Freshwater Inflows: 2010 and Beyond
Corpus Christi, Texas
8-10 February 2010

PROCEEDINGS

Texas Parks and Wildlife Department
Coastal Fisheries Division

Harte Research Institute
for Gulf of Mexico Studies

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Proceedings

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Executive Summary

The *Freshwater Inflows: 2010 and Beyond* workshop was hosted by the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi (TAMU-CC) and held during 8-10 February 2010 in Corpus Christi, Texas. Approximately 114 invited guests from various institutions and organizations attended the three-day conference. The purpose of the conference was to highlight the importance of freshwater inflows and to identify water management questions and approaches that protect estuaries. Through plenary sessions, discussion groups, and presentations, recommendations and goals for the future were established.

Day one began with a welcome address from Carter Smith, Executive Director of Texas Parks and Wildlife Department. This was followed by presentations given by speakers from Harte Research Institute (David Yoskowitz, Paul Montagna, and Larry McKinney), Texas Parks and Wildlife Department (Cindy Loeffler), and the Center for Research of Water Resources (George Ward). The day concluded with a poster session and reception. Day two started with speakers from Alabama (Marlon Cook), California (Cliff Dahm), Florida (Sid Flannery and Robin Craig), and Texas (Myron Hess and Todd Swannack) addressing freshwater inflow management issues. Karl Flessa from the University of Arizona was moved up on the schedule and spoke about the historical ecology and restoration of the Colorado River delta and estuary. After a panel discussion among speakers, Ed Lowe from St. John’s River Water Management District gave a luncheon presentation on predicting and managing hydroecological effects. Facilitated breakout group discussions met the rest of the afternoon. Day three began with Robert Twilley from Louisiana State University speaking about tradeoffs in eutrophication and ecosystem restoration. After a plenary session, Larry McKinney from Harte Research Institute wrapped up the conference with a review and summarization of potential solutions.

Synthesis of Workshop

Day One - Day one began with a welcome address from Carter Smith, Executive Director of Texas Parks and Wildlife Department. This was followed by presentations given by speakers from Harte Research Institute (David Yoskowitz, Paul Montagna, and Larry McKinney), Texas Parks and Wildlife Department (Cindy Loeffler), and the Center for Research of Water Resources (George Ward). The day concluded with a poster session and reception. (See Appendix A for the conference agenda).

Day Two - Day two started with speakers from Alabama (Marlon Cook), California (Cliff Dahm), Florida (Sid Flannery and Robin Craig), and Texas (Myron Hess and Todd Swannack) addressing freshwater inflow management issues. Due to unexpected travel delays, minor schedule modifications were made. Karl Flessa from the University of Arizona was moved up on the schedule and spoke about the historical ecology and restoration of the Colorado River delta and estuary. A panel discussion followed (see summary below). Ed Lowe from St. John's River Water Management District gave a luncheon presentation on predicting and managing hydroecological effects. Day Two concluded with facilitated breakout sessions, presentations of the breakout discussion results, and a poster session and reception. (See Appendix B for abstracts).

Panel Discussion (Day Two) - Panelists included above speakers: Sid Flannery (Southwest Florida Water Management District), Myron Hess (National Wildlife Federation), Robin Craig (Florida State University), Todd Swannack (Texas A&M University), Marlon Cook (Geological Survey of Alabama) and Cliff Dahm (Delta Science Program, Delta Stewardship Council). Cindy Loeffler (Texas Parks and Wildlife Department) was the moderator.

Panelists were asked to respond to the following questions:

1. What are your management goals?
2. How are management goals developed?
3. Are you doing adaptive management?
4. What are your "lessons learned"?

Management goals focused on water management decisions that would preserve a "sound ecological environment" with functions and processes intact and also protect individual species. In some cases litigation is driving the process, as is the case with endangered species. In other cases states are taking a more proactive approach to address issues before they reach the critical stage.

Management goals are often developed through stakeholder-based processes using biological and hydrological indicators to gage success. Management goals need to be defined as clearly as possible and based on the best available science to evaluate environmental effects.

Adaptive management is a goal for most and is either ongoing or is envisioned. Adaptive management should maintain input from stakeholders and be based on scientific data from scientific teams.

Lessons learned include the following:

- Keep it Simple – document everything and prepare to defend it
- Stakeholder buy in is important
- Set realistic goals

Day Three – Day Three began with the arrival of Robert Twilley, from Louisiana State University to speak about tradeoffs in eutrophication and ecosystem restoration. After a plenary session, Larry McKinney from Harte Research Institute wrapped up the conference with a review and summarization of potential solutions.

Facilitated Breakout Discussions

Facilitated breakout discussions were held to identify water management questions and approaches that protect estuaries. There were four breakout themes:

1. Data and monitoring needs, including innovative studies and monitoring technologies
2. Successful or new inflow recommendation methodologies
3. Stakeholder involvement and policy implementation
4. New modeling developments and analysis techniques

Each of the breakout themes is described below.

1. Data Monitoring Needs

Breakout Group Summary: Data and monitoring needs, including innovative studies and monitoring technologies
Facilitator: Rebecca Hensley, TPWD
Note taker: Amy Larimer, TPWD
Scribe: Chris Mace, TPWD

This session focused on data and monitoring needs and included innovative studies and monitoring technologies in order to help identify and secure freshwater inflows needed to protect thriving estuaries and coastal ecosystems. In an attempt to build upon successful tools and strategies and avoid a long ‘laundry’ list of needs, the group began by identifying some ‘successes’ for data and monitoring techniques/tools. Discussion then focused on possible or useful indicators (both biotic and abiotic), which led into discussion on actual data gaps for determining freshwater inflow needs and ecosystem health. Both monitoring and special studies were discussed in the context of data needs. Because all of these have a cost to achieve success, the group discussed funding needs and ways to be more effective in acquisition of funds. Details of this breakout session follow with a list of top priorities to consider.

The discussion of successes began with the attempt to identify successes in data and monitoring tools and then focus on lessons learned to help identify data gaps and needs. Of the data successes mentioned, these included continuous measurement of salinity and flow rates (hydrology). Other components included datasets with nutrient loads, species abundance and distribution data, precipitation and evapotranspiration data and other climate indicators. One noted substantial success included real-time versus field collection data sets that has allowed for faster access to these data. Examples given of successful data and data sharing programs for freshwater inflows were Texas Water Development Board (TWDB) Datasonde Program (current real time datasondes deployed along Texas coast) and Texas Coastal Ocean Observation Network (TCOON) run by the Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University-Corpus Christi (system with currently over 30 stations along the Texas coast with real-time water level and meteorological measurement). Monitoring techniques and tools that have been successful ranged from monitoring stations/systems (TCOON, U.S. Geological Survey (USGS) flow sites, dam release data, tidal data), models (future water availability, isohaline, hydrodynamic, human population, growth, ecosystem and spatial and temporal distribution models), GIS (including remote sensing, satellite imagery) to using vegetative data (e.g., submerged aquatic vegetation) versus freshwater inflow.

When assessing the impacts to aquatic systems with respect to freshwater inflow needs, biological indicators are selected to be the proxy of ecosystem health with respect to water quality and not water quantity. The discussion by the breakout session elaborated on the use and identification of sensitive indicator species or suites of indicators as well as other criteria to utilize when determining water quantity impacts to ecosystem health. The group discussed and listed various possible indicators to establishing criteria for ecosystem health and freshwater inflow needs. Some of the abiotic data that was mentioned included using sediment and wind data as part of the suite of parameters. Sediment data was considered to be a large component not often available but linked to various other biological indicators. Many biotic indicators were added to the list to include species of concern, invasives, birds, nekton, ichthyoplankton and phytoplankton communities (and their zonation), and oysters and oyster diseases. The breakout session members were very concerned that the indicators be specific to the system that is under investigation. A set of indicators will not work for all systems. One set of indicators in a natural area may not be the best set of indicators in a more disturbed or developed area. Because of the estuarine component and the wide variability of tolerances in many of these estuarine species and communities, it is important to select more sensitive indicators other than the first or obvious choice.

Previous work, discussed by the participants, have had successes with some indicators (e.g., *Vallisneria*, *Rangia*, oysters, white shrimp, and seagrasses) when they were used as bay specific indicators. Suggestions for moving from single indicators to many multiple parameter or community type indicators were added to the discussion. Specific life history stages and distribution data for each of those more critical life history stages were considered important. Identifying the connections of the life history stages with habitat and food sources is imperative in the process. Other types of indicators mentioned included vegetation types (submerged aquatic vegetation, wetlands), macrobenthic communities, measures of community structure/ ecosystem-defining species guilds (e.g., fish structure, oyster habitat, seagrasses, emergent marsh vegetation that is specific to fresh, brackish, salt marsh species, riparian habitat as carbon source) and using community effects models. The majority of the group agreed that it was important to choose the indicator/indicator suite for the specific area and for the specific goal to be achieved in the project.

Following the discussion regarding the need for additional data for indicator species (range, population monitoring, verification, timing of freshwater inflows, quality of flow), the group launched into a listing of data gaps and needs. These are listed below:

- Historical information of the ecosystem and changes over time to get some idea of what the baseline conditions might have been
- Need for long-term data sets (and define long term: years, decades, millennia)
- Clear understanding of what data is needed with sets of core parameters (should the core parameters be varied?)
- Proxy data (isotope ratios: Strontium, C, N; tree rings for historical growth patterns, conditions, freshwater) and the need for it to be digitized and readily accessible
- Knowledge of what the community looks like under “normal” conditions from monitoring activities- (and define ‘normal’ or desired)
- Availability of Macro-benthic community data (may have the data but needs to be digitized, web-based and readily accessible)
- Resolution of data (time and spatial scales). Data collected must be set up to be able to detect an ecological response
- Needing to compare other/older datasets with sampling design of current data sets
- Legacy data: compatibility and accessibility (old reprints, paper, sampling units not consistent with current ones)
- Inclusion of metadata (aids in multi-agency sharing)
- Sediment data (especially bed load data, with suspended solids)
- Erosion and geomorphology of area of interest
- Nutrient data, chemistry and sediment
- Water quantity versus water quality- measured at an ecologically important level
- Groundwater component of total stream flow

- Change in stream flow due to rare storm events- higher flows, higher sediment loads
- Utilizing all data collection opportunities- Storm response team/plan (example with Florida everglades: flyovers, sediment deposition, trash lines, changes over time from event, delayed mortality and succession, carbon loading, economic data/response/impact), National Resource Damage Assessment information
- Complete understanding of inputs/outputs
- Texas Center for Environmental Quality (TCEQ) data sets (upstream) and river Authorities
- Venues (like this conference) to share successes and failures (a gap that prevents us from not 'reinventing the wheel', not repeating mistakes, not sharing or having accessibility to other's current/ongoing efforts).

With data gaps and needs addressed, monitoring needs were discussed. The areas for additional monitoring included plankton monitoring versus flow data, benthic community monitoring, identifying specific organisms or suite of species to monitor for the specific areas of concern and fundamental data versus response to change. The group discussed the importance of including a strategy to include tiers of monitoring goals for a backup or suite of species to allow for better success, which is especially useful to help secure additional funding.

More specific monitoring/research needs began the discussion for special studies. Again, initial work should always be to consider and identify those key components (of freshwater inflows) that are lacking in any project design. Basic biological data for critical species is assumed to be available and often is not. Several individuals spoke to the concerns about making assumptions regarding available data and not doing basic literature reviews to identify these types of data gaps and special studies needed at the beginning of any process. There is often critical information that is lacking and it is often the key component for many indicator or response variables. The routine life history data for endangered or key species needs to be assessed and collected if not available. This additional work on key indicator species should include species, species complexes, watersheds, and ecosystems. By utilizing a triad approach (using two or more species and a broader ecosystem perspective), this minimizes the chance of having a poor selection of an indicator at the cost of the ecosystem and inflow needs of the resource. Working on more habitat specific special projects incorporating tidal flats, seagrasses and inflow needs of the ecosystem was emphasized. In many projects and studies 5-10 years is considered long-term. Longer time periods are needed to take into account variables impacting our freshwater inflows needs, such as sea level rise. All sampling, research, monitoring and other data efforts need to begin utilizing a longer time period for predictions, much like water authorities utilize. Even though this was mentioned last, the importance of utilizing economic considerations ("biggest bang for the buck") to justify programs and needs should be incorporated wherever feasible.

An important component of successfully providing for freshwater inflow needs is to ensure that we incorporate what would happen during a drought and the associated impacts of those conditions. Drought condition scenarios should address conditions that may be observed with expected climate change/sea level rise and we need to utilize a meteorological baseline. The scenarios should include a worst case scenario and what the damage control might be for that and other scenarios. By initially identifying what is biologically necessary to protect (during drought conditions) and adjusting the scale or ecological response with the scenarios (actual or virtual), then damage control becomes a tool to assist with adaptive management strategies. The drought information needs to link back to models and as mentioned previously, the output need to re-verified and retuned, until results are satisfactory for the established goals to be met. An example of how this has worked successfully is the USGS Cascade Project. This is an example of a process that crossed several areas of expertise and the combined effort of the partners provided a best case scenario for the project. This three year effort conducted in California at a cost of approximately four million dollars involved many specialists in their field, including climatologists, hydrologists, and biologists. These specialists determined important species and parameters and identified drought scenarios and indicators through the range of the inflow areas, (from the mountains to the bay). This emphasizes the importance and need of large partnerships to accomplish the tasks at hand. The items that need to be considered when designing a successful project and project goals include the participation and representation of the correct stakeholders group, allowing longer time periods for success and identifying the funds needed to accomplish these projects.

The breakout session group was clear in identifying items from lessons learned to designing better projects and management strategies. Various lessons learned from the participants included the need for more information regarding drought conditions in management strategies. Every project design needs to have clear goals and clear questions. Having a multipurpose design is useful but it is important to understand that problems associated with ‘piggybacking’ other projects onto the initial project design (due to man-power or budget constraints). Data collected to satisfy one project or program goal may not be useful to meet other goals. For different goals or questions asked, different scales of data may need to be collected. Predictive modeling was seen as effective but needs to be followed up with monitoring and/or verification. Using the process of adaptive management with these predictive models is important, but it is very important to continue revising the model and the verification process until the goal is achieved. Another area of lessons learned was reiterated from the data gaps discussion. The need for data exchange and working together to minimize duplication of data and data gaps and not ‘reinvent the wheel’ is critical for our successes especially during times of budget and manpower constraints. Examples of ways to share datasets and data activities included: University of Texas Hydrologic Information System, Nueces Delta project (only Corpus Christi Bay area, Coastal Bend Bays and Estuaries Program), and Priority Habitat Information System (PHINS) (previously managed by GOMA and now managed by Harte). There is a need for a Metadata clearing house since data sharing facilities were seen as beneficial.

As with all topics of discussion with respect to data, technology and research gaps, funding is critical for success in addressing these concerns and needs. Some of the avenues to focus efforts for successful acquisition of funds may be found by looking for unique linkages to broaden the availability of funding resources. An example given was to tie drought-related management concerns to climate change. This linkage now includes aspects associated with security issues and sea level rise, which allows grant proposals to be written for homeland security and Federal Emergency Management Agency (FEMA) funds or other disaster funds. Some additional options include looking at federal, state, and private entities in a different light. For some of these agencies (NOAA, USGS, EPA, River Authorities) data certainty is needed for long term contracts. This can increase the funding required to complete a project. With others states and countries, there may be entities that tax water use. Two examples of where and how this tax is being used to fund data and monitoring needs are Florida and Australia. In Florida, there is a water use fee/surcharge and in Australia, there is a 'tax.' Both earmark these dollars for freshwater inflow funding. In Australia, these funds account for about $8 million dollars/year. Information from other states, regions and countries (including both successful and failed ideas) needs to be incorporated to help obtain funding. A component also identified was the need to identify representation or a communication source for organizations that could provide information on successes, failures and funding. The National Ecological Observatory Network (NEON) was identified as an example that speaks to the desired data sharing aspects. As an example, NEON will collect data across the United States on the impacts of climate change, land use change and invasive species on natural resources and biodiversity. NEON is a project of the U.S. National Science Foundation, with many other U.S. agencies and non-governmental organizations cooperating. NEON will be the first observatory network of its kind designed to detect and enable forecasting of ecological change at continental scales over multiple decades. The data NEON collects will be freely and openly available to all users.

The need to identify how much money was needed for funding was brought up by some participants. The sheer quantity of funds needed might be so large as to appear unachievable. The breakout group discussed some priorities to identify potential funding methods that may help bring the funding needs to a more manageable amount. These priorities included funding the monitoring phase to validate models, obtaining long-term funding, establishing a legal need as a priority to assist in funding (then use the law to justify and obtain funds). It is critical to pick sensitive organisms (or suite of species) to monitor. With the management priorities or adaptive strategies, we must be willing to reallocate or change our priorities (e.g., change routine sampling to incorporate some of the goals and questions to facilitate success or acquisition in data gaps) when sufficient funds or resources are not available to accomplish everything.

The group listed their three priorities that were most critical from the session discussion as:

- Resolve data gaps
- Freshwater is the limiting element

- Monitor (verification) after modeling (prediction) and adjust modeling and monitoring efforts until satisfactory results are achieved (adaptive management).

2. New Inflow Recommendation Methodologies

Breakout Group Summary: Successful or new freshwater inflow recommendation methodologies
Facilitator: Barbara Dorf, TPWD
Note taker: Angela Schrift, TPWD
Scribe: Leslie Williams, TPWD

We began the breakout session by discussing what people want to know about the freshwater inflow process from three different perspectives: water managers, stakeholders, and scientists. Water managers were most concerned with having the certainty to be able to plan for future water demands by an increasing human population. They wanted information on development of off-channel reservoirs, fresh water inflow schedules, volumes, and potential new permittable water sources in the form of return flows.

Stakeholders were interested in having a better understanding of the freshwater inflow process and issues through greater information exchange with the public, primarily targeting major metropolitan areas. Education efforts could target newspapers, TV, public workshops, as well as curriculum development at the K-12 levels. Stakeholders were also concerned that goals and priorities for freshwater inflow management have not been clearly described, and they want to be part of that development process. Many do not understand the likely consequences and benefits to both people and the environment of various inflow management decisions, and therefore do not see the value in the process as a whole. Texas water rights laws are viewed as problematic and awareness that other states, such as Florida, have different systems which permit more flexibility in freshwater inflow management prompted a discussion of what sorts of changes in Texas might be possible. These possible changes included proportionally reducing all water rights permits to achieve inflow goals, once definite freshwater inflow requirements are scientifically established.

Scientists wanted management decisions to be based on clearly defined goals and best available scientific data, with established (and funded) long-term monitoring to evaluate environmental effects. They felt that stakeholders should be included in goal setting and be made aware of what changes have occurred in estuarine systems so they would know what has already been lost. Inflow goals should be set to maintain biological productivity and conserve biodiversity. Scientists noted that it was important that inflows be allowed to vary seasonally within a range which mimics natural flows. Biological indicator species or complexes should be estuary-specific and include both sessile species, which preserve environmental dynamics, as well as mobile species.

The breakout session continued with a discussion of what we should be doing now and what questions should be asked to determine what freshwater inflows should be. Stakeholders should be involved from the beginning and they should communicate what they want to achieve (ecotourism, better fishing, etc.). Florida has been successful in getting water set aside for the environment because people recognized the benefit of regulating freshwater inflow and put pressure on the government. Specific goals for indicator species, such as specific population size with acceptable tolerance ranges, should be set rather than losses of X% of a population. Rule implementation must be followed by monitoring to determine effectiveness, followed by regulatory change if needed. In Florida, monitoring is paid for by the permit holder under very specific and permit-by-permit guidance from regional agencies.

By looking at estuaries with previously altered inflows, it is easier to get an idea of what is likely to be lost with similar changes in other estuaries. Would the altered environment be acceptable to the unaffected estuary's constituents? To retain original estuarine characteristics by retaining natural freshwater inflows is always better than trying to restore an estuary to original conditions. Restoring natural inflow conditions may not recreate the same ecosystem in light of other changes such as channelization, dredging, etc.

Questions must be framed at an appropriate scale. Indicator organisms often operate at different scales than freshwater inflows. Spawning may occur at the same time every year in response to day length. Only after that time are early life history stages responsive to environmental conditions. Indicator species must be chosen that will respond to conditions we can manipulate. By protecting species more sensitive to inflow changes, less sensitive species will also be protected. Monitoring must include early life history stages of sensitive species and not just game fish that people are most familiar with, such as red drum or spotted seatrout. Benthic organisms are often very sensitive to changes in flow and should be included in monitoring.

Finally, altering freshwater inflow is not just about the water itself, but what is in the water. Nutrient availability data should be collected in addition to water volume and seasonality. Higher density monitoring via datasondes would give more detail than currently available to evaluate environmental change. Additional factors to monitor should include detailed profiles of chlorophyll, zooplankton, sediment loading, nutrients, oyster reefs, and seagrass beds.

3. Stakeholder Involvement and Policy implementation

<u>Breakout Group Summary</u>: Stakeholder involvement and policy implementation

<u>Facilitator</u>: Robin Riechers, TPWD

<u>Note taker</u>: Paul Silva, TPWD

<u>Scribe</u>: Ashley (Estep) Thompson, TPWD

The purpose of this breakout group was to evaluate the stakeholder involvement by identifying the pros and cons of the current process, potential problems and solutions, and how to improve stakeholder participation in the future.

The pros of the current system stressed that interaction and participation led to stakeholders having a better understanding of the different perspectives of not only the stakeholders but also the various state and federal entities involved. This understanding of the process allowed stakeholders to “buy in” to the project. Also, because of the diversity of the stakeholders it created a wide perspective of views and alternatives for consideration. Some believed that a deadline was needed to cause a sense of urgency and promote a focused debate or discussion of the main topics. The cons suggested that there could be a large knowledge gap between the stakeholders and the science team and the short timeline did not permit an adequate exchange of technical information or an explanation in layman’s terms. It was suggested that each stakeholder has their own agenda and it was difficult at times to keep the interests of the group as a whole in mind.

First, it was suggested that the task group be more stakeholder driven instead of state or federal agencies taking the lead. To do this several things need to take place. There needs to be effective communication between the stakeholders and the science team with a dialogue in layman’s terms for thorough understanding. Stakeholder concerns and input needs to be considered at the initial stage of the discussion, not after the science team has developed an action plan. It was suggested that there be an initial training presentation to the stakeholders to provide the scientific background and theory of the problem to allow the stakeholders to gain perspective on how the scientists are basing their decisions. Additional sessions should follow to provide more education as new information becomes available. Basically the stakeholders want to be educated and kept in the decision making loop throughout the process. In the same manner, the science team needs to understand the vision, goals, values and needs of the stakeholder and what services are important to them. This would promote stakeholder “buy-in” for the project.

Second, the stakeholders are generally a very small segment of the impacted population and they tend to be the same people in attendance for every meeting. It was suggested that funding be provided to allow stakeholders the opportunity to travel to the meetings. This funding could also be used to provide facilitators or science experts to attend the meetings. These meetings should be scheduled at a time and place that permits the maximum attendance of stakeholders, not during regular work hours. There needs to be a concerted effort to identify stakeholders of all ethnic and cultural backgrounds, economic status and ages to participate in the meetings. Potential future stakeholders, in addition to current stakeholders, that may be affected by on-going or proposed projects should also be notified. Landowners that live near rivers within the project area need to be sought out and contacted in person to request their input.

Stakeholders and the scientific team need to come to a consensus in developing an adaptive management program that addresses the needs of both the environment and the stakeholders. This program should maintain its input from the continuum of stakeholders and be based on scientific data from the scientific team. This data should include results from monitoring efforts as well as projection models that predict the future status. Time frames with specific procedures and desired outcomes should be developed and coordinated with mandates established in the Texas State legislature (SB1-Senate Bill 1 and SB3-Senate Bill 3). To better understand and develop the adaptive management plan, a historical review of the water rights pertaining to human needs should be conducted. Due to uncertainty (rainfall, population increase, water rights, and legislative changes) a method to hold all water rights at current levels or establish an option to buy back water needs to be investigated. It was suggested that the best way to obtain legislative or local government support was to provide field trips for officials to provide “hands-on” assessment of the environmental conditions.

Lastly, it was discussed that there is a need for community education and outreach to provide basic information as well as environmental fundamentals. This might include the overview of freshwater inflow to the bays and the benefits to the environment, organisms and humans. Explain how specific state legislation (e.g., SB1 and SB3 in Texas) will affect this interaction and how the state values the ecosystem services not only for the permanent stakeholders but for the visitors that use them. It was suggested that better stakeholder participation, commitment and buy-in could be achieved by not only educating the stakeholder, but by engaging them in committees and activities as well. This could be done at public hearings where proposed projects are presented as opposed to “scientific meetings” that might intimidate the ordinary stakeholder. Marketing plans need to be developed that target recreational users, urban populations and youth to explain the importance of freshwater inflow. This could be accomplished through county agricultural extension agents, 4-H, FFA and schools. All stakeholders must be given the opportunity to look at the big picture now and plan for the future to determine the most effective and efficient ways to address freshwater implications.

At the end of the session, the group was allowed one vote for each category (pros, cons, change stakeholder process, adaptive management, and education outreach). Presented below are breakout sessions’ top two rankings of each category and the session notes.

Pros and Cons of current process

Pros

1. Interaction-understanding perspectives
2. Diversity of stakeholders

Cons

1. Getting stakeholders and science team up to speed and on the same page
2. Process timeline often not long enough

Change Process

1. Effective communication of the science
2. More input from the stakeholders on the front end

Adaptive Management

1. Communicate inflows benefit to the environment as well as benefits to humans and the relationships to each other
2. Maintain and monitor the continuum of stakeholders to keep momentum

Education Outreach

1. Until it pertains to them on a personal level they won't change. i.e., Water restrictions

tied with above: Notion of engagement is a better goal (means) than education.

2. Marketing strategy to educate. i.e., Audubon Society.

4. New Modeling Developments and Analysis Techniques

Breakout Group Summary: New modeling developments and analysis techniques
Facilitator: Dan Opdyke, TPWD
Note taker: Jackie Robinson, TPWD
Scribe: Jan Culbertson, TPWD

This breakout group's discussion focused on four key modeling disciplines: (1) hydrodynamic/salinity, (2) sediment transport, (3) eutrophication, and (4) ecosystems. Discussions highlighted specific areas of innovative research and development as well as future needs.

A wide variety of hydrodynamic/salinity models for estuaries exist. Texas Water Development Board (TWDB) staff has traditionally used TX-BLEND, a 2-dimensional model that has been applied to all major Texas estuaries. TWDB has a current project to evaluate potential 3-dimensional replacement models. The authors of SELF, FVCOM, and UTBEST are currently under contract to apply their model to Corpus Christi Bay. TWDB staff will evaluate each model's performance and make a recommendation on which model might be best suited for application in Texas. In another effort, TWDB staff is developing a model of the San Bernard estuary that will include wetting and drying cycles of associated marshes. Future needs include more data and modeling in key marsh habitats, additional data in the interior of bays to provide calibration targets for models, and algorithms to decrease run times for 3-dimensional models.

Wetland loss, in part due to a paucity of sediment inputs, is occurring in Texas, Louisiana, and elsewhere. Little quantitative work describing sediment transport has been performed in Texas estuaries. The Harte Research Institute (HRI) is exploring the use of satellite imagery to quantify turbidity and indirectly estimate freshwater inflows. Additional data describing sediment loads at the mouths of major riverine inflows are necessary.

Where Texas bays have eutrophication problems, they are generally local. Other estuaries in the U.S., notably Chesapeake Bay, have more significant and systemic eutrophication issues. The Gulf of Mexico Alliance task force is currently evaluating water quality models. One factor currently limiting the application of eutrophication models in more Texas estuaries is the relative lack of data, compared to the more abundant water level, salinity, and fisheries data records.

Ecosystem modeling is gaining momentum in Texas and elsewhere. HRI has a model that describes the biomass of benthic communities as a function of salinity. TPWD has a model that describes oyster growth in Matagorda Bay and HRI is currently also working on an oyster model. EcoPath and EcoSim, a suite of ecosystem models that have been applied at various locations throughout the world, are being explored for use in Texas. An EcoPath model linking biomass and productivity to inflows is being developed for Galveston Bay by TPWD. Ecosystem modeling is a relatively new area of study and will be constrained by limited data for the foreseeable future. Additional data, especially data relevant to freshwater inflow effects, are necessary.

In closing, models linking inflows and salinity (hydrodynamic/salinity models) and salinity to biology (ecosystem models) have received the most attention and will continue to do so. Data will always be a limiting factor. Ecosystem models, particularly those with many species, have significant data requirements.

Plenary Session Discussion Highlights

The Plenary Session provided an opportunity to “compare notes” from earlier breakout sessions. There were common themes that spanned the breakout sessions. For example, lack of funding to support data collection programs necessary to predict freshwater inflow requirements is a common issue. Funding strategies need to be broad. Successful strategies should be shared, especially now as funding sources are becoming more restricted.

Data sharing was also a common theme. Readily accessible data was identified as a goal to be accomplished through digitizing of older data, implementation of meta-data clearing houses, and compatible data formats. Data collection should be prioritized and collection should be based on management goals.

The importance of stakeholder involvement was discussed. Different interest groups should first be identified and then mechanisms used to increase involvement. Stakeholder involvement is critical in goal setting, historic characterization of the target estuary and to allow for broad development of consensus in adaptive management programs. Stakeholders should also be involved in indicator(s) selection and informed of the benefits of using indicators that may not be their first choice (as with recreationally important fish species). Examples of estuaries that have been previously impacted should be used to determine if the altered environment would be acceptable to stakeholders of the unaffected system. The topic of indicators was discussed by several breakout groups. Indicators should also include water quality (not just quantity) and address nutrient and sediment parameters. Biological indicators should be selected using the appropriate scale and be area (estuary) specific and include sessile organisms. Biological indicator selection needs to be sensitive to life history stages that are impacted by freshwater inflow which, if protected, would benefit other species. Specific management goals for the selected indicator suite should also be identified.

Finally, the theme of legislative support was discussed. Some states may need to propose changes that could address strategies for achieving inflow goals once definite freshwater inflow requirements are scientifically established. Any rule implementation must be followed up by monitoring to determine effectiveness.

Appendix A: Conference Agenda

	Monday February 8, 2010
1:00 pm	Introduction and Welcome - Carter Smith, Executive Director, Texas Parks and Wildlife Department
1:30 pm	**Value of inflows** - David Yoskowitz, Harte Research Institute
2:00 pm	**Indicators of estuarine health** - Paul Montagna, Harte Research Institute
2:30 pm	**Break**
3:00 pm	**Threats to inflows: climate change, hydrologic alteration, increasing consumptive use** - George Ward, University of Texas, Center for Research of Water Resources
3:30 pm	**What is being done? How has science driven policy and how do we implement science to protect estuaries?** Cindy Loeffler, Texas Parks and Wildlife Department
4:30 pm	Wrap up of day 1 and Preview for day 2 - Larry McKinney, Executive Director, Harte Research Institute
5:00 pm	**Poster Session and Reception**
	Tuesday February 9, 2010
8:00 am (20 min. each)	**What are various states doing to address freshwater inflow management issues?**
	Southwest Florida - Sid Flannery, Southwest Florida Water Management District Texas - Myron Hess, National Wildlife Federation Apalachicola Bay, Florida - Robin Craig, Florida State University San Antonio Bay - Todd Swannack, Texas A&M University Alabama - Marlon Cook, Geological Survey of Alabama California - Dr. Cliff Dahm, CALFED Bay-Delta Program
10:00 am	**Break**
10:30 am	**Changes in catchment to the coast: tradeoffs in eutrophication and ecosystem restoration as defined by Florida Coastal Everglades and Mississippi River Delta**, Robert Twilley, Louisiana State University
11:00 am	Panel Discussion among speakers with prepared questions (e.g. what are your management goals? How are management goals developed? Are you doing adaptive management? Lessons learned?) Questions from the audience. Cindy Loeffler, Texas Parks and Wildlife Department
12:00 pm	Lunch - **Predicting and managing hydroecological effects: coping with complexity and uncertainty**, Ed Lowe, St John's River Water Management District, Florida
1:30 pm	**Facilitated breakout group discussions to target various issues. Topics include:** 1. Data and monitoring needs, including innovative studies and monitoring technologies 2. Successful or new inflow recommendation methodologies 3. Stakeholder involvement and policy implementation 4. New modeling developments and analysis techniques
4:00 pm	Facilitated breakout groups present discussion highlights
5:00 pm	**Reception**
	Wednesday February 10, 2010
8:30 am	**Putting the dead to work: historical ecology and restoration of the Colorado River delta and estuary**, Karl Flessa, University of Arizona, Department of Geosciences
9:15 am	Plenary session with questions about breakout sessions
10:15 am	**Break**
10:45 am	Review and summarization of potential solutions from breakout call to action, Larry McKinney, Harte Research Institute
11:30 am	Adjourn

Appendix B: Abstracts

Day 1

Value of Inflows

David Yoskowitz, Harte Research Institute, Texas A&M University-Corpus Christi

Water has value in its many different uses, such as drinking, irrigation, cooling, and recreation for example. What is the value of water when it is not used at all but remains in its body or course for what is referred to as "environmental flow"? Reducing freshwater flow in rivers and inflow into estuaries can lead to a loss of biodiversity, critical habitat, and important commercial and recreational fisheries. While individuals rarely use freshwater flow directly, they benefit from the impact that this flow has on ecosystem services, primarily in the area of recreation and ecotourism. So what are people willing to do or "pay" in order to protect these important services that are impacted by inflow. Evidence suggests that individuals are willing to separate themselves from a portion of their income in order to protect inflow. The question becomes: How do we then operationalize the protection of inflow? Is it the responsibility of various government entities or should NGOs and private citizens look at ways to protect flow?

Indicators of Estuarine Health

Paul Montagna, Harte Research Institute, Texas A&M University Corpus Christi

Estuaries are transition zones where salt water is diluted by fresh water. This mixing enhances productivity because of introduced nutrients, lowered salinity, and creation of wetland habitats. Many estuarine organisms require low salinities at specific times during the year as a cue for reproduction or to support the next crop of young, so inflow timing is critical as well. It is now generally acknowledged that there is a need to maintain freshwater inflows to downstream estuaries to maintain estuarine productivity. The challenge we face today is to determine the freshwater inflow needs of estuaries. This challenge is difficult because the management goals may not be clear. It is often stated that inflows are needed to maintain estuarine health. The word "health" is controversial in and of itself, because it implies that there is a standard that would maintain a "healthy" estuary. The solution is to use the common environmental quality language for environmental quantities. For example, in a typical environmental assessment, one first identifies the 1) pressure, 2) state, and 3) response. For environmental flows this translates into the 1) hydrological flow components, 2) the estuary hydrographic condition, and 3) the biological response. Thus, by simply identifying the acceptable ranges for conditions and responses, it is then possible to identify an acceptable flow regime.

Threats to inflows: Swilling and sweltering

George H. Ward, University of Texas

In the short-term, two principal factors that could potentially reduce freshwater inflows to the Texas coast are human water use and climate change. The potential effects of each, projected 50 years into the future, are examined to quantify their magnitudes. As an index, we employ the flow to the Texas coast downstream from the major reservoirs and water-supply infrastructures, aggregated into three major hydroclimatological zones and over the state. The 50-year projected changed climate under greenhouse scenario A2 is a 5% decrease in precipitation and a 2 degree C increase in temperature. With present water uses, this altered climate relative to normal would reduce the flow to the coast 24% statewide. This illustrates how the surface water budget acts as an amplifier for precipitation. With 50-year projected water uses, it becomes worse. We also examine drought conditions. These are grim.

Freshwater Inflows: What is Being Done?

Cindy Loeffler, Texas Parks and Wildlife Department

Identifying and providing freshwater inflows are among the many challenges facing water managers in coastal areas today. Growing demand for water supplies coupled with global climate change predictions will likely make existing coastal conservation challenges more difficult. A number of states and nations have attempted to address the issue, with varying degrees of success. Finding the balance between science and policy is also a challenge, as tradeoffs must be made. Ultimately, scientists, stakeholders and policy makers must work together to ensure protection of estuarine ecosystems.

Day 2

Use of a Percent-Of-Flow Approach For Determining Allowable Reductions Of Freshwater Inflow To Southwest Florida Estuaries.

Michael S. Flannery, Southwest Florida Water Management District

The Southwest Florida Water Management District has implemented a percent-of-flow approach to determine allowable reductions of freshwater inflows from rivers to their receiving estuaries. Long-term trends for a number of streamflow parameters at gaged sites are evaluated to determine if a river’s flow regime has experienced anthropogenic impacts. Depending on the nature of the impact (e.g. channelization vs. groundwater drawdown), a daily baseline flow record is created which may involve adjusting the gaged record to estimate a more naturalized flow regime. Modeling scenarios are then run for a defined baseline period in which a range of percentage withdrawal rates area applied to the baseline flow record. The bottom areas, water volumes, and shoreline lengths of a series of biologically important salinity zones are modeled to determine changes from baseline, with a reduction of these metrics by 15% considered a threshold for determining significant harm. Modeling has also been conducted for a number of ecological variables including the location of chlorophyll *a* maxima, dissolved oxygen concentrations, and the center of distribution and abundance for a number of fish and invertebrate species. Ecological analyses have focused upstream of the tidal river mouths because these zones are highly utilized as nursery areas by a wide range of estuarine dependent species and are considered to be the areas most sensitive to change. Established percent withdrawal limits have varied between seasons and flow ranges. The percent-of-flow approach has been implemented for the regulation of three existing water use permits and to determine allocation rules for potential water users for four other rivers. Water storage options that have been used in conjunction with the percent-of-flow approach have included offstream surface water reservoirs and groundwater aquifer-storage-recovery systems.

Freshwater Inflow Management in Texas, What's Being Done.

Myron Hess, National Wildlife Federation

Texas recently has launched a comprehensive new program to address environmental flow issues. In 2007, the Texas Legislature created a new process to help develop environmental flow standards for the state's rivers and estuaries. The consensus-based process is designed to proceed sequentially, and expeditiously, across the various river and bay system groupings. Expert science teams are directed to develop science-based recommendations for environmental flow regimes. Local stakeholder committees are then charged with overlaying policy considerations onto the science and developing recommendations for environmental standards and recommending strategies that could be used to meet the standards. The Texas Commission on Environmental Quality, after considering both sets of recommendations and other public input, will adopt formal environmental flow standards and, where appropriate, environmental flow set-asides. The first two expert science teams recently completed their flow regime recommendations with mixed results.

Protecting Inflows to Apalachicola Bay

Robin Kundis Craig, Florida State University College of Law

Apalachicola Bay in Florida is famous for its oysters -- but those oysters depend on inflows from the Apalachicola River, which in turn depend on Georgia's and the U.S. Army Corps of Engineers' management of the Apalachicola-Chattahoochee-Flint River (ACF) Basin.

Litigation to protect the flows into the Apalachicola River began decades ago and has continued through several phases, involving issues as basic as the Army Corps' statutory management authority and as complex as the flow regimes necessary to protect federally listed endangered species. This talk will review the history of the ACF Basin conflicts and describe in more detail the most recent decision from the U.S. District Court for the Middle District of Florida regarding management of water in the basin.

Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes

Todd M. Swannack, R. Douglas Slack, William E. Grant, Steve E. Davis III**,** Department of Wildlife and Fisheries Sciences**,** Texas A&M University

Jeffery R. Wozniak, Texas Research Institute for Environmental Studies, Sam Houston State University

Whooping cranes have been well studied; however, the links among environmental factors and their wintering ground dynamics are poorly understood. We studied the relationship between freshwater inflows feeding San Antonio Bay and the health of the endangered whooping crane population at Aransas National Wildlife Refuge. Field research included several studies of wetland and estuarine processes, plant ecology, and whooping crane food resources, specifically focusing on the environmental factors that affected the abundance and distribution of blue crab [*Callinectes sapidus*] and wolfberry fruit [*Lycium carolinianum*]. We also studied whooping crane response to human-induced disturbances within and adjacent to ANWR. Empirical findings were integrated to produce a quantitative model simulating crane responses to changes in food supply, temperature, salinity, and water levels in and around the ANWR salt marsh. Results of field studies indicated that bay salinity was demonstrably higher when freshwater inflows are low and wolfberry abundance was lower when mean summer salinity in the bay was high; the relationship between blue crab abundance and environmental factors could not be explained by simple models and was best explained by a suite of interacting environmental factors. The simulation model suggested relationships that are of potential importance to the assessment of crane ecology and that may be relevant to the evaluation of future freshwater diversions. During the 11-year time period simulated (1997-2007), food supply for cranes appeared to be more than adequate to meet crane energy.

Erosion and Sediment Transport into Mobile Bay, Alabama: The Horse is Out of the Barn. Can We Put Him Back In?

Marlon R. Cook, Geologic Survey of Alabama

Land-use change can have tremendous deleterious impacts on water quality and biological habitat of streams. This is particularly true in parts of Baldwin County where topographic relief and highly erodible soils are subjected to disturbances related to residential and commercial development. Parts of Baldwin County are undergoing widespread transitions in land use from forested and agricultural to commercial and residential.

The Geological Survey of Alabama in cooperation with local, state, and federal agencies investigated impacts of development on sediment loads entering Mobile Bay from the D'Olive and Tiawasee Creek watersheds in the Daphne area of west-central Baldwin County and Magnolia River in the Foley area of southwestern Baldwin County. Ten sites in the D'Olive-Tiawasee Creek watershed and 12 sites in the Magnolia River watershed were investigated.

Total sediment loads are composed of bed sediment and suspended sediment. Tiawasee Creek had the largest suspended sediment load (835 tons/yr). However, when the loads were normalized with respect to unit watershed area, an unnamed tributary to D'Olive Creek, D'Olive Creek, and Joe's Branch had the largest suspended sediment loads (352, 331, and 330 tons/mi^2/yr, respectively). D'Olive Creek had the largest bed sediment load (3,097 tons/yr) due to massive erosion of the stream channel upstream from the monitored site. After normalization of bed sediment loads, D'Olive Creek had the largest load (1,656 tons/mi2/yr). The largest total annual sediment load (3,716 tons/yr) was estimated for D'Olive Creek. When total sediment loads were normalized with respect to watershed area, the largest estimated load was in D'Olive Creek (1,987 tons/mi^2/yr).

Magnolia River is virtually undeveloped when compared to the D'Olive-Tiawasee Creek watershed and is currently being considered for "Outstanding Water" designation. The largest total sediment loads were estimated for Magnolia River (235 tons/mi^2/yr) and Weeks Creek (tributary of Magnolia River) (168 tons/mi^2/yr).

Local, state, and federal agencies and stakeholders have joined to form a working group in the D'Olive-Tiawasee Creek watershed to examine solutions for the erosion problems in the effected watersheds. Work has begun on a watershed plan to remediate current problems and to limit or prevent future damage to water bodies and habitat. The city of Magnolia Springs in cooperation with the city of Foley and local stakeholders are working to protect Magnolia River from problems that have occurred in other watersheds as a result of economic development.

Determining Flow Criteria for the California Bay-Delta

Cliff Dahm, Delta Science Program, Delta Stewardship Council

The California Delta lies at the heart of the water supply system for much of California. Inflows to the Delta from the Sacramento River, the San Joaquin River, and east side rivers provide the freshwater inputs to the Delta. Outflow to the Bay is presently about 87% of inflows in wet years, 69% of inflows in average years, and 51% of inflows in dry years. Use of freshwater in the Delta totals about 4% of inflows in wet years, 7% of inflows in average years, and 13% of inflows in dry years. Exports to the Bay area, the Central Valley, and Southern California are estimated at 9% of inflows in wet years, 24% of inflows in average years, and 36% of inflows in dry years. New State of California legislation in November 2009 requires the development of new flow criteria for the Delta ecosystem. By law, the flow criteria for the Delta ecosystem shall include volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. Determining necessary outflows to the Bay throughout the annual hydrograph will be critical components of the flow criteria that are currently being developed. This conference, "Freshwater Inflows: 2010 and Beyond", is very timely for this ongoing effort at setting flow criteria in the California Bay-Delta. The emerging approaches likely to be used in this process for the California Bay-Delta will be highlighted and discussed.

Changes in Catchment to the Coast: tradeoffs in eutrophication and ecosystem restoration as defined by Florida Coastal Everglades and Mississippi River Delta.

Robert R. Twilley, Louisiana State University

Catchment environments share a level of complexity in that they are linked over large scales by a river network, so that problems in downstream locations may be the result of decisions made thousands of km upstream. Coastal landscapes represent some of the most altered ecosystems worldwide and often integrate the effects of processes over their entire catchment, requiring systemic solutions to achieve restoration goals. Two examples of such large-scale watershed and coastal restoration efforts are the Mississippi River catchment and its deltaic coasts, and the Everglades ecosystem and Florida Bay. Extensive flooding and hurricanes between 1927 and 1935 in both the Mississippi River deltaic plain and the Everglades watershed resulted in major public work projects that drastically altered regional hydrology. In addition, major agricultural development in both catchments over the last four decades has increased levels of inorganic nutrients, leading to problems with eutrophication. The urgent need for wetland rehabilitation at landscape scales has been initiated in both regions through major hydrologic diversions to reconnect the catchment with coastal processes. We will compare the nutrient biogeochemistry of the clastic system of the Mississippi River watershed and deltaic coast with the carbonate system of the Everglades and Florida Bay. The Mississippi coastal region receives large inputs of nitrate from upstream agricultural activities where as eutrophication in the Everglades ecosystem is caused by phosphorus enrichment. Comparisons will be made among restoration efforts and will include: river-flood and storm surge pulsing, hurricane impacts, climate change, hypoxia, vegetation changes, protection vs. restoration, incremental adaptive management, levees, and social vulnerability. Eutrophication issues threaten to reduce the applicability of water resource management as part of major restoration strategies in both regions.

Predicting and managing hydroecological effects: coping with complexity and uncertainty

Ed Lowe, St John's River Water Management District

Estuarine ecosystems are extraordinarily complex, harboring a myriad of interacting species with each species responding differentially to fluctuations in a highly dynamic physical/chemical environment. The effects of freshwater inflows permeate virtually all of this complexity, so prediction and management of hydroecological effects can be daunting tasks. In a study of the hydroecology of the St. Johns River, the St. Johns River Water Management District is employing the following strategies for coping with ecosystem complexity and the associated scientific uncertainty. 1) Organize an interdisciplinary team. Hydroecological research and management requires interdisciplinary expertise and a well-defined mission. Integration of the work of numerous specialists is an emergent issue. 2) Develop conceptual models. These models aid integration among disciplines. Ideally, they illustrate plausible chains of causation, linking ecological effects to hydrologic or hydrodynamic changes, and the methods or models to be used for prediction. 3) Identify key effects and indicators. Because all species and effects cannot feasibly be considered, we must reduce complexity to a manageable level by identifying key effects and their associated indicators. Work proceeds on the assumption that prediction and management of these effects, and monitoring of their associated indicators, will sufficiently address ecosystem function and structure. 4) Characterize effects at the ecosystem level. This approach ensures integration of effects across ecosystem components and regions. It explicitly places the responsibility for ecological interpretations on scientists rather than policy makers. 5) Acknowledge, communicate, and manage uncertainty. Sound policies cannot be developed unless the degree of scientific uncertainty is clearly communicated to policy makers. Management actions constitute enactment of scientific hypotheses. Uncertainty requires that these hypotheses be verified or modified through the cycle of adaptive management. Ultimately, adaptive management is the appropriate response to our imperfect understanding of the complex hydroecology of estuaries.

Day 3

Putting the dead to work: historical ecology and restoration of the Colorado River delta and estuary

Karl W. Flessa, Department of Geosciences, University of Arizona

The Colorado River once delivered 17 billion cubic meters of water per year to the upper Gulf of California, creating an estuary that extended 70 km from the river's mouth. Today, the trickle of water that sometimes reaches the estuary is salty runoff from farmers' fields and effluent from water treatment plants. With 90 percent of the river's water diverted within the United States, most of the economic benefits are evident north of the border while most of the environmental costs to the delta and estuary are borne in Mexico. The rich record of "pre-dambrian" shell accumulations and kitchen middens document the estuary's former productivity, diversity, biotic interactions and the importance of river water to the life history of two species of commercially important sciaenid fish. Isotopic and sclerochronological analyses of pre-dambrian shells and otoliths also provide guidelines for habitat restoration. Salinity requirements, and thus minimum river flows, can be estimated for species that are now rare or endangered. While overfishing and bycatch in the upper Gulf of California also threaten habitats, fish stocks and the vaquita (an endemic harbor porpoise), effective fisheries management alone will not restore the estuary. Effective river management is also needed. To date, restoration efforts within Mexico are upstream of the estuary: in the Ciénega de Santa Clara, a large wetland supported by agricultural return flow from the US, and in the Río Hardy corridor, supplied by water from Mexican return flow and water treatment facilities. Reconnecting the river to its estuary requires only modest dredging of the remnant channel and secure allocation of water not currently suitable for agricultural or municipal use. Restoration is a challenge because of invasive species, the increased demand for water because of population growth and the decreased supply of water because of climate change. Nevertheless, a new cooperative effort among US and Mexican water agencies, US and Mexican environmental NGOs, and US and Mexican environmental agencies holds promise for cross-border efforts at restoring ecosystem services in riparian, wetland and estuarine habitats.