Stable isotopes provide insight into sources and cycling of dissolved nitrogen compounds in the Sacramento-San Joaquin Delta, California, USA

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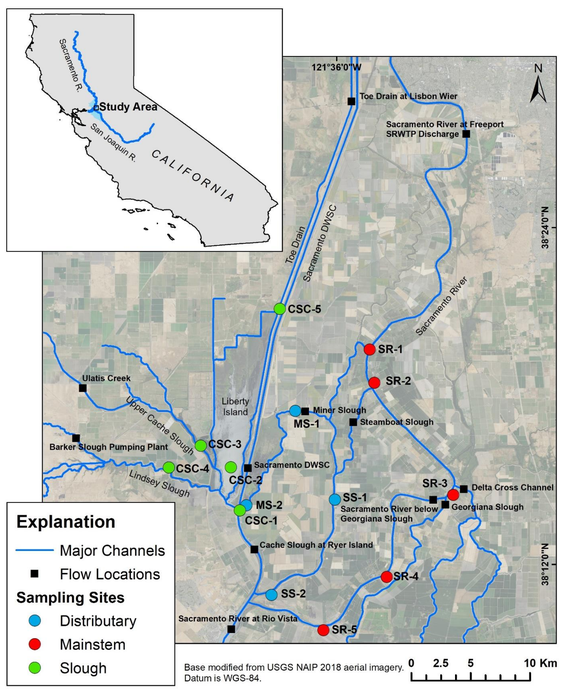
Introduction

The Sacramento-San Joaquin Delta (Delta) is a large inverted river delta located in central California, USA, that is fed primarily by the Sacramento River and is comprised of a complex network of distributaries, tributaries, and sloughs. The Delta has been substantially altered by anthropogenic activities including channelization, water diversion, and inputs of agricultural drainage and municipal wastewater. These alterations have a large impact on the concentration, speciation, and biogeochemical cycling of nitrogen (N), an element essential for biological processes. However, due to the Delta's hydrologic complexity and diversity of aquatic ecosystems, assessment of these impacts is challenging. To better understand N compound sources and biogeochemical processes in Delta aquatic environments we utilized a multi-tracer, multi-stable isotope approach that measured N species concentrations and stable isotope values monthly for a period of two years in samples collected from (1) the channelized mainstem of the Sacramento River, (2) two distributaries of the Sacramento River (Miner and Steamboat Sloughs), and (3) Sacramento River tributaries that connect with a large shallow wetland (Cache Slough Complex).

Study Area

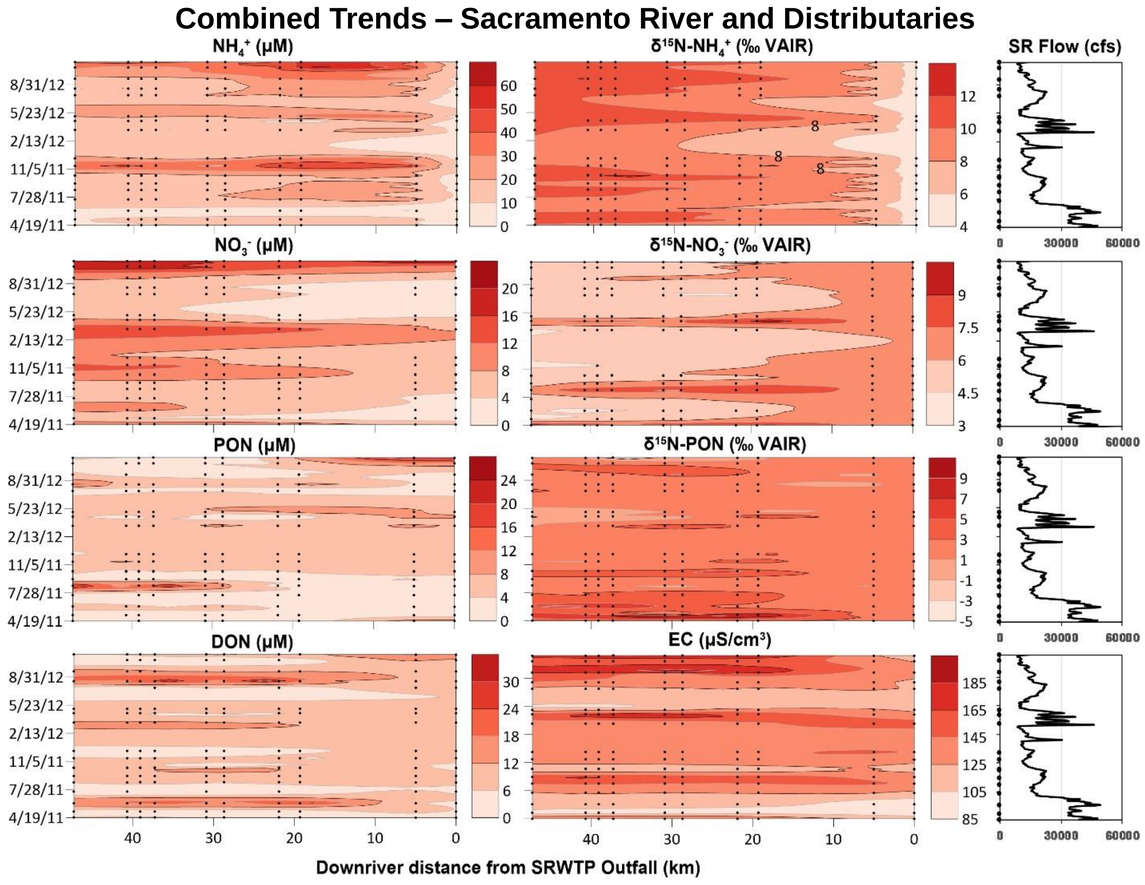


- Samples were collected from 4 distributary sites, 5 mainstem Sacramento River sites, and 5 Cache Slough complex sites between April 2011 and November 2012.
- Flow data was obtained from monitoring stations during the study period to complement and contextualize the data set.

Approach

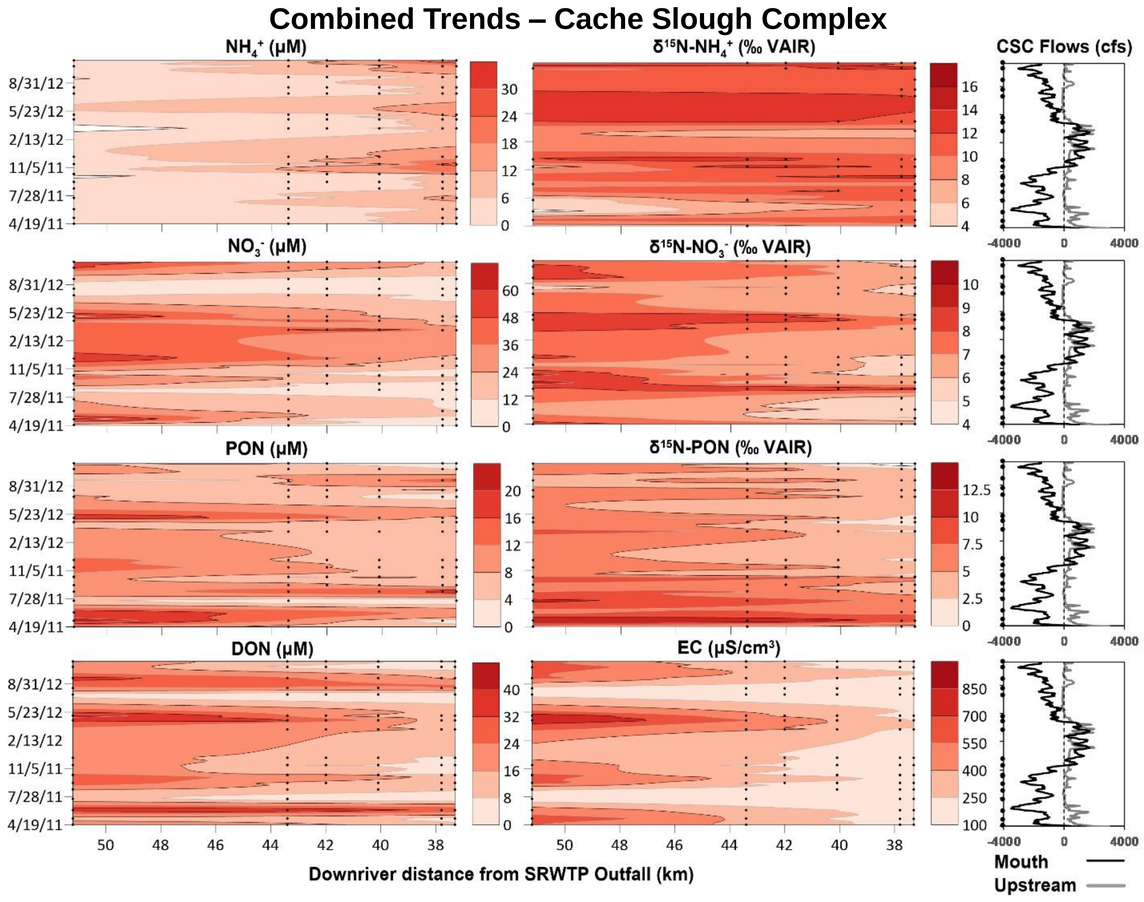
- Samples were analyzed for electrical conductivity (EC), dissolved and particulate N species parameters including nitrate, ammonium, dissolved organic N (DON), and particulate organic N (PON) as well as stable isotope parameters ($\delta^{15}N$ of nitrate, $\delta^{15}N$ of ammonium, and $\delta^{15}N$ of PON).
- Data was analyzed with respect to spatial and temporal variability and considered together with hydrological conditions to better understand sources, sinks, and biogeochemical processes affecting dissolved N compounds in the study area.

Combined Trends – Sacramento River and Distributaries



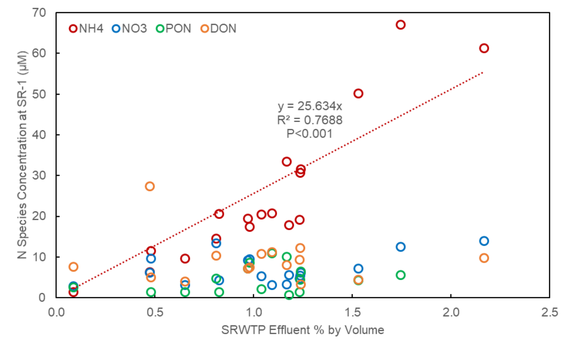
- Values for 0 and 5 km distances are generated from SRWTP and Sacramento River at Freeport monitoring data.
- After SRWTP addition (beginning at 5 km), ammonium tends to decrease and nitrate tends to increase with downstream distance. Initial ammonium concentrations vary inversely with flow.
- $\delta^{15}N$ of nitrate tends to decrease and $\delta^{15}N$ of ammonium tends to increase with downstream transit.
- No significant trends are seen in other parameters.

Combined Trends – Cache Slough Complex

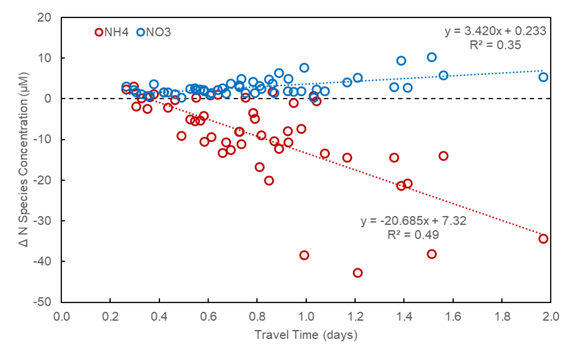


- N species concentrations and stable isotope values in the Cache Slough Complex are largely controlled by mixing between an upstream end member and inflow from the Sacramento River and distributaries.
- Relative to Sacramento River and distributaries, Cache Slough Complex upstream end member has higher EC, nitrate, PON, and DON concentrations, higher $\delta^{15}N$ values of nitrate and PON, and lower ammonium concentrations and $\delta^{15}N$ values.

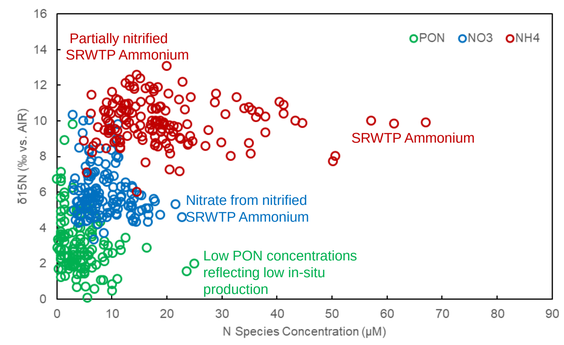
N Sources and Processes – Sacramento River and Distributaries



- Ammonium concentration at upstream sample location SR-1 is closely and significantly correlated with SRWTP effluent fraction
- No other N species concentrations are significantly correlated with SRWTP effluent fraction.

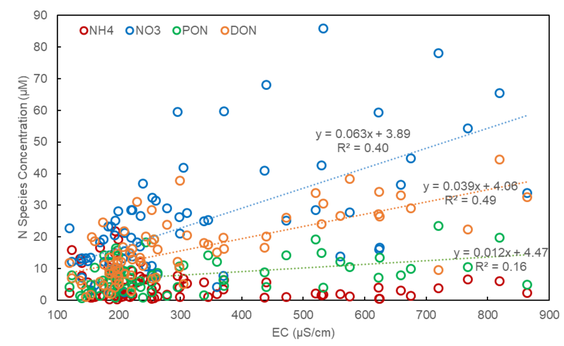


- Ammonium is lost and nitrate is gained during downstream transit along the Sacramento River and its distributaries.
- Nitrification can only account for a small fraction of ammonium lost, implying additional mechanisms of ammonium loss.

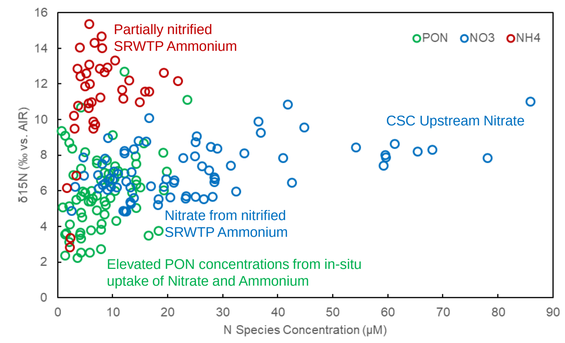


- SRWTP ammonium is the dominant source and is both attenuated and nitrified during downstream transit.
- This results in increasing $\delta^{15}N$ of ammonium values and decreasing $\delta^{15}N$ of nitrate values.

N Sources and Processes – Cache Slough Complex

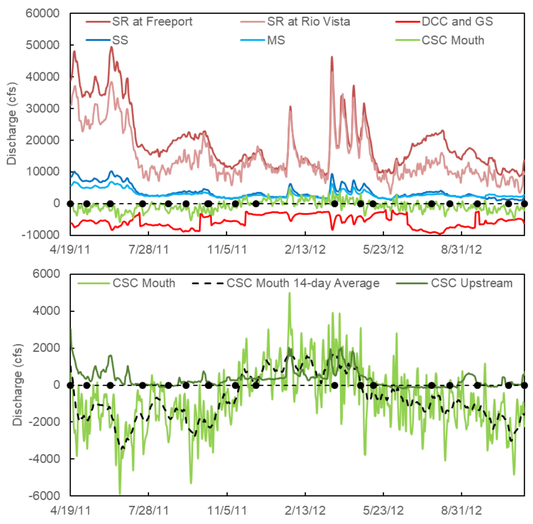


- EC is a useful conservative tracer of relative contribution of endmembers in the Cache Slough Complex.
- Cache Slough Complex upstream end member is consistent with tertiary treated wastewater and agricultural drainage influence.



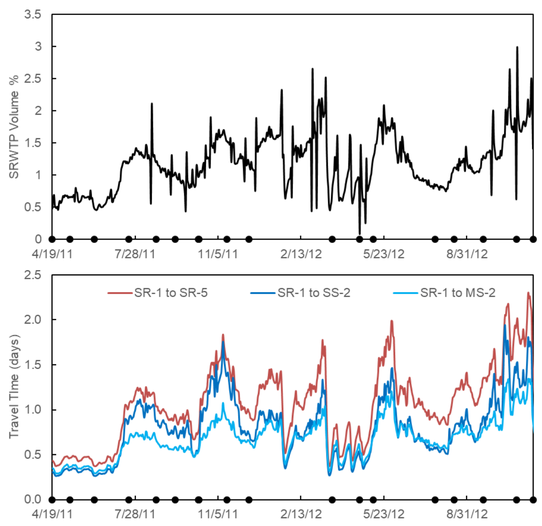
- N species concentrations and stable isotope values show mixing between upstream and Sacramento River and distributary end members.
- Higher PON concentrations and $\delta^{15}N$ values are indicative of increased primary productivity and in-situ uptake on nitrate and ammonium.

Hydrologic Conditions



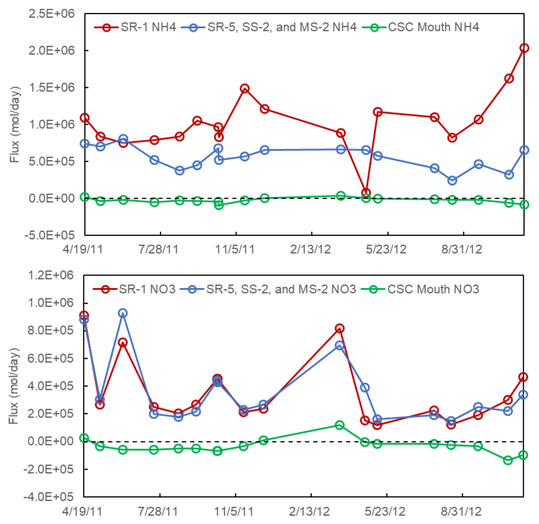
- Flows in the Sacramento River and its distributaries tend to be elevated in the winter and spring due the effects of rainfall and snowmelt in the watershed.
- Net flows in the Cache Slough Complex are much lower than in the Sacramento River and its distributaries and tend to be landward (negative) in the spring, summer, and fall, due to the effects of evapotranspiration and agricultural diversion, and seaward in the winter.

Effluent Fraction and Transit Times



- Volume % of SRWTP effluent in the Sacramento River generally varies inversely with river flow. Intermittent "spikes" in SRWTP volume % are the result of effluent holds.
- Travel times from upstream to downstream sampling locations in the Sacramento River and distributaries also generally vary inversely with river flow and are generally between 0.5 - 2.0 days.

Ammonium and Nitrate Fluxes



- Ammonium fluxes in the Sacramento River and distributaries decrease between upstream and downstream sampling locations, while nitrate fluxes are similar between upstream and downstream sampling locations.
- Ammonium and nitrate fluxes at the Cache Slough Complex mouth are small relative to those of the Sacramento River and distributaries and are landward except in the winter.

Conclusions

- **The Sacramento River and it distributaries receive ammonium from SRWTP which is both attenuated and nitrified during downstream transit.**
- **The Cache Slough Complex receives N from two distinct sources and has higher primary productivity than the Sacramento River and its distributaries.**