0.8308
Original	Whole Estuary	hzoop	~	chla	0.6665	0.0869	0.0000
Original	Whole Estuary	hzoop	~	potam	-0.3063	0.1236	0.0132
Original	Whole Estuary	hzoop	~	flow	-0.0945	0.1164	0.4168
Original	Whole Estuary	hzoop	~	temp	0.0526	0.1111	0.6358
Original	Whole Estuary	pzoop	~	chla	0.6103	0.0891	0.0000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Original	Whole Estuary	pzoop	~	potam	-0.0311	0.0832	0.7087
Original	Whole Estuary	pzoop	~	flow	-0.1998	0.0737	0.0067
Original	Whole Estuary	pzoop	~	hzoop	0.3791	0.0977	0.0001
Original	Whole Estuary	pzoop	~	temp	-0.0708	0.0688	0.3035
Original	Whole Estuary	fish	~	hzoop	0.2993	0.1312	0.0226
Original	Whole Estuary	fish	~	pzoop	0.1534	0.1253	0.2209
Original	Whole Estuary	fish	~	flow	0.1336	0.0849	0.1155
Original	Whole Estuary	fish	~	turbid	0.3977	0.0883	0.0000
Original	Whole Estuary	fish	~	temp	0.0631	0.0799	0.4301
Original	Whole Estuary	fish	~	potam	-0.3214	0.1086	0.0031
Original	Whole Estuary	fish	=~	estfish	0.8945	0.0345	0.0000
Original	Whole Estuary	fish	=~	estfish_stn	0.8767	0.0382	0.0000
Original	Whole Estuary	fish	=~	estfish_bsmt	0.7615	0.0648	0.0000
Original	Whole Estuary	estfish	~~	estfish	0.2000	0.0618	0.0012
Original	Whole Estuary	estfish_stn	~~	estfish_stn	0.2313	0.0670	0.0006
Original	Whole Estuary	estfish_bsmt	~~	estfish_bsmt	0.4201	0.0986	0.0000
Original	Whole Estuary	chla	~~	chla	0.8478	0.1005	0.0000
Original	Whole Estuary	hzoop	~~	hzoop	0.3800	0.0923	0.0000
Original	Whole Estuary	pzoop	~~	pzoop	0.1437	0.0417	0.0006
Original	Whole Estuary	fish	~~	fish	0.0740	0.0453	0.1023
Original	Whole Estuary	potam	~~	potam	1.0000	0.0000	
Original	Whole Estuary	potam	~~	flow	-0.5255	0.0000	
Original	Whole Estuary	potam	~~	temp	0.4520	0.0000	
Original	Whole Estuary	potam	~~	turbid	-0.6302	0.0000	
Original	Whole Estuary	flow	~~	flow	1.0000	0.0000	
Original	Whole Estuary	flow	~~	temp	-0.3772	0.0000	
Original	Whole Estuary	flow	~~	turbid	0.4185	0.0000	
Original	Whole Estuary	temp	~~	temp	1.0000	0.0000	
Original	Whole Estuary	temp	~~	turbid	-0.2278	0.0000	
Original	Whole Estuary	turbid	~~	turbid	1.0000	0.0000	

Table S4. Path coefficients for monthly-regional SEMS. The 'op' column defines the operation between the predictor and response where ~ refers to regression, ~~ refers to covariances, and ~= refers to latent variable manifestations. Covariances between exogenous variables do not have standard errors or p-values.

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	San Pablo	hzoop	~	chla_1	-0.0014	0.0637	0.9825
Upper trophic	San Pablo	hzoop	~	hzoop_1	0.3263	0.0628	0.0000
Upper trophic	San Pablo	hzoop	~	pzoop_1	0.0655	0.0659	0.3206
Upper trophic	San Pablo	hzoop	~	potam_1	-0.2117	0.0633	0.0008
Upper trophic	San Pablo	hzoop	~	estfish_bsmt_1	-0.1755	0.0675	0.0094
Upper trophic	San Pablo	hzoop	~	flow	-0.0197	0.0725	0.7853
Upper trophic	San Pablo	hzoop	~	temp	-0.0759	0.0682	0.2655
Upper trophic	San Pablo	hzoop	~	turbid	0.0360	0.0719	0.6161
Upper trophic	San Pablo	pzoop	~	hzoop_1	0.0540	0.0664	0.4164
Upper trophic	San Pablo	pzoop	~	pzoop_1	0.3476	0.0607	0.0000
Upper trophic	San Pablo	pzoop	~	potam_1	-0.1095	0.0640	0.0872
Upper trophic	San Pablo	pzoop	~	estfish_bsmt_1	-0.0293	0.0684	0.6681
Upper trophic	San Pablo	pzoop	~	flow	0.0756	0.0717	0.2921
Upper trophic	San Pablo	pzoop	~	temp	-0.0185	0.0682	0.7859
Upper trophic	San Pablo	pzoop	~	turbid	0.2150	0.0698	0.0021
Upper trophic	San Pablo	estfish_bsmt	~	hzoop_1	-0.1918	0.0595	0.0013
Upper trophic	San Pablo	estfish_bsmt	~	pzoop_1	0.1280	0.0611	0.0360
Upper trophic	San Pablo	estfish_bsmt	~	estfish_bsmt_1	0.3550	0.0617	0.0000
Upper trophic	San Pablo	estfish_bsmt	~	flow	0.0920	0.0679	0.1755
Upper trophic	San Pablo	estfish_bsmt	~	temp	-0.0319	0.0641	0.6190
Upper trophic	San Pablo	estfish_bsmt	~	turbid	0.2297	0.0660	0.0005
Upper trophic	San Pablo	estfish_bsmt	~	marfish_bsmt_1	0.0012	0.0611	0.9850
Upper trophic	San Pablo	estfish_bsmt	~	sbass1_bsmt_1	-0.0185	0.0651	0.7760
Upper trophic	San Pablo	hzoop	~~	hzoop	0.7540	0.0507	0.0000
Upper trophic	San Pablo	pzoop	~~	pzoop	0.7498	0.0508	0.0000
Upper trophic	San Pablo	estfish_bsmt	~~	estfish_bsmt	0.6412	0.0504	0.0000
Upper trophic	San Pablo	hzoop	~~	pzoop	-0.0424	0.0722	0.5568
Upper trophic	San Pablo	hzoop	~~	estfish_bsmt	-0.0656	0.0720	0.3622
Upper trophic	San Pablo	pzoop	~~	estfish_bsmt	-0.1228	0.0713	0.0849
Upper trophic	San Pablo	chla_1	~~	chla_1	1.0000	0.0000	
Upper trophic	San Pablo	chla_1	~~	hzoop_1	0.1250	0.0000	
Upper trophic	San Pablo	chla_1	~~	pzoop_1	-0.0095	0.0000	
Upper trophic	San Pablo	chla_1	~~	potam_1	0.0308	0.0000	
Upper trophic	San Pablo	chla_1	~~	estfish_bsmt_1	-0.0672	0.0000	
Upper trophic	San Pablo	chla_1	~~	flow	0.0526	0.0000	
Upper trophic	San Pablo	chla_1	~~	temp	0.0224	0.0000	
Upper trophic	San Pablo	chla_1	~~	turbid	-0.0446	0.0000	
Upper trophic	San Pablo	chla_1	~~	marfish_bsmt_1	-0.0197	0.0000	
Upper trophic	San Pablo	chla_1	~~	sbass1_bsmt_1	-0.2022	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	pzoop_1	0.0782	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	potam_1	-0.2007	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	estfish_bsmt_1	-0.2110	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	flow	-0.0200	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	San Pablo	hzoop_1	~~	temp	0.2136	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	turbid	0.0010	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	marfish_bsmt_1	-0.0599	0.0000	
Upper trophic	San Pablo	hzoop_1	~~	sbass1_bsmt_1	-0.1239	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	potam_1	-0.0352	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	estfish_bsmt_1	0.0251	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	flow	0.2441	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	temp	-0.1639	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	turbid	0.1955	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	marfish_bsmt_1	-0.2075	0.0000	
Upper trophic	San Pablo	pzoop_1	~~	sbass1_bsmt_1	0.1433	0.0000	
Upper trophic	San Pablo	potam_1	~~	potam_1	1.0000	0.0000	
Upper trophic	San Pablo	potam_1	~~	estfish_bsmt_1	0.2060	0.0000	
Upper trophic	San Pablo	potam_1	~~	flow	0.0436	0.0000	
Upper trophic	San Pablo	potam_1	~~	temp	-0.0726	0.0000	
Upper trophic	San Pablo	potam_1	~~	turbid	0.0736	0.0000	
Upper trophic	San Pablo	potam_1	~~	marfish_bsmt_1	0.0361	0.0000	
Upper trophic	San Pablo	potam_1	~~	sbass1_bsmt_1	0.1590	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	flow	0.2520	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	temp	-0.2459	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	turbid	0.2012	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	marfish_bsmt_1	0.0840	0.0000	
Upper trophic	San Pablo	estfish_bsmt_1	~~	sbass1_bsmt_1	0.3628	0.0000	
Upper trophic	San Pablo	flow	~~	flow	1.0000	0.0000	
Upper trophic	San Pablo	flow	~~	temp	-0.1859	0.0000	
Upper trophic	San Pablo	flow	~~	turbid	0.4303	0.0000	
Upper trophic	San Pablo	flow	~~	marfish_bsmt_1	-0.2332	0.0000	
Upper trophic	San Pablo	flow	~~	sbass1_bsmt_1	0.1682	0.0000	
Upper trophic	San Pablo	temp	~~	temp	1.0000	0.0000	
Upper trophic	San Pablo	temp	~~	turbid	-0.2611	0.0000	
Upper trophic	San Pablo	temp	~~	marfish_bsmt_1	0.1440	0.0000	
Upper trophic	San Pablo	temp	~~	sbass1_bsmt_1	-0.2778	0.0000	
Upper trophic	San Pablo	turbid	~~	turbid	1.0000	0.0000	
Upper trophic	San Pablo	turbid	~~	marfish_bsmt_1	-0.0830	0.0000	
Upper trophic	San Pablo	turbid	~~	sbass1_bsmt_1	0.3117	0.0000	
Upper trophic	San Pablo	marfish_bsmt_1	~~	marfish_bsmt_1	1.0000	0.0000	
Upper trophic	San Pablo	marfish_bsmt_1	~~	sbass1_bsmt_1	-0.0740	0.0000	
Upper trophic	San Pablo	sbass1_bsmt_1	~~	sbass1_bsmt_1	1.0000	0.0000	
Upper trophic	Suisun	hzoop	~	chla_1	0.0730	0.0613	0.2337
Upper trophic	Suisun	hzoop	~	hzoop_1	0.3490	0.0657	0.0000
Upper trophic	Suisun	hzoop	~	pzoop_1	0.0326	0.0616	0.5964
Upper trophic	Suisun	hzoop	~	potam_1	-0.2160	0.0626	0.0006
Upper trophic	Suisun	hzoop	~	estfish_bsmt_1	-0.0171	0.0597	0.7739
Upper trophic	Suisun	hzoop	~	flow	0.1848	0.0641	0.0039

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	Suisun	hzoop	~	temp	0.0247	0.0598	0.6791
Upper trophic	Suisun	hzoop	~	turbid	-0.1874	0.0618	0.0024
Upper trophic	Suisun	pzoop	~	chla_1	0.1858	0.0595	0.0018
Upper trophic	Suisun	pzoop	~	hzoop_1	0.1121	0.0689	0.1038
Upper trophic	Suisun	pzoop	~	pzoop_1	0.4106	0.0554	0.0000
Upper trophic	Suisun	pzoop	~	potam_1	-0.0852	0.0630	0.1763
Upper trophic	Suisun	pzoop	~	estfish_bsmt_1	0.0339	0.0595	0.5693
Upper trophic	Suisun	pzoop	~	flow	-0.1027	0.0648	0.1128
Upper trophic	Suisun	pzoop	~	temp	0.1897	0.0584	0.0012
Upper trophic	Suisun	pzoop	~	turbid	0.0352	0.0628	0.5748
Upper trophic	Suisun	estfish_bsmt	~	hzoop_1	0.1323	0.0691	0.0556
Upper trophic	Suisun	estfish_bsmt	~	pzoop_1	-0.0767	0.0666	0.2495
Upper trophic	Suisun	estfish_bsmt	~	estfish_bsmt_1	0.1690	0.0684	0.0135
Upper trophic	Suisun	estfish_bsmt	~	flow	-0.2100	0.0687	0.0022
Upper trophic	Suisun	estfish_bsmt	~	temp	0.0172	0.0642	0.7883
Upper trophic	Suisun	estfish_bsmt	~	turbid	0.2322	0.0641	0.0003
Upper trophic	Suisun	estfish_bsmt	~	sbass1_bsmt_1	0.2240	0.0644	0.0005
Upper trophic	Suisun	hzoop	~~	hzoop	0.6686	0.0485	0.0000
Upper trophic	Suisun	pzoop	~~	pzoop	0.6664	0.0484	0.0000
Upper trophic	Suisun	estfish_bsmt	~~	estfish_bsmt	0.7873	0.0471	0.0000
Upper trophic	Suisun	hzoop	~~	pzoop	0.2610	0.0643	0.0000
Upper trophic	Suisun	hzoop	~~	estfish_bsmt	-0.1029	0.0683	0.1318
Upper trophic	Suisun	pzoop	~~	estfish_bsmt	0.1848	0.0667	0.0056
Upper trophic	Suisun	chla_1	~~	chla_1	1.0000	0.0000	
Upper trophic	Suisun	chla_1	~~	hzoop_1	0.3588	0.0000	
Upper trophic	Suisun	chla_1	~~	pzoop_1	0.1026	0.0000	
Upper trophic	Suisun	chla_1	~~	potam_1	-0.0225	0.0000	
Upper trophic	Suisun	chla_1	~~	estfish_bsmt_1	-0.0464	0.0000	
Upper trophic	Suisun	chla_1	~~	flow	0.1857	0.0000	
Upper trophic	Suisun	chla_1	~~	temp	-0.1830	0.0000	
Upper trophic	Suisun	chla_1	~~	turbid	0.0068	0.0000	
Upper trophic	Suisun	chla_1	~~	sbass1_bsmt_1	-0.0850	0.0000	
Upper trophic	Suisun	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Upper trophic	Suisun	hzoop_1	~~	pzoop_1	0.2750	0.0000	
Upper trophic	Suisun	hzoop_1	~~	potam_1	-0.3374	0.0000	
Upper trophic	Suisun	hzoop_1	~~	estfish_bsmt_1	-0.0294	0.0000	
Upper trophic	Suisun	hzoop_1	~~	flow	0.3579	0.0000	
Upper trophic	Suisun	hzoop_1	~~	temp	-0.1467	0.0000	
Upper trophic	Suisun	hzoop_1	~~	turbid	0.1242	0.0000	
Upper trophic	Suisun	hzoop_1	~~	sbass1_bsmt_1	-0.0531	0.0000	
Upper trophic	Suisun	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Upper trophic	Suisun	pzoop_1	~~	potam_1	-0.1338	0.0000	
Upper trophic	Suisun	pzoop_1	~~	estfish_bsmt_1	0.2113	0.0000	
Upper trophic	Suisun	pzoop_1	~~	flow	-0.0472	0.0000	
Upper trophic	Suisun	pzoop_1	~~	temp	0.0876	0.0000	
Upper trophic	Suisun	pzoop_1	~~	turbid	0.0589	0.0000	
Upper trophic	Suisun	pzoop_1	~~	sbass1_bsmt_1	0.0573	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	Suisun	potam_1	~~	potam_1	1.0000	0.0000	
Upper trophic	Suisun	potam_1	~~	estfish_bsmt_1	-0.1251	0.0000	
Upper trophic	Suisun	potam_1	~~	flow	-0.2855	0.0000	
Upper trophic	Suisun	potam_1	~~	temp	0.0481	0.0000	
Upper trophic	Suisun	potam_1	~~	turbid	-0.3259	0.0000	
Upper trophic	Suisun	potam_1	~~	sbass1_bsmt_1	0.0260	0.0000	
Upper trophic	Suisun	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Upper trophic	Suisun	estfish_bsmt_1	~~	flow	-0.1253	0.0000	
Upper trophic	Suisun	estfish_bsmt_1	~~	temp	-0.0436	0.0000	
Upper trophic	Suisun	estfish_bsmt_1	~~	turbid	0.1400	0.0000	
Upper trophic	Suisun	estfish_bsmt_1	~~	sbass1_bsmt_1	0.4133	0.0000	
Upper trophic	Suisun	flow	~~	flow	1.0000	0.0000	
Upper trophic	Suisun	flow	~~	temp	-0.1649	0.0000	
Upper trophic	Suisun	flow	~~	turbid	0.2877	0.0000	
Upper trophic	Suisun	flow	~~	sbass1_bsmt_1	-0.1677	0.0000	
Upper trophic	Suisun	temp	~~	temp	1.0000	0.0000	
Upper trophic	Suisun	temp	~~	turbid	-0.2118	0.0000	
Upper trophic	Suisun	temp	~~	sbass1_bsmt_1	0.0619	0.0000	
Upper trophic	Suisun	turbid	~~	turbid	1.0000	0.0000	
Upper trophic	Suisun	turbid	~~	sbass1_bsmt_1	0.0758	0.0000	
Upper trophic	Suisun	sbass1_bsmt_1	~~	sbass1_bsmt_1	1.0000	0.0000	
Upper trophic	Sacramento	hzoop	~	chla_1	0.0370	0.0665	0.5779
Upper trophic	Sacramento	hzoop	~	hzoop_1	0.2120	0.0672	0.0016
Upper trophic	Sacramento	hzoop	~	pzoop_1	0.0391	0.0719	0.5861
Upper trophic	Sacramento	hzoop	~	corbic_1	0.0047	0.0662	0.9437
Upper trophic	Sacramento	hzoop	~	estfish_bsmt_1	-0.0843	0.0724	0.2443
Upper trophic	Sacramento	hzoop	~	flow	0.2414	0.0731	0.0010
Upper trophic	Sacramento	hzoop	~	temp	0.1107	0.0676	0.1016
Upper trophic	Sacramento	hzoop	~	turbid	0.1847	0.0664	0.0054
Upper trophic	Sacramento	pzoop	~	chla_1	0.2481	0.0568	0.0000
Upper trophic	Sacramento	pzoop	~	hzoop_1	0.1723	0.0602	0.0042
Upper trophic	Sacramento	pzoop	~	pzoop_1	0.2287	0.0620	0.0002
Upper trophic	Sacramento	pzoop	~	corbic_1	0.0304	0.0588	0.6057
Upper trophic	Sacramento	pzoop	~	estfish_bsmt_1	-0.0638	0.0643	0.3213
Upper trophic	Sacramento	pzoop	~	flow	-0.4357	0.0603	0.0000
Upper trophic	Sacramento	pzoop	~	temp	0.0815	0.0602	0.1756
Upper trophic	Sacramento	pzoop	~	turbid	0.0038	0.0602	0.9497
Upper trophic	Sacramento	estfish_bsmt	~	hzoop_1	0.1386	0.0667	0.0376
Upper trophic	Sacramento	estfish_bsmt	~	pzoop_1	0.0111	0.0683	0.8713
Upper trophic	Sacramento	estfish_bsmt	~	estfish_bsmt_1	0.1292	0.0702	0.0658
Upper trophic	Sacramento	estfish_bsmt	~	flow	-0.4352	0.0654	0.0000
Upper trophic	Sacramento	estfish_bsmt	~	temp	-0.0154	0.0647	0.8119
Upper trophic	Sacramento	estfish_bsmt	~	turbid	0.0601	0.0658	0.3614
Upper trophic	Sacramento	estfish_bsmt	~	sside_1	-0.0170	0.0648	0.7927
Upper trophic	Sacramento	estfish_bsmt	~	cent_1	-0.1254	0.0649	0.0534
Upper trophic	Sacramento	estfish_bsmt	~	sbass1_bsmt_1	0.0905	0.0676	0.1807
Upper trophic	Sacramento	hzoop	~~	hzoop	0.8160	0.0480	0.0000
Upper trophic	Sacramento	pzoop	~~	pzoop	0.6415	0.0501	0.0000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	Sacramento	estfish_bsmt	~~	estfish_bsmt	0.7311	0.0508	0.0000
Upper trophic	Sacramento	hzoop	~~	pzoop	0.2483	0.0675	0.0002
Upper trophic	Sacramento	hzoop	~~	estfish_bsmt	-0.0723	0.0716	0.3127
Upper trophic	Sacramento	pzoop	~~	estfish_bsmt	-0.0033	0.0720	0.9636
Upper trophic	Sacramento	chla_1	~~	chla_1	1.0000	0.0000	
Upper trophic	Sacramento	chla_1	~~	hzoop_1	0.1005	0.0000	
Upper trophic	Sacramento	chla_1	~~	pzoop_1	0.0716	0.0000	
Upper trophic	Sacramento	chla_1	~~	corbic_1	-0.0838	0.0000	
Upper trophic	Sacramento	chla_1	~~	estfish_bsmt_1	0.0105	0.0000	
Upper trophic	Sacramento	chla_1	~~	flow	0.1033	0.0000	
Upper trophic	Sacramento	chla_1	~~	temp	-0.0128	0.0000	
Upper trophic	Sacramento	chla_1	~~	turbid	0.1526	0.0000	
Upper trophic	Sacramento	chla_1	~~	sside_1	0.0026	0.0000	
Upper trophic	Sacramento	chla_1	~~	cent_1	0.0007	0.0000	
Upper trophic	Sacramento	chla_1	~~	sbass1_bsmt_1	-0.1068	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	pzoop_1	0.1557	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	corbic_1	-0.0029	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	estfish_bsmt_1	-0.0533	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	flow	0.2366	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	temp	-0.0604	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	turbid	-0.0169	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	sside_1	-0.2478	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	cent_1	-0.0408	0.0000	
Upper trophic	Sacramento	hzoop_1	~~	sbass1_bsmt_1	-0.0608	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	corbic_1	-0.0675	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	estfish_bsmt_1	0.2987	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	flow	-0.2656	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	temp	0.1255	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	turbid	0.0797	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	sside_1	0.0823	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	cent_1	0.0125	0.0000	
Upper trophic	Sacramento	pzoop_1	~~	sbass1_bsmt_1	0.1558	0.0000	
Upper trophic	Sacramento	corbic_1	~~	corbic_1	1.0000	0.0000	
Upper trophic	Sacramento	corbic_1	~~	estfish_bsmt_1	0.0587	0.0000	
Upper trophic	Sacramento	corbic_1	~~	flow	0.0111	0.0000	
Upper trophic	Sacramento	corbic_1	~~	temp	-0.1465	0.0000	
Upper trophic	Sacramento	corbic_1	~~	turbid	-0.0269	0.0000	
Upper trophic	Sacramento	corbic_1	~~	sside_1	-0.0415	0.0000	
Upper trophic	Sacramento	corbic_1	~~	cent_1	-0.1736	0.0000	
Upper trophic	Sacramento	corbic_1	~~	sbass1_bsmt_1	-0.0916	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	flow	-0.3233	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	temp	0.1322	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	turbid	0.1945	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	Sacramento	estfish_bsmt_1	~~	sside_1	0.0015	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	cent_1	-0.1100	0.0000	
Upper trophic	Sacramento	estfish_bsmt_1	~~	sbass1_bsmt_1	0.3098	0.0000	
Upper trophic	Sacramento	flow	~~	flow	1.0000	0.0000	
Upper trophic	Sacramento	flow	~~	temp	-0.2464	0.0000	
Upper trophic	Sacramento	flow	~~	turbid	0.0668	0.0000	
Upper trophic	Sacramento	flow	~~	sside_1	-0.1297	0.0000	
Upper trophic	Sacramento	flow	~~	cent_1	-0.1874	0.0000	
Upper trophic	Sacramento	flow	~~	sbass1_bsmt_1	-0.1226	0.0000	
Upper trophic	Sacramento	temp	~~	temp	1.0000	0.0000	
Upper trophic	Sacramento	temp	~~	turbid	0.0471	0.0000	
Upper trophic	Sacramento	temp	~~	sside_1	0.1189	0.0000	
Upper trophic	Sacramento	temp	~~	cent_1	0.1279	0.0000	
Upper trophic	Sacramento	temp	~~	sbass1_bsmt_1	0.1260	0.0000	
Upper trophic	Sacramento	turbid	~~	turbid	1.0000	0.0000	
Upper trophic	Sacramento	turbid	~~	sside_1	0.0922	0.0000	
Upper trophic	Sacramento	turbid	~~	cent_1	-0.1754	0.0000	
Upper trophic	Sacramento	turbid	~~	sbass1_bsmt_1	0.2705	0.0000	
Upper trophic	Sacramento	sside_1	~~	sside_1	1.0000	0.0000	
Upper trophic	Sacramento	sside_1	~~	cent_1	0.0630	0.0000	
Upper trophic	Sacramento	sside_1	~~	sbass1_bsmt_1	-0.0131	0.0000	
Upper trophic	Sacramento	cent_1	~~	cent_1	1.0000	0.0000	
Upper trophic	Sacramento	cent_1	~~	sbass1_bsmt_1	-0.2034	0.0000	
Upper trophic	Sacramento	sbass1_bsmt_1	~~	sbass1_bsmt_1	1.0000	0.0000	
Upper trophic	San Joaquin	hzoop	~	chla_1	0.2410	0.0649	0.0002
Upper trophic	San Joaquin	hzoop	~	hzoop_1	0.2078	0.0643	0.0012
Upper trophic	San Joaquin	hzoop	~	pzoop_1	-0.0274	0.0700	0.6953
Upper trophic	San Joaquin	hzoop	~	corbic_1	0.0683	0.0650	0.2939
Upper trophic	San Joaquin	hzoop	~	estfish_bsmt_1	0.0033	0.0678	0.9614
Upper trophic	San Joaquin	hzoop	~	flow	0.1946	0.0636	0.0022
Upper trophic	San Joaquin	hzoop	~	temp	0.1687	0.0642	0.0086
Upper trophic	San Joaquin	hzoop	~	turbid	-0.0411	0.0658	0.5323
Upper trophic	San Joaquin	pzoop	~	chla_1	0.2902	0.0579	0.0000
Upper trophic	San Joaquin	pzoop	~	hzoop_1	0.1556	0.0590	0.0083
Upper trophic	San Joaquin	pzoop	~	pzoop_1	0.3172	0.0598	0.0000
Upper trophic	San Joaquin	pzoop	~	corbic_1	-0.0619	0.0580	0.2856
Upper trophic	San Joaquin	pzoop	~	estfish_bsmt_1	0.0168	0.0613	0.7840
Upper trophic	San Joaquin	pzoop	~	flow	-0.1310	0.0585	0.0251
Upper trophic	San Joaquin	pzoop	~	temp	-0.0371	0.0592	0.5306
Upper trophic	San Joaquin	pzoop	~	turbid	0.0993	0.0592	0.0936
Upper trophic	San Joaquin	estfish_bsmt	~	chla_1	0.1388	0.0674	0.0396
Upper trophic	San Joaquin	estfish_bsmt	~	hzoop_1	0.1423	0.0668	0.0331
Upper trophic	San Joaquin	estfish_bsmt	~	pzoop_1	-0.0499	0.0703	0.4780
Upper trophic	San Joaquin	estfish_bsmt	~	estfish_bsmt_1	0.1936	0.0680	0.0044
Upper trophic	San Joaquin	estfish_bsmt	~	flow	-0.0907	0.0664	0.1718
Upper trophic	San Joaquin	estfish_bsmt	~	temp	-0.0278	0.0657	0.6725
Upper trophic	San Joaquin	estfish_bsmt	~	turbid	0.2109	0.0700	0.0026

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	San Joaquin	estfish_bsmt	~	sside_1	0.0556	0.0645	0.3892
Upper trophic	San Joaquin	estfish_bsmt	~	cent_1	-0.0757	0.0696	0.2765
Upper trophic	San Joaquin	estfish_bsmt	~	sbass1_bsmt_1	0.0682	0.0692	0.3241
Upper trophic	San Joaquin	hzoop	~~	hzoop	0.8100	0.0476	0.0000
Upper trophic	San Joaquin	pzoop	~~	pzoop	0.6637	0.0498	0.0000
Upper trophic	San Joaquin	estfish_bsmt	~~	estfish_bsmt	0.8100	0.0476	0.0000
Upper trophic	San Joaquin	hzoop	~~	pzoop	0.1653	0.0690	0.0165
Upper trophic	San Joaquin	hzoop	~~	estfish_bsmt	0.0518	0.0707	0.4634
Upper trophic	San Joaquin	pzoop	~~	estfish_bsmt	0.1910	0.0683	0.0052
Upper trophic	San Joaquin	chla_1	~~	chla_1	1.0000	0.0000	
Upper trophic	San Joaquin	chla_1	~~	hzoop_1	0.1547	0.0000	
Upper trophic	San Joaquin	chla_1	~~	pzoop_1	0.2907	0.0000	
Upper trophic	San Joaquin	chla_1	~~	corbic_1	-0.0521	0.0000	
Upper trophic	San Joaquin	chla_1	~~	estfish_bsmt_1	0.0762	0.0000	
Upper trophic	San Joaquin	chla_1	~~	flow	-0.0635	0.0000	
Upper trophic	San Joaquin	chla_1	~~	temp	0.0846	0.0000	
Upper trophic	San Joaquin	chla_1	~~	turbid	0.0354	0.0000	
Upper trophic	San Joaquin	chla_1	~~	sside_1	0.0746	0.0000	
Upper trophic	San Joaquin	chla_1	~~	cent_1	-0.1588	0.0000	
Upper trophic	San Joaquin	chla_1	~~	sbass1_bsmt_1	-0.0741	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	pzoop_1	0.1908	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	corbic_1	0.0909	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	estfish_bsmt_1	0.0051	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	flow	0.0721	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	temp	0.0453	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	turbid	-0.0432	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	sside_1	-0.0206	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	cent_1	-0.0556	0.0000	
Upper trophic	San Joaquin	hzoop_1	~~	sbass1_bsmt_1	0.1572	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	corbic_1	0.0264	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	estfish_bsmt_1	0.2523	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	flow	-0.0894	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	temp	0.1279	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	turbid	0.0642	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	sside_1	0.1144	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	cent_1	-0.1641	0.0000	
Upper trophic	San Joaquin	pzoop_1	~~	sbass1_bsmt_1	0.0772	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	corbic_1	1.0000	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	estfish_bsmt_1	-0.0338	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	flow	0.0827	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	temp	-0.0791	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	turbid	0.1426	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	sside_1	-0.2038	0.0000	
Upper trophic	San Joaquin	corbic_1	~~	cent_1	-0.1074	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Upper trophic	San Joaquin	corbic_1	~~	sbass1_bsmt_1	0.0590	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	flow	-0.1188	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	temp	0.1746	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	turbid	0.1361	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	sside_1	0.0405	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	cent_1	-0.1975	0.0000	
Upper trophic	San Joaquin	estfish_bsmt_1	~~	sbass1_bsmt_1	0.2177	0.0000	
Upper trophic	San Joaquin	flow	~~	flow	1.0000	0.0000	
Upper trophic	San Joaquin	flow	~~	temp	-0.0496	0.0000	
Upper trophic	San Joaquin	flow	~~	turbid	0.0996	0.0000	
Upper trophic	San Joaquin	flow	~~	sside_1	-0.0093	0.0000	
Upper trophic	San Joaquin	flow	~~	cent_1	0.0875	0.0000	
Upper trophic	San Joaquin	flow	~~	sbass1_bsmt_1	-0.1340	0.0000	
Upper trophic	San Joaquin	temp	~~	temp	1.0000	0.0000	
Upper trophic	San Joaquin	temp	~~	turbid	-0.0262	0.0000	
Upper trophic	San Joaquin	temp	~~	sside_1	0.1052	0.0000	
Upper trophic	San Joaquin	temp	~~	cent_1	-0.0145	0.0000	
Upper trophic	San Joaquin	temp	~~	sbass1_bsmt_1	-0.0369	0.0000	
Upper trophic	San Joaquin	turbid	~~	turbid	1.0000	0.0000	
Upper trophic	San Joaquin	turbid	~~	sside_1	-0.0400	0.0000	
Upper trophic	San Joaquin	turbid	~~	cent_1	-0.3208	0.0000	
Upper trophic	San Joaquin	turbid	~~	sbass1_bsmt_1	0.2649	0.0000	
Upper trophic	San Joaquin	sside_1	~~	sside_1	1.0000	0.0000	
Upper trophic	San Joaquin	sside_1	~~	cent_1	-0.1680	0.0000	
Upper trophic	San Joaquin	sside_1	~~	sbass1_bsmt_1	-0.0004	0.0000	
Upper trophic	San Joaquin	cent_1	~~	cent_1	1.0000	0.0000	
Upper trophic	San Joaquin	cent_1	~~	sbass1_bsmt_1	-0.0534	0.0000	
Upper trophic	San Joaquin	sbass1_bsmt_1	~~	sbass1_bsmt_1	1.0000	0.0000	
Lower trophic	San Pablo	din	~	din_1	0.4014	0.0495	0.0000
Lower trophic	San Pablo	din	~	chla	-0.1986	0.0537	0.0002
Lower trophic	San Pablo	din	~	hzoop_1	0.0553	0.0562	0.3250
Lower trophic	San Pablo	din	~	pzoop_1	-0.0954	0.0561	0.0892
Lower trophic	San Pablo	din	~	potam_1	-0.0176	0.0557	0.7512
Lower trophic	San Pablo	din	~	flow	-0.1759	0.0598	0.0033
Lower trophic	San Pablo	din	~	temp	-0.1217	0.0578	0.0354
Lower trophic	San Pablo	din	~	turbid	0.1304	0.0604	0.0307
Lower trophic	San Pablo	chla	~	din_1	0.0133	0.0666	0.8419
Lower trophic	San Pablo	chla	~	chla_1	0.2602	0.0624	0.0000
Lower trophic	San Pablo	chla	~	hzoop_1	-0.0264	0.0653	0.6856
Lower trophic	San Pablo	chla	~	potam_1	-0.0266	0.0644	0.6794
Lower trophic	San Pablo	chla	~	flow	0.0702	0.0689	0.3088
Lower trophic	San Pablo	chla	~	temp	0.1526	0.0665	0.0217
Lower trophic	San Pablo	chla	~	turbid	-0.0528	0.0701	0.4514
Lower trophic	San Pablo	potam	~	chla_1	0.0572	0.0473	0.2267
Lower trophic	San Pablo	potam	~	hzoop_1	-0.0729	0.0494	0.1399
Lower trophic	San Pablo	potam	~	pzoop_1	-0.1599	0.0486	0.0010

Model	Region	Response	op	Predictor	Effect	se	pvalue
Lower trophic	San Pablo	potam	~	potam_1	0.6291	0.0351	0.0000
Lower trophic	San Pablo	potam	~	flow	0.1029	0.0519	0.0473
Lower trophic	San Pablo	potam	~	temp	-0.0391	0.0505	0.4388
Lower trophic	San Pablo	potam	~	turbid	0.0335	0.0528	0.5256
Lower trophic	San Pablo	din	~~	din	0.6798	0.0469	0.0000
Lower trophic	San Pablo	chla	~~	chla	0.9113	0.0347	0.0000
Lower trophic	San Pablo	potam	~~	potam	0.5173	0.0409	0.0000
Lower trophic	San Pablo	din	~~	potam	-0.0959	0.0648	0.1389
Lower trophic	San Pablo	din_1	~~	din_1	1.0000	0.0000	
Lower trophic	San Pablo	din_1	~~	hzoop_1	0.0289	0.0000	
Lower trophic	San Pablo	din_1	~~	pzoop_1	-0.0128	0.0000	
Lower trophic	San Pablo	din_1	~~	potam_1	-0.0974	0.0000	
Lower trophic	San Pablo	din_1	~~	flow	-0.1323	0.0000	
Lower trophic	San Pablo	din_1	~~	temp	-0.1013	0.0000	
Lower trophic	San Pablo	din_1	~~	turbid	0.0761	0.0000	
Lower trophic	San Pablo	din_1	~~	chla_1	-0.2496	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	pzoop_1	0.0985	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	potam_1	-0.2169	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	flow	-0.0351	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	temp	0.1631	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	turbid	-0.0017	0.0000	
Lower trophic	San Pablo	hzoop_1	~~	chla_1	0.0987	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	potam_1	-0.0382	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	flow	0.2448	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	temp	-0.1293	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	turbid	0.1805	0.0000	
Lower trophic	San Pablo	pzoop_1	~~	chla_1	-0.0459	0.0000	
Lower trophic	San Pablo	potam_1	~~	potam_1	1.0000	0.0000	
Lower trophic	San Pablo	potam_1	~~	flow	0.0657	0.0000	
Lower trophic	San Pablo	potam_1	~~	temp	-0.0699	0.0000	
Lower trophic	San Pablo	potam_1	~~	turbid	0.0556	0.0000	
Lower trophic	San Pablo	potam_1	~~	chla_1	0.0048	0.0000	
Lower trophic	San Pablo	flow	~~	flow	1.0000	0.0000	
Lower trophic	San Pablo	flow	~~	temp	-0.1939	0.0000	
Lower trophic	San Pablo	flow	~~	turbid	0.3840	0.0000	
Lower trophic	San Pablo	flow	~~	chla_1	0.0009	0.0000	
Lower trophic	San Pablo	temp	~~	temp	1.0000	0.0000	
Lower trophic	San Pablo	temp	~~	turbid	-0.2925	0.0000	
Lower trophic	San Pablo	temp	~~	chla_1	-0.0679	0.0000	
Lower trophic	San Pablo	turbid	~~	turbid	1.0000	0.0000	
Lower trophic	San Pablo	turbid	~~	chla_1	-0.0347	0.0000	
Lower trophic	San Pablo	chla_1	~~	chla_1	1.0000	0.0000	
Lower trophic	Suisun	din	~	din_1	0.4433	0.0422	0.0000
Lower trophic	Suisun	din	~	chla	-0.1291	0.0401	0.0013

Model	Region	Response	op	Predictor	Effect	se	pvalue
Lower trophic	Suisun	din	~	hzoop_1	-0.0045	0.0460	0.9223
Lower trophic	Suisun	din	~	pzoop_1	0.0345	0.0418	0.4094
Lower trophic	Suisun	din	~	potam_1	0.0383	0.0447	0.3910
Lower trophic	Suisun	din	~	flow	-0.4247	0.0427	0.0000
Lower trophic	Suisun	din	~	temp	0.0375	0.0402	0.3509
Lower trophic	Suisun	din	~	turbid	0.1189	0.0428	0.0055
Lower trophic	Suisun	chla	~	din_1	-0.1259	0.0712	0.0771
Lower trophic	Suisun	chla	~	chla_1	0.1496	0.0647	0.0207
Lower trophic	Suisun	chla	~	hzoop_1	0.0701	0.0683	0.3048
Lower trophic	Suisun	chla	~	potam_1	0.0138	0.0691	0.8416
Lower trophic	Suisun	chla	~	flow	0.0775	0.0703	0.2704
Lower trophic	Suisun	chla	~	temp	-0.0637	0.0616	0.3014
Lower trophic	Suisun	chla	~	turbid	-0.0247	0.0664	0.7102
Lower trophic	Suisun	potam	~	din_1	0.0136	0.0451	0.7630
Lower trophic	Suisun	potam	~	chla_1	-0.0267	0.0412	0.5170
Lower trophic	Suisun	potam	~	hzoop_1	-0.0061	0.0456	0.8933
Lower trophic	Suisun	potam	~	pzoop_1	0.0724	0.0405	0.0735
Lower trophic	Suisun	potam	~	potam_1	0.7188	0.0323	0.0000
Lower trophic	Suisun	potam	~	flow	-0.1237	0.0443	0.0052
Lower trophic	Suisun	potam	~	temp	-0.0074	0.0391	0.8492
Lower trophic	Suisun	potam	~	turbid	-0.0762	0.0416	0.0667
Lower trophic	Suisun	din	~~	din	0.3799	0.0313	0.0000
Lower trophic	Suisun	chla	~~	chla	0.9021	0.0343	0.0000
Lower trophic	Suisun	potam	~~	potam	0.3551	0.0293	0.0000
Lower trophic	Suisun	din	~~	potam	0.0275	0.0623	0.6592
Lower trophic	Suisun	din_1	~~	din_1	1.0000	0.0000	
Lower trophic	Suisun	din_1	~~	hzoop_1	-0.3554	0.0000	
Lower trophic	Suisun	din_1	~~	pzoop_1	-0.0250	0.0000	
Lower trophic	Suisun	din_1	~~	potam_1	0.3039	0.0000	
Lower trophic	Suisun	din_1	~~	flow	-0.4524	0.0000	
Lower trophic	Suisun	din_1	~~	temp	0.1385	0.0000	
Lower trophic	Suisun	din_1	~~	turbid	-0.0792	0.0000	
Lower trophic	Suisun	din_1	~~	chla_1	-0.3110	0.0000	
Lower trophic	Suisun	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Lower trophic	Suisun	hzoop_1	~~	pzoop_1	0.3412	0.0000	
Lower trophic	Suisun	hzoop_1	~~	potam_1	-0.3143	0.0000	
Lower trophic	Suisun	hzoop_1	~~	flow	0.2977	0.0000	
Lower trophic	Suisun	hzoop_1	~~	temp	-0.1169	0.0000	
Lower trophic	Suisun	hzoop_1	~~	turbid	0.0996	0.0000	
Lower trophic	Suisun	hzoop_1	~~	chla_1	0.3444	0.0000	
Lower trophic	Suisun	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Lower trophic	Suisun	pzoop_1	~~	potam_1	-0.1232	0.0000	
Lower trophic	Suisun	pzoop_1	~~	flow	-0.0380	0.0000	
Lower trophic	Suisun	pzoop_1	~~	temp	0.0919	0.0000	
Lower trophic	Suisun	pzoop_1	~~	turbid	0.0002	0.0000	
Lower trophic	Suisun	pzoop_1	~~	chla_1	0.1449	0.0000	
Lower trophic	Suisun	potam_1	~~	potam_1	1.0000	0.0000	
Lower trophic	Suisun	potam_1	~~	flow	-0.3155	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Lower trophic	Suisun	potam_1	~~	temp	0.0303	0.0000	
Lower trophic	Suisun	potam_1	~~	turbid	-0.3586	0.0000	
Lower trophic	Suisun	potam_1	~~	chla_1	-0.0484	0.0000	
Lower trophic	Suisun	flow	~~	flow	1.0000	0.0000	
Lower trophic	Suisun	flow	~~	temp	-0.1557	0.0000	
Lower trophic	Suisun	flow	~~	turbid	0.2880	0.0000	
Lower trophic	Suisun	flow	~~	chla_1	0.1492	0.0000	
Lower trophic	Suisun	temp	~~	temp	1.0000	0.0000	
Lower trophic	Suisun	temp	~~	turbid	-0.1897	0.0000	
Lower trophic	Suisun	temp	~~	chla_1	-0.1651	0.0000	
Lower trophic	Suisun	turbid	~~	turbid	1.0000	0.0000	
Lower trophic	Suisun	turbid	~~	chla_1	-0.0119	0.0000	
Lower trophic	Suisun	chla_1	~~	chla_1	1.0000	0.0000	
Lower trophic	Sacramento	din	~	din_1	0.4119	0.0420	0.0000
Lower trophic	Sacramento	din	~	chla	-0.1708	0.0382	0.0000
Lower trophic	Sacramento	din	~	hzoop_1	0.0712	0.0388	0.0665
Lower trophic	Sacramento	din	~	pzoop_1	0.0601	0.0407	0.1394
Lower trophic	Sacramento	din	~	corbic_1	-0.0351	0.0378	0.3527
Lower trophic	Sacramento	din	~	flow	-0.4578	0.0398	0.0000
Lower trophic	Sacramento	din	~	temp	0.0425	0.0384	0.2681
Lower trophic	Sacramento	din	~	turbid	0.0946	0.0378	0.0124
Lower trophic	Sacramento	chla	~	din_1	-0.1602	0.0742	0.0309
Lower trophic	Sacramento	chla	~	chla_1	0.1865	0.0618	0.0025
Lower trophic	Sacramento	chla	~	hzoop_1	-0.0880	0.0622	0.1574
Lower trophic	Sacramento	chla	~	corbic_1	-0.0170	0.0613	0.7812
Lower trophic	Sacramento	chla	~	pzoop_1	-0.0961	0.0665	0.1486
Lower trophic	Sacramento	chla	~	flow	-0.0676	0.0702	0.3353
Lower trophic	Sacramento	chla	~	temp	0.1359	0.0608	0.0254
Lower trophic	Sacramento	chla	~	turbid	0.1277	0.0605	0.0348
Lower trophic	Sacramento	corbic	~	chla_1	0.0443	0.0545	0.4159
Lower trophic	Sacramento	corbic	~	hzoop_1	0.0099	0.0565	0.8610
Lower trophic	Sacramento	corbic	~	pzoop_1	-0.0154	0.0582	0.7913
Lower trophic	Sacramento	corbic	~	corbic_1	0.4627	0.0470	0.0000
Lower trophic	Sacramento	corbic	~	flow	0.0893	0.0589	0.1296
Lower trophic	Sacramento	corbic	~	temp	-0.0331	0.0561	0.5544
Lower trophic	Sacramento	corbic	~	turbid	-0.1241	0.0541	0.0217
Lower trophic	Sacramento	din	~~	din	0.3407	0.0289	0.0000
Lower trophic	Sacramento	chla	~~	chla	0.8883	0.0361	0.0000
Lower trophic	Sacramento	corbic	~~	corbic	0.7378	0.0441	0.0000
Lower trophic	Sacramento	din	~~	corbic	0.0005	0.0626	0.9938
Lower trophic	Sacramento	din_1	~~	din_1	1.0000	0.0000	
Lower trophic	Sacramento	din_1	~~	hzoop_1	-0.1732	0.0000	
Lower trophic	Sacramento	din_1	~~	pzoop_1	0.3422	0.0000	
Lower trophic	Sacramento	din_1	~~	corbic_1	-0.1725	0.0000	
Lower trophic	Sacramento	din_1	~~	flow	-0.4620	0.0000	
Lower trophic	Sacramento	din_1	~~	temp	0.1502	0.0000	
Lower trophic	Sacramento	din_1	~~	turbid	0.1484	0.0000	
Lower trophic	Sacramento	din_1	~~	chla_1	-0.2353	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Lower trophic	Sacramento	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	pzoop_1	0.1286	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	corbic_1	-0.0030	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	flow	0.2229	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	temp	-0.0223	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	turbid	-0.0495	0.0000	
Lower trophic	Sacramento	hzoop_1	~~	chla_1	0.0490	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	corbic_1	-0.1373	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	flow	-0.2681	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	temp	0.1706	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	turbid	0.0537	0.0000	
Lower trophic	Sacramento	pzoop_1	~~	chla_1	0.1070	0.0000	
Lower trophic	Sacramento	corbic_1	~~	corbic_1	1.0000	0.0000	
Lower trophic	Sacramento	corbic_1	~~	flow	0.0611	0.0000	
Lower trophic	Sacramento	corbic_1	~~	temp	-0.1698	0.0000	
Lower trophic	Sacramento	corbic_1	~~	turbid	-0.1016	0.0000	
Lower trophic	Sacramento	corbic_1	~~	chla_1	-0.0802	0.0000	
Lower trophic	Sacramento	flow	~~	flow	1.0000	0.0000	
Lower trophic	Sacramento	flow	~~	temp	-0.2116	0.0000	
Lower trophic	Sacramento	flow	~~	turbid	0.0625	0.0000	
Lower trophic	Sacramento	flow	~~	chla_1	0.0419	0.0000	
Lower trophic	Sacramento	temp	~~	temp	1.0000	0.0000	
Lower trophic	Sacramento	temp	~~	turbid	-0.0032	0.0000	
Lower trophic	Sacramento	temp	~~	chla_1	-0.0133	0.0000	
Lower trophic	Sacramento	turbid	~~	turbid	1.0000	0.0000	
Lower trophic	Sacramento	turbid	~~	chla_1	0.0913	0.0000	
Lower trophic	Sacramento	chla_1	~~	chla_1	1.0000	0.0000	
Lower trophic	San Joaquin	din	~	din_1	0.4074	0.0509	0.0000
Lower trophic	San Joaquin	din	~	chla	-0.1432	0.0514	0.0054
Lower trophic	San Joaquin	din	~	hzoop_1	-0.0149	0.0525	0.7763
Lower trophic	San Joaquin	din	~	pzoop_1	0.1161	0.0521	0.0259
Lower trophic	San Joaquin	din	~	corbic_1	0.0471	0.0522	0.3669
Lower trophic	San Joaquin	din	~	flow	-0.0499	0.0522	0.3385
Lower trophic	San Joaquin	din	~	temp	0.0530	0.0514	0.3025
Lower trophic	San Joaquin	din	~	turbid	0.2476	0.0554	0.0000
Lower trophic	San Joaquin	chla	~	din_1	0.1032	0.0642	0.1080
Lower trophic	San Joaquin	chla	~	chla_1	0.3312	0.0555	0.0000
Lower trophic	San Joaquin	chla	~	hzoop_1	0.0543	0.0598	0.3634
Lower trophic	San Joaquin	chla	~	corbic_1	0.0973	0.0593	0.1005
Lower trophic	San Joaquin	chla	~	flow	-0.1003	0.0591	0.0897
Lower trophic	San Joaquin	chla	~	temp	0.0180	0.0582	0.7570
Lower trophic	San Joaquin	chla	~	turbid	-0.0260	0.0660	0.6938
Lower trophic	San Joaquin	corbic	~	chla_1	0.0614	0.0588	0.2968
Lower trophic	San Joaquin	corbic	~	hzoop_1	-0.0238	0.0589	0.6866
Lower trophic	San Joaquin	corbic	~	pzoop_1	-0.0414	0.0594	0.4861
Lower trophic	San Joaquin	corbic	~	corbic_1	0.3178	0.0541	0.0000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Lower trophic	San Joaquin	corbic	~	flow	0.0811	0.0574	0.1577
Lower trophic	San Joaquin	corbic	~	temp	-0.0777	0.0571	0.1738
Lower trophic	San Joaquin	corbic	~	turbid	0.1846	0.0567	0.0011
Lower trophic	San Joaquin	din	~~	din	0.6504	0.0441	0.0000
Lower trophic	San Joaquin	chla	~~	chla	0.8517	0.0395	0.0000
Lower trophic	San Joaquin	corbic	~~	corbic	0.8078	0.0421	0.0000
Lower trophic	San Joaquin	din	~~	corbic	-0.0251	0.0625	0.6877
Lower trophic	San Joaquin	din_1	~~	din_1	1.0000	0.0000	
Lower trophic	San Joaquin	din_1	~~	hzoop_1	0.0278	0.0000	
Lower trophic	San Joaquin	din_1	~~	pzoop_1	0.0681	0.0000	
Lower trophic	San Joaquin	din_1	~~	corbic_1	0.0697	0.0000	
Lower trophic	San Joaquin	din_1	~~	flow	-0.0593	0.0000	
Lower trophic	San Joaquin	din_1	~~	temp	0.0016	0.0000	
Lower trophic	San Joaquin	din_1	~~	turbid	0.4203	0.0000	
Lower trophic	San Joaquin	din_1	~~	chla_1	-0.0661	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	hzoop_1	1.0000	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	pzoop_1	0.1941	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	corbic_1	0.0744	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	flow	0.1288	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	temp	0.0587	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	turbid	-0.0164	0.0000	
Lower trophic	San Joaquin	hzoop_1	~~	chla_1	0.1911	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	pzoop_1	1.0000	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	corbic_1	-0.0063	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	flow	-0.0671	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	temp	0.1698	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	turbid	0.0369	0.0000	
Lower trophic	San Joaquin	pzoop_1	~~	chla_1	0.2365	0.0000	
Lower trophic	San Joaquin	corbic_1	~~	corbic_1	1.0000	0.0000	
Lower trophic	San Joaquin	corbic_1	~~	flow	0.1161	0.0000	
Lower trophic	San Joaquin	corbic_1	~~	temp	-0.0887	0.0000	
Lower trophic	San Joaquin	corbic_1	~~	turbid	0.2097	0.0000	
Lower trophic	San Joaquin	corbic_1	~~	chla_1	-0.0004	0.0000	
Lower trophic	San Joaquin	flow	~~	flow	1.0000	0.0000	
Lower trophic	San Joaquin	flow	~~	temp	-0.0281	0.0000	
Lower trophic	San Joaquin	flow	~~	turbid	0.0829	0.0000	
Lower trophic	San Joaquin	flow	~~	chla_1	-0.0816	0.0000	
Lower trophic	San Joaquin	temp	~~	temp	1.0000	0.0000	
Lower trophic	San Joaquin	temp	~~	turbid	-0.0694	0.0000	
Lower trophic	San Joaquin	temp	~~	chla_1	0.0675	0.0000	
Lower trophic	San Joaquin	turbid	~~	turbid	1.0000	0.0000	
Lower trophic	San Joaquin	turbid	~~	chla_1	0.0734	0.0000	
Lower trophic	San Joaquin	chla_1	~~	chla_1	1.0000	0.0000	
Zooplankton	San Pablo	chla	~	chla_1	0.2043	0.0676	0.0025
Zooplankton	San Pablo	chla	~	hcope_1	0.0757	0.0697	0.2774
Zooplankton	San Pablo	chla	~	amphi_1	0.0294	0.0851	0.7303

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Pablo	chla	~	rotif_1	-0.0781	0.0730	0.2845
Zooplankton	San Pablo	chla	~	potam_1	-0.0063	0.0695	0.9277
Zooplankton	San Pablo	chla	~	flow	0.1414	0.0854	0.0977
Zooplankton	San Pablo	chla	~	turbid	-0.0901	0.0780	0.2482
Zooplankton	San Pablo	chla	~	temp	0.1580	0.0708	0.0256
Zooplankton	San Pablo	hcope	~	chla_1	0.0716	0.0655	0.2740
Zooplankton	San Pablo	hcope	~	hcope_1	0.2357	0.0683	0.0006
Zooplankton	San Pablo	hcope	~	pcope_1	0.0664	0.0697	0.3409
Zooplankton	San Pablo	hcope	~	potam_1	-0.1573	0.0678	0.0203
Zooplankton	San Pablo	hcope	~	flow	-0.0668	0.0768	0.3847
Zooplankton	San Pablo	hcope	~	turbid	-0.0161	0.0751	0.8304
Zooplankton	San Pablo	hcope	~	temp	-0.0505	0.0707	0.4750
Zooplankton	San Pablo	hcope	~	estfish_bsmt_1	-0.1302	0.0738	0.0777
Zooplankton	San Pablo	amphi	~	chla_1	0.0444	0.0322	0.1678
Zooplankton	San Pablo	amphi	~	amphi_1	0.7441	0.0295	0.0000
Zooplankton	San Pablo	amphi	~	flow	-0.2492	0.0393	0.0000
Zooplankton	San Pablo	amphi	~	turbid	-0.0106	0.0360	0.7673
Zooplankton	San Pablo	amphi	~	temp	0.0128	0.0336	0.7036
Zooplankton	San Pablo	amphi	~	estfish_bsmt_1	0.0418	0.0342	0.2211
Zooplankton	San Pablo	rotif	~	chla_1	-0.1723	0.0641	0.0072
Zooplankton	San Pablo	rotif	~	rotif_1	0.3775	0.0592	0.0000
Zooplankton	San Pablo	rotif	~	flow	0.1032	0.0746	0.1666
Zooplankton	San Pablo	rotif	~	turbid	0.0085	0.0733	0.9080
Zooplankton	San Pablo	rotif	~	temp	0.0551	0.0685	0.4210
Zooplankton	San Pablo	rotif	~	estfish_bsmt_1	0.0085	0.0688	0.9015
Zooplankton	San Pablo	pcope	~	hcope_1	0.0459	0.0683	0.5021
Zooplankton	San Pablo	pcope	~	pcope_1	0.3014	0.0638	0.0000
Zooplankton	San Pablo	pcope	~	potam_1	-0.1053	0.0662	0.1119
Zooplankton	San Pablo	pcope	~	flow	0.2014	0.0728	0.0056
Zooplankton	San Pablo	pcope	~	turbid	0.0808	0.0723	0.2635
Zooplankton	San Pablo	pcope	~	temp	0.1521	0.0677	0.0247
Zooplankton	San Pablo	pcope	~	estfish_bsmt_1	-0.0076	0.0722	0.9162
Zooplankton	San Pablo	chla	~~	chla	0.8987	0.0402	0.0000
Zooplankton	San Pablo	hcope	~~	hcope	0.8518	0.0455	0.0000
Zooplankton	San Pablo	amphi	~~	amphi	0.1932	0.0193	0.0000
Zooplankton	San Pablo	rotif	~~	rotif	0.8074	0.0484	0.0000
Zooplankton	San Pablo	pcope	~~	pcope	0.8022	0.0488	0.0000
Zooplankton	San Pablo	chla	~~	hcope	0.0567	0.0719	0.4302
Zooplankton	San Pablo	chla	~~	amphi	0.0509	0.0720	0.4791
Zooplankton	San Pablo	chla	~~	rotif	0.1034	0.0714	0.1477
Zooplankton	San Pablo	chla	~~	pcope	-0.0190	0.0721	0.7928
Zooplankton	San Pablo	hcope	~~	amphi	-0.0262	0.0721	0.7162
Zooplankton	San Pablo	hcope	~~	rotif	0.0404	0.0721	0.5752
Zooplankton	San Pablo	hcope	~~	pcope	-0.2385	0.0681	0.0005
Zooplankton	San Pablo	amphi	~~	rotif	-0.0812	0.0717	0.2573
Zooplankton	San Pablo	amphi	~~	pcope	-0.0215	0.0721	0.7655
Zooplankton	San Pablo	rotif	~~	pcope	0.0677	0.0718	0.3459
Zooplankton	San Pablo	chla_1	~~	chla_1	1.0000	0.0000	
Zooplankton	San Pablo	chla_1	~~	hcope_1	0.0931	0.0000	
Zooplankton	San Pablo	chla_1	~~	amphi_1	0.0826	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Pablo	chla_1	~~	rotif_1	0.0275	0.0000	
Zooplankton	San Pablo	chla_1	~~	potam_1	0.0189	0.0000	
Zooplankton	San Pablo	chla_1	~~	flow	0.0450	0.0000	
Zooplankton	San Pablo	chla_1	~~	turbid	-0.0746	0.0000	
Zooplankton	San Pablo	chla_1	~~	temp	0.0209	0.0000	
Zooplankton	San Pablo	chla_1	~~	pcope_1	0.0158	0.0000	
Zooplankton	San Pablo	chla_1	~~	estfish_bsmt_1	-0.0947	0.0000	
Zooplankton	San Pablo	hcope_1	~~	hcope_1	1.0000	0.0000	
Zooplankton	San Pablo	hcope_1	~~	amphi_1	0.0954	0.0000	
Zooplankton	San Pablo	hcope_1	~~	rotif_1	0.0683	0.0000	
Zooplankton	San Pablo	hcope_1	~~	potam_1	-0.1153	0.0000	
Zooplankton	San Pablo	hcope_1	~~	flow	-0.0409	0.0000	
Zooplankton	San Pablo	hcope_1	~~	turbid	-0.0195	0.0000	
Zooplankton	San Pablo	hcope_1	~~	temp	0.1573	0.0000	
Zooplankton	San Pablo	hcope_1	~~	pcope_1	-0.1426	0.0000	
Zooplankton	San Pablo	hcope_1	~~	estfish_bsmt_1	-0.2515	0.0000	
Zooplankton	San Pablo	amphi_1	~~	amphi_1	1.0000	0.0000	
Zooplankton	San Pablo	amphi_1	~~	rotif_1	-0.2845	0.0000	
Zooplankton	San Pablo	amphi_1	~~	potam_1	-0.0711	0.0000	
Zooplankton	San Pablo	amphi_1	~~	flow	-0.5277	0.0000	
Zooplankton	San Pablo	amphi_1	~~	turbid	-0.3219	0.0000	
Zooplankton	San Pablo	amphi_1	~~	temp	0.0788	0.0000	
Zooplankton	San Pablo	amphi_1	~~	pcope_1	-0.2108	0.0000	
Zooplankton	San Pablo	amphi_1	~~	estfish_bsmt_1	-0.2771	0.0000	
Zooplankton	San Pablo	rotif_1	~~	rotif_1	1.0000	0.0000	
Zooplankton	San Pablo	rotif_1	~~	potam_1	-0.1383	0.0000	
Zooplankton	San Pablo	rotif_1	~~	flow	0.1417	0.0000	
Zooplankton	San Pablo	rotif_1	~~	turbid	-0.0376	0.0000	
Zooplankton	San Pablo	rotif_1	~~	temp	0.0637	0.0000	
Zooplankton	San Pablo	rotif_1	~~	pcope_1	0.1840	0.0000	
Zooplankton	San Pablo	rotif_1	~~	estfish_bsmt_1	-0.0426	0.0000	
Zooplankton	San Pablo	potam_1	~~	potam_1	1.0000	0.0000	
Zooplankton	San Pablo	potam_1	~~	flow	0.0482	0.0000	
Zooplankton	San Pablo	potam_1	~~	turbid	0.0636	0.0000	
Zooplankton	San Pablo	potam_1	~~	temp	-0.0710	0.0000	
Zooplankton	San Pablo	potam_1	~~	pcope_1	-0.1363	0.0000	
Zooplankton	San Pablo	potam_1	~~	estfish_bsmt_1	0.2039	0.0000	
Zooplankton	San Pablo	flow	~~	flow	1.0000	0.0000	
Zooplankton	San Pablo	flow	~~	turbid	0.4229	0.0000	
Zooplankton	San Pablo	flow	~~	temp	-0.1983	0.0000	
Zooplankton	San Pablo	flow	~~	pcope_1	0.1709	0.0000	
Zooplankton	San Pablo	flow	~~	estfish_bsmt_1	0.2587	0.0000	
Zooplankton	San Pablo	turbid	~~	turbid	1.0000	0.0000	
Zooplankton	San Pablo	turbid	~~	temp	-0.2356	0.0000	
Zooplankton	San Pablo	turbid	~~	pcope_1	0.0777	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Pablo	turbid	~~	estfish_bsmt_1	0.1749	0.0000	
Zooplankton	San Pablo	temp	~~	temp	1.0000	0.0000	
Zooplankton	San Pablo	temp	~~	pcope_1	-0.0394	0.0000	
Zooplankton	San Pablo	temp	~~	estfish_bsmt_1	-0.2456	0.0000	
Zooplankton	San Pablo	pcope_1	~~	pcope_1	1.0000	0.0000	
Zooplankton	San Pablo	pcope_1	~~	estfish_bsmt_1	-0.0871	0.0000	
Zooplankton	San Pablo	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Zooplankton	Suisun	chla	~	chla_1	0.1474	0.0684	0.0312
Zooplankton	Suisun	chla	~	hcope_1	0.0711	0.0698	0.3083
Zooplankton	Suisun	chla	~	amphi_1	0.1379	0.0697	0.0480
Zooplankton	Suisun	chla	~	rotif_1	0.1108	0.0679	0.1024
Zooplankton	Suisun	chla	~	potam_1	-0.0505	0.0737	0.4934
Zooplankton	Suisun	chla	~	flow	0.0826	0.0719	0.2505
Zooplankton	Suisun	chla	~	turbid	0.0694	0.0741	0.3487
Zooplankton	Suisun	chla	~	temp	-0.1051	0.0657	0.1097
Zooplankton	Suisun	chla	~	mysid_1	-0.1691	0.0696	0.0151
Zooplankton	Suisun	hcope	~	chla_1	0.0408	0.0656	0.5339
Zooplankton	Suisun	hcope	~	hcope_1	0.3078	0.0650	0.0000
Zooplankton	Suisun	hcope	~	pcope_1	-0.1045	0.0639	0.1019
Zooplankton	Suisun	hcope	~	mysid_1	0.0493	0.0708	0.4858
Zooplankton	Suisun	hcope	~	potam_1	-0.1706	0.0668	0.0107
Zooplankton	Suisun	hcope	~	flow	-0.1349	0.0693	0.0518
Zooplankton	Suisun	hcope	~	turbid	-0.1192	0.0708	0.0926
Zooplankton	Suisun	hcope	~	temp	0.0647	0.0639	0.3109
Zooplankton	Suisun	hcope	~	estfish_bsmt_1	0.0502	0.0633	0.4277
Zooplankton	Suisun	hcope	~	rotif_1	0.1916	0.0634	0.0025
Zooplankton	Suisun	amphi	~	chla_1	-0.0427	0.0357	0.2310
Zooplankton	Suisun	amphi	~	amphi_1	0.7866	0.0263	0.0000
Zooplankton	Suisun	amphi	~	mysid_1	0.0765	0.0366	0.0366
Zooplankton	Suisun	amphi	~	flow	0.0076	0.0371	0.8368
Zooplankton	Suisun	amphi	~	turbid	-0.1031	0.0387	0.0078
Zooplankton	Suisun	amphi	~	temp	-0.0998	0.0355	0.0049
Zooplankton	Suisun	amphi	~	estfish_bsmt_1	-0.1761	0.0363	0.0000
Zooplankton	Suisun	rotif	~	chla_1	0.0193	0.0618	0.7554
Zooplankton	Suisun	rotif	~	rotif_1	0.3346	0.0585	0.0000
Zooplankton	Suisun	rotif	~	flow	0.2159	0.0631	0.0006
Zooplankton	Suisun	rotif	~	turbid	-0.0960	0.0636	0.1313
Zooplankton	Suisun	rotif	~	temp	0.0275	0.0610	0.6518
Zooplankton	Suisun	rotif	~	estfish_bsmt_1	-0.1808	0.0580	0.0018
Zooplankton	Suisun	pcope	~	hcope_1	-0.1253	0.0572	0.0285
Zooplankton	Suisun	pcope	~	pcope_1	0.4045	0.0515	0.0000
Zooplankton	Suisun	pcope	~	mysid_1	0.1146	0.0610	0.0604
Zooplankton	Suisun	pcope	~	potam_1	0.0459	0.0604	0.4468
Zooplankton	Suisun	pcope	~	flow	0.1307	0.0599	0.0291
Zooplankton	Suisun	pcope	~	turbid	-0.1378	0.0614	0.0248
Zooplankton	Suisun	pcope	~	temp	0.2276	0.0533	0.0000
Zooplankton	Suisun	pcope	~	estfish_bsmt_1	0.0262	0.0564	0.6422
Zooplankton	Suisun	pcope	~	rotif_1	0.1692	0.0557	0.0024
Zooplankton	Suisun	mysid	~	chla_1	0.1795	0.0569	0.0016

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Suisun	mysid	~	hcope_1	0.0695	0.0594	0.2422
Zooplankton	Suisun	mysid	~	pcope_1	0.1138	0.0561	0.0427
Zooplankton	Suisun	mysid	~	amphi_1	-0.1320	0.0589	0.0249
Zooplankton	Suisun	mysid	~	mysid_1	0.3722	0.0583	0.0000
Zooplankton	Suisun	mysid	~	flow	-0.1675	0.0581	0.0039
Zooplankton	Suisun	mysid	~	turbid	0.2577	0.0612	0.0000
Zooplankton	Suisun	mysid	~	temp	0.1020	0.0564	0.0702
Zooplankton	Suisun	mysid	~	estfish_bsmt_1	-0.0265	0.0581	0.6485
Zooplankton	Suisun	chla	~~	chla	0.8525	0.0427	0.0000
Zooplankton	Suisun	hcope	~~	hcope	0.7913	0.0460	0.0000
Zooplankton	Suisun	amphi	~~	amphi	0.2487	0.0231	0.0000
Zooplankton	Suisun	rotif	~~	rotif	0.7361	0.0479	0.0000
Zooplankton	Suisun	pcope	~~	pcope	0.5993	0.0459	0.0000
Zooplankton	Suisun	mysid	~~	mysid	0.6220	0.0469	0.0000
Zooplankton	Suisun	chla	~~	hcope	0.2176	0.0650	0.0008
Zooplankton	Suisun	chla	~~	amphi	-0.0149	0.0682	0.8265
Zooplankton	Suisun	chla	~~	rotif	0.1833	0.0659	0.0054
Zooplankton	Suisun	chla	~~	pcope	0.0220	0.0682	0.7464
Zooplankton	Suisun	chla	~~	mysid	0.1326	0.0670	0.0478
Zooplankton	Suisun	hcope	~~	amphi	-0.0818	0.0677	0.2274
Zooplankton	Suisun	hcope	~~	rotif	-0.0176	0.0682	0.7962
Zooplankton	Suisun	hcope	~~	pcope	0.1178	0.0673	0.0797
Zooplankton	Suisun	hcope	~~	mysid	0.3066	0.0618	0.0000
Zooplankton	Suisun	amphi	~~	rotif	0.0899	0.0676	0.1838
Zooplankton	Suisun	amphi	~~	pcope	0.1690	0.0663	0.0107
Zooplankton	Suisun	amphi	~~	mysid	-0.0963	0.0676	0.1542
Zooplankton	Suisun	rotif	~~	pcope	0.0949	0.0676	0.1602
Zooplankton	Suisun	rotif	~~	mysid	0.0442	0.0681	0.5165
Zooplankton	Suisun	pcope	~~	mysid	0.0915	0.0676	0.1763
Zooplankton	Suisun	chla_1	~~	chla_1	1.0000	0.0000	
Zooplankton	Suisun	chla_1	~~	hcope_1	0.2085	0.0000	
Zooplankton	Suisun	chla_1	~~	amphi_1	0.1632	0.0000	
Zooplankton	Suisun	chla_1	~~	rotif_1	0.2629	0.0000	
Zooplankton	Suisun	chla_1	~~	potam_1	-0.0333	0.0000	
Zooplankton	Suisun	chla_1	~~	flow	0.1784	0.0000	
Zooplankton	Suisun	chla_1	~~	turbid	0.0038	0.0000	
Zooplankton	Suisun	chla_1	~~	temp	-0.1893	0.0000	
Zooplankton	Suisun	chla_1	~~	mysid_1	0.0814	0.0000	
Zooplankton	Suisun	chla_1	~~	pcope_1	0.0554	0.0000	
Zooplankton	Suisun	chla_1	~~	estfish_bsmt_1	-0.0223	0.0000	
Zooplankton	Suisun	hcope_1	~~	hcope_1	1.0000	0.0000	
Zooplankton	Suisun	hcope_1	~~	amphi_1	-0.0564	0.0000	
Zooplankton	Suisun	hcope_1	~~	rotif_1	-0.0131	0.0000	
Zooplankton	Suisun	hcope_1	~~	potam_1	-0.2747	0.0000	
Zooplankton	Suisun	hcope_1	~~	flow	0.0143	0.0000	
Zooplankton	Suisun	hcope_1	~~	turbid	0.1907	0.0000	
Zooplankton	Suisun	hcope_1	~~	temp	-0.0464	0.0000	
Zooplankton	Suisun	hcope_1	~~	mysid_1	0.3694	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Suisun	hcope_1	~~	pcope_1	0.0531	0.0000	
Zooplankton	Suisun	hcope_1	~~	estfish_bsmt_1	0.0084	0.0000	
Zooplankton	Suisun	amphi_1	~~	amphi_1	1.0000	0.0000	
Zooplankton	Suisun	amphi_1	~~	rotif_1	0.2319	0.0000	
Zooplankton	Suisun	amphi_1	~~	potam_1	0.3420	0.0000	
Zooplankton	Suisun	amphi_1	~~	flow	-0.0576	0.0000	
Zooplankton	Suisun	amphi_1	~~	turbid	-0.3454	0.0000	
Zooplankton	Suisun	amphi_1	~~	temp	0.0837	0.0000	
Zooplankton	Suisun	amphi_1	~~	mysid_1	-0.2408	0.0000	
Zooplankton	Suisun	amphi_1	~~	pcope_1	0.2147	0.0000	
Zooplankton	Suisun	amphi_1	~~	estfish_bsmt_1	-0.3082	0.0000	
Zooplankton	Suisun	rotif_1	~~	rotif_1	1.0000	0.0000	
Zooplankton	Suisun	rotif_1	~~	potam_1	-0.0484	0.0000	
Zooplankton	Suisun	rotif_1	~~	flow	0.2172	0.0000	
Zooplankton	Suisun	rotif_1	~~	turbid	-0.1159	0.0000	
Zooplankton	Suisun	rotif_1	~~	temp	-0.0435	0.0000	
Zooplankton	Suisun	rotif_1	~~	mysid_1	-0.0142	0.0000	
Zooplankton	Suisun	rotif_1	~~	pcope_1	0.2869	0.0000	
Zooplankton	Suisun	rotif_1	~~	estfish_bsmt_1	-0.1522	0.0000	
Zooplankton	Suisun	potam_1	~~	potam_1	1.0000	0.0000	
Zooplankton	Suisun	potam_1	~~	flow	-0.3025	0.0000	
Zooplankton	Suisun	potam_1	~~	turbid	-0.3648	0.0000	
Zooplankton	Suisun	potam_1	~~	temp	0.0305	0.0000	
Zooplankton	Suisun	potam_1	~~	mysid_1	-0.2872	0.0000	
Zooplankton	Suisun	potam_1	~~	pcope_1	0.0818	0.0000	
Zooplankton	Suisun	potam_1	~~	estfish_bsmt_1	-0.1156	0.0000	
Zooplankton	Suisun	flow	~~	flow	1.0000	0.0000	
Zooplankton	Suisun	flow	~~	turbid	0.2973	0.0000	
Zooplankton	Suisun	flow	~~	temp	-0.1584	0.0000	
Zooplankton	Suisun	flow	~~	mysid_1	-0.0603	0.0000	
Zooplankton	Suisun	flow	~~	pcope_1	-0.0027	0.0000	
Zooplankton	Suisun	flow	~~	estfish_bsmt_1	-0.1207	0.0000	
Zooplankton	Suisun	turbid	~~	turbid	1.0000	0.0000	
Zooplankton	Suisun	turbid	~~	temp	-0.1942	0.0000	
Zooplankton	Suisun	turbid	~~	mysid_1	0.2132	0.0000	
Zooplankton	Suisun	turbid	~~	pcope_1	-0.2165	0.0000	
Zooplankton	Suisun	turbid	~~	estfish_bsmt_1	0.1250	0.0000	
Zooplankton	Suisun	temp	~~	temp	1.0000	0.0000	
Zooplankton	Suisun	temp	~~	mysid_1	0.0308	0.0000	
Zooplankton	Suisun	temp	~~	pcope_1	0.1468	0.0000	
Zooplankton	Suisun	temp	~~	estfish_bsmt_1	-0.0425	0.0000	
Zooplankton	Suisun	mysid_1	~~	mysid_1	1.0000	0.0000	
Zooplankton	Suisun	mysid_1	~~	pcope_1	0.1006	0.0000	
Zooplankton	Suisun	mysid_1	~~	estfish_bsmt_1	0.2646	0.0000	
Zooplankton	Suisun	pcope_1	~~	pcope_1	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Suisun	pcope_1	~~	estfish_bsmt_1	-0.0836	0.0000	
Zooplankton	Suisun	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Zooplankton	Sacramento	chla	~	chla_1	0.1487	0.0674	0.0274
Zooplankton	Sacramento	chla	~	hcope_1	-0.0245	0.0750	0.7442
Zooplankton	Sacramento	chla	~	clad_1	0.1861	0.0750	0.0130
Zooplankton	Sacramento	chla	~	amphi_1	0.0556	0.0677	0.4119
Zooplankton	Sacramento	chla	~	rotif_1	-0.0436	0.0713	0.5412
Zooplankton	Sacramento	chla	~	corbic_1	-0.0241	0.0675	0.7209
Zooplankton	Sacramento	chla	~	flow	-0.0298	0.0768	0.6985
Zooplankton	Sacramento	chla	~	turbid	0.0993	0.0705	0.1591
Zooplankton	Sacramento	chla	~	temp	0.1246	0.0700	0.0750
Zooplankton	Sacramento	hcope	~	chla_1	-0.0119	0.0510	0.8162
Zooplankton	Sacramento	hcope	~	hcope_1	0.1275	0.0713	0.0737
Zooplankton	Sacramento	hcope	~	pcope_1	-0.1308	0.0589	0.0264
Zooplankton	Sacramento	hcope	~	mysid_1	0.0575	0.0750	0.4430
Zooplankton	Sacramento	hcope	~	corbic_1	0.1252	0.0511	0.0142
Zooplankton	Sacramento	hcope	~	flow	-0.4977	0.0537	0.0000
Zooplankton	Sacramento	hcope	~	turbid	0.1148	0.0603	0.0570
Zooplankton	Sacramento	hcope	~	temp	0.1271	0.0566	0.0248
Zooplankton	Sacramento	hcope	~	estfish_bsmt_1	0.0097	0.0606	0.8724
Zooplankton	Sacramento	clad	~	chla_1	-0.0349	0.0553	0.5279
Zooplankton	Sacramento	clad	~	clad_1	0.3562	0.0551	0.0000
Zooplankton	Sacramento	clad	~	pcope_1	0.0156	0.0575	0.7858
Zooplankton	Sacramento	clad	~	flow	0.4278	0.0569	0.0000
Zooplankton	Sacramento	clad	~	turbid	0.0036	0.0588	0.9515
Zooplankton	Sacramento	clad	~	temp	0.0500	0.0562	0.3737
Zooplankton	Sacramento	clad	~	estfish_bsmt_1	0.0190	0.0588	0.7471
Zooplankton	Sacramento	amphi	~	chla_1	0.0575	0.0589	0.3289
Zooplankton	Sacramento	amphi	~	amphi_1	0.5137	0.0479	0.0000
Zooplankton	Sacramento	amphi	~	flow	0.0560	0.0651	0.3900
Zooplankton	Sacramento	amphi	~	turbid	-0.0209	0.0615	0.7334
Zooplankton	Sacramento	amphi	~	temp	-0.0437	0.0609	0.4733
Zooplankton	Sacramento	amphi	~	estfish_bsmt_1	-0.0788	0.0638	0.2168
Zooplankton	Sacramento	rotif	~	chla_1	-0.0809	0.0618	0.1904
Zooplankton	Sacramento	rotif	~	rotif_1	0.1514	0.0617	0.0141
Zooplankton	Sacramento	rotif	~	flow	0.3815	0.0631	0.0000
Zooplankton	Sacramento	rotif	~	turbid	-0.0500	0.0644	0.4371
Zooplankton	Sacramento	rotif	~	temp	-0.0735	0.0633	0.2453
Zooplankton	Sacramento	rotif	~	estfish_bsmt_1	-0.0153	0.0664	0.8183
Zooplankton	Sacramento	pcope	~	hcope_1	-0.1137	0.0798	0.1541
Zooplankton	Sacramento	pcope	~	pcope_1	0.2568	0.0635	0.0001
Zooplankton	Sacramento	pcope	~	clad_1	-0.1284	0.0663	0.0528
Zooplankton	Sacramento	pcope	~	mysid_1	0.0593	0.0841	0.4803
Zooplankton	Sacramento	pcope	~	corbic_1	0.0593	0.0604	0.3263
Zooplankton	Sacramento	pcope	~	flow	-0.1825	0.0702	0.0094
Zooplankton	Sacramento	pcope	~	turbid	-0.2354	0.0662	0.0004
Zooplankton	Sacramento	pcope	~	temp	0.0702	0.0644	0.2754
Zooplankton	Sacramento	pcope	~	estfish_bsmt_1	-0.0648	0.0679	0.3403
Zooplankton	Sacramento	pcope	~	chla_1	0.1408	0.0615	0.0220
Zooplankton	Sacramento	mysid	~	hcope_1	-0.0181	0.0716	0.8000

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Sacramento	mysid	~	pcope_1	-0.0674	0.0595	0.2567
Zooplankton	Sacramento	mysid	~	mysid_1	0.1746	0.0732	0.0171
Zooplankton	Sacramento	mysid	~	amphi_1	-0.0800	0.0509	0.1159
Zooplankton	Sacramento	mysid	~	flow	-0.4276	0.0569	0.0000
Zooplankton	Sacramento	mysid	~	turbid	0.2362	0.0602	0.0001
Zooplankton	Sacramento	mysid	~	temp	0.0851	0.0573	0.1372
Zooplankton	Sacramento	mysid	~	estfish_bsmt_1	0.0617	0.0612	0.3130
Zooplankton	Sacramento	chla	~~	chla	0.9072	0.0374	0.0000
Zooplankton	Sacramento	hcope	~~	hcope	0.5949	0.0471	0.0000
Zooplankton	Sacramento	clad	~~	clad	0.6076	0.0475	0.0000
Zooplankton	Sacramento	amphi	~~	amphi	0.7131	0.0485	0.0000
Zooplankton	Sacramento	rotif	~~	rotif	0.7730	0.0483	0.0000
Zooplankton	Sacramento	pcope	~~	pcope	0.7542	0.0485	0.0000
Zooplankton	Sacramento	mysid	~~	mysid	0.6195	0.0479	0.0000
Zooplankton	Sacramento	chla	~~	hcope	0.0339	0.0698	0.6272
Zooplankton	Sacramento	chla	~~	clad	0.1754	0.0677	0.0096
Zooplankton	Sacramento	chla	~~	amphi	0.0255	0.0698	0.7151
Zooplankton	Sacramento	chla	~~	rotif	0.1079	0.0690	0.1181
Zooplankton	Sacramento	chla	~~	pcope	-0.0658	0.0695	0.3439
Zooplankton	Sacramento	chla	~~	mysid	0.1153	0.0689	0.0943
Zooplankton	Sacramento	hcope	~~	clad	-0.1212	0.0688	0.0782
Zooplankton	Sacramento	hcope	~~	amphi	0.0831	0.0694	0.2307
Zooplankton	Sacramento	hcope	~~	rotif	-0.0134	0.0698	0.8481
Zooplankton	Sacramento	hcope	~~	pcope	0.1099	0.0690	0.1112
Zooplankton	Sacramento	hcope	~~	mysid	0.3949	0.0590	0.0000
Zooplankton	Sacramento	clad	~~	amphi	0.0062	0.0698	0.9296
Zooplankton	Sacramento	clad	~~	rotif	0.1420	0.0684	0.0379
Zooplankton	Sacramento	clad	~~	pcope	-0.0687	0.0695	0.3229
Zooplankton	Sacramento	clad	~~	mysid	-0.1335	0.0686	0.0516
Zooplankton	Sacramento	amphi	~~	rotif	-0.1795	0.0676	0.0079
Zooplankton	Sacramento	amphi	~~	pcope	-0.1251	0.0687	0.0687
Zooplankton	Sacramento	amphi	~~	mysid	0.1489	0.0683	0.0293
Zooplankton	Sacramento	rotif	~~	pcope	0.1818	0.0675	0.0071
Zooplankton	Sacramento	rotif	~~	mysid	0.0033	0.0698	0.9619
Zooplankton	Sacramento	pcope	~~	mysid	0.1957	0.0672	0.0036
Zooplankton	Sacramento	chla_1	~~	chla_1	1.0000	0.0000	
Zooplankton	Sacramento	chla_1	~~	hcope_1	0.0323	0.0000	
Zooplankton	Sacramento	chla_1	~~	clad_1	0.1603	0.0000	
Zooplankton	Sacramento	chla_1	~~	amphi_1	-0.0234	0.0000	
Zooplankton	Sacramento	chla_1	~~	rotif_1	-0.0038	0.0000	
Zooplankton	Sacramento	chla_1	~~	corbic_1	-0.1008	0.0000	
Zooplankton	Sacramento	chla_1	~~	flow	0.0939	0.0000	
Zooplankton	Sacramento	chla_1	~~	turbid	0.1184	0.0000	
Zooplankton	Sacramento	chla_1	~~	temp	-0.0308	0.0000	
Zooplankton	Sacramento	chla_1	~~	pcope_1	-0.1408	0.0000	
Zooplankton	Sacramento	chla_1	~~	mysid_1	0.0978	0.0000	
Zooplankton	Sacramento	chla_1	~~	estfish_bsmt_1	-0.0117	0.0000	
Zooplankton	Sacramento	hcope_1	~~	hcope_1	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Sacramento	hcope_1	~~	clad_1	-0.3390	0.0000	
Zooplankton	Sacramento	hcope_1	~~	amphi_1	-0.0206	0.0000	
Zooplankton	Sacramento	hcope_1	~~	rotif_1	-0.2335	0.0000	
Zooplankton	Sacramento	hcope_1	~~	corbic_1	0.0427	0.0000	
Zooplankton	Sacramento	hcope_1	~~	flow	-0.3322	0.0000	
Zooplankton	Sacramento	hcope_1	~~	turbid	0.1964	0.0000	
Zooplankton	Sacramento	hcope_1	~~	temp	0.2201	0.0000	
Zooplankton	Sacramento	hcope_1	~~	pcope_1	0.2074	0.0000	
Zooplankton	Sacramento	hcope_1	~~	mysid_1	0.6384	0.0000	
Zooplankton	Sacramento	hcope_1	~~	estfish_bsmt_1	0.2948	0.0000	
Zooplankton	Sacramento	clad_1	~~	clad_1	1.0000	0.0000	
Zooplankton	Sacramento	clad_1	~~	amphi_1	0.0988	0.0000	
Zooplankton	Sacramento	clad_1	~~	rotif_1	0.3174	0.0000	
Zooplankton	Sacramento	clad_1	~~	corbic_1	0.0639	0.0000	
Zooplankton	Sacramento	clad_1	~~	flow	0.3619	0.0000	
Zooplankton	Sacramento	clad_1	~~	turbid	-0.0777	0.0000	
Zooplankton	Sacramento	clad_1	~~	temp	-0.0825	0.0000	
Zooplankton	Sacramento	clad_1	~~	pcope_1	-0.1996	0.0000	
Zooplankton	Sacramento	clad_1	~~	mysid_1	-0.3593	0.0000	
Zooplankton	Sacramento	clad_1	~~	estfish_bsmt_1	-0.2134	0.0000	
Zooplankton	Sacramento	amphi_1	~~	amphi_1	1.0000	0.0000	
Zooplankton	Sacramento	amphi_1	~~	rotif_1	-0.0998	0.0000	
Zooplankton	Sacramento	amphi_1	~~	corbic_1	0.1414	0.0000	
Zooplankton	Sacramento	amphi_1	~~	flow	0.1215	0.0000	
Zooplankton	Sacramento	amphi_1	~~	turbid	0.1530	0.0000	
Zooplankton	Sacramento	amphi_1	~~	temp	-0.0645	0.0000	
Zooplankton	Sacramento	amphi_1	~~	pcope_1	-0.1515	0.0000	
Zooplankton	Sacramento	amphi_1	~~	mysid_1	-0.0314	0.0000	
Zooplankton	Sacramento	amphi_1	~~	estfish_bsmt_1	0.0404	0.0000	
Zooplankton	Sacramento	rotif_1	~~	rotif_1	1.0000	0.0000	
Zooplankton	Sacramento	rotif_1	~~	corbic_1	0.0891	0.0000	
Zooplankton	Sacramento	rotif_1	~~	flow	0.2436	0.0000	
Zooplankton	Sacramento	rotif_1	~~	turbid	-0.1848	0.0000	
Zooplankton	Sacramento	rotif_1	~~	temp	-0.1064	0.0000	
Zooplankton	Sacramento	rotif_1	~~	pcope_1	0.1329	0.0000	
Zooplankton	Sacramento	rotif_1	~~	mysid_1	-0.2124	0.0000	
Zooplankton	Sacramento	rotif_1	~~	estfish_bsmt_1	-0.1981	0.0000	
Zooplankton	Sacramento	corbic_1	~~	corbic_1	1.0000	0.0000	
Zooplankton	Sacramento	corbic_1	~~	flow	0.0137	0.0000	
Zooplankton	Sacramento	corbic_1	~~	turbid	-0.0562	0.0000	
Zooplankton	Sacramento	corbic_1	~~	temp	-0.1736	0.0000	
Zooplankton	Sacramento	corbic_1	~~	pcope_1	0.0532	0.0000	
Zooplankton	Sacramento	corbic_1	~~	mysid_1	-0.1027	0.0000	
Zooplankton	Sacramento	corbic_1	~~	estfish_bsmt_1	0.0570	0.0000	
Zooplankton	Sacramento	flow	~~	flow	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	Sacramento	flow	~~	turbid	0.0868	0.0000	
Zooplankton	Sacramento	flow	~~	temp	-0.2383	0.0000	
Zooplankton	Sacramento	flow	~~	pcope_1	-0.1934	0.0000	
Zooplankton	Sacramento	flow	~~	mysid_1	-0.3225	0.0000	
Zooplankton	Sacramento	flow	~~	estfish_bsmt_1	-0.3306	0.0000	
Zooplankton	Sacramento	turbid	~~	turbid	1.0000	0.0000	
Zooplankton	Sacramento	turbid	~~	temp	0.0372	0.0000	
Zooplankton	Sacramento	turbid	~~	pcope_1	-0.2587	0.0000	
Zooplankton	Sacramento	turbid	~~	mysid_1	0.2534	0.0000	
Zooplankton	Sacramento	turbid	~~	estfish_bsmt_1	0.1655	0.0000	
Zooplankton	Sacramento	temp	~~	temp	1.0000	0.0000	
Zooplankton	Sacramento	temp	~~	pcope_1	0.0725	0.0000	
Zooplankton	Sacramento	temp	~~	mysid_1	0.2238	0.0000	
Zooplankton	Sacramento	temp	~~	estfish_bsmt_1	0.1404	0.0000	
Zooplankton	Sacramento	pcope_1	~~	pcope_1	1.0000	0.0000	
Zooplankton	Sacramento	pcope_1	~~	mysid_1	0.2210	0.0000	
Zooplankton	Sacramento	pcope_1	~~	estfish_bsmt_1	0.1379	0.0000	
Zooplankton	Sacramento	mysid_1	~~	mysid_1	1.0000	0.0000	
Zooplankton	Sacramento	mysid_1	~~	estfish_bsmt_1	0.3664	0.0000	
Zooplankton	Sacramento	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Zooplankton	San Joaquin	chla	~	chla_1	0.2672	0.0637	0.0000
Zooplankton	San Joaquin	chla	~	hcope_1	0.1126	0.0631	0.0742
Zooplankton	San Joaquin	chla	~	clad_1	0.1581	0.0665	0.0174
Zooplankton	San Joaquin	chla	~	rotif_1	-0.0981	0.0624	0.1158
Zooplankton	San Joaquin	chla	~	corbic_1	0.0128	0.0626	0.8384
Zooplankton	San Joaquin	chla	~	flow	-0.0590	0.0672	0.3802
Zooplankton	San Joaquin	chla	~	turbid	0.0112	0.0657	0.8651
Zooplankton	San Joaquin	chla	~	temp	0.0805	0.0639	0.2076
Zooplankton	San Joaquin	hcope	~	chla_1	0.1832	0.0576	0.0015
Zooplankton	San Joaquin	hcope	~	hcope_1	0.3517	0.0560	0.0000
Zooplankton	San Joaquin	hcope	~	pcope_1	-0.0004	0.0599	0.9953
Zooplankton	San Joaquin	hcope	~	corbic_1	0.1195	0.0587	0.0416
Zooplankton	San Joaquin	hcope	~	flow	-0.1397	0.0599	0.0196
Zooplankton	San Joaquin	hcope	~	turbid	-0.0995	0.0600	0.0974
Zooplankton	San Joaquin	hcope	~	temp	0.1862	0.0583	0.0014
Zooplankton	San Joaquin	hcope	~	estfish_bsmt_1	-0.1921	0.0587	0.0011
Zooplankton	San Joaquin	clad	~	chla_1	0.1214	0.0555	0.0288
Zooplankton	San Joaquin	clad	~	clad_1	0.5258	0.0487	0.0000
Zooplankton	San Joaquin	clad	~	pcope_1	-0.0380	0.0541	0.4822
Zooplankton	San Joaquin	clad	~	flow	0.1784	0.0540	0.0010
Zooplankton	San Joaquin	clad	~	turbid	-0.0475	0.0557	0.3937
Zooplankton	San Joaquin	clad	~	temp	0.1086	0.0545	0.0462
Zooplankton	San Joaquin	clad	~	estfish_bsmt_1	-0.0909	0.0533	0.0880
Zooplankton	San Joaquin	amphi	~	chla_1	-0.0310	0.0661	0.6389
Zooplankton	San Joaquin	amphi	~	amphi_1	0.2139	0.0647	0.0009
Zooplankton	San Joaquin	amphi	~	flow	-0.0053	0.0669	0.9372
Zooplankton	San Joaquin	amphi	~	turbid	0.1600	0.0673	0.0174
Zooplankton	San Joaquin	amphi	~	temp	0.0851	0.0669	0.2036

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Joaquin	amphi	~	estfish_bsmt_1	0.0488	0.0681	0.4736
Zooplankton	San Joaquin	rotif	~	chla_1	0.0341	0.0649	0.5991
Zooplankton	San Joaquin	rotif	~	rotif_1	0.1144	0.0632	0.0704
Zooplankton	San Joaquin	rotif	~	flow	0.3039	0.0616	0.0000
Zooplankton	San Joaquin	rotif	~	turbid	-0.0721	0.0653	0.2694
Zooplankton	San Joaquin	rotif	~	temp	0.0015	0.0661	0.9821
Zooplankton	San Joaquin	rotif	~	estfish_bsmt_1	0.1726	0.0649	0.0078
Zooplankton	San Joaquin	pcope	~	chla_1	0.2025	0.0604	0.0008
Zooplankton	San Joaquin	pcope	~	hcope_1	-0.0537	0.0594	0.3659
Zooplankton	San Joaquin	pcope	~	clad_1	0.0816	0.0624	0.1910
Zooplankton	San Joaquin	pcope	~	pcope_1	0.4463	0.0532	0.0000
Zooplankton	San Joaquin	pcope	~	corbic_1	-0.0524	0.0580	0.3657
Zooplankton	San Joaquin	pcope	~	flow	0.0259	0.0624	0.6781
Zooplankton	San Joaquin	pcope	~	turbid	-0.0739	0.0618	0.2314
Zooplankton	San Joaquin	pcope	~	temp	0.0111	0.0605	0.8546
Zooplankton	San Joaquin	pcope	~	estfish_bsmt_1	-0.0463	0.0612	0.4494
Zooplankton	San Joaquin	chla	~~	chla	0.8404	0.0441	0.0000
Zooplankton	San Joaquin	hcope	~~	hcope	0.6963	0.0487	0.0000
Zooplankton	San Joaquin	clad	~~	clad	0.5961	0.0464	0.0000
Zooplankton	San Joaquin	amphi	~~	amphi	0.9043	0.0375	0.0000
Zooplankton	San Joaquin	rotif	~~	rotif	0.8660	0.0421	0.0000
Zooplankton	San Joaquin	pcope	~~	pcope	0.7176	0.0478	0.0000
Zooplankton	San Joaquin	chla	~~	hcope	0.1084	0.0682	0.1120
Zooplankton	San Joaquin	chla	~~	clad	0.2741	0.0638	0.0000
Zooplankton	San Joaquin	chla	~~	amphi	-0.0085	0.0690	0.9018
Zooplankton	San Joaquin	chla	~~	rotif	0.1316	0.0678	0.0523
Zooplankton	San Joaquin	chla	~~	pcope	-0.0534	0.0688	0.4379
Zooplankton	San Joaquin	hcope	~~	clad	0.0735	0.0686	0.2839
Zooplankton	San Joaquin	hcope	~~	amphi	0.0292	0.0689	0.6724
Zooplankton	San Joaquin	hcope	~~	rotif	0.0194	0.0690	0.7784
Zooplankton	San Joaquin	hcope	~~	pcope	0.0380	0.0689	0.5812
Zooplankton	San Joaquin	clad	~~	amphi	-0.1240	0.0679	0.0681
Zooplankton	San Joaquin	clad	~~	rotif	0.0443	0.0689	0.5203
Zooplankton	San Joaquin	clad	~~	pcope	0.1267	0.0679	0.0620
Zooplankton	San Joaquin	amphi	~~	rotif	0.0641	0.0687	0.3512
Zooplankton	San Joaquin	amphi	~~	pcope	0.0349	0.0689	0.6124
Zooplankton	San Joaquin	rotif	~~	pcope	0.2498	0.0647	0.0001
Zooplankton	San Joaquin	chla_1	~~	chla_1	1.0000	0.0000	
Zooplankton	San Joaquin	chla_1	~~	hcope_1	0.1451	0.0000	
Zooplankton	San Joaquin	chla_1	~~	clad_1	0.2464	0.0000	
Zooplankton	San Joaquin	chla_1	~~	rotif_1	0.0859	0.0000	
Zooplankton	San Joaquin	chla_1	~~	corbic_1	-0.0408	0.0000	
Zooplankton	San Joaquin	chla_1	~~	flow	-0.0416	0.0000	
Zooplankton	San Joaquin	chla_1	~~	turbid	0.0692	0.0000	
Zooplankton	San Joaquin	chla_1	~~	temp	0.0770	0.0000	
Zooplankton	San Joaquin	chla_1	~~	pcope_1	-0.0251	0.0000	
Zooplankton	San Joaquin	chla_1	~~	estfish_bsmt_1	0.0864	0.0000	
Zooplankton	San Joaquin	chla_1	~~	amphi_1	0.0104	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	hcope_1	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Joaquin	hcope_1	~~	clad_1	0.0937	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	rotif_1	-0.1050	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	corbic_1	0.0913	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	flow	-0.2094	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	turbid	-0.0037	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	temp	-0.0186	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	pcope_1	0.1186	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	estfish_bsmt_1	-0.0519	0.0000	
Zooplankton	San Joaquin	hcope_1	~~	amphi_1	0.0180	0.0000	
Zooplankton	San Joaquin	clad_1	~~	clad_1	1.0000	0.0000	
Zooplankton	San Joaquin	clad_1	~~	rotif_1	0.1367	0.0000	
Zooplankton	San Joaquin	clad_1	~~	corbic_1	0.0664	0.0000	
Zooplankton	San Joaquin	clad_1	~~	flow	0.1692	0.0000	
Zooplankton	San Joaquin	clad_1	~~	turbid	-0.1476	0.0000	
Zooplankton	San Joaquin	clad_1	~~	temp	0.0048	0.0000	
Zooplankton	San Joaquin	clad_1	~~	pcope_1	0.2513	0.0000	
Zooplankton	San Joaquin	clad_1	~~	estfish_bsmt_1	-0.0298	0.0000	
Zooplankton	San Joaquin	clad_1	~~	amphi_1	-0.2041	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	rotif_1	1.0000	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	corbic_1	0.0933	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	flow	0.1607	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	turbid	-0.0195	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	temp	0.1038	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	pcope_1	0.2522	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	estfish_bsmt_1	-0.0309	0.0000	
Zooplankton	San Joaquin	rotif_1	~~	amphi_1	0.0162	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	corbic_1	1.0000	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	flow	0.1218	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	turbid	0.1504	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	temp	-0.0930	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	pcope_1	0.0398	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	estfish_bsmt_1	-0.0287	0.0000	
Zooplankton	San Joaquin	corbic_1	~~	amphi_1	0.0550	0.0000	
Zooplankton	San Joaquin	flow	~~	flow	1.0000	0.0000	
Zooplankton	San Joaquin	flow	~~	turbid	0.0945	0.0000	
Zooplankton	San Joaquin	flow	~~	temp	-0.0543	0.0000	
Zooplankton	San Joaquin	flow	~~	pcope_1	0.0592	0.0000	
Zooplankton	San Joaquin	flow	~~	estfish_bsmt_1	-0.1034	0.0000	
Zooplankton	San Joaquin	flow	~~	amphi_1	-0.0928	0.0000	
Zooplankton	San Joaquin	turbid	~~	turbid	1.0000	0.0000	
Zooplankton	San Joaquin	turbid	~~	temp	-0.0363	0.0000	
Zooplankton	San Joaquin	turbid	~~	pcope_1	-0.1606	0.0000	
Zooplankton	San Joaquin	turbid	~~	estfish_bsmt_1	0.1398	0.0000	
Zooplankton	San Joaquin	turbid	~~	amphi_1	0.2021	0.0000	
Zooplankton	San Joaquin	temp	~~	temp	1.0000	0.0000	

Model	Region	Response	op	Predictor	Effect	se	pvalue
Zooplankton	San Joaquin	temp	~~	pcope_1	0.1389	0.0000	
Zooplankton	San Joaquin	temp	~~	estfish_bsmt_1	0.1919	0.0000	
Zooplankton	San Joaquin	temp	~~	amphi_1	-0.0479	0.0000	
Zooplankton	San Joaquin	pcope_1	~~	pcope_1	1.0000	0.0000	
Zooplankton	San Joaquin	pcope_1	~~	estfish_bsmt_1	0.0890	0.0000	
Zooplankton	San Joaquin	pcope_1	~~	amphi_1	-0.0226	0.0000	
Zooplankton	San Joaquin	estfish_bsmt_1	~~	estfish_bsmt_1	1.0000	0.0000	
Zooplankton	San Joaquin	estfish_bsmt_1	~~	amphi_1	0.0123	0.0000	
Zooplankton	San Joaquin	amphi_1	~~	amphi_1	1.0000	0.0000	