Economic Effects of Freshwater Flows through the Colorado River Delta

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Introduction

In the spring of 2014, a historic and iconic reconnection of the Colorado River to the Sea of Cortez occurred, thanks to the implementation of Minute 319, a binational agreement which in part set the framework for international cooperation to bring environmental river flows back to the Colorado River Delta. Prior to that spring pulse flow, what once was a deltaic ecosystem consisting of thousands of acres of lush riparian and estuarine habitat, had been reduced to only a tiny fraction of its former size, driven by upstream diversion and damming of the river. Minute 319 addresses the need to better understand the ecological benefits that result from a release of water such as the one that occurred in 2014. Many benefits accrue to the region beyond and as a result of the ecological benefits. These benefits include economic benefits, such as changes in productivity of marine fisheries, recreation benefits, and benefits to agriculture.

The objective of this project is to identify potential economic benefits and values for Upper Gulf of California marine ecosystems as linked to the effects of freshwater flows from the Lower Colorado River and the implementation of Minute 319 in providing flows and integrate that information into the context of past research on economic values of water in the Delta.

Fisheries economics aims to quantify and analyze the effects of interdependent anthropogenic, biological, and environmental influences on fisheries. Estuaries are an environmental variable and key input to fisheries recruitment, productivity, and profitability for many species. The estuaries of the Colorado River Delta, now degraded due to lack of freshwater flows resulting from upstream damming and diversion, once provided key spawning and nursery habitat for important commercial species, the top two being shrimp and gulf corvina. Furthermore, the river provides important inputs such as nutrients, sediment, and detritus into the Upper Gulf.

The Upper Gulf of California is considered as the northernmost section of the Sea of Cortez, and the principal fishing communities in the area are Puerto Peñasco, Sonora; Golfo de Santa Clara, Sonora; and San Felipe, Baja California. These three communities engage in artisanal-scale fishing using “pangas”, small boats with off-board motors, as well as some industrial trawling for shrimp, based primarily out of Puerto Peñasco. The communities are heavily dependent upon fishing to support livelihoods, both directly through fishing, as well as through the fisheries value chain (processors, distributors, gear dealers, service providers, etc.). This economic dependence, coupled with environmental degradation due to lack of freshwater, places great pressure on marine resources in the region.

Past literature has provided estimates of the linkage between Colorado River flows and Upper Gulf of California marine productivity. Galindo-Bect & Glenn (2000) found that for shrimp in the Upper Gulf, catch was correlated with 1 year-lagged river flows, exhibiting a correlation coefficient of 0.67, statistically significant at the 99% level. Aragon & Calderon (2000) found shrimp postlarvae abundance to be positively correlated with river flows with a correlation coefficient of 0.88, significant at the 95% level. Rowell, et al (2005) found evidence that the Colorado River Delta provides key estuary habitat important to gulf corvina early in their life cycle using isotope analysis of corvina otoliths. Finally, Calderon & Flessa (2009) analyzed catch data and found correlations between catch and lagged river flows at 1 year lag for shrimp.
and 4 years lag for corvina. This analysis uses these established time lags to estimate the effects of incidental river flows on fisheries.

**Arizona Water Context**

Fresh water flows in the Lower Colorado River are a key issue embedded in water sharing agreements among the Colorado River Basin U.S. states, as well as in agreements between the U.S. and Mexico, such as Minute 319. Considering that the Colorado River is fully-allocated, if not over-allocated, providing instream flows for the environment requires tradeoffs between existing users, such as agricultural, municipal, and industrial users. These tradeoffs must consider the value that water provides in each context. The Lower Colorado River provides important benefits both in the U.S. and Mexico, including economic benefits, ecological benefits, livelihoods, recreation opportunities, and cultural benefits.

Minute 319, a binational (US-Mexico) agreement amending the 1944 Treaty governing the Colorado River provides for sharing surpluses and shortages between the two countries, and allows Mexico to store water in Lake Mead. It includes provisions on the restoration of the Colorado River Delta, providing base flows, a pulse flow, and the framework for environmental monitoring of the changes resulting from those environmental flows. While that framework includes monitoring of flow level and ecosystem response, there is a need to better understand the economic effects on communities and livelihoods in the region.

This research builds upon an existing body of work (Schuster 2012, Kerna 2012) quantifying the value of water in the Colorado River Delta. Integrating this information will help improve policymaker and community understanding of economic effects of changing freshwater flows through the Colorado River Delta and help to inform policy dialogue and water management decisions.

**Methods**

This analysis employs a series of models and methodologies in order to estimate the impacts of Colorado River flows to the Upper Gulf of California regional economy via fisheries productivity changes from a number of different approaches.

The first step in the process is to estimate the relationship between river flows and fisheries. This was done through two strategies. The first was to use econometric modeling to estimate a functional relationship between river flows and fisheries catch, introducing control variables to account for influences on fisheries productivity outside of river flows. The second strategy to quantify the effects of...
freshwater on the fisheries was to apply a bioeconomic trophic-level model called Atlantis (Ainsworth, et al, 2012) to the Upper Gulf to model the effects of freshwater flows over time. 11 separate scenarios were modeled, ranging from base flows alone at varying salinity levels and flow rates, pulse flows alone at varying salinity levels and flow rates, a combination of pulse flows and base flows, and flow scenarios that model past flow events, including river flows in 1993 and pre-dam flow levels.

The output of the econometric model in turn feeds into either an input-output model to estimate regional economic impacts, or into an enterprise model to estimate impacts on profitability to a single-boat fishing enterprise. Regional input-output tables were constructed using regionalization methods. Integrating outputs from the input-output model, as well as information on average water applied and area planted by crop in the Mexicali Valley region, a tradeoff analysis was performed to assess the potential for mutually beneficial tradeoffs resulting from shifting water from agriculture to the environment benefiting fisheries.

The study relies upon government data sources, data collected from researchers and non-governmental organizations, and also data gathered through field work in the region where informal interviews were carried out with fishermen, cooperative leaders, buyers, processors, conservationists, and other stakeholders in the region. Limitations of the data included a small number of observations for catch, effort, and price, inconsistencies between different sources, and lack of data capturing the extent of illegal fishing effort.

Past research integrated into this project includes economic data collected through visitor surveys at key Delta recreation sites (2012-14), though interviews with outfitters and other recreation-linked enterprises (2012-13), and through in-depth surveys of farmers in Mexicali Valley irrigation communities (2012).

**Key Findings**

**Econometric Model**

Catch data was regressed on river flow data lagged in accordance with the approximate life cycle of each species, shrimp (1 year) and gulf corvina (4 years). Different functional forms were tested for their explanatory power, including models with linear, quadratic, and cubic flow terms. Log-log models and first difference models were also tested. Control variables were introduced:

- 1-year lagged catch data to correct for first-order autocorrelation in the catch data
- The MEI ENSO index, lagged in accordance with the life cycle of the species, to account for environmental variations beyond river flows
- Market prices for each species

For both species, models were obtained which showed overall statistical significance at the 95% confidence level (using an F test), and statistically significant river flow coefficients, also at or above the 95% confidence level. The best models for shrimp catch included lagged catch and lagged river flow, either linear or quadratic. The preferred model for corvina included lagged catch, lagged river flows (quadratic), lagged MEI ENSO index, and an interaction term of
corvina price and the price of corvina swim bladder. In all cases in which the river flow coefficient was statistically significant, it was positive. These results indicate a positive relationship between fisheries catch and lagged river flows.

**Atlantis Model**

The Atlantis model predicted a small positive increase in marine biomass as a result of the changes in river flows. Details of the assumptions of the Atlantis Model and results of the flow scenarios runs are provided by Duval (2015).

**Economic Impact Analysis**

The economic impact analysis relies on projections of changes in catch resulting from a series of river flow scenarios compared to a baseline of zero flows into the Upper Gulf in order to estimate the changes in productivity as ‘shocks’ to the regional economy. The models estimated that river flows between 1 to 10 m$^3$/sec could yield modest increases in economic output to the region, taking into account the ripple effects of the increased production through regional fisheries value chains and wages paid to labor and household consumption. Details of economic impacts calculations and assumptions are provided by Duval (2015).

The largest impacts accrue to the agricultural, forestry, and fisheries sector, at nearly 80% of economic output stimulated by the economic shock. Following that, manufacturing receives roughly 9% of the impact due to the heavy reliance on gasoline and diesel as an input to production in fisheries, as well as increased demand for equipment. Finally, labor sees about 5% of the economic impact. The remaining impact is split amongst remaining sectors of the regional economy.

**Panga Enterprise Analysis**

The single boat, ‘panga’ enterprise level model relies on projected total catch for each fishery and an estimate of the number of boats operating in the fisheries. Compared to a baseline of zero river flows, flow levels of between 1 to 10 m$^3$/sec show to boost profitability for the boats by roughly 4 to 14% for the high flow scenario, but by only a small margin for the lowest flow scenario.

**Tradeoff Analysis**

The tradeoff analysis modeled the economic impacts of fallowing alfalfa, cotton, and wheat in the Mexicali Valley, as well as shifting alfalfa to wheat and cotton in order to make water available for the environment. This in turn was compared to the gains in fisheries productivity that would result from the same quantity of water made available by that crop fallowing or shifting. Though most scenarios showed a significant negative economic impact stemming from reductions in agricultural production and a small increase in output resulting from fisheries, some small economic output gains were possible for both sectors through shifting alfalfa to cotton to free up water for the marine environment. The analysis assumes no negative effects on productivity resulting from shifting crops and also does not take into account any compensation.
that might have to be provided to the farmers in order for them to fallow their fields and forego the income associated with that production.

**Summary**

This analysis shows positive gains in economic output and productivity in Upper Gulf of California fisheries resulting from increases in freshwater inflows from the Colorado River. Catch data for shrimp and gulf corvina, the region’s two top commercial species, exhibits positive correlations with lagged river flows. On an enterprise level, small gains in profitability could result from increases in freshwater inflows. Possible gains in output to agriculture and fisheries could be achieved through crop shifting from alfalfa to cotton in order to make water available for the environment.

These results inform the tradeoffs that are being made in choosing to divert or not divert water for consumptive use in the Delta region. The tradeoffs do not occur solely between agriculture and fisheries, but rather between many economic sectors and non-economic uses. There are many values of water for the environment in the Delta, and this study builds upon that body of existing research. Schuster (2012) estimated net returns to water in agriculture in the Mexicali Valley and found that returns were $1,060.68 pesos ($111.78 USD) per thousand cubic meters applied per hectare for durum wheat and $194.79 pesos ($20.53 USD) per thousand cubic meters applied per hectare for cotton. Kerna (2012) calculated visitors willingness to pay for water-based recreation in the Delta using contingent valuation method and found median willingness to pay of $168 pesos (~$13 USD) per car per entry for Campo Baja Cucapah and Campo Mosqueda on the Rio Hardy and $97 pesos (~$7.50 USD) per car per entry for Morelos Dam, San Felipito, and Cienega de Santa Clara.

Integrating these estimates of value of water in the Delta provides an opportunity to create a larger system model of the Delta water economy to explore tradeoffs of shifting water allocation between municipal, agricultural, and environmental uses, and the net changes in regional productivity, profitability, and employment.
References


