Title:

Development of a physical dynamical approach to monitoring nutrient dynamics at the landscape scale in the Sacramento San Joaquin Delta using a combination of fixed station and boat-based measurements

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Abstract

Changes in nutrient inputs to the Delta due to wastewater treatment plant upgrades will affect processing of nutrients within the Delta. Also, wetland restoration is expected to change nutrient demand within the Delta. However, the ability to assess these effects quantitatively across the Delta is hampered by the low sampling frequency (monthly, typ.) of existing grab-sample-based monitoring programs. Recently, continuous nutrient monitoring stations have been established, but they are limited to a relatively few fixed locations.

Here we propose to develop a method that uses data from the existing continuous nutrient monitoring together with data from the existing flow monitoring to assess nutrient dynamics in the Delta. We envision that, once developed and demonstrated, this method may be incorporated into existing monitoring programs to evaluate current conditions, assess effects of changing wastewater discharge, as well as evaluate changes due to wetland restoration, flow alteration and other management actions.

Need

The State has a compelling interest in understanding how the Delta aquatic ecosystem will respond to upcoming changes to Sacramento's Regional WWTP. The impact of the upgrade will extend throughout the estuary, with potential consequences to water quality, ecosystem services, and water supply reliability. A program of research and enhanced monitoring is urgently needed to provide early warning about unexpected effects, and as a component of adaptive management. The proposed work will document current conditions and develop novel monitoring approaches that can help scientists and managers predict how the ecosystem will respond to these changes.

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Proposed Work

Problem

The ability to quantitatively understand nutrient dynamics (transformations, losses, uptake) in the Delta is hampered by the low spatial and temporal sampling frequency of existing grab-sample-based monitoring programs, and the fixed locations at which continuous nitrate data is collected (Novick et al. 2015). Given planned changes in nutrient inputs to the Delta due to wastewater treatment plant upgrades, it becomes important to understand if changing loading will affect internal processing of nutrients within the Delta at the landscape scale. Nutrient demand is also expected to change within the Delta as a consequence of large scale wetland restoration and future changes in organic matter loading (Wollheim et al. 2014). At present, there are no existing approaches that permit us to understand how source-related changes in nutrient inputs are propagated spatially across the Delta and into the estuary.

Here we propose to develop a method for rapidly and inexpensively assessing nutrient dynamics in the Delta at the landscape scale. We envision that such a method may be incorporated into a monitoring program for the purpose of evaluating current conditions and the effects of prospective changes in wastewater discharge of nutrients.

Objective

The objective of this research effort is to develop the numerical analytical framework and companion field data collection techniques necessary to assess changes in nutrient dynamics across Delta aquatic landscapes as part of ongoing monitoring programs. The proposed approach leverages existing nutrient and water velocity time series to estimate spatial distributions and assess biological rates. This work is intended as a proof-of-concept /feasibility study.

Critical management need

Given that nutrient inputs to the Delta are expected to change significantly in the future as a consequence of planned modifications the Sacramento Regional WWTP as well as for other reasons mentioned above, monitoring programs such as those conducted by IEP, DWR, USGS, and the Delta RMP will benefit from the ability to rapidly and inexpensively assess nutrient attenuation across the aquatic landscape, and to identify in space and time the areas and processes related to that loss. The proposed work is aimed at developing this capability and must be completed in advance of the planned WWTP upgrade to permit data collection prior to, during and subsequent to the upgrade.

Approach

The proposed approach is to quantify the difference between the spatial distribution in nutrient concentrations that may be "expected" if nutrients were transported conservatively purely by advection (by the tidal currents), and the actual measured spatial distribution of nutrients. The deviation between these two is a quantitative indication of the extent to which biological processes are attenuating nutrients during transport. Resulting maps of the magnitude of the deviation define the spatial extent of effects and locate areas exhibiting elevated demand. The approach relies on continuous concurrent measurements of nutrient concentrations and water velocity to construct an estimate of the "expected" spatial distribution of nutrients based on the assumption of pure advection. The actual "observed" distribution of nutrients is obtained via a vessel conducting continuous onboard measurements while moving at high speed across the measurement frame during slack tide (Fichot et al. 2015; Downing et al. 2016; Wollheim et al. 2014). This approach has previously used to successfully estimate the location and extent of primary production in an estuary using dissolved oxygen (Vallino, Hopkinson, and Garritt 2005), and for production of CO_2 in lakes (Crawford et al. 2015). While we are adapting the approach to focus on nutrients – we hope to add the capability to assess primary production using this method in the near future.

Characterization of “observed” concentration field

Central to this approach is the ability to rapidly collect high-quality and high-spatial-resolution nutrient concentration data. The approach is to make high frequency (1/sec) measurements from a high-speed boat across the measurement frame. This is made possible through the recent development of a boat-mounted flow-through sampling system that can be operated at high speeds (~20 mph), permitting rapid collection of high-quality measurements over large regions, within the context of a single tide (Fichot et al., 2014; Downing et al., 2016). The resulting data is then mapped to the simultaneously-collected geopositional data (GPS) to generate maps with high spatial resolution (Figure 1). USGS has previously demonstrated that these measurements are useful for calibration of remote sensing data (Fichot et al., 2014) and for calculation of environmental reaction rates over residence time gradients (Downing et al., 2016). On-board measurements will include ones for nitrate, ammonium, temperature, conductivity, dissolved oxygen, chlorophyll-a, blue-green algal pigments, and others.

Also key to this effort is the USBR-funded Delta nutrient monitoring network which collects continuous nutrient data at high frequency at key locations within the Delta, which also provides observed conditions, but at a coarser spatial scale. Continuous measurements of water quality in the Delta have provided a new window into the gap between discrete monthly measurements, continuous habitat quality information, and linkages between nearby sites in the estuary (Downing et al. 2009; Bergamaschi et al. 2012). The existence of these stations provides the foundational data necessary for calculating nutrient concentrations of water passing into the study area. Station measurements will include nitrate, ammonium, temperature, conductivity, dissolved oxygen, chlorophyll-a, blue-green algal pigments, and others.

While boat transects provide the ability to identify zones of nutrient cycling at high spatial resolution periodically, the nutrient monitoring network provides the ability to calculate cycling continuously, serving as a sentinel of changing conditions in the Delta and estuary.

Modeling of “expected” concentration field

The idea behind this proposal is that instead of developing the expected concentration using a full numerical model as has been done previously for oxygen (Vallino, Hopkinson, and Garritt 2005), it can be modeled rapidly, inexpensively and – eventually – in an automated fashion using data from the existing flow measurement network in which the USGS and DWR collect flow (stage, velocity, discharge) data. Currently, we are interpolating constituent values between stations onto a grid as is shown in Figure 3, which we have implemented in real-time on the Bay/Delta Live (BDL) website (see http://www.bayDeltalive.com/skip/home.blue.tpl/home.blue.tpl). Figure 3 shows the salt field during the drought, using salinity as an example, but linear interpolation to a grid can be done for any constituent, provided there is adequate coverage.

Spatial distribution plots like those in Figure 3 show that constituent distributions in the Delta can be conceptually thought of as coherent, well-behaved fields – the dispersion terms in the transport equations virtually guarantee this (discussed shortly). Moreover, animations of constituent field movements available from BDL show that that vast majority of the tidal-timescale constituent variability measured at a fixed sites is the result of a slowly varying (> tidal timescale) constituent field sloshing back and forth past our sensors with the tidal currents. Thus, the majority of tidal timescale variability in constituent time series occurs because spatial constituent gradients significantly vary over the tidal excursion. The tidal excursion is the distance a neutrally buoyant particle travels in ½ tide cycle ~ 6 hours). Figure 4 shows that the tidal excursions can be quite long relative to the channel length, especially in the western Delta where the tidal excursions are on the order of 8 miles. While interpolation can yield the approximate spatial distribution of constituents (Figure 3), the true details of the gradients in the constituent fields can significantly deviate from interpolation because of fronts and other physical attributes of the flow field.

In this study, we propose to explore using a combination of the 1D transport equation (discussed shortly) and data assimilation (also discussed shortly) to fill in the details of the spatial structure in constituent fields between sampling stations in the Delta.

Given the complexity of the Delta's geometry – a network of interconnected canals – we anticipate that this approach will not work well everywhere. However, it is highly likely it will work within significant portions of the Delta, especially in the northern Delta, because the assumptions inherent in the 1D transport equation are likely met at tidal timescales (< 6 hours) and at the distances between stations, which are, in many cases, less than the tidal excursion (by design).

Modeling Approach

Coupling data with the 1D transport equation to improve prediction of constituent spatial distributions

The 1D transport equation is

$$\frac{\partial c}{\partial t} = -u(e)\frac{\partial c}{\partial x} + D\frac{\partial^2 c}{\partial x^2} + S \qquad (1)$$

Where *c* is the concentration of a generic constituent, *t* is time, *u*(*e*) is the Eulerian, or fixed site current speed, *x* is the along channel direction and *S* is a source and/or sink term. Although it may be possible to estimate S from fixed site data based on differencing the estimates of the other three terms, especially when $D\frac{\partial^2 c}{\partial x^2}$ is small (this is often true in many of the narrow channels in the delta) compared to S. The high speed transects will provide the data to quantify S in order to make comparisons with fixed site estimates to see where and when the fixed site estimates are reasonable (if at all). Fixed site estimates may work well during blooms, often the period of greatest interest, because S is as large as it gets relative to the other terms in equation (1)..

The justification for using the 1D transport equation as opposed to the full 3D Shallow water equations is the channels in the Delta are functionally canals – narrow, prismatic channels, with minimal natural geomorphologic bathymetric variability. Moreover, our intent is to extend the usefulness of the data presently collected at current monitoring stations for management decisions: to provide a regional scale perspective on how the system is functioning that obviates the need to examine dozens of time series plots. The basic idea is to combine velocity data with constituent data already being collected at the same station to provide: (1) spatial maps to managers of constituent fields that include the best, though perhaps not exact, representation of gradients (e.g. compensate for the "smearing" of the gradients when we use linear interpolation to estimate the constituent fields as is shown in figure 3), (2) spatial maps registered to a constant point in tide (at slack water), that, when strung together over days (say over the 14 day spring/neap cycle), will provide estimates of the tidally averaged (net) movement of constituent fields, (3) estimate, where possible, the dispersion term ($D\frac{\partial^2 c}{\partial x^2}$, based on specific conductance, or some other conservative tracer. For conservative constituents, the source/sink term, S in Eq. (1), is zero. The fixed site data do not support a multi-dimensional approach because, among other things, the constituent data are point measurements typically made near the bank. Lateral and vertical variability are simply not measured, though vertical and lateral transects taken at a variety of locations in the delta have shown this variability is generally small, an additional argument for the use of Eq. (1).

For most constituents, in most places in the Delta, transport at tidal timescales is advection dominated (Figure 5). In terms of the equation 1, this means that dispersive processes, $D\frac{\partial^2 c}{\partial x^2}$, and variations due to sources and sinks are relatively small compared to advection, or

$$\frac{\partial c}{\partial t} \approx -u(e)\frac{\partial c}{\partial x} \qquad (2)$$

Equation (2) shows that the temporal variability in a constituent measured at a fixed site ($\frac{\partial c}{\partial t}$) is mostly due to ($\approx$) the currents ($-u(e)$) pushing a spatial distribution ($\frac{\partial c}{\partial x}$) past our site. We know this, in part, because the constituent extremes (maximum and minimum) and tidal current maximums are in quadrature (e.g. 90 degrees out of phase). In other words, the constituent maxima and minima typically occur at slack tide. Whether the minimum or maximum occurs at slack after ebb or slack after flood depends on the sign of the gradient (i.e. increases up or down estuary).

Equation 2 tells us we can make a first-pass estimate of constituent spatial distributions within a tidal excursion of our measurement locations by combining constituent concentrations and velocity measurements, but, the estimate can be significantly in error. The magnitude of the error will depend on how well the Eulerian fixed site velocity represents the Lagrangian velocity along the tidal excursion trajectory and the relative importance of the neglected terms in Eq.(1). However, these estimates can be improved based on an understanding of the in the impacts dropping terms in Eq.(1).

We will use several techniques, based on scaling arguments, to improve the initial estimates, which will be based on advection alone, Eq. (2). These techniques should work well when measurement locations are less than a tidal excursion apart, resulting in an overlap in measured values. This overlap can be used to calibrate and verify the relationships used to predict the spatial structure between stations using conservative constituents. These techniques may also be used for permanent measurement stations that are separated by greater than a tidal excursion for conservative constituents or for sources and sinks whose characteristic timescales are much longer than the tidal timescale of 6 hours, if temporary autonomous measurement stations are deployed for short durations between the permanent stations to validate assumptions.

Technique 1 – Euler-Lagrange transformation

We know measurement of the velocity of a water parcel measured at a fixed site, $u(e)$ – an Eulerian velocity – does not necessarily represent the velocity that water parcels experience as they travel between sites. The velocity of the water parcel as it travels along its' flow path between sites is called the Lagrangian velocity. So an Eulerian/Lagrangian transformation for each measurement location – essentially a relationship between the fixed site velocity measurements and the velocity a parcel of water experiences – may be used to improve estimates. This can be done using the timing of a high-gradient front at each station to deduce the tidal excursion integrated Lagrangian velocity for stations within a tidal excursion. In some cases, it may be more accurate to use drifter experiments. In either case, given that the bathymetry in the Delta is fairly static, these relationships should be relatively static in time; although they may need to be updated after a large flood, but not every year.

Technique 2 – Use of a conservative tracer

Once the Euler-Lagrangian transformation at a station is determined, the continuous time series of conductivity -- a conservative tracer (e.g. no *S* term in equation 1) -- may be used to determine the dispersive term $D\frac{\partial^2 c}{\partial x^2}$. If the timing of the peak of the front of a conservative tracer measured at one site matches the arrival time of the peak of the same front at a down current site, then a correction based on the second derivative of the spatial distribution may be made to account for differences in the shape of the front because dispersion does not affect arrival timing, only advection does.

Technique 3 – Data assimilation or pattern matching
If the tidal excursion is longer than the distance between stations, pattern matching could be used to conform the predicted spatial structure from an upcurrent site to the actual measurements made at the down-current site. In other words, change the shape and timing of the predicted spatial structure at the downstream site by applying empirical corrections. For example, if the peaks in a front arrive early at the down current site compared to the measured data there, then the Lagrangian current speed needs to be slower between stations. Similarly, if the concentration is lower at the down–current measurement location a dispersive or sink term correction may be appropriate. Conversely, if the concentration at a down-current site is greater, a source term may be appropriate.

Study area and field measurements

Two study areas were chosen for this proof-of-concept study to represent areas at the extremes of anticipated transit times. The study areas are the region between Freeport and Isleton on the Sacramento River, and the region of the lower Cache Slough and Sacramento River defined by the stations at Cache Slough at Liberty Island, and Sacramento River at Decker Island. As an alternative, we may elect to use the reach between Decker Island and Mallard Island, depending on availability of data.

Transects collecting the high-frequency boat-based measurements will be conducted twice, once in July and once in October 2017, corresponding to periods of high nutrient transformation based on analysis of historical data (Novick et al., 2015).

Timeline

Development of numerical methods will begin immediately upon commencement of the project. Transect data will be collected in July 2017 and October 2017, focusing on low flow periods. Data will be analyzed immediately after collection and maps will be available to interested parties. Draft deliverables will be available 12 months after commencement of the project.

Deliverables

The primary expected deliverable from this project will be a USGS technical series publication or a journal article, as appropriate. Additional deliverables will be maps and data generated by the project.

Budget

WAGES AND BENEFITS	COSTS
PI 1	$66,200
PI 2	$20,000
PI 3	$55,000
Lead Tech	$5,000
Chemist	$2,600
Data Specialist	$5,100
Tech	$1,000
OTHER	
Laboratory analyses	$2,000
Boat Costs	$1,000
Vehicle Costs	$400
Supplies	$1,900
Travel	$7,600
USGS COOP Matching Funds	**($14,800)**
Total Request	**$153,000**

Budget Justification

Wages and benefits are requested for personnel associated with project.

Analytical costs are for analysis of 30 field validation samples.

Travel costs are for field travel, and travel to a conference to present results.

Boat and vehicle costs are to support field activities associated with project.

No honoraria or equipment purchases are anticipated.

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Figures

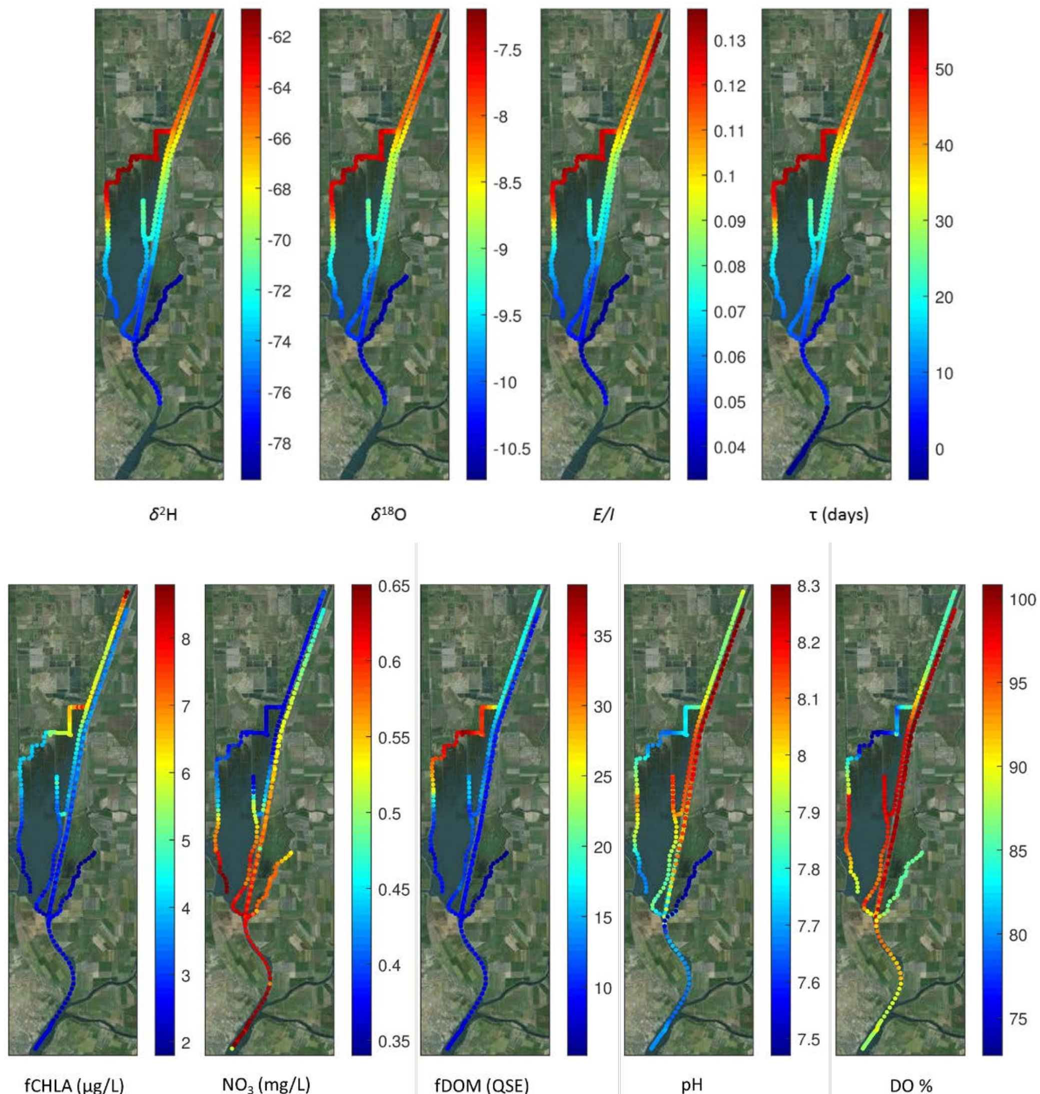

Figure 1. Maps showing results of high speed collection of water isotopes, which permits calculation of evaporation rates and ultimately, water residence times (top).Maps showing measured water quality parameters (fCHLA, NO3, fDOM, pH and DO saturation; bottom).

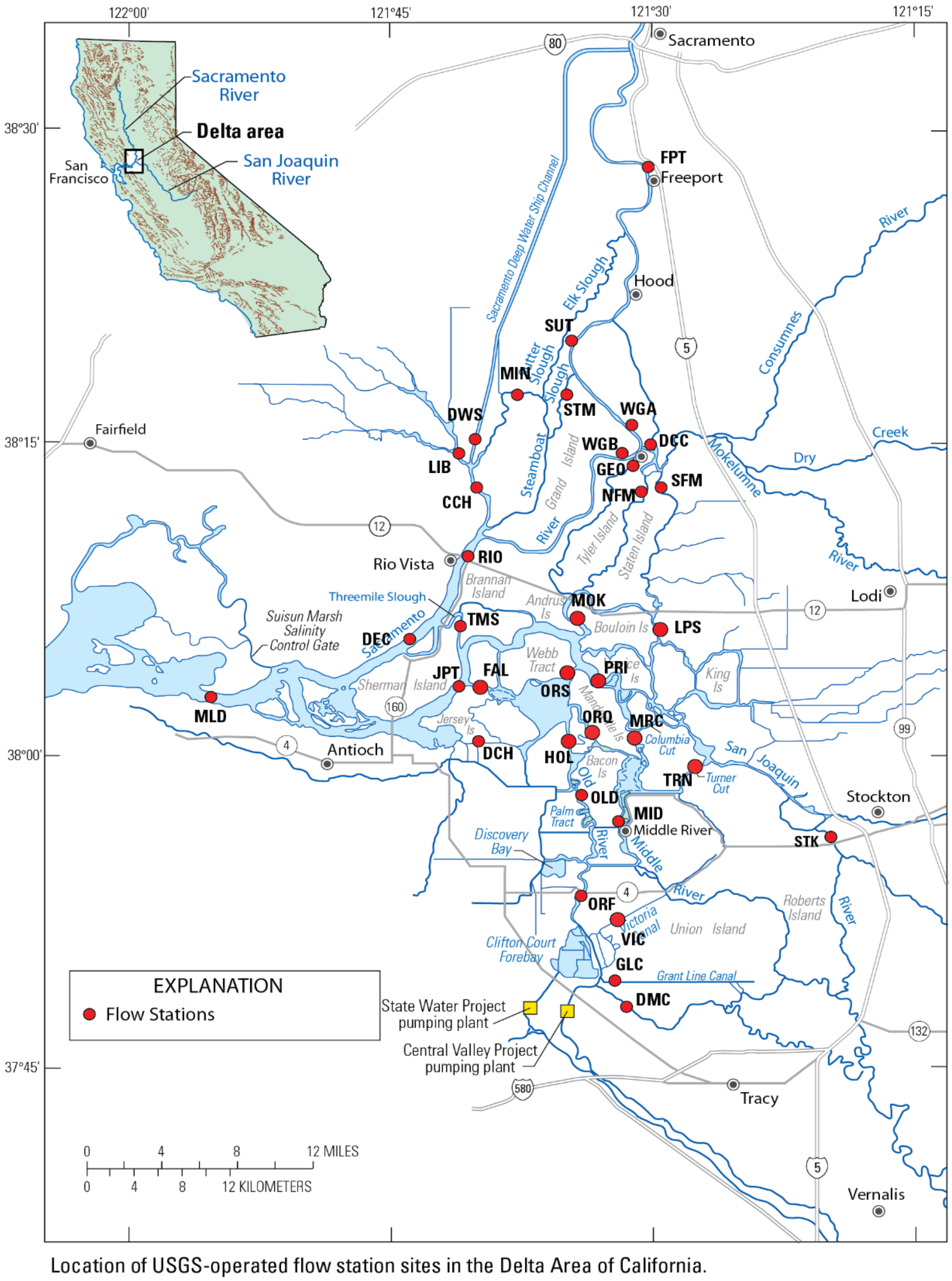

Figure 2 - Location of USGS fixed site flow and water quality sampling locations.

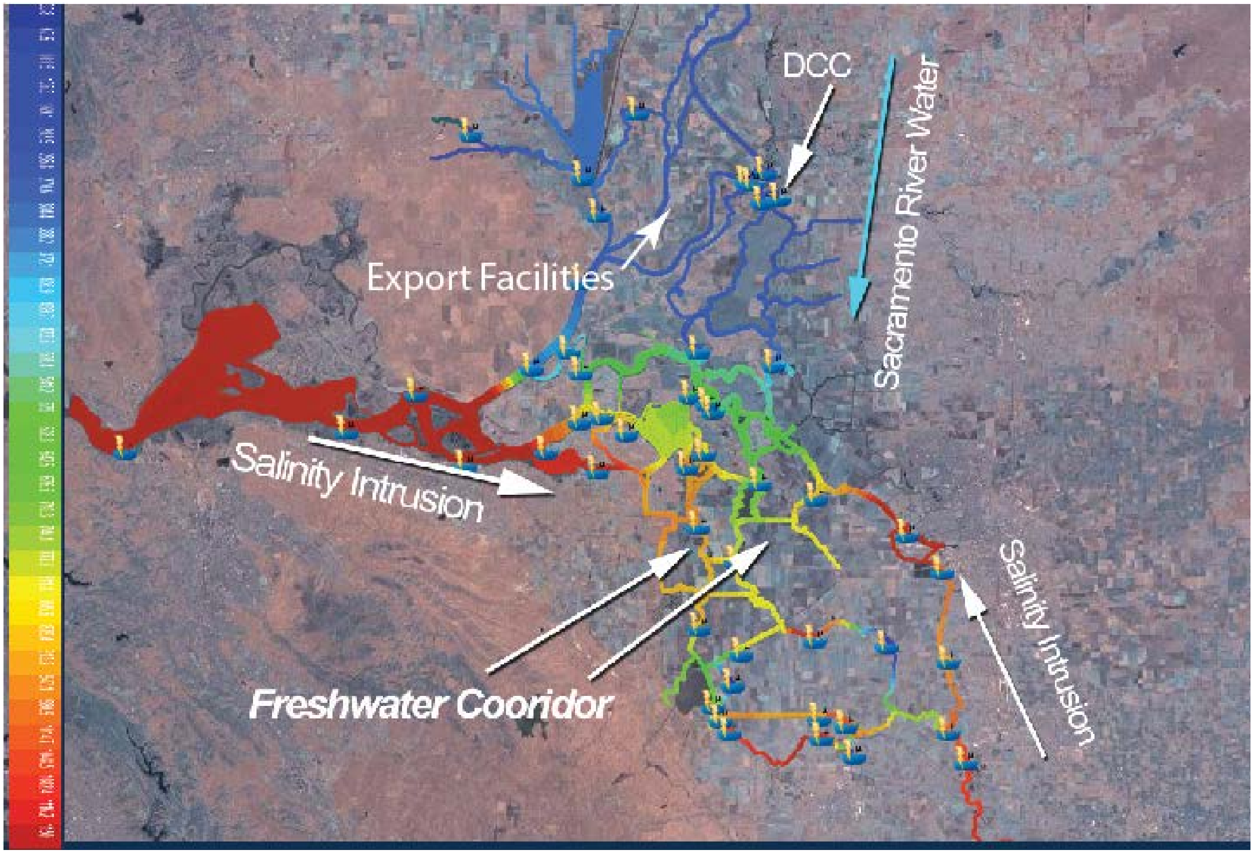

Figure 3 - Color map of the salt field based on linear interpolation between sampling stations (shown as "lightning bolts" (courtesy of 34North).

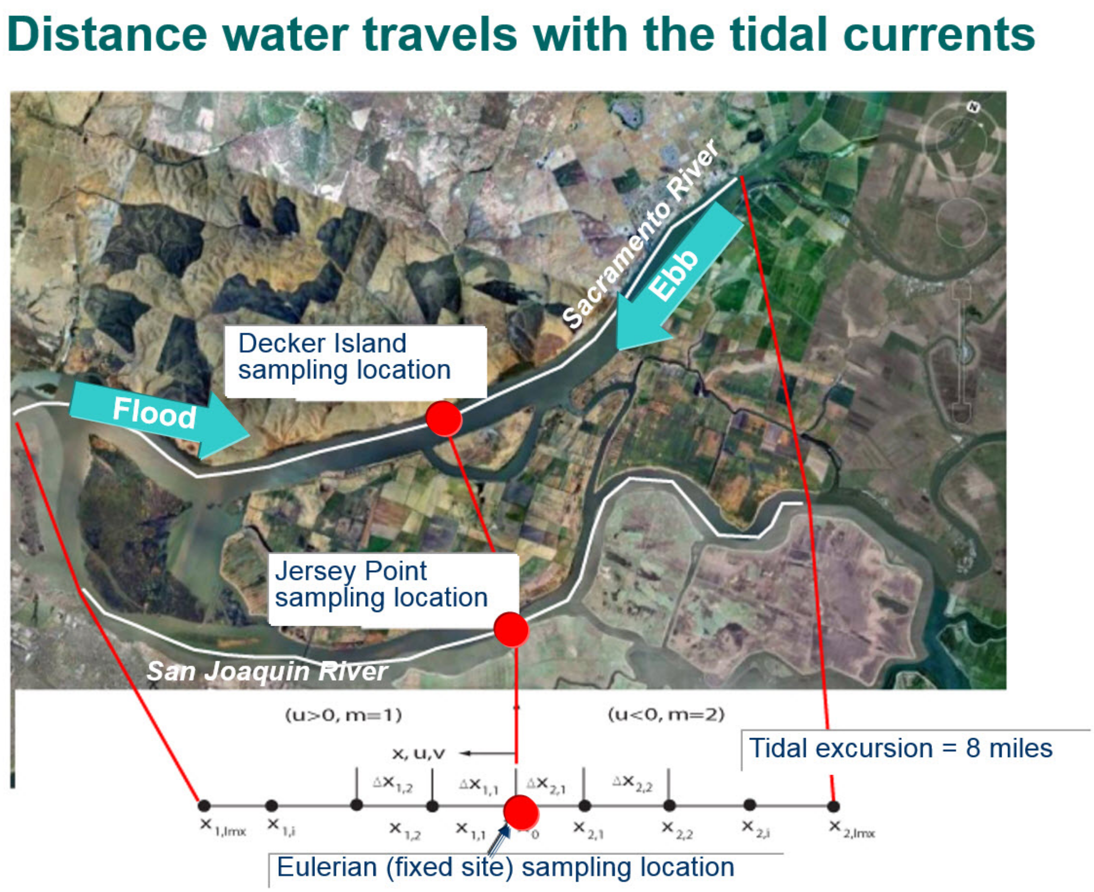

Figure 4 - Example tidal excursions in the western Delta, for a sampling location at Jersey Point and at Decker Island. A Lagrangian grid shown at the bottom of the figure based on the time integral of the local velocity at time steps since slack water.

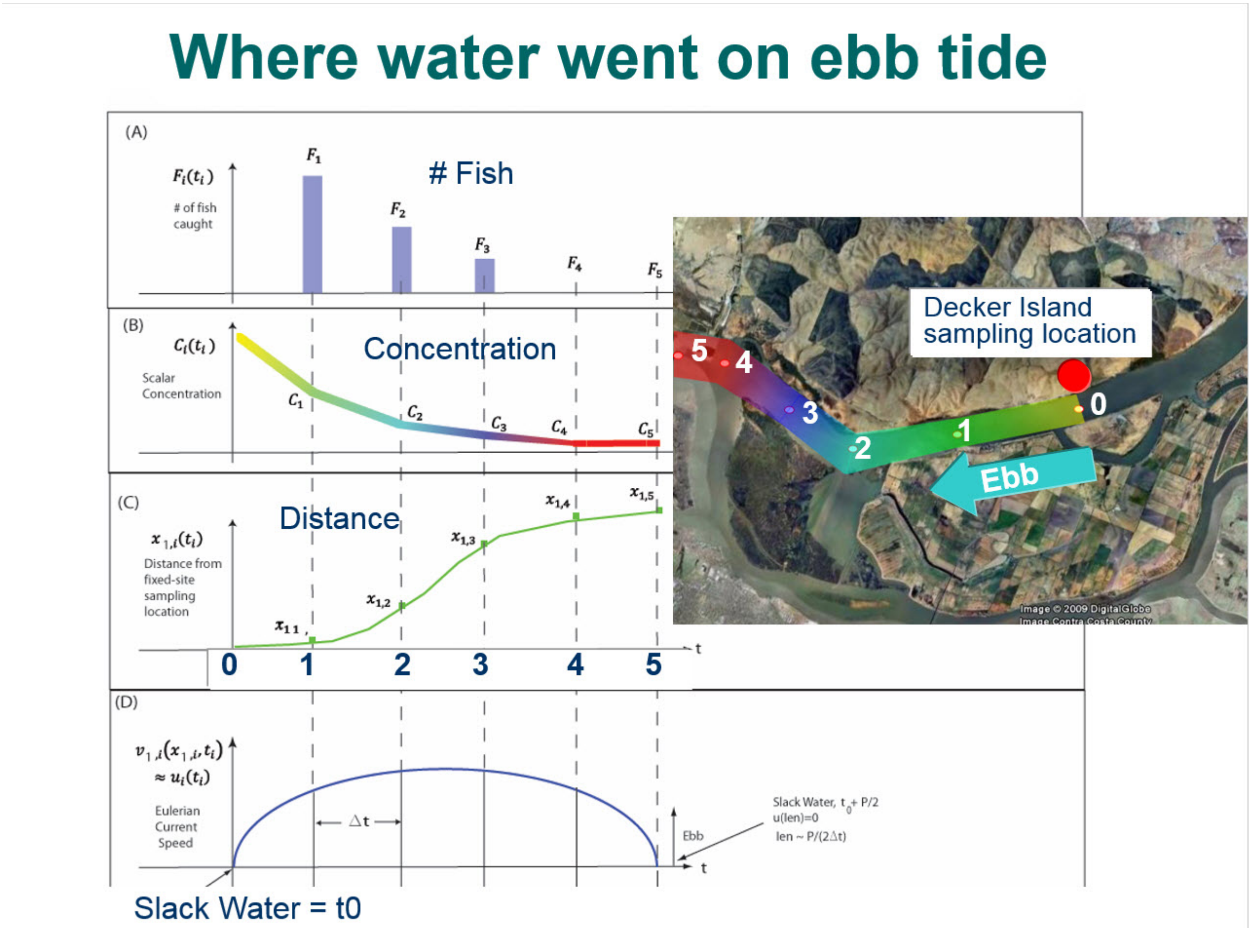

Figure 5 - A conceptual example of where water and constituents in the water went on an ebb tide, shown on map, based on time series measurements of velocity (e.g. advection) and a constituent (time series measurements shown on left). This figure assumes that the highest concentrations (shown in color with red representing the greatest concentrations) are seaward of Decker Island (think salt field).

Resumes *(alphabetical order)*

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APPOINTMENTS:

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RECENT AND RELEVANT PUBLICATIONS:

Fichot, C. G., B. D. Downing, B. A. Bergamaschi, L. Windham-Myers, M. Marvin-DiPasquale, D. R. Thompson, and M. M. Gierach (2015), High-Resolution Remote Sensing of Water Quality in the San Francisco Bay–Delta Estuary, Environmental Science & Technology, doi:10.1021/acs.est.5b03518.

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CURRENT SYNERGISTIC FIELD ACTIVITIES:

1) PROJECT TITLE: The USGS Aquatic Real Time habitat and water quality network. FUNDING SOURCE: Various

2) PROJECT TITLE: Interactions between physical processes and suspended sediment quality in relation to spawning migrations of delta smelt. FUNDING SOURCE: US Fish and Wildlife

3) PROJECT TITLE: Dynamics of zooplankton in the Cache Slough Complex (Kimmerer lead PI). FUNDING SOURCE: SFCWA

RECENT ACADEMIC COLLABORATORS:

Emmanuel Boss (University of Maine); Alexander Parker (California Maritime Academy); Cedric Fichot (JPL); Frances Wilkerson (Romberg Tiburon Center, SFSU); Julien Moderan (Romberg Tiburon Center, SFSU); Peter Hernes (UCDavis); Richard Dugdale (Romberg Tiburon Center, SFSU); Thomas Harter (UCDavis,); William Horwath (UCDavis); Wim Kimmerer (Romberg Tiburon Center, SFSU).

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BRIEF BIO

Jon Burau is a project chief with the Water Resources division of the U.S. Geological Survey in Sacramento. He received his formal training at UC Davis and at Stanford University in environmental fluid mechanics and has spent over 30 years monitoring and studying transport processes in San Francisco Bay and the Delta using analysis of field data and numerical models. As the hydrodynamics project chief, he oversees a staff of roughly 20 who, among other things, operate and maintain approximately 50 flow and water quality stations in the Delta

SELECTED PUBLICATIONS (Emphasis on Collaborative Research)

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PRIMARY RESEARCH INTEREST

My principle interest is in the study of nutrients and organic matter (dissolved and particulate) to better understand its impact on ecosystem function. My research involves the use of in-situ, high frequency sensor and laboratory measurements to better understand complex biogeochemical cycling of nutrients and organic matter in rivers, estuaries and the coastal ocean. Measuring water quality using optical sensor technology represents a significant new direction in water quality research, where cycling of nutrients and organic matter can be measured in-situ, on time scales ranging from seconds to years.

EDUCATION

2004 M.S., CA State University Sacramento, H ydrogeology/Geology. 2002 B.S., CA State University Sacramento, Geology.

PROFESSIONAL EXPERIENCE

1999 – Present: Research Hydrologist (RGE), USGS, CA Water Science Center, Sacramento.

PUBLICATIONS

Saraceno, J.F., Shanley, J.B, and Downing, B.D., 2016. Clearing the waters: Progress on turbidity corrections to field fluorescence measurements. Limnology and Oceanography. DOI:10.1002/lom3.10175

Kraus, T.E.C., K.D. Carpenter, B.A. Bergamaschi, A.E. Parker, E.B. Stumpner, B.D. Downing, N. M. Travis, F.P. Wilkerson, C. Kendall, and T.D. Mussen, 2017. A river-scale Lagrangian experiment examining controls on phytoplankton dynamics in the presence and absence of treated wastewater effluent high in ammonium. Limnology and Oceanography. DOI: 10.1002/lno.10497

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Byrd, K.B., Windham-Myers, L., Leeuw, T., Downing, B., Morris, J.T., & Ferner, M.C. (2016). Forecasting tidal marsh elevation and habitat change through fusion of Earth observations and a process model. Ecosphere, 7(11), e01582. doi:10.1002/ecs2.1582

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Spencer R.G.M, Pellerin, B.A., Bergamaschi, B.A., Downing, B.D., Kraus, T.E.C., Smart, D.R., Dahlgren, R.A., and Hernes, P.J. 2007. Diurnal variability in riverine dissolved organic matter composition determined by in situ optical measurement in the San Joaquin River (California, USA). Hydrol. Process.: 21, 3181-3189.

CLASSES HELD / INSTRUCTION

2011 – USGS/CUAHSI Sensor Workshop: In Situ Optical Water Quality Sensor Networks. June 8-10, 2011 at the National Conservation Training Center Shepherdstown, West Virginia.
2009 - CUAHSI/USGS/UVM Sensor Workshop: In situ Optical Sensors for Water Quality. August 2-5, 2009 at the Rubenstein Ecosystem Science Laboratory, University of Vermont, Burlington, Vermont. Sponsored by CUAHSI, USGS, and UVM.
2008 - Earth Science Geology 8, CA State University Sacramento. 3 lecture units.
2006 - Earth Science Geology 8, CA State University Sacramento. 4 lecture units.
2005 - Earth Science Laboratory, Geology 8L, CA State University Sacramento. 2 lecture units

CURRENT MEMBERSHIPS IN PROFESSIONAL SOCIETIES

- American Chemical Society (ACS)
- Association for the Sciences of Limnology and Oceanography (ASLO)
- American Geophysical Union (AGU)
- American Association for the Advancement of Science (AAAS)
- Coastal Estuarine Research Federation (CERF)

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EDUCATION

M.I.T.	Civil and Environmental Engineering	Ph.D.	*2001*
Rutgers University	Civil and Environmental Engineering	B.S.	*1992*

PROFESSIONAL EXPERIENCE

San Francisco Estuary Institute *2011-present*
Richmond, CA
Senior Scientist, Co-Director of Clean Water
Program Lead Scientist, SFB Nutrient Management Strategy

Swiss Federal Institute of Technology (ETH-Zürich) and *2007-2011*
Swiss Federal Institute of Aquatic Science and Technology (EAWAG)
Zurich, Switzerland
Senior Researcher

Harvard School of Public Health *2001-2007*
Department of Environmental Health
Research Fellow (2001-2002), Research Associate (2002-2007),
Center Scientist - Center for Children's Environmental Health (2004-2006)

Massachusetts Institute of Technology *1995-2001*
Department of Civil and Environmental Engineering
Research Assistant

University of New Orleans *1994-1995*
Department of Civil and Environmental Engineering
Research Associate

Orleans Parish Public Schools, New Orleans LA *1992-1994*
Teacher: sixth, seventh, and eighth grade mathematics

MAJOR PROJECTS and PAST FUNDING EXAMPLES

Nutrient Management Strategy for San Francisco Bay, PI: DB Senn ~$4.0mill 2012-present; ~$1.4 mill/yr anticipated 2017-2019

Foundation for the Study of Lake Geneva, *Real-time mapping and measurement of methane ebullition and fate in the River Rhone Delta, Lake Geneva*, PI: DB Senn; $190,000 (2011-2012)

Competence Center Environment and Sustainability (CCES), *African Dams Project (ADAPT): Adapt planning and operation of large dams to social needs and environmental constraints - an integrated water resource management study in the Zambezi Basin,* co-PI:DB Senn; $1.4mill (project period: 2007-2011)

US National Science Foundation (NSF) –*Impact of Hurricanes on Mercury Biogeochemistry and Methylation in the Gulf of Mexico* PI: DB Senn, jointly with RP Mason (UConn) $180,000 (project period: 2005-2007)

NOAA Oceans and Human Health Initiative, *Coastal Eutrophication:Implications for Mercury Methylation, Mercury Biomagnification, and Human Health.* PI: DB Senn; $830,000 (project period: 2004-2008)

SELECTED PEER REVIEWED PUBLICATIONS (* D Senn as PI)

*Liu B, LA Schaider, RP Mason, NN Rabalais, JP Shine, DB Senn (2015) Controls on methylmercury accumulation in northern Gulf of Mexico sediments, Estuarine, Coastal, and Shelf Science. 159: 50-59, doi:10.1016/j.ecss.2015.03.030

Schaider LA, DB Senn, ER. Estes, DJ. Brabander, JP Shine (2014) Sources and fates of heavy metals in a mining-impacted stream: Temporal variability and the role of iron oxides. Science of The Total Environment, 490: 456-466, http://dx.doi.org/10.1016/j.scitotenv.2014.04.126.

Kunz MJ, DB Senn, B Wehrli, EM Mwelwa, A Wüest (2013) Optimizing turbine withdrawal from a tropical reservoir for improved water quality in downstream wetlands. Water Resources Research,49(9): 5570-5584. doi: 10.1002/wrcr.20358

*Blank N, AG Hudsun, P Vonlanthen, O Seehausen, CR Hammerschmidt, DB Senn (2013) Speciation leads to divergent methylmercury accumulation in sympatric whitefish. Aquatic Sciences, doi:10.1007/s00027-012-0271-6

*Zurbrügg R, S Suter, MF Lehmann, N Blank, B Wehrli, DB Senn. (2013) Organic C and N export from a tropical dam-impacted floodplain system (Kafue Flats, Zambia) Biogeochemistry 10(1):23-38. doi:10.5194/bg- 10-23-2013.

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*Kunz M, A Wueest, B Wehrli, J Landert, DB Senn (2011) Impact of a large tropical reservoir on riverine transport of sediment, carbon, and nutrients to downstream wetlands. Water Resources Research 47(12), doi:10.1029/2011WR010996

*DelSontro T, MJ Kunz, T Kempter, A Wueest, B Wehrli, DB Senn (2011) Spatial heterogeneity of methane ebullition in a large tropical reservoir. Environmental Science & Technology. 45 (23), 9866-9873. doi:10.1021/es2005545

*Kunz M, A Vollenweider, FS Anselmetti, B Wehrli, A Wüest, DB Senn (2011) Sediment accumulation and carbon, nitrogen, and phosphorous deposition in the large tropical reservoir Lake Kariba (Zambia/Zimbabwe). JGR-Biogeosciences. G03003, doi:10.1029/2010JG001538.

*Lincoln R, JP Shine, EJChesney, DJ Vorhees, P Grandjean, DB Senn (2011) Methyl-mercury exposure among recreational anglers in coastal Louisiana Environmental Health Perspectives, 119:245–251 doi: 10.1289/ehp.1002609

*Senn DB, EJ Chesney, JD Blum, MS Bank, A Maage, JP Shine (2010) Stable isotope (N, C, Hg) study of methylmercury sources and trophic transfer in the northern Gulf of Mexico. Environmental Science & Technology. doi: 10.1021/es902361j

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*MS Bank, EJ Chesney, JP Shine, A Maage, DB Senn (2007) Mercury bioaccumulation and trophic transfer in sympatric snapper species from the Gulf of Mexico. Ecological Applications 17(7)

Senn, DB, JE Gawel, JA Jay, HF Hemond, JL Durant (2007) Long-term fate of a pulse arsenic input to a eutrophic lake. Environmental Science & Technology 41(9): 3062 -3068.

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Senn DB, S Griscom, C Lewis, J Galvin, M Chang, JP Shine (2004) Equilibrium sampler for determining copper free metal ion concentration. Environmental Science & Technology 38(12):3381-3386.

Senn DB, HF Hemond (2002) Nitrate controls on iron and arsenic in an urban lake. Science 296: 2373-2376.