

California Water Resources Center



Annual Report 2001 – 2002

July 1, 2001 – June 30, 2002

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UC Center for Water Resources

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FROM THE DIRECTOR



Dr. John Letey

The Water Resources Center (WRC) is a multicampus research unit in the University's Division of Agriculture and Natural Resources and is charged with stimulating and coordinating research and information dissemination on water. The Center was first funded in 1957 by the California legislature as a University-wide organized research unit. Over the years, its mission has expanded from an early focus on the State Water Project to one that encompasses virtually all water and water-related issues.

In 1964, the Center became part of a national network of university water research institutes when it was designated the California Water Resources Research Institute by the Governor and President of the University under the terms

of the federal Water Resources Research Act of 1964. As the state's designated federal research institute, the center is responsible for water research coordination and administration activities that extend beyond the University of California to all state and private universities in California.

The Coordinating Board, comprised of academic senate members from the U.C. campuses, serves as the governing body of the Center. The Advisory Council participates with the Coordinating Board members in reviewing research proposals and discussing business matters at joint meetings.

The largest proportion of the WRC budget goes to supporting research projects on a broad range of water-related issues. The annual progress reports on these projects are included within this publication. The projects serve the dual role of developing knowledge and training students.

The WRC provides the major support budget for the Water Resources Center Archives, located on the Berkeley campus. However, the financial and other support services by various donors and the Advisory Board to the Water Resources Center Archives are acknowledged and greatly appreciated. A more detailed report on the Archives is presented on page 8 of this annual report.

I take this opportunity to express appreciation and thanks to members of the Coordinating Board and Advisory Council for their contribution to the success of the WRC.



THE COORDINATING BOARD

The Coordinating Board establishes policy for the Center and makes final decisions regarding the allocation of available funds. It is chaired by the Vice President of Agriculture and Natural Resources, through whom it reports directly to the President of the University. The Board composed of at least 13 faculty members from diverse disciplines and various administrative, teaching and research responsibilities. All members have a strong interest in water-related research. Eight of the nine campuses of the University are represented on the Board. The Board normally meets twice yearly (either in person or via phone conferencing), although special committees of the Board may meet from time to time throughout the year and individual members attend Center-sponsored meetings and conferences. Members serve as liaisons or as contacts on their own campuses, as well as to agencies, citizens, faculty, and students in water-related research. These liaison interactions contribute valuable insights in establishing policy for the Water Resources Center. Members of the Coordinating Board during 2001-2002 were:

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The Advisory Council consists of representatives of the California Department of Water Resources, State Water Quality Control Board, California Department of Fish and Game, California Department of Health Services, U.S. Geological Survey, Environmental Protection Agency, as well as at-large membership from the water community.

The Council members serve a very effective liaison function between the Water Resources Center and the public and private organizations that are involved in the management, development, control and use of water resources. One meeting was held in conjunction with the Coordinating Board. The Advisory Council is particularly helpful in providing useful evaluations of research proposals as part of the Center's annual research review cycle. Members of the Advisory Council during 2001-2002 were:

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RESEARCH ACTIVITY BY CAMPUS

LOCATION	2001 - 2002		
	PROJECTS FUNDED	GRADUATE STUDENTS SUPPORTED	UNDERGRADUATE STUDENTS SUPPORTED
UC Berkeley	8	9	9
UC Davis	4	8	9
UC Irvine	2	2	9
UC Los Angeles	2	4	0
UC Riverside	7	7	5
UC San Diego	0	0	0
UC Santa Barbara	1	2	0
UC Santa Cruz	1	1	0
TOTAL	25	34	31

Total Research funds allocated during the 2001 – 2002 fiscal year:

Approximately \$ 694,000

Additional funding WRC projects received from other sources:

Approximately \$1,684,262



INFORMATION PROGRAM ACTIVITIES

THE WATER RESOURCES CENTER ARCHIVES

Mission and Scope

The mission of the Water Resources Center Archives (WRCA) is to develop and maintain a collection of water-related materials to meet the research needs of the University of California's system-wide instructional, research, and service programs. Established in 1957, the collection is relied upon by the University community as well as government agencies, corporate professionals, and the public.

WRCA is a research library with more than 146,000 cataloged items. The scope of the collection includes fresh water supply and quality, groundwater, municipal and industrial water uses, flood control, water reuse, sewerage and waste disposal, river mechanics, coastal engineering, estuaries, water pollution, and water law. WRCA collects a variety of types of materials including printed reports, government documents, books, manuscripts, maps, videos, photographs, and electronic resources. The collection concentrates on materials relating to California and the West, although there are national and international materials in the collection as well.

Access to the Collection

WRCA is a member of the Online Computer Library Center (OCLC), an international database that currently contains more than 45 million records in

the Library of Congress' Machine Readable Catalog (MARC) format. The system indicates which member library holds a given title, and is both a shared cataloging resource and interlibrary borrowing mechanism. Since 1983, all new WRCA material has been cataloged onto the OCLC database.

OCLC regularly uploads all of the recent cataloging records from all nine UC campuses. This cumulative tape is then uploaded to the Melvyl® Catalog, the University of California's online catalog database. Melvyl® is searchable on the World Wide Web (<http://www.melvyl.ucop.edu>). This makes the WRCA's collection available nationally and internationally.

In October 1998, WRCA became a participant in the California Digital Library's Online Archive of California (OAC), a union database of encoded archival finding aids. Finding aids provide detailed descriptions and outlines of archival collections and are essential tools for understanding the true content of a particular collection. The OAC is searchable at the collection, repository, and institutional levels, or the entire database can be searched for documents or photographs on particular subjects. Currently the Water Resources Center Archives has over 120 finding aids on the OAC, which expands use of the archival

collections. WRCA's collections can be found at <http://www.oac.cdlib.org/dynaweb/ead/berkeley/wrca/>.

In September 2001, WRCA purchased five new PC's for each staff in order to replace out-dated computers.

Use of the Collection

Use of the collection in 2001-2002 included 12,112 transactions (titles used on the premises and borrowed). Users, by category, were as follows: graduate students – 24%, undergraduate students - 18%, faculty and staff - 6%, interlibrary loans - 10%, general public - 42%.

Staff Changes

In December 2001, Randal Brandt, the Technical Services Librarian, left the Archives to accept a position at The Bancroft Library on the UC Berkeley campus. Randal had worked for over seven years at the Archives. Randal had expertise in cataloging and knowledge of the manuscript and photograph collections as well as extensive web skills. The Archives was able to recruit for a librarian to assume the Technical Services duties. Paul Atwood assumed his new duties in summer 2002.

In June 2002, Elizabeth Redies, the Technical Services Library Assistant, decided to retire after 18 years of service to the Water Resources Center. Elizabeth worked for six years at the UCLA Archive and then transferred to the UCB Archive in 1990. Her cataloging expertise will be greatly missed, but we wish Elizabeth well in this new endeavor.

California Colloquium on Water

In fall 2000, WRCA, in conjunction with the Center for California Studies, Boalt School of Law, and the Colleges of Engineering, Natural Resources and Letters & Science started a new lecture series. In fall 2001, the Metropolitan Water District of Southern California also became a sponsor of this

series. The *California Colloquium on Water* series hosts four lectures each semester on the second Tuesday of the month. This lecture series has proven to be very popular and was continued during fall 2001 and spring 2002. Distinguished speakers from the fields of natural sciences, engineering, social sciences, humanities and law are invited to speak to students, faculty and the general public about water resources in order to contribute to informed decision making. All lectures are free. Speakers and topics presented in the fall and spring series were as follows:

Fall 2001

- | | |
|-----------|---|
| September | Vince Resh, Professor of Entomology and Parasitology, UC Berkeley: <i>Ecology of Mediterranean Streams</i> |
| October | Joe Sax, Director, Professor of Law, Boalt School of Law, UC Berkeley: <i>Public Trust: Philosophical and Legal Implications for California's Future</i> |
| November | Patrick Wright, Director, CALFED Bay-Delta Program: <i>The CALFED Bay-Delta Program and the Future of California Water Policy</i> |
| December | Takashi Asano, Professor of Civil and Environmental Engineering, UC Davis: <i>The Role of Water Reclamation and Reuse in Water Resources Management</i> (Recipient of the 2001 Stockholm Water Prize) |

Spring 2002

- | | |
|----------|---|
| February | Peter Moyle, Professor of Fish Biology, UC Davis: <i>Alien Invaders, Endangered Natives, and Declining Fisheries:</i> |
|----------|---|

March	<i>A History of Fish in the Upper San Francisco Estuary</i> Bill Simmons, Professor of Anthropology, Brown University: <i>Water and the Creations of Indian California</i>
April	David K. Todd, President, Todd Engineers and Professor Emeritus, UC Berkeley: <i>Managing Groundwater Resources</i>
May	Dr. John Cassidy, Consulting Water Resources Engineer: <i>Role of Dams in Water Resources</i>

Conferences and Exhibits

In fall 2001, the Archives exhibited at the Biennial Groundwater Conference in Sacramento.

Publications

WRCA produces two publications - *Selected Recent Accessions*, a bi-monthly list of new publications, and *WRCA News*, a newsletter that is published three times per year. These publications are distributed free-of-charge in paper format to approximately 400 subscribers. They are also available in electronic format on the WRCA web site (<http://www.lib.berkeley.edu/WRCA/>)

The Water Resources Center Archives and the Harmer E. Davis Transportation Library collaborated on the publication of a calendar for the year 2002 that featured historic photographs of ferryboats in the San Francisco-Oakland Bay Area. All of the photographs in **Smokestacks on the Bay** are courtesy of the National Maritime Historical Park in San Francisco. The calendar was published with generous sponsorship from Moffatt & Nichol Engineers. Thirteen hundred calendars were distributed to donors of the two libraries and sold in local bookstores, or via mail order.

The two libraries have recently completed compiling a calendar for the year 2003 again featuring images of historic San Francisco Bay ferries. These images are also from the pictorial collections of the National Maritime Historical Park located in San Francisco. Publication of the 2003 calendar will be again be sponsored by Moffatt & Nichol Engineers.

Web Site and Online Resources

The Water Resources Center Archives continues to develop and expand its web site. The web site includes an introduction to the library's print and electronic resources, lists of archival and video collections, specialized research guides, and all library publications. It also provides links to the California Digital Library (which includes Melvyl® and the Online Archive of California), electronic reference resources, article indexes, electronic journals, and other online resources. In July 2000, the Internet Resources section of the WRCA web site was selected as a "Key Resource" by Links2Go, an extensive Internet search and directory service (<http://www.links2go.com/topic/Hydrology>)

The online resources provided by the Water Resources Center Archives help researchers get up-to-date information. Different systems provide information in bibliographic, full-text, or data forms. *Water Resources Abstracts* contains bibliographic citations to journals, books, documents, and reports on hydrology and other areas of water-related research. This system is now accessible to UC Berkeley students, faculty, and staff via the WRCA web site. WRCA also maintains subscriptions to two key CD-ROM databases: *U.S.G.S. Peak Values* and *U.S.G.S. Daily Values*, both published by Hydrosphere, Inc. WRCA staff members are experts at locating and retrieving data and information from all of these electronic resources.

Fundraising and Fee-For-Service

WRCA continues its fundraising activities. The Advisory Board to the Water Resources Center Archives continues to meet semiannually and to assist with outreach and fundraising strategies.

WRCA continues to expand the use of the collection and increase outside revenues by providing fee-based document delivery services to non-UC requestors. Requests are received via OCLC, telephone, fax, or e-mail.

Joe Johnson Memorial Fund

In April 2002 Professor Emeritus Joseph (Joe) William Johnson passed away peacefully at the age of 93. In addition to his long and distinguished career as a professor of Hydraulic Engineering at the University of California, Berkeley, from 1942 to 1975, Joe Johnson was one of the founders of the Water Resources Center Archives (WRCA).

In the mid-1950's, Joe Johnson and Morrrough P. O'Brien recognized the need for an archive devoted to collecting information about water resources in California and the west. Throughout the early years, Joe Johnson was intimately involved in helping the Archives become established. At that time, he knew all the major players in California water and was instrumental in procuring many high-profile collections for the Archives: Bernard Etcheverry, Charles Gilman Hyde, James Dix Schuyler and Walter Leroy Huber. Under his guidance, the Archives developed its unique classification scheme and began to compile its unique collection.

Today, the Archives is the finest library and archive of its kind in the United States. A fund has been established at the Water Resources Center Archives in memory of Joe Johnson. Any contributions will be used for special projects.

Grants

In May 2001, the Water Resources Center Archives was awarded a continuing grant of \$10,000 from the San Francisco Foundation to continue to update an online inventory of projects which have received grants from the Foundation's Bay Fund. WRCA will continue to develop this web site and provide more links to other related restoration information systems. In May 2002, WRCA was awarded a follow-up grant for \$8,000 to continue to add newly funded projects to the online system and upgrade WRCA's Bay Fund web site for projects that were funded in 2002.

The inventory is housed on the Information Center for the Environment's (ICE) web-based system at UC Davis (<http://ice.ucdavis.edu/>). ICE hosts a variety of inventories offering information about restoration, mitigation and conservation projects in, or bordering, California. The inventory is a file in the Natural Resource Projects Inventory (NRPI). An important component of the grant is the design and implementation of a community outreach effort to contact schools, libraries, local organizations and businesses to increase awareness of the inventory and encourage its use. In May 2001, a postcard was sent out to over 200 Bay Area public libraries and schools announcing the SF Bay Fund web site located at <http://www.lib.berkeley.edu/WRCA/bayfund/>

The Water Resources Center Archives was also awarded a grant for \$4,500.00 from the National Endowment for the Humanities to purchase archival supplies that will help to preserve valuable documents in the manuscript collection.

Research Category I

Hydrology Climatology and Hydraulics

This category encompasses the physical processes that lead to water availability for human use on land, in lakes, streams and aquifers. Examples of investigations that logically fall in this category include studies of precipitation and stream-flow relationships, weather forecasting, climate modification, micrometeorological processes linking atmospheric water, solar energy, water use by plants (both commercial and native), and available soil moisture, hydrologic and hydraulic modeling and processes, and the development of databases.





Application of a New Model for Groundwater Age Distributions: Modeling and Isotopic Analysis of Artificial Recharge in the Rialto-Colton Basin, California

Timothy R. Ginn
Civil and Environmental Engineering
UC Davis

Linda Woolfenden
United States Geological Survey
Water Resources Division
Sacramento, CA

Project Summary

The "banking" of water in aquifers has drawn much interest lately as a strategy for managing the water reserves. The ability of any given aquifer to serve as reservoir and filter for waters, such as, reclaimed wastewater, is indicated by the groundwater residence time, or age. Banking is being considered at the Rialto-Colton basin aquifer, via infiltration through the Linden ponds (Figure 1). Age serves as a useful indicator of ground water renewability and the feasibility of using aquifers for water storage, and equally importantly, it is a measurable parameter.

Carbon-14 (C^{14}) isotope is normally used as a tracer to compute the ground water ages. To determine age at a point in space and time in an aquifer, one measures the C^{14} activity there and with known activity in influent, calculates age as the time required for the radioactive decay to reduce the activity of the influent to that of the measured, with corrections for geochemical reactions. This project characterizes these reactions in the Rialto-Colton basin aquifer in Southern

The ability of any aquifer to serve as reservoir and filter for waters, such as reclaimed wastewater, is indicated by the groundwater residence time, or age. Carbon-14 (C^{14}) isotope is normally used as a tracer to compute the ground water ages. A comprehensive reactive transport with established set of geochemical reactions over the entire aquifer is being developed to estimate the age of groundwater in the Rialto-Colton basin aquifer which is being considered for banking water imported from Northern California.

California and quantifies their effects on C^{14} data by simulating reactive transport in the aquifer over several thousand years. The information is then used to estimate the groundwater age directly by solving the age.

In the aquifer, the geochemical reactions may alter the initial C^{14} content of the influent through gain, loss or dilution of the dissolved inorganic carbon as the water travel through the system. The impacts of geochemical reactions on the C^{14} activity

of the influent water in the aquifer has been accomplished by employing the geochemical codes PHREEQC which simulates the chemical reactions of water and NETPATH which simulates the flow paths through the aquifer.

For the initial study, the Rialto-Colton aquifer is divided into 4 primary flowpaths that follow the general direction of groundwater flow from NW to SE (Figure 1): 1) A-A' middle water bearing unit, 2) A-A' lower water bearing unit, 3), B-B' middle water bearing unit, and 4) B-B' lower water bearing unit . We found that the most dominant reactions that affect C^{14} activity of the influent water, and hence ground water ages, are silicate weathering, clay precipitation, cation exchange, calcite precipitation/dissolution, and organic matter oxidation. For the A-A' lower unit flowpath that runs parallel to and east of an unnamed fault, the age of the water ranges approximately between 3,000 to 16,000 years with ages increasing from 3,000 years at the beginning of the flowpath, to 13,000 years at the end of the flowpath. For the B-B' lower unit flowpath that lies on the west of the unnamed fault, the ground water age ranges approximately between 500-14,000 years from the beginning to the end of the flowpath. Both of the lower water bearing units do not demonstrate the effects of mixing with younger waters from the Linden pond and the nearby creeks, e.g. Lytle Creek, which is expected. For the A-A' middle unit, the mixing of the native ground water with the Lytle Creek water is discovered between the first 3 and 6 miles downgradient along the flowpath. The ground water age ranges between 200-1,300 years with the start location of the flowpath having the oldest water. The effect of mixing between the native water with the younger Lytle Creek water exhibited such that the ages of the water farther than 3 miles downgradient are younger than that at the beginning flowpath and the youngest water is located

approximately 5-6 miles downgradient. For the B-B' middle unit, the range of ground water ages is about 300-8000 years. There is no apparent mixing of the native ground water with any other recharge source. The mixing of the native water with the imported water from Linden pond is however expected particularly somewhere on the A-A' middle water bearing flowpath. We hope to resolve this anomaly as described next.

The preliminary investigation involves sophisticated chemical reaction modeling, along with highly simplified flow path simulation. To treat both reactions and transport realistically, we will develop a comprehensive reactive transport model with the established set of geochemical reactions over the entire aquifer, instead of only the 4 independent flowpaths. This will be accomplished by employing HBGC123D implemented with isotopic calculation step for computing C^{14} and stable C^{13} contents of the water. Computed carbon contents will be calibrated with the measured carbon contents to assess the amount of imported recharge into the Linden pond. Future research will also develop the RAFT flow and reactive transport code for generating steady state and transient ground water age distributions by using the age equations formulated by Ginn.

Professional Presentations

Tim Ginn, Memory and Exposure-Time in Subsurface Fate and Transport, Oregon State University, Spring Hydrology Seminar, May 23, 2002.

Student Training

Uma Seeboonruang, graduate; Ph.D., Civil and Environmental Engineering, UC Davis

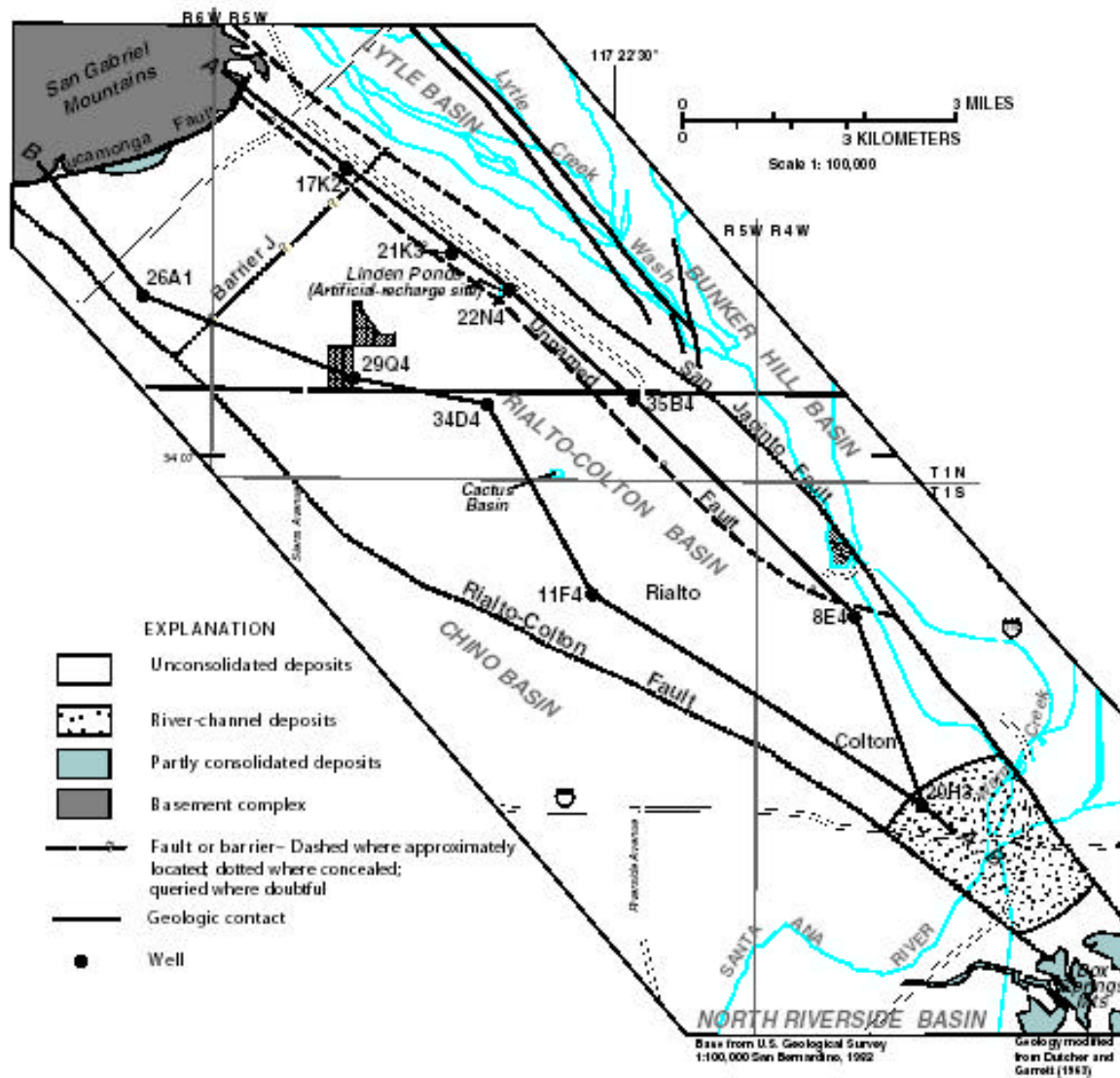
Rachael Terpstra, graduate; Civil and Environmental Engineering, Undergraduate, UC Davis

Collaborative Efforts

Collaboration with Jack Gwo, author of the code Hydrogeobiochem (HGBC); student Uma Seeboonruang is creating a computer code for interpolating conventional (MODFLOW) simulated groundwater velocity files to render HGBC-compatible velocity files; this code will be shared with other HGBC users via Dr. Gwo.

Keywords

Groundwater age distribution, carbon-14 age dating, groundwater flow, artificial recharge, mathematical modeling, heterogeneity





Assessment of the Structure and Function of Natural Hydraulic Jumps

Gregory B. Pasternack
Land, Air and Water Resources
UC Davis

Project Summary

Detailed measurements of bed and water surface profiles controlling three hydraulic jumps were conducted using our river truss on the upper South Fork American River, California and on Cache Creek, California. The truss is specially designed for high-velocity flows that may not be waded, and allows point measurements at a higher resolution than any point measurement previously available. This system has also been used with process measurement sensors such as the time-domain reflectometer (TDR) to measure air content (e.g. Vallé and Pasternack, 2002), pressure, and velocity. While the prototype system sufficiently acquires topographic and process data, new research grants leveraged by this project will allow for the development of the next-generation system that will remarkably improve the system's capabilities. The additional funds will also allow further development of sensors capable of high frequency measurements in complex turbulent conditions.

In addition to the air content measurements discussed in Vallé and Pasternack (2002), the project has

expanded into detailed measurements of the water surface topology and complex bed geometry associated with natural

Our results clearly illustrate the complex dynamics of natural hydraulic jumps, suggesting that the governing assumptions pertinent to most hydraulic designs are violated when dealing with natural hydraulic jumps. Thus, proper construction of jumps for ecological or restorative uses requires further study of jumps in-situ over a wide range of lithologies and discharges.

hydraulic jumps. Supercritical (i.e. upstream of the jump) water surface profiles exhibited rapidly varying planar, convex, and concave shapes, while subcritical (i.e. downstream of the jump) water surface profiles exhibited gradually varying planar shapes. Bed surface profiles exhibited highly complex local channel morphologies with rapidly varying and undulating topographies upstream of hydraulic jumps, and scour holes, furrows, undulations, and coarse alluvial elements below. The flow depth typically varied significantly over the surface area of each

jump, with coefficients of variation ranging from 48-51%. These results clearly illustrate the complex dynamics of natural jumps, suggesting that the governing assumptions pertinent to most hydraulic designs are clearly violated when dealing with natural hydraulic jumps. Thus, proper construction of jumps for ecological or restorative uses requires further study of jumps in-situ over a wide range of lithologies and discharges. Development of field equipment capable of measurements in these complex conditions is required. The initial results from this study have helped to develop a framework from which future research can be guided systematically and from which natural jumps may be constructed.

The second year of this project provided significant advances in the area of fluvial research and culminated in new grants to promote further research. Most notable was the acquisition of competitive funding that secures an additional 3 years of research building on the progress made during this 2-year project. The new grant comes from the National Science Foundation (NSF) and provides \$255,010 beginning 9/15/02. In addition, the AGU Horton Research Grant was awarded to the project's Ph.D. student Brett Vallé, demonstrating the quality of work being performed and the significance of the results.

Publications

Vallé, B.L. and Pasternack, G.B., TDR Measurements of Hydraulic Jump Aeration in the South Fork of the American River, *California Geomorphology* 42: 1-2, 2002.

Professional Presentations

Vallé, B.L. and Pasternack, G.B., High-Resolution Field Measurements of Water and Bed Surface Profiles for two Bedrock Downsteps on the Upper South Fork American River, California, *Eos Trans. AGU*, 82(47), Fall Meet. Suppl., Abstract H52B-0388, 2001.

Student Training

Brett Vallé, graduate, Ph.D.; Hydrology, UC Davis
Chien Wang, graduate, M.S.; Hydrology, UC Davis
Emily Corwin, Undergraduate; Hydrology, UC Davis
Joe Wheaton, Undergraduate; Hydrology, UC Davis
Kate Trimlett, Undergraduate; Evolution and Ecology, UC Davis
Eric Buer, Undergraduate; Hydrology, UC Davis

Additional Funding

National Science Foundation Proposal 0207713, "Hydraulic Jump Mechanics and Channel Interactions in Mountain Rivers." 2002-2005. Funded: \$255,010.

Horton Research Grant, American Geophysical Union. 2002-2003. Amount: \$10,000.

Keywords

River restoration, hydraulic jumps, aerated flow, mountain streams, channel hydraulics



Right bank view of Shady Jump on the upper South Fork American River



Hydrodynamics of Shallow Water Habitats in the Sacramento-San Joaquin Delta

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UC Berkeley

Project Summary

The exchange dynamics between shallow water habitats in the Sacramento-San Joaquin Delta (the Delta) and the adjoining channels have been analyzed using numerical simulations. These modeling activities focused on: (1) determining the salinity of shallow-water habitats adjacent to tidal channels and how the salinity depends on the geometry of the opening; and (2) exploring how temperature variations in the Delta alter these channel-shallow exchanges.

Shallow-water Habitat Salinities

The development of a shallow water habitat adjacent to northern San Francisco Bay (the North Bay) usually begins with the creation of an opening in a levee adjoining a tidal channel in the bay. For ecological considerations, the resulting salinity of the shallow water habitat is of critical concern. One difficulty in designing these habitats lies in the fact that the salinity in the channels of the North Bay can vary by 5-10 parts per thousand on the tidal timescale through the advection of the salinity field by tidal currents. As a result, the timing of the exchange of waters between the channel and the shallows relative to the tidal currents in the

channel will largely determine the mean salinity of these “off-channel” habitats.

To address this question, we have focused on an analytic solution, which will be most useful for management considerations. The approach is to link two one-dimensional solutions to predict the timing of the average flow between the channel and the shoal. The first is a simple tidal model of the flows and salinities in the channel, which includes as a prescribed parameter the phasing between the tidal stage and the tidal currents. The second model is a one-dimensional parameterization of the exchange flows between the channel and the shallows, which are driven by the difference in stage between the channel and the shallows, but is resisted by a frictional force that will

The salinity in shallow off-channel water bodies of the Sacramento-San Joaquin Delta will exceed the mean channel salinity by as much as several parts per thousand depending on the timing of the exchange flows and the geometry of the transition. From a management perspective, this may provide a mechanism for controlling the salinity in the shallow-water habitat.

depend on the geometry of the opening. Solving the cross-sectionally averaged momentum equation for the exchange flow, we determine the timing and salinity of the waters flowing into the shallow water habitats as a function of the mean channel salinity, the salinity gradient along the channel, the phasing of currents and stage in the channel, and a drag coefficient for the channel-shallow transition.

The solution indicates that the salinity in these shallow off-channel water bodies will exceed the mean channel salinity by as much as several parts per thousand, due to the timing of the exchange flows, but depends on the geometry of the transition through the integrated drag coefficient. To determine appropriate values of the drag coefficient, we used the three-dimensional hydrodynamic model, TRIM3d. The model was run for an idealized channel-shallow geometry for four different geometric cases. The results of the three-dimensional simulation were integrated to reproduce the one-dimensional parameterization used in the analytic solution, and each term in the one-dimensional equation was evaluated to determine the average drag coefficient. The salinity in the shallow water habitat may change by as much as 5 parts per thousand depending on the geometry of the transition. From a management perspective, this may provide a mechanism for controlling the salinity in the shallow-water habitat. For a given geometry, these results would determine the optimal location for the shallow-water habitat, in order to achieve desired salinities.

Temperature Effects on Exchanges

In September 2001, using direct hydrodynamic observations, it was seen that the exchange between Mildred Island and the adjoining channel was generally a typical jet-structure during the flooding tide. However, on warm days, the jet structure was modified during the afternoon due to the effects of temperature stratification and wind. As a result, we have begun development of a temperature module for use in TRIM3d. This activity is still underway and will continue under funding received from CALFED.

Professional Presentations

Stacey, Mark, Mildred Island, Lake, Lagoon or Estuary. What is it?, . PI Organizational meeting for CALFED funded activity, USGS, Menlo Park, California, February 6, 2002

Student Training

Seungjin Baek, M.S./Ph.D., Civil and Environmental Engineering, UC Berkeley.

Additional Funding

The three-dimensional modeling work begun under the WRC funding has led to a longer-term collaborative study with the USGS and funded by CALFED for \$113,000.

Collaborative Efforts

The Mildred Island study was a collaboration with the USGS which occurred in advance of the CALFED funding described in the previous section.

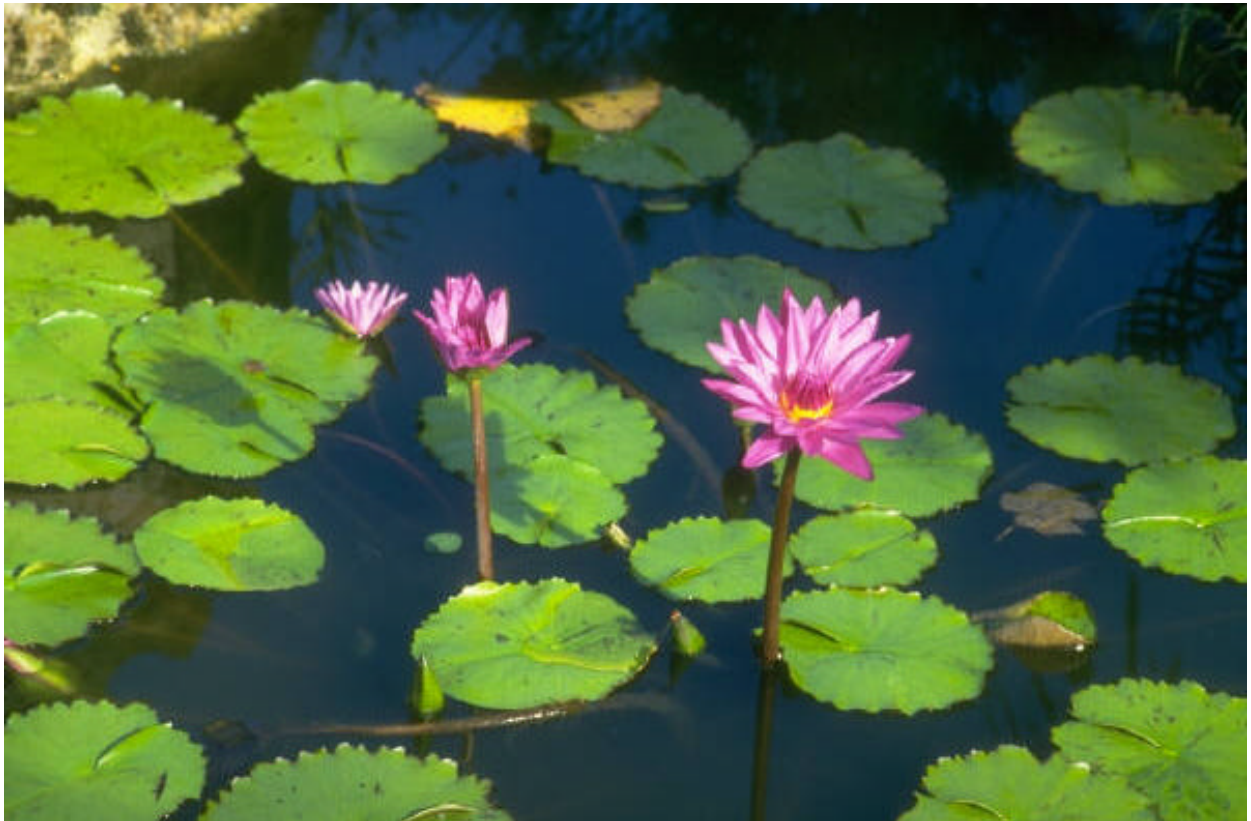
Keywords

Sacramento-San Joaquin Delta, shallow-water habitats, channel-shallow exchanges, hydrodynamic modeling

Research Category II

Aquatic Ecosystems

This category encompasses basic observational, analytical and theoretical knowledge about aquatic environments and ecosystems. Research areas of interest include biological, chemical and physical mechanisms that govern the behavior of aquatic ecosystems including work on the classification, transport and impact of contaminants and pollutants. Also included in this category are studies of the use of artificial ecosystems for water reclamation, fundamental investigations related to wetland management, studies of the impact of land use practices on aquatic habitats and reconstruction ecology.





Freshwater Mussels in California's North Coastal Streams: Current Status and Geomorphic Controls

Kurt Cuffey
Geography
UC Berkeley

Project Summary

Very little is currently known about the freshwater mussels that inhabit California's rivers, with neither their current status nor the controls on their distribution being characterized well. Yet mussels could potentially provide important information for watershed-scale environmental planning and for assessment of impacts of recent human activity. These mussels, which can live for as long as one century, are sensitive to hydrologic and sediment conditions in river channels, and are dependent on host fish (particularly salmonids) for reproduction.

To help develop methods for using mussels as environmental recorders, we have surveyed and analyzed their occurrence along an entire eight-kilometer stretch of the South Fork Eel River (in the University of California's Angelo Coast Range Preserve). Here we found robust populations of two species, *Margaritifera falcata* and *Anodonta californiensis*, a California "species of special concern". Their distribution is highly variable spatially, with the majority of individuals living in discrete areas of very high population density. Throughout, the mussels live almost exclusively along the banks of pools (the river has pronounced

alternating pool and riffle morphology), and are strongly associated with two types of substrate (root mats of sedges, and bedrock interstices). Observations and hydraulic modeling show that mussels live in locations that are most protected from stresses induced by fast water flow during rainy-season floods.

Mussels, which can live for as long as one century, are sensitive to hydrologic and sediment conditions in river channels, and are dependent on host fish (particularly salmonids) for reproduction. Surveys on their occurrence showed that mussels live in locations that are most protected from stresses induced by fast water flow during rainy-season floods. Their distribution is highly variable spatially, with the majority of individuals living in discrete areas of very high population density.

These results indicate that: (1) random surveys of small sections of rivers do not provide an accurate assessment of mussel populations, (2) results from mussel studies in other regions of North America are not directly applicable in the unique climatic and topographic conditions of California's mountains, and (3) mussel

populations in California's mountain rivers may be vulnerable to increases of flood magnitude that can accompany land-use and climatic change. To continue moving toward the goal of developing the use of mussels as environmental recorders, we are now beginning to analyze mussel growth rates and ages at the Eel River study site, and at sites along the Pit River.

Publications

Howard, J., and K.M. Cuffey, Hydrologic and geomorphic controls on the distribution of freshwater mussels in a California North Coast Range river. *Journal of the North American Benthological Society*, 22(1), pp 63-77, 2003.

Professional Presentations

Cuffey, K.M, Freshwater mussels in California's north coastal streams: Current status and geomorphologic controls, given by J. Howard at the meeting of the North American Benthological Society, Pittsburgh, PA, May 28, 2002.

Student Training

Jeanette Howard, Ph. D. student, Department of Geography, UC Berkeley.

Collaborative Efforts

The project has benefited greatly from collaborations with:

- Dr. Mary Power, Professor of Integrative Biology, UC Berkeley
- Dr. Jayne Brim-Box, United States Geological Survey

Keywords

Rivers, ecology, mussels, coast ranges, Eel River



The Influence of Introduced Trout on the Diversity and Structure of Native Aquatic Invertebrate Communities in High Sierran Streams

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Sierra Nevada Aquatic Research
Laboratory
University of California
Mammoth Lakes

Scott D. Cooper
Ecology, Evolution and Marine Biology
UC Santa Barbara

Project Summary

The introduction of non-native fish, primarily trout, to Sierran lakes and streams has been linked to declines and losses in over half the 70 species of native amphibians and fish in the Sierra. Because aquatic communities in the High Sierra evolved in the absence of fish predators, these systems may be especially vulnerable to the introduction of fish. Invertebrate communities of streams are often composed of dozens of species with diverse roles in food webs and are primary prey of trout. Despite their diversity, integral ecological roles, and potential for use in ecological assessments, aquatic invertebrates are among the most poorly known of all faunal groups in the Sierra Nevada. This objective of this study is to provide information on the effects of introduced trout on stream ecosystems, and data on the distribution and diversity of stream invertebrates in the central Sierra Nevada.

Using a paired watershed approach, we surveyed 7 stream pairs in the first year of the project (summer 2000), and 15 stream pairs in the second year (summer 2001).

Fishless streams were contrasted with adjacent matched streams containing trout. Fishless streams typically contained a somewhat greater diversity of total taxa and of large invertebrate predators than found in matched trout streams. In addition, trout streams contained a greater total percentage of the dipteran family chironomidae (midges) than fishless streams.

Fishless streams were contrasted with adjacent matched streams containing trout. Our surveys consisted of sampling the benthic invertebrate communities of riffle and pool habitats within defined 150 meter length study reaches. Data on the physical stream habitat, water chemistry, algal and organic matter food resources and fish density were also collected to analyze the interrelationships of environmental setting and trout on invertebrate community structure and diversity.

Preliminary laboratory results on invertebrate communities from streams surveyed during the first year of the study suggest some consistent differences between the stream pairs. Fishless

streams typically contained a somewhat greater diversity of total taxa and of large invertebrate predators than found in matched trout streams. In addition, trout streams contained a greater total percentage of the dipteran family chironomidae (midges) than fishless streams. Members of this diverse family of small flies often increase in abundance when algae or organic matter become more available as food or habitat. If trout limit the number, diversity, or feeding activity of invertebrates consuming algae and organic matter, the growth of small and productive midges may be released as an indirect effect. In the first completed data set from the study, contrasts of algal periphyton between all 21 paired study streams show that indeed, fish-containing streams contained significantly greater density of algae (Wilcoxon signed-rank test, $p < .01$). Sample processing and invertebrate identification are nearly complete (40 of 42 streams), and further analysis of this data will explore the community structure alterations that may produce the difference observed in algal density.

Our studies were predicated on surveys completed 50 years ago as part of a review of the fish habitat status of Yosemite that showed the distribution of fishless streams. We found that many of these streams now contain fish but we also documented unknown fishless streams during explorations of streams with natural waterfall or cascade barriers to fish migration. Some streams we had expected to sample also had intermittent flow and had to be removed from our list of study sites. Though intermittent streams are interesting and important habitats, and may be important refugia from fish predation, we have restricted the scope of this study to contrasts of perennial streams with and without fish in order to isolate the main effect of the influence of introduced trout.

Another approach to investigating the influence of trout in Yosemite stream communities was initiated by Erik Silldorff, a participating graduate student from UCSB supported by the project. Erik compared benthic invertebrates above and below waterfalls forming natural barriers to fish migration. Little difference was found in the diversity of communities above waterfalls (lacking fish) relative to those below, but a large endemic mayfly (Edmundsius agilis) was absent or substantially reduced, and flatworms were rare when fish were present, and the abundance of midges was again increased. These waterfall surveys add both a new approach to answering the study question and a data set that exceeds the 50 stream reach goal of the project. The presence of the endemic mayfly Edmundsius is an interesting re-discovery of an insect that had not been reported from Sierra streams since it was first described about 50 years ago.

The results of this study will have important implications to aquatic resource planning within Yosemite and elsewhere in the high Sierra in balancing management of historically fishless streams for preservation of native stream diversity and function along with recreational fishing use. The study may be used to help identify strategies for expanding the extent of fishless habitat and native fauna, and provide a context for understanding the role of trout introductions in the function and biological integrity of mountain stream ecosystems.

Professional Presentations

E.L. Silldorff, D.B. Herbst, and S.D. Cooper. (presented by Erik Silldorff), The Role of Exotic Trout in Structuring Stream Invertebrate Communities, National meeting of the North American Benthological Society, LaCrosse, Wisconsin, June 5, 2001.

Silldorf, E.L., Saving a Rare Endemic Mayfly: The Impact of Trout Introductions in the Sierra Nevada on *Edmundsius agilis* (Siphonuridae), National meeting of the North American Benthological Society, Pittsburgh, Pennsylvania, June 1, 2002.

Student Training

Erik Silldorff, graduate, Ph.D.; Ecology, Evolution and Marine Biology, UC Santa Barbara

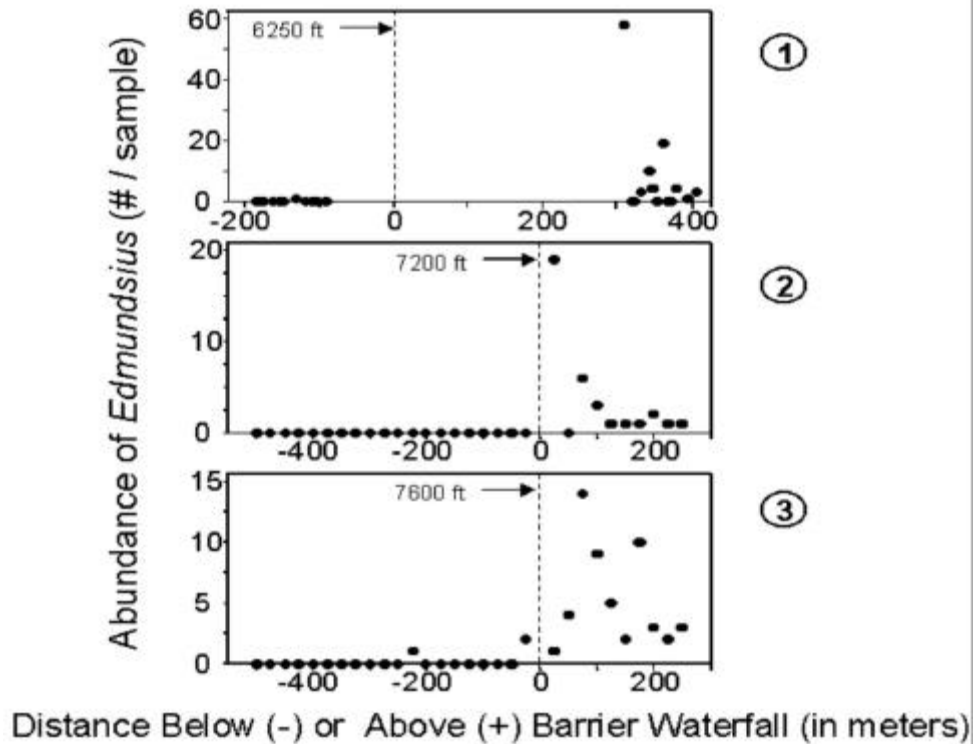
Tom Kennedy, graduate, Ph.D.; Biology, University of Alabama, Tuscaloosa.

Additional Funding

The Nature Conservancy, Research Program, Mellon Foundation provided \$143,708 (June 1, 2000 – December 31, 2000). The WRC funding served as a seed that helped in obtaining this additional project support.

Keywords

Aquatic insects, benthic invertebrates, non-native species, predation, Sierra Nevada, stream ecosystems, stream habitat management, trout, Yosemite National Park



The distribution of *Edmulndsius agilis* above and below waterfall barriers to fish migration



Conservation Genetics of the Tidewater Goby- *Eucyclogobius newberri*

David K. Jacobs
Organismal Biology, Ecology and Evolution
UC Los Angeles

Project Summary

The tidewater goby is a federally-listed endangered species. It primarily inhabits the summer-closed estuaries along the California Coast. Human modifications of estuaries to fully closed or open status has resulted in the elimination of tidewater gobies from the San Francisco Bay area, Orange County, and a number of other localities around the State. Hydrography of streams is also implicated in the demise of the gobies, as many populations have been extirpated during periods of drought or flood. (Lafferty et al, 1999).

We documented that tidewater gobies have substantial genetic subdivision with the isolation of a set of regional phylogenetic units or clades across the State (Dawson et al. 2001). It is especially interesting that the San Diego County populations not only were isolated genetically from those in the rest of the state but also had diverged significantly implying a very long history of isolation from other populations. This observation led to the establishment of a distinct population segment under the auspice of Endangered Species Act to protect this unique genetically isolated unit.

Tidewater gobies inhabiting the estuaries along the California coast are endangered. The study showed that the proximity of populations along the mid coast that are genetically isolated is unprecedented for a vertebrate taxon presumed to have the ability to disperse through the sea. In terms of local population differentiation, the tidewater goby is the most genetically differentiated vertebrate on the Pacific Coast with far more genetic structure than salmonids.

To document the genetic isolation of populations, the tidewater goby from Salmon Creek in Sonoma County to Bennetts Slough in Monterey County were studied. This work involved recovery of 15 control region gene sequences from each of 15 locations throughout the study area . We also investigated the genetic consequences of natural and artificial re-colonization in populations from Ventura to Topanga. Thirty (894base) mitochondrial control regions were generated from individuals from 5 localities that represented the long lived population (Ventura and Santa Clara), the naturally re-colonized population (Ormon and

Topanga) and artificially re-colonized population (Malibu).

The results suggest that: a) the regional genetic variation is limited, b) 52 fish introduced into Malibu were sufficient to capture much of the genetic variation present, and c) the recent re-colonization of Topanga had a single mitochondrial type due to founder effect. The proximity of populations along the mid coast that are genetically isolated is unprecedented for a vertebrate taxon presumed to have the ability to disperse through the sea. Thus in terms of local population differentiation the tidewater goby is the most genetically differentiated vertebrate on the Pacific Coast with far more genetic structure than salmonids. Genetic isolation is strongly correlated with the absence of sandy substrate in the intertidal zones. This suggests that dispersal is taking place in the adult phase of life history. If larval dispersal were important, substrate should not be this critical. We infer that dispersal occurs as longshore movement of adults following flood events that force from their preferred stream mouth habitat. Such dispersal would be limited to sandy stretches by the benthic nature and substrate preference of these fish.

The results of this research project provide an important component of the information required for appropriate management of the tidewater goby. We have been in contact with a number of workers in the regional offices of the Fish and Wildlife Service, which is charged with the management of this taxon at the federal level, as well as with a range of parties with a stake in the management of tidewater goby habitat. We also received additional funding from other public agencies on assessing impacts of proposed estuarine modifications and on reintroduction.

References

Dawson, M. N. J. Staton & D. K. Jacobs, Phylogeography of the Tidewater Goby, *Eucyclogobius newberryi* (Teleostei, Gobiidae), in Coastal California. *Evolution*, v. 55 pp. 1167 - 1179, 2001.

Lafferty, K. D., C. C. Swift & R. F. Ambrose, Postflood persistence and recolonization of endangered tidewater goby populations, *North American Journal of Fisheries Management*. V.19 pp. 618-622, 1999.

Publications

Dawson, M. N, K. D. Louie, M. Barlow, D. K. Jacobs & C. C. Swift, Comparative phylogeography of sympatric sister species *Clevelandia ios* & *Eucyclogobius newberryi* (Teleostei, Gobiidae), across the California Transition Zone. *Molecular Ecology*. v. 11pp. 1065-1075, 2002.

Barlow, Michelle, Phylogeographic Structure of the Tidewater Goby, *Eucyclogobius newberri* (Teleostei: Gobiidae), in the San Francisco Bay Area and Ventura County: Implications for Conservation Management pp. 76. Unpublished Master's Thesis, UCLA, 2002.

Abstracts

Jacobs, D. K., Cryptic species and cryptic introductions in marine conservation - Examples from jellyfish, fish and molluscs. *Experimental Approaches to Conservation Biology*, Sponsored by UCLA Institute of the Environment, Abstracts With Program, 2002.

Barlow, M. A., M. N Dawson¹, & D. K. Jacobs, Phylogeographic structure of the tidewater goby, *Eucyclogobius newberri* (Teleostei: Gobiidae), in the San Francisco Bay area and Ventura County, Implications for conservation management. *Western Society of Naturalists 82nd Annual Meeting Abstracts* p. 23, 2001.

Jacobs, D. K., M. Barlow, R. Kelly & N. Monoukis, Cryptic species, cryptic introductions and west coast phylogeography: examples from jellyfish, molluscs and fish. Western Society of Naturalists 82nd Annual Meeting Abstracts p. 35, 2001.

Professional Presentations

David K. Jacobs, Scales of Evolution in the Sea from Phylogeography and Cryptic Species to Onshore /Offshore Patterns, Cal. State Northridge, October, 2001.

David K. Jacobs, Influences of Global Process on Mesozoic Marine Patterns and Late Cenozoic Marine Speciation, U C Riverside, April 2002.

Student Training

Michelle Barlow, graduate, MS, Organismic Biology Ecology & Evolution UC Los Angeles.

Nicholas Manoukis, graduate, Organismic Biology Ecology & Evolution, UC Los Angeles.

Additional Funding

We received \$20,000 from North County Transit Agency and \$5,000 from the National Fish and Wildlife Foundation.

Collaborative Efforts

We continue to collaborate with Camm Swift, an emeritus curator of ichthyology the Los Angeles County Museum of Natural History. We have also received assistance from Dan Holland of Camp Pendleton, as well as from Holly Mendonca currently of Bodega Marine Lab and Jere Smith of Cal State San Jose

Keywords

Tidewater goby, estuary, population genetic, phylogeography, D-loop, cytochrome B, microsatellite, speciation, metapopulation



Assessing the Response of Degradative Biofilms to Groundwater Pollutants

Jay D. Keasling
Chemical Engineering
UC Berkeley

Eric S. Gilbert
Chemical Engineering
UC Berkeley

Project Summary

Bacteria play an important role in detoxifying organic chemicals present in polluted groundwater. At sites where intrinsic bioremediation is employed, the clean-up of subsurface contaminants is dependent on the catalytic abilities of indigenous microorganisms. Alternatively, direct application of specific degrader microorganisms to enhance in situ biodegradation is under consideration for treatment of several recalcitrant groundwater pollutants, including MTBE. In recent years there has been a growing appreciation among microbial ecologists that most bacteria in the environment live in communities of microorganisms attached to surfaces, or biofilms. Moreover, it has been recognized that the metabolism of complex organic pollutants often involves the concerted efforts of multi-species bacterial consortia. This shift in our understanding of the structure and function of microbial communities could impact the methods that are used to treat these contaminants and the models that predict rates of groundwater decontamination. Hence, there is a need to understand the interactions between contaminants and bacteria in biofilms and new parameters that more accurately

Bioremediation employing engineered microorganisms, if implemented properly, is effective in the in situ detoxifying target pollutants in ground water. However, the metabolism of complex organic pollutants in aquifer often involves the concerted efforts of multi-species bacterial consortia present in communities of microorganisms. This study explored the dynamic interactions of microorganisms involved in parathion degradation in biofilms and suggested the strategies for designing in situ bioremediation.

describe the contaminant-bacteria interactions must be defined.

To study the interactions between two organisms in a biodegradative biofilm, we have examined the degradation of parathion by an engineered consortium of microorganisms: (1) *Escherichia coli* SD2 harbored two plasmids, one encoding the gene for parathion hydrolase, and a second carrying a green fluorescent protein marker and (2) *Pseudomonas putida* KT2440 pSB337 contained a *p*-nitrophenol-inducible plasmid-borne operon encoding the genes for *p*-

nitrophenol mineralization. The co-culture effectively hydrolyzed 500 μM parathion and prevented the accumulation of *p*-nitrophenol in suspended culture. Kinetic analyses were conducted to characterize the growth and substrate utilization of the consortium members. Parathion hydrolysis by *E. coli* SD2 followed Michaelis-Menten type kinetics. The *p*-Nitrophenol mineralization by *P. putida* KT2440 pSB337 exhibited substrate inhibition kinetics. The growth of both strains was inhibited by increasing concentrations of *p*-nitrophenol, with *E. coli* SD2 completely inhibited by 600 μM *p*-nitrophenol and *P. putida* KT2440 pSB337 substantially inhibited by 1600 μM *p*-nitrophenol. Cultivation of the consortium as a biofilm indicated that the two species could cohabitate as a population of attached cells. Analysis by confocal microscopy showed that the biofilm was predominantly comprised of *P. putida* KT2440 pSB337, and that the distribution of *E. coli* SD2 within the biofilm was heterogeneous. Overall, the use of biofilms for the construction of degradative consortia may prove beneficial.

In addition we have examined the interactions of the two organisms in a biodegradative biofilm by developing a mathematical simulation. The simulation represents the growth of microbial unit cells in a three-dimensional domain modeled after a repeating section of a constant depth film fermenter. Cell growth in the biofilm was assumed to be limited by a single substrate, the transport of which, like all other solutes in the simulation, was represented by Brownian diffusion. Other solutes accounted for in the simulation were cell growth inhibitors and secondary metabolites secreted by the cells. Upon division, one daughter cell replaced the mother cell and the other daughter cell displaced adjacent biofilm cells in the direction of least resistance. In addition to growth and division, the simulation also accounted for cell death and cell lysis. Potentially, any number of

different microbial species and solute types, as well as interactions among them can be accommodated in the biofilm growth simulation.

The simulation was implemented to study the results of various levels of transport limitation on a growing single species biofilm. In a system with rapid solute diffusion, cells throughout the biofilm grew at their maximum rate, and no solute gradient was formed over the biofilm thickness. In increasingly transport-limited systems, the rapidly-growing fraction of the biofilm population decreased, and was found exclusively at the biofilm-liquid interface. Trans-biofilm growth substrate gradients also deepened with increasing transport limitation.

Autoinhibitory biofilm growth was simulated for various rates of microbially-produced inhibitor transport. Inhibitor transport rates affected both the biofilm population dynamics and the resulting biofilm structures. The formation of networks of void spaces in slow-growing regions of the biofilm and the development of columns in the fast-growing regions suggested a possible mechanism for the microscopically-observed evolution of channels in flow cell biofilms.

A promising approach for reducing groundwater pollution is bioremediation, a "green" technology that takes advantage of the enzymatic capabilities of bacteria to decontaminate chemical toxicants. An advantage of bioremediation over other cleanup technologies is its potential for in situ treatment of contaminated sites. Another major advantage of bioremediation over "pump and treat" technologies is that it effects the destruction of the target pollutants, rather than merely their relocation. Results of this research improved our understanding of the interactions of groundwater contaminants with degradative biofilms. This information is relevant to modeling the fate of groundwater contaminants, and

could contribute to reduced toxicant exposure for populations obtaining their drinking water from subsurface water supplies.

Publications

E. S. Gilbert, A. Khlebnikov, S. E. Cowan, and J. D. Keasling, Analysis of biofilm structure and gene expression using fluorescence dual labeling, *Biotechnol. Prog.* 17:1180-1182, 2001.

E. S. Gilbert, A. W. Walker, J. D. Keasling, A constructed microbial consortium for biodegradation of the organophosphorus insecticide parathion. *Applied Microbiology and Biotechnology*, "in press", 2003.

Professional Presentations

E. S. Gilbert & J. D. Keasling. American Society for Microbiology General Meeting, Los Angeles, California, 2000.

E. S. Gilbert & J. D. Keasling, American Chemical Society National Meeting, San Francisco, California, 2000.

E. S. Gilbert & J. D. Keasling, Biofilms American Society of Microbiology, Big Sky, Montana, 2000.

Student Training

Eric S. Gilbert, post-doctoral research fellow; Chemical Engineering, UC Berkeley

Ivan Chang, Undergraduate, Bioengineering, UC Berkeley

Keywords

Biofilm, biodegradation, bioremediation, confocal microscopy, green fluorescent protein, computer modeling, microbial ecology



Examining the Relative Influence of Riparian and Upland Land Cover and Land Use on Instream Habitats: Improved Methods for the Russian River Basin

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Project Summary

Numerous studies have established that large woody debris (LWD) plays a critical role forming and maintaining habitat for anadromous fish. However, nearly all of these studies have been conducted in the conifer-dominated forests of the Pacific Northwest (PNW). In California, anadromous fish also utilize watersheds dominated by hardwoods. Although managers are currently trying to restore habitat for anadromous fish in these watersheds, very little is known about the role of LWD in shaping this habitat. In this study, we are examining the relationships between riparian vegetation, instream LWD, and fish habitat in hardwood watersheds. We are studying riparian and landscape-scale influences on aquatic habitat in the Russian River basin and other hardwood-dominated watersheds in Northern California. Progress has been made in three primary areas: Riparian vegetation, large woody debris, and in-stream habitat.

We conducted field work examining the above described interactions in 25

In hardwood forest streams large woody debris forms pools that provide shelter for anadromous fish. Living key pieces are particularly important for stabilizing debris jams. In this study area, the level of embeddedness (the amount of fine sediment within spawning gravels) is negatively correlated with the amount of forest cover in the watershed.

hardwood-dominated streams in Northern California. Although the loading of woody debris (volume of LWD per unit area of channel) in hardwood streams was considerably lower than values reported from streams in conifer-dominated forests in the PNW, we found many of the same relationships between instream wood and fish habitat. For example, debris-formed pools had significantly greater cover (i.e. shelter) values than any other pool type. In hardwood streams with relatively high LWD loading, the majority of pools were formed by woody debris and, across streams, the occurrence of pools was positively correlated to LWD loading. Because hardwood debris is considerably

smaller than that derived from mature conifers, single pieces of hardwood debris rarely formed a pool. Instead, pool formation was generally influenced by complex debris jams that spanned or partially spanned the channel. These jams were often stabilized by the presence of living trees within the debris jam. Many riparian hardwoods have resilient growth forms such that they can be pushed over into the stream, become part of a debris jam, and then continue living and growing as long as their root system maintains contact with the bank. This “living LWD” results in more stable debris jams because key pieces of the debris jam are stabilized by their living root masses and do not decay.

Improved methods for characterizing hardwood riparian corridors through remote sensing

The structure and extent of the riparian forest strongly influences the amount and size of LWD that enters a channel. Because of the important relationship between riparian vegetation, LWD, and fish habitat, land managers seek methods to monitor and characterize the quality of riparian vegetation within a basin or across a region. We are developing techniques to characterize riparian corridors in hardwood-dominated regions using high-resolution remotely sensed imagery. We are collaborating with a scientist at California State University, Sonoma, to analyze riparian corridors in the Sonoma Valley using ADAR - high-resolution (4 m), multi-spectral imagery. The techniques that will allow us to: 1) identify riparian corridors on the landscape; 2) quantify their width and extent (i.e. presence of gaps); and 3) characterize their species composition and structure (e.g. size, maturity).

Landscape-scale influences on aquatic habitat

We also studied how land use and land cover (LULC) across the landscape influences habitat within streams. In

particular, we are examining the relationship between LULC at various scales and the embeddedness (the amount of fine sediments) of spawning gravels utilized by anadromous fish. We are utilizing 10 m Digital Elevation Models (DEMs) to designate unique watersheds above each of 380 reaches in the Russian River basin that have been surveyed for fish habitat, including embeddedness values, by the California Department of Fish and Game. Within these watersheds we are investigating the relationship between gravel embeddedness and LULC at several scales: 1) a 30 m buffer surrounding the reach; 2) the same buffer but also extended varying distances above the reach; and 3) the entire watershed above the reach. Initial results indicate that the LULC of the entire watershed explains the most variability in the embeddedness values; the level of embeddedness is positively correlated with the amount of agriculture and development in the watershed, while it is negatively correlated with the amount of forest and chaparral in the watershed. We are currently using the same data sources to develop a Hydrological Proximity Model (HPM) that creates an index to describe the way that LULC interacts with runoff patterns over the entire watershed. We will then examine whether the outcomes of HPM provide additional explanatory power.

Publications

Opperman, J. and A. Merenlender, Factors influencing the success of riparian restoration in the Russian River basin: deer, sheep, and hydrology. *Proceedings of the California Riparian Habitat and Floodplains Conference*, in-press.

Professional Presentations

Opperman, J. and A. Merenlender. Restoration of riparian corridors and large woody debris in California's hardwood-dominated watersheds. Joint Annual Meeting of the Ecological Society of

America and the Society for Ecological Restoration, Tucson, Arizona, August, 2002.

Opperman, J. and A. Merenlender. Evaluating riparian restoration projects to guide anadromous fish habitat restoration in California's hardwood-dominated watersheds, American Fisheries Society Annual Meeting (California-Nevada Chapter), Lake Tahoe, April, 2002.

Opperman, J., C. Brooks, A. Merenlender, and Z. Young. Large woody debris and fish habitat in hardwood-dominated streams of the Russian River Basin, Poster presented at the Salmonid Restoration Federation Annual Conference, Ukiah, California, March, 2002.

Opperman, J. and A. Merenlender. Large woody debris and habitat for endangered fish in California's Mediterranean-climate watersheds, San Francisco Bay Area Conservation Biology Symposium, San Francisco State University, California, January, 2002.

Opperman, J. Riparian restoration in the Russian River basin, California Riparian Habitat and Floodplains Conference, Sacramento, California, March 2001.

A channel-spanning debris jam creating a pool with high shelter values. The piece of wood in the foreground (in the shape of a Y rotated counter-clockwise) is a living red willow (*Salix laevigata*) which has fallen into the stream but is still rooted and living. This living key piece traps much of the other wood in the debris jam.

Student Training

Michael Gerstein, Undergraduate, Environmental Science, UC Berkeley
Sanaz Mamarsedegghi, Undergraduate, Conservation and Resource Studies, UC Berkeley

Susan Mahler, Ph.D. student, Environmental Science, Policy and Management, UC Berkeley
Jeff Opperman, Ph.D., Environmental Science, Policy and Management, UC Berkeley

Additional Funding

This research project is also being supported by the following grant: "Influences of riparian vegetation and landscape-scale factors on salmonid habitat in Mediterranean-climate hardwood watersheds," from California Department of Fish and Game. 2001-2003, \$93,000.

Collaborative Efforts

We are collaborating on imagery analysis with Professor Ross Meentemeyer, Department of Geography, Sonoma State University, California.

Keywords

Buffer strips, riparian, watershed, scale, land use, salmon habitat, restoration, GIS, remote sensing





Restoring Alpine Lake Ecosystems Through Control of Trout Spawning

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Project Summary

Non-native trout have been widely introduced into historically fishless lakes in the Sierra Nevada with massive negative ecological effects. There is a growing interest in returning some lakes to a fishless condition, yet progress in this direction is being hampered by lack of information on factors limiting populations of introduced trout in high elevation lakes. There are two primary components to this study:

Self-sustainability of Trout Populations in High Sierra Lakes

During the period 1994-1996, stocking was suspended for 5+ years in 33 lakes in the John Muir Wilderness Area (JMW). This provided the opportunity to (1) determine what proportion of lakes in the JMW study area contain self-sustaining rainbow trout (*Oncorhynchus mykiss*) or golden trout (*Oncorhynchus mykiss aguabonita*) populations, (2) quantify the effects of halting fish stocking on those trout populations that are self-sustaining, and (3) identify the factors that might influence trout population self-sustainability. At these lakes, we collected trout population data in 2001 and

What proportion of currently-stocked golden and rainbow trout populations in the alpine Sierra Nevada are self-sustaining? Evidence suggested that at least 21 of the 33 lakes in the John Muir Wilderness Area contained self-sustaining populations. Supplemental stocking provides no benefit when lakes have self-sustaining population. An additional 45 lakes in the same area is being examined to increase the sample size and to generalize the findings.

compared the results to those generated from an identical data collection effort conducted at the time of the stocking termination (1995-1996; Knapp, unpublished data). Based on previous research on trout populations in the study area (Knapp, unpublished data), we hypothesized that a majority of currently stocked trout populations were in fact self-sustaining. For self-sustaining trout populations, we also predicted that halting stocking would have either no effect or a positive effect on fish growth rates. A positive effect on growth rates might occur if halting stocking reduced fish population densities.

This is the first study that addresses the question of what proportion of currently stocked golden and rainbow trout populations in the alpine Sierra Nevada are self-sustaining. Management of these lakes has historically been predicated on the assumption that few or none of these introduced trout populations are self-sustaining. We found evidence that 79% of the populations in the 33 experimental lakes in this study showed some level of recruitment resulting from natural reproduction. Our conservative definition of population self-sustainability suggested that 64% of the experimental lakes included in this study contained self-sustaining trout populations, while another 15% showed very low recruitment. Trout populations in these latter lakes are unlikely to be self-sustaining over the long term. Our results suggest that many of the golden and rainbow trout populations in the High Sierra are likely self-sustaining. In addition, our results suggest that supplemental stocking of lakes provides no benefit when lakes contain self-sustaining trout populations. Population density and maximum fish size (a measure of individual growth rates) were similar in experimental and control lakes following the 5+ year stocking hiatus. Although no detrimental effects of stocking on recipient trout populations were apparent (e.g., reduced fish sizes resulting from increased population densities), a permanent cessation of stocking in those lakes with low levels of natural reproduction may eventually produce a lower density fish population with higher individual growth rates.

We are collecting the same data from an additional 45 lakes in the JMW during Summer 2002 in order to increase our sample size and increase the generality of these findings.

Factors Influencing The Persistence of Brook Trout Populations in Sierra Nevada Lakes

We have collected population data (density, individual sizes, age class distribution) as well as physical measures from (depth, area, elevation, temperature, amount of spawning habitat, and littoral zone substrate) from 70 brook trout lakes in Yosemite National Park to (1) examine the role of spawning habitat in limiting brook trout populations, (2) quantify the influence of lake physical factors (lake elevation, lake area, lake depth, mid-summer water temperature, and conductivity) in influencing brook trout density, and (3) determine what influence climatic variables such as winter precipitation and summer temperatures have on brook trout spawning timing and dynamics. . In addition, we have conducted snorkel surveys in approximately 60 of these lakes in order to identify and quantify the areal extent of spawning habitat. The data will be used at inputs of a matrix population model to determine what factors enable brook trout populations to persist in high elevation lakes in the Sierra Nevada.

Preliminary evidence shows that spawning habitat is a limiting factor in influencing brook trout recruitment. The magnitude of annual recruitment in these populations also appears to be episodic, and is likely influenced by climatic factors such as winter precipitation and summer temperatures. These preliminary results indicate that changing global weather patterns may significantly alter brook trout recruitment in the future.

Publications

Armstrong, T.W., and R.A. Knapp, Response by Trout Populations in Sierra Nevada Alpine Lakes to an Experimental Halt to Stocking. *Report to the California Dept. of Fish and Game*. 36 pp, 2002.

Professional Presentations

Armstrong, T.W., Response by Trout Populations in Sierra Nevada Alpine Lakes to an Experimental Halt to Stocking, Presented to the California Department of Fish and Game, Sacramento, California, March 26, 2002.

Armstrong, T.W., and R.A. Knapp, Is Stocking Necessary to Maintain Populations of Introduced Trout in the Sierra Nevada?, Sierra Nevada Aquatic Research Laboratory - spring seminar series, Mammoth Lakes, California, May 9, 2002

Student Training

Trip Armstrong, Graduate Group in Ecology, Ph.D. student, UC Davis

Additional Funding

\$25,000 from California Department of Fish and Game, 1 year

Collaborative Efforts

Dr. Roland Knapp, researcher, UC Santa Barbara

Keywords

Reproduction, spawning habitat, self-sustainability, redd, brook trout, golden trout, restoration, introduced species, alpine lakes



Effects of Fine Sediment Storage on Food Web Structure and Juvenile Salmonid Rearing in North Coast California Rivers

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Project Summary

Excessive loading of fine sediments into western rivers has degraded spawning and rearing habitat for salmonids, and contributed substantially to their declines. Impacts on salmon redds have been studied extensively, but effects on juvenile rearing are less well documented. In a field experiment in the South Fork Eel River, we investigated the impacts of deposited fine sediment on juvenile steelhead trout. Our experimental design allowed us to isolate the effects of fine bed sediments from other covarying factors and to reveal the mechanisms of their effects. Increasing levels of embeddedness with deposited fine sediment (from zero to 100%) decreased growth and survival of juvenile steelhead trout. The nearly linear decreases in growth resulted from decreased food availability and metabolic costs of increased activity and intraspecific aggression. The invertebrate community changed from one of more available prey

Excessive loading of fine sediments into western rivers has degraded spawning and rearing habitat for salmonids, and contributed substantially to their declines.

to one of unavailable burrowing taxa with higher levels of deposited fine sediment. Steelhead in more heavily embedded channels showed more continuous movement and aggression and higher incidence of injury. This study shows a direct impact of riverbed composition on salmonid rearing success, which has been identified as a life history bottleneck in models informing efforts to recover these populations.

Professional Presentations

Mary Power (presenter), Blake Suttle, Camille McNeely, and Jonathan Levine
ESA Abstract, Effects of fine bed sediments on juvenile steelhead and food webs supporting them, Tuscon, AZ, August 4-9, 2002

Student Training

Blake Suttle, graduate, Ph.D., Integrative
Biology, UC Berkeley
Camille McNeely, graduate, Ph.D.,
Integrative Biology, UC Berkeley
Rebecca Doubledee, graduate, Ph.D.,
Integrative Biology, UC Berkeley
Mary Sorenson, Undergraduate,
Integrative Biology, UC Berkeley
Joe Sapp, Undergraduate, Integrative
Biology, UC Berkeley
Jesse Walker, Undergraduate, Integrative
Biology, UC Berkeley
Stacy Evans, high school intern,
Laytonville High School

Keywords

Juvenile steelhead growth and behavior,
rearing habit, fine sediment,
embeddedness, river bed texture, river
food web

Research Category III

Water Quality

Research in this category encompasses all factors and processes affecting the quality of the sources of surface and groundwater regardless of the use, and the quality and treatment of water in the transportation and distribution systems. Topics that fall within this category include studies of the sources and the nature of contaminants including those emanating from agricultural and industrial processes, effects of contamination on human health, plant and wildlife, wastewater treatment and reclamation processes, and retrospective evaluations of the effectiveness and impacts of different strategies utilized in California for improving water quality and for preventing water quality degradation.





Development of a Liquid Membrane Technique to Measure the Temporal Variation in "Bioavailable" Copper and Nickel in the South San Francisco Bay

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UC Santa Cruz

Project Summary

South San Francisco Bay has been designated as an impaired water body under the Federal Clean Water Act because the "total concentration" of dissolved copper and nickel in the water often exceeds the numerical limits set in the water quality objectives. There is strong evidence, however, to suggest that most of this nickel and some of the copper is complexed to anionic hydrophilic ligands such as ethylenediamine tetraacetic acid (EDTA) that are not directly assimilated by microorganisms. Copper is also strongly bound to natural organic ligands in a form that is not directly available to the plankton community. The aim of this project is to measure the concentration of "bioavailable" copper and nickel in South San Francisco Bay. The bioavailability of trace metals to phytoplankton (with respect to both toxicity and biolimitation) is generally correlated to the free or inorganic metal ion concentrations rather than the total metal concentration of the water.

In order to determine the free or labile fraction of copper or nickel, the total

dissolved concentration of these metals has to be determined first. The concentrations of alkali and alkaline earth ions and dissolved organic matter (DOM) are rather high in estuarine waters. Because of the interferences by these substances, it is difficult to accurately measure trace amounts of Ni and Cu present in the estuarine water. A separation and concentration step to remove the trace metals of interest from the complex background chemical matrices of the water is therefore necessary. Solvent extraction has been the most common sample concentration method used for this purpose. Solvent extraction methods although very reliable, are time consuming and difficult to automate because they are not readily adapted to flow injection systems of the instruments commonly used in elemental analysis.

An on-line chelating resin column partitioning Inductive Capillary Plasma – Mass Spectroscopy method was developed to determine the dissolved nickel and copper in South San Francisco Bay estuarine water.

The first task of this project was to develop an automated flow injection method for determination of total copper and nickel concentration in estuarine water. This method employs a chelating resin packed in a mini column to partition and concentrate the trace metals in the water sample from the interfering alkali and alkaline earth ions prior to on-line determination by inductively coupled plasma mass spectrometry (ICP-MS). The performance of this new on-line ICP-MS method was compared to outcomes of the well established solvent extraction graphite furnace atomic absorption spectrometry (SE-GFAAS) method.

To obtain total dissolved copper concentrations comparable to those measured by the SE-GFAAS, it was necessary to destroy the DOM in the acidified water samples prior to on-line chelating resin column partitioning ICP-MS determination. The discrepancy was especially pronounced in samples from South San Francisco Bay, which had high concentrations of dissolved organic carbon.

To determine the free copper and nickel concentration in South San Francisco Bay, we have developed a membrane-based separation technique that employs an automated on-line flow system consisting of a peristaltic pump, electrically actuated

valves and a membrane filtration unit. The membrane holder was custom-machined in our machine shop. It consists of two circular Teflon blocks each with circular grooves like an Archimedes spiral. The entire set-up is computer controlled via a digital I/O card to switch valves and start or stop the peristaltic pump. Copper and nickel concentration is determined off-line by GFAAS after membrane extraction.

Publications

Kuria Ndung'u, Robert P. Franks, Kenneth W. Bruland and A. Russell Flegal, Organic complexation and total dissolved trace metal analysis in estuarine waters: Comparison of solvent-extraction GFAAS and chelating resin flow injection ICP-MS Analysis, *Analytica Chimica Acta*, "in press".

Post-doctoral Researcher Training

Kuria Ndungu, Ph.D., post-doctoral research at the Department of Ocean Sciences, UC Santa Cruz

Keywords

Trace metals, bioavailability, copper, nickel, chemical speciation, supported liquid membrane, South San Francisco Bay Estuary



Tunable Immunosorbents for the Remediation of Atrazine - and Simazine - Contaminated Water

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Ashok Mulchandani
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Project Summary

The immunotechnology provides a promising analytical tool to detect pollutants in the environment with high affinity and specificity. However, conventional immunoassays are time consuming and expensive. In this work, tunable immunosorbents was designed for the detection of atrazine in the contaminated water. Elastin-like polypeptides (ELP) are protein biopolymers consisting of repeating pentapeptide units VPGVG that can undergo a reversible phase transition by either increasing the temperature or ionic strength of the solution. We have engineered fusions of ELP to a single chain antibody for atrazine to obtain sorption materials with tunable phase-transition properties and demonstrated that this tunable immunosorbent can detect atrazine at concentrations that were lower than the maximum contamination level permitted in the National Primary Drinking Water Standard (3 ppb). The successful development of these biopolymers illustrates a new technology for an economical and highly efficient detection of diverse pollutants.

Water samples with known amounts of atrazine were evaluated by the assay we developed. The good agreement between the measured and the actual atrazine concentrations indicates that the assay is accurate and reliable.

Phase Separation Immunoassay for Atrazine

The principle of the competitive phase-separation immunoassay for atrazine is based on thermally triggered precipitation of the antibody-atrazine complex in the presence of HRP (horse radish peroxidase) -labeled atrazine. After separation of the immuno-complex from the reagents, the amount of HRP-labeled atrazine is easily quantified. Although the absolute values varied slightly in different experiments, the calibration curve for atrazine from four replicate measurements are shown in Figure 1. The observed IC_{50} (50% inhibitory concentration) was in the order of 0.16 ppb and the detection limit was 0.01 ppb. An excellent linear relationship ($y = -19.328\ln(x) + 13.408$, $R^2 = 0.9928$ where y is the atrazine concentration and x is the % inhibition) was found between the concentration range of 0.02 ppb to 1 ppb.

The accuracy of the assay is summarized in Table 1. Water samples with known amounts of atrazine were evaluated by the assay we developed and the atrazine concentrations in the water were calculated using the linear correlation established from the calibration. The good agreement between the measured and the actual atrazine concentrations indicates that the assay is accurate and reliable.

To demonstrate the selectivity of the immunoassay, other triazines (prometryne and simazine) and pesticides (paraoxon, carbaryl, and 2,4-D) were included. There was virtually no interference for all of the pesticides tested (data not shown). Cross reactivity was observed with the other triazines tested, however, the sensitivity was significantly lower, with the IC_{50} values of 10.73 ppb for simazine and 2.60 ppb for prometryne. The findings are in line with the specificity reported for the parent monoclonal atrazine antibody demonstrating that fusion to the elastin domain has no effect on selectivity.

Professional Presentations

Jae-Young Kim, Tunable biopolymers for environmental remediation and monitoring, ACS annual meeting, Boston, August, 2002.

Jae-Young Kim, Tunable biopolymers for environmental remediation and monitoring AICHE, Indianapolis, November, 2002.

Student Training

Jae-Young Kim, graduate student, Ph. D, Environmental Toxicology, UC Riverside

Collaborative Efforts

We are collaborating with Prof. George Georgiou on improving the expression of ELP-scAb

Keywords

Antibodies, detection, elastin, atrazine, simazine

Figure 1. Phase separation immunoassay by tunable immunosorbent.

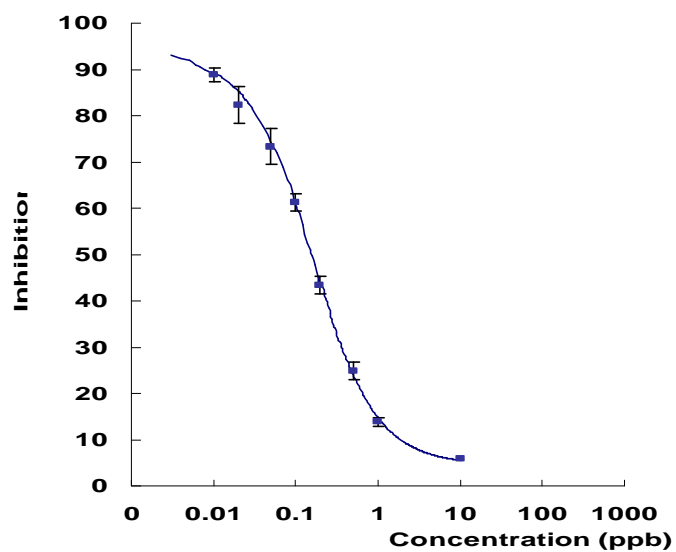


Table 1. Atrazine Concentrations of Water as Measured by The Immunoassay

Actual Atrazine (ppb)	Measured Atrazine (ppb) ^a	Recovery (%)
0.025	0.0261 ± 0.0059	104.50
0.25	0.2312 ± 0.0519	92.46
0.5	0.4820 ± 0.0622	96.39

^aValues are mean of five determinations ± standard deviation.



Application of Acoustic Pressure Waves in Aquifer Remediation and Mobilization of Entrapped Organic Liquids

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Civil and Environmental Engineering
UC Irvine

Project Summary

The potential application of acoustic waves to remediate groundwater aquifers contaminated with dense nonaqueous phase liquids (DNAPLs) is investigated. Dense nonaqueous phase liquids (DNAPLs), such as trichloroethylene (TCE), perchlorethylene (PCE), and carbon tetrachloride (CTC) are commonly used as degreasers and solvents in industries and in laundries for dry cleaning. Unfortunately, they are also common groundwater contaminants. Because they are more dense than water, they sink to deeper portions of groundwater aquifers potentially contaminating larger volume of the groundwater than their counterparts, the light nonaqueous phase liquids (LNAPLs), such as the components of gasoline. Compounding the problem, the aqueous solubilities and biodegradability of DNAPLs are very low, resulting in long-lasting sources of contamination. Currently, the primary method for remediating groundwater contaminated with DNAPLs is to pump-and-treat. The pump-and-treat methodology involves pumping out great volumes of groundwater from the contaminated

Under simulated conditions of groundwater aquifer, the mass transport and dissolution of dense nonaqueous phase liquid were significantly enhanced by the application of acoustic wave. If the observations can be demonstrated in field scale operations, this approach is potentially beneficial in reducing the time requirements and costs to remediate contaminated groundwater.

aquifer and treating them to remove the contaminants. Due to the low solubility of DNAPLs, pump-and-treat is a long and costly process to remediate the contaminated aquifers. Acoustic waves may increase the dissolution and aqueous transport of DNAPLs in the groundwater aquifers thus enhance the efficiency of the pump and treat methodology.

Laboratory experiments employing water-saturated packed columns were designed to test the effects of acoustic waves on the mass transport and dissolution of DNAPLs. Results showed that there were significant increases in the mass transport rates in the porous media due to the addition of acoustic pressure waves. The

enhanced mass transport in saturated porous media by acoustic pressure waves were quantified.

When known volumes of DNAPL were injected into the water saturated packed columns and subjected to a range of acoustic wave frequencies and pressures amplitudes, 100% increases in the effluent concentrations were observed, in comparison to the case with the no acoustic wave treatment. The increase in effluent concentrations suggests that the addition of acoustic waves increase the mass transfer of the DNAPL from the nonaqueous phase to the aqueous phase which in turn leads to faster dissolution and shorter remediation time. The percentage of increases in the effluent concentrations, compared to the base case of no acoustic pressure, were proportional to the applied acoustic pressure. The increase of DNAPL concentration in the effluent is attributed to the change in pore space geometry and DNAPL water interfacial areas by the application of acoustic pressure waves.

Under simulated conditions of groundwater aquifer, the mass transport and dissolution of dense non-aqueous phase liquid were significantly enhanced by the application of acoustic wave. If the observations can be demonstrated in field scale operations, this approach is potentially beneficial in reducing the time requirements and costs to remediate contaminated groundwater. Results showed the enhancement of both mass transport and DNAPL dissolution in water

saturated porous media due to the application of acoustic pressure waves. This research illustrated the potential benefits of reduced remediation times and costs in employing the pump and treat technology in remediating contaminated groundwater and the possible rapid development of field scale applications. Further investigation is required however, to isolate and describe the exact mechanisms responsible for the observed phenomena.

Publications

Vogler, E. T. and C. V. Chrysikopoulos, Experimental investigation of acoustically enhanced solute transport in porous media, *Geophysical Research Letters*, 29(15), 10.1029/2002GL015304, 2002.

Vogler, E. T. and C. V. Chrysikopoulos, Effect of acoustic waves on solute transport in porous media, *Proceedings of the international conference Protection and Restoration of the Environment VI, Volume II*, edited by A.G. Kungolos, A.B. Liakopoulos, G.P. Korfiatis, A.D. Koutsospyros, K.L Katsifarakis, and A.C. Demetracopoulos, pp. 921-926, Skiathos, Greece, 2002.

Student Training

Eric T. Vogler, graduate, Ph.D. student; Civil & Environmental Engineering, UC Irvine.

Keywords

Acoustic waves, remediation, organic liquids, pump-and-treat



Fate of Viruses, Endocrine Disrupters, and Nitrogen in Non-Conventional On-site Wastewater Treatment Processes: A Technical and Economic Analysis

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UC Davis

Project Summary

As much as 10% of residential households in California rely on onsite wastewater disposal systems. Discharges from such systems are primary sources of pollutants in California's rivers and lakes. The conventional design criteria for onsite systems are no longer adequate, particularly for key water contaminants including nitrogen, viruses, and endocrine disrupters. California is one state that has not yet adopted statewide regulations for onsite sewage disposal systems. The conventional onsite wastewater systems (utilizing a septic tank and soil adsorption system) are not adequate for meeting the increasingly challenging onsite treatment and reuse needs in California. The California Assembly passed AB 885 in 2000 requiring the State Water Resources Control Board, on or before January 1, 2004, to adopt statewide regulations for onsite wastewater disposal systems. It will be challenging to develop rational statewide regulations for a state with wide variation in soils, onsite wastewater system densities, and sensitivity of the receiving environment. Research is needed to examine the technical and economic efficacy of enhanced onsite

As much as 10% of residential households in California rely on onsite wastewater disposal systems. The conventional onsite wastewater systems (utilizing a septic tank and soil adsorption system) are not always adequate for meeting the increasingly challenging onsite treatment and reuse needs in California. The ability of three advanced and one conventional (septic tanks) onsite wastewater treatment systems to remove viruses, nitrogen, and endocrine disrupters are evaluated.

wastewater treatment systems relative to conventional soil based systems for removal of viruses, nitrate, and endocrine disrupters.

The ability of three advanced and one conventional (septic tanks) onsite wastewater treatment systems to remove viruses, nitrogen, and endocrine disrupters are compared. The advanced treatment systems represent the state of the art in onsite wastewater treatment systems, namely, an aerobic biofilter system utilizing high porosity media, an aerobic suspended growth system, and an aerobic suspended growth system with

bioaugmentation. The performance of soil adsorption systems will be assessed by applying effluents to soil columns and sampling at incremental depths to assess the attenuation of wastewater constituents with depth.

In contrast to previous studies that have characterized the performance of these treatment systems in terms of conventional water quality parameters such as the BOD and total suspended solids, the current study will evaluate the capability of onsite wastewater treatment systems to remove viruses and endocrine disrupters and the potential for bioaugmentation to improve treatment.

Publications

Leverenz, H., L. Ruppe, G. Tchobanoglous, and J. Darby, Evaluation of High-Porosity Medium in Intermittently Dosed, Multi-Pass Packed Bed Filters for the Treatment of Wastewater, *Journal of Small Flows*, V2, N2, 28-35, 2001.

Student Training

Loret Ruppe, Ph.D. student, Civil and Environmental Engineering, UC Davis
Harry Leverenz, Ph.D. student, Civil and Environmental Engineering, UC Davis
Julietta Trejo, Ph.D. student Civil and Environmental Engineering, UC Davis
Eric Tawney, Undergraduate, Civil and Environmental Engineering, UC Davis
Angel Aracelli, Undergraduate; Civil and Environmental Engineering, UC Davis
Sarah Aaby, Undergraduate; Civil and Environmental Engineering, UC Davis
Erin Oneida, Undergraduate; Civil and Environmental Engineering, UC Davis
Olivia Virgadamo, Undergraduate; Civil and Environmental Engineering, Cal Poly, San Luis Obispo

Additional Funding

Survey of Alternative Onsite Sewage Treatment and Disposal Systems for the State Water Resources Control Board, \$48,365, June 15, 2001 – December 31, 2002

Research Experiences for Undergraduate Students, National Science Foundation, \$10,000.

Keywords

Decentralized wastewater management, viruses, nitrate, endocrine disrupters, aerobic biofilter, septic tank



Perchlorate Removal in Groundwater by Perchlorate Reductases from the Perchlorate Respiring Bacterium, Perc1ace

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Project Summary

Perchlorate (ClO_4^-) is an important energetic component of solid rocket fuel. The major source of ClO_4^- pollution is the military, space program and supporting industries. Waste water generated from the manufacturing, maintenance, and testing of solid rocket propellants can contain NH_4 perchlorate in the grams per liter concentration range. Perchlorate is recalcitrant in the environment and is potentially toxic to various forms of life, humans in particular. California Department of Health Services adopted the action level of 18 ppb for perchlorate in potable water.

Physicochemical water treatment technologies (e.g. membrane and ion-exchange systems) have been considered for the ClO_4^- remediation but they are expensive and not practical for ClO_4^- removal from the ground water. Moreover, these processes produce high salt waste streams contaminated with perchlorate and require further treatment to remove residual ClO_4^- . Microbial reduction of ClO_4^- to environmentally-acceptable innocuous end products is currently an area of intense interest. Microorganisms that

Perchlorate reductase enzyme was identified and isolated from the ClO_4^- respiring bacterium, perc1ace. The biochemical properties of the enzyme were characterized. Biotechnological methods are being developed to mass produce cell-free recombinant enzyme to be used in designing and testing the enzymatic reactors for reduction of perchlorate in water.

reduce perchlorate to chloride and molecular oxygen have been isolated. For designing an efficient biological-based ground water ClO_4^- remediation strategy, the biochemical and molecular data on the enzymatic reduction of ClO_4^- are needed.

The ClO_4^- respiring organism, perc1ace when grown using either ClO_4^- or NO_3^- as a terminal electron acceptor produced ClO_4^- reductase to a significant extent. The ClO_4^- reductase activity appeared to be within the periplasmic space, with activities as high as $14,000 \text{ nmol}^{-1} \text{ min}^{-1} \text{ mg protein}^{-1}$, indicating that it is a soluble enzyme. A ClO_4^- reductase from cell-free extracts of perc1ace was purified 10-fold by ion-exchange and molecular exclusion fast protein liquid chromatography (FPLC). The

ClO_4^- reductase catalyzed the reduction of ClO_4^- at a V_{\max} and K_m of 4.8 Units mg protein^{-1} and 34.5 μM , respectively. Maximal activity was recorded at 25-30°C and pH 7.5 – 8.0. *perc1ace* ClO_4^- reductase is a dimer with molecular masses of 35.07 kDa and 75.1 kDa determined by SDS-PAGE and MALDI-TOF/MS. To study the genetic determinants of ClO_4^- reductase, the amino terminal sequences of tryptic peptides of the approximately 35 kDa ClO_4^- reductase subunit were obtained by electrospray mass spectrometry. GenBank Blast analysis of the amino acid sequences revealed homology to reductases. In batch studies of *in vitro* reduction of perchlorate, *perc1ace* ClO_4^- reductase reduced perchlorate in water with either NADH or methyl viologen as electron donor. Addition of *perc1ace* ClO_4^- reductase to ion-exchange (IEX) brine impacted with ClO_4^- substantially enhanced ClO_4^- removal by salt tolerant bacteria.

Additional studies are focusing on the molecular characterization of the genetic determinants of ClO_4^- bioreduction by *perc1ace* by cloning the genes using degenerate primers designed from the amino acid sequences of ClO_4^- reductase tryptic peptides and over-expression of recombinant ClO_4^- reductase. Such a recombinant enzyme available in large quantities can be immobilized and safely used for the treatment of perchlorate contaminated ground water on site. Treatment systems designed to employ mass produced cell-free enzymes catalyze the ClO_4^- reduction reaction without the production of biomass wastes. Moreover, the spent enzymes can be regenerated and reused, substantially reducing cost.

Publications

Okeke, B.C., Giblin, T. and Frankenberger Jr. W.T., Reduction of perchlorate and nitrate by salt tolerant bacteria, *Environmental Pollution*, 118, 357-363, 2002.

Giblin, T. and Frankenberger Jr. W.T., Perchlorate and nitrate reductase activity in the perchlorate respiring bacterium *perc1ace*, *Microbiological Research*, 156, 311 – 315, 2002.

Losi, M.E., Giblin, T., Hosangadi, V. and Frankenberger, W.T., Bioremediation of perchlorate-contaminated groundwater using a packed bed biological reactor. *Bioremediation Journal*, 6, 97-104, 2002.

Giblin, T., Losi, M.E., Hosangadi, V. and Frankenberger, W.T., Bacterial perchlorate reduction in simulated reverse osmosis rejectate. *Bioremediation Journal*, 6, 105-111, 2002.

Student training

The project provided practical training for over 30 students enrolled in Environmental Science 155 through several hours of laboratory classes on “Bioremediation of perchlorate in ground water”. The project also supported in part, a post-doctoral fellow (Benedict C. Okeke) to carry out the study.

Keywords

Ground water, contamination, perchlorate, perchlorate reductase, enzyme purification, peptide sequencing, gene cloning, enzyme over-expression, on-site bioremediation.



Biodegradation of Estrogenic Compounds and Its Enhancement in a Membrane Bioreactor

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UC Berkeley

Project Summary

Human and animal wastes are potential sources of estrogens to the environment since only a fraction of them is expected to be removed during the conventional wastewater treatment. Because these compounds mimic the effect of a natural hormone, they may disrupt the endocrine system of exposed species and the reproductive systems of aquatic fauna when the treated effluents are discharged. This study examines the removal of estrogenic activity by the activated sludge process, commonly employed in treating municipal wastewater.

A yeast-based bioassay procedure developed is capable of quantifying estrogenic activity of multiple hormonal compounds in water equivalent to 0.1 to 100 $\mu\text{g/L}$ of 17-beta-estradiol. Laboratory experiments demonstrated that the activated sludge process may reduce the estrogenic activity of wastewater by up to 40%.

A previously developed yeast-based assay was modified to detect the estrogenic activity in wastewater samples. The assay was capable to quantify estrogenic activity

in a range equivalent to between approximately 100 ng/L to 100 $\mu\text{g/L}$ of the 17-beta-estradiol (E2) with sensitivity as low as 0.03 ng E2/L and is sensitive to the concentrations of environmental estrogens typically found in wastewater. Because of its sensitivity to multiple compounds, the new assay is a useful tool for screening for the estrogenic activity. Comparing with existing chemical methods, the newly developed bioassay procedure is simpler and covers a wider range of compounds. This feature is important because the degradation by-products of some estrogens in the influent are also active estrogens. For example, E2 is metabolized to estrone and estriol, which are estrogenic. Assaying methods tracking only limited substances may give a false impression of effective removal of estrogenic substances and underestimate the estrogenic properties of treatment plant effluents and solids disposed of into the environment. Activated sludge treatment experiments were carried out to determine the removal of estrogenic activity from wastewater. Results showed that treatment process with 2g/L of activated sludge reduced the total estrogenic activity of wastewater by up to 40% within 10-14 days.

Student Training

Eleanor Wozei, graduate, Ph.D.; Civil and Environmental Engineering, UC Berkeley
Xiang Sun, Undergraduate, UC Berkeley
Angela Arpke, Undergraduate, Milwaukee School of Engineering through UC Berkeley SUPERB program

Collaborative Efforts

Collaboration with Prof. David Sedlak, UC Berkeley group.

Keywords

Estrogens, wastewater treatment, membrane bioreactor



Emplacement and Release of Brines from the Subsurface

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UC Berkeley

Project Summary

Groundwater contamination resulting from the creation and release of dense brines is a common occurrence, but is rarely acknowledged. Brines can be generally defined as aqueous solutions with a total dissolved solids (TDS) concentration in excess of $10,000 \text{ mg L}^{-1}$. In addition to increased TDS, brines have a greater density and viscosity than that of freshwater. The most widespread and widely recognized occurrence of brine-induced groundwater contamination is seawater intrusion into coastal aquifers. Seawater has a TDS concentration of about $30,000 \text{ mg L}^{-1}$ and a density and viscosity only slightly greater than that of freshwater. Other examples of groundwater contamination resulting from brine releases are ammonium perchlorate spills, acid mine drainage, landfill leachate plumes, and unintentional releases from nuclear waste processing facilities. TDS concentrations of these highly concentrated brines can be in excess of $500,000 \text{ mg L}^{-1}$ with densities and viscosities much greater than that of freshwater. Since most spills occur at or near the land surface, brines can

contaminate aquifers only if they reach the groundwater table through infiltration through the vadose zone.

Studies are initiated to quantify the vadose zone transport mechanisms of brine. Laboratory scale experiments have been established to investigate the effects of density and viscosity of brine and displacement rates and permeability on the instability at brine/freshwater interfaces that subsequently determines the mixing of two phases and transport of brine.

Little is currently understood about the transport of brines in the vadose zone. The ultimate objective of this research is to improve the understanding of brine fate by quantifying vadose zone transport mechanisms, but this also requires some effort to understand brine migration in water saturated porous media. During brine release at the soil surface, the brine moves as a wetting fluid vertically through the vadose zone, displacing residual pore water at the wetting front. At the brine/freshwater interface, gravitational instabilities will induce mixing. Once the

brine release has stopped, the vadose zone will drain to residual brine saturation. During subsequent freshwater infiltration events, the freshwater wetting front displaces residual brine and creates a brine "halo" ahead of the freshwater wetting front. At this freshwater/brine interface viscous instabilities will induce mixing since the viscosity of the displacing freshwater is less than the viscosity of the brine.

A laboratory-scale experimental program has been established to specifically address the issues of mixing at the unstable brine/freshwater interfaces. This experimental program takes place in two phases. During the first phase, fully saturated, one-dimensional vertically downward displacements, the mixing zone is measured as brine displaces freshwater and as freshwater displaces brine. The dependence of mixing zone size as a function of brine physical parameters, i.e. density and viscosity, and experimental parameters, i.e. displacement rate, column permeability, and column diameter, will be determined. Experimental data reported by others indicate that as brine displaces freshwater, the flow will be gravitationally

unstable, but will be stabilized by the viscosity difference. The gravitational instability tends to dominate over the viscous stabilization and overall mixing is enhanced. As freshwater displaces brine, the flow will be gravitationally stable, but will be destabilized by the viscosity difference. The gravitational stabilization tends to dominate over the viscous destabilization and overall mixing is suppressed. Expected completion of the first experimental phase is September 1, 2002. The second experimental phase, unsaturated one-dimensional vertically downward displacements, will repeat the experiments of phase 1 in an unsaturated system. Expected completion of the second experimental phase is April 1, 2003.

Student Training

Tracey Flowers, Graduate, Ph.D.,
Environmental Engineering, UC Berkeley

Keywords

Mass transfer, density driven flow,
ammonium perchlorate, groundwater
pollution, vadose zone



Is Urban Runoff a Source of Human Pathogenic Viruses to Recreational Beach Waters?

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UC Irvine

Project Summary

To assess the impact of urban runoff on the coastal water quality, water samples were collected at 21 sites in 11 rivers and creeks along the Southern California coast for bacteriological and virological examinations during summer 2000. The water samples were tested for the presence of three types of human viruses (adeno, entero and hepatitis A viruses) using nested- and RT-PCR methods. In addition, they were tested for three types of fecal indicator bacteria (total coliform, fecal coliform and enterococcus) as well as the somatic and F-specific coliphage.

Trace of hepatitis virus signals were found in 81% of the water samples collected at 21 sites in 11 rivers and creeks along the Southern California coast during the summer of 2000. Urban runoff is a major contributor to coastal water pollution.

Human viruses were detected in sample volume as low as 105 ml of water. Hepatitis A viruses were the most frequently found, and were detected in 81% of water samples we collected at the urban rivers of Southern California. All of sites that tested positive for

adenovirus (52%) were also positive for entero and hepatitis A viruses. The fecal indicator bacteria were found in all of the water samples examined. There was, however, not a clear relationship between fecal indicator concentrations and the presence of human viruses in the water. At the site where the quality of its water ranked second best in terms of the bacterial indicators, all three types of human viruses were detected.

To understand the seasonal dynamics of pollutant loads from the urban runoff, water samples were collected at the mouths of the Los Angeles River, the San Gabriel River, and the Santa Ana River during both the wet and dry seasons. Human viruses were most frequently found at the mouth of the Los Angeles River. In general, both fecal indicator bacteria and human viral densities of the water at the river mouths were associated with storm events. The first storm of the wet season most likely carried a heavy pathogen load and were expected to impact the coastal water quality more than subsequent storm events. Urban runoff is a major contributor to coastal water pollution.

Professional Presentations

Sunny Jiang, Adenovirus as an Index of Human Viral Contamination, EPA Contamination Source Tracking Workshop, February, 2002.

Sunny Jiang, Detection of Human Adenoviruses in Coastal Waters of Southern California, Pacific Rim Shellfish Conference, San Diego, California. April 4-6, 2001

Sunny Jiang, Is Urban Runoff a Source of Human Pathogenic Viruses to Recreational Beach Waters?, Ballona Wetland Foundation Conference, Los Angeles, California. May 17-18, 2001

Sunny Jiang, Recreational Risks, Viruses on the Beaches, 101st Annual meeting of American Society for Microbiology, Orlando, Florida. May 20-24, 2001

Sunny Jiang and Weiping Chu, American Society of Limnology and Oceanography Summer Meeting, Victoria, British Columbia, Canada, June 10-14, 2002

Sunny Jiang, Relationships Between Pathogens and Fecal Indicator Bacteria: What do Indicators Indicate?, 82nd Annual meeting of American Association for the Advancement of Science, Pacific Division, Irvine, California, June 17-20, 2001

Student Training

Sam Choi, graduate student, MS; Environmental Analysis and Design, UC Irvine.

Miyuki Fujita, Undergraduate, Applied Ecology, UC Irvine

Clifford Tse, Undergraduate, Applied Ecology, UC Irvine

Elaine Jacinto, Undergraduate, Applied Ecology, UC Irvine

Joanne Choe, Undergraduate, Applied Ecology, UC Irvine

Jennifer Cheng, Undergraduate, Applied Ecology, UC Irvine

Desiree Eakin, Undergraduate, Applied Ecology, UC Irvine

Amana Rafeigue, Undergraduate, Applied Ecology, UC Irvine

Dalisa Tran, Undergraduate, Applied Ecology, UC Irvine

Kevan Savage, Undergraduate; Applied Ecology, UC Irvine.

Additional Funding

\$400,000. "Real time PCR detection of Human viruses and indicators in water". Water Environment Research Foundation. March 1, 2002 - February 30, 2004.

\$36,179. "Determining the relationship between fecal indicators and human pathogenic viruses in Newport Bay Watershed". August 15, 2001 - August 14, 2002. Contract with City of Newport Beach

Collaborative Efforts

County of Orange, California. Investigation of pollution source at a small watershed of Southern California.

Keywords

Viruses, urban runoff, bacteriophage



The Effect of Soil Water Content on Organic Chemical Sorption During Transport Through Unsaturated Soil

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Project Summary

Significant regions of California and other parts of the country used for farming are comprised of coarse-textured soils that commonly remain at relatively low water content in the subsurface, even when subjected to irrigation. In the past, it has often been assumed that chemical sorption is insignificant in coarse-textured subsurface regimes, because these zones are generally low in organic carbon. This study challenges that assumption, on the grounds that simple partitioning models of the type used in virtually all transport models predict that soils low in water content can produce significant attenuation of dissolved organic chemicals. For example, it is shown that assuming zero sorption in a sandy soil profile from the Central Valley of California underestimates the travel time to ground water by nearly a factor of three under the typical irrigation management. Clearly, it is important to determine the degree to which sorption can slow down the migration of dissolved chemicals in soils of low water content and carbon. However, virtually no experimental tests of this hypothesis have been carried out in the past.

Conventional wisdom dictates that organic chemical pollutants are not expected to be strongly sorbed by sandy soils, since the soils are coarse in texture and low in organic carbon. Results of preliminary experiments demonstrated that the transport of organic solute in sandy soils was significantly retarded in comparison to that of the water flow when the soil moisture content of soils decreased. As the cropland soils are frequently under relatively low water contents, this finding may have significant implications for pesticide transport in the vadose zone.

Work performed during the first year of this project focused on construction of our experimental system, and execution of the first set of transport experiments. Cylindrical columns containing repacked sandy soil from agricultural areas in Fresno, California were connected to pressure control devices so that the columns could be maintained at a constant unsaturated water content during flow experiments. Two chemicals, bromide (a

tracer) and bromacil (a mobile pesticide) were added as pulse inputs to the inlet end of the column and monitored continuously at the outlet end until all of the chemicals had moved through the column. The concentration profile from the bromide was used to measure the water velocity and the degree of chemical dispersion in the system, while the bromacil concentration record was used to determine to what extent the sorption process operated in unsaturated sandy soil containing only small amounts of organic carbon. Our preliminary results show that the sorption process does operate as predicted from sorption equations. As the water content of soil decreases, the extent to which the chemical transport is retarded in comparison to that of the water flow increases. As a result, serious errors can be made in predicting travel times to ground water if this mechanism is neglected. Our data also suggests that the process is rate-limited at higher water velocities, so that kinetic equations are necessary to accurately describe the shape of the concentration pulse as it exits the columns. However, it is not necessary

to use kinetic equations to estimate the mean travel time of the pesticide through the column. The overall effect of sorption is to make the travel time of a sorbing compound relatively insensitive to variations in water content so that simple model predictions based on mean water content will result in reasonable estimates of travel time from the root zone to ground water. These estimates will be of great value to pesticide regulators seeking to determine whether a given compound may be used without harm to underground water supplies.

Student Training

Han Song On, Ph.D; Soil Science, University of Seoul, Korea (currently visiting student researcher, UC Riverside)

Collaborative Efforts

Prof. Dong-Ju Kim, University of Seoul, on sabbatical leave at UC. Riverside

Keywords

Solute transport, travel times, groundwater contamination, adsorption



Abiotic Nitrogen Removal Mechanisms in Rapid Infiltration Wastewater Treatment Systems

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Engineering
UC Riverside

David M. Crohn
Environmental Sciences
UC Riverside

Project Summary

Nitrogen management is an important element of a water reuse plan, especially where groundwater recharge using reclaimed wastewater is being practiced. In these situations, land based municipal wastewater treatment systems such as rapid infiltration (RI) treatment are favored because of the direct recharge associated with the system and for their lower costs. In RI systems, biological nitrification-denitrification is considered to be the primary nitrogen removal mechanism. However, depending on the soil characteristics of the RI systems, other mechanisms such as adsorption within the soil matrix may also provide significant temporary nitrogen removal. Ongoing monitoring at a 150,000 m³/d (40 MGD) RI facility in Southern California (Rapid Infiltration and Extraction (RIX) Facility, City of San Bernardino) suggests that nitrogen removal efficiency at this facility is a function on the fraction of ammonium nitrogen in the influent. As the percentage of ammonium nitrogen in the influent increases, the apparent nitrogen removal efficiency improves. It was hypothesized

that this phenomenon is related to the high mica content the soils found at this RI facility, and that the major nitrogen removal mechanism may be ammonium adsorption rather than biological nitrification-denitrification. This distinction is important because the capacity of soil to adsorb ammonium is limited. Thus, with time, the adsorption capacity will be exhausted and system nitrogen removal will decrease. An important objective for research in this case was to determine the ammonium adsorption capacity of the soil at the RIX facility

On-going monitoring at a 150,000 m³ per day reclaimed wastewater rapid infiltration facility suggested that the nitrogen removal efficiency of the groundwater recharging process was in proportion to fractions of nitrogen in the ammonium form. Further investigations showed that no ammonium adsorption occurred with the first 10 feet of the soil and biological reduction of nitrogen was significant despite of low organic carbon content in the influent water

During this first year of study soil samples from various depths and locations at the RIX facility were collected and the absorption of ammonium was measured in the laboratory. To separate nitrogen removal via adsorption versus that from biological activity, tests were performed with both sterilized and non-sterilized soil and wastewater samples. It was determined that little or no ammonium adsorption occurred on samples within the first 10 feet of soil depth and only limited adsorption occurred at 13.5 feet. The adsorption capacity below 13.5 feet has not yet been determined.

Results from laboratory testing, however, show that biological nitrogen removal reactions are significant in the upper soil layers. These results were also supported from recent analyses of samples collected from subsurface samplers (lysimeters), which were recently installed at the RIX facility by the plant personnel. An interesting observation has been that a relatively large amount of nitrogen is removed biologically with a small amount of organic content in the wastewater. Generally, much higher amounts of

biodegradable organic matter is needed to achieve the amount of nitrogen removal experienced at the RIX facility.

During the next year we plan to ascertain the adsorption capacity of the deeper soils to the groundwater depth of 25 to 30 feet. In addition, we plan to look at various options at sustaining the high level of nitrogen removal currently experienced at RIX.

Student Training

Kevin Bell, graduate, M.S., Chemical and Environmental Engineering, UC Riverside

Araceli Arellano, Undergraduate, Chemical Engineering, UC Riverside

Tuong-Phu Ngo, Undergraduate, Environmental Engineering, UC Riverside

Collaborative Efforts

Valerie Housel, City of San Bernardino

Chris Amrhein, UC Riverside

Keywords

Rapid infiltration, water reuse, nitrogen control, nitrogen fixation, land treatment, groundwater recharge



Core drilling for soil samples



Full rapid infiltration basin, San Bernardino, CA.



Landscape Level Controls on Nitrate-Nitrogen in Forested and Chaparral Catchments of Southern California

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UC Riverside

Mark Fenn
US Forest Service Forest Fire
Laboratory
Riverside

Mark Poth
US Forest Service Forest Fire
Laboratory
Riverside

Project Summary

The mountains of Southern California receive amongst the highest rates of anthropogenic N deposition in the world ($\sim 40 \text{ kg ha}^{-1} \text{ yr}^{-1}$) and as a result stream water NO_3^- concentrations in smog-impacted summer-dry montane ecosystems in the Los Angeles air basin are the highest for natural catchments in North America. The localized nutrient enrichment in the mountains surrounding the Los Angeles metropolitan area may be the precedent for the future of forests and other ecosystem types near urbanizing areas in the western United States, as emissions of NO_x and NH_3 increase with urban expansion.

Terrestrial ecosystems with semiarid climates have limited capacity to process and retain chronic inputs of N. Available data indicates that stream flow from watersheds under heavier influences of the smog generated in Los Angeles have higher NO_3^- concentrations than those that

The nitrate concentration of stream flows in Devil Canyon - a photochemical smog-impacted watershed in the semiarid Southern California - varies drastically in time and space. For small and ephemeral streams, the nitrate in the catchments enters the stream through the flushing of winter rains and its concentrations are influenced by the mass dilution. For large and perennial streams, the nitrate in the water is dominated by groundwater seeping to the surface and its concentrations remain high throughout the season.

are farther away. However, the NO_3^- concentrations of stream flows in a watershed are extremely variable. The stream flow through the Devil Canyon catchment in the western San Bernardino Mountains, 100 km east of Los Angeles is a case in point. Although aerial N deposition should be similar throughout the Devil Canyon watershed, NO_3^-

concentrations vary by several orders of magnitude among the sampling sites. The spatially varied distribution of NO_3^- in stream flow provides a unique opportunity to investigate the landscape scale dynamics of biogeochemical and hydrologic processes that exert the greatest control on NO_3^- export from semi-arid forested catchments with elevated N deposition. We conducted detailed water quality sampling at eight streams in the Devil Canyon watershed. So far we have been able to reach several conclusions from our observations.

1. The NO_3^- and dissolved organic carbon (DOC) concentrations of water increase as the stream flow increases. In a couple of the smaller streams, there is a noticeable first “flush” of NO_3^- at the onset of the winter rainy season and then it is followed by a drop in NO_3^- concentrations as stream flow continues at a level higher than the base flows of the summer and fall. The increase in NO_3^- with stream flow in the larger streams at the commencement of the rainy season may also indicate a flushing process. However, we do not observe a decrease in NO_3^- concentrations as the rainy season progresses indicating that a flushing process is not so apparently responsible for the increases of NO_3^- in the larger streams.
2. The strong correlation of DOC and NO_3^- concentrations may indicate a denitrification control on NO_3^- input to streams. The concept of a denitrification control on stream nitrate and DOC concentrations is further bolstered by results of longitudinal surveys and mass balance analyses that indicating plant uptake and denitrification in the riparian zone, rather than a mass dilution process, are responsible for the decline in NO_3^- concentrations.

3. Perennial streams have high NO_3^- concentrations while ephemeral streams do not. This difference points to groundwater as the source of the high levels of NO_3^- we observe in the perennial streams. Geochemical mixture modeling for the watershed indicates that the perennial streams of the watershed are dominated by groundwater seeping to the surface in all seasons. The mixture modeling also indicate a disconnect between the streams of the watershed and the surrounding landscape since stream composition bears little resemblance to soil water from zero-tension lysimeters in the watershed. Furthermore, the evidence indicates a decoupling of the impact of N deposition on terrestrial and aquatic systems in Mediterranean climates. The primary reason for the decoupling involves the asynchrony between when atmospheric deposition occurs (summer), the time period of maximum soil NO_3^- availability and leaching (winter), and the time of maximum plant N demand (spring).

Our results have important implications for wildlife and water resources management agencies as they respond to the adverse impacts of atmospheric N deposition on water quality. For wildlife managers the findings indicate that the streams with the best habitat, those with large and consistent flows, are those most likely to be impacted by the effects of N deposition. For water resource managers the results indicate that the times when they are most likely to get water for recharge or for filling reservoirs, periods of high flow, are also the periods which are expected to have the highest nitrate concentrations indicating less of a chance to use waters draining deposition impacted watersheds to dilute groundwater impacted by historic agricultural groundwater contamination.

Publications

Meixner, T. M., E. Fenn, and M. A. Poth, Nitrate in Polluted Mountainous Catchments With Mediterranean Climates In Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection, *Proceedings of the 2nd International Nitrogen Conference on Science and Policy. The Scientific World*, 1, DOI 10.1100/tsw.2001.324.
Meixner T., E. B. Allen, K Tonnessen, M. Fenn, and M. Poth, Atmospheric Nitrogen Deposition: Implications for Park Managers of Western U.S. Parks, *Park Science*, 21(2), p. 30-33, 2002.

Meixner, T., and M. E. Fenn, Riparian Areas as Biogeochemical Filters, Mediterranean Climates and the Telescoping Ecosystem, A Cross-Cultural Perspective on Current Problems in Ecosystem and Natural Resources Management: An International Course on Issues Related to Ecosystem Management. Ed. J. Tenhunen, University of Bayreuth, Bayreuth, Germany, 2002.

Professional Presentations

J. McGovern, The Role of Hyporheic and Riparian Processes on Controlling Nitrogen Flux in a Mediterranean-Type Montane Environment, Chemical and Environmental Engineering Annual Graduate Student Conference, Riverside, California, August 28, 2001.

T. Meixner, Nitrate in Polluted Mountainous Catchments With Mediterranean Climates Abbreviated title- Mediterranean Climate Nitrate, In Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection: Proceedings of the 2nd International Nitrogen Conference on Science and Policy, Potomac, Maryland, October 17, 2001.

T. Meixner, Aquatic Impacts of Atmospheric Deposition in a Mediterranean Climate: The Asynchrony Hypothesis, CEA-CREST Annual Conference, Pasadena, California, May 8, 2002.

T. Meixner, Riparian Areas as Biogeochemical Filters, Mediterranean Climates and the Telescoping Ecosystem, A Cross-Cultural Perspective on Current Problems in Ecosystem and Natural Resources Management: An International Course on Issues Related to Ecosystem Management, Berchtesgaden, Germany, May 23, 2002.

Student Training

Jeff McGovern, MS student, Chemical and Environmental Engineering, UC Riverside.

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Keywords

Water quality, basin hydrology, atmospheric deposition, biogeochemical processes of nitrogen, San Bernardino mountains



Development of a Rapid, Sensitive and Quantitative Method to Detect Infective Hepatitis A Virus in Water

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Project Summary

To assess the potential risk of infection resulting from exposures to enteric viruses in drinking water, techniques enabling real time detection and quantification of these viruses are essential. The molecular beacon (MB) is a gene probe, that forms a hairpin-shaped structure which has a fluorescence dye (fluorophore) attached at one end and a fluorescence quencher at the other end. Its single-strand nucleic acid sequence at the two ends complementarily match, and therefore binds to form a stem portion of the hairpin. The remainder of the probe is unmatched therefore folds to form a loop. When the probe is folded, no fluorescence is emitted as the fluorophore is positioned next to the quencher. However, when the probe binds with its target DNA template (hybridization), it becomes fluorescent as the hairpin structure unfolds separating the quencher from the dye. The intensity of fluorescence emitted is proportional to numbers of target DNA templates hybridized. This is ideal in providing real-time monitoring and quantification of target amplicons during the polymerase chain reaction (PCR). A reverse transcription-PCR assay based on molecular beacons

To assess the potential risk of infection resulting from exposures to enteric viruses in drinking water, techniques enabling real time detection and quantification of these viruses are essential. The method developed in this study should improve our ability to provide rapid and efficient results for the detection and quantification of viruses in samples from environmental waters.

was developed for the rapid and specific detection of the Hepatitis A virus.

The forward primer (HAV6 5'-AAT GTT TAT CTT TCA GCA ATT AA-3') and the reverse primer (HAV6073 5'-CTC CAG AAT CAT CTC CAA C-3') were designed to amplify a 91-base pair fragment of a highly conserved region of the VP3 capsid region of the hepatitis A virus. A molecular beacon (5'-6-FAM-CGC TAT TTT GCT CCT CTT TAT CAT GCT ATG G ATAGCG-DABCYL-3') containing a 25-bp probe moiety, which is flanked by two 6-bp arms (underlined), was designed to target an internal region of the PCR amplicon. Either intact hepatitis A viruses or extracted RNA was used for amplification.

A 2-step RT-PCR procedure was developed. Samples were held initially at 95°C for 5 min and the reverse transcription was performed at 25°C for 10 min, 42°C for 60 min, and 100°C for 5 min. It was followed by 40 PCR cycles of denaturing at 95°C for 1 min, annealing at 55°C for 1 min, extension at 72°C for 1 min. Fluorescent measurements were made during the annealing steps. At the end of each PCR run, data were automatically analyzed by the system and amplification plots were obtained. Any fluorescent signal that was 10-fold higher than the standard deviation of the mean baseline emission was indicative of a positive detection.

Using the MB-based RT-PCR assay (Figure 1), a detection limit of 1 plaque forming unit (PFU) per PCR reaction was obtained. The specificity of the MB-based PCR assays was evaluated using a variety of other enteric organisms, and only

hepatitis A virus was positively identified. The method developed in this study should improve our ability to provide rapid and efficient results for the detection and quantification of viruses in samples from environmental waters.

Professional Presentations

Oymon Leong, Development of a Rapid, Sensitive, and Quantitative Method to Detect Enteric Viruses in Water, American Society for Microbiology Annual Meeting Salt Lake City, Utah, May 20, 2002

Student Training

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Keywords

Drinking water, groundwater, recycled water, artificial recharge, hepatitis A virus, pathogens, viruses, microbiology, monitoring, measurement methods

Detection of Hepatitis A Virus using the Molecular Beacon

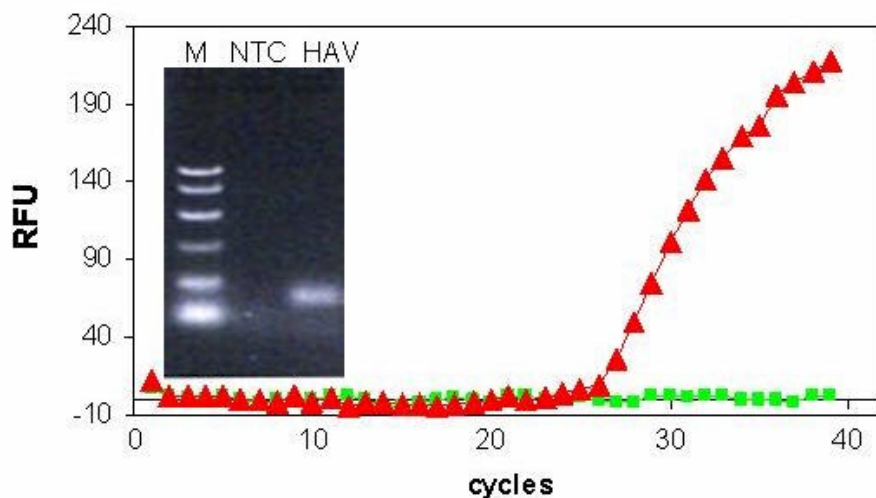


Figure 1: The design of the beacon allows for detection of HAV (▲). No increase in fluorescence is seen when target (NTC) is absent (■).

Research Category IV

Water Development and Management Alternatives

This category encompasses methods and techniques for formulating and evaluating water resources planning, development and management alternatives. Topics that logically fall in this category include policies and planning and operating water supply systems, conjunctive use of surface and subsurface storage, alternative uses for reclaimed and low quality water markets and water pricing and development and improved criteria for water project planning.





Modeling and Optimization of Water Quality in a Large-Scale Regional Water Supply System

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Project Summary

In a regional water distribution system involving multiple source water of varying quality, water agencies often find that it is necessary to employ blending at certain control points in the system to ensure the quality of water they deliver. We are developing a mathematical model that simulates the operation of regional-scale water distribution system and optimizes the quality of the distributed water.

In general, the water distribution system is represented by a network, in which supply sources, reservoirs, ground-water basins, junctions and demands are represented by different types of nodes; pumping stations, hydroelectric power plants, and pipes are arcs linking the nodes. In this network, water available at various nodes may be delivered to any designated location through the arcs which may be directional or undirectional. An undirectional arc allows water to flow in either direction, but not in both directions at the same time. Waters from different sources with different water quality are considered as distinct commodities, which concurrently share a single water distribution system. The objective function optimizes the volumes and quality of water at the

delivery points. Blending requirements are treated as constraints and specified for each control points in the water distribution system. The mixing is assumed to be that incoming waters of different quality are instantaneously mixed at the merging junction and that the outgoing water from the junction has the same blend.

A mathematical model is developed to simulate the regional water distribution network of the Metropolitan Water District and to evaluate the operations that optimize the volume and quality of water at the delivery points.

The operation of the multicommodity flow model is optimized by employment of a hybrid genetic algorithm (GA) and a generalized reduced gradient algorithm (GRG). First, the GA is used to globally search for the directions of all two-way flow arcs in the planning horizon. With the directions of all two-way flow arcs determined, GRG algorithm optimizes the objective function of the multicommodity model for fitness evaluation and chromosome evolution. The proposed approach is an iteration procedure between the GA and GRG. This approach has the following advantages: (1) it

converts an undirected network to a directed network that is amiable to standard optimization, (2) it separates the highly nonlinear two-way flow constraints from the gradient-based algorithm, and (3) GA with multiple starting points increases the likelihood of reaching a global optimum.

The proposed model was tested and verified on a simplified, but realistic water distribution system. It was then applied to the water distribution system of the Metropolitan Water District of Southern California (MWD). MWD supplies water to a population of approximately 17 million people in Southern California with a service area of 5,200 square miles. Additionally, sensitivity analyses were performed to analyze the impact of blending requirements. The results demonstrate the applicability of the proposed model to a real-world, large-scale regional water distribution system.

Professional Presentations

Tu, M-Y., F. T-C. Tsai, and W.W-G. Yeh
Optimization of water distribution and water quality by genetic algorithm and nonlinear programming. Fall Annual Meeting, American Geophysical Union, San Francisco, California, December 10-14, 2001.

Student Training

Ming-Yen Tu, Ph.D. student, program in water resources, UC Los Angeles.
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Keywords

Water supply system, water quality, optimization, water resources management, multicommodity flow, nonlinear programming, genetic algorithm, sensitivity analysis

Research Category V

Water Law, Institutions and Policy

This category encompasses all institutional arrangements (including laws and regulations) that are available or potentially available for developing and managing water resources. Topics which logically fall in this category include institutional arrangements for managing water scarcity, institutional arrangements for managing groundwater (both quantitatively and qualitatively), potential institutional conflicts associated with specific water development and management alternatives and the evolution of water management institutions in California. There is an especially compelling need for policy studies which involve analytical investigations of alternative polities for dealing with all aspects of California's water situation.





Economic Incentives and Policies to Improve Water Quality in a Binational Watershed

Linda Fernandez
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Project Summary

Efforts on the project addressing water quality in the Tijuana binational watershed are enabling cost and benefit measures to compare policy options for the U.S. and Mexico to pursue in handling wastewater emissions in a transboundary pollution context. Thus far, I have learned the following information from different project tasks:

1. The economic value of public health and environmental costs from water quality degradation constitutes a significant amount of value. Damages were quantified by correlating increased incidences of illness to recreational exposure to poorer water quality in coastal areas downstream in the U.S. (San Diego beaches). These results can have significant consequences on wastewater treatment options.
2. From the GIS modeling of researchers at San Diego State University, it has been possible to correlate the urban runoff concentrations of pollutants with incidences of illness at the coast. There is more than a seasonal occurrence of this runoff, that suggests the persistent flow of

Efforts on the project addressing water quality in the Tijuana binational watershed are enabling cost and benefit measures to compare policy options for the U.S. and Mexico to pursue in handling wastewater emissions in a transboundary pollution context

industrial and domestic waste that is not connected to a formal wastewater treatment system needs comprehensive binational attention.

3. I have found cost estimates from project plans submitted to the Border Environmental Cooperation Commission for both of a conventional wastewater treatment plant for both countries and costs of constructed wetlands for wastewater treatment on the Tijuana side of the border.

4. I am finding that there are complex factors in determining the feasibility of regulatory and market-based strategies (taxes, tradable permits) to manage the impacts of contaminated surface and subsurface waters on coastal water quality. Among these factors is the institutional infrastructure (NAFTA) of the

area (between U.S. and Mexico). Assessing what should be added costs on traded goods from waste generated means the scope of payment for border environmental improvement should include tax paying consumers far away from the border. I am trying to determine if the institutional payments through NAFTA for environmental improvement adequately compensate for the environmental damages at the border. Preliminary results suggest they are not. Assuming they are not, I am exploring potential policy alternatives to help pay for water pollution mitigation in the Tijuana estuary

Student Training

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Keywords

Economic analysis, economic policies,
water quality, binational watershed



Negotiating Contentious Claims to Water: Shifting Institutional Dynamics for the Allocation of Water Between the Eel and Russian River Basins

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Project Summary

Water is the most essential and contested resource in California. The widespread redistribution of water in the west not only alters the natural landscape, but also serves to redistribute people, wealth and power. Understanding why particular groups achieve, maintain or lose control over a region's water is central to achieving more equitable and stable water allocation solutions. The setting for this research is two Northern California watersheds connected by a hydropower project that has diverted Eel River water into the Russian River since 1908. The resulting growth, development and prosperity that followed in the Russian River watershed was not matched in the Eel, where over the century the fishery so important to the security and welfare of downstream communities including the Round Valley Tribes, is close to extinction.

At the time of its initial construction in 1905, the hydropower project and its diversion were strongly supported by Russian River watershed residents favoring the economic development it would bring.

To achieve a stable and just settlement, all parties need to expand their boundaries of concern to encompass the two linked watersheds, and they should explore a water balance model that incorporates conjunctive use of surface and groundwater in both basins.

However, while Eel River communities opposed the project and its water diversion, they were not able to stop it. In addition, the Round Valley Tribes with senior water and fishing rights on the Eel were excluded from the decision making process throughout most of the century. At the time of the project's construction, there was no legal impediment to diverting Eel River water through the power plant into the Russian River. Only 2cfs were legally required to be sent down the Eel below the dam to satisfy prior water rights. However, after the 1913 California Water Commission Act and the 1920 Federal Water Power Act, a water appropriator was required to be licensed by the state, and power plants on navigable waters were required to be licensed by the federal government. Today decisions about water

diversions are affected by multiple legal mandates and agency jurisdictions. Initially the Federal Energy Regulatory Commission had primary jurisdiction over most decisions regarding hydropower and water flow regimes. New legislation including the National Environmental Policy Act, the Endangered Species Act, the Clean Water Act, and the Federal Wild and Scenic River Act, along with their state counterparts, as well as modifications to the Federal Power Act, provided fresh opportunities for public participation and inclusion of environmental values in decision-making. By mid-century there were restrictions on water imported from a different basin, and by the end of the century new case law and increased recognition of federal tribal trust responsibilities provided the Round Valley Tribes with greater authority to press their claims. In addition, today there are increased resources available to both tribal and environmental groups to pursue their concerns.

This second year annual report links ideas from social movement theory and historical institutionalism into a framework that explains why control over the diverted Eel River water has shifted over time. Research demonstrates how an evolving legal/institutional regime produces layers of rules, each with a particular historically rooted underpinning. Each new legal/institutional layer reflects its own ideology and mandate and this expanded polity creates overlapping jurisdictions and rules. The resulting friction between increasing sets of federal, state and local agencies has served to open up avenues for groups who support increased flows in the Eel River to enter the decision making process and press their claims. This synergy between shifts in the institutional regime, and the ability of groups to take advantage of the resulting political opportunities, has altered both the decision making process and the allocation of water between the Eel and Russian River watersheds. The result

promises to be more water in the Eel River and a greater emphasis on restoration of both rivers and their fisheries.

While balancing the needs of all communities affected by the diversion is likely to remain central in future negotiations, today control over the diverted water is still contested. Although more parties are now represented in the negotiations, most remain focused on their own requirements and continue to strategize on ways to control the allocation of the diverted water. To achieve a stable and just settlement, all parties need to expand their boundaries of concern to encompass the two linked watersheds, and they should explore a water balance model that incorporates conjunctive use of surface and groundwater in both basins. The existing Eel-Russian River Commission, consisting of representatives from the five counties bordering the two rivers, has been a useful forum for bringing some of the parties together in discussion. A broader membership and a neutral facilitator/chair could strengthen the Commission by creating stronger vertical linkages between county, state and federal representatives and local groups. This could potentially turn the forum into an effective arena to research and negotiate an equitable and enduring allocation regime.

Publications

Landridge, Ruth, Changing Legal Regimes and the Allocation of Water Between Two California Rivers, *Natural Resources Law Journal*, Spring 2002, In Press.

Student Training

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Keywords

Water allocation, interbasin diversion, legal regimes



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