SCIENTIFIC REVIEW REPORT
San Acacia Fish Passage

Compiled by:

PBS&J
1120 Cedar
Missoula, MT 59802

Prepared for:

MIDDLE RIO GRANDE ENDANGERED SPECIES COLLABORATIVE PROGRAM
U.S. Bureau of Reclamation
555 Broadway NE
Suite 100
Albuquerque, NM 87102-2352

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1.0 INTRODUCTION

The middle Rio Grande Collaborative Program has sought an independent review of the requirement, included in the 2003 Biological Opinion (United States Fish and Wildlife Service (USFWS) 2003) for the Rio Grande silvery minnow (RGSM), to install fish passage at the San Acacia Diversion Dam (SADD). This report presents the results of an assessment by an independent review panel ("the Panel") of whether this requirement for fish passage at SADD is based on sound science. A draft version of this report was submitted on January 13, 2011 followed by a panel presentation on January 26, 2011 in Albuquerque. Comments from the discussion during that meeting and written comments submitted have been considered in the finalization of this report.

2.0 PANEL SELECTION PROCESS

A list of prospective review panelists was compiled by PBS&J, a contractor to the United States Bureau of Reclamation (Reclamation). These panelists were screened to help minimize the potential for perceived conflicts. Reclamation made final decisions on which panelists would be included and which would be removed from consideration due to potential conflicts. The primary evaluation factor for choice of panelists was past work in the middle Rio Grande. Specifically, if prospective panelists had a history of conducting research or providing opinions on water and biology issues in the middle Rio Grande, it was perceived that they may be unable to provide an independent and unbiased review of current policies and decisions.

The Panel participants are as follows:

- Dr. Jim Garvey, Southern Illinois University
- Dr. Will Graf, University of South Caroline
- Dr. Robb Leary, Montana Fish Wildlife & Parks
- Dr. Ed Peters, Professor Emeritus, University of Nebraska
- Dr. Larry Weber, University of Iowa

A Curriculum Vitae for each Panel member is provided in Appendix A.

In addition, George Cairo, a technical advisor on irrigation systems operation, was also included on this contract.

3.0 REVIEW PROCESS

The Panel was provided the project website: http://www.middleriogrande.com//Default.aspx?tabid=467 where all reference documents are posted. The Panel reviewed documents that each of them felt informed their conclusions related to answering the posed question. The exact question posed to the Panel was:

"Based on current data and information, is the requirement to implement fish passage at SADD for Rio Grande silvery minnow based on sound science?"

In general, the Panel defines "sound science" as an investigation that includes sharply defined research questions, reasonable hypotheses developed from empirical or theoretical approaches, reliable data,

meaningful tests of hypotheses, conclusions that are supported by synthesis of the available data, and conclusions that have been subjected to peer review.

Two members of the Panel, Dr. Jim Garvey and Dr. Robb Leary, met with agency representatives at the Reclamation office in Albuquerque on September 9, 2010. This meeting included a field trip to the project site. The Panel subsequently met at the Reclamation office in Albuquerque on October 25 and 26, 2010. Dr. Will Graf was the only Panel member not available for this meeting. During this meeting a conference call was held with Dr. Tom Turner and Dr. Megan Osborne of the University of New Mexico to discuss past genetics studies related to the RGSM. The Panel then proceeded to review studies and documents and draft sections of the report. The report text was reviewed in full by each Panel member and represents the consensus of the group.

4.0 WHAT THE PANEL TAKES AS A GIVEN

The following statements are those that the Panel takes as either proven or assumed fact. These statements form the basis of the subsequent analysis and conclusions:

1. There are numerous studies that have been conducted on the middle Rio Grande generally, and the RGSM specifically, that appear to be thorough, scholarly, and without serious defect.
2. There are fewer RGSM in the middle Rio Grande (MRG) than there were historically.
3. A substantial drop in RGSM numbers has been documented since 1973 when Cochiti Dam was finished.
4. Habitat changes (e.g. channel form, substrate size, etc.) have been modified from what was historically used by RGSM throughout the MRG.
5. RGSM are non-migratory, small-bodied fish.
6. RGSM are short-lived (1 to 2 years) in the MRG but can live much longer in captivity.
7. RGSM cannot currently move upstream past SADD, Isleta Diversion Dam, or Angostura Diversion Dam.
8. Numbers of RGSM in Angostura and Isleta reaches have been fluctuating widely over the past few decades.

5.0 REVIEW OF SCIENCE

The following topics are those that most directly inform the decision to include passage as an element of the Reasonable and Prudent Alternative (RPA) in the 2003 Biological Opinion. The Panel evaluated these topics to determine whether sound science was used in the determination of the necessity of fish passage at SADD for the recovery of the species.

5.1 Physical Constraints on Species Success

The science behind this topic will help answer the question: Are there physical constraints other than the fish barrier at SADD that would factor into the success of fish passage at SADD?

The protection of the endangered RGSM and the restoration of a sustainable population of the fish in the middle Rio Grande ecosystem are taking place within a particular environmental context. This biophysical environmental system includes the water and sediment flows through the river system, channel, floodplain, and vegetation communities that directly interact with the river. The RGSM is a species that evolved in a fluvial system that has undergone rapid change during the past century and a

half. The maintenance of a stable population of the species must now take place in system conditions that are different from those in the natural river.

The following brief review condenses conclusions drawn from extensive stream flow and sediment data as well as a very large body of literature available on the fluvial system of the Rio Grande in New Mexico. Water and sediment data are available from the U.S. Geological Survey public web site, including some of the longest records and highest quality data of any river basin in the country. General reviews of the historical development of the river environment have been provided by Albert (1848), Fergusson (1931), Graf (1994), Thompson (1965), and Wendorf (1954). Example reviews of the hydrology including water and sediment in the system include Burkholder (1928), Dewey et al. (1979), and Graf (1994). The geomorphology of the channel and floodplain has been the subject of such works as Happ (1948), Lagasse (1980), Massong et al. (2006), Porter and Massong (2004), and Woodson (1961). The riparian forestry was the focus of such efforts as those by Hink and Omart (1984), Meyer and Hepler (2007), and Van Cleave (1935). The classic work on tamarisk is that of Robinson (1965).

5.1.1 Water Flows

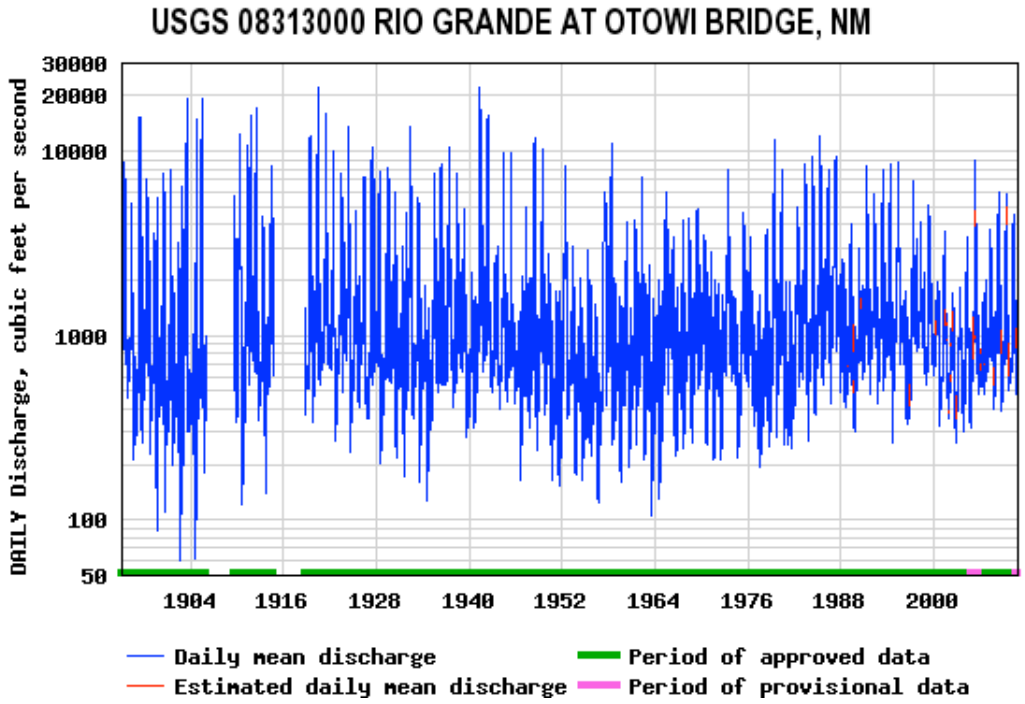
Changes in the Rio Grande in the reaches included in the Middle Rio Grande Conservancy District have been the products of adjustments in river discharges of water and sediment controlled partly by natural processes in the upstream watershed, and partly by engineering works that constitute the water-control infrastructure. These changes are especially important in the San Acacia reach of the river. Stream gage records from the Rio Grande at Otowi Bridge, north of Santa Fe, provide an exceptionally long-term view of the river's discharge entering the reaches of the river in the District. Although there are substantial withdrawals from the river between Otowi Bridge and San Acacia Diversion Dam, the Otowi record provides insight to the long-term general trends in flow (Figure 1).

The record of daily flows of the Rio Grande at Otowi from 1895 to the present has two short gaps (Figure 1), but otherwise it reveals three essential characteristics with implications for fish populations: high inter-annual variability, general increases and decreases in longer term averages, and frequent periods of very low or no flows. Although the overall average discharge through the entire record is about 1,000 cfs at this gage, the inter-annual fluctuations are so great that discharges as high as 200,000 cfs have occurred within a few years of discharges as low as 200 cfs. The variability is a natural product of the semi-arid basin drained by the river, a climate characterized by wide variation of rainfall from one year to the next.

The inter-annual variability was greater under pre-dam conditions since the installation of the present water-control infrastructure has served to reduce the variation by allowing large volumes of water storage. These efforts at flood reduction are apparently one reason that the variability in the first half of the record shown in Figure 1 is more than in the second half, when more control structures have been available on the Rio Chama (upstream from Otowi Bridge). In the middle reaches of the Rio Grande closer to San Acacia Diversion Dam, the reduction in variability is also evident, with remarkably less variation after the installation of Cochiti Dam in 1973 (Figure 2). The reduction in variability has been gradual, probably because the dams have been completed at various times rather than all at once (Table 1). Any restoration effort targeting the RGSM will have to take this reduced variability of daily flows into account.

The streamflow records at Otowi and San Felipe also reveal the effects of decadal variability on the long-term mean flows in the Rio Grande. Periods of generally higher flows alternate with periods of generally lower flows. Higher flows were common in the 1910s, 1940s, 1960s, 1980s, and the early 2000s, while lower flows were common in intervening decades. The long-term trend appears to be a gradual decrease in flow volumes, largely obscured by the shorter term variability from year to year.

Figure 1. Daily streamflow record for the Rio Grande at Otowi Bridge, New Mexico, 1895 – 2008. Data and graph from U.S. Geological Survey.



The flow record for the Rio Grande floodway (the remaining primary river channel rather than the conveyance channel) shows that very low flows are common throughout the record of the last 50 years, and in many cases the flow has been essentially zero (Figure 3). This record implies that restoration efforts to benefit the RGSM should take into account the real and recurring condition of a dry river channel.

Table 1. Significant Dates in the Installation of Water Control Infrastructure Affecting the MRCD. Data from Graf (1994) and the National Inventory of Dams, U.S. Army Corps of Engineers

Year of Installation	Structure
1913	First major dam on the Rio Grande: Rio Grande Dam, Colorado
1935	El Vado Dam, Rio Chama
1937	Completion of present San Acacia Diversion Dam
1952	Jemez Dam, Jemez River
1954	Completion of major channelization works upstream of San Acacia Dam
1957	Rehabilitation of San Acacia Diversion Dam
1963	Abiquiu Dam, Rio Chama
1970	Galisteo Dam, Galisteo Creek
1973	Cochiti Dam, Rio Grande

5.1.2 Sediment Flows

The sediment transported by the Rio Grande is, along with the water that provides the transport energy, highly variable from year to year and on longer time scales. Generally, in the late 1800s the river probably carried more sediment than in previous centuries as a result of widespread erosion in the

Figure 2. Daily streamflow record for the Rio Grande at San Felipe, New Mexico, 1959 – 2008. Data and graph from U.S. Geological Survey.

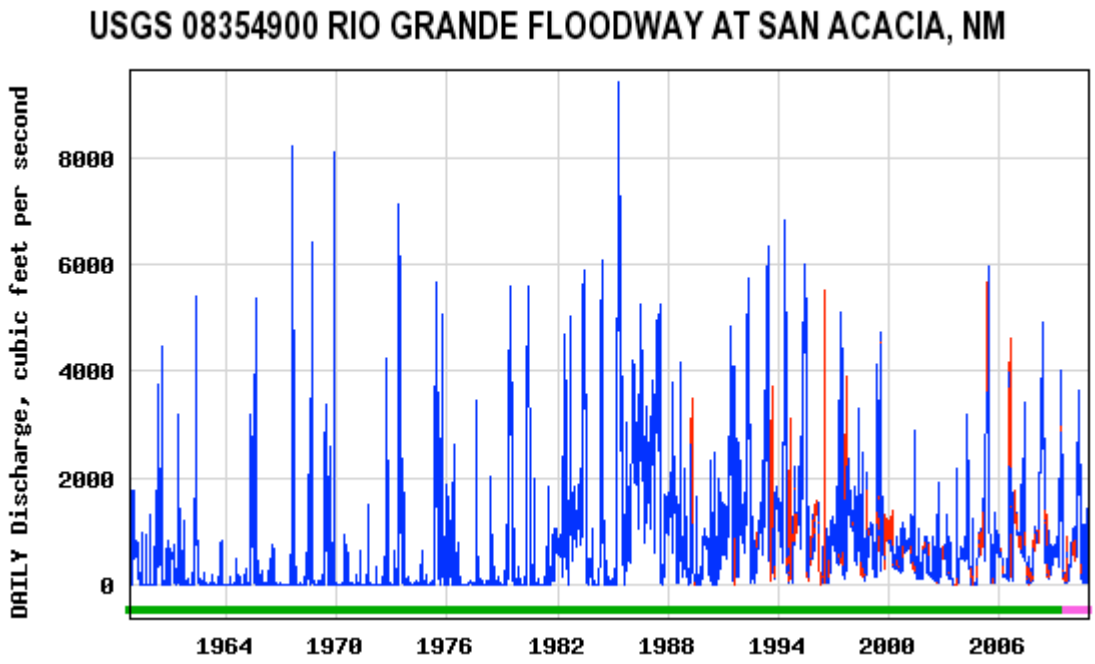
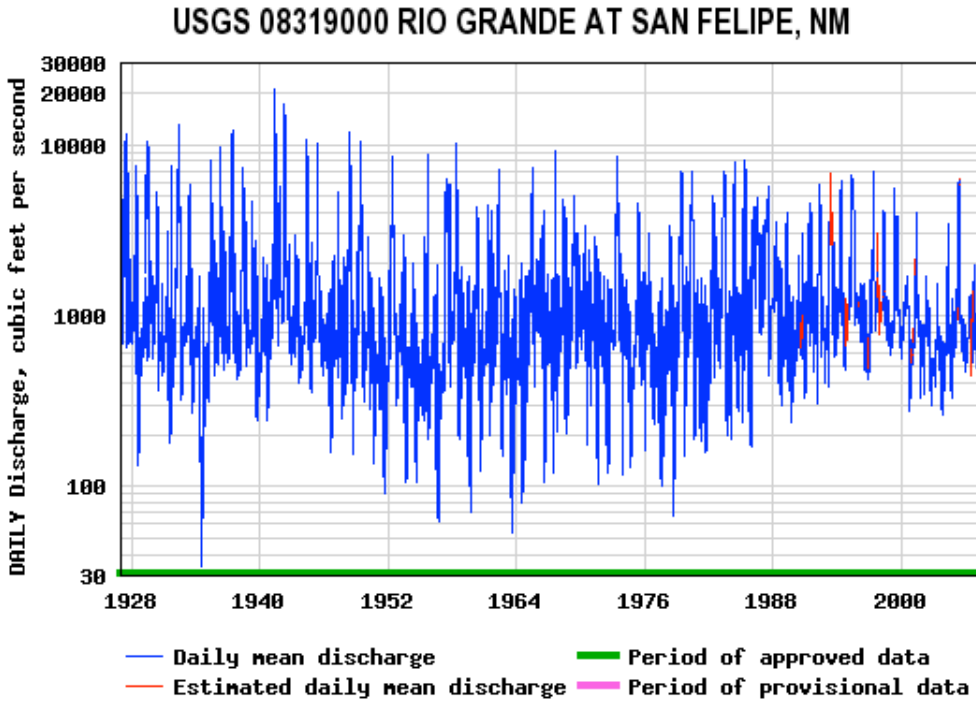


Figure 3. Daily streamflow record for the Rio Grande Floodway at San Acacia, New Mexico, 1926 – 2008. Data and graph from U.S. Geological Survey.



watershed. This increase in sediment loading was probably the result of a high flow period for water discharges and land-use practices related to logging, grazing, and farming that did not conserve soils and sediments in the basin. Sediments washing into the river from slopes and contributed from tributary streams came to rest in extensive deposits along the aggrading channel, awaiting the next high flow for further transport downstream.

Since the middle 1940s, enough sediment discharge data are available to deduce general modern trends in sediment flows. During the last 70 years, the amount of sediment flowing past the stream gage at Otowi Bridge and entering the middle Rio Grande from upstream has gradually been declining. This result is expected given the gradual decline in stream flow from climate change, and a reversal of unwise land-use patterns. Elsewhere, downstream from San Acacia Diversion Dam, the Rio Puerco contributed large amounts of sediment to the system during the 1950s, about 4 times as much as was coming downstream from the Rio Grande watershed. By the 1980s, the sediment contributions from tributaries had declined, partly because of engineering structures such as Jemez Dam on the Jemez River. The result is that now more sediment leaves the middle Rio Grande than enters it, so the river channel is degrading.

5.1.3 Geomorphic Changes

The flows of water and sediment in the Rio Grande have shaped its geomorphology and have introduced considerable change to the river's landscape. The original natural character of the river was a wide, shallow, unstable braided channel with many islands, bars, and subsidiary channels. During the late 1800s, highly variable discharges with some major floods combined with high sediment inputs produced a river that widened and deposited blankets of sediment on the nearby landscape. The result was a wide river and a wide active flood plain. Because of the large amounts of sediment entering the system, the river was aggrading; that is, the channel was slowly filling its valley with sediment deposits. During this period from the late 1880s to the 1920s (arbitrarily) the river was unstable and wide with a variety of habitats based on water depth and velocity, and with a flood plain that was actively connected to the channel by frequent floods (Figure 4).

Beginning in the 1920s, the construction of levees along the channel margin began to restrict channel width. Pilot channels designed to straighten the natural river, combined with increasingly restrictive levees, brought about major changes to the middle Rio Grande. By the late twentieth century, these local engineering works along with increased control of flows by dams with large storage reservoirs upstream created the sluice-like channel of today. The Rio Grande is now a single thread channel with a highly simplified geometry and a limited array of habitats based on flow depths and velocities. Generally, the river now is deeper, narrower, and faster than the system it replaced. The flood plains that once were connected to the main channel are now isolated from the channel (Figures 5A and 5B).

The reduction of sediment loading into the channel along with the narrowing of the channel has resulted in the last 2 to 3 decades in the excavation of the channel bed. This degradation has entrained previously stored sediments and swept them downstream to be deposited in Elephant Butte Reservoir and in the river reach immediately upstream from the reservoir. These processes created vertical banks along the channel, and a further narrowing of the flow into a relatively fast moving stream compared to the one that existed prior to engineering works.

These geomorphic changes have special significance for the fishes and birds that had evolved to use the river for habitat. Fishes such as the RGSM evolved with a high variety of aquatic conditions all within a short distance of each other, meaning that many ecological requirements were likely within a short swimming distance. Fishes had the use of flood plains during high flow events that represented a substantial expansion of their potential area of activity. In the modern river, the range of habitats is restricted, and the focusing of the channel into a single thread from its original braided condition implies a significant loss of ecosystem complexity and variety.

Figure 4. The channel of the Rio Grande a short distance upstream from San Acacia Diversion Dam in 1905. Photograph by R. H. Chapman, U.S. Geological Survey.

5.1.4 Riparian Vegetation

Riparian vegetation along the Rio Grande is intimately connected to the river's hydrology and geomorphology (Figures 6A and 6B). Under entirely natural circumstances, before the arrival of humans, the river banks were likely to have been lined with cottonwood and willows extending in a narrow ribbon along the river at and near the banks. The islands and bars in the braided channel were not likely to be forested because of the ephemeral nature of those features in the unstable channel. The lack of vegetation on the islands and bars provided those forms with little protection from erosion, so the features were constantly changing their shapes, sizes, and locations. Native vegetation of the forested strips along the channel margins provided some resistance to lateral channel migration.

The arrival of European settlers brought about harvesting of the riparian forest for fuel and construction purposes, and by the late 1800s the channel margins of the middle Rio Grande were largely devoid of trees and shrubs. During this period of numerous very high flows and great variability of flows, augmented by a large sediment supply, the channel and near-channel system was unstable, making the revegetation of native trees difficult (but not impossible). The slow return of cottonwood and willow was retarded during the middle twentieth century because of competition from invasive species, particularly tamarisk or salt cedar. The invasive tamarisk grew faster than the native species, colonized moist sandy surfaces that were in abundance in the middle Rio Grande, and had more effective root systems to tap groundwater than the native species with shallower tap roots. This aggressive shrub or tree came to cover vast areas of the channel margins and flood plains, and it grew so quickly that it was able to colonize and

thus stabilize bars and islands (Figure 6A and 6B). Numerous federal, state, and local projects have sought to eradicate tamarisk, but with little long-lasting success.

The present ecosystem in the middle Rio Grande has dense forests of tamarisk covering flood plains, islands, and bars, with some other species such as invasive Russian olive along channel high water marks and some natives such as cottonwood and willow. These forests serve to anchor sediments and greatly reduce the mobility of forms associated with the channel. Down-cutting of the channel is aided by having channel margins protected from erosion to some degree by the dense tree growth. Thus, although the forest vegetation may not directly influence the aquatic habitats for fish, it works in concert with the hydrologic and geomorphic systems to create habitats that are very much unlike those found in an entirely natural Rio Grande.

5.1.5 Summary

The Rio Grande of the early twenty-first century is very much unlike the river that existed prior to human influences. The original, natural, unregulated river was driven by highly variable flows of water, decadal variability in mean flow conditions, and moderately high sediment loads. The river was a complex braided system of numerous channels with shifting islands and bars and a wide variety of aquatic habitats with different depths and flow velocities. The system was bounded by riparian forests of cottonwood and willow. Fish that evolved in that system, including the RGSM, were attuned to such conditions. The present river has flows that are relatively consistent from one time to the next though they retain some decadal variability, and sediment loads are much lower than the natural system. The river has a single thread channel and a simplified geomorphology. Dense vegetation, particularly tamarisk, contributes to the simplification and relative stability of the system. Efforts to restore and maintain a sustainable population of native fishes including the RGSM may improve with the passage of fish over dams and other obstacles, but these efforts are unlikely to return the population to its former numbers because the fluvial system that once supported those numbers no longer exists.

Figure 5A. The channel of the Rio Grande downstream from San Acacia Diversion Dam in 1905, showing a broad channel and (on the opposite side) an active floodplain with a falling sand dune on the left. Same view as Figure 5B. Photo by R.H. Chapman, U.S. Geological Survey.

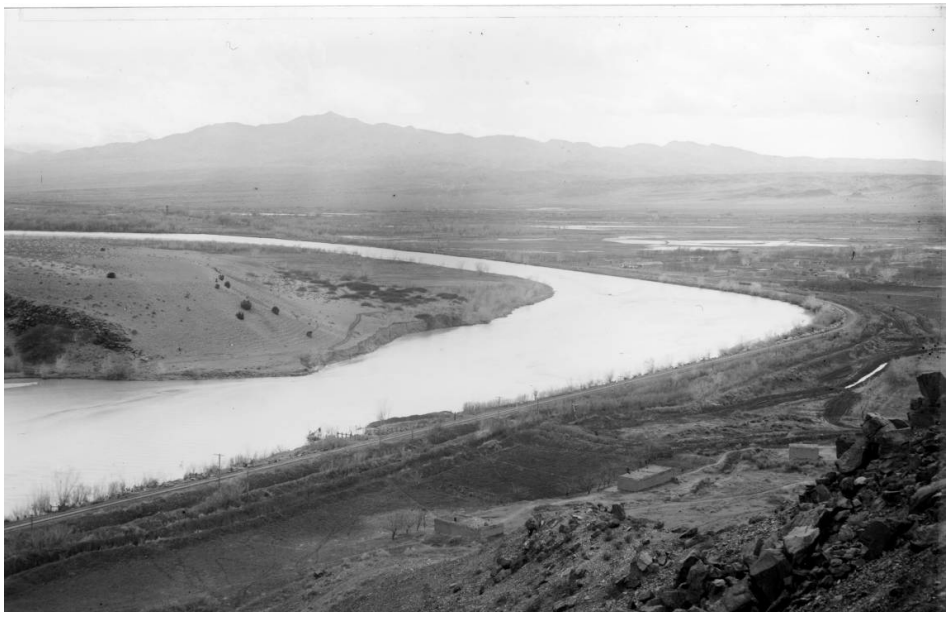


Figure 5B. The channel of the Rio Grande downstream from San Acacia Diversion Dam in 1989, showing a narrowed channel and a largely stable floodplain. Same view as Figure 5A. Photo by W.L. Graf.

Figure 6A. The channel of the Rio Grande upstream from San Acacia Diversion Dam in 1905, showing a wide channel with no forest vegetation and heavily grazed sand dune field in the foreground. Same view as in Figure 6B. Photo by R.H. Chapman, U.S. Geological Survey.

Figure 6B. The channel of the Rio Grande upstream from San Acacia Diversion Dam in 1989, showing a narrowed channel and a forested flood plain that is largely stable. Controled grazing has allowed revegetation of the dune field. Same view as in Figure 6A. Photo by W.L. Graf.

5.2 Ecology and Abundance

The best science pertaining to this topic will help to answer the question: Has the ecology and abundance of the RGSM been affected by the diversion dams on the MRG?

5.2.1 Ecology

The middle Rio Grande (between the current locations of Cochiti Dam and the headwaters of Elephant Butte Reservoir) has experienced drastic changes since the closure of the upstream Cochiti Dam in 1973. As noted in section 5.1.1, inter-annual variability of flows in the middle Rio Grande has decreased markedly over the period of record for gages at Otowi and San Felipe (USGS data). Prior to the closure of dams along the upper and middle Rio Grande and its tributaries, avulsions (abrupt shifts in channel location) occurred more frequently as large quantities of sediment were imported into the river channel. The historic time for peak flows, between April and June, which corresponded with the time of snowmelt in southern Colorado and northern New Mexico has been damped or eliminated by the capture of this runoff in upstream reservoirs and has reduced sediment import downstream. As stated in section 5.1.2, during the past 70 years the amount of sediment flowing past the stream gage at Otowi Bridge has been declining gradually. As a result of the decline of channel avulsions and overall sediment input, currently more sediment is transported from the middle Rio Grande than enters this reach of river. Because of the combination of these factors, from 1935 to 1989 the area of active channel in the middle Rio Grande has decreased by 52 percent from 8,973 ha to 4,345 ha.

In addition to the loss of active channel area during this time period, there has also been a change in channel morphology. The active channel has shifted from that of an aggrading braided channel with a sand substrate to a single, more incised channel with more of a gravel-cobble substrate. The RGSM has persisted through this rapid series of physical and hydrological alterations, but its range has shrunk by over 90 percent. In addition to the RGSM, which is endangered, there were an additional 20 native species. Of those, nine have been extirpated, two are extinct, three are rare and seven are still common (Calamusso et al. 2005). Similar changes have been documented in many riverine systems across North America and segmentation of habitat by dams, large and small, is a common denominator in the declines of many fish species (Rinne et al. 2005).

We compared information on the RGSM in the middle Rio Grande from published and unpublished studies to information available for other *Hybognathus* species, particularly the western silvery minnow (*H. argyritis*) and the plains minnow (*H. placitus*). Although information from other localities is pertinent, most of the comparisons are made with populations studied in the lower Platte River, Nebraska (Peters et al. 1989, Peters and Holland 1994, Fessell 1996, Yu and Peters 1997).

The factors that influence the ecology of a species are divisible into abiotic and biotic categories. In general the recovery plans for the RGSM have done a good job of identifying its abiotic and biological requirements. The following summary gives examples of how the literature describes these requirements. A synthesis of this information in terms of how it relates to the recovery of RGSM, however, is not known to exist.

5.2.1.1 Abiotic Factors

Discharge Volume: The decrease in the timing and magnitude of annual high flow events may have multiple effects on the RGSM. Spawning of RGSM has been associated with increased flow events in May and June (Platania and Dudley 2008). This corresponds closely to the timing of historic high flow

events associated with snowmelt in headwaters areas. Damping of, or elimination of, these runoff events by water storage in upstream reservoirs has interfered with reproduction by adult RGSM. In addition, there has likely been a decrease in periodic high flow events of sufficient magnitude to destabilize sand bars and shifts the river from a braided channel to a single channel. A braided river generally has a more diverse mosaic of shallow and deep habitats and swift to slow water velocities scattered across the width of the active channel than a single channel river. The braided river geomorphic condition is illustrated in several early 20th century photos included in section 5.1 of this report and it also is typical of other mid-American rivers such as the lower Platte River in Nebraska. In addition, Bovee et al. (2008) conducted an instream flow simulation of the middle Rio Grande and found that within the current active channel the habitat for the RGSM was maximized at discharges between 40 and 200 cfs. However, they also noted that at flows above 1,000 cfs numerous secondary channels would be inundated forming connected backwaters and flowing channels. This would generate habitat similar to that found in the pre-impoundment condition for the middle Rio Grande.

Water Depth: Most descriptions of preferred water depth for RGSM generally used descriptors like shallow. However, median depth use by RGSM shifted from 11-20 cm during summer to 31-40 cm during winter (Dudley and Platania 1997). In 2007, the Technical Advisory Group established water depth habitat suitability criteria for RGSM to be used in an instream flow simulation on the middle Rio Grande of 5 to 50cm (Bovee et al. 2008). In the Platte River in Nebraska, Peters et al. (1989) and Peters and Holland (1994) assigned the highest suitability (1.0) to depths between 10 and 20 cm for western silvery minnow and plains minnow. Thus, in general, it appears that *Hybognathus* species prefer relatively shallow water.

Water Velocity: Studies have shown that larval RGSM seek low velocity habitats where they may grow to lengths of 39-41mm by late autumn (Pease et al. 2006, Dudley and Platania 1997). From graphs (Remshardt 2008; Figure 5 in revised recovery plan) RGSM appear to have a positive association with pools, backwaters and embayments. There was probably more of this type of habitat in the un-dammed Rio Grande; "described as wide, perennially flowing, aggrading river with shifting sand substrate" (Dahm et al. 2005). In 2007, the Technical Advisory Group established water velocity habitat suitability criteria for RGSM to be used in an instream flow simulation on the middle Rio Grande of 1 to 40 cm/s for adults and 1-30 cm/s for juveniles (Bovee et al. 2008). For comparison, in the Platte River in Nebraska, Peters et al. (1989) and Peters and Holland (1994) assigned the highest suitability (1.0) to water mean column velocities of 0 for western silvery minnow and between 0 and 30 cm/s for plains minnow . Yu and Peters (1997) found that both western silvery minnow and plains minnow selected for areas with low velocity (Froude Number <0.21). Thus, in general, it appears that *Hybognathus* species prefer relatively shallow, low-velocity water.

Rate of Transport of Eggs: The spawning behavior and the buoyant eggs of RGSM are described by Platania and Altenbach (1998). RGSM eggs drift with the current for up to about 50 hours before hatching and embryos drift for several more days, depending on water temperature. The RGSM early life stages are, therefore, transported downstream considerable distances before they develop into larvae that are able to move to areas for feeding and growth (Platania 2000). Under present geomorphic conditions in the middle Rio Grande, this period of drift may move the eggs and embryos over 138 km downstream from the areas where they were spawned (Dudley and Platania 2007). If suitable low velocity habitats were available closer to spawning areas (such as in the braided channels of the pre-impoundment Rio Grande) more eggs and larvae may develop sufficiently to remain closer to their spawning site rather than drifting downstream. An important finding, however, is that retention of artificial eggs within the Angostura and Isleta reaches is enhanced when they are released on the ascending limb of the spring hydrograph (Widmer et al. 2010) suggesting, almost counter intuitively, that high flows create more slow velocity habitat. High flows, therefore, may be an important factor influencing reproductive success.

Water Temperature: Since spawning of RGSM occurs at temperatures between 18-24C (Platania and Dudley 2006), the coincidence of these conditions with increases in the discharge volume appears to be critical to the continued reproductive success of the species. Laboratory studies of development from an embryo to a larva require, 4 days at 25C, 7 days at 20C and 10 days at 15C during which time they may drift further downstream (Dudley and Platania 2007). In addition to water temperatures during the spawning season, influencing the potential length of downstream drift, elevated temperatures during summer periods of river desiccation may adversely affect the survival of the RGSM and other species native to the middle Rio Grande (Calamusso et al. 2005). For comparison, a study of temperature tolerances of common Platte River species by Fessell (1996) found a mean Critical Thermal Maximum of 35.6C and a Mean Death Point of 38.3C for *Hybognathus spp.* Studies on temperature tolerances of RGSM would seem to be important to the development of flow criteria for this species.

Turbidity / Suspended Solids: Several studies have noted the reduction in turbidity that has accompanied the closure of dams upstream from the middle Rio Grande. This, along with stabilization of discharge, has led to a narrowing of the channel of the Rio Grande and a shift to a substrate dominated more and more by gravel and cobble-sized materials (section 5.1). It should be noted that RGSM and the other species native to the middle Rio Grande almost certainly evolved under turbid water conditions. Studies on the food habits of RGSM specimens collected in 1874 support the conclusion that those individuals lived in turbid water and fed over silt and sand substrates (Shirey et al 2008). Furthermore, the occurrence of turbidity values that are higher in the summer than the winter may be a reason why the fish use shallower water during the summer as the turbidity may be acting as a form of cover, protecting them from predation (see similar mechanism in Miner and Stein 1996). Thus reduced turbidity may be adversely influencing many abiotic and biotic factors important to continued persistence of the fish.

Salinity: Increased salinity negatively affects RGSM egg survival (Cowley et al. 2009). Therefore, keeping salinity levels low is probably an overall benefit to RGSM. However, salinity levels in the Rio Grande as indicated by diatom taxa present in the digestive tracts of RGSM adults collected in 1874 and 1978 (Shirey et al. 2008) showed no differences in salinity levels. At this time, therefore, salinity may be an insignificant factor influencing RGSM viability.

Other Chemical Parameters: The mix of organic and inorganic chemical species that RGSM encounter through a life time has undoubtedly changed over the past century. It is probably not useful to explore the individual effects of each on an individual basis, since they occur in a constantly changing mixture over a range of concentrations. Buhl (2002), however, did find that, among other chemicals tested, copper and ammonia were the most toxic to RGSM. How chemical factors interact and impact the RGSM populations is not clear.

Substrate: Several studies of the substrate composition in different reaches of the Rio Grande have noted a shift from silt and sand substrates toward sand and gravel or gravel and cobble substrates. Remshardt (2007) found sand as the most common substrate used by RGSM followed by silt and gravel. However, silt was the substrate that was most used in relation to its occurrence (Figure 7 in revised draft recovery plan, USFWS 2010). The same substrates were used by RGSM year around. For comparison, in the lower Platte River, silt was determined to be the most suitable substrate for both western silvery minnow and plains minnow. These findings relate directly to the potential for altered geomorphologic, hydrologic, and related ecological changes as potential primary factors influencing the likelihood of the continued persistence of the fish.

Cover: Although Figure 6 in the revised recovery plan (USFWS 2010) shows that the majority of RGSM were found away from any type of shoreline feature or cover, open water was not positively associated with the occurrence of RGSM. Shoreline and shoreline vegetation showed a positive association with

occurrence. Eddy habitat was also positively associated with RGSM occurrence. This again raises the possibility that suspended solids/turbidity may be an important factor for providing "cover" to RGSM (again see Miner and Stein 1996). This may be of great importance to YOY individuals as they utilize the shallow slow areas of the river.

For comparison, the lower Platte River is turbid and the many small fishes (including small *Hybognathus spp.*) are most abundant in the shallow, low velocity areas with silt and sand substrate at the toes of sandbars (Peters et al. 1989). These areas are seldom associated with debris or other categories of cover. Such habitat is now relatively uncommon in the middle Rio Grande.

5.2.1.2 Biotic Factors

Fecundity and Reproduction: The spawning habits of RGSM are well documented and the importance of an adequate drift distance for development seems well supported (Platania and Altenbach 1998). Its reproductive behavior of spawning batches of pelagic eggs during high river discharge events undoubtedly evolved as a response to a free flowing, highly dynamic river system. This behavior of spawning with an abrupt rise in river stage, which was historically generated by spring snowmelt, is common among many species of fish across the Great Plains of North America and elsewhere (Dudley and Patania 2007). Furthermore, its ability to spawn early in its life (age 1) may be an adaption to living in a variable environment like the Rio Grande. With such an early age of maturity the fish could essentially repopulate suitable tributaries and main channel areas within one year after droughts. However, if access to these areas is blocked by insurmountable barriers, their ability to repopulate these areas will be diminished.

Feeding and Nutrition: All members of the genus *Hybognathus* are herbivorous. They feed on diatoms which they scrape or nibble from the substrate or the aufwuchs community (Hlohowskyj et al. 1989). Studies of the diatoms consumed by RGSM in the Rio Grande have shown differences in the taxonomic composition of the food items in the guts of fish collected in 1874 and 1978. These differences point to an overall shift in the food resources in the Rio Grande that may be deleterious to the RGSM populations (Shirey et al. 2008).

Age and Growth: Age 0 RGSM appear in samples collected during June and may grow to between 30 and 60 mm SL by December of the same year. As age 1 individuals (40 to 70 mm SL), this cohort comprises most of the spawning population the following year. Few wild individuals reach age 2 or age 3, reaching lengths up to 89 mm SL (Remshardt 2008). In captivity they may survive to reach age 11 and 73 mm SL (pers. comm. Buhl in: USFWS 2010) suggesting the middle Rio Grande may be, at best, marginal habitat for the species.

Mortality Factors: The specific mortality factors acting on RGSM have not been clearly delineated. Recent studies have found that age 0 fish comprise most of the population by December of a given year with age 2 and 3 fish comprising only a small fraction of the population sampled (Remshardt 2007). However, this may not always have been the case since Cowley et al. (2006) found specimens collected in 1874 were up to age 5. As stated previously, individuals in captive populations have been known to survive to age 11 (pers. comm. Buhl in USFWS 2010) and taken together these data again suggest the middle Rio Grande may now be, at best, marginal habitat for the species.

Predation: If RGSM are subjected to higher predation rates by avian predators in their preferred habitats they may move into deeper water habitats occupied by piscine predators (USFWS 2010). Under normal turbidity conditions, they would have been protected from avian predators in shallow water and sight feeding piscivores in deeper water. In addition, the combination of a loss in shallow side channel habitats and turbid water conditions afforded by the historically braided Rio Grande has now been replaced by a

single deeper, clearer channel. Under these conditions RGSM forced into open water habitats may now be subjected to predation on a year around basis. In addition, the introduction of sight feeding predators to the Rio Grande's main channel habitats, increases predation risk even more for small fish species like RGSM (Calamusso et al. 2005). This can certainly be exacerbated during desiccation events as the minnows are forced into remaining pools of water along with potential piscine predators (e.g. Matthews and Marsh-Matthews 2007).

Parasites and Diseases: Parasites, diseases and lesions tend to increase as RGSM are placed under increased stress, such as high water temperatures and confinement in pools (USFWS 2010).

Competition: Since the fish species assemblage in the Rio Grande now contains a substantial proportion of non-native fishes (Dudley et al. 2010, in this report native cyprinids dominated the catch) there is increased potential for competition from introduced minnows such as happened in the Pecos River (Bestgen and Platania 1991). Even though Dudley et al. (2010) found that native cyprinids dominated the collections from the middle Rio Grande, there is concern that introductions of herbivorous species like the plains minnow could quickly decimate RGSM populations (Calamusso et al. 2005). The Panel discussed the possibility that construction of a by-pass around what are now effective barriers to upstream movement may allow other non-native species to more easily move upstream into the core of RGSM habitat. These non-native species may be carriers of parasites and diseases, and be competitors with or predators on the RGSM.

5.2.2 Abundance

As a result of range contraction and reduction of suitable habitat within its current area of occurrence, the total population of RGSM is much smaller today than in the historic past (Calamusso et al. 2005). Reach specific estimates show wide variation and it is not really clear how stocking to augment the population influences these estimates. For comparison, in the lower Platte River, a decline in abundance of 98 percent for western silvery minnow and 93 percent for plains minnow was documented during a period of drought between 1987 and 1993 (Peters and Holland 1994). Subsequent to 1993 collections of both plains minnow and western silvery minnow were more common and individuals more numerous after high flows led to an apparent increase in these populations, but there are no quantitative data to track the magnitude of this population change.

Population estimates for small bodied fishes in medium to large rivers is a difficult task and this is made even more difficult by handling restrictions necessary to protect individuals of an endangered species. The decline in abundance of the RGSM in association with the much reduced range of the species is a great concern to its continued existence. Any species, restricted to as small a portion of its natural range as RGSM are currently, is susceptible to a variety of local perturbations that may lead to its extinction.

5.2.3 Summary

In as much as the irrigation diversion dams at San Acacia and other locations are a part of those habitat alterations, they do indeed adversely affect the ecology and abundance of the RGSM. However, it is not clear that completion of the SADD fish passage project will ameliorate these alterations and by itself significantly lead to the recovery of the RGSM.

Over the past century there have been changes in the biotic interactions of RGSM with other species in the Rio Grande ecosystem. However, in order to be an effective component of recovery for the RGSM, the SADD project needs to be coordinated with overall habitat recovery in the middle Rio Grande.

Even if genetic issues are not a concern, the constricting range of the RGSM places it at increased risk of extirpation.

5.3 Upstream Movement

The science surrounding this topic of movement of RGSM within the MRG system will help answer the question: Is there a positive rheotropic response to move upstream?

5.3.1 Ecology of Upstream Movement of RGSM

Living in a flowing environment requires stream fishes to be able to maneuver in flowing water. Most fishes initially respond positively to an increase in flow by swimming into it (i.e., positive rheotaxis), likely as an interaction between the flowing water and the lateral line system, which orients fish into the flow (Montgomery et al. 1997). Whether fish then opt to move upstream, hold station, or move out of the flow depends on a complex set of conditions (Nestler et al. 2008). Moving forward into flow or holding station incurs an energetic cost but may place the fish in a desirable location (e.g., near food, away from predators). Moving out of flow into slackwater may have energetic advantages but may place the fish in otherwise poor conditions (e.g., poor water quality, near competitors, accessible to predators).

Why would upstream movement occur if it incurs an energetic cost? The behavioral motivation behind moving upstream within flowing water varies greatly among fishes. For example, many species of fish migrate upstream within flowing water to complete some aspect of their life history while many others do not. They also may migrate upstream to avoid predictably unfavorable conditions downstream such as seasonal drying - but only if a permanent water source (e.g., a lake) is available upstream.

Upstream movement must have some overall benefit that outweighs the energetic cost (Table 2). One example is mature adults moving upstream to natal areas that provide nursery conditions for larvae and that also provide low-energy, downstream dispersal opportunities for juveniles (Pacific salmon). Another example is immature individuals (American eels) dispersing upstream to avoid negative interactions downstream such as intraspecific competition, predation, or poor environmental conditions. Thus, an upstream migration in this context is defined as a large-magnitude, upstream movement of many individuals within a specific set of life stages (Lucas and Baras 2001; Table 2). In contrast, upstream movement may be non-migratory, influenced by individual-based decisions related to food availability, predator avoidance, reproduction, genetic disposition, etc. (Table 2). In fact upstream movement may simply occur randomly among some individuals within a population. The distribution of "dispersal likelihood" among individuals within populations is likely leptokurtic, with some individuals moving much greater distances than average counterparts (Rodriguez 2010). Problems face both individuals migrating en masse in migratory populations or rare dispersal-prone individuals in non-migratory species. In addition to natural hazards posed by swimming upstream, streams and rivers have been altered by humans in many ways, all too frequently impeding movement (Ickes et al. 2001; Bednarek 2001). Natural impediments to fish passage occur as well (Schaefer 2001); such as when streams become dry, creating a series of disconnected pools.

For the RGSM, net upstream movement within the middle Rio Grande has been suggested as important to the recovery of the species (Alo and Turner 2005; Bestgen et al. 2010). Upstream movement is hindered by a series of diversion dams. Thus, populations are considered as separate in each of the "pooled" reaches. The Recovery Plan for the RGSM calls for the establishment of fish passage structures at dams as a Priority 2 Action Item (USFWS 2010) to reconnect populations that are apparently isolated in each reach.

Table 2. Comparison of Patterns of Upstream Movement Between Species with Migratory and Non-migratory Life History Patterns. Based on Brower and Malcolm (1991).

	Migratory	Non-Migratory
Number of individuals moving	Many	Few
Life stages moving	Very specific	Indiscriminate
"motivation"	Complete life cycle or respond to predictable environmental change	Avoid poor conditions or access resources
Energy cost	High	High

However, the question remains whether upstream movement is a significant mechanism affecting dispersal of RGSM and thereby mixing of individuals among subpopulations. Downstream movement by zygotes, embryos, and larvae as well as adults may be the primary mechanism of population mixing, with upstream movement historically having a small impact (Figure 7a). If this is true, then the overall ecological benefit of promoting upstream movement by building passageways around diversion dams in the middle Rio Grande may be small relative to the benefits of alternative recovery efforts (Figure 7c). However, RGSM may "stack up" below the pooled areas below dams during stream drying (Bestgen and Platania 1991). If more water is available upstream of dams, then moving upstream would be beneficial to those local fish.

The general understanding of RGSM movement as it relates to environmental conditions is improving. The RGSM is a small-bodied (reaching a maximum body size of about 75 mm standard length) and short-lived (about 2-years in the field) cyprinid. The small body size and short life span of this species likely limit the distance which an individual can move during its lifetime (although exceptions exist; see Bond 1996, Lucas and Baras 2001 for reviews). Of course, this assumption needs to be tested for the RGSM with more long-term monitoring of tagged individuals. It is fairly certain that RGSM are a non-migratory species, with individuals dispersing from slackwater locations where they settled from the drift as larvae (Pease et al. 2006). Lab research where adult RGSM swimming ability was tested in swim chambers suggests that they are fairly capable swimmers (Bestgen et al. 2010). Swimming endurance (the time that a fish can hold station at a fixed flow velocity) varied in a negative exponential fashion with velocity (Bestgen et al. 2010). Endurance declined substantially at velocities > 0.6 m/s. At flows less than 0.5 m/s, swimming endurance of some RGSM was sufficiently high that these individuals would have been able to swim upstream up to 40 km/day. Swimming ability likely varies among individuals as a function of exercise, energetic condition, and genetics. To date, the best available science only has explored the impact of exercise on upstream swimming ability (Bestgen et al. 2010).

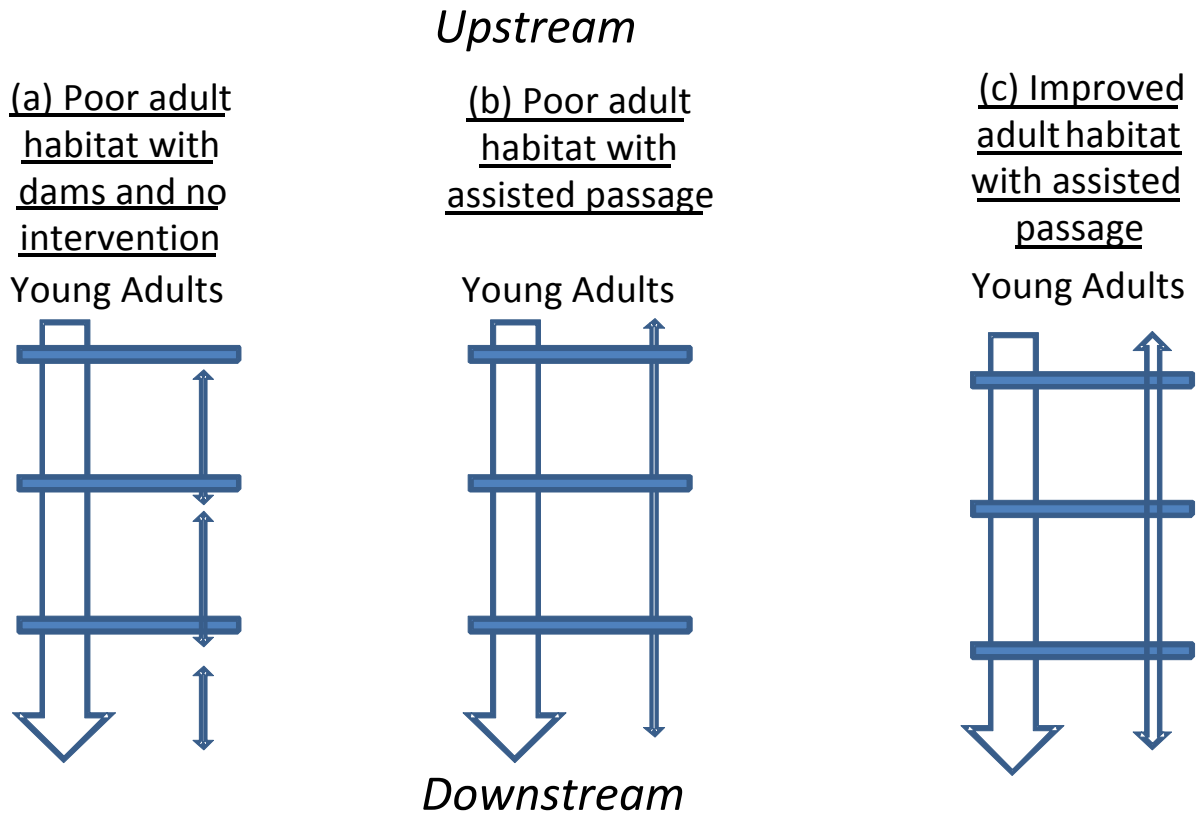
Lab research suggests that at least some RGSM individuals are capable of moving relatively long distances (e.g., 100 km). Field research is needed to test whether this is indeed possible and ecologically relevant. In the present, degraded river habitat configuration, RGSM are more frequently found in sand-silt areas of low velocity (Remshardt and Tashjian 2003), suggesting that they frequent slackwater conditions. Because they are not typically found in flowing water within the main channel their use of this area to move in large numbers throughout the river is likely not common. Quantifying movement of small-bodied species in a large river system is daunting. However, significant strides have been made for RGSM. During 2001 through 2002, a comprehensive study of RGSM movement was conducted using visible implant elastomer (VIE) tags (Platania et al. 2003). About 12,000 RGSM were released at two locations in the San Acacia Reach, of which 66 individuals (< 1 percent) were recaptured up to 100 days post release. From the data presented in the report, it appears that 15 of these recaptured individuals moved upstream from their release site, with one fish moving 25 km upstream (Platania et al. 2003). Most fish were recaptured within the vicinity of their release. VIE tags have high retention rates and low mortality (Bolland et al. 2009). Thus, this study provides a rather robust and unique picture into patterns

of dispersal of RGSM and likely other small-bodied fish in arid rivers. As predicted earlier, the distribution of movement was apparently leptokurtic with most fish moving little but a few dispersing large distances upstream. The authors of the VIE effort concluded that RGSM are not migratory (Platania et al. 2003) supporting predictions in Figure 7c that the potential for net downstream movement always has been greater (due to mass movement of young downstream).

Complementary field research to the VIE effort explored how tagged RGSM behaved around the Alameda drinking water diversion dam in the Albuquerque- Isleta Reach of the middle Rio Grande. A rock-ramp fish passage structure around this dam was completed in 2007 (Figure 8). To evaluate whether RGSM successfully used the structure, upstream and downstream PIT (passive integrated transponder) antennae were emplaced in the structure and used to monitor movement of RGSM implanted with PIT tags (Remshardt and Archdeacon 2010). PIT tags are a very useful innovation in documenting animal movement. They respond by broadcasting individual information about the tagged fish when tags come into contact with an antenna and are energized. Thus, the relative response of tags at each antenna indicates when a fish approached the structure. The sequence of responses also suggests whether fish moved upstream or downstream (i.e., successfully passed). On 15 June 2009, 4275 PIT-tagged RGSM were released at locations above and below the Alameda diversion dam. The passageway was monitored continuously during 15 June 2009 through 27 September 2010. Fish were detected until 15 June 2010. After that time, no more fish were found. A total of 169 unique observations occurred, representing 84 individual RGSM. Detection (not necessarily passage) at the passage device was related to distance of initial release (Figure 9). More fish released upstream were detected at the passage device than those released downstream (Figure 9). An apparent outlier was the proportion of fish released only 0.5 km upstream from the passage ramp, which were more frequently detected (Figure 9). Complete passage upstream as indicated by detection by both antennae occurred for 8 of the 84 individuals. Twelve passed completely downstream. From these data, it is clear that passage is possible in both directions. However, an apparently small proportion of tagged fish in the river came into contact with the structure.

How might these PIT tag results be extrapolated to the entire population? Population estimates based on occupancy data plus site-specific sampling has been conducted in the middle Rio Grande for about 5 years (Dudley et al. 2010). This methodology used the relative proportion of habitats available to RGSM combined with density estimates in these areas (Dudley et al. 2010). If the data are remotely robust, the current population density of RGSM in the reach of the passage structure may be 1.2 million. Applying the proportion of fish encountering and passing through the structure (8 out of 4275), suggests that a small number of fish are moving in a net upstream direction (about 2200 fish). Obviously, several assumptions are involved here, including that all of the released fish had an equal probability of encountering the structure (which is untrue), that PIT tag retention was high (which is supported by Archdeacon et al. 2009), and that mortality during the study period was negligible. If these potential problems have a minor impact on results, the VIE and PIT tag efforts suggest that the net upstream movement of adult RGSM is likely very small, even when population size is large. During years when recruitment is low and population density is low, movement may be negligible.

Figure 7. Hypothetical comparison of patterns of downstream and upstream movement hypothesized for silvery minnow. This figure is intended as a conceptual diagram by which future research may be directed.



Arrows indicate net direction of movement. Width of arrows indicates relative density of individuals within the population moving. Habitat within reaches is poor limiting movement within them. Upstream movement is blocked by dams (vertical bars). Fishways or physical transplantation (i.e. assisted passage) of fish allows fish to move past dams.

Figure 8. Alameda diversion dam and fish passage structure (Remshardt and Archdeacon 2010).

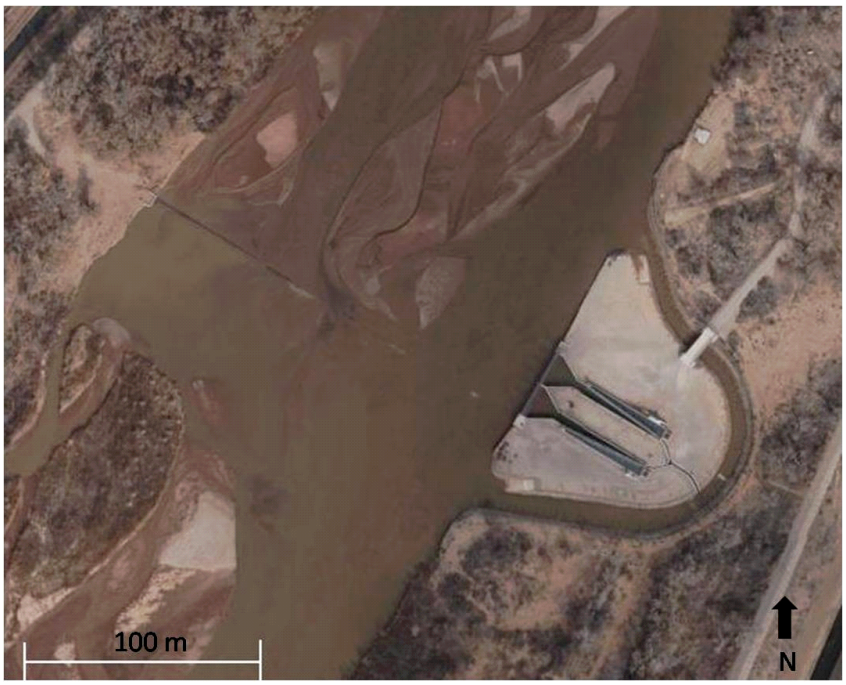
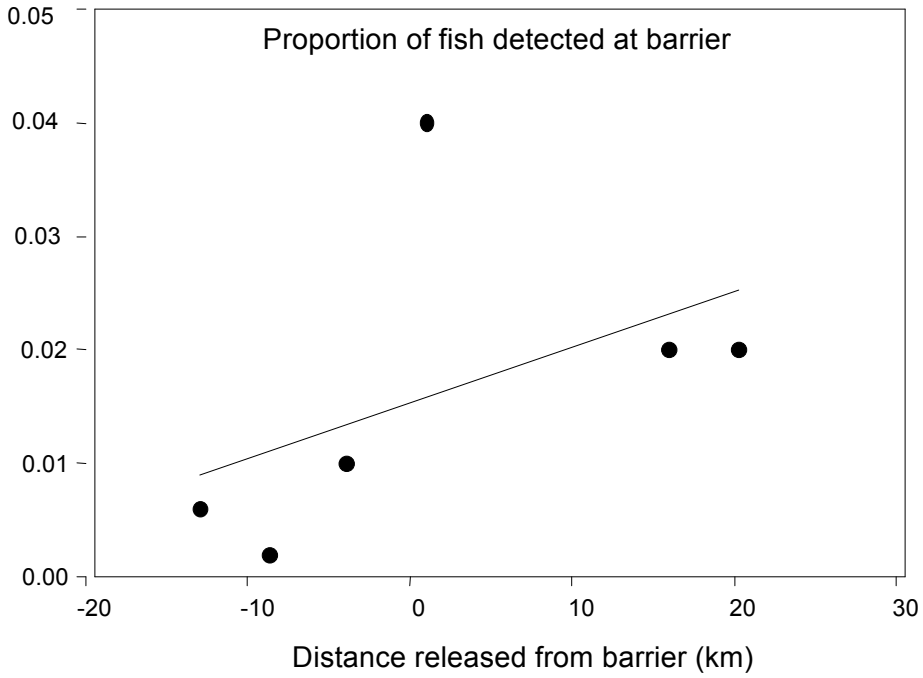


Figure 9. Proportion of detections of PIT tagged RGSM at Alameda diversion dam and fish passage structure (Remshardt and Archdeacon 2010) . These data suggest that fish released upstream had a higher probability of occurring at the dam than those released downstream. This suggests net downstream movement.



5.3.2 Summary

The current best available science supports the conclusion that most dispersal and thereby "mixing" of the subpopulations in the reaches of the middle Rio Grande occurs during early life when embryos and larvae are drifting downstream (Figure 7). Adults move rarely; if movement occurs, net adult movement is typically downstream (Figure 9). Some long-range (several kilometers) upstream movement by adults does occur and is likely possible within each reach as long as flows are less than 0.5 m/s. However, under the current river habitat conditions, "random" net upstream movement of adults is likely going to be limited not only by diversion dams but by the geomorphology and hydrology throughout each reach (Figure 7a; Nestler et al. 2008). Some RGSM may "pile up" below dams during dry periods, likely because these are pooled areas. If pooled water is available upstream of diversion dams, then passage would aid the subset of the population at these locations, although the potential contribution of this movement to the population is unknown. The river is now deeper and restricted to a single channel (see previous sections). In the past when the river was wider and braided, adults likely dispersed upstream via slow-flowing, interconnected secondary channels. This option is now restricted and upstream movement is likely a rare occurrence even within reaches. Of course, this assumption needs to be confirmed. But to this point, no information quantifying within reach movement as a function of habitat, environmental effects, and population dynamics is available. Net upstream or downstream movement is likely driven by a host of state-dependent factors that may differ dramatically among RGSM individuals. RGSM do not move en masse in a migratory fashion. No science is available on what external and internal factors cause RGSM individuals to move among habitats within the river. Drying, food availability, and predation are likely candidates and require research to confirm their relative effects.

Building fish passage at this time may be having the proverbial "cart get before the horse". Given the apparently small proportion of individuals moving upstream either within reaches or through structures between reaches, capturing individuals within reaches and transplanting them among reaches is probably the most cost effective method for mixing individuals at this juncture. This approach is similar to salvage efforts occurring within reaches during channel drying, except at a larger, multi-reach scale. According to the data available, physically moving (e.g., via seining and transport in trucks) about 2,000 individuals annually between reaches currently may have the same net effect as a fish passage structure. Rather than building passageways, habitat restoration within reaches to maximize connectivity within them should be the highest priority. A conceptual research hypothesis to follow at this juncture is that fish passage structures will not become effective at the river-wide scale until significant improvements to channel morphology and hydrology encourage natural upstream (and downstream) dispersal both within reaches and in the vicinity of diversion-dam passageways if they are installed (see Figure 7c; Nestler et al. 2008). Under improved, rehabilitated reach-wide conditions, researchers and managers will be able to generate a more realistic set of expectations for patterns of movement and thus set more accurate benchmarks (i.e., number of fish expected to move between reaches per year) for movement across barriers.

A very insightful approach would be to monitor long-term movement of RGSM within a reach as habitat restoration occurs. If habitat restoration is linked to instream movement, then trends in movement (i.e., dispersal) should increase accordingly. This finding would then support implementing passageways as a second-tier tactic toward restoring connectivity in the middle Rio Grande.

5.4 Swimming Ability

The science pertaining to this topic will help answer the question: Can RGSM actually use a fish passage structure?

In general, implementation and ultimate success of fish passage structures may be described as the cumulative success of fish passage components as follows:

1. Are the target species attracted to, or do they assemble in areas near the entrance to the fish passage structure?
2. Once the target species are in the vicinity of the fish passage structure, will they accept the entrance conditions and enter into the passage structure?
3. Having entered into the passage structure will the fish pass through the structure? Passage through the structure is a function of both an acceptance of hydrodynamic conditions within the structure and an individual fishes swimming strength.
4. Having passed through the bypass structure do the fish find suitable, available habitat upstream of the fish passage structure?
5. Having found suitable habitat upstream of the structure is there a measurable increase in species population abundance and/or diversity.

The following sections will expand upon the general fish passage components described above and provide specific application for RGSM at SADD.

5.4.1 Entrance Attraction

Is there sound science to support the assumption that RGSM will be attracted to, or will assemble in the area near, the entrance to a fish passage structure at SADD?

It is reported (Platania et al. 2003) that large concentrations of RGSM have been found immediately downstream of diversion dams, including at SADD, in late summer and fall suggesting that movement is occurring at this time and that individuals are accumulating in the immediate tailwater areas of SADD. However, in addition to presence of fish in the area, local flow conditions play a significant role in the likelihood of fish finding, recognizing and accepting a fish passage entrance as a suitable passage route for continued movement. Factors to be considered in locating a passage structure entrance include entrance width, submergence depth, location with respect to hydraulic conditions in the tailrace, total passage discharge, discharge per unit width, and seasonal/operational changes to tailwater hydraulic conditions, amongst others.

Fish employ species dependent strategies to advantageously use hydraulic patterns to meet their movement objectives; i.e., they may follow shear lines along high energy flows in search of food sources or may be bank oriented to follow low energy pathways during upstream migrations (see e.g. Nestler et al.2008). The Rio Grande is characterized by large flow variations in a given year, and large variations year to year. These flow variations may result in significant changes in tailrace flow conditions, thereby affecting passage effectiveness. It is unclear if any qualitative or quantitative information exists with respect to flow conditions in the tailrace at SADD. Lastly, there is no evidence that tailrace flow conditions have been considered in the preliminary design and assessment of fish passage at SADD. Thus, there is great uncertainty about what flow conditions are required to effectively attract RGSM to tailrace areas and whether or not these conditions can be effectively achieved given the conditions present in the river. Additional information with respect to the movement behavior of RGSM in the tailrace region of SADD, therefore, is needed to fully assess the behavioral response to tailrace flow conditions.

Will RGSM accept the entrance conditions and enter into the passage structure?

Many fish species make movement decisions based on local hydrodynamic cues. For example, Goodwin et al. (2006) demonstrated that juvenile salmon movement patterns could be simulated based on a combination of rules describing their response to relative acceleration thresholds, changes of depth and desire to move toward water with increasing velocity. It was also determined that juvenile salmon would exhibit avoidance characteristics for hydrodynamic environments that had rapid accelerations,

decelerations, upwelling, or high-energy turbulent structures. Although these behavioral characteristics seemed to be consistent across different salmon species the particular thresholds of attractiveness and avoidance have not been determined.

Goodwin et al. (2006) report behavior of salmonids showing repeated rejection at a downstream passage facility entrance due to local acceleration patterns. Factors to be considered include the local acceleration/deceleration fields, upwelling, turbulence patterns, pressure fluctuations/vibrations, and noise, amongst others. Although Bestgen et al. (2010) report the swimming strength characteristics of RGSM and feasibility of a few selected bypass configurations, very little is known about the specific entrance conditions that may be found as an attractant or deterrent to RGSM seeking a passage route. Additional prototype testing of active migrants at a field location along the Rio Grande is essential to reducing the risk of rejection of the entrance conditions.

Having entered into the structure will the fish pass through the structure?

Passage through the structure is a function of both an acceptance of hydrodynamic conditions within the structure and an individual fishes swimming strength. Similar to the entrance hydrodynamics, the flow conditions in the passage structure are equally important to the continued utilization and passage through the bypass structure. Key design parameters include: discharge per unit width, slope, overall width, resting areas, longitudinal and span-wise placement flow blockages, instantaneous and average velocity conditions, and flow depth. A report and peer reviewed publication (Bestgen et al. 2003 and Bestgen et al. 2010, respectively) present results of laboratory tests for a few selected fish bypass configurations designed with the aim toward a nature-like condition. These data are important and appear to be the only quantitative data available with respect to the RGSM's swimming strength and movement behavior. It must be kept in mind, however, that these data were obtained from captive fish released within a passage structure. They, therefore, provide little insight into whether or not they voluntarily would subject themselves to such conditions.

5.4.2 Summary

The *Study and Preliminary Design Development of a Fish Passage Facility for San Acacia Diversion Dam* (HDR 2006) report identifies "attraction" as being of critical importance. It, however, falls well short of fully identifying the key parameters needed to increase the likelihood of successful attraction. Nor does it provide quantifiable measures for the most relevant design parameters (both engineering and biological) required for attraction. The report acknowledges that "there is limited experience to directly draw upon to define attraction cues. Therefore, experience from many related studies provides the best available insight on attraction." Unfortunately, the report continues by presenting anecdotal information and conversational information as the basis for entrance design. This pales in comparison to the data needed for this magnitude of project to minimize the risk of failure and potentially avoidable loss of fiscal resources. The report relies upon the work reported by Bestgen (2003) and Bestgen et al. (2010) which is useful and well-documented, however, it does not test the volitional response of fish seeking and accepting a bypass facility. Lastly, HDR (2006) does not indicate how parameters were selected for siting the entrance, designing the entrance conditions or the internal features of the passage facility.

Due to the high degree of uncertainty, it is recommended that the team engaged in design of fish passage at SADD develop a strong science-based adaptive management approach to answering the questions raised above. This approach should clearly describe the known and unknown design parameters (both engineering and biological) and utilize laboratory, computational and field experimentation to increase their understanding, quantify design parameters and reduce the risk of failure of constructing a full scale fish bypass system at SADD (or other diversion dams).

5.5 Genetic Diversity

The science pertaining to this topic will help answer the question: Has the genetic diversity of the RGSM been adversely impacted by diversion dams?

5.5.1 Introduction

The RGSM, *Hybognathus amarus*, is protected as an endangered species under the United States Endangered Species Act (USFWS 1994). It historically occupied most of the Rio Grande and Pecos River drainages. Now, however, it is restricted to a single, 244 km reach of the middle Rio Grande in New Mexico (USFWS 2010). The division of this reach into three segments by, north to south, the Angostura Diversion Dam, the Isleta Diversion Dam, the San Acacia Diversion Dam, and Elephant Butte Reservoir, which is considered unsuitable habitat for the RGSM (USFWS 2010), is considered to be one of the numerous threats to the species' persistence (USFWS 1999, 2003, 2006, 2010). For example, the 2010 Recovery Plan (USFWS 2010) states on page 25 "The presence of diversion dams (Angostura, Isleta, and San Acacia Diversion Dams) prevents the recolonization of upstream habitats (Platania 1995b) and has reduced the species' effective population size (N_e) to critically low levels (Alo and Turner 2005, Osborne et al. 2005)." Although downstream movement over the diversion dams is possible, upstream passage is considered to be precluded. Thus, depending on the amount of downstream gene flow it is possible that the dams have fragmented the RGSM in the middle Rio Grande into three genetically divergent subpopulations each with relatively low N_e.

From a genetics perspective, fragmentation is the substantial reduction in gene flow among historically connected populations due to physical or biological habitat alteration or degradation. Fragmentation can potentially have adverse genetic impacts on the continued persistence of populations because of reduced gene flow. Reduced gene flow is expected to result in lower N_e which over time is concomitantly expected to result in increased genetic divergence among populations because of genetic drift and reduced genetic variation within populations because of genetic drift and inbreeding (Allendorf and Luikart 2007). Low N_e is also expected to result in significant stochastic, temporal genetic changes within populations because of increased genetic drift.

The potential genetic effects of fragmentation can be detected over relatively short time scales especially in species like the RGSM that have a short generation time. For example, creek chubs, *Semotilus atromaculatus*, in North Carolina appear to represent a good example of the above phenomena except population viability data are lacking. Skalski et al. (2008) used data from 17 microsatellite loci to estimate levels of genetic variation within and amounts of genetic divergence among eight native populations inhabiting a largely interconnected stream/river network (River samples) and eight native populations now inhabiting fragmented tributaries to Falls Lake because of the construction of a dam in 1981 (Fragmented samples). The reservoir habitat is considered to largely be unsuitable for creek chubs as they are very rarely encountered in such environments. Their results indicated the River samples had higher within population genetic variation as estimated by average expected heterozygosity (H_e) than the Fragmented populations (River mean=0.537, Fragmented mean=0.450, Wilcoxon two-sample test $P<0.001$). Although there was no significant difference between the River and Fragmented samples in levels of pairwise genetic divergence, as estimated by F_{ST}, the pattern of genetic divergence differed between the groups. Among the River samples, amounts of genetic divergence between samples were positively associated with geographic distance suggesting a stepping-stone pattern of gene flow. That is, as geographic distance increases amounts of gene flow decreases resulting in higher divergence. In contrast, no such association was observed among the fragmented samples suggesting amounts of gene flow are independent of geographic distance which is expected for highly isolated populations.

Fish passage at the diversion dams is a required recovery action for the RGSM (USFWS 2010) because fragmentation of the habitat is considered to be a factor in the species' decline. This fragmentation is perceived to have resulted in critically low levels of N_e. This reduction in N_e is further perceived to have resulted in a loss of genetic diversity from the species. Thus, it is believed "Promoting the ability of Rio Grande silvery minnow to independently disperse between sub-reaches can increase reproduction among sub-populations, thereby increasing effective population size and maximizing the retention of genetic diversity." (USFWS 2010 page 80). Here we review the genetics literature of RGSM to examine whether the data support the premise the dams have resulted in fragmentation, low N_e, and a loss of genetic diversity in RGSM.

5.5.2 Taxonomic Status

To our knowledge, the first genetic investigation of RGSM was that of Cook et al. (1992). At this time, there was some debate over whether or not the RGSM was synonymous with one or more other species of *Hybognathus*. Thus, the purpose of this investigation was to examine the taxonomic status of RGSM. Allozyme data clearly indicated the RGSM to be highly divergent from other *Hybognathus* species and other cyprinid genera confirming its taxonomic distinction.

5.5.3 Genetic Differences among Reaches and Years

Annual genetic monitoring of RGSM using mitochondrial DNA (mtDNA) and nuclear DNA microsatellite loci began in 1999 and has continued to the present (Osborne and Turner 2010). The sample obtained by Cook et al. (1992) collected in 1987 was also available for analysis. Results indicated that there were no significant microsatellite allele frequency or mtDNA haplotype frequency differences among RGSM collected from the three different reaches of the middle Rio Grande defined by the diversion dams in any year. There were, however, some slight genetic differences detected between some annual collections. These differences mainly involved a comparison of the 2002 to the other samples using either microsatellite or mtDNA data. These data, therefore, suggest that from 1987-2010 that downstream gene flow has been of sufficient magnitude such that the RGSM in the middle Rio Grande constitute a single population and that the genetic characteristics of this population have fluctuated only slightly over the time of the study. Thus, in terms of allele and haplotype frequencies there are no data suggesting that the diversion dams have genetically fragmented the RGSM into divergent subpopulations. Furthermore, the relative temporal stability of the allele and haplotype frequencies suggests that N_e over the time of the study has not been exceptionally low.

5.5.4 Genetic Variation within the Middle Rio Grande Population

Levels of genetic variation in RGSM have been monitored by estimating H_e and allelic richness (A_R) at microsatellite loci and haplotype diversity (h) and haplotype richness (A_{RH}) from the mtDNA data for each sample. A_R, however, was not estimated for the 1987 and 1999 samples because of small sample sizes (Osborne and Turner 2010). There was a significant positive correlation between H_e (r^2=0.685, P<0.01), A_R (r^2=0.742, P<0.01), and A_{RH} (r^2=0.559, P<0.01) and time, but no significant correlation existed between h and time (r^2=0.058, P>0.05) Thus, overall it appears that levels of genetic variation in the RGSM have increased from 1987 to the present. These data, therefore, do not support the premise that the dams have resulted in a loss of genetic diversity from the population, at least over the time of the study. They also further suggest that N_e has not been critically low.

RGSM appear to constitute a single isolated population. In such situations, genetic diversity is generally expected to increase at an exceptionally slow rate via mutation. Thus, we find it curious that levels of genetic variation in the population have detectably increased over the period of study.

Captive propagation and supplementation of RGSMs in the middle Rio Grande began in 2000 (Remshardt 2008, Remshardt et al. 2009). This program has primarily relied on the capture of eggs from the middle Rio Grande in the San Acacia reach. These eggs are hatched in captivity and most of the resulting fish are stocked back into the river in the fall of the capture year or the spring of the following year. Some of the fish, however, are retained as captive broodstock and the progeny of these fish are also stocked. Until fall of 2005, stocking was confined to the Angostura reach (Remshardt 2007, 2010). Between fall of 2005 and 2007, stocking occurred in all reaches (Remshardt 2007, 2010). Since 2008 because of increasing population size little stocking has occurred (Remshardt 2010).

At this time, it is uncertain what influence stocking has had on the genetic characteristics of RGSM. It is certainly possible that stocking may be at least partially, if not solely, responsible for the observed increased amounts of genetic diversity. We used the data presented by Osborne and Turner (2010) in an attempt to assess the likelihood of this possibility. Based on microsatellite data, there was no significant difference (Wilcoxon two-sample test, $P>0.50$) in mean H_e between 13 samples from the river (mean=0.818) and seven samples produced from the capture of eggs (0.818), between the river samples and 38 lots produced by captive breeding (0.810, $P>0.10$), and between the lots produced by the capture of eggs and captive breeding ($P>0.10$). Although there was no significant difference ($P>0.20$) in mean A_R between the river (13.866) and egg capture samples (13.374), the mean A_R among the captive bred lots (12.227) was significantly lower than that observed in the river ($P<0.001$) and egg capture samples ($P<0.01$). Fairly similar results were obtained from the mtDNA data. There was no significant difference in mean *h* between the river (0.581) and egg samples (0.619, $P>0.50$), the river and captive bred samples (0.607, $P>0.20$), and the egg and captive bred samples ($P>0.90$). Mean A_{RH} did not significantly between the river (7.085) and egg capture samples (6.267, $P>0.10$) or between the egg capture and captive bred samples (5.712, $P>0.10$). In contrast, mean A_{RH} was significantly lower ($P<0.01$) in the captive bred than river samples.

The above results indicate that levels of genetic variation are generally similar between the river fish and stocking sources except that individual lots produced from captive breeding tend to have lower A_R and A_{RH} probably because each lot is produced from a relatively small number of parents. When the captive bred lots are considered as a whole, however, they appear to have higher A_R than generally observed in the river fish (Osborne et al. 2006). Since stocking uses individuals from many captive bred lots, the above results are certainly compatible with the possibility that the stocking of RGSMs has helped to at least maintain and possibly has enhanced levels of genetic diversity in the river population. Whether or not this is the case, however, remains uncertain. It is equally unknown, however, whether without stocking that levels of genetic variation would have been maintained between 1987 and 2010.

5.5.5 Effective Population Size

Using microsatellite data, N_e has been estimated in the river population using two procedures (Peel et al. 2004, NE; Wang 2001 MLNE) based on the temporal variance in allele frequencies between samples for the 1987 and 1999-2010 samples (Osborne and Turner 2010). These procedures estimate the average N_e per generation over the number of generations separating two samples. For RGSM, the generation time is about one year (USFWS 2010) so samples from two consecutive years estimate the N_e for that generation. Thus, we plotted the N_e estimates obtained by comparing samples from consecutive years using the 1999-2010 samples against time to investigate temporal variation in RGSM N_e. The 1987 to 1999 comparison was excluded from this analysis since it is the estimate of the average N_e over 12 generations and, therefore, is not strictly comparable to the per generation variance observed from 1999-2010.

Interestingly, there was no correlation ($r^2=0.024$, $P>0.05$) between the two estimates of N_e, but in general MLNE generally gave a higher estimate of N_e than NE. This lack of correlation is somewhat disturbing as it suggests that one or both of the estimators may not be very accurate. Interpretation of the following

results, therefore, must be made cautiously as there is substantial uncertainty about the accuracy of the N_e estimates.

Using only the 1999-2010 data and consecutive pairs of samples, there was no correlation between the NE (r^2=0.000, P>0.05) and MLNE (r^2=0.059, P>0.05) estimates and time. Thus, from 1999 through 2010 the N_e of the RGSM appears to have been relatively stable about a harmonic mean value of 220 (NE) or 415 (MLNE) depending on the estimator used. In contrast, the lack of correlation may simply reflect the potential inaccuracy of the N_e estimates obscuring any potential association.

Osborne et al. (2010) estimated N_e in RGSM using the procedure of Waples and Do (2008, LDNe) based on linkage disequilibrium. We could not examine whether or not there was a correlation between LDNe and time because the data were only presented graphically. The LDNe estimates, however, were generally one to two orders of magnitude higher than those obtained from the temporal estimators. The large disparity between the temporal and linkage disequilibrium estimates suggests that there is probably either a downward bias in the temporal estimates, an upward bias in the disequilibrium estimates, or both. Thus, it is not possible to determine which, if any, of the estimates is the most reliable. Regardless of the estimator used, however, the estimates are considerably larger than the critically low value of 100 reported in the recovery plan and do not support this contention (USFWS 2010, pages 26 and 37).

Using microsatellite data from the 1999-2001 river samples, Alo and Turner (2005) estimated the ratio of N_e to census size (N_c) for RGSM to be about 0.001. They suggested that this low ratio was due to high "…variance in productivity among spawning localities and variance in reproductive success among individuals…" (Alo and Turner 2005, page 1144). They further speculate that the high variance in reproductive success "…is potentially strongly enhanced by river fragmentation…" (Alo and Turner 2005, page 1144). Although other factors such as altered hydrograph, channelization, entrainment in diversion channels, river drying and intermittency, and competition or predation from non-native species have not, or sparsely, been investigated as other potential causes for the apparently high reproductive variance among RGSMs independent of fragmentation, the speculation it is driven by fragmentation seems to have been accepted (e.g. Osborne et al. 2005; Turner et al. 2006; USFWS 2010). Furthermore, there is great uncertainty about the accuracy of the N_e and N_c estimates and the reliability of the ratio estimate, therefore, is undoubtedly questionable. Finally, if estimates of N_e based on disequilibrium are used the ratio would increase one to two orders of magnitude.

5.5.6 Comparisons with other Rio Grande and Pecos River Species

Unfortunately, RGSM do not exist anywhere without the presence of the diversion dams. This complicates the ability of elucidating the effects of the dams fragmenting the habitat on reproductive success of the fish independent of other possible causes. Thus, attempts to determine the effects of habitat fragmentation of the dams per se on RGSM reproductive success have been conducted using comparisons to other riverine cyprinids (e.g. Turner et al. 2006; Osborne et al. 2010). The results of such comparisons, however, must be interpreted cautiously as no two species or environments are identical.

Turner et al. (2006) observed that in the middle Rio Grande the flathead chub, *Platygobio gracilis*, which produces sessile eggs, had higher N_e and N_e/N_c estimates than RGSM. This suggests that, everything else being equal and not considering the uncertainty associated with the accuracy of the estimates, the pelagic spawning of RGSM may lead to higher variance in reproductive success than sessile spawning. The results, however, shed no light on the potential for this phenomenon to be exacerbated by the diversion dams.

Turner et al. (2006) also observed that the introduced plains minnow, *H. placitus*, another pelagic spawning species, in the Pecos River had substantially higher N_e and N_e/N_c estimates than RGSM.

Osborne et al. (2010) observed a positive association between estimates of N_e and density in Pecos bluntnose shiner, *Notropis simus pecosensis*, another pelagic spawning cyprinid, collected from the upper most stretch of the Pecos River from which the plains minnow was collected. Depending on which estimate of N_e was used, they observed either a negative (temporal estimates) or positive (linkage disequilibrium estimate) association between N_e and density in RGSM. The stretch of the Pecos River they sampled lacks diversion dams and is not supplemented with either the plains minnow or Pecos bluntnose shiner. It was suggested (Turner et al. 2006) that it was the lack of the dams, or their presence in the middle Rio Grande, that generally accounts for the differences observed between the two *Hybognathus* species for N_e and N_e/N_c and a combination of the dams and supplementation (Osborne et al. 2010) for the different associations between N_e and density observed between the RGSM and Pecos bluntnose shiner. It is acknowledged, however, that other differences such as larger and more stable nursery habitat in the Pecos River, differences in the degree of habitat alteration, differences in habitat quality, and differences in fisheries management are also likely involved (Turner et al. 2006; Osborne et al. 2010). Thus, overall because of the difficulties in comparing species and different habitats and the questionable reliability of the N_e estimates it appears that the results of these studies have provided little, if any, conclusive evidence that the presence of the diversion dams per se in the middle Rio Grande is a significant factor influencing RGSM N_e.

5.5.7 Conclusions

1) Despite the presence of three diversion dams, RGSM in the middle Rio Grande appear to constitute a single panmictic population. Thus, it appears that although the dams fragment the species' habitat into three reaches they have not genetically fragmented the species into genetically divergent subpopulations.
2) Levels of genetic variation appear to have increased in the RGSM population from 1987-2010. To what extent this increase may be due to the stocking of captively reared or bred fish is unknown. It is also unknown, however, whether, without stocking, levels of genetic variation would have been maintained over this period of time. Regardless, there is no evidence for a decrease in levels of genetic variation in the population.
3) Depending on the temporal estimator used, N_e of the RGSM population appears to have been in the range of a couple hundred to four hundred over the time period of 1999-2010. In contrast, N_e appears to have been in the thousands over this span of time when it is estimated based on linkage disequilibrium. The large disparity between the temporal estimates and between them and the linkage disequilibrium estimates suggests that there is probably either a downward bias in the temporal estimates, an upward bias in the disequilibrium estimates, or both and brings into question the accuracy of the estimates. With these caveats in mind, however, none of the estimates suggest a critically low N_e for the RGSM**.**
4) Based on temporal estimates of N_e, the ratio N_e/N_c for RGSM was estimated to be about 0.001. If LDNe values are used, however, then the ratio generally increases one to two orders of magnitude. The low temporal based ratio was suggested to be at least partially attributable to high variance in reproductive success among individuals. It was also speculated that this variance in reproductive success is enhanced by the diversion dams. There is no conclusive support to the latter speculation. Furthermore, the accuracy of the N_e and N_c estimates, and thus their ratio, remains unknown.
5) Interpretation of comparisons using different species and environments are fraught with problems as no two species or environments are identical. Not surprisingly, therefore, such comparisons have not provided clear evidence that the diversion dams per se have increased variance in reproductive success of RGSM and reduced N_e.

6.0 WHAT ARE DATA/KNOWLEDGE GAPS

The factors discussed in this section are those that could substantially affect the effectiveness of the recovery plan for RGSM. The uncertainty surrounding these factors was evaluated by the Panel and leads to conclusions about prioritization of passage projects.

1. Non-native fishes: the provision of fish passage at SADD may aid not only RGSM but also other species of fish that may compete with or consume RGSM.
2. Canal/ditch entrainment: entrainment of fish in ditches, the floodplain, and canals may preclude recovery of RGSM in spite of efforts to provide upstream passage.
3. Larval drift: Is this the primary mechanism of population mixing among the reaches of the Rio Grande? How significant a mortality factor does drift constitute?
4. Natural degree of positive rheotropic response: if the RGSM does not have a tendency to migrate upstream, the passage structure may not be effective. The impact of dispersal patterns both within and potentially among dammed reaches (with passage) needs to be compared.
5. What is the controlling constraint: There are many negative pressures on RGSM numbers. Providing upstream fish passage may not be the controlling constraint and, therefore, may not be an effective aspect of the recovery plan even if passage is successful.
6. Without a clear step-wise, adaptive, recovery plan it is difficult to feel confident that fish passage at SADD would benefit the RGSM. A conceptual model (or "road map") for recovery would be composed of incremental steps with explicit feedback mechanisms (i.e. monitoring plans and an adaptive management framework) that could be trusted as a reliable process by which activities could be fine-tuned and success documented.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The Panel feels there are three aspects to the phrase "sound science": design, analysis, and interpretation. In terms of design, the Panel considers the science conducted within the auspices of the RGSM recovery plan has generally been sound. Monitoring and studies conducted by University of New Mexico, USFWS, and others, appear to the Panel to be thorough and credible. With the exception of the 1987 genetic sample, fish were collected throughout the species' range in the middle Rio Grande minimizing any potential for chance spatial differences among locations to significantly influence the data.

The Panel also feels that the analysis of scientific data gather related to RGSM has been sound. It must be kept in mind, however, that there is often considerable uncertainty about how the results of many individual studies directly relate to RGSM recovery. There appears to have been no synthesis of the results from many different studies into a single comprehensive documentation of what factors appear to be having major detrimental effects on RGSM. For example, the middle Rio Grande appears to contain a single random mating population of RGSM, probably due to egg and larval drift. Levels of genetic variation within the population appear to have been increasing over time. To what extent this may be a consequence of the stocking program is unknown but it is also uncertain whether this trend would be present without stocking. There is much uncertainty about the reliability of the N_e estimates but, taken at face value they suggest it is not critically low. Finally, if the N_e to N_c ratio is about 0.001 as reported even successful passage and survival of 20,000 RGSM would increase N_e by only about 20. Thus, even if passage is successful there is a good possibility it will have little or no impact on the genetic characteristics of the population.

There is also much uncertainty about how effective passage will be. There seems to be little understanding of what factors would effectively attract the fish to the passage way, subsequently what

factors would lead to passage, and whether or not passed fish would survive given all the other significant biologic, hydrologic, and geomorphic changes that have occurred in the river. The influence of successful passage on the demographics of RGSM, therefore, is presently uncertain at best. Probably the only way to conclusively determine to what degree passage will affect the abundance of RGSM is to build a ladder or, more advisably, a prototype facility, and then use true adaptive management to adjust the recovery plan. Overall, therefore, the likelihood of significant use of a fish passage structure at SADD and the resultant benefit to the abundance and genetic diversity of RGSM is uncertain at best and may be low. The Panel recommends more research into the relationship between genetic diversity and dam fragmentation as well as the influence of habitat mitigation within reaches on movement, growth, survival, and reproductive success of RGSM before fish passage at SADD is attempted.

The uncertainty (lack of sound science) surrounding the directive to provide fish passage at SADD is due primarily to the lack of an understandable framework within which the project may be viewed. The suite of activities that are part of the recovery plan for RGSM do not appear to be a part of a clear roadmap with feedback mechanisms along the way to help ensure that funding is being used for the greatest possible benefit.

For example, a smaller, field-based, study that would include a prototype of the ladder inlet would provide valuable, conclusive data about the tendencies of RGSM to locate and enter a fish ladder as is being proposed. This would remove some of the major uncertainties raised in this report with respect to the utility of fish using the ladder. A step-by-step road map with adaptive management mechanisms is a critical step to moving beyond politics and ensuring rapid, effective steps can be taken to recover the RGSM. Also, field-oriented research that determines the mechanisms influencing dispersal of RGSM in the Rio Grande is needed to determine under what conditions and to what extent populations will use fish passage structures.

Besides conducting additional research, the panel feels RGSM recovery could greatly be enhanced by synthesizing the results of numerous previous studies into a comprehensive document to aid recovery efforts. There are a lot of good data available but because there is limited, or no, connection among the various studies there is considerable uncertainty about the need for, and potential efficacy of, any proposed recovery action. By synthesizing the data much of this uncertainty may be reduced, or disappear altogether.

It should be noted that it is not a conclusion of this report that fish passage at SADD will categorically not result in any benefit to RGSM. Rather, it is the Panel's conclusion that the inevitable uncertainties surrounding species recovery have not been resolved to the extent that this project (fish passage at SADD) can be undertaken with confidence that it will provide the desired benefit to RGSM.

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Platania, S. P. and R. K. Dudley. 2008. Spatial spawning periodicity of Rio Grande silvery minnow during 2008. Report to U. S. Bureau of Reclamation, Albuquerque, New Mexico. 41p.

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USFWS (United States Fish and Wildlife Service). 2010. Rio Grande silvery minnow recovery plan. U.S. Fish and Wildlife Service. Albuquerque, NM.

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Waples, R. S. and C. Do. 2008. LDNE: a program for estimating effective population size from data on linkage disequilibrium. Molecular Ecology Resources 8:753-756.

Wendorf, F. 1954. A reconstruction of northern Rio Grande prehistory. American Anthropoligist 56:200-221.

Widmer, A. E., J. J. Fluder, J. W. Kehmeier, C. N. Medley, and R. A. Valdez. 2010. Drift and retention of pelagic spawning minnow eggs in a regulated river. River Research and Applications.

Woodson, R. C. 1961. Stabilization of the middle Rio Grande in New Mexico, American Society of Civil Engineers, Journal of the Waterways and Harbors Division 87:1-15.

Yu, S. L. and E. J. Peters. 1997. Use of Froude Number to determine habitat selection by fish. Rivers, 6(1):10-18.

APPENDIX A

Panelist Curricula Vitae

EDWARD J. PETERS, Ph.D.

6270 N County Road M, Loretta, WI, 54896 (715) 266-2550
epeters@unlnotes.unl.edu Edward.J.Peters@gmail.com

PROFESSOR-EMERITUS
School of Natural Resource Sciences
University of Nebraska-Lincoln
Lincoln, NE

SENIOR CONSULTANT
Parham & Associates Environmental Consulting, LLC
1014 Blue Jay Way, Suite 100
Gallatin, TN 37066

PROFESSIONAL PROFILE

Dr. Peters is Professor Emeritus at the University of Nebraska and senior natural resource consultant with Parham & Associates Environmental Consulting, LLC. He is an expert in fisheries and natural resources management with over 33 years of experience as an educator and researcher. In his collaborations with federal, state, local and non-governmental organizations, Dr. Peters assesses how river flows influence game fish, non-game fish, and endangered fish populations. He also delivers numerous technical and public presentations and has authored many publications on rivers and streams in central and western U.S.

EDUCATION

Ph.D. 1974 BRIGHAM YOUNG UNIVERSITY
MAJOR: ZOOLOGY MINOR: GEOLOGY
DISSERTATION TITLE: The effects of highway construction on the fish populations in the Weber River near Henefer, Summit County, Utah.

M.S. 1970 BRIGHAM YOUNG UNIVERSITY
MAJOR: ZOOLOGY MINOR: BOTANY
THESIS TITLE: Changes with growth in selected body proportions of the woundfin minnow (*Plagopterus argentissimus* Cope: Cyprinidae).

B.S. 1967 WISCONSIN STATE UNIVERSITY-STEVENS POINT
MAJORS: CONSERVATION and BIOLOGY

TEACHING EXPERIENCE

UNIVERSITY OF WISCONSIN-STEVENS POINT: COLLEGE OF NATURAL RESOURCES
(summer 2010)

Water 380: Summer Camp program for UWSP Natural Resources students

UNIVERSITY OF NEBRASKA - LINCOLN: SCHOOL OF NATURAL RESOURCE SCIENCES
(1997 to 2005)

FISHERIES SCIENCE
ICHTHYOLOGY
FISHERIES BIOLOGY
FOOD, AGRICULTURE, AND NATURAL RESOURCE SYSTEMS (recitation)

UNIVERSITY OF NEBRASKA-LINCOLN: DEPARTMENT OF FORESTRY, FISHERIES AND WILDLIFE
(1975 to 1997)

FISHERIES SCIENCE: Developed and taught since 1976. This was the first Fisheries course taught in the College of Agriculture and it emphasized the estimation of biological statistics of fish populations and their application to fish management.

INTRODUCTION TO NATURAL RESOURCES: Developed and taught since 1976. This was the first Natural Resources course taught at UNL and was currently the basic course in the Natural Resources Major.

FISHERIES BIOLOGY: Developed and taught since 1978. Emphasized the study of factors which influence fish productivity in freshwater.

ICHTHYOLOGY: Taught since 1980. This course emphasized the anatomy, physiology, ecology, evolution and systematics of fishes.

INTEGRATED RESOURCES MANAGEMENT: Developed and taught 1990 to 1993. This capstone course for Natural Resources Majors emphasized the interrelated nature of management decisions.

MOUNT MERCY COLLEGE: DEPARTMENT OF BIOLOGY
(1972 to 1975)

INVERTEBRATE ZOOLOGY
VERTEBRATE ZOOLOGY
NONVASCULAR PLANTS
VASCULAR PLANTS
ECOLOGY
EVOLUTION
DESERT ECOLOGY (field trip course)

BRIGHAM YOUNG UNIVERSITY: DEPARTMENT OF ZOOLOGY
(1971 to 1972)

GENERAL ZOOLOGY

RESEARCH EXPERIENCE

2008

Initiated work on a literature review on pallid sturgeon funded by the Platte River Recovery Implementation Program

2006
Completed the Final Report on the Nebraska stream fisheries inventory project.

2005
Completed field work and submitted the Final Report on the jointly funded Platte River project.
Completed field work on the Nebraska stream fisheries inventory project.

2004
Continued field work on the jointly funded Platte River project.
Continued field work on the Nebraska stream fisheries inventory project.

2003
Continued field work on the jointly funded Platte River project.
Initiated field work on the Nebraska stream fisheries inventory project funded by the Nebraska Game and Parks Commission.
Graduated three M.S. students.

2002
Continued field work on the jointly funded Platte River project.
Completed field work and submitted the Final Report on the Branched Oak lake project.

2001
Continued field work on the jointly funded Platte River project.
Completed field work and submitted the Final Report on the Lake Ogallala project.
Graduated three M.S. students.

2000
Continued work on the Lake Ogallala project.
Continued work on the Branched Oak Lake project.
Completed work on U. S. Fish and Wildlife Service grants on Platte River.
Initiated work five year project on the lower Platte River funded jointly by a consortium of Natural Resources
Districts, the Nebraska Game and Parks Commission and the US Fish and Wildlife Service.

1999
Continued work on the Platte River and Lake Ogallala projects.
Initiated work on the Branched Oak Lake project funded by the Nebraska Game and Parks Commission.

1998
Initiated work on the Platte River project which included larval fish sampling and pallid sturgeon telemetry and habitat use funded by the US Fish and Wildlife Service.
Continued work on the Lake Ogallala project.
Graduated two M..S students.

1997
Continued work on the Lake Ogallala project.
Participated in the Lake Ogallala chemical renovation.
Graduated one M.S. Student.

1996
Completed the final report on the initial lake Ogallala project.
Completed Final Report on the EPA R-EMAP project.
Initiated work on the revised Lake Ogallala Project funded by the Nebraska Game and Parks Commission.
Completed field work on the Sturgeon Project.
Graduated three M.S. students and two PhD students.

1995
Completed work and submitted the Final Report on the thermal tolerance study.
Continued work on the Lake Ogallala project

Continued work EPA R-EMAP project.
Initiated work on the biology of sturgeon in the Platte River funded by the US Fish and wildlife Service.
Graduated four M.S. students.

1994

Completed the final report for the Platte River project.
Continued work on the thermal tolerance study.
Initiated work on the Lake Ogallala project funded by the Nebraska Game and Parks Commission
Initiated work on a stream survey project funded by the US EPA through R-EMAP.

1993

Completed research on development of suitability criteria for Platte River fishes and the creel survey of the lower Platte River.
Initiated work on thermal tolerances of selected Platte River fishes supported by the US Fish and Wildlife Service.

1992

Initiated a creel survey study on the lower Platte River and began comparison of habitat suitability criteria between the lower Platte and the central Platte fishes.
Graduated one M.S. student.

1991

Initiated study on Biodiversity of the central Platte River (fishes) funded by the US Fish and Wildlife Service.
Finalized contracts with four Natural Resources Districts, the Platte River Whooping Crane Trust and the Nebraska Game and Parks Commission under the title "Biological and economic analyses of the fish communities in the Platte River".
Completed work and prepared the final report for the Studies of Channel catfish in the lower Platte River project.

1990

Continued work on the Platte River project.

1989

Continued work on the Platte River project.
Graduated one M.S. student.

1988

Completed work and prepared the final report for on the Platte River project.
Initiated study on the Platte River funded by the U.S. Army Corps of Engineers and the Nebraska Game and Parks Commission.
Completed faculty development leave.
Graduated one M.S. student.

1987

Continued work on the Platte River project.
Began faculty development leave.
Graduated two M.S. students.

1986

Developed contracts with the Lower Platte North Natural Resources District and the Nebraska Game and Parks Commission for study of instream flow requirements of fish and aquatic invertebrates in the lower Platte River. Completed courses on the use and application of Instream Flow Incremental Methodology.
Graduated one M.S. student.

1985
Began negotiations for the study of instream flow requirements of fish and aquatic invertebrates in the Platte River. Research appointment adjusted to 30%.

1984
Completed introductory course in the Instream Flow Incremental Methodology.
Graduated four M.S. students.

1983
Completed work on the Maple Creek Model Implementation Plan study.
Continued fish population surveys in the Little Blue River drainage.
Graduated one M.S. student.

1982
Continued work on Maple Creek.
Continued fish population surveys in the Little Blue River drainage.

1981
Continued work on Maple Creek.
Continued fish population surveys in the Little Blue River drainage.

1980
Completed study of white perch in Buckley Creek Reservoir and completed evaluation of liming project.
Continued work on Maple Creek.
Conducted fish population survey of the Big Blue River Basin for the U.S. EPA.

1979
Conducted application of lime to Buckley Creek Reservoir to reduce turbidity.
Initiated study of channel catfish movement and growth in the Little Blue River.
Continued the Maple Creek project.

1978
Completed work on the Nine Mile Creek irrigation return flow study.
Continued work on the white perch project.
Conducted research on the impacts of the Guernsey silt run on fish and macroinvertebrates in the North Platte River.
Initiated an evaluation of watershed erosion and sediment control on the fishes of Maple Creek.
Obtained research appointment of 21 %.
Graduate two M.S. students.

1977
Began study of the impact of an introduced fish species (white perch) on the fisheries of Buckley Creek reservoir.
Started a study of the impacts of irrigation return flow on the invertebrates and trout spawning habitat of Nine Mile Creek.
Awarded a summer faculty research fellowship to develop an Experiment Station project.

1976
Initiated research program at UNL (no official research appointment).
Received two University Research Council grants to support graduate thesis research projects on the study of fish distribution in the Salt Creek drainage and a study of the production rates of aquatic insects in a turbid reservoir.

1974 to 1975
Directed undergraduate independent study research studies in biology at Mount Mercy College.

1967 to 1974

Graduate thesis and dissertation research under the direction of Dr. David White.
Assisted with a variety of aquatic and terrestrial research projects.

1966

Wild rivers fish, macroinvertebrate and water chemistry survey of northeast Wisconsin under the direction of Dr. George Becker.
Conducted an undergraduate research project on the distribution of fishes in the Wisconsin River in Portage County, Wisconsin.

RELATED PROFESSIONAL EXPERIENCE

American Fisheries Society
Member since 1968, active in state chapter activities, regular participant in North Central Division meetings, elected to and served on state, division and national committees.

American Society of Ichthyologists and Herpetologists
Member 1970 - 2008.

North American Benthological Society
Member since 1970 - 2006, irregular participant in national meetings.

Nebraska Academy of Sciences
Member since 1975, regular participant and contributor to annual meetings, elected biological and medical sciences section coordinator, session chairman on several occasions.

Wisconsin Academy of Sciences, Arts and Letters
Member since 1965 (life member 2000).

Society of Sigma Xi
Elected to membership 1970, elected to Nebraska chapter offices: membership coordinator 1984-1986, President 1989-1990.

Center for Great Plains Studies
Elected a Fellow 1982.

State and University committees including; the Aquaculture Task Force, the Prairie Bend Technical Advisory Group, the 404 Task Force, the UN Water Policy Steering Committee, UNL Faculty Senate, College of Agriculture Instructional Improvement Committee, the Natural Resources Curriculum Committee, the Agricultural Research Division Advisory Council and the Curriculum Revitalization Task Force.

Pallid sturgeon peer review of the lower Yellowstone River Intake Diversion Report, U S Bureau of Reclamation contract to PBS&J (2009-2010)

Review of US Fish and Wildlife Service proposal to designate shovelnose sturgeon as threatened due to similarity of appearance to pallid sturgeon (2009)

FUNDED RESEARCH PROJECTS (chronological listing)

1976
A distributional study of the fishes in the Salt Creek drainage, UNL Research Council, $700, (1976-1978)

Production rates of aquatic insects in a turbid reservoir, UNL Research Council, $813, (1976-1978)

1977
Effects of irrigation return flow on Nine-Mile Creek, Nebraska Natural Resources Commission, $14,299, (1977-1978)

Impact of an introduced species on the fisheries resources of Nebraska, Nebraska Water Resources Center, $20,000, (1977-1980)

Summer faculty research fellowship, Nebraska Agricultural Experiment Station, $1,500 (1977)

1978
Effects of a silt run on the biota of the North Platte River near Guernsey, Wyoming, Nebraska Water Resources Center, $8,500 (1978)

Impact of watershed sediment control on the biota of Maple Creek, Nebraska Department of Environmental Control, $75,000 (1978-1983)

1979
Effects of applications of lime on the turbidity in Buckley Creek Reservoir, Nebraska Water Center and the Little Blue Natural Resources District, $6,600 (1979-1984)

1980
A fish population survey of the Big Blue River basin, U.S. Environmental Protection Agency, $873 (1980)

1986
Instream flow requirements of fish and aquatic invertebrates in the lower Platte River, Nebraska Game and Parks Commission, $190,400 (1986-1988)

Instream flow requirements of fish and aquatic invertebrates in the lower Platte River, Lower Platte North Natural Resources District, $40,000 (1986-1988)

1988
Platte River Fisheries Study, U.S. Army Corps of Engineers, $40,000 (1988-1990)

Studies of Channel Catfish in the lower Platte River, Nebraska Game and Parks Commission, $196,140 (1988-1991)

1991
Distribution and abundance of fishes in the central Platte River, U.S. Fish and Wildlife Service, $22,300 (1991-1992)

1992
Biological and economic analyses of fish communities in the Platte River, (1992-1993)

Nebraska Game and Parks Commission, $176,264
Central Platte Natural Resources District, $10,000
Lower Platte North Natural Resources District, $10,000

Lower Platte South Natural Resources District, $10,000
Papio/Missouri Natural Resources District, $10,000

Development of an aquatic mesocosm facility, U.S. Fish and Wildlife Service, $50,000 (1992-1993)

Influences of vegetation on wildlife and fisheries populations in the central Platte, River, U.S. Fish and Wildlife Service, $80,000 (1992-1994)

1993
Critical thermal maxima of selected fishes in the Platte River, U.S. Fish and Wildlife Service, $80,000 (1993-1995)

1994
Population structure and food habit analyses of alewife, rainbow trout and other selected fishes in Lake Ogallala, Nebraska Game and Parks commission, $133,500 (1994-1996)

Measuring the health of Nebraska's fisheries, Nebraska Department of Environmental Quality, $156,235 (1994-1995)

1995
Studies of sturgeon in the Platte River, U.S. Fish and Wildlife Service, $54,000 (1995-1997)

1996
Alewife and trout studies in Lake Ogallala, Nebraska Game and Parks Commission, $170,010 (1996-1999)

1998
Pallid sturgeon in the lower Platte River, U. S. Fish and Wildlife Service, $96,720 (1998 - 2001)
Endangered fishes of the lower Platte River, U.S. Fish and Wildlife Service, $76,560 (1997 - 2001)

1999
Branched Oak Reservoir evaluation project, Nebraska Game and Parks Commission, $193,413 (1999 - 2001)

2000
Ecology and management of sturgeons in the lower Platte River, Nebraska Game and Parks Commission, $701,000 (2000 - 2005)
Ecology and management of pallid sturgeon and sturgeon chub in the lower Platte River, Pallid sturgeon / sturgeon chub task force, $550,000 (2000 - 2005)

2003
Nebraska statewide stream fisheries inventory, Nebraska Game and Parks Commission, $459,575 (2003-2006)

2006
Publication of the Ecology and management of sturgeon in the lower Platte River, Nebraska, Nebraska Game and Parks Commission, $40,000 (2006 – 2008)

2008
A review of literature which pertains to the use of the lower Platte River by pallid sturgeon, Platte River Recovery Implementation Program, $32,000 (2008 – 2009)

GRADUATE STUDENT THESES (all at the University of Nebraska – Lincoln)

1978
Lund, J.C.
Production rates of benthic insects in a turbid reservoir. M.S.
Maret, T.R.
The fishes of the Salt Creek basin, Nebraska. M.S.
1983
Winter, R.L.
A test of lake chubsucker, *Erimyzon succetta*, as forage for largemouth bass, *Micropterus salmoides*, in small eastern Nebraska impoundments. M.S.
1984
Chapin, C.A.
Effects of agricultural lime on the water quality and benthic fauna in a turbid Nebraska reservoir. M.S.
Klammer, J.A.
Food and feeding of rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) in two Nebraska sandhills streams. M.S.
Shadle, J.J.
A study of the crayfish (*Orconectes immunis*) in an intermittent Nebraska stream. M.S.
Walker, S.R.
Abundance and movement of channel catfish, *Ictalurus punctatus*, in the Little Blue River, Nebraska. M.S.
1986
Schleiger, S.L.
Interspecific interactions of a green sunfish (*Lepomis cyanellus*) and creek chub (*Semotilus atromaculatus*) in small stream in southeast Nebraska. M.S.
1987
Angle, L.A.
Effects of sediment addition on the drift of aquatic macroinvertebrates in Nine Mile Creek, Nebraska. M.S.
Zaroban, D.W.
A field test of habitat evaluation procedures for creek chub (*Semotilus atromaculatus*) and channel catfish (*Ictalurus punctatus*). M.S.
1988
Bunnell, D.B.
Habitat utilization and movement of adult channel catfish and flathead catfish in the Platte River, Nebraska. M.S.
1989
Callam, M.A.
Use of prepositioned electrofishing grids to assess habitat suitability for *Notropis stramineus*, *N. lutrensis* and *N. blennius* in the Platte River, Nebraska. M.S.
1992
Yu, Shyi-Liang
Logistic regression models of habitat use by three cyprinids in the Platte River, Nebraska. M.S.
1995
Chapman, R.C.
Movements of channel catfish in the Platte River, Nebraska. M.S.
Ihrie, D.B.
A test of the ecoregion classifications of Nebraska streams using discriminant analysis. M.S.
McBride, M.J.
Aquatic macroinvertebrates of the central Platte River, Nebraska. M.S.
Michl, G.T.
A test of the Index of Biotic Integrity for streams in the sandhills region of Nebraska. M.S.

1996

Fessell, B.P.
Thermal tolerances of Platte River fishes: Field and laboratory studies. M.S.

Laux, E.A.
The biology of alewife *Alosa pseudoharengus* in Lake Ogallala, Nebraska. M.S.

Messaad, I.A.
Histological responses of red shiner (*Cyprinella lutrensis*) to atrazine terbufos, and their mixture. PhD

Porath, M.T.
Influence of prey availability on walleye *Stizostedion vitreum*. M.S.

Yu, S.L.
Factors affecting habitat use by fish species in the Platte River, Nebraska. PhD

1997

Hofpar R.L.
Biology of shovelnose sturgeon in the lower Platte River, Nebraska M.S.

1998

Barrow, T. M.
Factors affecting movements of rainbow trout (*Oncorhynchus mykiss*) in Lake Ogallala, Nebraska. M.S.

2000

Pearson, T. J.
The use of benthic macroinvertebrates by rainbow trout (*Oncorhynchus mykiss*) in Lake Ogallala, Nebraska. M.S.

Reade. C. N.
Larval fish drift in the lower Platte River, Nebraska. M.S.

2001

Hodkin, C. A.
Population characteristics and food habits of the white perch (*Morone americana*) in Branched Oak Lake, Nebraska. M.S.

Huxoll, C. M.
Movement of rainbow trout and brown trout in relation to water quality and food availability in Lake Ogallala, Nebraska. M.S.

Snook, V. A.
Movements and habitat use by hatchery-reared pallid sturgeon in the lower Platte River, Nebraska. M.S.

2003

Kopf, S. M.
Habitat use by chubs of the genera *Macrhybopsis* and *Platygobio* in the lower Platte River, Nebraska. M.S.

Shuman, D. A.
The age and size distribution, condition, and diet of the shovelnose sturgeon *Scaphirhynchus platorynchus* in the lower Platte River, Nebraska. M.S.

Swigle, B. D.
Movements and habitat use by shovelnose sturgeon and pallid sturgeon in the lower Platte River, Nebraska. M.S.

PUBLICATIONS (chronological listing)

White, D.A. and E.J. Peters. 1969. A method of preserving color in aquatic vertebrates and invertebrates. Turtox News, 47:296-297.

Barton, J.R., D.A. White, P.V. Winger, and E.J. Peters. 1971. The effects of highway construction on the hydrology and hydrobiology of the Weber River near Henefer. Final report to the Utah Division of Fish and Game and the Utah Department of Highways. 86p.

Barton, J.R., E.J. Peters, D.A. White, and P.V. Winger. 1972. Bibliography on the physical alteration of the aquatic habitat (channelization) and stream improvement. Brigham Young University, Multilith Series, Provo, Utah. 30p.

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Peters, E.J. 1987. The sunfish, NEBRASKAland Magazine, 65:10-17.

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Peters, E. J. and J. E. Parham. 2006. Pallid sturgeon and sturgeon chub in the lower Platte River 2000-2004. Final report to the Pallid Sturgeon / Sturgeon Chub Task Force, Lincoln, Nebraska.

Shuman, D. A. and E. J. Peters. 2007. Evaluation of pulsed gastric lavage on the survival of captive shovelnose sturgeon. Journal of Applied Ichthyology 23(2007): 521-524.

Shuman, D. A., J. E. Parham and E. J. Peters. 2007. Stock characteristics of shovelnose sturgeon in the lower Platte River, Nebraska. Journal of Applied Ichthyology 23(2007): 484-488.

Peters, E. J. and J. E. Parham. 2008. Ecology and management of sturgeon in the lower Platte River, Nebraska. Nebraska Game and Parks Commission, Technical Report No. 18, Lincoln, Nebraska.

Rinne, J. N., R. M. Hughes, B. Calamusso, L. Nico, D. L. Galat, E. J. Peters, B. Snyder, R. A. Daniels and T. R. Maret. 2008. Changes in fish assemblages in the United States: extent, causes, and conservation. American Fisheries Society Symposium 49:1717 – 1728.

MANUSCRIPTS IN PREPARATION

Peters, E. J. , R. Hrabik, S. Schainost, R. Stasiak. 20xx. Field guide to the fishes of Nebraska. University of Nebraska, School of Natural Resources, Lincoln, Nebraska.

HONORS AND AWARDS

1979
Elected President of the Nebraska Chapter of the American Fisheries Society

1989
Elected President of the University of Nebraska Chapter of the Society of Sigma Xi

Outstanding Professor Award
by Delta Tau Delta Fraternity

1991
Elected President of the Nebraska Chapter of the American Fisheries Society

1993
University of Nebraska-Lincoln, Outstanding Teaching Award

2003
Appointed to the Committee on Endangered and Threatened Species of the Platte River
by the National Research Council of the National Academy of Science

2004
Holling Family Award for Teaching Excellence
by the University of Nebraska-Lincoln, College of Agricultural Sciences and Natural Sciences

Outstanding Club Advisor Award
by the University of Nebraska Wildlife Club

2005
Award of Excellence
by the Nebraska Chapter of the American Fisheries Society

Citation of Achievement
by the State of Nebraska, Game and Parks Commission

Lifetime Achievement Award
by the Nebraska Wildlife Federation

Name James E. Garvey

Title Professor, Zoology, College of Science
Director, Fisheries and Illinois Aquaculture Center, Graduate School

Date of Birth 11 July 1968

Address 173 Life Sciences II
Fisheries and Illinois Aquaculture Center (FIAC)
Department of Zoology
1125 Lincoln Drive
Southern Illinois University – Carbondale
jgarvey@siu.edu
http://www.science.siu.edu/zoology/garvey/index.html
http://fisheries.siu.edu
http://fishdata.siu.edu (curator)

Education

1998	Post-Doctoral Fellow, Queens University, Ontario
1997	Ph.D., Zoology, The Ohio State University, Ohio
1992	M.S., Zoology, The Ohio State University, Ohio
1990	B.A., *cum laude*, Zoology, Miami University, Ohio

Professional Experience

2010-	Professor, Department of Zoology, Southern Illinois University
2009-	Director, Fisheries and Illinois Aquaculture Center, Southern Illinois University
2008-2009	Interim Director, Fisheries and Illinois Aquaculture Center, Southern Illinois University
2005-2008	Associate Director, Fisheries and Illinois Aquaculture Center, Southern Illinois University
2005-2010	Associate Professor, Department of Zoology, Southern Illinois University
2000-2005	Assistant Professor, Department of Zoology, Southern Illinois University
1998-2000	Assistant Professor, Division of Biology, Kansas State University
1997-1998	Postdoctoral Fellow, Department of Biology, Queens University, Ontario
1997	Research Associate, Department of Zoology, The Ohio State University
1996-1997	Presidential Fellow, Graduate School, The Ohio State University
1990-1996	Graduate Research Associate, Department of Zoology, The Ohio State University
1990-1996	Graduate Teaching Associate, Department of Zoology, The Ohio State University
1988-1990	Research Technician, Department of Zoology, Miami University
1988	Student Researcher, School for Field Studies, St. John, U.S. Virgin Islands

Academic Advisers

Administrative Mentor – Dr. C.C. Kohler, former Director of FIAC
Faculty Mentor – Dr. R.J. Sheehan, River and Physiological Ecology
Postdoctoral - Dr. W.C. Leggett, Fish Ecology
M.S. and Ph.D. - Dr. R.A. Stein, Aquatic Ecology
B.A. - Dr. R.W. Winner, Aquatic Toxicology

Fields of Research Competence

Aquatic ecology, fish ecology, basic and applied fish biology, limnology, food web dynamics, life history modeling. My current research follows three basic themes:

1. Understanding how bioenergetics and various life history characteristics of fishes and other ectotherms vary along environmental gradients to affect population dynamics and community interactions in lakes and rivers.

   Key citations:

   Garvey, J.E. et al. 2003. Energetic adaptations along a broad latitudinal gradient: implications for widely distributed communities. BioScience 53(2):141-150.

   Garvey, J.E. et al. 2009. Searching for threshold shifts in spawner recruit relationships. Canadian Journal of Fisheries and Aquatic Sciences 66:312-320.

2. Determining the relative impact of abiotic and biotic characteristics of aquatic systems on the movement and spatial distribution of fishes through effects on physiology and biotic interactions.

   Key citations:

   Garvey, J.E. et al. 2004. Interactions among allometric scaling, predation and ration affect size-dependent growth and mortality of fish during winter. Ecology 85(10):2860-2871.

   Garvey, J.E. et al. 2007. A hierarchical model for oxygen dynamics in streams. Canadian Journal of Fisheries and Aquatic Sciences 64:1816-1827.

3. Exploring the impact of spatial scale on species interactions, with particular relevance to the invasion potential of exotic species.

   Key citations:

   DeGrandchamp, K.L., **J.E. Garvey**, and L.A. Csoboth. 2007. Linking reproduction of adult Asian carps to their larvae in a large river. Transactions of the American Fisheries Society 136:1327-1334.

   Lohmeyer, A.M., and **J.E. Garvey**. 2009. Placing the North American invasion of Asian carp in a spatially explicit context. Biological Invasions 11:905-916.

Administrative Duties at Fisheries and Illinois Aquaculture Center (FIAC)

Plan and implement actions that fulfill the research and graduate training mission of the FIAC – an interdisciplinary research laboratory and training facility with considerable laboratory and office infrastructure and over fifty personnel, including faculty members, graduate assistants, post-doctoral associates, researchers, administrative assistants, and undergraduate technicians.

Courses at Southern Illinois University

Foraging Ecology, Zoology 485 - (3 hours, Spring 2010)
Conservation Biology, Zoology 410 – (3 hours, Fall 2009)
Limnology, Zoology 415 – (3 hours, Fall 2007, 2008; web site: http://fisheries.siuc.edu/water/)
Aquatic Ecosystem Management, Zoology 585C – (3 hours, Summer 2007)
Principles of Ecology, Biology 307- (3 hours, Spring 2006)
Fish Ecology, Zoology 485-2 – (3 hours, Spring 2004)
Fisheries Conservation and Management, Zoology 466 - (3 hours; Fall 2000-2007; course web site: http://www.science.siu.edu/zoology/materials/zool466/index.html)
Advanced Fisheries Management, Zoology 569 - (3 hours; Spring 2001)
Fisheries Seminar, Zoology 586 - (1 hour; Fall 2001 [fisheries science sociology], Fall 2005 [review of "A Primer of Ecological Statistics"])
Fish Stock Assessment, Zoology 568 - (2 hours; Spring 2002)
Fish Biology, Zoology 306 – (Occasionally lectured, Spring 2003)
Dynamics of Exploited Fish Populations, Zoology 585Z – (3 hours, Spring 2005)

Courses at Kansas State University

Fish Ecology, Biology 697 - (3 hours; 1 year)
Ichthyology, Biology 542 - (3 hours; 1 year)

Courses at Ohio State University

Honors General Biology - Prepared and conducted laboratory sessions (1 year)
Introduction to Ecology - Developed course and occasionally lectured (5 years)

Completed Graduate Students at Southern Illinois University

Heather A. Calkins, M.Sc. 2010. Linking Asian carp distributions to food availability in the Mississippi River. Biologist with Fish and Wildlife Service.

Dawn R. Sechler, M.Sc. 2010. Diets of YOY shovelnose sturgeon in the Mississippi River. Biologist at Florida State University.

Kathyrn Emme, M.Sc. 2008. Synchrony in recruitment of fishes in tributaries of the Ohio River. Fisheries Biologist, Kentucky Department of Fish and Wildlife.

Adam Lohmeyer, M.Sc. 2007. Larval Asian carp in the Upper and Middle Mississippi River: an index of establishment and dispersal potential. Commercial Fisher, Alaska.

Rob Colombo, Ph.D. 2007. Demographics and the ecological role of the channel catfish (*Ictalurus punctatus*) in commercially exploited and unexploited reaches of the Wabash River with implications for the flathead catfish (*Pylodictis olivaris*). Assistant Professor, Eastern Illinois University

Sara J. Tripp, M.Sc. 2007. Reproductive biology of shovelnose sturgeon in the Middle Mississippi River. Researcher II, Southern Illinois University

David Knuth, M.Sc. 2006. Effects of abiotic and biotic factors on bluegill reproduction and growth in seven unexploited surface coal mine lakes. Missouri Department of Conservation.

Laura A. Csoboth M.Sc. 2006. Early life history of fishes in restored and unrestored backwaters. HRD Environmental Consulting Firm.

Kelly L. DeGrandchamp, M.Sc. 2006. Habitat selection and movement of bighead carp and silver carp in the lower Illinois River. US Army Corps of Engineers.

Douglas W. Schultz, M.Sc. 2005. An evaluation of fish movement between the Illinois River and lower Swan Lake, an associated backwater. Biologist, Minnesota Department of Natural Resources.

Brian Koch, M.Sc. 2005. Elevated organochlorines in the brain-hypothalamic-pituitary complex of intersexual shovelnose sturgeon. Illinois Environmental Protection Agency

S. Reid Adams. Ph.D. 2004. Fish community dynamics in off-channel habitats of the Mississippi River: patterns across space, time, and hydrologic gradients. Assistant Professor, University Central Arkansas.

Robert E. Colombo, M.Sc. 2004. Reproductive demographics and early life history of the shovelnose sturgeon. Ph.D. candidate, SIUC.

Christopher J. Williamson, M.Sc. 2004. Population demographics and feeding ecology of silver carp in the Middle Mississippi River. Employed by Missouri Department of Conservation.

Neal Jackson, M.Sc. 2004. Age, growth and mortality of shovelnose sturgeon, *Scaphirhynchus platorynchus*, in the middle Mississippi and lower Wabash Rivers, Illinois. Employed by Kentucky Department of Fish and Wildlife.

Brian J. O'Neill, M.Sc. 2003. Scale-dependent interrelationships among fish, landscape characteristics, and amphibian assemblages in forest ponds. Employed by Red Wing Environmental, Louisville, Kentucky.

Andrea Jackson, M.Sc. 2002. Status and characteristics of the sturgeon chub, *Macrhybopsis gelica*, and sicklefin chub, *Macrhybopsis meeki*, of the Middle Mississippi River. Employed by U.S. Fish and Wildlife Service, Colorado.

Post-Doctoral Fellows

Dr. Timothy Spier, 2001-2004. Demographics of Pallid Sturgeon. Assistant Professor, Western Illinois University, Fall 2004.

Current Graduate Students

Quinton Phelps, Ph.D., Recruitment of sturgeons in the Mississippi River corridor. (anticipated graduation: fall 2010)

Allison Asher, Ph.D., Population dynamics of paddlefish (start: summer 2010)

Nicolle MacVey, M.Sc., Paddlefish overwinter survival (start: summer 2010)

Jenny Johnson, M.Sc., Habitat selection of young sturgeon (start: fall 2009)

Bill Hintz, Ph.D., Sturgeon recruitment in the Mississippi River system (start: fall 2009)

Graduate Committees at Southern Illinois University

Kim Parks, M.Sc. (graduated 2003), Paris Collingsworth, M.Sc. (graduated 2003), Devon Keeney, Ph.D. (graduated 2004), Kim Elkin, M.Sc. (graduated 2003), Ryan Oster, M.Sc. (graduated 2003), John Ackerson, M.Sc., Leonard Pitcher, M.Sc. (graduated 2003), Kurt Regester, Ph.D., Michael Flinn, Ph.D., Becky Schwab, M.Sc., Mike Thomas, M.Sc. (graduated 2004), Lance Schuler, Ph.D., Matt Roberts, M.Sc. (graduated 2004), Nicholas Gaskill, M.Sc., Aaron Schrey, Ph.D., Checo Colon-Gaud Ph.D. (Examination Chair), Roberto Brenes, Ph.D. (Examination Chair), Yu Ping Ding, Ph.D. (Examination Chair), Ryan Boley M.Sc., Amanda Rugenski, Ph.D., Amanda Harwood, Ph.D.

Graduate Committees at Kansas State University

Sally Schrank, Biology, M.Sc. (graduated 2000); Nicole Gerlanc, Biology, M.Sc. (graduated 1999)

Undergraduate REU or Thesis Students (* denotes resulted in publication)

Jodi Vandermyde, summer 2007, SIUC (Clean Energy/IDNR/Center for Ecology Internship); John West, summer 2007, SIUC; John Zeigler, fall 2005, SIUC; Matt Wegener, fall 2005, SIUC; Dean Sherman, summer 2003, SIUC; Matt Roberts*, spring 2001, SIUC; Tad Uchiyama, spring 2000, Kansas State University; Catherine Mohr, summer 1999, Kansas State; Jacqueline Beaudoin, 1998, Queens University; Aimee H. Fullerton*, 1995, Ohio State; Joanne Dujnic, 1993, Ohio State; Nicholas S. Donovan*, 1992, Ohio State; Heather M. Thomas*, 1991, Ohio State

Funded Grants at Southern Illinois University (> $3 M)

Monitoring a commercial fishery for Asian carp in the Illinois River waterway. $1,117, 0000. Garvey, Trushenski, and Whitledge. July 2010-July 2011. Illinois Department of Natural Resources. (state)

Fish passage in the Upper Mississippi River System. $329,411. Tripp and Garvey. June 2010- June 2011. U.S. Army Corps of Engineers. (federal)

Early life history dynamics of young sturgeon in the Mississippi River. $230,000. Garvey and Tripp. June 2010- June 2011. U.S. Army Corps of Engineers. (federal)

Evaluating movement of fish in the St. Johns-New Madrid Floodway. Tripp and Garvey. $79,000. September 2009 - August 2010. U.S. Army Corps of Engineers, Memphis District (federal)

Monitoring Population Status and Movement of Native and Non-native Fishes in the Upper Mississippi River. **Garvey** and Brooks. $400,000. May 2009 – September 2009. U.S. Army Corps of Engineers (includes projects for sturgeon, fish passage, New Madrid Floodway, and Asian carps; Federal)

Status of Aquatic Resources on Sparta National Guard Property. $25,000. Garvey. Illinois Department of Military Affairs. 2008-2009 (State)

Pallid sturgeon reproduction in the Mississippi River. $199,000. Garvey, Brooks, Herzog, Hrabik. Spring 2008. U.S. Army Corps of Engineers, Navigation and Ecosystem Sustainability Program (Federal – Cooperative Ecosystem Study Unit Program)

Maintenance of a fish passage monitoring network in the Upper Mississippi River. $165,000. Garvey and Brooks. Spring 2008. U.S. Army Corps of Engineers, Navigation and Ecosystem Sustainability Program (Federal – Cooperative Ecosystem Study Unit Program)

Development of a hydrological monitoring network at the Mississippi River Wetland Field Station. $54,000. Whiles, Baer, Battaglia, Hellgren, **Garvey**, Whitledge, Williard. Spring 2007. ORDA Interdisciplinary Grant Program. (University)

Development of a Geographic Information System for Asian carps. $20,000. September 2006-September 2007. **Garvey**. U.S. Fish and Wildlife Service. (Federal)

Monitoring Population Status and Movement of Native and Non-native Fishes in the Upper Mississippi River. **Garvey** and Brooks. $304,000. May 2006 – September 2007. U.S. Army Corps of Engineers (includes projects for sturgeon, fish passage, and Asian carps; Federal)

Age-Related Demographics of Asian Carp in the Illinois River. ORDA Undergraduate Research Award with Matt Wegener. $1,500. July 1, 2005 - June 30, 2006. (University)

Larval fish assemblages in the Illinois River. ORDA Undergraduate Research Award with Shea Cox. $1,500. July 1, 2005 - June 30, 2006. (University; declined by Cox)

Fish Passage Evaluation in the Upper Mississippi River. U.S. Army Corps of Engineers, Rock Island District. **Garvey**. $38,000. Oct. 1, 2004-Sept. 2005. (Federal)

Swan Lake Habitat Rehabilitation and Enhancement Project: Post-Project Monitoring of Fish Movement, Fish Community, Waterfowl, Water Quality, Vegetation, and Invertebrates. US Army Corps of Engineers, St. Louis District. Second Year. **Garvey**, Brooks, Eichholz, and Chick. $281,000. Oct. 1, 2004-Sept. 2005. (Federal)

Evaluation of Native and Non-Native Fishes in the Upper Mississippi River with Focus on *Scaphirhynchus* Sturgeons and Aquatic Nuisance Species. US Army Corps of Engineers, St. Louis District and Waterways Experiment Station, Vicksburg, MS. **Garvey**. $286,000. Oct. 1. 2004 – September 30, 2005. (Federal)

Demographics of Pallid Sturgeon in the Middle Mississippi River. US Army Corps of Engineers, St. Louis District. **Garvey**. $253,000. Oct. 1, 2003-September 30, 2004. (Federal)

Swan Lake Habitat Rehabilitation and Enhancement Project: Post-Project Monitoring of Fish Movement, Fish Community, Waterfowl, Water Quality, Vegetation, and Invertebrates. US Army Corps of Engineers, St. Louis District. **Garvey**, Neumann, Brooks, Eichholz, and Chick. $270,000. Oct. 1, 2003-Sept. 2004. (Federal)

Managing ponds for amphibian assemblages. USDA Forest Service. **Garvey** and Lips. $10,000. May 1, 2003-Sept. 30, 2003. (Federal)

Winter habitat use by selected Ohio River fishes in Smithland and Belleville Pools. Segment II. West Virginia Department of Natural Resources/US Army Corps of Engineers. **Garvey**. $46,200. July 1, 2003 - June 30, 2004. (Federal)

Spatial distribution of hybrid striped bass in a coal-firing power plant lake. ORDA Undergraduate Research Award with Dean Sherman. $1,500. July 15, 2003 - June 30, 2004. (University)

Aquatic assessment of the Sparta National Guard Training Facility. Illinois Department of Military Affairs. **Garvey**, Heidinger, Whiles, and Lydy. $148,566. September 1, 2002-November 15, 2003. (State/Federal)

Demographics of Pallid Sturgeon in the Middle Mississippi River. US Army Corps of Engineers, St. Louis District. **Garvey** and Heidinger. $275,000. Nov. 30, 2002-September 30, 2003. (Federal)

Demographics of Pallid Sturgeon in the Middle Mississippi River. Army Corps of Engineers, St. Louis District. Heidinger and **Garvey**. $244,000. May 1, 2002-September 30, 2002. (Federal)

Intensive Basin Survey Internship Program: Little Wabash and Lower Kaskaskia Rivers. Illinois Environmental Protection Agency. **Garvey** and Burr. $36,238. May 15, 2002-June 30, 2003. (State)

Winter Habitat Use by Selected Ohio River Fishes in Smithland and Belleville Pools. Segment I. West Virginia Department of Natural Resources/US Army Corps of Engineers. **Garvey** and Sheehan. $138,800. July 1, 2001 - September 30, 2003. (Federal)

An Assessment of Aquatic Community Structure in Ponds of the Shawnee National Forest. USDA Forest Service. **Garvey**, Whiles, and Lips. $2,000. July 1, 2001-June 30, 2002. (Federal)

Bioenergetics and Survival of Largemouth Bass During Winter: Are Community Interactions Important? ORDA Creative Research Grant Program. $21,780. **Garvey**. July 1, 2001- June 30, 2002. (University)

Wabash River Catfish Assessment Project. Indiana Department of Natural Resources. $143,000. Heidinger, Sheehan, and **Garvey**. July 1, 2001 - June 30, 2004. (State)

Age validation of red-spotted sunfish. ORDA Undergraduate Research Award with Matt Roberts. $1,000. July 1, 2001 - June 30, 2002. (University)

Funded Grants at Kansas State University

Participated in research instrumentation grant (L. Johnson, lead PI) titled "Acquisition of a Stable Isotope Ratio Mass Spectrometer in the Kansas State University - University of Kansas-Creighton University Consortium" to NSF, $175K, February 1999 (Federal)

NSF LTER supplement titled "Assessing How Crayfish Influence Food Web Dynamics in a Tallgrass Prairie Stream", $35K, August 1999 (1 year; Federal).

University Small Research Grant, $2K, April 1999 (1 year; University).

NSF-EPSCoR First Award titled "Interactions between ecosystems and life history strategies: predicting fish community structure in lentic systems", $40K, December 1999 (1 year; State/Federal).

Funded Grants at The Ohio State University and Miami University

Assisted in development and writing of funded, Ohio Division of Wildlife project entitled, "Evaluating mechanisms of largemouth bass recruitment in Ohio reservoirs", $350K to R.A. Stein, July 1994 (2 years; State)

Assisted in organization and writing of funded, NSF grant entitled "Intermediate regulation of reservoir communities: strong regulators, stochasticity, and the generality of the trophic cascade", $100K to R.A. Stein, The Ohio State University and $100K to D.R. DeVries, April 1994 (2 years; Federal)

Helped organize and write three funded, NSF-sponsored Research Experiences for Undergraduates (REU) projects associated with NSF-funded project entitled, "Intermediate regulation of aquatic ecosystems: pursuing the generality of the trophic cascade hypothesis", $18K to R.A. Stein, The Ohio State University, 1992-1994 (1 year each; Federal)

Assisted in writing of funded, REU project associated with NSF project entitled, "Predation, herbivory, and disturbance: structuring forces in the littoral zone community of north temperate lakes", $5K to R.A. Stein, The Ohio State University, May 1991 (1 year; Federal)

Received Maher Undergraduate Research Award for undergraduate research project entitled, "Toxicity of copper to the green alga, *Chlamydomonas reinhardtii*

(Chlorophycea), as affected by humic substances of terrestrial and freshwater origin", $400, Miami University, January 1990 (1 year; University)

Honors and Awards

2008 Illinois Award, Illinois Association of Wastewater Agencies, Evanston, Illinois

2001 Best Oral Presentation, Annual Meeting of the Illinois Chapter of the American Fisheries Society, February 2001

2000 Best Oral Presentation, 2000 Annual Meeting of the Kansas Chapter of the American Fisheries Society, Manhattan, Kansas

1999 Article titled "Competition between larval fishes in reservoirs: the role of relative timing of appearance" (co-author, R.A. Stein) was among 5 nominated by a selection committee for Best Paper in Transactions of the American Fisheries Society (out of ~100 articles)

1999 American Society of Limnology and Oceanography's DIALOG III Symposium, Bermuda, October 1999

1998 Graduate Faculty Status, Kansas State University, November 1998

1996 Best Poster, Annual Meeting of the American Fisheries Society, Dearborn, Michigan, August 1996

1996 University Presidential Fellowship, July 1996

1995 Honorable Mention, Best Oral Presentation, Annual Meeting of the American Fisheries Society, Tampa, Florida, August 1995

Student Awards

2010 Nicolle MacVey, Walleyes Unlimited Scholarship, July 2010 (national)

2010 Quinton Phelps, Lewis Osborne Best Student Platform Presentation Award, Illinois American Fisheries Society Meeting, Rend Lake, Illinois, February 2010 (Provides travel support to national AFS meeting) (regional)

2009 Quinton Phelps, Student Mentee Award, American Fisheries Society Annual Meeting, Nashville, TN (national)

2009 Quinton Phelps, Richard E. Blackwelder Student Achievement Award, Department of Zoology (department, one of Zoology's highest honors)

2009 Dawn Sechler, Student Research Grant, Illinois Chapter of the American Fisheries Society, $500 (state)

2009 Quinton Phelps, Student Research Grant, Illinois Chapter of the American Fisheries Society, $480 (state)

2008 Dawn Sechler, Semi-finalist, Janice Lee Fenske Memorial Award, North Central Division, American Fisheries Society (regional)

2008 Quinton Phelps, College of Science, Todd Fink Memorial Conservation Award (college)

2008 Dawn Sechler, Best Poster Award, Illinois Chapter of the American Fisheries Society, Rockford, IL (state)

2006 Rob Colombo, Department of Zoology, Foote and Foote Graduate Teaching Award (department)

2006 Rob Colombo, Best Paper, Mississippi River Research Conference, LaCrosse, Wisconsin (regional)

2005 Rob Colombo, Skinner Travel Award, American Fisheries Society Meeting, Anchorage, Alaska, September 2005 (national)

2005 Laura Csoboth, Student Travel Award, Early Life History Section, American Fisheries Society, Barcelona, Spain, July 2005 (international)

2005 Rob Colombo, Lewis Osborne Best Student Platform Presentation Award, Illinois American Fisheries Society Meeting, Moline, Illinois, March 2005 (Provides travel support to national AFS meeting) (regional)

2005 Rob Colombo, Kelly DeGrandchamp, and Doug Schultz. Student Travel Awards, Illinois American Fisheries Society Meeting, Moline, Illinois, March 2005 (state)

2004 Brian Koch, National Society of Environmental Toxicology and Chemistry, Jeff Black Student Award (national)

2004 Dean Sherman, Honorable Mention, Best Poster Award, Undergraduate Research Forum, Southern Illinois University, Carbondale, March 2004 (university)

2004 Laura Csoboth, Student Travel Award, Illinois American Fisheries Society Meeting, Champaign, Illinois, March 2004 (state)

Professional Service

2009 Reviewer, Great Lake Fishery Commission proposal

2009 Reviewer, USGS Columbia Environmental Research Center, draft research product (report)

2009 Program Co-Chair, 2009 Midwest Fish and Wildlife Conference Planning Committee, Springfield, IL

2009 Panelist, NSF Graduate Research Fellowship Program, Ecology, February 2009, Arlington, VA

2009	Reviewer, Hudson River Foundation proposal
2008	Past-president, Illinois Chapter of the American Fisheries Society
2008	SIUC Representative, Cooperative Ecosystems Study Unit
2006-present	Webmaster, Illinois Chapter of the American Fisheries Society
2007	President, Illinois Chapter of the American Fisheries Society
2007	Site Reviewer, USGS Upper Mississippi Environmental Research Center, LaCrosse, WI, Sept. 10 -14, 2007
2007	Reviewer, USGS Long-term Monitoring Program 10- Year Report, 189 pages
2007	Reviewer, National Science Foundation, Ecology Panel, October 2007
2006	President-elect, Illinois Chapter of the American Fisheries Society
2006-2007	Chair, Farm Bill Advisory Committee, American Fisheries Society
2006	Reviewer, National Science Foundation, Ecology Panel & Biological Oceanography Program (N=2)
2006	Reviewer, National Fish and Wildlife Foundation proposal
2005	Participant, Pallid Sturgeon Recovery Team meeting to decide stocking strategies in the Missouri and Mississippi River basins, Denver, Colorado
2005	Member, Committee to Draft Pallid Sturgeon Conservation Plan for the Middle Mississippi River
2005-2006	Member, Systems Evaluation Team for Environmental Management Program in the Upper Mississippi River, US Fish and Wildlife Service, US Army Corps of Engineers, and US Geological Survey
2005	Secretary-Treasurer, Illinois Chapter of the American Fisheries Society
2005	Reviewer, US Army Corps of Engineers Scope of Work, Barge Entrainment by Larval and Adult Fish
2005	Reviewer, Great Lake Fisheries Commission grant proposal
2005	Reviewer, National Science Foundation proposals, Ecology Panel (2 proposals)
2004	Member, American Society of Limnology and Oceanography's DIALOG VI Symposium, Selection Committee, Dauphin Island Marine Lab, Alabama (July 2004; reviewed 96 applications from recent PhDs)

2004	Reviewer, National Science Foundation proposal, Ecology Panel (RUI proposal)
2004	Member, Skinner Award Committee, American Fisheries Society (second term; reviewed 49 applicants)
2004-present	North Central Representative, Early Life History Section, American Fisheries Society.
2003	Workshop Presenter, Analysis of Fisheries Data, Illinois Chapter of the American Fisheries Society Continuing Education Workshop, Springfield, Illinois, April 2003
2003	Moderator, River Session, Illinois Chapter of the American Fisheries Society, Rend Lake, IL, February 2003
2002	Reviewer, National Science Foundation proposal, Ecology Panel, August 2002
2002	Chair, Student Judging of Oral Presentations, National American Fisheries Society Meeting, Baltimore, Maryland, August 2002
2002-2005	Associate Editor, *Transactions of the American Fisheries Society* (handle ~ 10 manuscripts per year)
2001-2003	Judge, Regional Science Fair, SIUC campus, February 2001-2003
1999-2001	Member, Skinner Award Committee, American Fisheries Society (first term)
2001	Reviewer, National Science Foundation proposal, Ecology Panel, February 2001
2001	Moderator, Fisheries Session, Illinois Renewable Natural Resources Meeting, February 2001
2000	Judge, Student Paper Presentations, American Fisheries Society National Meeting, August 2000
1994-present	Peer Reviewer of journals including *Behaviour, Biological Invasions, Canadian Journal of Zoology, Canadian Journal of Fisheries and Aquatic Sciences, Transactions of the American Fisheries Society, North American Journal of Fisheries Management*, *Ecology*, *Ecological Applications*, *Fisheries, Fisheries Management and Ecology, Great Basin Naturalist*, *American Midland Naturalist, Prairie Naturalist, Journal of Plankton Research, Animal Behaviour, Journal of the North American Benthological Society, Journal of Fish Biology, Environmental Biology of Fishes, Northwest Science, North American Journal of Aquaculture*, *Proceedings of the Royal Academy of Science –Great Britain, Journal of Applied Ichthyology, Journal of Animal Ecology, Hydrobiologia, Limnology and Oceanography* (average 8 reviews per year)

1999	Participant, Kansas EPSCoR Conference, Topeka, April 1999
1999	Judge, Fourth Annual University Graduate Research Forum, Kansas State University, April 1999
1999	Participant, Kansas Department of Wildlife and Parks Channel Catfish Planning Meeting, March 1999
1999	Judge, Biology Graduate Research Forum, Division of Biology, February 1999
1998	Co-organized and moderated symposium entitled, "Managing across ecological gradients: searching for generality across variable ecosystems", 1998 American Fisheries Society Meeting, Hartford, Connecticut

Society Memberships

2003-present	Member, American Institute of Biological Sciences
1990-present	Ecological Society of America
1990-present	American Fisheries Society
1990-present	North American Benthological Society
2001-present	Illinois Chapter of the American Fisheries Society
1999-present	Full Member, Sigma Xi
1999-2000	Kansas Chapter of the American Fisheries Society

University Service

2009-	Senator, Faculty Senate Representative for College of Science, 3-year term (elected)
2009-2010	Member, Governance Committee, Faculty Senate
2009-	Member, Middle Mississippi River Wetland Field Station Advisory Committee
2009	Chair, Aquaculture Faculty Search Committee, Department of Zoology, SIUC
2009-2010	Member, Todd Fink Memorial Award Selection Committee
2008	SIUC Representative, North Central Regional Aquaculture Center Science Committee
2007	Member, SIUC Department of Zoology, Aquaculture/Fish Physiology Faculty Search Committee, Fall 2007

2007-2009	Touch of Nature Advisory Board, SIUC
2007-2009	Member, Doctoral Fellowship panel, SIUC
2005	Member, SIUC Department of Zoology, Fisheries Faculty Search Committee, Spring 2005
2005-2006	Member, Faculty Seed Grant Committee, Biological Science Panel, ORDA
2004-2005	Member, Advisory Committee, Department of Zoology
2003	Member, SIUC Department of Zoology, Aquaculture/Fish Physiology Faculty Search Committee, Spring 2003
2002	Member, SIUC Department of Zoology, River Fisheries Faculty Search Committee, Fall 2002
2002	Participant, University Faculty Calling Program (call prospective undergraduate students), April 2002
2001	Member, Advisory Committee, Department of Zoology, Southern Illinois University, 2001-
2001	Member, Graduate School Picnic Planning Committee, Southern Illinois University, Fall 2001
2000	Member, SIUC Department of Zoology, Limnology Faculty Search Committee, Fall 2000
1999-2000	Faculty Adviser, Student Subunit of the American Fisheries Society, Kansas State University
1999-2000	Member, Konza Prairie Research Natural Area Faculty Advisory Committee
1999-2000	Member, Fisheries and Wildlife Biology Curriculum Committee, Division of Biology, R. Robel, Chair
1999-2000	Member, Edler Award Committee, Division of Biology, Kansas State University
1991, 1996, 1997	Member, Council of Graduate Students, Ohio State
1997	Member, University Research Computing Advising Committee, Ohio State

Invited Presentations

2010 Department of Biology, Eastern Illinois University, Charleston, March 2010

2009 Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana-Champaign, November 2009

2009 College of Agricultural Sciences, SIUC, Brazil Agricultural Minister Visit, May 2009

2008 Department of Biology, Saint Louis University, November 2008

2008 Department of Biology, Kent State University, Kent, Ohio, October 2008

2008 Participant, Round-table discussion on Mississippi River research and management; Mississippi River Research Consortium, Davenport, Iowa, April 2008.

2007 Presenter, Bridging the Gap: addressing critical uncertainties in North American sturgeon conservation and recovery. Symposium, American Fisheries Society Meeting, San Francisco, CA, September 2007

2007 Department of Forestry and Natural Resources, Purdue University, March 2007

2006 Ecology, Evolution, and Organismal Biology Seminar Series, The Ohio State University, January 2006

2005 Chicago Sanitary Shipping Canal, Invasive Species Barrier stakeholder meeting, June 2005

2005 Water Resources Program, Utah State University, March 2005

2004 Fish and Wildlife Seminar Series, Michigan State University, October 2004

2004 Ecology and Evolutionary Biology Seminar Series, Michigan State University, October 2004

2004 Lake of Egypt Association of Property Owners, Lake of Egypt, Illinois, June 2004

2003 Upper Mississippi River Conservation Committee, Prairie du Chien, Wisconsin, August 2003

2002 Ecology Consortium, Southern Illinois University, Carbondale, November 2002

2000 Sam Parr Biological Station, Illinois Natural History Survey, June 2000

2000 Northeast Division Meeting of the American Fisheries Society, April 2000

2000 Department of Zoology, University of Wisconsin - Madison, February 2000

1999 Department of Biology, William Jewell College, Missouri, September 1999

1998 Department of Biology, Queens University, Kingston, Ontario, January 1998

1997 Apple Valley Fishing Club, Apple Valley, Ohio, October 1997

1996 Department of Biological Sciences, University of Pittsburgh, December 1996.

Technical Reports (Selected reports available at http://fishdata.siu.edu)

R.C. Brooks, S.J. Tripp, and **Garvey, J.E.** 2008. Evaluation of a prototype ultrasonic detection system for quantifying fish movement in the Upper Mississippi River. Year 3. Annual Progress Report, US Army Corps of Engineers, St. Louis District and Rock Island District. 90 pages

R.C. Brooks, S.J. Tripp, and **Garvey, J.E.** 2007. Evaluation of a prototype ultrasonic detection system for quantifying fish movement in the Upper Mississippi River. Year 2. Annual Progress Report, US Army Corps of Engineers, St. Louis District and Rock Island District. 56 pages.

Garvey, J.E. 2007. Spatial assessment of Asian carp population dynamics: development of a spatial query tool for predicting relative success of life stages. US Fish and Wildlife Service. 45 pages. Spatial tool at http://fishdata.siu.edu/carptools

Garvey, J.E., and multiple co-authors. 2007. Swan Lake Habitat Rehabilitation and Enhancement Project: Post-Project Monitoring of Water Quality, Sedimentation, Vegetation, Invertebrates, Fish Communities, Fish Movement, and Waterbirds. US Army Corps of Engineers. 608 pages.

Garvey, J.E., E.J. Heist, R.C. Brooks, D.P. Herzog, R.A Hrabik, and K.J. Killgore. 2006. Current status of the Pallid Sturgeon (*Scaphirhynchus albus*) in the Middle Mississippi River: Habitat, Movement, and Demographics. Final Report – St. Louis District, US Army Corps of Engineers. 475 pages. (http://fishdata.siu.edu/pallid)

Garvey, J.E., R.C. Brooks, and S.J. Tripp. 2006. Evaluation of a prototype ultrasonic detection system for quantifying fish movement in the Upper Mississippi River. Annual Progress Report, US Army Corps of Engineers, St. Louis District and Rock Island District. 32 pages.

Garvey, J.E., K.L. DeGrandchamp, C.J. Williamson. 2006. Growth, fecundity, and diets of Asian carps in the Upper Mississippi River system. U.S. Army Corps of Engineers Technical Note, ERDC, Waterways Experimental Station. ERDC/TN ANSRP-06.

Colombo, R., **J.E. Garvey**, and R.C. Heidinger. 2005. Population Demographics of Catfish in Fished and Unfished Reaches of the Wabash River. Final Report to Indiana Department of Natural Resources, Federal Aid in Sport Fish Restoration Program, 128 pages.

Garvey, J.E., R. Brooks, M. Eichholz, J. Chick. 2005. Swan Lake Habitat Rehabilitation and Enhancement Project: Post-Project Monitoring of Fish Movement, Fish Community, Waterfowl, Water Quality, Vegetation, and Invertebrates. Year 1 Summary to US Army Corps of Engineers, St. Louis District. 135 pages.

Garvey, **J.E.**, M.L. Lydy, M.R. Whiles, and R.C. Heidinger. 2004. Aquatic environmental assessment of the Sparta Illinois National Guard Training Facility. Final Report. 137 pages.

Garvey, J.E., and M.R Whiles. 2004. An assessment of national and Illinois dissolved oxygen water quality criteria. Illinois Association of Wastewater Agencies. 56 pages.

Garvey, **J.E.**, M.L. Lydy, M.R. Whiles, and R.C. Heidinger. 2004. Aquatic environmental assessment of the Sparta Illinois National Guard Training Facility. Annual Progress Report. 62 pages.

Hrabick, R.A., K. J. Killgore, T. Spier, and **J.E. Garvey**. 2004. Pallid sturgeon recovery update. Issue 14. Edited by R. Wilson. Publication of the Pallid Sturgeon Recovery Team. p. 15.

Garvey, J.E., S.Welsh, and K.J. Hartman. 2003. Winter habitat used by fishes in Smithland Pool and Belleville Pool, Ohio River. Final Report. U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers. 295 pages.

Spier, T. and **J.E. Garvey**. 2003. Demographics of pallid sturgeon project. Annual Report. U.S. Army Corps of Engineers. 3 pages.

Garvey, J.E., B.D. Dugger, M.R. Whiles, S.R. Adams, M.B. Flinn, B.M. Burr, and R.J. Sheehan. 2003. Responses of fish, waterbirds, invertebrates, vegetation, and water quality to environmental pool management: Mississippi River Pool 25. U.S. Army Corps of Engineers. 181 pages.

Garvey, J.E. 2002. Winter habitat used by fishes in Smithland Pool, Ohio River. U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers, 90 pages.

Garvey, J.E., and R.J. Sheehan. 2001. Winter habitat associations of riverine fishes: predictions for the Ohio River, U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers, 39 pages.

Garvey, J.E., R.A. Wright, R.A. Stein, E.M. Lewis, K.H. Ferry, and S.M. Micucci. 1998. Assessing the influence of size on overwinter survival of largemouth bass in Ohio on-stream impoundments. Ohio Division of Wildlife Final Report. Federal Aid in Sport Fish Restoration Program 29, 288 pages.

Stein, R.A., and **J.E. Garvey**. 1996. A review of a technical report prepared for the Cuyahoga River (Ohio) Community Planning Organization by EnvironScience Inc.

Theses and Dissertations

Garvey, J.E. 1997. Strong interactors and community structure: testing predictions for reservoir food webs, Ph.D. dissertation, 235 pages.

Garvey, J.E. 1992. Selective predation as a mechanism of crayfish species replacement in northern Wisconsin lakes. M.S. thesis, The Ohio State University, 88 pages.

Policy Statements/Editorials

Garvey, J.E. (Written as Chair of Farm Bill Advisory Committee). 2007. Farm Bill 2007: placing fisheries upstream of conservation provisions. Fisheries 32(8):399-404.

Popular Press

Garvey, J.E. 2005. A tale of two sturgeons. Outdoor Illinois. April, pp. 11-13.

Book Chapters

4. Phelps, Q.E, S.J. Tripp, **J.E. Garvey**, D.P. Herzog, D.E. Ostendorf, J.W. Ridings, J.W. Crites, and R.A. Hrabik. 2010. Ecology and habitat use of larval and age-0 paddlefish in the unimpounded Middle Mississippi River. Paddlefish Management, Propagation, and Conservation in the 21st Century: Building From 20 Years of Research and Management. American Fisheries Society, Bethesda, Maryland. (Peer reviewed)

3. Chipps, S.R., and **J.E. Garvey.** 2007. Chapter 11: Assessment of food habits and feeding patterns. Pages 473-514 in M.L. Brown and C.S. Guy, editors. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda, Maryland. (Peer reviewed)

2. DeVries, D.R., **J.E. Garvey**, and R.A. Wright. 2009. Chapter 5: Early life history and recruitment. Pages105-133 *in* S. Cooke and D. Philipp, editors. Centrarchid fishes: diversity, biology, and conservation. Wiley-Blackwell Scientific.

1. **Garvey, J.E.,** and S.R. Chipps. Accepted pending revision. Quantifying diets and energy flow. Third edition of Fisheries Techniques, American Fisheries Society. 97 MS pages, 1 table, 4 figures, 8 boxes. (Peer reviewed)

Book Reviews

2. **Garvey, J.E.** 2005. Sustaining hope for fisheries in the 21st century. Review of "Sustainable Management of North American Fisheries" Edited by E.E. Knudsen, D.D. MacDonald, and Y. K Muirhead. American Fisheries Society, Bethesda. 2004. 281 pp. Appeared in BioScience 55(10):3-5. (Invited)

1. **Garvey, J.E.** 2003. Searching for scales in fisheries. Review of "Hierarchical Perspectives on Marine Complexities: Searching for Systems in the Gulf of Maine" by Spencer Apollonio. Columbia University Press, New York. 2002. 229 pp. Appeared in BioScience 53(10):1004-1006. (Invited)

Peer-Reviewed Publications

53. Phelps, Q.E., G. Whitledge, and J.E. Garvey. In press. Identifying origin of sturgeon larvae in the Mississippi River using elemental analysis. Canadian Journal of Fisheries and Aquatic Sciences.

52. Phelps, Q.E., S.J. Tripp, **J.E. Garvey**, D.P. Herzog, D.E. Ostendorf, J.W. Ridings, J.W. Crites, and R.A. Hrabik. 2010. Water temperature and river stage influence mortality and abundance of naturally occurring Mississippi River *Scaphirhynchus* sturgeons. North American Journal of Fisheries Management 30:767-775.

51. Phelps, Q.E., S.J. Tripp, **J.E. Garvey**, D.P. Herzog, D.E. Ostendorf, J.W. Ridings, J.W. Crites, and R.A. Hrabik. 2010. Habitat use during early-life history infers recovery needs for *Scaphirhynchus* sturgeon. Transactions of the American Fisheries Society 139:1060-1068.

50. **Garvey, J.E.**, B. Ickes, and S. Zigler. 2010. Challenges in merging fisheries research and management: the Upper Mississippi River experience. Hydrobiologia 640:125-144.

49. Wahl, N.C., Q.E. Phelps, **J.E. Garvey**, S.T. Lynott, and W.E. Adams. 2009. Comparisons of scales and sagittal otoliths to back-calculated lengths-at-age of crappies collected from Midwestern waters. Journal of Freshwater Ecology 24(3):469-475.

48. Phelps, Q.E., D.P. Herzog, R.C. Brooks, V.A. Barko, D.E Ostendorf, J.W. Ridings, S.J. Tripp, R.E. Colombo, **J.E. Garvey**, and R.A. Hrabik. 2009. Seasonal comparison of catch rates and size structure using three gear types to sample sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management 29:1487-1495.

47. Colombo, R., Q. Phelps, C.M. Miller, **J.E. Garvey**, R.C. Heidinger, and N. Richards. 2010. Comparison of channel catfish age estimates and resulting population demographics using two common structures. North American Journal of Fisheries Management.

46. Schrey, A., R. Colombo, **J. Garvey**, and E. Heist. 2009. Stock structure of shovelnose sturgeon analyzed with microsatellite DNA and morphological characters. Journal of Applied Ichthyology 6:625-631.

45. **Garvey, J.E.**, R.A. Wright, and E.A. Marschall. 2009. Searching for threshold shifts in spawner recruit relationships. Canadian Journal of Fisheries and Aquatic Sciences 66:312-320.

44. Tripp, S., Q. Phelps, R. Colombo, **J. Garvey**, B. Burr, D. Herzog, and R. Hrabik. 2009. Maturation and reproduction of shovelnose sturgeon in the Middle Mississippi River. North American Journal of Fisheries Management 29(3):730-738.

43. Tripp, S.J, R.E. Colombo, and **J.E. Garvey**. 2009. Declining recruitment and growth of shovelnose sturgeon in the Middle Mississippi River: implications for conservation. Transactions of the American Fisheries Society 138:416-422.

42. Lohmeyer, A.M., and **J.E. Garvey**. 2009. Placing the North American invasion of Asian carp in a spatially explicit context. Biological Invasions 11:905-916.

41. DeGrandchamp, K.L., **J.E. Garvey**, and R.E. Colombo. 2008. Habitat selection and dispersal of invasive Asian carps in a large river. Transactions of the American Fisheries Society 137:33-44.

40. Csoboth, L.A., and **J.E. Garvey**. 2008. Lateral exchange of larval fish between a restored backwater and a large river in the east-central U.S. Transactions of the American Fisheries Society 137:45-56.

39. Flinn, M.R. Whiles, S.R. Adams, and **J.E. Garvey**. 2008. Biological responses to contrasting hydrology in backwaters of Upper Mississippi River Navigation Pool 25. Environmental Management 41:468-486.

38. **Garvey, J.E.**, M.R. Whiles, and D. Streicher. 2007. A hierarchical model for oxygen dynamics in streams. Canadian Journal of Fisheries and Aquatic Sciences 64:1816-1827.

37. Colombo, R.E., **J.E. Garvey**, N.D. Jackson, R. Brooks, D.P. Herzog, R.A. Hrabik, and T.W. Spier. 2007. Harvest of Mississippi River sturgeon drives abundance and reproductive success: a harbinger of collapse? Journal of Applied Ichthyology 23:441-451.

36. DeGrandchamp, K.L., **J.E. Garvey**, and L.A. Csoboth. 2007. Linking reproduction of adult Asian carps to their larvae in a large river. Transactions of the American Fisheries Society 136:1327-1334.

35. Jackson, N.J., **J.E. Garvey**, and R.E. Colombo. 2007. Comparing aging precision of calcified structures in shovelnose sturgeon. Journal of Applied Ichthyology 23:444-451.

34. Colombo, R.E., Q.E. Phelps, **J.E. Garvey**, and R.C. Heidinger. 2008. Gear-specific population demographics of channel catfish in a large unimpounded midwestern river. North American Journal of Fisheries Management 28:241-246.

33. Colombo, R.E., **J.E. Garvey**, and P.S. Wills. 2007. A guide to the embryonic development of the shovelnose sturgeon (*Scaphirhynchus platorynchus*), reared at a constant temperature. Journal of Applied Ichthyology 23:402-410.

32. Schultz, D., **J.E. Garvey**, and R. Brooks. 2007. Backwater immigration by fishes through a water control structure: implications for connectivity and restoration. North American Journal of Fisheries Management 27:172-180.

31. Colombo, R.E., **J.E. Garvey**, and P.S. Wills. 2007. Gonadal development and sex-specific demographics of the shovelnose sturgeon in the Middle Mississippi River. Journal of Applied Ichthyology 23:420-427.

30. Adams, S.R., M.B. Flinn, B.M. Burr, M.R. Whiles, and **J.E. Garvey**. 2006. Ecology of larval blue sucker (*Cycleptus elongatus*) in the Mississippi River. Ecology of Freshwater Fish 15:291-300.

29. Koch, B.T, **J.E. Garvey**, M.J. Lydy. 2006. Elevated organochlorines in the brain-hypothalamic-pituitary complex of intersexual shovelnose sturgeon. Environmental Toxicology and Chemistry 25:1689-1697.

28. Heatherly, T., II, M.R. Whiles, D. Knuth, and **J.E. Garvey**. 2005. Diversity and community structure of littoral zone macroinvertebrates in southern Illinois reclaimed surface mine lakes. American Midland Naturalist 154(1):67-77.

27. Vanni, M.J., K.K. Arend, M.T. Bremigan, D.B. Bunnell, **J.E. Garvey**, M.J. González, W. H. Renwick, P.A. Soranno, and R.A. Stein. 2005. Linking landscapes and food webs: effects of omnivorous fish and watersheds on reservoir ecosystems. BioScience 55:155-167.

26. Williamson, C.J., and **J.E. Garvey**. 2005. Growth, mortality, fecundity, and diets of newly established silver carp in the Middle Mississippi River. Transactions of the American Fisheries Society 134:1423-1430.

25. Flinn, M.B., M.R. Whiles, S.R. Adams, and **J.E. Garvey**. 2005. Macroinvertebrate and zooplankton responses to emergent plant production in upper Mississippi River floodplain wetlands. Archiv für Hydrobiologie 162:187-210.

24. Ostrand, K.G., S.J. Cooke, **J.E. Garvey**, and D.H. Wahl. 2005. The energetic impact of overwinter prey assemblages on age-0 largemouth bass. Environmental Biology of Fishes 72(3):305-311.

23. **Garvey, J.E.**, K.G. Ostrand, and D.H. Wahl. 2004. Interactions among allometric scaling, predation and ration affect size-dependent growth and mortality of fish during winter. Ecology 85(10):2860-2871.

22. Whiles, M.J., and **J.E. Garvey**. 2004. Aquatic resources of the Shawnee and Hoosier National Forests, USDA Forest Service. Aquatic resources of the Shawnee-Hoosier National Forest. Pages 81-108 in Frank R. Thompson, III editor. The Hoosier-Shawnee Ecological Assessment. General Technical Report, NC-244. USDA, Forest Service, North Central Research Station. (peer-reviewed)

21. Colombo, R.E., P.S. Wills, and **J.E. Garvey**. 2004. Use of ultrasound imaging to determine sex of shovelnose sturgeon *Scaphirhynchus platorynchus* from the Middle Mississippi River. North American Journal of Fisheries Management 24:322-326.

20. Roberts, M.R., JE. Wetzel, III, R.C. Brooks, and **J.E. Garvey**. 2004. Daily incrementation in the otoliths of the red spotted sunfish, *Lepomis miniatus*. North American Journal of Fisheries Management 24:270-274.

19. **Garvey, J.E**., and E.A. Marschall. 2003. Understanding latitudinal trends in fish body size through models of optimal seasonal energy allocation. Canadian Journal of Fisheries and Aquatic Sciences 60(8):938-948.

18. Micucci, S.M., **J.E. Garvey**, R.A. Wright, and R.A. Stein. 2003. Individual growth and foraging responses of age-0 largemouth bass to mixed prey assemblages during winter. Environmental Biology of Fishes 67(2):157-168.

17. **Garvey, J.E**., J.E. Rettig, R.A. Stein, D.M. Lodge, and S.P. Klosiewski. 2003. Scale-dependent associations among fish predation, littoral habitat, and distributions of native and exotic crayfishes. Ecology 84(12): 3339-3348.

16. **Garvey, J.E**., R.A. Stein, R.A. Wright, and M.T Bremigan. 2003. Largemouth bass recruitment in North America: quantifying underlying ecological mechanisms along environmental gradients Black bass: ecology, conservation and management. Edited by D. Philipp and M. Ridgway. American Fisheries Society Symposium 31:7-23. (peer-reviewed)

15. **Garvey, J.E.**, D.R. DeVries, R.A. Wright, and J.G. Miner. 2003. Energetic adaptations along a broad latitudinal gradient: implications for widely distributed communities. BioScience 53(2):141-150.

14. **Garvey, J.E.**, T.P. Herra, and W.C. Leggett. 2002. Protracted reproduction in sunfish: the temporal dimension in fish recruitment revisited. Ecological Applications 12:194-205.

13. **Garvey, J.E.**, R.A. Wright, K.H. Ferry, and R.A. Stein. 2000. Evaluating how local- and regional- scale processes interact to regulate growth of age-0 largemouth bass. Transactions of the American Fisheries Society 129:1044-1059.

12. Fullerton, A.H., **J.E. Garvey**, R.A. Wright, and R.A. Stein. 2000. Overwinter growth and survival of largemouth bass: interactions among size, food, origin, and winter duration. Transactions of the American Fisheries Society 129:1-12.

11. Wright, R.A., **J.E. Garvey**, A.H. Fullerton, and R.A. Stein. 1999. Using bioenergetics to explore how winter conditions affect growth and consumption of age-0 largemouth bass. Transactions of the American Fisheries Society 128:603-612.

10. **Garvey, J.E.**, and R.A. Stein. 1998. Competition between larval fishes in reservoirs: the role of relative timing of appearance. Transactions of the American Fisheries Society 127:1023-1041.

9. **Garvey, J.E.**, R.A. Wright, and R.A. Stein. 1998. Overwinter growth and survival of age-0 largemouth bass: revisiting the role of body size. Canadian Journal of Fisheries and Aquatic Sciences 55:2414-2424.

8. **Garvey, J.E.**, N.A. Dingledine, N.S. Donovan, and R.A. Stein. 1998. Exploring spatial and temporal variation within reservoir food webs: predictions for fish assemblages. Ecological Applications 8:104-120.

7. **Garvey, J.E.**, and R.A. Stein. 1998. Linking bluegill and gizzard shad assemblages to growth of age-0 largemouth bass in reservoirs. Transactions of the American Fisheries Society 127:70-83.

6. Lodge, D.M., R.A. Stein, K.M. Brown, A.P. Covich, C. Brönmark, **J.E. Garvey**, and S.P. Klosiewski. 1998. Predicting impact of freshwater exotic species on native biodiversity: challenges in spatial and temporal scaling. Australian Journal of Ecology 23:53-67.

5. **Garvey, J.E**., E.A. Marschall, and R.A. Wright. 1998. From star charts to stoneflies: detecting relationships in continuous bivariate data. Ecology 79(2):442 447.

4. Schaus, M.H., M.J. Vanni, T.E. Wissing, M. Bremigan, **J.E. Garvey**, and R.A. Stein. 1997. Nitrogen and phosphorus excretion by the detritivorous gizzard shad (*Dorosoma cepedianum*) in a reservoir ecosystem. Limnology and Oceanography 42(6):1386-1397.

3. **Garvey, J.E**., R.A. Stein, and H.M. Thomas. 1994. Assessing how fish predation and interspecific prey competition influence a crayfish assemblage. Ecology 75:532-547.

2. **Garvey, J.E.**, and R.A. Stein. 1993. Evaluating how chela size influences the invasion potential of an introduced crayfish, *Orconectes rusticus*. American Midland Naturalist 129:172-181.

1. **Garvey, J.E.**, H.A. Owen, and R.W. Winner. 1991. Toxicity of copper to the green alga, *Chlamydomonas reinhardtii* (Chlorophycea), as affected by humic substances of terrestrial and freshwater origin. Aquatic Toxicology 19:89-96.

Oral Presentations and Posters

99. Tripp, S., Q. Phelps, and J.E. Garvey. Ecology and habitat use of paddlefish in the unimpounded Middle Mississippi River. Midwest Fish and Wildlife Conference, Springfield, IL, December 2009. (Poster presentation by Tripp).

98. Phelps, Q., Tripp, S., D. Herzog, and J.E. Garvey. Seasonal Comparison of Catch Rates and Size Structure Using Three Gear Types to Sample Sturgeon in the Middle Mississippi River. Midwest Fish and Wildlife Conference, Springfield, IL, December 2009. (Oral presentation by Phelps).

97. Calkins, H., and **J.E. Garvey**. Linking habitat use and phytoplankton consumption of silver carp in the upper and middle Mississippi River. National American Fisheries Society Meeting, Nashville, TN, September 2009 (Oral presentation by Calkins)

96. Brooks, R., S. Tripp, **J. Garvey**, and 5 co-authors. Fish passage throughout pools 20-26 of the Upper Mississippi River. National American Fisheries Society Meeting, Nashville, TN, September 2009 (Oral presentation by Tripp)

95. Boley, R., A. Schrey, D. Sechler, **J.E. Garvey**, and E. Heist. Genetic identification of larval pallid sturgeon, shovelnose sturgeon, and their hybrids in the middle Mississippi River. National American Fisheries Society Meeting, Nashville, TN, September 2009 (Poster presentation)

94. Heist, E., **J.E. Garvey**, and 8 co-authors. Status of pallid sturgeon. Invited presentation. Acipenseriformes Symposium, National American Fisheries Society Meeting, Nashville, TN, September 2009 (Oral presentation by Heist)

93. Whitledge, G., Q. Phelps, and **J.E. Garvey**. Identifying river of origin for age-0 sturgeon in the middle Mississippi River using fin ray microchemistry. National American Fisheries Society Meeting, Nashville, TN, September 2009 (Oral presentation by Whitledge)

92. Colombo, R., **J.E. Garvey**, and 11 co-authors. Distribution, life history, and population status of shovelnose sturgeon. Invited presentation. Acipenseriformes Symposium, National American Fisheries Society Meeting, Nashville, TN, September 2009 (Oral presentation by Colombo)

91. Brooks, R., **J. Garvey**, M. Hill, S.J. Tripp, H.A. Calkins, T. Spier, N. Bloomfield, T. Moore, D. Herzog, and R. Hrabik. Fish Passage Throughout Pools 20-26 of the Upper Mississippi River. 41st annual Mississippi River Research Consortium, LaCrosse WI, 30 April 2009. (Oral presentation by Tripp)

90. Sechler, D., Q. Phelps, and **J.E. Garvey**. Diet composition of young-of-year *Scaphirhynchus* sturgeon in the middle Mississippi River: Does foraging behavior change with season, macrohabitat and total length of fish? Meeting of the IL Chapter of the American Fisheries Society, Quad Cities, IL. March 2009. (Oral presentation by Sechler)

89. Calkins, H.A., and **J.E. Garvey**. Linking habitat use of silver carp to phytoplankton consumption in the Mississippi River. Meeting of the IL Chapter of the American Fisheries Society, Quad Cities, IL. March 2009. (Poster presentation)

88. Calkins, H.A., and **J.E. Garvey**. Movement, Habitat Use and Phytoplankton Consumption of Silver Carp in the Mississippi River. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation).

87. Tripp, S.J., Q.E. Phelps, D. Herzog, and **J.E. Garvey**. Habitat Use of Young-of-Year Pallid Sturgeon in the Middle Mississippi River. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation).

86. Ratterman, N., N. Wahl, Q.E. Phelps, and **J.E. Garvey**. Comparing Scale and Sagittal Otolith Back-Calculated Lengths at Age in Crappies. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation)

85. Seibert, J.R., Q.E. Phelps, S.J.Tripp, and **J.E. Garvey**. Seasonal Diet Composition of Adult Shovelnose Sturgeon in the Middle Mississippi River. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation)

84. Sechler, D.R., Q.E. Phelps, N.C. Wahl, and **J.E. Garvey**. Diet Composition of Young-of-Year Sturgeon in the Middle Mississippi River. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation)

83. Phelps, Q.E., S.J. Tripp, D. Herzog, and **J.E. Garvey**. Early life history of pallid sturgeon in the Middle Mississippi River. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Oral presentation by Phelps)

82. Wagner, C., M. Nannini, **J.Garvey**, and D. Wahl. Influence of fall condition and prey abundance on overwinter success of age 0 largemouth bass. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio, December 2008. (Poster presentation)

81. Phelps, Q., R. Colombo, **J.E. Garvey**, and R.C. Heidinger. Comparison of channel catfish age estimates and resulting population demographics using two common structures. American Fisheries Society Meeting, Ottawa, Canada, August 2008. (Poster presentation)

80. Sechler, D., Q. Phelps, and **J.E. Garvey**. Diet composition of juvenile shovelnose sturgeon in the Middle Mississippi River. American Fisheries Society Meeting, Ottawa, Canada, August 2008. (Poster presentation)

79. **Garvey, J.E.**, S.M. Bartell, and T. Keevin. Predicting local extinction of pallid sturgeon in the Mississippi River. American Fisheries Society Meeting, Ottawa, Canada, August 2008. (Oral presentation)

78. **Garvey J.E.** Asian carp in cyberspace. Illinois River Barrier Panel Meeting, Chicago, IL, June 2008. (Oral presentation)

77. **Garvey, J.E.** Searching for thresholds in spawner–recruit data. Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, Illinois, March 2008. (Oral presentation)

76. Phelps, Q.P., A.M. Lohmeyer, G.W. Whitledge, and **J.E. Garvey**. 2007. Black crappie nest site selection: habitat characteristics and anthropogenic influences in a small reservoir. Midwest Fish and Wildlife Conference, Madison, Wisconsin. December 2007. (Poster presentation).

75. **Brooks, R.**, J.E. Garvey, S.J. Tripp, M. Hill, T. Spier, D. Herzog, and R. Hrabik. Fish movement in the middle and upper Mississippi River. Midwest Fish and Wildlife Conference, Madison, Wisconsin. December 2007. (Oral presentation by Brooks).

74. Lohmeyer, A.M., and **J.E. Garvey**. Larval Asian Carp in the Upper and Middle Mississippi River: an index of establishment and dispersal potential. National meeting of the American Fisheries Society, San Francisco, CA. September 2007. (Poster presentation).

73. Phelps, Q.P., T.C. Allen, R.D. Davinroy, and **J.E. Garvey**. A laboratory examination of substrate, water depth, and light use at two water velocity levels by juvenile pallid and shovelnose sturgeon. National meeting of the American Fisheries Society, San Francisco, CA. September 2007. (Oral presentation by Phelps).

72. Lohmeyer, A.M., and **J.E. Garvey**. Larval Asian Carp in the Upper and Middle Mississippi River: an index of establishment and dispersal potential. Annual meeting of the IL Chapter of the American Fisheries Society, Findlay, Illinois. February 2007. (Oral presentation by Lohmeyer).

71. Tripp, S.J., R.C. Brooks, M. Hill, M. Mangan, T. Spier, D. Herzog, R. Hrabik, and **J.E. Garvey**. Fish movement in the Mississippi River. Annual meeting of the IL Chapter of the American Fisheries Society, Findlay, Illinois. February 2007. (Oral presentation by Tripp).

70. **Garvey, J.E.** and R.E. Colombo. Comparative stock assessment between the Wabash and Mississippi Rivers. Annual meeting of the IL Chapter of the American Fisheries Society, Findlay, Illinois. February 2007. (Oral presentation by Garvey).

69. DeVries, D.R., **J.E. Garvey**, and R.A. Wright. Searching for generality in centrarchid recruitment: a prescription for research. National Meeting of the American Fisheries Society, Lake Placid, New York. September 2006. (Oral presentation by DeVries).

68. Colombo, R.E., **J.E. Garvey**, and R.C. Brooks. Effect of harvest on demographics of sturgeon. National Meeting of the American Fisheries Society, Lake Placid, New York. September 2006. (Oral presentation by Colombo).

67. **Garvey, J.E.** Spatial reproductive patterns of Asian carp in the Illinois River and Upper Mississippi River. Habitat use of Asian carps in the Illinois River. Asian Carp Symposium, Peoria, Illinois. August 2006. (Oral presentation by Garvey).

66. DeGrandchamp, K.L., and **J.E. Garvey.** Habitat use of Asian carps in the Illinois River. Asian Carp Symposium, Peoria, Illinois. August 2006. (Oral presentation by DeGrandchamp).

65. **Garvey, J.E.** Spatial reproductive patterns of Asian carp in the Illinois River and Upper Mississippi River. Meeting of the Chicago Barrier Advisory Committee. (Oral presentation by Garvey).

64. Colombo, R.E., **J.E. Garvey**, and R.C. Brooks. Effect of harvest on demographics of sturgeon. Annual Meeting of the Mississippi River Research Committee, LaCrosse, Wisconsin. April 2006. (Oral presentation by Colombo; won best student paper).

63. DeGrandchamp, K.L., and **J.E. Garvey.** Habitat use of Asian carps in the Illinois River. Illinois Chapter of the American Fisheries Society Annual Meeting, Rend Lake, IL. March 2006. (Oral presentation by DeGrandchamp).

62. Tripp, S.J., **J.E. Garvey**, and R.C. Brooks. Reproductive status of shovelnose sturgeon in the Middle Mississippi River. Illinois Chapter of the American Fisheries Society Annual Meeting, Rend Lake, IL. March 2006. (Oral presentation by Tripp).

61. Colombo, R.E., **J.E. Garvey**, and R.C. Brooks. Effect of harvest on demographics of sturgeon. Illinois Chapter of the American Fisheries Society Annual Meeting, Rend Lake, IL. March 2006. (Oral presentation by Colombo).

60. DeGrandchamp, K., **J.E. Garvey**, and R. Brooks. Habitat use and movement patterns of Asian carp in the lower Illinois River. American Fisheries Society Annual Meeting, Anchorage, Alaska. Sept. 2005. (Oral presentation by DeGrandchamp).

59. Knuth, D. and **J.E. Garvey**. Effect of adult size and littoral habitat on larval sunfish production in unexploited lakes. American Fisheries Society Annual Meeting, Anchorage, Alaska. Sept. 2005. (Oral presentation by Knuth).

58. Colombo, R., **J.E. Garvey**, and R. Heidinger. Comparing the demographics of channel catfish populations from fished and un-fished regions of the Wabash River. American Fisheries Society Annual Meeting, Anchorage, Alaska. Sept. 2005. (Oral presentation by Colombo).

57. Csoboth, L., **J.E. Garvey**, and R. Brooks. Seasonal ichthyoplankton exchange between a restored backwater and a large river. American Fisheries Society Annual Meeting, Anchorage, Alaska. Sept. 2005. (Oral presentation by Csoboth).

56. Schultz, D., **J.E. Garvey**, K. DeGrandchamp, and L. Csoboth . Seasonal Fish Movement between the Illinois River and a Restored Backwater. American Fisheries Society Annual Meeting, Anchorage, Alaska. Sept. 2005. (Poster presentation by Schultz).

55. Csoboth, L., **J.E. Garvey**, and R. Brooks. Seasonal ichthyoplankton exchange between a restored backwater and a large river. 29th Annual Larval Fish Conference, Early Life History Section, American Fisheries Society, Barcelona, Spain. July 2005. (Oral presentation by Csoboth).

54. **Garvey, J.E.** Dynamics of shovelnose and pallid sturgeon in the Middle Mississippi River. River Resources Action Team Annual Meeting, June 2005. (Oral presentation by Garvey).

53. DeGrandchamp, K., **J.E. Garvey**, and R. Brooks. Habitat use and movement patterns of Asian carp in the lower Illinois River. Midwest Ecology and Evolution Conference, Carbondale, IL, March 2005. (Oral presentation by DeGrandchamp).

52. Colombo, R., **J.E. Garvey**, and R. Heidinger. Comparing the demographics of channel catfish populations from fished and un-fished regions of the Wabash River. Midwest Ecology and Evolution Conference, Carbondale, IL, March 2005. (Oral presentation by Colombo).

51. Knuth, D. and **J.E. Garvey**. Effect of adult size and littoral habitat on larval sunfish production in unexploited lakes. Midwest Ecology and Evolution Conference, Carbondale, IL, March 2005. (Oral presentation by Knuth).

50. Csoboth, L., **J.E. Garvey**, and R. Brooks. Seasonal ichthyoplankton exchange between a restored backwater and a large river. Illinois Chapter of the American Fisheries Society Meeting, Moline, Illinois, March 2005. (Oral presentation by Csoboth).

49. Colombo, R., **J.E. Garvey**, and R. Heidinger. Population dynamics of catfish in fished and unfished reaches of the Wabash River. Illinois Chapter of the American Fisheries Society Meeting, Moline, Illinois, March 2005. (Oral presentation by Colombo; won Best Paper Award).

48. Schultz, D., **J.E. Garvey**, K. DeGrandchamp, and L. Csoboth. Fish movement between the Illinois River and lower Swan Lake, an associated backwater. Illinois Chapter of the American Fisheries Society Meeting, Moline, Illinois, March 2005. (Oral presentation by Schultz).

47. DeGrandchamp, K., **J.E. Garvey**, and R. Brooks. Movement Patterns and Habitat Use of Bighead and Silver Carp in the Lower Illinois River. Illinois Chapter of the American Fisheries Society Meeting, Moline, Illinois, March 2005. (Oral presentation by DeGrandchamp).

46. Colombo, R., **J.E. Garvey**, and R. Heidinger. Population dynamics of catfish in the Wabash River. Midwest Fish and Wildlife Conference, Indianapolis, IN, December 2004. (Oral presentation by Colombo; 3rd Best Fisheries Student Presentation)

45. Braeutigam, B. and **J.E. Garvey**. Barge Passage Effects on Flow in Sheltered Fish Habitats Adjacent to the Main Channel. Midwest Fish and Wildlife Conference, Indianapolis, IN, December 2004. (Ohio River Symposium, Oral presentation by Braeutigam; invited)

44. **Garvey, J.E.**, B. Braeutigam, K. Emme, and A. Plauck. Relative Habitat Use of Fishes in Smithland Pool, Ohio River: Interactions between Abiotic Conditions and Winter Refuges. Midwest Fish and Wildlife Conference, Indianapolis, IN, December 2004. (Ohio River Symposium, Oral presentation; invited)

43. Koch, B., **J.E. Garvey**, and M.J. Lydy. Organochlorine accumulation in Middle Mississippi River shovelnose sturgeon: intersexuality and reproductive consequences. Society for Environmental Toxicology and Chemistry, Portland, Oregon, November 2004. (Poster by Koch)

42. Williamson, C., and **J.E. Garvey**. Growth and mortality of silver carp: implications for its rise to dominance in the Middle Mississippi River. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Oral presentation by Williamson)

41. Spier, T., **J.E. Garvey**, R. Heidinger, R.J. Sheehan, and R. Colombo. Pallid and shovelnose sturgeon movement and habitat usage in the Middle Mississippi River. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Poster presentation)

40. Sherman, D. and **J.E. Garvey**. Assessing how temperature and oxygen affect spatial distribution and potential interactions of hybrid striped bass in a power cooling lake. Office of Research Development and Administration, Research Enriched Academic Challenge (REACH) conference, Southern Illinois University Carbondale, 2004 (Poster presentation)

39. Koch, B., **J.E. Garvey**, and M.J. Lydy. Organochlorine accumulation in Middle Mississippi River shovelnose sturgeon: intersexuality and reproductive consequences. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Oral presentation by Koch)

38. Emme, K., A. Plauck, and **J.E. Garvey**. Seasonal habitat use and dynamics of centrarchids and catostomids in tributaries of the lower Ohio River. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Oral presentation by Emme)

37. Braeutigam, B., **J.E. Garvey**, and T. Spier. Barge passage effects on flow in sheltered fish habitats adjacent to the main channel. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Oral presentation by Braeutigam)

36. Schrey, A., R. Colombo, B. Sloss, and **J.E. Garvey**. Genetic and morphological investigation of shovelnose sturgeon from the Middle Mississippi and Wabash Rivers. American Fisheries Society Annual Meeting, Madison, Wisconsin, August 2004. (Oral presentation by Schrey)

35. Flinn, M.B., M.R. Whiles, S.R. Adams, and **J. E. Garvey**. Water level management and hydrologic disturbance gradients in backwaters of a Mississippi River navigation pool: responses of macroinvertebrates and benthic organic matter. Annual Mississippi River Research Committee Meeting, La Crosse, Wisconsin, March 2004. (Oral presentation by Flinn)

34. Emme, K.E., and **J.E. Garvey**. Movement of suckers in tributaries of the lower Ohio River. Annual Meeting of the North American Benthological Society, Vancouver, British Columbia, Canada, June 2004. (Poster presentation)

33. Colombo, R.E., **J.E. Garvey**, and P.S. Wills. A guide to the embryological development of the shovelnose sturgeon. Annual Meeting of the American Society of Ichthyologists and Herpetologists, Norman, Oklahoma, May 2004. (Poster presentation)

32. Sherman, D.M, **J.E. Garvey**, and A.T. Plauck. The spatial distribution of hybrid striped bass and its potential interactions with other species in a power plant lake. SIUC Undergraduate Research Symposium, March 2004. (Poster presentation; won Honorable Mention out of ~ 40 posters)

31. Williamson, C.J., and **J.E. Garvey**. Growth and mortality of silver carp: implications for its rise to dominance in the Middle Mississippi River. Illinois Chapter of the American Fisheries Society, Champaign, IL, March 2004. (Oral presentation by Williamson)

30. Koch, B.T., **J.E. Garvey**, and M. Lydy. The effects of land use on organochlorine accumulation in middle Mississippi River shovelnose sturgeon: intersexuality and reproductive consequences. Illinois Chapter of the American Fisheries Society, Champaign, IL, March 2004. (Oral presentation by Koch)

29. Csoboth, L.A., D.W. Schultz, K. DeGrandChamp, **J.E. Garvey**, and R.M. Neumann. Fish response at a backwater-river interchange: the Swan Lake rehabilitation and enhancement project. Illinois Chapter of the American Fisheries Society, Champaign, IL, March 2004. (Poster presentation)

28. Colombo, R.E., **J.E. Garvey**, and R.C. Heidinger. Comparing demographics of channel catfish in fished and un-fished reaches of the Wabash River. 64th Meeting of the Midwest Fish and Wildlife Conference. Kansas City, December 2003. (Oral presentation by Colombo)

27. Spier, T., **J.E. Garvey**, R.C. Heidinger, R.J. Sheehan, P. Wills, K. Hurley, R.E. Colombo, R.C. Brooks. Pallid and shovelnose sturgeon movement and habitat usage in the middle Mississippi River. 64th Meeting of the Midwest Fish and Wildlife Conference. Kansas City, December 2003 (Oral presentation by Spier)

26. Marschall, E.A., and **J.E. Garvey**. Understanding latitudinal trends in fish body size through models of optimal seasonal energy allocation. 88th Meeting of the Ecological Society of America, Savannah, Georgia, July 2003 (Oral presentation by Marschall)

25. Braeutigam, B.J., and **J.E. Garvey**. Winter habitat used by fish in Smithland Pool, Ohio River. Ohio River Research Review, Indiana, August 2003. (Oral presentation by Braeutigam)

24. **Garvey, J.E.** Importance of flood-plain connectivity to fish assemblages in the Mississippi River. Middle Mississippi River Workgroup Meeting, Carbondale, IL, June 2003. (Oral presentation by Garvey)

23. O'Neill, B.J., **J.E. Garvey**, M.R. Whiles, and K.R. Lips. Scale-dependent interrelationships among, fish, landscape characteristics, and ambystomatid salamanders in forest ponds. Annual Meeting of the American Society of Ichthyologists and Herpetologists, Manaus, Brazil, June 2003 (Oral presentation by O'Neill)

22. Spier, T., **J. Garvey**, R. Heidinger, R. Sheehan, P. Wills, and K. Hurley. Demographics and habitat usage of pallid sturgeon in the Middle Mississippi River. Meeting of the Illinois Chapter of American Fisheries Society, Rend Lake, IL, February 2003 (Oral presentation by Spier)

21. Jackson, N.D., **J.E. Garvey**, R.C. Heidinger, and R.J. Sheehan. Age and mortality of shovelnose sturgeon, *Scaphirhynchus platorynchus*, in the Middle Mississippi River and Lower Wabash Rivers, Illinois. Meeting of the Illinois Chapter of American Fisheries Society, Rend Lake, IL, February 2003 (Oral presentation by Jackson)

20. Flinn, M.B., S. R. Adams, M.R. Whiles, **J.E. Garvey**, B.M. Burr, and R.J. Sheehan. Fish and macroinvertebrate responses to environmental pool management in Mississippi River Pool 25. Meeting of the Illinois Chapter of American Fisheries Society, Rend Lake, IL, February 2003 (Oral presentation by Flinn)

19. Colombo, R.E., **J.E. Garvey**, R.C. Heidinger and R.J. Sheehan. Population demographics of channel catfish *Ictalurus punctatus* in the Wabash River. Meeting of the Illinois Chapter of American Fisheries Society, Rend Lake, IL, February 2003 (Oral presentation by Colombo)

18. **Garvey, J.E.** Early growth of centrarchids along a productivity gradient: setting the stage for future interactions. American Fisheries Society Meeting, Baltimore, MD, August 2002 (Oral presentation)

17. Ostrand, K.G., S.J. Cooke, **J.E. Garvey**, D.H. Wahl. Age-0 largemouth bass: the overwinter effects of prey type on growth and spring swimming performance. American Fisheries Society Meeting, Baltimore, MD, August 2002 (Oral presentation by Ostrand)

16. **Garvey, J.E.**, S.M. Micucci, R.A. Wright, and R.A. Stein. Prey assemblage structure during winter influences the condition of age-0 largemouth bass. Midwest Fish and Wildlife Meeting, Des Moines, IA, December 2001 (Oral presentation)

15. **Garvey, J.E.** Using optimal allocation models to explain latitudinal trends in recruitment of largemouth bass. Illinois Renewable Natural Resources Conference, Peoria, IL, February 2001 (Oral presentation; received Best Oral Presentation)

14. Bremigan, M.T., R.A. Stein, and **J.E. Garvey**. Variable gizzard shad recruitment and its effects along a reservoir productivity gradient. American Society of Limnology and Oceanography Meeting - Copenhagen, Denmark, June 2000 (Poster presentation).

13. Evans-White, M., W.K. Dodds, and **J.E. Garvey**. Crayfish biomass, growth, and production in a tallgrass prairie stream. North American Benthological Society Meeting, Colorado, May 2000 (Oral presentation by Dodds).

12. **Garvey, J.E.** Patterns of sportfish recruitment in natural lakes and reservoirs: do generalities exist? Kansas Chapter of the American Fisheries Society Meeting, February 2000 (Oral presentation; received Best Oral Presentation).

11. **Garvey, J.E.** From fish in lakes to crayfish in prairie streams: searching for general recruitment mechanisms and ecosystem consequences. KSU Ecology Research Seminar Series, November 1999 (Oral presentation).

10. **Garvey, J.E.**, T.P. Herra, and W.C. Leggett. Mechanisms underlying the spatial distribution of larval sunfish (*Lepomis* spp.) in Lake Opinicon, Ontario. American Fisheries Society Meeting - Charlotte, North Carolina, August 1999 (Oral presentation).

9. **Garvey, J.E.** Interactions between ecosystems and life histories: predicting fish community structure in lakes. Kansas EPSCoR Conference, Topeka, KS, April 1999 (Poster presentation).

8. **Garvey, J.E.** and E.A. Marschall. Using energy allocation patterns to explain latitudinal trends in largemouth bass recruitment. American Fisheries Society Meeting -Hartford, Connecticut, August, 1998 (Oral presentation).

7. **Garvey, J.E.** and R.A. Stein. Timing of larval appearance influences exploitative competition between age-0 gizzard shad and bluegill in reservoirs. American Fisheries Society Meeting - Monterey, California, August, 1997 (Oral presentation).

6. Wright, R.A., **J.E. Garvey**, A.H. Fullerton, and R.A. Stein. Evaluating winter energetics of age-0 largemouth bass: comparing models with experiments. American Fisheries Society Meeting - Monterey, California, August, 1997 (Oral presentation by Wright).

5. **Garvey, J.E.**, A.H. Fullerton, R.A. Wright, and R.A. Stein. 1996. Exploring interactions among winter temperature, food availability, and energetics of young-of-year largemouth bass. American Fisheries Society Meeting - Dearborn, Michigan (Poster presentation; received Best Poster).

4. Lodge, D.M., R.A. Stein, S.P. Klosiewski, K.M. Brown, A.P. Covich, C. Brönmark, and **J.E. Garvey**. 1995. Spatial and temporal scaling of the impact of exotic species: evidence from a multi-lake survey and multi-scale lake experiments. Symposium on "Spatial and Temporal Scaling of Ecological Processes", Monash University, Australia. (Oral presentation by Lodge).

3. **Garvey, J.E.**, A.H. Fullerton, R.A. Wright, and R.A. Stein. 1995. How variation in latitudinal temperatures influences size-selective overwinter survival in young-of-year (YOY) largemouth bass. American Fisheries Society Meeting - Tampa, Florida (Oral presentation; received an Honorable Mention).

2. **Garvey, J.E.**, N.A. Dingledine, N.S. Donovan, and R.A. Stein. 1993. Indirect effects of limnetic competition among prey on a littoral predator. Ecological Society of America Meeting - Madison, Wisconsin. ESA Bulletin 74:245 (Oral presentation).

1. **Garvey, J.E.**, R.A. Stein, and H.M. Thomas. 1992. Selective predation as a mechanism of crayfish species replacement in northern Wisconsin lakes. North American Benthological Society Meeting - Louisville, Kentucky. NABS Bulletin 9:88 (Oral presentation).

<u>Hosted Speakers at Department of Zoology, Southern Illinois University</u>

2008 Dr. Stuart Ludsin, The Ohio State University, Spring

2006 Dr. David Lodge, University of Notre Dame, Spring

2006 Dr. Roy Stein, The Ohio State University, Spring

2001 Dr. Bill Perry, Illinois State University, Fall

2000 Dr. Mary Bremigan, Michigan State University, Fall

Workshops and Miscellaneous Activities

2009-	List moderator, sturgeon inter-basin communication mailing list (> 150 participants), STURGEON-L@siu.edu
2009	Invited judge, Illinois Junior Science and Humanities Symposium oral presentations, March 2009 at SIUC
2009	Interviewed, Heartland News (local television), fisheries interaction with SIUC Child Development Laboratory, February 2009
2008-	Adviser, SIUC Student Subunit of the American Fisheries Society
2008	Interviewed by Southeastern Missourian newspaper on pallid sturgeon telemetry
2007-	Webmaster & LAN Administrator, SIUC Fisheries and Illinois Aquaculture Center
2007	Interviewed on WSIU Radio for piece on conservation genetics and sturgeon, November 2007
2007	Invited participant, Research Needs and Management Strategies for Pallid Sturgeon Recovery, St. Louis, MO. Hosted by Ruckelshaus Institute; July 31-August 2
2007	Participant, BioSonics hydroacoustics workshop, Seattle, WA, January 22-27
2006	Interviewed on Marketplace, nationally syndicated radio show
2006	Research featured on the SIUC Media Communications and Southern Spotlights outlets
2005	Participant, multi-state shovelnose sturgeon regulation meeting (invited), Cape Girardeau, Missouri, April 2005
2004-2006	Technical consultant, four hearings before the Illinois Pollution Control Board, produced numerous reports and exhibits
2004-	List-serve manager, Student Subunit of American Fisheries Society, SIUC, SIUAFS-L@siu.edu
2004	Consultant, development of new dissolved oxygen criteria for Illinois surface waters, Illinois Association of Wastewater Agencies
2004	Multi-state shovelnose sturgeon regulation meeting (invited), Cape Girardeau, Missouri, January 2004
2003	Contributor, SIUC Ecology Consortium, Reasonable and Moderate Extension document for Center status

2003	Participant, River Research Action Team (RRAT) workgroup, Middle Mississippi River, spring 2003
2003	Participant, Species Viability workshop-Hoosier National Forest, March 2003
2002	Leader, Development of the Fisheries and Illinois Aquaculture Center's contribution to SIUC Collaborative Ecosystem Study Unit proposal, spring 2002
2001	Consultant, Hydrological assessment of Shawnee and Hoosier National Forests
2001	Participant, Workshop on the Qualitative Habitat Evaluation Index, Ohio EPA, Aug. 1-2, 2001
2000	Participant, SIU Department of Zoology, Population Biology Seminar, Fall Semester
1999	Participant, Konza Prairie Research Natural Area Burning Workshop, spring 1999
1999-2000	Member, Kansas Amphibian Monitoring Project
1999	Learning styles and active learning: making the connection, Kansas State University
1998-2001	Participant, NSF-funded watershed project in Ohio, 1998-2001. Collaborators include M. Vanni, R. Stein, M. Bremigan, P. Soranno, M. Gonzalez

DR. LARRY J. WEBER
-Resume-

Present Position and Address

Professor, IIHR- Hydroscience & Engineering (IIHR)
Department of Civil and Environmental Engineering
The University of Iowa, Iowa City, Iowa 52242
Tel: [319]-335-5597 (O); Fax (319) 335-5238
e-mail: larry-weber@uiowa.edu
Internet site: http: www.iihr.uiowa.edu

Professional Preparation

- Undergraduate, Civil and Environmental Engineering, University of Iowa, 1989
- M.S. Civil and Environmental Engineering, University of Iowa, 1990
- Ph.D. Civil and Environmental Engineering, University of Iowa, 1993

Appointments

- Director, IIHR – Hydroscience and Engineering, The University of Iowa, May 2004 – present
- Associate Professor, Department of Civil and Environmental Engineering, The University of Iowa, Aug. 2001to Present
- Assistant Professor, Department of Civil and Environmental Engineering, The University of Iowa, Aug. 1996 to Aug. 2001
- Research Engineer, IIHR Hydroscience and Engineering, The University of Iowa, Jan. 1993 to Aug. 1996

Publications

- Den Bleyker, J.S., Weber, L.J. and Odgaard, A.J., "Development of a Flow Spreader for Fish Bypass Outfalls", North American Journal of Fisheries Management. Vol. 17, No. 3, August, 1997.
- Sinha, S.K., Weber, L.J. and Odgaard, A.J., "Using Computational Tools to Enhance Fish Bypass", HydroReview, Vol. 18, No. 1, February, 1999.
- Meselhe, E.A., Weber, L.J., Odgaard, A.J., and Johnson, T., "Numerical Modeling for Fish Diversion Studies", Journal of Hydraulic Engineering, ASCE, Vol. 126, No. 5, May, 2000.
- Muste, M., Meselhe, E.A., Weber, L.J., and Bradley, A.A., "Coupled Physical-Numerical Analysis of Flows in Natural Waterways", Journal of Hydraulic Research, IAHR, Vol. 39, No. 1, January 2001.
- Weber, L.J., Shumate, E.D. and Mawer, "Experimental on Flow at a 90° Open-Channel Junction ", Journal of Hydraulic Engineering, ASCE, Vol. 127, No. 5, May 2001.
- Huang, J., Weber, L.J. and Lai, Y.G., "Three-Dimensional Numerical Simulation of Flow in an Open-Channel Junction", Journal of Hydraulic Engineering, ASCE, Vol. 128, No. 3, March 2002.
- Lai, Y.G., Weber, L.J., and Patel, V.C., "A Non-hydrostatic Three-Dimensional Model for Hydraulic Flow Simulation – Part I: Formulation and Verification," Journal of Hydraulic Engineering, ASCE, Vol. 129, No. 3, March 2003, pp 196-205.
- Lai, Y.G., Weber, L.J., and Patel, V.C., "A Non-hydrostatic Three-Dimensional Model for Hydraulic Flow Simulation – Part II: Validation and Application," Journal of Hydraulic Engineering, ASCE, Vol. 129, No. 3, March 2003, pp 206-214.

Synergistic Activities

In recent research activities, my student and I have focused on numerous physical and numerical model studies relative to environmental river engineering on the Snake and Columbia Rivers. We have become known as leading experts in the field of modeling and design of fish passage facilities. In particular, the numerical model developed through this work, U2RANS, has continually met the challenges of application to innovative designs for juvenile passage. This model has led the field of numerical modeling of fish passage facilities and continues to set the standard for cost effectiveness and scientific complexity. U2RANS is the only model directly linked with an ecological model with behavioral tracking algorithms for simulating salmonid responses to their local hydrodynamic field. This work has been funded by the US Army Corps of Engineers, public power utilities and private power utilities.

Collaborators & Other Affiliations

(i) Collaborators

Dr. John Nestler, US Army Corps of Engineers, ERDC, Vicksburg, Mississippi

(ii) Graduate and Post Doctoral Advisors

Dr. Wilfrid Nixon, The University of Iowa

(iii) Thesis Advisor and Postgraduate-Scholar Sponsor

4 Ph.D. Students:
Dr. Yenory Morales Chaves, Delft Hydraulics
Dr. Kevin Nielsen, Carrol College of Helena Montana
Dr. Heqing Huang, University of South Carolina
Dr. Jianchun Huang, US Bureau of Reclamation
Dr. Huei Tau Oyang, Taiwan

14 M.S. Students

Curriculum Vitae

ROBB F. LEARY
SSN 040 54 5020

Montana Fish, Wildlife & Parks
Division of Biological Sciences
University of Montana
Missoula, Montana 59812

Phone (406) 243-6725
Fax (406) 243-4184
E-mail robb.leary@mso.umt.edu

Birth: April 11, 1955 Hartford, Connecticut

Education:

B.S. Natural Resources-Fisheries Biology, University of Massachusetts-Amherst, May, 1977
M.S. Natural Resources-Fisheries Biology, University of Wisconsin-Stevens Point, December 1979
Ph.D. Zoology, University of Montana-Missoula, December 1986

Research Interests: Evolutionary Genetics, Conservation Biology, and Fisheries Biology

Positions: Research specialist in the University of Montana Conservation Genetics Laboratory February 1984 to October 2005.

Fish Conservation Geneticist for Montana Fish, Wildlife & Parks October 2005 to Present.

Honors: 1984 Theodius Dobzhansky Prize awarded by the Society for the Study of Evolution.

Professional Services:

Montana Arctic Grayling Restoration Committee 1989-present
Montana Bull Trout Restoration Committee 1995-present
Montana Cutthroat Trout Technical Committee 1996-present

Societies:

American Fisheries Society
Genetics Society of America
Society for Conservation Biology
Society for Molecular Biology and Evolution
Society for the Study of Evolution

Teaching Experience:

Since 1992 I have conducted over 20 week long Fish Genetics courses for the United States Fish and Wildlife Service's National Conservation Training Center. The course covers the basics of genetics and population genetics and evolution, discusses various biochemical genetics techniques for the collection of population genetic data, the strengths and weaknesses of these techniques in terms of addressing particular issues, and finally discusses the usefulness of the data in terms of the management and conservation of wild and captive fish populations. Upon completion of the course, participants are eligible for two semester hours of undergraduate college credit.

For performance evaluation contact:

June McIlwain
United States Fish and Wildlife Service
National Conservation Training Center
698 Conservation Way, Room 220 IW
Shepherdstown, West Virginia 25443

Phone: (304) 876-7439
Fax: (304) 876-7225
E-mail: june-mcilwain@fws.gov

Peer Reviewed Publications:

Imhof, M., R. Leary, and H. E. Booke. 1980. Population or stock structure of lake whitefish, *Coregonus clupeaformis*, in northern Lake Michigan as assessed by isozyme electrophoresis. Canadian Journal of Fisheries and Aquatic Sciences: 37:783-793.

Leary, R., and H. E. Booke. 1982. Genetic stock analysis of yellow perch from Green Bay and Lake Michigan. Transactions of the American Fisheries Society 111:52-57.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1983. Developmental stability and enzyme heterozygosity in rainbow trout. Nature 301:71-72.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1983. Consistently high meristic counts in natural hybrids between brook trout and bull trout. Systematic Zoology 32:369-376.

Allendorf , F. W., K. L. Knudsen, and R. F. Leary. 1983. Adaptive significance of differences in the tissue-specific expression of a phosphoglucomutase gene in rainbow trout. Proceedings National Academy of Sciences USA 80:1397-1400.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1984. Superior developmental stability of heterozygotes at enzyme loci in salmonid fishes. American Naturalist 124:540-551.

Allendorf, F. W., and R. F. Leary. 1984. Heterozygosity in gynogenetic diploids and triploids estimated by gene-centromere recombination rates. Aquaculture 43:413-420.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1984. Major morphological effects of a regulatory gene: *Pgm1-t* in rainbow trout. Molecular Biology and Evolution: 1:183-194.

Leary, R. F., F. W. Allendorf, S. R. Phelps, and K. L. Knudsen. 1984. Introgression between westslope cutthroat trout and rainbow trout in the Clark Fork River drainage, Montana. Proceedings Montana Academy of Sciences 43:1-18.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1985. Developmental instability and high meristic counts in interspecific hybrids of salmonid fishes. Evolution 39:1318-1326.

Gyllensten, U., R. F. Leary, F. W. Allendorf, and A. C. Wilson. 1985. Introgression between two cutthroat trout subspecies with substantial karyotypic, nuclear, and mitochondrial genomic divergence. Genetics 111:905-915.

Leary, R. F., F. W. Allendorf, K. L. Knudsen, and G. H. Thorgaard. 1985. Heterozygosity and developmental stability in gynogenetic diploid and triploid rainbow trout. Heredity 54:219-225.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1985. Developmental instability as an indicator of reduced genetic variation in hatchery trout. Transactions of the American Fisheries Society 114:230-235.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1985. Inheritance of meristic variation and the evolution of developmental stability in rainbow trout. Evolution 39:308-314.

Allendorf, F. W., and R. F. Leary. 1986. Heterozygosity and fitness in natural populations of animals. Pages 57-76 in M. E. Soule, editor. Conservation Biology: The Science of Scarcity and Diversity, Sinauer Associates, Inc.

Allendorf, F. W., J. E. Seeb, K. L. Knudsen, G. H. Thorgaard, and R. F. Leary. 1986. Gene-centromere mapping of 25 loci in rainbow trout. Journal of Heredity 77:307-312.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1987. Differences in inbreeding coefficients do not explain the association between heterozygosity at allozyme loci and developmental stability in rainbow trout. Evolution 41:1413-1415.

Leary, R. F., F. W. Allendorf, S. R. Phelps, and K. L. Knudsen. 1987. Genetic divergence and identification of seven cutthroat trout subspecies and rainbow trout. Transactions of the American Fisheries Society 16:580-587.

Leary, R. F., F. W. Allendorf, S. R. Phelps, and K. L. Knudsen. 1988. Population genetic structure of westslope cutthroat trout: genetic variation within and between populations. Proceedings Montana Academy of Sciences 48:57-70.

Allendorf, F. W., and R. F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology 2:170-184.

Lesica, P., R. F. Leary, F. W. Allendorf, and D. E. Bilderback. 1988. Lack of genetic diversity within and among populations of an endangered plant, *Howellia aquatilus*. Conservation Biology 2:275-282.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1989. Genetic differences among rainbow trout spawned on different days within a single season. Progressive Fish-Culturist 51:10-19.

Leary, R. F., and F. W. Allendorf. 1989. Fluctuating asymmetry as an indicator of stress: implications for conservation biology. Trends in Ecology and Evolution 4:214-217.

Leary, R. F., and H. E. Booke. 1990. Starch gel electrophoresis and species distinctions. Pages 141-170 in C. B. Schreck and P. B. Moyle, editors. Methods for Fish Biology. American Fisheries Society.

Leary, R. F., and J. E. Peterson. 1990. Effects of water-hardening eggs in a betadine or erythromycin solution on hatching success, development, and genetic characteristics of rainbow trout. Progressive Fish-Culturist 52:83-87.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1991. Effects of rearing density on meristics and developmental stability of rainbow trout. Copeia 1991:44-49.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1992. Genetic, environmental, and developmental causes of meristic variation in rainbow trout. Acta Zoologica Fennica 191:79-95.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1993. Null alleles at two lactate dehydrogenase loci in rainbow trout are associated with decreased developmental stability. Genetica 89:3-13.

Leary, R. F., F. W. Allendorf, and S. H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath river drainages. Conservation Biology 7:856-865.

Leary, R. F., F. W. Allendorf, and G. K. Sage. 1995. Hybridization and introgression between introduced and native fish. American Fisheries Society Symposium 15: 91-101.

Williams, R. N., D. K. Shiozawa, J. E. Carter, and R. F. Leary. 1996. Genetic detection of putative hybridization between native and introduced rainbow trout populations of the upper Snake River. Transactions of the American Fisheries Society 125:387-401.

Leary, R. F., W. R. Gould, and G. K. Sage. 1996. Success of basibranchial teeth in indicating pure populations of rainbow trout and failure to indicate pure populations of westslope cutthroat trout. North American Journal of Fisheries Management 16: 210-213.

Leary, R. F., and F. W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Transactions of the American Fisheries Society 126:715-720.

Kanda, N., R. F. Leary, and F. W. Allendorf. 1997. Population genetic structure of bull trout in the upper Flathead River drainage. Pages 299-308 in W. C. MacKay, M. K. Brewin, and M. Monita, editors. Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Williams, R. N., R. F. Leary, and K. P. Currens. 1997. Localized genetic effects of a long-term stocking program on resident rainbow trout in the Metolius River, Oregon. North American Journal of Fisheries Management 17:1079-1093.

Allendorf, F. W., R. F. Leary, P. Spruell, and J. K. Wenberg. 2001. The problems with hybrids: setting conservation guidelines. Trends in Ecology and Evolution 16: 613-622.

Kanda, N., R. F. Leary, P. Spruell, and F. W. Allendorf. 2002. Molecular genetic markers identifying hybridization between Colorado River-greenback cutthroat trout complex and Yellowstone cutthroat trout or rainbow trout. Transactions of the American Fisheries Society 131:312-319.

Kanda, N., R. F. Leary, and F. W. Allendorf. 2002. Evidence of introgressive hybridization between bull trout and brook trout. Transactions of the American Fisheries Society 131:772-782.

Knudsen, K. L., C. C. Muhlfeld, G. K. Sage, and R. F. Leary. 2002. Genetic structure of Columbia River redband trout populations in the Kootenai River drainage, Montana, revealed by microsatellite and allozyme loci. Transactions of the American Fisheries Society 131:1093-1105.

Allendorf, F. W., R. F. Leary, N. P. Hitt, K. L. Knudsen, L. L. Lundquist, and P. Spruell. 2004. Intercrosses and the U.S. Endangered Species Act: should hybridized populations of westslope cutthroat trout be included as westslope cutthroat trout? Conservation Biology 18:1203-1213.

Allendorf, F. W., R. F. Leary, N.P. Hitt, K. L. Knudsen, M. L. Boyer, and P. Spruell. 2005. Cutthroat trout hybridization and the U. S. Endangered Species Act: One species, two policies. Conservation Biology 19:1326-1328.

Brunelli, J. P., G. H. Thorgaard, R. F. Leary, and J. L. Dunnigan. 2008. Single-nucleotide polymorphisms associated with allozyme differences between inland and coastal rainbow trout. Transactions of the American Fisheries Society 137:1292-1298.

George J. Cairo, P.E.

GEORGE CAIRO ENGINEERING, INC. - Principal Engineer

Civil/Agricultural Engineering, Water Resources, & Conveyance Design

Education

M.S., 1994, Agricultural and Biosystems Engineering, University of Arizona
B.S., 1992, Agricultural and Biosystems Engineering, University of Arizona
A.S., 1991, Engineering Sciences, Pima College

Professional Registrations

Arizona: Registered Civil Engineer No. 35878

Distinguishing Qualifications

- Extensive Indian Client experience, including engineering services to the Gila River Indian Community (GRIC) on the Pima-Maricopa Irrigation Project (P-MIP), GRIC Tribal Projects, Salt-River Pima Maricopa Indian Community (SRPMIC), Colorado River Indian Tribes (CRIT), and the Tohono O'odham Nation for the Tohono O'odham Farming Authority (TOFA)
- Founder and Principal Engineer of GEORGE CAIRO ENGINEERING, INC.
- Founder and President of CAIRO CANAL SOLUTIONS, LLC.
- Expertise in irrigation systems and water resources planning, design, construction and management
- University of Arizona College of Engineering Alumni Association 2006 Professional Achievement Award for prominence in the field of Agricultural and Water Resources Engineering
- Design engineer for a Phoenix water resources project that received the American Consulting Engineers Council Grand Award
- Design engineer for a California water resources project that received the Clair A. Hill Award for Excellence by the Association of California Water Agencies (ACWA)
- United States Committee on Irrigation and Drainage (USCID) – Board Member (2 Term)
- 2002 American Society of Agricultural Engineers (ASAE) – Arizona State Section Chair
- Southwest Indian Agricultural Association (SWIAA) – Corporate Board Member (2 Term)
- GCE Firm Wide Client Service, Marketing and Business Development Manager
- American Academy of Water Resources Engineering (AAWRE) – Diplomat Water Resources Engineering
- University of Arizona Agricultural & Biosystems Engineering Advisory Committee Member
- University of Arizona Hispanic Alumni Association – Board Member
- MPS CTE Biotechnology Advisory Board – Board Member
- Authored and Co-authored several publications on agricultural engineering, irrigation, and water resources topics

George J. Cairo, P.E., Principal Engineer

Relevant Experience

Mr. Cairo is a Principal and co-founder of GEORGE-CAIRO ENGINEERING, INC. (GCE) and he has more than eighteen years of experience in agricultural engineering and conveyance design. He is responsible for the daily operations of the GCE Central Arizona Office and the Imperial Valley Office as well as providing project/design management and engineering support as a member of multidiscipline teams on a variety of water resources, capital improvement, and conveyance projects. He has extensive experience in irrigation systems planning, design and operations, water resources engineering, supply and demand analyses, municipal and irrigation water conveyance and distribution, recharge, and water conservation. Furthermore, he has expertise in open channel design, hydraulic structures, flow measurement, HEC-RAS steady, and unsteady state hydraulic modeling, irrigation reservoirs, and agricultural water quality. As a principal engineer he is also responsible for quality control and quality assurance reviews of all GCE Central Arizona and Imperial Valley project deliverables as well as development of firm design standards.

Representative Projects

Water Resource Engineering Representative Projects

- **San Carlos Irrigation and Drainage District (SCIDD) - Ashurst-Hayden Diversion Dam Head Works Rehabilitation and Florence-Casa Grande Canal Settling Basin Construction, Florence, AZ.** Mr. Cairo is a senior participant in a team design for rehabilitating an 88 year old, 9 bay, head works structure and design of a 1,800 foot settling basin. GCE was responsible for designing and calculating the hydraulics through the structure, canal, settling basin, and over a 160 ft long weir. We helped prepare specifications, design and constructability reviews, alignment layouts, and supported project coordination. GCE also lead the efforts in land acquisition of over 200 acres and coordinated an MOU between the Bureau of Indian Affairs, Bureau of Reclamation, San Carlos Irrigation Project, and San Carlos Irrigation and Drainage District. GCE supported consultants with evaluation and drafting of the Environmental Assessment and the Class III (Intensive) Cultural Report. Processed a draft Jurisdictional Delineation with Army Corp of Engineers and completed a Nationwide Permit for the planned construction within the waterways of the United States.

- **Haydon Building Corporation – City of Mesa CAP Turnout – Temporary Cofferdam Design, Maricopa County, AZ.** As Project Manager Mr. Cairo lead the structural design and hydraulic modeling used for the hydraulic analysis of the final design of a temporary steel cofferdam structure to be placed within Reach 2 of the Central Arizona Project (CAP) Canal for the installation of the New Mesa South Turnout. The cofferdam is required to isolate the area of the proposed new Mesa South Turnout so the construction can take place while the CAP canal remains in service to maintain the required flow of 950 cfs. The hydraulic modeling of the CAP canal was performed using the US Army Corp's Hydrologic Engineering Centers River Analysis System (HEC-RAS) version 4.0 software. An existing model of the CAP's Reach 2 was created and validated. Afterwards, the temporary cofferdam design concept was modeled to determine the hydraulic effects it would have on the contracted section, as well as the entire reach. Hydraulic flow regime data from the model was used in the structural design of the cofferdam which utilized steel plates, bracing and neoprene seats for seating on the lining.

- **Salt River Project (SRP) - Hydrologic Engineering Services for the Pinal Central-ABLE 500kv T/L Electric Transmission Pole Foundations.** As Project Manager Mr. Cairo lead the hydrologic engineering services in support of design of new drilled pier reinforced concrete foundations within and along the flood plain of the Gila River near Florence, Arizona. The scope included complete field topographic surveys and the preparation of an existing and future conditions HEC-RAS hydraulic model for use in determining hydraulic parameters along the Gila River. The hydraulic model incorporated the topographic changes expected as the result of the two sand and gravel mining operations in the vicinity of the proposed transmission poles. The 500-year, 100-year, and 25-year flow events were modeled. The work included an engineering geomorphic analysis, with the primary emphasis on estimating lateral bank erosion and in-channel scour potential along the study reach of the Gila River. All findings of the fast tracked project and recommendations were summarized in a report for SRP.

George J. Cairo, P.E., Principal Engineer

- **Program Coordinating Committee (PCC) - Imperial Irrigation District Reservoir Bathometric Surveys and Sediment Quantity Estimates, Imperial, CA.** As Project Manager lead the bathometric surveys and sediment removal evaluations of the six PCC reservoirs located within the IID service area and encompassing about 236 surface acres. This work was needed to minimize spillage and maintain operational capacities and flexibility in the lateral interceptor systems. GCE used an Odom Hydrotrac single frequency portable hydrographic Echo Sounder coupled with a GPS unit to perform the bathometric surveys. GCE generated a ½ foot contour interval map of each reservoir and estimated sediment removal requirements. Sediment removal alternatives were evaluated taking into consideration operational requirements of the reservoirs. All findings and recommendations were summarized in a report and presented to the PCC.

- **Imperial Irrigation District (IID) – Quantification Settlement Agreement (QSA) Efficiency Conservation Definite Plan, Imperial, CA.** Mr. Cairo as part of a Team of Irrigation Industry Leading Professionals worked on the IID QSA Efficiency Conservation Definite Plan (Plan). The Plan is required for the IID, its growers and landowners to develop substantial amounts of conserved water for transfer to the San Diego County Water Authority and the Coachella Valley Water District for a term of 45 years, renewable to 75 years. The projects needed to achieve improved system and On-farm efficiency will require certain levels of service and delivery flexibility. These envisioned improvements include lateral interceptors, canal concrete lining, pipelining, long crested weirs, mid-lateral reservoirs, seepage interceptors, tail water recovery systems and pump back systems as part of the program. Mr. Cairo and GCE were responsible for all construction unit cost estimate data used for system analysis and modeling efforts to develop the Plan as well as construction cost estimating in support of this complex project. Further all project demonstration irrigation improvement facilities were designed by GCE under the direction of Mr. Cairo.

- **Barioni Lakes Development Project – Constructed Lake Design, Imperial, CA.** As Project Principal is currently leading the conceptual and final design of several constructed multiuse lakes as part of the 1,700 acre Barioni Lakes Development. The lake design will incorporate raw water inflows from the Imperial Irrigation District (IID) and will be used to irrigate the retention basin and open space landscape areas. The lakes will provide flows to a project wide pressurized irrigation system and will serve as an emergency outfall for the storm retention system. Edge treatments, aesthetics, and operations and maintenance features were provided in the design. Hydraulic, drainage studies and water supply as well as use analysis were conducted including the study of multiple IID canals and drains as part of several conveyance options in support of permitting requirements.

- **Gila River "Verde Pit": Sand and Gravel Mining Operations Permitting, Buckeye, AZ.** Under his direction as Project Manager GCE staff performed data collection and coordination efforts, site visits, hydraulic modeling using HEC-RAS, sediment-transport analysis, and pit-scour analysis for the proposed 180 acres, 100' depth "Verde Pit". Mr. Cairo helped prepare the conceptual and final mining design site plans, reclamation plans and a summary report required for the application and subsequent obtaining of a Floodplain Use Permit. Design elements included the perimeter flood protection berm and including layout and geometry and scour protection with state of the art launching rip-rap design. Mr. Cairo also helped provide ongoing Project Administration and coordination with client and the Maricopa County Flood Control District and the ultimate contractor of the sand and gravel mining facilities.

- **CAWCD – Lower Santa Cruz River Effluent Diversion Feasibility Study, Tucson, AZ.** As Project Manager Mr. Cairo is lead the study for the Central Arizona Project (CAP, CAWCD). The scope included a feasibility study for the diversion and conveyance of effluent from the Lower Santa Cruz River for off-channel groundwater recharge. The feasibility study included the development of conceptual level design alternatives for a river diversion including an infiltration gallery versus surface diversion concepts; feasibility analysis of gravity and pumped conveyance systems; and preparation of construction cost estimates for comparison of alternatives. Alternatives were evaluated with the use of a Decision Support Matrix due to the complexity of issues. Project elements included sediment management and flow measurement considerations as well as existing system

integration. As part of the study an assessment of river channel scour and potential lateral migration were determined and results incorporated into the preliminary design concepts. The Lower Santa Cruz Replenishment Project (LSCRP) was jointly developed by CAWCD and the Pima County Flood Control District. The LSCRP is a Constructed Underground Storage Facility permitted by State Law to recharge 50,000 acre-feet annually of CAP water. The LSCRP has been in operation continuously since June 2000 and stores approximately 40,000 acre-feet of water diverted from the CAP aqueduct each year.

- **New River Task Force (Task Force) and Imperial Irrigation District (IID) – Finney-Ramer Wetland Site Alamo River Drop Structure Design, Imperial Valley, CA.** As Project Manager lead the feasibility analysis and preliminary design for a river diversion and drop structure to be constructed within the Alamo River in Imperial County, California. The purpose of the Drop Structure is to raise the water elevation of the river by approximately 5-feet in order to convey water from the Alamo River into the proposed Finney-Ramer Wetland located adjacent to the River. Key project issues included coordination with CALTRANS to determine upstream bridge impacts and requirements, analysis and design of a gravity conveyance channel or pipeline from the drop structure to the wetlands, preliminary design of the Alamo River drop structure, environmental compliance investigation, investigation of historic flows, constructability analysis, and survey and topographic mapping for the project design.

- **New River Task Force (Task Force) and Imperial Irrigation District (IID) – NR 19 Constructed Wetland Conceptual and Final Design, Imperial Valley, CA.** As Project Manager lead the conceptual and final design for the NR19 Imperial constructed wetlands. The project wetlands system is located on a 104-acre parcel of land that straddles the New River downstream to the existing Imperial Site. The primary function of the wetland is to improve the water quality of the New River, which is currently a combined product of municipal, industrial and agricultural drainage from south of the International Border and local agricultural drainage. The wetlands consist of two separate systems a 60 acre north site and 40 acre south site which straddle the New River and operate independently of each other. Major elements of the work include sediments basins, multiple treatment cells, hydraulic control and flow measurement structures. Design criteria include earthwork balancing on-site, operational flexibility and low maintenance concepts.

- **Gila River Indian Community (GRIC) – Retention Basin Parks, Tribal Projects Development, AZ. As** Project Manager lead the preliminary and final design of five (5) retention basin parks for new GRIC Community subdivisions. Park amenities include basketball courts, ramadas, picnic tables; children's play equipment, sidewalks, and paths. A drainage impact analysis was included in the scope of work.

- **Paradyne Corporation - Eyherabidi Dairy Waste Management System, Litchfield Park, AZ.** Project Manager for the design of this state of the art waste management system. The system design included taking the waste stream from the dairy milk parlor and using polymer injection, a flocculation tank, clarifier unit, aeration tank, and specialty imported belt filter press to separate solids and treat the waste stream. Design elements included a dual cell HDPE lined effluent storage pond. Gated concrete flow control structures, conveyance pipelines and appurtenances. Through the use of a reuse tank and the designed effluent storage ponds processed flows will be used for irrigation of alfalfa fields.

- **Tohono O'odham Farming Authority (TOFA) - Water Management Plans, Tohono O'odham Nation, AZ.** Project Manager, lead the effort to develop jointly with the Nation, TOFA, and other relevant stakeholders state of the art Water Management Plans for the Papago (3,600 acres), Shuk Toak (2,100 acres), San Lucy (2,700) acres, and Vaiva Vo (2,060 acres) TOFA farming operations. These water management plans include a summary of data collection activities, farm level water budgets, water management and conservation measures, legal and institutional considerations, water resources inventories, soils and crop information, water rights, assessment of on-farm operations, and recommended water management measures.

- **Tohono O'odham Farming Authority (TOFA) - Papago Farm Expansion and Redevelopment Feasibility Study, Tohono O'odham Nation, AZ.** Project Manager, lead the study for the redevelopment and expansion of

the Papago Tribal Farm. The goal of the study is to assist TOFA in creating an Indian owned and operated agricultural enterprise that creates economic and social opportunities in the Chukut-Kuk District of the Nation, a district where few employment opportunities currently exist. The scope is multidisciplinary and broad based considering the agricultural engineering, agricultural economics, and agronomy and soil science disciplines.

- **Tucson Water – Roger Road Recharge Phase III and Sweetwater Recharge Facilities Modifications, Tucson, AZ.** As Design Manager was responsible for the preliminary and final design of Tucson Waters' Basin 9 recharge expansion site, including the 12 acre basin, 32 inch to 20 inch HDPE site conveyance piping, discharge orifice plate flow regulators, 3 concrete baffled outlet discharge structures, above grade Flow Meter and MOV stations, about 2,000 linear feet of reinforced concrete drainage channel, earthwork analysis and design, access roadway, landscaping, extraction well piping, above grade chlorine contact basin discharge piping, and miscellaneous existing system modifications.

- **Frito-Lay - Wind Drift Analysis, Casa Grande, AZ.** As Lead Project Engineer, assisted Frito-Lay in completion of their ADEQ application for approval to construct wastewater disposal facilities. Performed a computational theoretical wind drift analysis on four center pivot sprinkler systems used to apply process potato wash water on agricultural lands to verify regulatory compliance of the system.

- **Tehama Colusa Canal Authority – Fish Passage Improvement Project at the Red Bluff Diversion Dam, Willows, CA.** Provided planning support and senior review for the Tehama Colusa Canal Authority (TCCA) irrigation districts water demand model developed for integration into the fish passage and agricultural water delivery reliability analysis, as part of the TCCA Phase II Fish Passage Improvement Project. Cropping patterns, historical and present water use, future agricultural practices and potential changes to the current river diversion schedule were considered. A special challenge was the different operational practices and data of the TCCA member District's.

- **CALFED - Agricultural Water Quality Criteria Study, Bay Delta, CA.** As a Project Engineer, provided technical support to the CALFED (California Department of Water Resources in concert with many federal and other state water and environmental agencies and stakeholders) effort to remediate the San Francisco Bay Delta. Acted as staff extension to the water quality team of rural constituencies, including area of origin, agricultural water user, mining, and agricultural drainage. As technical staff for this committee, developed water quality databases, list and levels of key water quality parameters, and contributed to a program of actions to address water quality issues in the Delta. Prepared a final report summarizing water quality criteria for agricultural supply.

- **Central Valley Project Improvement Act (CVPIA) – Tributary Production Enhancement Program, Central Valley, CA.** As Lead design engineer, led efforts to develop conceptual designs and estimates of costs for actions and evaluations identified in the Anadromous Fisheries Restoration Program (AFRP). AFRP actions and evaluations addressed as part of this project included new fish screens, fish ladders, placement of spawning gravel, setback levees, bank protection, riparian restoration, habitat studies, fish monitoring programs, and others.

- **East County Water Supply Management Study Phase II, Contra Costa County, California.** As Project Engineer, generated plan-level conveyance alignments, design concepts, and cost estimates including projected O & M costs, for five proposed complex water supply options. Developed hydraulic project design criteria and estimated unit cost for plan-level system layouts and cost estimates. Interacted with multiple irrigation districts, water agencies and other stakeholders to develop baseline conditions for conveyance analysis and option adaptability. Conveyance components designed included lining of open channels and raising of lined canals, small and large diameter pipelines and appurtenances, conveyance tunnels, pumping plants (including large lift stations), siphons, diversions, turnouts, and fish screens. Utility conflicts and special crossings were also identified and addressed in the analysis.

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- **California Rice Industries Association (CRIA) - Environmental and Conservation Balance Sheet for the California Rice Industry, Sacramento, California.** As Task Manager, performed literature research and updated and expanded the information presented in the CRIA Environmental and Water white papers. Updated information associated with agricultural productivity, fisheries, water use, and soils. The focus of the work involved presenting, in a predominantly graphical format, efforts and successes by, as well as the challenges to, the Rice Industry in the realm of environmental stewardship. The audience was the environmental community and major clients of the Industry. Published documents available through the World Wide Web.

- **City of Phoenix - Tres Rios Demonstration Wetlands, Phoenix, AZ.** As Lead Engineer, prepared the final design layout of artificial wetland ponds meeting natural curvature and acreage criteria, as well as avian related features, and available space constraints. Responsible for the hydraulic design and operational analysis of the overall system. Design responsibilities included hydraulic flow control, diversion structures, and flow measurement (V-notch weirs) structures. Also performed extensive earthwork analysis as part of design optimization. This project ultimately received the American Consulting Engineers Council Grand Award for a Water Resource Project.

- **City of Tempe - Rio Salado Town Lake Project, Tempe, AZ.** As Project Engineer, conducted utility research and developed digital layers for the project site. Utility layers were used to determine potential impacted facilities in the vicinity of the planned lakefront and inflatable dam areas. Designed various water supply facilities including well connections and modifications, and open channel hydraulic linkages. Conducted on-site collection of groundwater monitoring well data for use in hydrogeologic studies, and water balance assessment.

- **USBR Mid-Pacific Region - Butte Creek Water Supply and Fish Passage Plan, Chico, CA.**, As Project Engineer, assisted with a feasibility study to remove several dams on Butte Creek as part of the Butte Creek Water Supply and Fish Passage Plan. As part of the study, responsible charge included the analysis and plan-level design concepts for a 200 cfs concrete lined canal for diverting water into the Butte Creek. Rocky and rolling terrain provided special design challenges. Conceptually designed unique riprap transitions and outfalls into the Butte Creek, based on design criteria aimed at minimizing impacts to local anadromous fish.

- **Western Canal Water District (WCWD) - Butte Creek Siphon and Dam Removal Project, Butte Creek, CA.** As Project Engineer, performed an extensive analysis of the project area using a HEC-RAS hydraulics model. The model was used to calibrate roughness coefficients for a hydraulic profile of Butte Creek in the study area using historic project design flows and standard project flows to evaluate freeboard estimates. The model was also used to estimate vertical velocity profiles and near bed velocities incorporated into scour and sediment analysis.

- **Salt River Pima Maricopa Indian Community (SRPMIC), CAP Pipeline and Reservoir Design, Maricopa County, AZ.** As Project Engineer, responsible for the establishment, layout, and production of temporary construction and permanent easement limits for final construction design documents. Assisted in the final design plans and specifications submittal review for 3 miles of 42- to 66-inch diameter pipeline, 3,700 horsepower pump station, and 50 acre-foot regulating reservoir.

Irrigation Engineering Representative Projects

- **Gila River Indian Community (GRIC) P-MIP – Reach IA Lining Private Irrigation Facility Relocation Project, Pinal County, Arizona.** Mr. Cairo was project manager for the design to relocate private irrigation facilities that will be impacted by the Pima Canal, Reach IA Lining and Rehabilitation Project. These private irrigation facility relocations consist of demolition and removal of 1,450 linear feet of existing irrigation ditch located within the Pima Canal right-of-way. Included in the project is design of approximately 4,500 feet of new irrigation ditch and 1,000 linear feet of 36" HDPE pipe with an alternative for cast-in-place pipe. Modification of two existing private irrigation wells and reconfiguration of delivery and control structures are included in the design. A highly critical aspect of this project is the coordination with multiple construction contractors and

impacted farmers to evaluate cost saving alternatives and coordinate construction activities as to not impact a very strict irrigation schedule.

- **Central Arizona Project (CAP) – CAP Pool 23 and 24 Canal Lining Raise and Improvements, Scottsdale, AZ.** As Project Manager Mr. Cairo lead the alternatives analysis and final design for raising the CAP canal lining rail to mitigate the hydraulic impacts due to localized subsidence through the Scottsdale Metropolitan area. The scope of work included raising the canal rail in Pools 23 and 24 two and one half feet (2.5) vertical for about 38,200 linear feet. In addition approximately 21 in-line impacted facilities were mitigated due to the lining raise requiring lining details or structural improvements including canal overchutes, road bridges, pedestrian bridges, drainage inlets, turnouts and structure connections. Design criteria included construction while the canal is in service with limited reduction in flows or water levels. Field Surveys and earthwork analysis were included in the scope of work. All submittals including plans and specifications were developed to meet CAP standards.

- **Maricopa Water District (MWD) – Beardsley Canal – Padelford Wash Siphon Improvements, Maricopa County, AZ.** As Project Manager Mr. Cairo is leading the preliminary analysis and final design of a 372 foot long double barrel 120 inch diameter RGRCP pipe in-line siphon for the Maricopa Water District's Beardsley Canal crossing of the Padelford Wash. The Rancho Cabrillo and Rancho Mercado Developments require the concentration of flows thru a controlled engineered channel past the district Main Beardsley Canal. The design includes a launching rip-rap armor apron for scour protection and considerations for seasonal and long term phasing of operations. The scope of work also includes the preparation of contract documents, special provisions and supplemental specifications to address canal lining and ancillary improvements. Full bidding and construction contract administration and inspection will be performed for this project in 2007.

- **Russo Farms – Private Irrigation System Improvements, Avondale, AZ.** As Project Manager Mr. Cairo led the preliminary and final design for private irrigation facilities required to mitigate the Sedella Development impacts. The design scope included 2,600 linear feet of concrete lined irrigation delivery ditch with a design flow of 12.5 cfs and 900 linear feet of concrete lined irrigation delivery ditch with a design flow of 7.5 cfs. The design also included hand placed concrete flow control sections and tie-ins to existing deliveries and ditch connections with in-line jack gates, total of four locations and in-line siphons. Hydraulic analysis included pipeline installation limits optimization merged with design delivery requirements.

- **Truman Farms – Private Irrigation System Improvements, Surprise, AZ.** As Project Manager Mr. Cairo led the preliminary and final design for private irrigation facilities required to mitigate impacts of the Sarah Ann Ranch Development. The design was for irrigation deliver and conveyance for 40 acres of surface border strip irrigated citrus utilizing a 24 inch diameter RGRCP delivery pipeline and risers with alfalfa valves. Design elements also included a flow measurement weir structure and gross bar screen inlet structure.

- **Shea Homes - Avalea Development Lateral E-10 Relocation and Improvements, Maricopa, AZ.** As Project Manager Mr. Cairo led the preliminary and final design for the relocation and pipelining of about one and half miles, 9,010 lineal feet of existing canal with a design capacity of 35 cfs, including the relocation of three turnouts, and the addition of a two new deliveries. The pipeline was segmented into 1,332 lineal feet of 48 inch diameter pipeline including a siphon crossing of a large wash area, and a 42 inch diameter segment about 6,638 lineal feet. The design incorporated flow measurement and flow control structures, in addition to an irrigation pump bay flow control combination structure. The pump bay was designed to incorporate two pumps relocated from an existing facility and installed to meet the needs of a new delivery. All structures included motor operated gates with local control incorporated into the districts operational standards and scheme. Special consideration was given to construction while the canal system is in service with a limited water outage period. The scope of work also included coordination and preparation of contract documents with both the irrigation district as well as the USBR in regards to legal rights-of-way, encroachments, and abandonment.

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- **Shea Homes - Avalea Development Lateral E-10 Steen Road Relocation and Improvements, Maricopa, AZ.** As Project Manager Mr. Cairo led the preliminary and final design for the design, hydraulic analysis and final design of 568 feet of pipeline and relocation of the existing canal E-10 lateral due to the Avalea Development. These project elements included the relocation of the E-10 lateral out of the future Steen road right-of-way, replacing the existing E-10 pipeline crossing under Steen road with a new parallel pipeline, construction of a new flow control structure / check structure, relocating 2 existing irrigation pumps, relocating two deliveries and constructing two new deliveries. The E-10 pipeline consisted of 568 feet of 54" diameter RGRCP that conveys 50 cfs and required the construction of an inlet headwall, turning manhole and flow control structure. The first delivery relocation required the relocation of two 2000 gpm irrigation pumps from the existing inlet headwall to the new flow control structure 500 ft downstream and the installation of 430 feet of 18" diameter class 150 PVC pipe to connect to the existing PVC pipeline.

- **MCDOT - Ellsworth Road Project 68927, Gilbert, AZ.** As lead design engineer for impacted irrigation facilities for approximately 6 linear miles of the Ellsworth Road widening and improvement project. Designs included demolition and relocation of lined and unlined irrigation ditches, drainage ditches, siphon extensions, and concrete flow division boxes.

- **Maricopa Water District (MWD) - On-Call General Engineering Services, Waddell, AZ.** Program Manager currently leading the MWD urbanization impacts permitting, planning, design, and construction services efforts. GCE developed collaboratively with the District a permitting, design and plan review and construction inspection program. Relocations or modifications to the Districts facilities due to development and urbanization are designed by GCE or reviewed for compliance with hydraulic design criteria if done by others. Also, impacts to MWD operations and maintenance are evaluated, and construction inspections are performed to ensure compliance with plans and specifications. Complex modifications to facilities as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Twelve Oaks Phase I and II Development Flow Control Structure Improvements
  - Cortessa Development Interim Structure Design
  - Russell Ranch Lateral 6 Facility Improvements
  - Sarah Ann Ranch Development
  - Sedella Development
  - District System Mapping and Plat Book
  - Private Irrigation Design Standards and Details
  - District Standard Details and Specifications Package

- **New Magma Irrigation and Drainage District (NMID) - On-Call Design Plan Review and Construction Services, Queen Creek, AZ.** Program Manager is currently leading the NMID urbanization impacts plan review and construction services efforts. GCE developed collaboratively with the District a permitting, plan review and construction inspection program. Relocations or modifications to the Districts facilities due to development and urbanization are reviewed for compliance with set forth hydraulic design criteria, impacts to operations and maintenance, and subsequently construction inspection is performed to ensure compliance with plans and specifications. Complex modifications to facilities as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Standard District Details including canal lining, manholes, siphon inlet and outlet structures, headwalls, etc.
  - Pecan Creek South dual chamber flow measurement structure, manhole, and structure connection details
  - Gary Road Improvements siphon extension, check drop and turnout structures
  - Laredo Ranch A3 Pump Farm Turnout modifications and dual chamber flow measurement structure
  - On-Farm Tailwater Sedimentation Basin Design
  - Bella Vista Lateral C-A Relocation
  - Felix Farms Pipeline Design

- Cornerstone Homes Development
- Laredo Ranch Development

- **Imperial Irrigation District (IID) – Water Department Construction and Maintenance Section On-Call Service Agreement, Imperial, CA.** Mr. Cairo as Program Manager is currently leading delivery of all Construction and Maintenance Section On-Call Service Agreement Tasks including:
  - Rose Pump Station Upgrade Design
  - Imperial Unit Maintenance Manual

- **Maricopa-Stanfield Irrigation and Drainage District (MSIDD) - On-Call General Engineering Services, Coolidge, AZ.** Program Manager currently leading the MSIDD urbanization impacts efforts for the MSIDD. Relocations or modifications to the Districts facilities due to development and urbanization are designed by GCE or reviewed for compliance with hydraulic design criteria if done by others. Also, impacts to MSIDD operations and maintenance are evaluated, and construction inspections are performed to ensure compliance with plans and specifications. Modifications to facilities and impact mitigation as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Standard Details and Specifications Package
  - Amarillo Creek Development
  - Avalea Development - Steen Road Relocation
  - Avalea Development – Lateral E-10 Relocation
  - Sunset Canyon Development – Lateral W-L-B Relocation

- **Central Arizona Irrigation and Drainage District (CAIDD) - On-Call General Engineering Services, Coolidge, AZ.** Program Manager currently leading the CAIDD urbanization impacts permitting, planning, design, and construction services efforts. GCE developed collaboratively with the District a permitting, design and plan review and construction inspection program. Relocations or modifications to the Districts facilities due to development and urbanization are designed by GCE or reviewed for compliance with hydraulic design criteria if done by others. Also, impacts to CAIDD operations and maintenance are evaluated, and construction inspections are performed to ensure compliance with plans and specifications. Modifications to facilities and impact mitigation as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Standard Details and Specifications Package
  - Robson Ranch Development
  - Phillip Farms Development

- **Hohokam Irrigation and Drainage District (HIDD) - On-Call General Engineering Services, Coolidge, AZ.** Program Manager currently leading the HIDD urbanization impacts permitting, planning, design, and construction services efforts. GCE developed collaboratively with the District a permitting, design and plan review and construction inspection program. Relocations or modifications to the Districts facilities due to development and urbanization are designed by GCE or reviewed for compliance with hydraulic design criteria if done by others. Also, impacts to HIDD operations and maintenance are evaluated, and construction inspections are performed to ensure compliance with plans and specifications. Modifications to facilities and impact mitigation as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Standard Details and Specifications Package
  - Verona Estates Development
  - Brighton Village Development

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- **Queen Creek Irrigation District (QCID) - On-Call General Engineering Services, Queen Creek, AZ.** Program Manager currently leading the QCID urbanization impacts program. This involves the coordination and due diligence for the United States Bureau of Reclamation review and permitting approval process for impacts to federally owned interest. GCE developed collaboratively with the District a permitting and federal due diligence review and assistance program. Relocations or modifications to the Districts facilities due to development and urbanization are reviewed by GCE for compliance with federal permitting requirements for acquisition, abandonment, relocation and or facilities modification.

- **San Carlos Irrigation and Drainage District (SCIDD) - On-Call General Engineering Services, Coolidge, AZ.** Program Manager currently leading the SCIDD urbanization impacts permitting, planning, design, and construction services efforts. GCE developed collaboratively with the District a permitting, design and plan review and construction inspection program. Relocations or modifications to the Districts facilities due to development and urbanization are designed by GCE or reviewed for compliance with hydraulic design criteria if done by others. Also, impacts to SCIDD operations and maintenance are evaluated, and construction inspections are performed to ensure compliance with plans and specifications. Modifications to facilities and impact mitigation as directed by the District are designed by GCE for the developers. GCE projects managed Include the following:

  - Standard Details and Specifications Package
  - Valley Vista Development
  - Desert Ridge Development
  - Acacia Farms Development
  - Westfield Park Development
  - Picacho Crossing Development
  - Monterra South Development
  - Tuscany Development
  - Desert Views Development
  - Carlton Commons

- **Colorado River Indian Tribes (CRIT) – Irrigation Project Development Plan Update, Parker, AZ.** As Project Manager lead the evaluation and update of the CRIT Irrigation Project Development Plan Update. The previous master plan was outdated as far as technology and capital construction costs and did not meet with CRIT Plans to modernize its irrigation system. GCE collected data, conducted field assessments, evaluated the current development plan and its cost estimating methods, and reviewed plans for the addition of SCADA sites to the system. GCE used present day cost estimating methods and projected construction methods to update the Short Term Improvement List capital construction costs. All future costs were indexed for the CPI.

- **Maricopa Water District (MWD) – Beardsley Canal Station 13 Emergency Spillway, Waddell, AZ.** As Project Manager, lead the canal hydraulic analysis, preliminary and final design of the Beardsley Canal Station 13 Automated Emergency Spillway Facilities consists of a gated triple box culvert sized to spill 200 cfs into the adjacent cross drainage wash for emergency protection. The system outlet includes a reinforced concrete vertical drop structure and stilling basin with channel erosion control. Gates are to be automated and tied into the districts existing SCADA system for remote monitoring and control.

- **Maricopa Water District (MWD) – White Tank Foothills Development Cross-Cut Canal and Lateral 9 Facility Improvements, Waddell, AZ.** As Project Manager lead the hydraulic analysis and final design of the MWD Cross-Cut Canal and Lateral 9 canal pipelining and confluence Improvements. Due to the White Tank Foothills Development impacting MWD facilities, design and relocation pipelining of their existing Cross-Cut Canal and Lateral 9 including flow control and confluence facilities was required. The scope included a detailed hydraulic analysis to evaluate irrigation service and operational requirements. Improvements included pipelining about 0.5 mile of the Cross-Cut Canal and about 1 mile of Lateral 8, a new confluence flow control and division

structure, in-line flow measurements structures, manholes, relocation of delivery facilities, and canal inlet and outlet headwall structures.

- **Maricopa Water District (MWD) – Cortessa Development Cross-Cut Canal and Lateral 8 Confluence Improvements, Waddell, AZ.** As Project Manager lead the hydraulic analysis and final design of the MWD Cross-Cut Canal and Lateral 8 Confluence Improvements. Due to the Cortessa Development impacting MWD facilities, design and relocation of their existing Cross-Cut and Lateral 8 flow control and confluence facilities was required. The scope included a detailed hydraulic analysis to evaluate irrigation service and operational requirements. Improvements included pipelining of the Cross-Cut Canal and Lateral 8, a new confluence flow control and division structure, in-line flow measurements structures, manholes, well piping modifications, relocation of delivery facilities, and canal inlet and outlet headwall structures.

- **Imperial Irrigation District (IID) –South Alamo Canal State Route 7 (SR-7) Crossing Dual 60-Inch Siphon, Imperial Valley, CA.** As Project Manager lead the preliminary analysis and final design of a 400 foot long dual 60-inch HDPE pipe siphon for the Imperial Irrigation District to mitigate the crossing of Caltrans State Route 7 (SR-7). Design elements included inlet and outlet headwall structures, transitions, canal gates, 3,800 linear feet of raised canal rail and modified structures. The project also included a 120 cfs pumped by-pass for construction and soils dewatering. Preliminary planning included an alternatives analysis for crossing mitigation and a present worth analysis of the preferred options for selection of the preferred alternative. Design challenges included groundwater, a short construction schedule, and operational and maintenance issues due to sediment and algae.

- **University of California Davis - Division of Agricultural and Natural Resources (ANR) – Desert Research and Extension Center (DREC) Irrigation Water System, , El Centro, CA.** As Project Manager completed the Irrigation Water System Project for the UC Davis Desert Research and Extension Center. The project consisted of a phased approach to design and preparation of construction plans and technical specifications to provide the 255 acre DREC with an efficient, reliable, and flexible pressurized irrigation system to support agricultural education and research. Scope elements include a new pumping station with centrifugal pumps, pressure tank and pressurized distribution system providing on-demand water to each field on the Center, reservoir improvements including concrete lining, and an expanded 60 acre underground pipe tailwater system. Topographic and hydraulic design surveys were conducted for all project elements.

- **Imperial Irrigation District (IID) – Rose Pump Station Design, Imperial, CA** GCE was tasked by the Imperial Irrigation District (IID) to evaluate the potential drainage impacts from Caltrans new Highway 111 expressway on their agricultural drainage system. Based on the added flows it was recommended that an additional pump be installed at the IID's Rose Pump Station to increase the pumping capacity. GCE worked collaboratively with IID engineering, construction and maintenance and drainage maintenance section staff to establish design criteria for this pump station project. Standardization of equipment, use of precast materials, safety and maintenance considerations were emphasized. Subsequently GCE designed a "state of the art ", drainage pump station with a total design flow of 50 cfs. Project elements included pre cast construction for the pump forebay lower section, fine and gross trash racks, bulkheads for maintenance, electronic level sensors and controls, power drop and control panel, safety requirements, discharge facilities, pump supports, backflow prevention system, and outlet energy dissipation design. Local IID construction methods and groundwater were also considered in the design. Project deliverables included final plans and specifications including a new standard IID specification for the drainage pumps.

- **Imperial Irrigation District (IID) – State Route 7 (SR-7) System Impacts, Imperial, CA.** As Project Manager lead the effort to evaluate impacts to the Imperial Irrigation District due to construction of 3 miles of new State Route 7 (SR-7). Scope elements include the assessment of operational impacts to zanjero water delivery routes due to limited access. Assessment of impacts to the Districts drainage system due to Expressway storm runoff. Impacts to the District maintenance program due to increased facilities, modified facilities, or limited access. Recommendations as well as preliminary and final design of required impact mitigation measures. These include

automation of flow control structures with Flumegates and Present Worth Life Cycle Analysis for identified impacts including additional future operational, maintenance, replacement, and removal costs to establish the recommended cost recovery for the District Appurtenances including manholes and clean-outs, and two minor drainage crossings are included in the scope of work.

- **Imperial Irrigation District (IID) - Highway 111 Brawley Bypass Stage I System Impacts, Imperial, CA.** As Project Manager lead the effort to evaluate impacts to the Imperial Irrigation District due to construction of about 2 miles of new Highway 111 Expressway Brawley Bypass Stage I. Scope elements include the assessment of operational impacts to zanjero water delivery routes due to limited access. Assessment of impacts to the Districts drainage system due to Expressway storm runoff. Impacts to the District maintenance program due to increased facilities, modified facilities, or limited access. Recommendations as well as preliminary and final design of required impact mitigation measures. These include automation of flow control structures with Flumegates and Present Worth Life Cycle Analysis for identified impacts including additional future operational, maintenance, replacement, and removal costs to establish the recommended cost recovery for the District.

- **Imperial Irrigation District (IID) - Highway 111 Units 1, 2, and 3 System Impacts, Imperial, CA.** As Project Manager lead the effort to evaluate impacts to the Imperial Irrigation District due to construction of about 10 miles of new Highway 111 Expressway Units 1, 2, and 3. Scope elements include the assessment of operational impacts to zanjero water delivery routes due to limited access. Assessment of the impacts to the Districts drainage system due to Expressway storm runoff. Impacts to the District maintenance program due to increased facilities, modified facilities, or limited access. Recommendation's as well as preliminary and final design of required impact mitigation measures. These include the Rose Pump Station improvements and automation of flow control structures with Flumegates. Also, a Present Worth Life Cycle Analysis for identified impacts including additional future operational, maintenance, replacement, and removal costs was performed to establish the recommended cost recovery for the District.

- **Imperial Irrigation District (IID) – Engineering Services Section On-Call Service Agreement, Imperial, CA.** Program Manager currently leading delivery of all Engineering Services Section On-Call Service Agreement Tasks including:
  - Engineering Services Section Master Project Scheduling
  - Check Gate and Delivery Aluminum Slide Gate Structural Analysis and Design Modification
  - Drainage Sump Pump Standard Shop Drawings and Pump Specifications
  - Update District CADD Standards
  - Drainage System Modeling and Impact Analyses
  - Federal Stimulus Grant Applications for Water Conservation Projects

- **Imperial Irrigation District (IID) - Brawley Bypass Stages II and III, Impacted Irrigation and Drainage Facilities Design, Imperial, CA.** Project Manager for this design and construction project involving IID Water Department facility relocations associated with the Caltrans Highway 111/78 Brawley Bypass Stages II and III. The Brawley Bypass is a four lane divided expressway. The scope of work includes administration, planning, preliminary and final design, and construction support for impacted facilities including the IID Best and Oakley canals and the Stanley lateral, the Central Main Canal, in-line structures agricultural drains, drainage sumps and associated appurtenances. Farmer interface and on-farm impacts coordination is required for coordinated designs. Also, operations and maintenance impacts of IID facilities beyond the project footprint and identification of right-of-way requirements to support IID relocations are being conducted by GCE.

- **Imperial Irrigation District (IID) – All-American Canal Lining Project (AACLP), Imperial Valley, CA.** Mr. Cairo served as a Technical Specialist and Task Leader in supporting the preliminary and final design of the All-American Canal. Considered one of the most significant water resources projects in the western United States this project when completed will conserve and transfer enough water to serve about 0.5 million residents in Southern California. The scope includes the preliminary and final design of about 23 linear miles of 10,100 cfs concrete lined canal. This will involve about 25 million cubic yards of excavation and the placement of about 1.8

million cubic yards of concrete lining. In addition to major earthwork, design challenges included canal tie-ins at existing hydroelectric power drops while maintaining the canal in service. GCE responsibilities also included all utility coordination and the design of ancillary facilities.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) –Southside Canal Reach II - Rehabilitation and Lining Project, Sacaton, AZ.** As Project/Design manager on this project was responsible for preliminary and final design of about 24.7 miles of unreinforced concrete lined canal using prescribed operations-based design criteria. The new canal includes replacing a reach of earthen canal with a new lined section, removal and replacement of an existing lined reach, and raising the canal rail of an existing lined reach. The design flow is 385 cfs, and the scope of the project includes, 2 siphons, 2 in-line measurement structures, 6 well retrofits, 6 check structures, 1 crossing of Interstate-10, 42 turnouts, 3 sump turnouts, and the 4-mile post 30 cfs lift station discharge retrofit. The project also included rehabilitation of about 7.6 linear miles of flood protection levee and 7 cross drainage structures. Under his direction, final unsteady state hydraulic modeling and verification of operational design criteria for the system with CanalMan was conducted.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) – Blackwater Area Main Canals Preliminary Design, Sacaton, AZ.** As lead Project Engineer, responsible for the design of open channel irrigation conveyance facilities for a planned 146,000 acre agricultural development using water sources from the Gila River, Central Arizona Project (CAP), and groundwater. The design included 23-miles of main stem canal with design flows ranging from 2,600 cfs to 1,850-cfs. Project tasks included a system-wide water supply analysis, assistance in design criteria setting, construction logistics, steady- and non-steady state canal modeling with CanalMan. Design also includes 2,600-cfs confluence, 3 miles of supercritical system siphons, unique combination radial and overshot gate structures, conventional radial gate structures, vertical drop structures ranging from 2 to 17 feet, and flow measurement structures.

- **Yuma County Water User's Association (YCWUA) – Canal Improvement Project, Canal Lining & Structures, Yuma, AZ.** Project Principal for the final design of the YCWUA Canal Improvement Project. The project serves about 55,000 acres and funding for the project includes a 50 percent cost share Water Conservation Grant from the NADBank. Project elements consists of about 15 miles of concrete lined canals with design flows ranging from 100 cfs to 20 cfs, slide gate and overshot check structures, turnouts, flow measurement, and about 650 linear feet of 60 inch pipeline, flow division stand boxes, and modifications to numerous structures. Construction is to be phased over a three year period with short construction schedules due to limited canal dry-up periods.

- **Bard Water District – Reservation Main Canal Improvement Project, Yuma, AZ.** Project Principal for the planning and design of the Reservation Main Canal Improvement Project for the Bard Water District. The project serves about 14,676 acres comprised of about 7,556 acres of the Quechan Indian Reservation and 7,120 acres of private lands. Planning efforts include routing, capacity, maintenance, operational and constructability phasing studies. Key design elements include a new 450 cfs turnout on the All-American Canal, over 20 linear miles of concrete and flexible polyurethane lined canals ranging in flows from 450 cfs to 20 cfs, check structures, turnouts, flow measurement and road crossings. Funding for this project included a 50 percent cost share Water Conservation Grant from the NADBank. Construction is to be phased over a three year period with short construction schedules due to limited canal dry-up periods.

- **Marine Corps Air Station (MCAS) - Station Ordnance Area Phase II, Part C Irrigation System Relocation, Yuma, AZ.** Project Manager for the relocation of the Yuma Mesa Irrigation and Drainage District (YMIDD) B7.0 Lateral outside of the new Station Ordnance Area. Project elements include topographic surveys, and plans and specifications for about 6,600 linear feet of new concrete lined canal 40 cfs, one turnout off of the YMIDD B7.0 Lateral, 72 high flow turnouts, 4 road crossings, check gates, flow measurement, structure modifications, and demolition. In addition, a Water Management Plan and Construction Phasing Plan for the limited available dry-up and construction schedule were prepared.

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- **Granite Construction Company - P-MIP Southside Canal Construction Engineering Services, Inc., Sacaton, AZ.** Project Manager for the construction related general engineering services on this canal construction project. The project scope included the design of about 600 linear feet of canal realignment at Interstate-10 suitable for slip form concrete lining installation. In addition, construction surveys, staking, and as-built drawings were prepared for approximately 5,650 linear feet of 100 cfs irrigation canal lateral, about 845 linear feet of 40 cfs irrigation ditch, a single long crested weir, two long crested slide gate check structures, farm turnouts, stilling wells, a wasteway turnout and outlet structure, and two animal escape ramps. Construction for these facilities was conducted during a limited dry-up period due to crop winter water demands.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) – Main Canal Reach I-Rehabilitation and Lining Project, Sacaton, AZ.** As Project/Design Manager was responsible for the final design of 20 miles of unreinforced concrete lined canal with flows of 2,000 cfs to 1,300 cfs, 22 check structures, 22 drop structures, 3 siphons up to 10-feet diameter, 19 bridges, 44 turnouts, 2 spillways, 1 wasteway, 3 miles of reinforced supercritical chute with flow of 2,000 cfs, and 2 measurement structures. Under his direction, final non-steady state hydraulic modeling and verification of operational design criteria for the system with CanalMan was conducted. He was responsible for the preliminary design of sediment removal facilities and final design of the system confluence.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) – North Side Alignment Study, Sacaton, AZ.** As Design Manager was responsible for developing alternative routes and layout criteria for a proposed 2,600 cfs main canal to convey Central Arizona Project flows onto the Gila River Indian Community. Preferred alignments were selected and conceptual designs and costs developed. Special design challenges included cross drainage, rocky terrain, and a crossing of the Gila River.

- **Colorado River Indian Tribes (CRIT) - Irrigation System Rehabilitation Project, Parker, AZ.** As Task Manager, developed project design criteria, including the determination of local crop consumptive use estimates. Prepared final design documents for high-flow (30 cfs) on-farm irrigation turnouts and distribution conveyance laterals and ditches for on-farm delivery of diverted Colorado River water. Responsible for the final design of Main Stem flow measurement flumes, radial gate checks structures, turnouts, flow transitions, wasteway structures, and siphons with design flows up to 300 cfs. Portions of the design work involved strict hydraulic constraints requiring special consideration for future operations. Acted as owner agent for construction inspection of the Schedule A flow control and measurement structures package. Special construction techniques were emphasized due to limited Dry-Up time of the canal system for construction, including prefabrication of large structures on-site.

- **City of Tracy - Food Process Water Reuse Facility Phase 1, Tracy, CA.** As Task Manager, prepared preliminary design documents for alternative Heinz food process water Land Application Systems. Four alternative sites and two optional systems were evaluated. Option one was for 300-acre sites without onsite storage and Option two was for 167-acre sites with onsite storage. The primary water supply for the site consisted of treated food process water with a low pH. The land application facilities were designed for a pH of 4.0 and accommodated a peak treatment plant out-flow of 2.6 million gallons per day. The project included developing production and O&M costs associated with irrigating alfalfa using border strip surface irrigation systems with an onsite tailwater recovery system.

- **Gila River Indian Community (GRIC) - Pima-Maricopa Irrigation Project (P-MIP) - Alignment Study Blackwater Area, Sacaton, AZ.** As Project Engineer, assisted in preparing the preliminary Alignment Study of the Blackwater Area for the GRIC P-MIP Project. Prepared conceptual level design documents and quantity and cost estimates for alternative canal routing studies to deliver Central Arizona Project (CAP) and Gila River water to the anticipated 146,300 acres of project lands. Responsibilities included the Southside Canal alignment conceptual design for approximately 19.3 miles with a design flow of 2,400-cfs. Designs concepts included large energy dissipation structures, drop chutes, pipe chutes, radial gates structures, flow bifurcations, and turnouts. Evaluated water supplies and consumptive use demands within the project area and assisted in the generation

of a water supply analysis report. Also, prepared a hydropower assessment of the Southside-Pima Interconnect alignment.

- **Arizona Department of Water Resources (ADWR) - Water Duty Study, Phoenix, AZ.** As Project Engineer, responsible for data collection coordination of the participating ADWR Active Management Areas involved in the water duty study. Conducted participant interviews and gathered available supporting information for the study reference database. Generated, and managed the project database used in the agriculture water use, level basin irrigation, and irrigation economic studies associated with the analysis of economic impacts of maximum conservation on agriculture.

- **American Maize Products Inc. - Land Application System, Dimmitt, TX.** As Task Manager, conducted a siting analysis for a proposed industrial wastewater land application system. Performed on-site field ring infiltrometer test to determine initial and final soil infiltration rates. Retrofitted existing irrigation and domestic wells for groundwater sampling program, and performed groundwater samplings for studied constituents. Multiple land application systems were evaluated, including center pivot, linear move, rain cannons, and surface irrigation.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) - Sediment Management System, Coolidge, AZ.** As Project Manager, lead the planning and preliminary design for the sediment management system to trap and remove sediment from Gila River water being diverted into the Pima Canal for irrigation. The system was designed for a flow of 600 cfs using two ½-mile-long parallel settling basins with a trap efficiency of 35 percent, to remove 405,000 cubic yards of sediment per year. Scope included developing alternatives for sediment removal and handling, and the design of a turnout to divert flow into the basins with overshot leaf gates. This innovative design allowed for the control of sediment bed load entrained into the system. Also designed were basin overflow weirs to drain standing water in the basins using downward opening overflow weir gates.

Surveying Representative Projects

- **San Carlos Irrigation and Drainage District (SCIDD) – District Mapping and Structures Survey, Casa Grande, Coolidge, and Florence, AZ.** Mr. Cairo was project manager for the survey and design team during the survey and mapping of the SCIDD facilities including 21 miles of canal and hydraulic structures from Ashurst-Hayden Diversion Dam to the Pima canal and approximately 40 miles from the Pima lateral to the end of the Florence- Casa Grande Canal. Survey also included over 250 structures and over 500 cross-sections on the districts' main canal (Florence-Casa Grande Canal). The structures were surveyed to enhance the aerial topography and to collect hydraulic properties for design. The Zanjeros for each division were interviewed for information on flow characteristics and potential problems that could be fixed with the planned design. Site plans and hydraulic properties tables were generated for each structure.

- **Imperial Irrigation District (IID) Managed Marsh Mitigation Project Construction Staking, Calipatria, CA.** This project consisted of 320 acres of constructed wetlands by the Imperial Irrigation District as mitigation for the water conservation projects associated with the Quantification Settlement Agreement. GCE was part of the team that planted the vegetation in 12 ponds that were constructed. GCE working with project biologist located and staked contour lines as the boundaries for the planting of the different types of vegetation that required various depths of water submergence. In the field it was found that the ponds were not constructed per the contract plans and GCE had to adjust its method of staking to fit the available plants for the different depths of water submergence. Mr. Cairo served as the Project Manager on this project.

- **Gila River Indian Community (GRIC) PMIP – Reach IA Pima Feeder Canal Lining & Siphon Realignment. Coolidge, AZ.** Mr. Cairo was project principal on this water outage construction staking project which included an outlet structure from the CAP canal with erosion control matting, 2,800 lineal feet of new canal, 240 lineal feet of double 120" siphon, inlet and outlet siphon structures, animal crossing bridge and animal escape ramp. All

structure forms were surveyed to check final elevation for contractor. Staking was done for canal, O&M road, irrigation by-pass and all structure layouts.

- **Imperial Irrigation District (IID) - Transmission Line Upgrades, Imperial Valley, CA.** Mr. Cairo as project principal is leading the support of the IID Energy Department expansive transmission line upgrades projects, total of four. GCE is currently helping to Secure ROW required for transmission line expansion and/or upgrades and substation extensions which require timely due diligence to identify potential lands issues that could impact the project. GCE is assisting in identifying jurisdictional boundaries and requirements, such as encroachment permits, and property ownership/existing easements or ROWs, through the review of existing records and project related documents. Using the results of the study reports and onsite investigations of the project areas, GCE is identifying and recommending any mitigation/resolution of issues to ensure the project can proceed without undue delays. GCE is performing the necessary surveys and land investigations to determine which individuals and agencies must be contacted to discuss and resolve issues, land ownership and easements associated with the use of the affected land for the ROW of the various projects. GCE is supporting IID Real Estate in land acquisition and preparation of maps and documents as required. Total of 36 miles transmission line upgrades and substation site ROW is being supported.
- **Gila River Indian Community (GRIC) Tribal Project Development (TPD) – District 4 ADOT SR-587 Improvements. Sacaton, AZ.** This construction staking project managed by Mr. Cairo included widening of SR-587 by adding acceleration and deceleration lanes at two access locations including full permitting and coordination with ADOT. In support of the highway modifications an existing drainage box culvert was extended and a 1,300 lineal feet of GRIC Public Works water line installed.
- **Imperial Irrigation District (IID) - 230 KV KN/KS Transmission Line Tubular Pole Upgrade Project, Niland, CA.** Mr. Cairo is the Project Manager for this IID upgrade to the existing 230-kV "KN/KS" transmission line from Midway Substation located near Niland, California to the Coachella Valley Substation in Coachella, California.. This reach contains both lattice towers and tubular steel poles constructed in the late 1980's. Due to problems experienced with excessive wind, there was a need to upgrade the existing structures in order to withstand extreme wind load cases within this reach. Under the Project, forty-one (41) existing transmission tubular steel poles were either replaced or upgraded to a two pole structure. As required GCE conducted the required field surveys to find and/or set monuments including property corners, section corners, etc. as required to establish required mapping information. The purpose of the surveys was to field locate IID or required property corners for IID Energy interest. The surveys were prepared in accordance with "California Boundary Surveys Minimum Standards". GCE also performed construction staking and as-built surveys for this project.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) – Main Canals Right-of-Way Surveys and Parcel Maps, Sacaton, AZ.** As Project Manager was responsible for the field surveying and preparation of parcel maps for the additional rights-of-way needed for the rehabilitation and betterment of the Pima Lateral - Reach IA, a 12 mile reach of 2000 cfs concrete lined canal planned for construction. The scope included researching existing surveys and mapping of record, collecting field survey data in coordinates tied to the Gila River Indian Community's survey grid, breaking down the approximately 13 sections in which additional rights-of-way were needed, establishing existing right-of-way lines in the field and also establishing the new right-of-way lines, with property corners set on the new right-of-way lines. A constructability evaluation to determine any additional requirements was completed and incorporated in the final requirements and parcel maps for USBR land acquisition. All parcel maps were completed to USBR Map standards.

- **New River Task Force (Task Force) and Imperial Irrigation District (IID) – Land Surveying and Analysis for Potential Wetland Sites, Imperial Valley, CA.** As principal in charge provided the QA/QC for this major land surveying and hydraulic analysis project. The project consisted of a two step approach to determine the feasibility of gravity flow for the installation of sediment removal and constructed wetland facilities on 43 potential sites covering approximately 4800 acres in the river bottom areas of the Alamo and New Rivers. A project wide

survey control network was established and documented in a written report. Site visits and transect surveys were prepared for all 43 sites and full topographic surveys conducted for those sites determined to be feasible for gravity flow installations. A detailed report was prepared to document findings and recommendations.

- **Central Arizona Project (CAP) – Green-Up Area Project Urban Fencing – Phase 1, Scottsdale, AZ.** As Project Manager, Mr. Cairo is lead the design of approximately 20 miles of 4 strand barbed wire fencing to encompass the CAP property extending from CAP milepost 121.6 (Akin Lane Bridge) to milepost 141.1 east of Grand Avenue. The purpose of this project is to fence the north side property alignment along this reach of the CAP Canal in order to provide a demarcation line and enforceable area for trespassing. The fence design includes pull post sections every 650 linear feet and at all corners, gate design details, wash crossing details, signage details, fence tie-ins and revisions of exiting facility drawings. All submittals including plans, AutoCAD files and specifications are in strict accordance with CAP Standard's. The design for this project includes the use of CAP GIS system data as a basis for design. As part of supplemental data collection GCE performed due diligence and field surveys to set about 52 missing property corners and prepared associated survey Parcel Maps to CAP Standards for County recording.

- **Central Arizona Project (CAP) – Canal Turnout and Pump Station Forebay Bathometric Surveys and Sediment Quantity Estimates, Eloy, AZ.** As Project Manager lead the bathometric surveys and sediment removal evaluations of the Central Arizona Project Main Canal Central Main, San Xavier Pump Station Forebay and approximately 7,000 lineal feet of concrete channel. This work was needed as part of sediment removal efforts required to maintain operational capacities and flexibility in the system. GCE used an Odom Hydrotrac single frequency portable hydrographic Echo Sounder coupled with a GPS unit to perform the bathometric surveys. GCE generated ½ foot contour interval maps of each location and the canal channel reach and estimated sediment removal requirements. Sediment removal alternatives were evaluated taking into consideration operational requirements of the facilities.

Flood Control and Hydrology Representative Projects

- **Pima Maricopa Indian Project (PMIP) – Blackwater Reach III – Southside Canal Santa Cruz Siphon Scour Analysis, Pinal County, AZ.** As Project Manager lead the hydrologic and scour analysis study for a portion of the Lower Santa Cruz Wash as part of the engineering services for the Blackwater Reach III – Southside Canal (Southside) rehabilitation design. Part of the rehabilitation includes the design of a proposed new double barrel siphon with a design flow of 400 cfs under the Santa Cruz Wash, located approximately 2 miles south of Highway 87 and 7 miles west of Coolidge in Pinal County, Arizona. To prevent damage to the new siphon installation and protect the project investment, a hydrologic study and scour analysis was completed to determine the depth below the Santa Cruz Wash bed at which the siphon should be placed. Geotechnical data, hydrologic data and field surveyed topography were used to create a HEC-RAS Hydraulic Model of the Santa Cruz Wash in order to estimate the hydraulic flow regime and determine the active scour depth. A Technical Memorandum was completed with recommendations based on the results of the scour analysis performed.

- **Imperial Irrigation District (IID) – Central Drain Basin Drainage Model, Phase I & II, Imperial Valley, CA.** Mr. Cairo as Project Manager is currently leading the development of a surface and subsurface drainage model for the Imperial Irrigation District Central Drain Basin. This includes an approximate drainage basin of about 51,000 acres of mixed farm land, urbanizing land development, and commercial areas with a system flow path of about 21.3 miles. The state of the art model will be based on the Civil Storm Hydrologic Modeling Software Platform. The ultimate model is to be a valley wide Drainage Base Model for current and future development impact analysis. Phase 1 of the project includes: data collection, hydrologic-hydraulic model selection, hydrology analysis, defining the baseline condition, and developing the baseline model. Phase II is the evaluation of the storm drain design for the proposed Desert Lakes Subdivision.

- **Wonderstone Hydrology and Drainage Diversion Berm Design, North Shore, CA.** Served as Project Manager for the Wonderstone Aggregate Specific Plan: Hydrology and Drainage Diversion Channel and Berm

Design. The Specific Plan Area fro gravel mining is located in a low-lying area between the Santa Rosa Mountains on the west and the northwestern region of the Salton Sea on the east. Numerous ephemeral washes exist across the Specific Plan Area that flow towards the Salton Sea, the largest of which is Wonderstone Wash with a watershed area of 13 square miles. Three of the washes including Wonderstone Wash are Federal Emergency Management Agency (FEMA)-designated 100-year floodplains. Scope of work included hydrology of the contributing watersheds, development of hydraulic models for washes, design of in-channel flow division structures, channel training sections for re-directing washes and preparation of permit support documents.

- **Yuma County Water Users' Association - Yuma Valley Drainage Improvement Project, Yuma, AZ.** Served as Design Manager for the preliminary and final design of this complex multifaceted project. The project scope is intended to increase the drainage capacity of the existing Yuma Mesa Conduit which is utilized to control ground water in the Yuma Valley via a network of shallow wells and pipelines. Project elements included replacement drainage wells, about 10,000 linear feet of 16 inch diameter discharge lines, about 5,000 linear feet of new electrical powerline, and open to closed system pressurization modifications. In addition, a new concrete bifurcation structure providing an outlet to the MODE, the Colorado River, and a connection for a future drainage discharge was designed.

- **Maricopa Water District (MWD) and Flood Control District of Maricopa County (MCFCD) – White Tanks Flood Retarding Structure #3 North Inlet Channel Beardsley Canal Replacement Sections, Waddell, AZ.** Project Manager for this joint client project lead the canal hydraulic analysis, preliminary and final design of the MWD Main Stem Beardsley Canal replacement sections required to construct the diversion of the Waterfall Wash into a triple 10' x 5' RCBC crossing and a Quad 10' x 5' RCBC crossing. Preliminary and finals plans and specifications were generated for the crossing including canal lining details and impacted facility design details for the MWD Lateral 6 crossing including replacement and connections concepts.

- **Yuma County Flood Control District (YCFCD) – East Mesa, Area Drainage Study, Yuma, AZ.** Project Principal for the YCFCD East Mesa-Area Drainage Study. The study area is primarily agricultural with low density residential. The planned development in the area is residential with commercial corridors and localized industrial uses. The scope includes an inventory and field survey of Drainage structures including agricultural drain canals, natural drainage channels and washes, highway drains and localized drainage structures. Complete hydrology and drainage calculations and design, and assessment of existing conditions, recommended levels of flood protection, and drainage improvements for the area are included in the Area Drainage Study.

- **ADOT - State Route 68 Drainage Design Build, Kingman, AZ.** As Senior Consultant provided senior design review of post construction design build drainage design plans acting as owner agent for 13.27 linear miles of Arizona State Highway – Route 68. The project consisted of approximately 75 drainage system installations along the alignment, including riprap lined and unlined open channels, culvert pipes, hydraulic structure modifications, and energy dissipation facilities. The design review scope included the hydraulic design, civil aspects, and compliance with submittal review comments.

- **Baylor College of Medicine – Flood Mitigation Alternatives Analysis, Houston, TX.** As Task Manager conducted an assessment of the 2001 Tropical Storm Allison storm event which caused extensive economic and collateral losses to the Baylor College of Medicine. The scope included an engineering evaluation of flood-proofing alternatives and recommendations for improvements. To accomplish this work, a fundamental understanding of the events was developed using physically inventoried data from the site, a hydrologic and hydraulic analysis, and study of the rainfall event. Flood mitigation alternatives were framed in an overall decision matrix which considered economics and institutional factors among others. Based on the results a preferred alternative was recommended.

- **Gila River Indian Community (GRIC) Pima-Maricopa Irrigation Project (P-MIP) –– Southside Canal Flood Protection System Rehabilitation Design, Sacaton, AZ.** GCE is currently working on the Flood Protection

Levee Rehabilitation Design as part of the overall P-MIP GRIC- Southside Canal Reach II - Rehabilitation and Lining Project. GCE is responsible for the preliminary and final design of about 24.7 miles of unreinforced concrete lined canal which includes replacing a reach of earthen canal with a new lined section, removal and replacement of an existing lined reach with a design flow of 385 cfs including inline structures which need to be protected from cross-drainage. The levee system includes about 6 miles in linear length, seven (7) cross-drainage structures, new spillway structure, outlet channel rip-rap armor protection and regrading improvements of the outlet channels. The design included field topographic surveys and DTM development and an in-depth earthwork analysis to balance the levee section and canal section improvements.

- **Multnomah County Drainage District - Flowserve Manufacturing Pump Inspection, Portland, OR.** As Task Manager and owner's agent, traveled to Byron Jackson's large pump manufacturing plant (Flowserve) in Mexico City, Mexico. On-site inspected the manufacturing progress on 5 large (6-foot-diameter impeller) pumps, and monitored a high pressure pump test pumps prior to shipping. Due to large potential liquidated damages on behalf of the pump manufacture, served as a bilingual technical liaison for schedule, production, and delivery coordination.

- **Union Pacific Railroad (UPRR) - Subsurface Drainage Design, Roseville, CA.** As Task Manager responsible for layout and design of a subsurface (tile) drainage system for the UPRR West Coast rail (switchyard) bowl. The main design objective was to evacuate excess stormwater from the tracks in the large bowl area by infiltration through the surface ballast material, then collect and discharge it through a subsurface drainage system. Design components included more than 100 miles of collection and main lines, drop inlets, and discharge structures.

Municipal Water and Sewer Representative Projects

- **Harquahala Valley Irrigation District (HVID) – Scottsdale Waterline Easement Assessment, Harquahala, AZ.** Project Manager for an easement constructability analysis for multiple pipeline installation scenarios and prepared plan level cost estimates for an in easement versus out of easement installation comparison for the Harquahala Valley Irrigation District. The purpose of the study was to evaluate the impacts to the Districts ability to export water within the canal corridor in the future if they were to allow the City of Scottsdale to construct a proposed conveyance export pipeline within their existing easement.

- **Gila Bend – Sewer Main Extension Project, Holt Interstate Services, Gila Bend, AZ.** Project Manager for the Sewer Main Extension intended to provide future service to the Interstate-10 and Butterfield Trail intersection area of Gila Bend. The project scope includes survey, mapping, and final design of about 2,800 linear feet of sewer main (8 inch diameter). The sewer main is an extension of the existing Town of Gila Bend system.

- **City of Sedona – Long Term Effluent Disposal Design Modifications 1 Through 4, Sedona, AZ.** Design Manager for preliminary and final design of the second phase of the City of Sedona LTEDDM program. Tasks included modifying the existing Aquifer Protection Permit and development of a surface hydrologic model suitable for use to design runoff containment berms for effluent disposal areas. A new effluent pump station designed to deliver effluent to the new Area 1 disposal area, and existing Areas 2, 2B, and 3 via four dedicated 75 hp vertical turbine pumps in a wet well arrangement. Also, a new 40 acre sprinkle effluent disposal system for Area 1 was designed utilizing a buried ductile iron main line and above grade HDPE laterals with manual valves. Detailed hydraulic modeling, including surge analysis served as the basis of the design. Additional tasks included a detailed analysis and resulting modifications to the existing plant water system to improve overall plant operations.

- **Pajaro Valley Water Management Agency - Import Pipeline Alignment Preliminary Engineering, Watsonville, CA.** As Task Manager, conducted studies to refine approximately 23 miles of the import pipeline alignment and prepared preliminary designs for critical crossings. Import pipeline construction methods, easement requirements, Pajaro River, and UPRR crossings were addressed, as well as seismic considerations. Prepared design drawings and a technical memorandum summarizing the work performed.

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- **City of Avondale – Indian School Road 20 inch Waterline, Avondale, AZ.** Design Manager for preliminary and final design documents for approximately 5,780 linear feet of 20-inch ductile iron pipe distribution waterline. The project included 4 connections to existing system waterlines, all valves, fire hydrants, fittings, rubberized asphalt pavement replacement, and a crossing of the Agua Fria River. Additional design elements included the crossing of two Flood Control District of Maricopa County soil cemented levee banks by the pipeline, and scour protection in the river.

- **Birchfield Mobile Home Park – Sewer Main Extension Project, Town of Gila Bend, AZ.** Served as Project Manager for the preliminary and final design, as well as services during construction for the Birchfield Mobile Home Park sewer main extension. The project scope was to provide city (Town of Gila Bend) sewer service to the Mobile Home Park which was not in compliance with ADEQ. The accelerated scope of work included about 1,450 linear feet of sewer main extension and service connections for 76 units, including 46 mobile homes and 30 recreational vehicle spaces.

- **Tucson Water - Pima Mine Road 36-Inch Recharge Pipeline, Tucson, AZ.** As Project Engineer, conducted initial utility research and mapping to determine potential conflicts along approximately 2.7 miles of the proposed pipeline corridor. Special crossings addressed included an interstate highway undercrossing and a river overcrossing. Assisted in preparing predesign level submittal documents.

- **Tucson Water - Roger Road Water Reclamation Facilities Expansion, Tucson, AZ.** As Lead Project Engineer, performed utility research and mapping of existing and planned utilities within envisioned project pipeline alignment corridor. Designed preliminary and final vertical and horizontal alignment for a 12-inch ductile iron conveyance pipeline for delivery of secondary effluent to existing, and proposed future wetlands groundwater recharge site. Project included crossing of the Santa Cruz River and soil cemented banks. Complex operational constraints existed therefore various scenarios were evaluated and based on the results of the study operational and desire criteria were established.

- **City of Sedona - 12-inch Reuse Pipeline Pre-design Technical Memorandum (TM), Sedona, AZ.** As Project Engineer, assisted in generating the pipeline predesign documents for 12-inch 6 mile proposed pipeline alignment corridor. Responsible charge included utility conflict research, pipe material suitability analysis, valve design, selection and placement, and other appurtenances.

Renewable Energy Representative Projects

- **8 Minute Energy – Photovoltaic Solar Plant Project, Niland, CA.** Mr. Cairo is the Project Principal for this green energy project involving the development of a 320 acre photovoltaic solar power plant located in the Imperial Valley near Niland, California. GCE is tasked on this project is to provide engineering support to prepare permit drawings necessary to secure the environmental and conditional use permits from the County of Imperial to construct the plant. The work to date has consisted of locating existing easements on the site drawings; locating new facilities on the site plan; locating existing power lines, canals, drains, and county roads on the plans; and calculation of usable areas for the photovoltaic panels within the two 160 acre parcels. In addition, GCE staff has provided consulting services to the project proponents regarding water use for a cover crop, discussions with the Imperial Irrigation District regarding future water use and the necessary Will Serve Letter to the County of Imperial, as well as communications with the landowner regarding historical cropping and water use on the parcels.

- **California Renewable Energies (CRE) – Sugar Cane Ethanol Generation Plant General Engineering Services, Brawley, CA.** Under his direction as Project Manager GCE in support of the new planned sugar cane ethanol generation plant has been conducting general civil, agricultural and irrigation engineering support services for this project. Demonstration sugar cane planting, due diligence support efforts and land acquisition

and site planning services have also been provided. In addition to water supply assessment and improvement studies.

Membership in Professional Organizations

Alpha Epsilon - Agricultural Engineering Honorary
American Society of Agricultural Engineers (ASAE), 2002 Arizona State Section Chair
American Society of Civil Engineers, ASCE
Colorado River Water Users Association, CRWUA
Fraternal Order of the Engineer
Southwest Indian Agricultural Association, SWIAA (Board Corporate Member)
University of Arizona Agricultural and Biosystems Engineering Advisory Committee (Committee Member)
Agri-Business Council of Arizona (ABC)
American Academy of Water Resources Engineering (AAWRE)
American Water Works Association (AWWA)
American Public Works Association (APWA)
Arizona Water & Pollution Control Association (AWPCA)
University of Arizona Hispanic Alumni Association (Board Member)
California Agricultural Irrigation Institute (CII)
U.S. Committee on Irrigation and Drainage, USCID (Board Member)

Supplemental Information

Prior to his association with GCE, Mr. Cairo worked on a variety of soil and water conservation engineering projects as a Soil Conservation Engineering Aid with the USDA – Natural Resource Conservation Service NRCS (Formerly the Soil Conservation Service, SCS). He assisted with soil and water conservation planning, design, and implementation of on-farm best management practices, including erosion control practices, on-farm irrigation water management, and compliance monitoring of the federal conservation cost sharing program. In the Imperial Valley he was a member of the first Irrigation Water Management Mobil Lab Team specializing in irrigation evaluation of surface irrigation systems. Furthermore, he was responsible for a Summer Irrigation Water Management Program in southern San Diego County, managing and conducting irrigation system evaluations on surface, and pressurized sprinkle and drip systems. Special challenges were encountered in evaluation of complex microirrigation pressurized systems used to irrigate avocados, kiwis, and other Mediterranean crops on rocky, hilly terrain.

Publications

Co-authored the following publications:

Increasing Canal System Capacity While In Service. Proceedings 2nd International Conference on Irrigation and Drainage USCID (2002).

Environmental and Conservation Balance Sheet for the California Rice Industry. Report for the California Rice Industry Association, Internet publication www.calrice.org, August, 1996.

Electromigration of Nitrates in Soils. American Society of Civil Engineers, Journal of Irrigation and Drainage, Vol. 122, No. 5, September/October, 1996. ASAE Paper No. 11547.

Electro-Osmotic Removal of Nitrates From Soils. Research report prepared for the National Food & Energy Council. EPRI Report # RP2782-1992-4A (1993).

Electro-Osmotic Removal of Nitrates from Soils. American Society of Agricultural Engineers National Summer Meeting (1993). ASAE Paper No. 932077.

Electro-Osmosis Effectiveness in Reducing Tillage Draft Force Energy Requirements. Research project report prepared for the National Food & Energy Council (1992).

George J. Cairo, P.E., Principal Engineer