It's the Economy, Stupid: How the Great Recession May Increase the Risk of Shipping-Mediated Introductions of Nonindigenous Species into the San Francisco Bay-Delta

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Commercial shipping activity is recognized as a major pathway for the introduction of nonindigenous species (NIS) into coastal waters around the globe, including the San Francisco Bay-Delta (SFBD). Ship biofouling (i.e. the attachment or association of aquatic organisms to underwater ship surfaces) has been identified as the most potent coastal vector of species introductions in many parts of the world and, unlike ship ballast water, biofouling is often unregulated.

A major side-effect of the recent Great Recession was a dramatic reduction in shipping activity resulting from fewer goods being purchased and shipped around the globe. Many ships were effectively unemployed, waiting at anchor in long-term layup for a rebounding economy and more goods to deliver. For those vessels that continued to trade during the recession, the fuel saving practice of "slow steaming" (i.e. traveling slower to reduce overall fuel consumption) became more commonplace, and continues for many vessels through the economic recovery today. Unfortunately, the practices of remaining stationary for prolonged periods of time in coastal environments and traveling at slow speeds increase the likelihood of biofouling accumulation and organism survival on ships. The prevalence of these practices was evaluated for ships arriving to ports within the SFBD using ship-reported data submitted annually from 2008-2013. An annual increase in the number and duration of extended residency periods, as well as a year-over-year reduction in the mean traveling speed of vessels that have arrived at ports within the SFBD was observed. These recession-exacerbated risk factors are likely increasing the probability of biofouling colonization on ships and the transportation of NIS into California. These results are being used to inform the development and eventual implementation of biofouling management regulations to reduce the likelihood of biofouling-mediated introductions of NIS into California.

Keywords: Nonindigenous, invasive, species, shipping, biofouling, hull, vector, slow steaming, layup
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Projected Impacts of Climate, Urbanization, and Water Management on Waterfowl Habitats and Ecology in California

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The Central Valley (CV) of California contains some of the most important habitats for waterfowl, shorebirds, and other waterbirds in North America. Most waterbird habitats in the CV, which include wetlands, flooded rice fields, and other agricultural lands rely on managed surface water supplies stored in reservoirs and delivered via a complex system to a wide array of competing water users. Water supplies vary with snow pack, temperature, and precipitation, all of which are projected to change substantially under some global climate models; land use and water management can also greatly impact water supplies. Waterbird food availability, which varies with the area, timing, and productivity of habitats, is a key factor limiting waterbirds during migration and winter affecting body condition and other aspects of their ecology. Thus, the Central Valley Joint Venture (CVJV) uses a food energy (bioenergetics) modeling approach to establish habitat conservation objectives for each CV basin. We developed necessary data and adapted a CV Water Evaluation and Planning (WEAP) model to investigate impacts of various climate, urbanization, and water management scenarios on waterbird habitats and ecology. For each scenario, we modeled water supplies and demands in the adapted WEAP model and estimated resulting landscape change. The area and timing of supported waterbird habitats based on WEAP results was then included in a bioenergetics model to quantify potential waterfowl food deficits. Initial modeling results focusing on Butte Basin indicate that under some scenarios, water supplies will not be adequate to maintain habitat at the levels necessary to support CVJV goal populations of waterfowl and result in late-winter food deficits for waterfowl. We are currently evaluating additional water management scenarios and expanding our efforts into other CV regions.

Keywords: waterbirds, WEAP model, Central Valley, habitat, bioenergetics, CVJV, water supplies
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Agricultural Losses from Salinity in California's Sacramento-San Joaquin Delta

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Sea level rise, flooding, new exports infrastructure may increase future water salinity for local agricultural production in California's Sacramento-San Joaquin Delta. Increasing salinity in crop root zones often decreases crop yields and crop revenues. Salinity effects are nonlinear and vary with crop choice and other factors including drainage and residence time of irrigation water. We explore changes in agricultural production in the Delta under various combinations of water management, large-scale flooding and future sea level rise. Water export alternatives include through-Delta water exports, dual conveyance (through a peripheral tunnel or canal) and the flooding of five western islands with and without peripheral exports. We employ results from previous hydrodynamic simulations of likely changes in salinity for irrigation water at points in the Delta. We connect these irrigation water salinity values into a detailed agro-economic model of Delta agriculture to estimate local crop yield and farm revenue losses. Previous hydrodynamic modeling work shows that sea level rise is likely to increase salinity from 4% to 130% in this century, depending on the increase in sea level and location. Changes in water management under dual conveyance increase salinity mostly in the western Delta, and to a lesser extent in the north, where current salinity levels are now quite low. Because locations likely to experience the largest salinity increases already have a lower-value crop mix, the worst case losses are less than one percent of total Delta crop revenues. This result also holds for salinity increases from permanent flooding of western islands that serve as a salinity barrier. Salinity increases could have smaller economic effects on Delta farming than other changes in the Delta such as retirement of agricultural lands following large-scale flooding and habitat development. Integrating hydrodynamic, water salinity, and economic models can provide insights into controversial management issues.

Keywords: Salinity, Hydro-Economic Models, Agriculture; Habitat, Climate Change, Sea Level, Flooding
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Ensuing Delta Wetland Restoration Heightens Water Quality Concerns for Southern California… or Not?

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Delta carbon quality, cycling dynamics, and bioavailability are key considerations for fisheries restoration and for drinking water management. But what happens when Delta carbon is exported south? Will carbon exported from Delta habitat restoration efforts cause a surge in toxic disinfection byproducts in Southern California's drinking water supply? This is the final study in a series of investigations of organic carbon along California's State Water Project (SWP) aqueduct and associated reservoirs. The study traces an assembly of chemical biomarkers and other water quality parameters, including lignin derived phenols, fatty acids, stable carbon isotopes, bioavailability, disinfection byproduct formation potential, and others as they advect from the Delta through SWP facilities. Taken together, these parameters enable close examination of organic carbon degradation and production trends within the SWP.

Given the weeks-to-months residence time that Delta water spends in the SWP, plus major and minor algae blooms, photoxidation, bacterial degradation and assimilation, the study underscores the potentially significant roles of organic carbon production and degradation in the SWP. Carbon turnover appears to vary seasonally and based on flow rate/residence time within the SWP system. Periods of especially high carbon export from the Delta frequently (though not religiously) coincide with SWP management actions that support longer residence times – for example, routing of Delta water to storage during wet winter months. Key insights regarding Bay-Delta management and ecosystem sustainability include what appears to be at least a partial disconnect between Delta carbon export and the transport of Delta carbon to Southern California. At the same time, organic carbon production within the SWP may offset such losses.

Keywords: Delta, Restoration, Organic Carbon, Disinfection Byproduct, Carbon Export, Wetlands
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Operational Ecosystem Modeling to Support Adaptive Management – Lessons from 40 Years of Decision Support for the Great Lakes

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Problem statement: Managing large interconnected systems of water bodies presents complex challenges; model simulations are essential to assessing causes of ecological outcomes, and effects of changes in management and ambient conditions. For many years, the Great Lakes community has used models to support management. Models were used reactively in the 1970s to develop target phosphorus loads to address eutrophication, the adoption of which in the Great Lakes Water Quality Agreement (GLWQA) restored the health of the Lakes. The reemergence of eutrophication in response to the introduction of invasive species has made apparent the limitations of reactive approaches.

Approach: To stay abreast of emerging problems, proactive adaptive management is needed. Scenario-type ecological forecasts can support adaptive management, simulating operational actions using integrated ecosystem models. Models that integrate flows, water chemistry, and ecological outcomes translate data into understanding and support decisions through simulation of management alternatives. An "Operational Ecosystem Modeling" approach has been developed for Saginaw Bay in Lake Huron on behalf of NOAA to help meet the requirements of the GLWQA 2012 Protocol, which calls for adaptive management to deal with harmful algal blooms.

Results: Invasive dreissenids play an important role through their impact on light, plankton production, and phosphorus cycling, but the key is reducing nonpoint source loads of bioavailable phosphorus. The scenario simulations show that phosphorus load reductions on the order of 50 - 75% are needed to reduce harmful algal blooms to acceptable levels.

Conclusions/Relevance: The complexity of the Bay Delta system presents similar challenges. Adaptive management is critical for this system, given climate change and other uncertainties, and can be supported by operational ecosystem modeling to help understand outcomes and recalibrate actions as the system responds. The presentation will provide real-world lessons learned about the potential power of integrated modeling as part of an adaptive management approach.

Keywords: Adaptive Management, Decision Support, Invasive Species, Eutrophication, Operational Ecosystem Modeling
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Reconciling Fish, Farms and Fowl on the Yolo Bypass

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Traditional habitat restoration that attempts to recreate pre-development conditions within a protected area is no longer possible at large enough geographic scales in California for the diversity of native species that currently lack sustainable habitats. Reconciliation ecology recognizes this reality and encourages land and water managers to re-engineer human-dominated landscapes to be more inclusive of native species' preferences without eliminating human uses. California's Yolo Bypass, an engineered floodplain on the Sacramento River, is an excellent case study for this new approach to native species management. This talk presents results from a multi-objective analysis of the Yolo Bypass to suggest approaches that balance economic and ecological objectives for a wide array of species. Results suggest that significant habitat improvement is possible with little annual economic losses for farmers, and further that agricultural land uses can prove important and useful in the habitat mosaic for fish and birds on the bypass.

Keywords: floodplain, reconciliation, multiobjective modeling, Yolo Bypass
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Fish, Farms, and Fowl on the Yolo Bypass: Measuring the Benefits and Impacts of Floodplain Restoration

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The Yolo bypass is a multi-benefit flood management facility intentionally managed to reduce flood risk for Sacramento, provide habitat for migratory birds, and produce agricultural crops. Research demonstrating the value of inundated floodplain for juvenile salmon has led state and federal agencies to consider changes to Fremont Weir that would allow active management of the bypass for fisheries benefits in addition to its other purposes. Fremont Weir is a 1.75 mile-long, seven-foot high concrete structure located at the upstream end of the Yolo Bypass, which passively allows water to flow into the bypass only when the stage of the Sacramento River exceeds 33.5 feet – the elevation of the weir crest. State and federal planners are now evaluating designs that would create an operable, gated-opening in Fremont Weir to allow fish and floodwaters onto the bypass when flows are significantly below the crest of the weir. Farmers and waterfowl managers are concerned that more frequent inundation would reduce benefits for agriculture and waterfowl. We used the estimated annual habitat (EAH) method to evaluate the benefits and impacts of different scenarios on fish, waterfowl, and agriculture. EAH quantifies the area of floodplain inundated for a specified duration, timing, and frequency and is useful in determining the suitability of a floodplain as "habitat" for fish, wildlife, or even agricultural crop species. Operational scenarios that keep the proposed weir gate open later in the spring provide greater benefit for fish but with more impact to agriculture and waterfowl. The total benefits and impacts of later opening is limited, however, because late season inundation already occurs under existing conditions when high flows spill over the weir crest in wet years. Operations of a gated-opening, however, could allow better management of these late season events for fish while minimizing new impacts to agriculture and waterfowl.

Keywords: Yolo Bypass, Floodplain Habitat, Agricultural Impacts, Operable Weir, EAH
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Measuring the Compatibility of Agricultural Crops with Periodic Floodplain Inundation on the Lower San Joaquin River

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Restoration of inundated floodplain habitat is essential to the restoration of Chinook salmon populations and other fish and wildlife species in California and beyond. Several state and federal plans call for the restoration of thousands of acres of floodplain habitat in the Central Valley of California, but farmers fear that floodplain restoration activities would diminish agricultural production.

We combined coarse economic analysis with a newly developed approach for measuring floodplain habitat suitability to quantify the suitability of periodically inundated floodplains for various agricultural crops. The estimated annual habitat (EAH) method (Matella and Jagt, 2013) generates area-duration-frequency (ADF) curves to quantify the area of floodplain inundated for a specified duration, timing, and frequency and can thus be useful in determining the suitability of a floodplain as "habitat" for a wild species or a cultivated agricultural crop. We plotted the timing, frequency, and duration of inundation on floodplain lands along the lower San Joaquin River and compared it to cropping patterns and inundation tolerances of the agricultural crops planted on the same lands. We then used production value data to estimate how fully removing levees might impact agricultural production values. Due to extreme hydrograph alteration by upstream dams, the impact of levee removal on agricultural production value is surprisingly small. For example, a late May 15,000 cfs flood event (occurring approximately 1 in 7 years) would decrease production value by $4 million.

This analysis demonstrates that it may be possible to advance floodplain restoration for fish and bird habitat during the winter months without significantly impacting agricultural activities during the growing season. More broadly it demonstrates how the EAH method can be used to calculate the benefits that levees provide for agricultural production.

Keywords: agriculture, floodplain restoration, reconciliation, estimated annual habitat (EAH) method
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Building Capacity for Multi-Benefit Water Management: Governance Arrangements in California's Integrated Regional Water Management Process

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Sustainable management of the Bay-Delta system depends upon building multi-benefit strategies across the state that reduce pressure on the Bay-Delta ecosystem, while also supporting more reliable water supplies. The Integrated Regional Water Management (IRWM) program is intended to help accomplish this by fostering collaborative planning among diverse local interests at regional scales. Supported by $1.5 billion in bond funds, 48 IRWM regions have formed over the past decade, including 17 in the Sacramento and San Joaquin River basins. So far, there has been little study of the functioning and outcomes of these regional collaborations. In particular, the success of the IRWM process depends upon sustained engagement from participants with diverse but interdependent interests. Yet, previous research suggests that collaborations with more diverse participation can be more difficult to manage and sustain. What is the extent of participation in IRWM planning, and what governance arrangements are most effective at sustaining diverse engagement?

I explore these questions through an analysis of participation and governance structures in 19 IRWM regions. Drawing upon a review of governance documents and interviews with over 70 IRWM participants, I find that sustaining partnerships between stakeholders with diverse interests requires a significant, on-going investment in coordination, brokering, and outreach activities. Regional governance structures must support undertaking these activities in a manner that advances the interests of all participants. My research indicates that IRWM regions investing the most in coordination activities are managed by a lead agency with a relatively broad mandate and a scale of operations that matches the IRWM region. Regions without such entities have either formed new organizations or share coordination tasks, but often face challenges in sustaining these arrangements. These findings provide insights into the governance structures needed to help generate multi-benefit approaches that balance water supply and ecosystem needs.

Keywords: collaboration, local partnerships, multiple benefits, watershed management, regional planning
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The Untapped Potential of California's Water Supply: Efficiency, Reuse, and Stormwater

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For much of the 20th century, California's water supply strategy has meant building reservoirs and conveyance systems to store and divert surface waters, and drilling groundwater wells to tap our aquifers. Hundreds of billions of federal, state, and local dollars have been invested in these supply options, allowing the state to grow to nearly 40 million people with a $2 trillion economy. But traditional supply options are tapped out. Rivers are over-allocated even in wet years. There is a dearth of new options for surface reservoirs, and those that exist are expensive, politically controversial, and offer only modest improvements in water supply for a relatively few users. Groundwater is so severely overdrafted that there are growing tensions among neighbors and damage to public roads, structures, and, ironically, water delivery canals from the land subsiding over depleted aquifers.

But solutions to our water problem exist. They are being implemented to varying degrees around the state with good results, with the potential to do much more. The Natural Resources Defense Council, Pacific Institute, and UC Santa Barbara Professor Robert Wilkinson examined the opportunities for four cost-effective and technically feasible strategies -- urban and agricultural water conservation and efficiency, water reuse, and stormwater capture -- to improve the ability of cities, farmers, homeowners, and businesses to cope with drought and address longstanding water challenges in California. The analysis concludes that these strategies can provide 10.8 million to 13.7 million acre-feet per year of water in new supplies and demand reductions, improving the reliability of our current system and reducing the risks of shortages and water conflicts.

The analysis also examines the extent to which California overdrafts groundwater basins and exceeds sustainable levels of diversion from the Delta watershed on an average basis, and the ability of these strategies to fill that gap.

Keywords: water use efficiency, reuse, recycling, stormwater capture, groundwater overdraft, Delta
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