COVER PAGE

RESOURCE MANAGEMENT IN A CHANGING CLIMATE: UNDERSTANDING THE RELATIONSHIPS BETWEEN WATER QUALITY AND GOLDEN ALGA DISTRIBUTION IN THE PECOS RIVER, NEW MEXICO AND TEXAS

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The total length of this proposal and the length of Technical Proposal and Evaluation Criteria section are within the guidelines of the RFP.

EXECUTIVE SUMMARY

Golden alga (*Prymnesium parvum*) is a harmful algal species primarily found in marine systems, though present and invasive in brackish inland waters of at least 20 U.S. states. This species was first recorded in the Pecos River in 1985 and has since invaded other associated systems (e.g. sinkhole habitats, reservoirs). The toxins released by golden alga can be fatal to fishes, bivalves, crayfish, and gilled amphibians; the ecological and economical impacts of golden alga blooms have been immense. Recent research suggests that the frequency and severity of golden alga blooms will increase under altered flow regimes as a result of climate change, although the mechanisms leading to bloom formation and toxicity are complex and elusive. Our primary goal in this proposed research is to enhance our understanding of the environmental conditions, specifically water quality variables, which promote or regulate golden alga bloom formation in the Pecos River system. Our approach will include sampling a wide range of habitats and environmental conditions throughout the middle and lower Pecos River basin within the Desert LCC region, across an 18 month time-span to account for seasonal and phenological events. We will utilize a suite of univariate and multivariate statistical techniques to relate occurrence and density of golden alga to environmental factors and other co-occurring organisms. The proposed research will benefit managers of the Pecos River, of its associated reservoirs and unique habitats (sinkholes on the Bottomless Lakes State Park and Bitter Lakes National Wildlife Refuge), and of its resident aquatic biota by identifying specific water quality attributes that promote golden alga bloom development and potential toxicity to several aquatic species of concern. More specifically, the information obtained may be useful to the management of surface water and its associated watershed either to prevent or to mitigate conditions that result in toxic algal blooms. Additional benefits will be to the recreational users of these systems, including anglers utilizing sport fisheries in the region. The technical goal and management applications of this proposed project thus clearly fit within the science priorities shared by Bureau of Reclamation and Desert LCC partners (primarily Task Area B).

TECHNICAL PROPOSAL

Background

General. Golden alga (GA; *Prymnesium parvum*) is a harmful algal species primarily found in marine systems but is also present and invasive in brackish inland waters of at least 20 U.S. states (Sager et al. 2008; Southard et al. 2010; Lutz-Carrillo et al. 2010). When nitrogen and phosphorus are imbalanced or scarce, GA releases a suite of toxins that affect gilled aquatic organisms such as fish, bivalves, crayfish, and (gilled) amphibians (Ulitzur and Shilo 1966). One highly visible side effect of toxic GA blooms is large quantities of dead and dying fish on the surface of impacted water bodies. Depending on the distribution of GA in a system, fish kills can be confined to small areas such as coves or widespread across an entire lake or river stretch (Roelke et al. 2010a).

The ecological and economical impacts of GA have been immense. In Texas alone, an estimated 34 million fish valued at $13M have been lost due to GA (Southard et al. 2010). In addition, the economic losses to communities surrounding affected lakes has been estimated to be in the millions of dollars (Oh and Ditton 2005; Oh and Ditton 2006). Despite repeated fish kills in many lakes across multiple river basins, the impacts to fish populations are quite variable

among GA-impacted systems. For instance, one of our recently completed studies suggested that all but one fish species (blue catfish) in the Brazos River basin (Texas) has recovered to conditions existing before the first incidence of a toxic GA bloom; whereas nine of twelve species in the Upper Colorado River basin (Texas) have exhibited sustained declines in abundance since the emergence of GA in 2001 (VanLandeghem et al. *in preparation*). This large discrepancy in the impacts of GA on fish populations is best explained by differences in the frequency and severity GA blooms between the basins. Specifically, GA blooms in the Brazos River occur about once every 2 years and last for 1 month or less (Roelke et al. 2010a; Roelke et al. 2010b), whereas in the Upper Colorado River, blooms occur every year and often last for 6 or more months (M. VanLandeghem et al., unpublished data, Texas Parks and Wildlife, unpublished data). Environmental conditions in the Upper Colorado River system therefore appear to be relatively favorable for GA bloom formation and toxicity compared to other river systems in Texas.

Water quality characteristics such as pH, salinity, and nutrients have been shown to influence GA bloom formation and toxicity in the Brazos River basin in central Texas (Roelke et al. 2010a; Roelke et al. 2010b; Valenti et al. 2010). However, these associations also may vary among river basins given the markedly different impacts of GA to fish populations mentioned in the preceding paragraph as well as the natural variability in environmental conditions across systems. For example, in contrast to the findings in the central Texas portion of Brazos River just mentioned, a recently completed study from our laboratory in the upper reaches of the Brazos River suggested a positive association between total water hardness and GA toxicity, but no association between toxicity and pH or salinity (Meyer 2009; VanLandeghem et al. *submitted*). Further, an ongoing study by our laboratory suggests that fluoride, sulfate, and water hardness are higher in Upper Colorado River reservoirs experiencing repeated toxic GA blooms and fish kills compared to nearby reservoirs where GA is present but has never been lethally ichthyotoxic (M. VanLandeghem et al., unpublished data). It appears, therefore, that environmental conditions in the impacted reservoirs of the Upper Colorado River may be especially favorable to GA toxicity. Curiously, in these impacted reservoirs, we have recorded lethal GA ichthyotoxicity in the summer at temperatures as high as 29°C (M. VanLandeghem et al., unpublished data), despite previous suggestions that GA blooms in the south-central U.S. occur exclusively in winter and early-spring (Roelke et al. 2010b).

Clearly, the environmental factors that determine GA bloom formation and toxicity vary among river systems and basin-specific information regarding associations between water quality and GA are needed for appropriate management of GA-impacted systems.

Pecos River, trust resources, and golden alga. The Pecos River is a stream arising in the Sangre de Cristo Mountains in New Mexico, flowing 1490 km through eastern New Mexico and far-west Texas before reaching its confluence with the Rio Grande near Amistad reservoir (Rhodes and Hubbs 1992). Dissolved salts from the Pecos Valley, low rainfall, high evaporation rates, water supply development, and few freshwater tributaries all contribute to generally high, but variable, salinities throughout the middle and lower sections of the Pecos River (Rhodes and Hubbs 1992; Linam and Kleinsasser 1996; Hoagstrom 2009). Conductivity measurements between 1141 uS/cm and 14370 uS/cm were reported in a 1987 study of the Pecos River in Texas (Linam and Kleinsasser 1996).

Distribution of the fish fauna in the Pecos River is largely influenced by salt tolerance, with only a few euryhaline species present in highly saline areas and many species present near

freshwater inflows (Rhodes and Hubbs 1992; Linam and Kleinsasser 1996; Hoagstrom 2009). One native species of interest is the Pecos pupfish (*Cyprinodon pecosensis*). This species was once the most abundant fish in the Pecos River (Echelle and Conner 1989), but hybridization with the introduced sheepshead minnow (*Cyprinodon variegatus*; Echelle et al. 1997) and habitat loss and degradation (Minckley et al. 1991) have led to the classification of this species as threatened in New Mexico and Texas (Garrett et al. 2002) and critically endangered by the IUCN (http://www.iucnredlist.org/apps/redlist/details/6163/0). A hybrid swarm has supplanted populations of pure Pecos pupfish downstream from Loving, New Mexico (Wilde and Echelle 1992). Only a few small remnant populations of pure *C. pecosensis* exist in small oxbow lakes and gypsum sinkhole lakes in Bitter Lakes National Wildlife Refuge and in gypsum sinkhole lakes located in the Bottomless Lakes State Park in New Mexico (Rosenfield et al. 2004).

In addition to hybridization and habitat loss, GA is another serious threat to the remaining pure *C. pecosensis* populations. GA has been present in the Pecos River since at least 1985, when it was identified as the cause of a series of fish kills between Iraan (Texas) and Amistad reservoir (James and De la Cruz 1989; Southard et al. 2010). Toxic GA blooms have resulted in mass mortalities of Pecos pupfish (Southard et al. 2010) and may favor range expansion of the *C. pecosensis* x *C. variegates* hybrid by reducing predator density (Rhodes and Hubbs 1992). GA ichthyotoxicity has been detected in three gypsum sinkhole lakes in New Mexico, including two in the Bottomless Lakes State Park (the third is privately-owned; S. Denny et al., NMDGF, unpublished data); these lakes are one of the last remaining habitats containing pure *C. pecosensis* populations. GA toxicity has also been detected in other parts of the New Mexico portion of the Pecos River, including large reservoirs (e.g. Brantley, Red Bluff), run-of-river reservoirs, as well as main stream segments (S. Denny et al., NMDGF, unpublished data; S. Twidwell, TPWD, unpublished data). Free-flowing areas of the Pecos River also provide habitat for other aquatic species of interest such as the blue sucker (*Cycleptus elongates*), Pecos bluntnose shiner (*Notropis simus pecosensis*), gray redhorse (*Moxostoma congestum*), the threatened gastropod Pecos assiminea (*Assiminea pecos*), and the critically endangered bivalve Texas hornshell (*Popenaias popeii*)—all of which may be impacted by GA.

Changing climate and golden alga in the Pecos River. GA is a threat to aquatic life throughout the Pecos River, and a changing environment may exacerbate and perhaps also change the geographic spread of GA bloom formation. Some studies have suggested that the frequency and severity of GA blooms will increase under altered flow regimes as the result of climate change, specifically changes in rainfall patterns and abundance (Roelke et al. 2010b). Inflows into GA-affected reservoirs have been shown to reduce salinity to levels below what allows GA growth (Roelke et al. 2010b), to reduce GA cell and toxicity density by dilution (Schwierzke-Wade et al. 2010), and to provide nutrient pulses that alleviate nutrient limited conditions that promote GA toxin release (Roelke et al. 2010a). These studies, however, were conducted on the central portion of the Brazos River system in Texas, which has much lower ($\leq$ 2.5 ppt) salinities and receives substantially more rainfall than the Pecos River or other river systems in west Texas, such as the Upper Colorado River. Thus, the impacts of climate change on GA bloom formation in the Pecos River may be considerably different than those described in the central Brazos River and elsewhere given their large differences in environmental conditions. As previously discussed, the environmental conditions that promote GA bloom formation vary among river basins. Therefore, in order to understand the influence of climate change-associated water quality on GA in the Pecos River, and ensuing impacts on several aquatic species of concern, we must

first understand the environmental factors that drive GA bloom formation specifically in the Pecos River.

Technical goal and specific task

The goal of this proposed study is to develop an understanding of the environmental conditions, specifically of water quality attributes, which promote and regulate golden alga bloom formation *in situ* in the Pecos River system. The specific task of the project is to establish specific water quality standards that can be used by management agencies to prevent the further spread of golden alga and to mitigate its impacts on those locations that are already being impacted by it. This task will be achieved by establishing the associations between golden alga density and standard water quality factors, specific ions, and total nutrients including nutrient fractions.

Management of natural resources that are affected by water resources management in a changing climate in the Pecos River

Reservoir flushing is one proposed management strategy to control GA blooms in large reservoirs; for example, this practice has been shown to terminate GA blooms in Brazos River reservoirs of central Texas (Roelke et al. 2010a). This strategy, however, is not applicable to the majority of the affected area of the Pecos River basin where prolonged drought conditions greatly limit the amount of water that can be released. Also, the gypsum sinkhole lakes of eastern New Mexico are fed exclusively by groundwater, and therefore water flushing is not a viable option even in high precipitation years. An alternative strategy might be to manage land and/or water uses in a manner that prevents the establishment of water chemistry conditions that promote or allow GA growth and bloom formation. This proposed study will address the relationship between GA blooms and water chemistry conditions that are unique to the Pecos River basin.

The proposed research will benefit managers of the Pecos River and associated water bodies (e.g. gypsum sinkhole lakes) by providing information that may lead to the development of strategies to protect aquatic life, including species of concern, from GA. In particular, this proposed study will identify specific levels of water quality constituents that promote GA bloom development in the Pecos River basin. Similar to water quality guidelines (e.g. minimum dissolved oxygen levels) used by federal and state environmental protection agencies for protection of aquatic life, the information gained from the proposed study could be utilized as water quality criteria in a water management plan aimed at reducing/preventing the impacts of GA on aquatic organisms in the Pecos River basin.

Additional benefits will be to the users of these systems, most notably anglers utilizing the sport fisheries of larger reservoirs and gypsum sinkhole lakes. Benefits from this research may also extend to other water bodies impacted by GA. For example, the environmental conditions in the Pecos River more closely match those of Nevada and Arizona, which have recently experienced GA blooms, than the environmental conditions of the Brazos River in central Texas, where the majority of GA research in North America has been conducted.

In conclusion, the research proposed here will advance our understanding of the environmental and water chemistry factors that regulate GA blooms in the Pecos River and associated water bodies. This information is needed to provide context for assessing the

influence of climate change and land use change on the current GA problem in the Pecos River basin and on the potential spread of GA to currently unaffected areas.

Stages of proposed project

We anticipate a high degree of success at each stage of this proposed project given our previous experience with similar projects (field, laboratory, data mining) and technical/statistical approaches, and the quality of information that we have gained from these previous efforts.

I. Selection of sampling locations

Proposed sampling locations, upstream to downstream, include (Figure 1):

- Mirror Lake, a lake within the Bottomless Lakes State Park (BLSP) in New Mexico made of 3 linked gypsum sinkhole lakes. Contains a population of pure Pecos pupfish that has been used as the source population for many studies on this species. The golden alga status of this lake is unknown.
- Inkwell Lake, a gypsum sinkhole lake in BLSP. Small populations of pure Pecos pupfish are present in the gypsum sinkhole lakes of the BLSP. Golden alga was identified by NMDGF as early as May 2006 and has been recorded on multiple occasions between 2006 and 2010 (S. Denny, personal communication and shared database).
- Brantley Lake, large reservoir on the Pecos River north of Carlsbad, New Mexico. Popular sportfishing destination. Golden alga identified as early as August 2003, and high cell densities and toxicity recorded on several occasions between 2003 and 2010 (S. Denny, unpublished data).
- Pecos River free-flowing site near Highway 31 bridge, New Mexico. Golden alga identified as early as September 2003, and toxicity has been recorded on several occasions between 2003 and 2010 (S. Denny, personal communication and shared database). An extremely high density of golden alga (269,000 cells/mL) was also reported in February 2004.
- Red Bluff reservoir, large reservoir on the Pecos River located on the Texas/New Mexico border. Golden alga fish kills reported as early as 1985 (Southard et al. 2010).
- Pecos River free-flowing site near Coyanosa, Texas. Golden alga monitored regularly 2006-2011.
- Pecos River free-flowing site near Girvin, Texas. The peak salinity in the Pecos River is known to occur near Girvin (Rhodes and Hubbs 1992) and golden alga presence and toxicity has been recorded at this site.
- Pecos River free-flowing site near Independence Creek. Golden alga status is unknown, but this site is the site of a freshwater inflow and is known to contain a high diversity of fish species (Rhodes and Hubbs 1992).

These sites include a wide range of habitats/environmental conditions present throughout the Pecos River basin, including several sites where golden alga is known to be present.

II. Selection of water quality and golden alga variables

We propose to sample the following variables at each proposed site:

- Standard water quality variables: temperature, dissolved oxygen, salinity/specific conductance, total dissolved solids, pH, turbidity, oxidation-reduction potential, water flow (using standard, calibrated field instruments)
- Specific ions: chloride (determined with standard, calibrated field instrument), fluoride, sulfate, calcium and magnesium (hardness cations) (quantified in our laboratory using standard analytical techniques)
- Total nutrients and nutrient fractions: ortho-phosphate, total phosphorus, total Kjeldahl nitrogen, nitrate+nitrite, ammonia (shipped to a dedicated analytical chemistry laboratory, Tarleton Institute for Applied Environmental Research [TiAER] for NELAP certified low-level quantification)
- Relative cyanobacteria densities and total chlorophyll (using a field fluorometer)
- Golden alga density (using standard cell counting techniques with a hemocytometer). GA toxicity will not be quantified under the proposed research due to constraints of the standard fathead minnow bioassay typically utilized to enumerate toxicity (Southard and Fries 1995), or the zebrafish embryo bioassay developed in our laboratory (Meyer, 2009). Specifically, whereas fathead minnow salinity tolerance is about 8 mg/L and zebrafish embryo tolerance is 2-4 mg/L, salinities of 8 mg/L and higher have been recorded in the gypsum sinkhole lakes in the Bottomless Lakes State Park (S. Denny, personal communication and shared database) and as high as 14 mg/L near Girvin, Texas (Linam and Kleinsasser 1996). These areas include three of our proposed sampling locations (see above), and the effects of high salinity could lead to erroneous reporting of golden alga-related mortality. However, understanding the influence of water quality on golden alga density and distribution is sufficient to allow resource managers to address the root cause of golden alga-related mortality as eliminating or reducing golden alga cell density will clearly reduce its impacts on aquatic life. Although some researchers have suggested there is no relationship between golden alga cell density and toxicity, we have data suggesting otherwise for the Upper Colorado River, TX, and the Pecos River basin, NM/TX. There is a strong relationship between golden alga cell density and the probability of lethal ichthyotoxicity in the Upper Colorado River basin (Figure 2) and the Pecos River basin (Figure 3). In fact, our data suggest that, in the Pecos River basin, a reduction in golden alga density from 50,000 cells/mL to 10,000 cells/mL would result in a 60% reduction in the probability of lethal ichthyotoxicity. Thus, GA cell density provides a simple and easy-to-measure variable to assess the GA toxic potential of water bodies.

III. Sampling schedule

All sites will be sampled once every 2 months for 18 months (9 total sampling events), from January 2012 to July 2013. This period will encompass the expected peak golden alga season (winter/early-spring) for two separate years and also include off-peak periods (summer/fall).

IV. Statistical analyses

A suite of univariate and multivariate techniques will be used to relate occurrence and density of golden alga to environmental factors and other co-occurring organisms (e.g., cyanobacteria). Chlorophyll measurements are useful as an indicator of phytoplankton biomass, with

concentrations reflecting the integrated effect of stressors such as nutrient loading. Relationships among golden alga densities, cyanobacteria densities, and total chlorophyll will be assessed with correlation analysis, and each will be used as the dependent variable in subsequent regression procedures to identify important spatial and temporal physical and chemical associations. Because we are measuring many physical and chemical variables that may exhibit complex spatial and temporal associations (Rahel and Jackson 2007), variation in golden alga abundance/incidence will be analyzed with classification and regression trees (CART). This methodology recursively splits a matched data set of categorical variables (for classification trees) or continuous variables (for regression trees) into progressively smaller mutually exclusive groups, using binary splits based on predictor variables (De'ath and Fabricius, 2000; Prasad et al. 2006). Classification and regression tree models have advantages over parametric statistical analyses (e.g., multiple regression models) because of the applicability to cases in which the relationships between variables are strongly nonlinear or involve high-order interactions.

All samples (sites/times) will be ordinated with a principal components analysis (PCA) based on measured environmental variables to create an environmental template. Occurrence/densities of golden alga will be mapped onto this multivariate template to a visually interpretable assessment of how the species is responding to spatial and temporal environmental variation across the region.

V. Anticipated problems or major difficulties in performing or accomplishing proposed work

No specific problems are anticipated, however, access to river sites in Texas may require the crossing of private land, and thus, landowner permission. Landowners have previously allowed golden alga sampling at the proposed Coyanosa site and the Independence Creek site can be accessed via The Nature Conservancy-owned property. Landowners are generally interested in our research as golden alga has resulted/can result in fish kills on their properties.

Prior studies that relate to the project or that will inform the project

- We are currently collaborating with Texas Parks and Wildlife Department on an extramurally funded research project with a specific task dealing with landscape-level associations between water quality and golden alga abundance and toxicity in the Upper Colorado River, Texas—a project similar to the one presently proposed for the Pecos River. A second task of this project addresses the influence of difference climate change scenarios for green-house gas concentrations (i.e., carbon dioxide) on the ability of golden alga to grow.
- We are currently engaged in a large, multidisciplinary and extramurally fundedproject with several collaborators examining the effects of climate change on reservoir water quality and presence of golden alga throughout Texas, focusing on the Colorado and Brazos River basins.
- We have collaborated with Shawn Denny of New Mexico Department of Game and Fish, analyzing golden alga and water quality data collected on the New Mexico portion of the Pecos River between 2003 and 2010.

- We are currently conducting fish surveys on the Pecos River in Texas at localities matching those of Linam and Kleinsasser (1996). The goal of this research is to identify long-term changes in fish assemblages at local and regional scales.
- We recently completed a research project examining water quality and its influence on ichthyotoxicity in urban- and rural-influenced streams—one finding of this study was that golden alga toxicity in the upper reaches of the Brazos is associated with a higher degree of urbanization (manuscript submitted for publication).
- We recently completed a study quantifying the impacts of golden alga on fish populations in the Brazos River and Upper Colorado River basins in Texas (manuscript soon to be submitted for publication).

Sources and support for non-federal funding

Non-federal match funds for this project will be provided by Texas Tech University. Specific items include (1) two-month salary/fringe funds per year for two years for project investigator (Dr. Chris Taylor); and (2) full salary, fringe and tuition/fees contributions for current PhD student assigned to work on project for two years (Mr. Matt VanLandeghem).

In addition, we have close working relationships with state natural resources management agencies in Texas (Texas Parks and Wildlife Department) and New Mexico (Department of Game and Fish). These agencies are not providing funding for this proposed project; however, they have made available to us databases of water quality, golden alga, and fisheries that will be of critical value to this project (see also Letters of Project Support).

PROJECT EVALUATION CRITERIA

Technical Merit

Subcriterion No. 1: Project Scope

- Under which Task Area(s) A–C does the proposed project most closely apply?
- What is the primary objective (question to be answered) of the proposed project? Articulate how the primary objective directly ties to the task area(s) identified?
- What are the specific tasks that will be undertaken to reach the proposed project objective?

  This proposed project can be most closely housed under Task Area B (Projecting the resiliency and vulnerability of natural or cultural resources that affect or are affected by water resources management in a changing climate), although it can also be applied to parts of Task Areas A (Projecting future water availability and quality) and C (Assessing and evaluating natural or cultural resources management practices and adaptation opportunities). This project best matches Task B because the primary objective of this proposed project is to identify the environmental conditions (i.e. water quality) within the Pecos River that are conducive to blooms of the invasive golden alga. Golden alga toxins can be lethal to fish, bivalves, snails, the aquatic phase of amphibians, some other algae and bacteria, and therefore can have a substantial impact on aquatic communities. Although golden alga is not known to be toxic to humans and is therefore not a threat to

water supplies or infrastructure, high density blooms can cause an increase in turbidity, which can violate municipal water quality regulations (as occurred in Big Spring, Texas in December 2009). Golden alga has also been identified in the habitat of the threatened Pecos pupfish, as well as other aquatic species of concern. The specific task of the project is to establish specific water quality standards that can be used by management agencies to prevent the further spread of golden alga and to mitigate its impacts on those locations that are already being impacted by it. Sampling standard and advanced water quality constituents at several sites covering a variety of habitats (sinkhole lakes, reservoirs, free-flowing areas) within the Pecos River basin will allow us to identify environmental conditions favorable for golden alga bloom formation and toxicity. The project objective and task also apply to Task Area A, as management of water quantity may be also necessary to achieve a specified water quality to prevent golden alga blooms; and to Task Area C, as the management of water quantity and quality for golden alga control will undoubtedly need to be adaptable to changing environmental conditions (e.g. air temperature, rainfall) and competing uses (e.g. municipal/agricultural supply).

Subcriterion No. 2: Ability to accomplish project scope

Describe the project team's ability to accomplish the project scope by including:

- How will the budget be allocated to each of the tasks identified?
- Who are the members of the project team, and what tasks will each member perform? Describe each project team member's affiliation with an eligible applicant as defined within section III.A. If all members have yet to be identified (for example, a research assistant or a graduate student), please identify the number to be hired.
- What are the credentials of each of the project team members?
- Have the project team members accomplished projects similar in scope to that proposed in the past either as Principal Investigators or team members?
- Is the project team capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement?

There is single task associated with the project objective and all funds requested or contributed will be applied to the completion of this task.

This proposed project is a closely integrated team effort. The core team will consist of two faculty members (Drs. Reynaldo Patiño and Chris Taylor) and two graduate students (Mr. Matt VanLandeghem, Ph.D. student; and M.S. student to be hired for project). All current members of this team are currently working together and successfully on other projects. Dr. Patiño will be overall project manager. He is Leader of the Texas Cooperative Fish and Wildlife Research Unit, a cooperative unit under the auspices of Texas Tech University, Texas Parks and Wildlife Department, U.S. Geological Survey, U.S. Fish and Wildlife Service, and The Wildlife Management Institute. He is also professor in the Department of Natural Resources Management and Department of Biological Sciences at Texas Tech University. Although a federal employee of the USGS, he is legally authorized to serve on behalf of Texas Tech University in his current capacity as Principal Investigator and Project Manager for university projects. Dr. Patiño is primary advisor for Mr. Matt VanLandeghem (Ph.D. student on project, see below),

and with Dr. Taylor will co-advise the new M.S. student who will be hired for the project. Dr. Patiño has over 30 years of experience conducting laboratory and field research. He has extensive experience conducting and managing multidisciplinary projects involving teams of Ph.D. level university and agency scientists and advising graduate students. Dr. Patiño has served on peer-review and advisory panels for state, national and international institutions. The geographic scope of his field research is national (U.S. – west, southwest) and international (Mexico). His primary research expertise is in the impacts of water quality on aquatic vertebrates at the organismal and landscape-ecology levels, and this is the research area where he will contribute to the project.

Dr. Christopher Taylor is professor in the Department of Natural Resources Management at Texas Tech University. His role in the project will be as co-Principal Investigator. He will co-advise the new M.S. student and is currently member of Mr. VanLandeghem's advisory committee. Dr. Taylor's research program currently focuses on the effects of modified flow regimes on riverine fishes and he has worked on river systems across the southern United States and in Mexico. Dr. Taylor has 25 years of experience as a stream ecologist, has been the P.I. or Co-P.I. on numerous federal grants, and has published extensively in his field. Another important contribution of Dr. Taylor to the project will be his extensive experience with biostatistics.

Mr. VanLandeghem will work as graduate student on the project. Over the course of his completed M.S. and current Ph.D. programs, Mr. VanLandeghem has acquired the knowledge and expertise necessary to carry out field fisheries and aquatic projects. At Texas Tech, he has been working on the question of water quality, golden alga, and impacts on fisheries in Texas primarily in the Upper Colorado River and Brazos River systems. Mr. VanLandeghem and the new M.S. students will be responsible for activities such as field measurements and sample collections, sample/data handling and analysis, data handling and analysis.

Both Drs. Patiño and Taylor have served as Principal Investigator on multiple similar projects, both successfully completed and currently ongoing. Dr. Patiño is currently Project Director for a multidisciplinary project addressing the impacts of climate change on water quality, golden alga, and fish communities in Texas reservoirs; and Dr. Taylor is co-Principal Investigator on this study. Dr. Patiño also currently directs a Texas Parks and Wildlife Department-funded study of the relationships between water quality and golden alga toxin activity. Dr. Taylor currently has a funded research project to examine the importance of connectivity and isolation on fish assemblage attributes in the Rio Grande and tributaries in the Trans-Pecos region of Texas.

Three of the four members of the team are already in place and therefore they are ready to begin the project immediately upon entering into a financial agreement. The M.S. position will be advertised as soon as notice of the grant award has been released and it is expected that the position will be filled possibly in the fall semester of 2011 (if internal TTU graduate is identified) or the spring semester of 2012.

Relevance of the project to the LCC

- What is the geographic extent of the project? What is the relevance of the results of the project to a broader geographic area?

- Does the project complement existing efforts within the geographic area of the LCC? For example, several State and Federal entities are evaluating climate change impacts within the boundaries of the LCC, including Reclamation's Colorado River Basin Study and the Bureau of Land Management's Rapid Ecoregional Assessments. Explain how the proposed project relates to similar efforts within the LCC and how the proposed project will complement rather than duplicate or complicate those efforts. Applicants should make a reasonable effort to explore related ongoing projects in the project area within the LCC.
- What is the expected benefit of the proposed project to partners within the LCC? Explain how the proposed project will help address specific resource management issues within the LCC, including:

  - ✓ Will the proposed project benefit water management within the LCC? Will it benefit the management of other natural or cultural resources? Explain how.
  - ✓ Will the results inform resource management actions immediately upon completion of the proposed project or will additional work be required?
  - ✓ Is there support for the proposed project from resource managers or other partners within the LCC (identify any partners or letters of support).

  Geographically, this proposed project is centered on the middle and lower Pecos River basin in eastern New Mexico and far-west Texas. Information gained from this study will not only benefit resource managers in the Pecos River basin, but will also be useful for agencies tasked with golden alga control throughout the desert southwest. Specifically, the environmental factors that regulate golden alga bloom formation and toxicity can vary considerably among river basins. The environmental factors in the Pecos River basin are anticipated to more closely match those in Arizona and Nevada, which have recently also experienced golden alga blooms, than those in central Texas, where the majority of golden alga research in North America has been conducted.

  Some of the existing efforts in the Desert LCC are addressing conservation issues related to climate change, threatened and endangered species, and water resources in the Colorado River, as well as invasive species such as the salt cedar. Our proposed project complements these efforts by addressing similar issues, but in a different river basin located within the Desert LCC. In addition, Dr. Patiño is currently involved in projects related to water quality and its impacts to fish communities in the lower Colorado River basin (Arizona and Nevada) that are of relevance in the context of water quantity (drought) and of interest to federal agencies such as National Park Service and U.S. Geological Survey, and to regional agencies such as the Southern Nevada Water Authority.

  Expected benefits from this proposed study include advice to water management within the Desert LCC, specifically the Pecos River basin, by providing tenable water quality management goals or standards for control of the invasive golden alga, which is a threat to aquatic organisms, including several species of concern. Consequently, water management goals developed by this study may also be useful to the management of trust species of concern to state and federal natural resource management agencies within the LCC.

Results from the proposed study will be available almost immediately following the completion of the project. Much of the proposed water quality information is collected on-site, and laboratory analyses are completed within 28 days of collection. We can also share preliminary data with resource managers throughout the project's duration when requested.

State agencies within the Desert LCC supporting this project include New Mexico Department of Game and Fish and Texas Parks and Wildlife Department. Also, Region 2 of the U.S. Fish and Wildlife Service State (Texas Fish and Wildlife Conservation Office) provided a letter of support.

Dissemination of Results

- If spatially explicit data or tools are being developed, describe how this information will be made available to Geographic Information System platforms and provided to partners within the LCC.
- Describe the anticipated number and type of peer reviewed scientific journal articles.
- Describe the number and type of presentations regarding the results of the project. For example, presentations at scientific conferences or presentations to resource managers within the LCC.

Spatially explicit data for sampling locations and distribution of golden alga findings will be generated by this study. These data can be provided in raw form to any partner within the Desert LCC and advice will be sought from Bureau of Reclamation for how to develop useful platforms to meet their needs.

At least 2-3 peer-reviewed journal articles are anticipated. One will address the spatial distribution of golden alga and changes in distribution since its first appearance in the Pecos River (the databases already provided to us by NMDGF and TPWD will support this manuscript); a second manuscript will deal with the associations between water quality and bloom formation and will include the suggested water quality goals (standards); and a third manuscript may consist of an overview and synthesis at the broad landscape level of the conditions (water quality and bloom formation) in different river systems throughout the Desert LCC (data from the current study as well as other studies in the literature or being conducted by the project PIs will form the basis for this manuscript). We estimate that at least 4-5 scientific presentations will be given based on data from the proposed project. Fora for these presentations will include annual conferences for professional associations such as American Water Resources Association, Southwestern Association of Naturalists, American Fisheries Society, Texas Chapter of the American Fisheries Society, Arizona-New Mexico Chapter of the American Fisheries Society. As appropriate or requested, ad hoc presentations will be made to resource managers within the Desert LCC.

Connection to Reclamation Project Activities

- How is the project connected to Reclamation project activities?
- Does the applicant receive Reclamation project water?
- Is the project on Reclamation project lands or involving Reclamation facilities?
- Is the project in the same basin as a Reclamation project or activity?

- Will the proposed work contribute water to a basin where a Reclamation project is located?

Results of the proposed project will assist Desert LCC partners in the development of resilience and adaptation strategies, such as Reclamation West-Wide Climate Risk Assessments and Service Priority Species Conservation, for resources in the region. The applicant does not receive Reclamation project water and the proposed work will not contribute water to a basin where a Reclamation project is located, only information regarding the water's quality.

Cited Figures

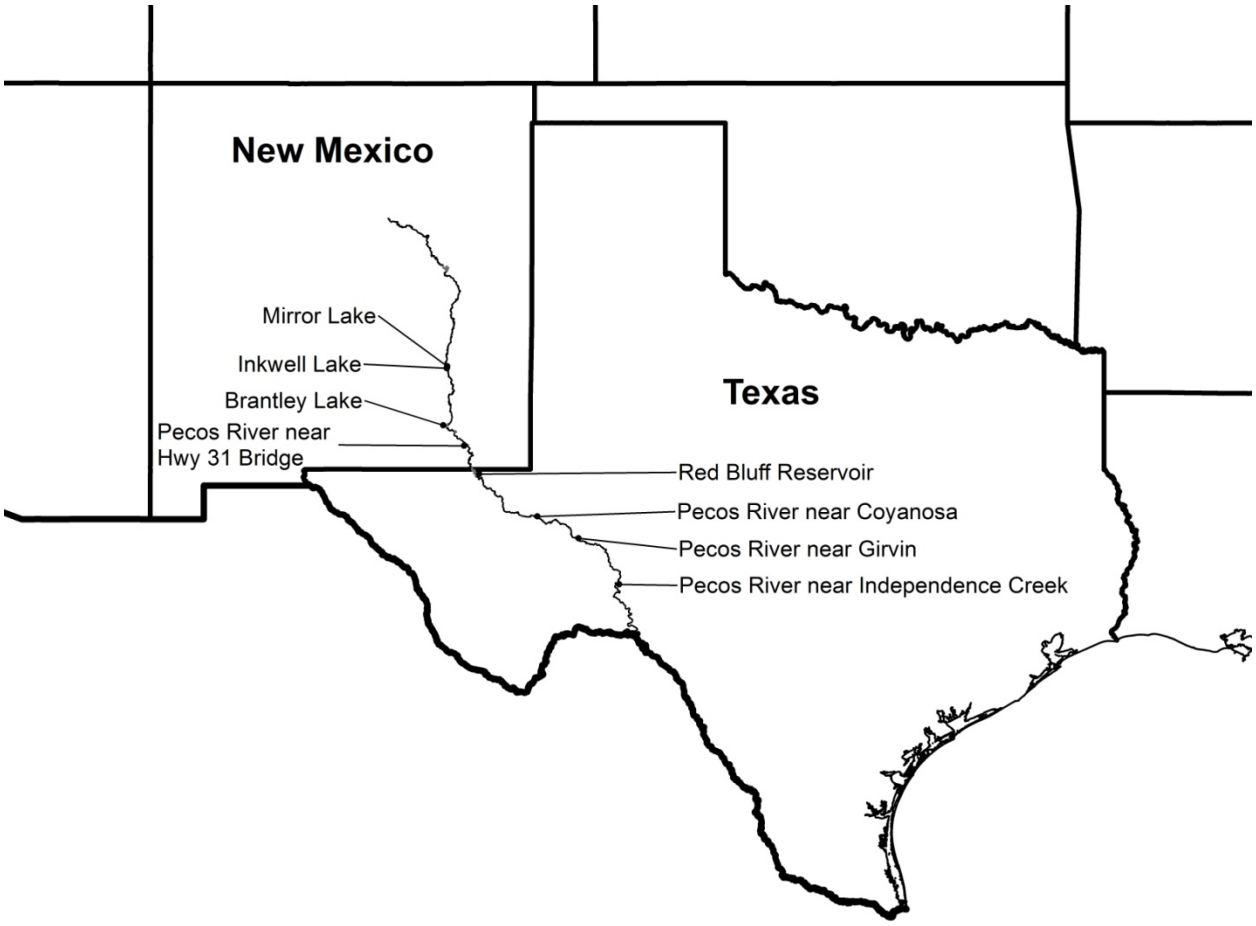

Figure 1. Map of proposed sampling sites on the Pecos River within the Desert LCC. These sites provide a mixture of aquatic environments (gypsum sinkhole lakes: Mirror Lake, Inkwell Lake; large reservoirs: Brantley Lake, Red Bluff Reservoir; and several free flowing areas) present in the Pecos River basin across New Mexico and Texas.

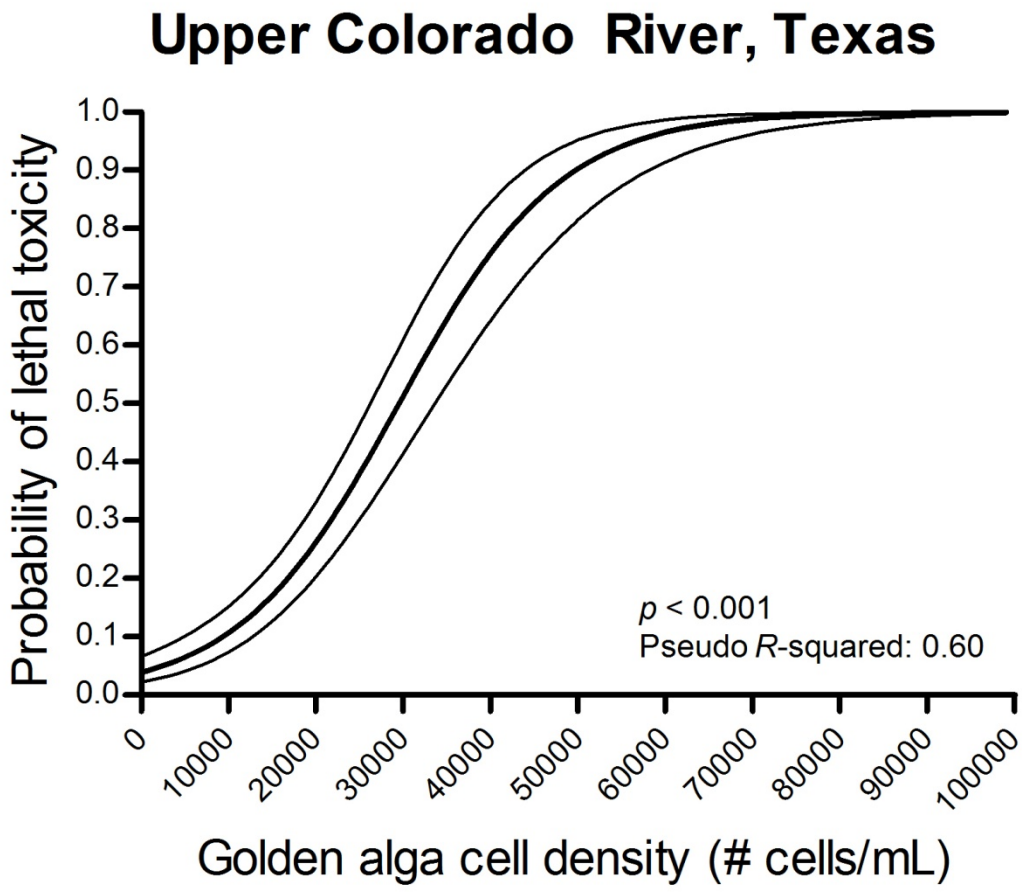

Figure 2. Relationship between golden alga density and probability of lethal toxicity in the Upper Colorado River, Texas (predicted probability and 95% confidence interval). Although some researchers have suggested that there is no relationship between toxicity and golden alga density, this figure shows a strong relationship for the Upper Colorado River basin. Reducing the impacts of golden alga on aquatic organisms may therefore be achieved by reducing golden alga density.

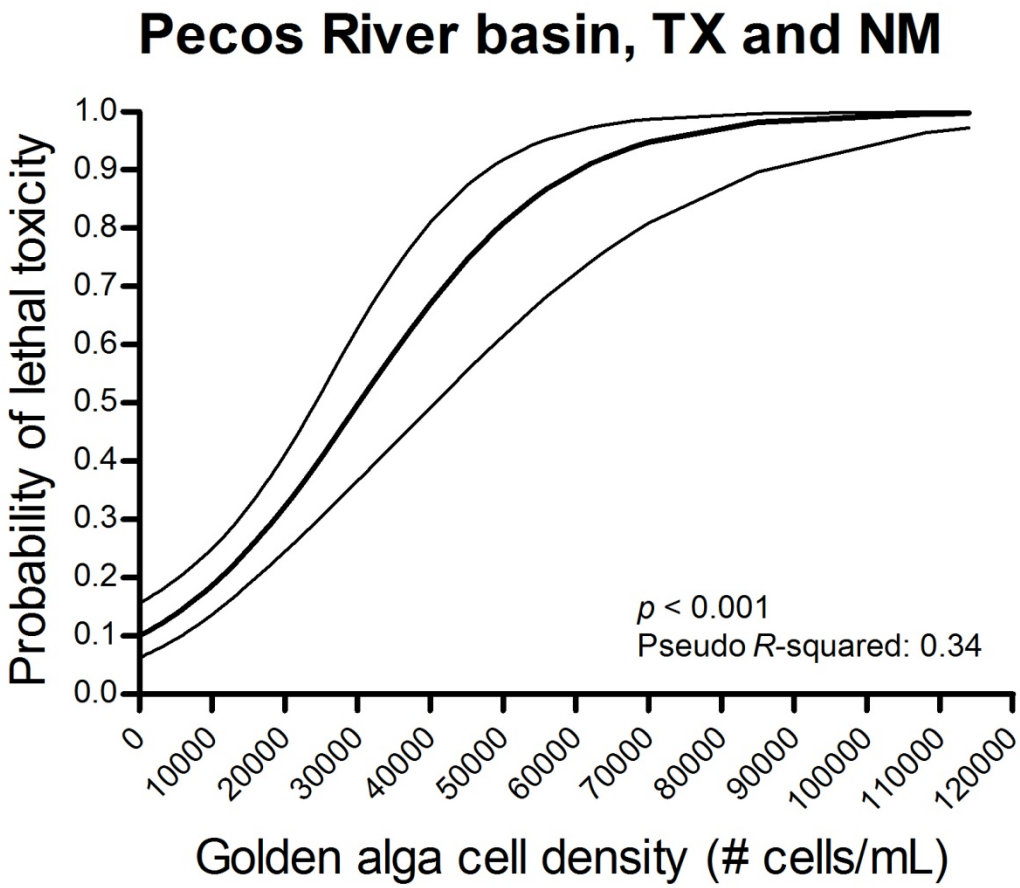

Figure 3. Relationship between golden alga density and probability of lethal toxicity in the Pecos River basin, New Mexico and Texas (predicted probability and 95% confidence interval). Although some researchers have suggested that there is no relationship between toxicity and golden alga density, this figure shows a strong relationship for the Pecos River basin. By understanding the environmental factors that influence golden alga density and distribution, water quality management goals can be established for mitigation of golden alga and reducing its impacts on aquatic organisms.

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Post-Project Benefits

- Information that may lead to the development of strategies to protect aquatic life, including species of concern, from GA impacts by identifying specific levels of water quality variables that enhance the risk of GA bloom development and toxicity in the Pecos River basin.
- Additional recreational benefits from this work will extend to anglers utilizing the sport fisheries of larger reservoirs and gypsum sinkhole lakes, and other recreational users of water resources in the basin.
- Knowledge gained from this study may be useful for other states and/or river basins where GA has been a problem, especially in the arid southwest.

Potential Environmental Impacts

All proposed field work will involve non-destructive data collection and will not impact the surrounding environment, water delivery systems or any archeological sites in the region. There are federally listed fishes that occur in the Pecos River and associated sinkhole habitats, but they will not be affected by any of our proposed activities.

Required Permits or Approvals

There are no permits or approvals that are required to initiate the proposed research. Should access to private property be deemed necessary for the field portion of this project, the necessary landowner permits would be obtained in writing and kept on file.

Funding Plan and Letters of Commitment

Summary of Non-Federal and Federal Funding Sources

Non-Federal Entities	
Texas Tech University	$99,016
Requested Reclamation Funding:	$96,856
Total Project Funding:	**$195,871**

The non-Reclamation share of the project costs will be in the form of salary, fringe, tuition and fees provided by Texas Tech University. This is detailed in the budget and budget narrative (see below). There are no other sources of funding (monetary or in-kind contributions) committed to the project so there are no letters of commitment.

Letters of Project Support

– 3 pages follow

GOVERNOR
Susana Martinez

DIRECTOR AND SECRETARY
TO THE COMMISSION
Tod W. Stevenson

STATE OF NEW MEXICO
DEPARTMENT OF GAME & FISH

One Wildlife Way
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For information call: (505) 476-8000
To order free publications call: (800) 862-9310

August 2, 2011

Desert-Landscape Conservation Cooperative
Bureau of Reclamation
Acquisition Operations Group
Attn: Michelle Maher
Mail Code: 84-27810
P.O. Box 25007
Denver, CO 80225

Re: Desert-LCC proposal from Texas Tech University

Dear Proposal Review Committee members:

The Department supports the proposal being submitted to the Desert-LCC by Texas Tech University researchers, "Resource management in a changing climate: understanding the relationships between water quality and golden algae distribution in the Pecos River, New Mexico and Texas." Golden alga was first documented in New Mexico in 1988. Since 2002 it has plagued the lower portion of the Pecos River in New Mexico with almost annual fish kills. Several species of greatest concern according to the NM Comprehensive wildlife plan have been impacted including Pecos pupfish, blue sucker, grey redhorse, smallmouth buffalo, and many sport fishes as well.

More information and analysis of water quality and it's relationship with golden algae caused fish kills will be helpful in future mitigation of fish kills in the Pecos river, and help to predict what other areas will be susceptible to golden-algae caused fish kills as possible climate change impacts water quality. Information gathered and analyzed in this project may also help managers modify water delivery and storage regimes to lessen the impacts of golden algae.

Please give this proposal full consideration.

Sincerely,

Tod W. Stevenson

Tod. W. Stevenson
Director

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S. Reed Morian
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Wimberley

Lee M. Bass
Chairman-Emeritus
Fort Worth

Carter P. Smith
Executive Director

July 29, 2011

Desert-Landscape Conservation Cooperative
Bureau of Reclamation
Acquisition Operations Group
Attn: Michelle Maher
Mail Code: 84-27810
P.O. Box 25007
Denver, CO 80225

Re: Desert-LCC proposal from Texas Tech University

Dear Proposal Review Committee members:

The Inland Fisheries Division of Texas Parks and Wildlife Department strongly supports the proposal being submitted to the Desert-LCC by Texas Tech University researchers, "Resource management in a changing climate: understanding the relationships between water quality and golden alga distribution in the Pecos River, New Mexico and Texas." The first documented bloom of golden alga occurred in the Texas portion of the Pecos River in 1985. Toxic blooms have since spread to other segments of the Pecos River and to other river basins in Texas and elsewhere and have caused serious ecological damage and mortality of game and non-game fishes, including the endangered Pecos pupfish in the Pecos River.

An understanding of the relationships between water quality and golden alga in the Pecos River would be useful to the management of fish and fisheries resources in this river and to efforts to mitigate current impacts. This knowledge may help assess the risk that toxic blooms will continue to spread as water quality conditions change according to projections based on climate change and other human activities. The results of the study could also help in the identification of potential refugia for threatened species by providing information on water quality conditions that are less conducive to algal blooms.

We hope you can give a favorable review to the Texas Tech proposal. Please let me know if you will need additional information from our agency.

Sincerely,

Gary E. Saul, PhD
Director of Inland Fisheries

GES:dh

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Texas Fish and Wildlife Conservation Office
500 East McCarty Lane
San Marcos, Texas 78666
512-353-0011 ext 236

Desert-Landscape Conservation Cooperative
Bureau of Reclamation
Acquisition Operations Group
Attn: Michelle Maher
Mail Code: 84-27810
P.O. Box 25007
Denver, CO 80225

Re: Desert-LCC proposal from Texas Tech University

Dear Proposal Review Committee members,

The proposal prepared by Texas Tech University, "Resource management in a changing climate: understanding the relationships between water quality and golden alga distribution in the Pecos River, New Mexico and Texas" has the strong support of the Texas Fish and Wildlife Conservation Office, United States Fish and Wildlife (USFWS). The USFWS considers golden algae to be a serious threat to fisheries in the region and supports research that is needed to manage the impacts of this threat. As a result of golden algae blooms at several Texas Parks and Wildlife State Hatcheries, the USFWS has produced striped bass for the State of Texas at Inks Dam National Fish Hatchery since 2006. The economic impacts of golden algae blooms are great, and yet we have a limited understanding of the causes of the fish killing blooms.

The Texas Tech proposal aims to investigate relationships between water quality and golden algal blooms in the Pecos River. As conflicts over the use of water resources grow in intensity, this information will become increasingly important for fish and wildlife managers to anticipate future impacts of human activities, including climate change, on trust resources and to evaluate management options. The proposed study is therefore timely and important.

We look forward to seeing this project funded.

Sincerely,
Mike Montagne, Project Leader

Michael Montagne

Official Resolution

– 1 page follows

TEXAS TECH UNIVERSITY
Office *of* Research Services

August 4, 2011

Bureau of Reclamation
Acquisition Operations Group
P.O. Box 25007
Denver, CO 80225

Reference: "Resource Management in a Changing Climate: Understanding the Relationships between Water Quality and Golden Alga Distribution in the Pecos River, New Mexico and Texas"

To Whom it May Concern:

Texas Tech University is pleased to present the above entitled proposal submitted to your recent Funding Opportunity Announcement, R11SF81307, under the direction of Dr. Reynaldo Patino. If funded, Texas Tech University does agree to provide the required 1:1 cost share in the amount of $99,353, which will cover the 2 year duration of this proposed project. This will include 2 months of academic salary of co-PI Dr. Chris Taylor (plus associated fringe benefits and allowable indirect costs) and 12 months of salary for PhD graduate student assistant, Matt VanLandeghem (plus associated fringe benefits and tuition and fees (paid as compensation) and allowable indirect costs).

As the Authorizing Official for Texas Tech University, I can confirm that all appropriate programmatic and administrative personnel at Texas Tech University do support and have approved the submission of this application, as evidenced by my signature below.

Very truly yours,

Kathleen H. Harris, Ed.D.
Senior Associate V. President
for Research

KH/sds

Project Budget Application

Budget Proposal (1 page follows)

	$/Unit and Unit	Quantity	FY 2012 TTU Match	FY 2012 Reclamation Funding	FY 2012 Total
SALARY			**$34,792**	**$16,000**	**$50,792**
Dr. Chris Taylor - 2 months salary	$48.44/hour	346.66 hours	$16,792		
Graduate Research Assistant (M.S.- 12 months)	$15.40/hour	1039.2 hours	$18,000	$16,000	
Graduate Research Assistant (Ph.D. - 12 months)	$17.32/hour	1039.2 hours			
Fringe			**$4,079**	**$4,048**	**$8,127**
Full-time employees	18% + insurance		$3,899		
Part-time employees	1% + insurance (if applicable		$180	$4,048	
TRAVEL			**$0**	**$3,440**	**$3,440**
Lubbock-Pecos River 2 people @ 3 days/trip @ 4 trips/year	$85/day per diem	4 trips		$2,040	
Lubbock-Pecos River - round trip	$350/trip gas	4 trips		$1,400	
SUPPLIES			**$0**	**$4,450**	**$4,450**
Field supplies (water sampling bottles, shipping containers)				$250	
GPS units				$600	
Handheld water flow meter				$1,000	
Laboratory supplies (water analysis reagents, standards, pipetters, analytical probe supplies)				$2,000	
SAS and ArcGIS licenses				$300	
Office and computer supplies				$300	
Contractual			**$0**	**$7,200**	**$7,200**
Nutrient analysis by Tarleton State University				$7,200	
OTHER			**$6,136**	**$8,886**	**$15,022**
Tuition and Fees			$6,136	$7,086	
Postage for shipping samples				$1,800	
DIRECT			**$45,007**	**$44,024**	**$89,031**
OVERHEAD (10%)			**$4,501**	**$4,402**	**$8,903**
TOTALS			**$49,508**	**$48,426**	**$97,934**

	$/Unit and Unit	Quantity	FY 2013 **TTU match**	FY 2013 **BR**	FY 2013 Total
SALARY			**$ 34,792**	**$ 16,000**	**$ 50,792**
Dr. Chris Taylor - 2 months salary	$48.44/hour	346.66 hours	$ 16,792		
Graduate Research Assistant (M.S.- 12 months)	$15.40/hour	1039.2 hours	$ 18,000	$ 16,000	
Graduate Research Assistant (Ph.D. - 12 months)	$17.32/hour	1039.2 hours			
Fringe			**$ 4,079**	**$ 4,437**	**$ 8,516**
Full-time employees	18% + insurance		$ 3,899		
Part-time employees	1% + insurance (if applicable		$ 180	$ 4,437	
TRAVEL			**$ -**	**$ 4,300**	**$ 4,300**
Lubbock-Pecos River 2 people @ 3 days/trip @ 5 trips/year	$85/day per diem	5 trips		$ 2,550	
Lubbock-Pecos River - round trip	$350/trip gas	5 trips		$ 1,750	
SUPPLIES			**$ -**	**$ 2,850**	**$ 2,850**
Field supplies (water sampling bottles, shipping containers)				$ 250	
Laboratory supplies (water analysis reagents, standards, pipetters, analytical probe supplies)				$ 2,000	
SAS and ArcGIS licenses				$ 300	
Office and computer supplies				$ 300	
Contractual			**$ -**	**$ 7,200**	**$ 7,200**
Nutrient analysis by Tarleton State University				$ 7,200	
OTHER			**$ 6,136**	**$ 9,240**	**$ 15,376**
Tuition and Fees			$ 6,136	$ 7,440	
Postage for shipping samples				$ 1,800	
DIRECT			**$ 45,007**	**$ 44,027**	**$ 89,034**
OVERHEAD (10%)			**$ 4,501**	**$ 4,403**	**$ 8,903**
TOTALS			**$ 49,508**	**$ 48,430**	**$ 97,937**

Budget Narrative

Salaries and Wages

Dr. Reynaldo Patiño is program manager and is Unit Leader for the Texas Cooperative Fish & Wildlife Research Unit at Texas Tech University. No salary is requested for Dr. Patiño.

TTU match

- Dr. Christopher Taylor is Professor in the Department of Natural Resources Management at Texas Tech University and is providing two months of salary; $16,792/yr for FY 2012 and 2013 for a total of $33,584.
- Matthew VanLandeghem is a Graduate Research Assistant (Ph.D. student) whose annual salary of $18,000/yr is part of the TTU match for both years for a total of $36,000.

BR funds

- A second graduate student (M.S.) will be recruited for this project; salary is $16,000/yr for both years for a total of $32,000.

Fringe Benefits (Note: the actual fringe amount in part depends on voluntary employee selections of health insurance plan. For new employees, it is an estimated standard amount. Fringes are calculated at 18% of salary plus actual health insurance for Dr. Taylor. Fringes are calculated at 1% of salary for graduate students plus average health insurance budgeted for the TBN student).

TTU match

- Fringe for Dr. Taylor is $3,899/yr for a total of $7,798.
- Mr. VanLandeghem's actual fringe is $180/yr for a total of $360.

BR funds

- Estimated fringe for the new M.S. student is $4,048 in FY 12 and $4,437 in FY13, for a total of $8,485.

Travel

BR funds

- Travel costs will include per diem for 2 people at $85/day. Each trip will require 3 days of travel and $350 in gasoline per round trip from Lubbock to the Pecos River sample sites. Four round trips will take place in fiscal year 2012 and five in fiscal year 2013. Total per diem is thus estimated at $4,590 and total gasoline at $3,150. All travel will be for the purpose of taking *in situ* measurements and collecting water samples in the field and will be charged to the Bureau of Reclamation.

Equipment

BR funds

- Equipment in the budget will be charged to the Bureau of Reclamation and includes a GPS unit ($600) and a handheld flow meter ($1,000). These prices are estimated from vendor information available on-line but exact prices may change by the time of purchasing. The GPS unit is for geographical referencing of sample collecting sites, and the flow meter is necessary for measuring *in situ* water flow rates.

Materials and Supplies

BR funds

- These items consist of miscellaneous field and laboratory supplies ($250/yr and $2,000/year, respectively), office/computer supplies ($300/yr), and licenses for SAS and ArcGIS ($300/yr). Costs were determined from past experience doing similar types field and laboratory sample collections and analyses. The Bureau of Reclamation will be charged for materials and supplies.

Contractual

BR funds

- Nutrient analysis will be conducted by the Tarleton Institute for Applied Environmental Research (TIAER), part of Tarleton State University, and is estimated at a total of $14,400. The breakdown of this cost, per sample, is as follows: low level total phosphorus ($47.20), total Kjeldahl nitrogen ($26.25), nitrogen as ammonia ($23.78), low level nitrogen as nitrate-nitrite ($45.19), and low level orthophosphate ($49.36). This calculated total cost per sample is $191.78; however, we anticipate incurring a premium charge for low level orthophosphate samples due to the short holding time for these samples (48 hours) and time required to ship them from eastern New Mexico/far-west Texas to central Texas (location of TIAER). The estimated cost of the premium charge is $8.00 per sample; thus, the total cost per sample is estimated as $200. Overall, at $200 per sample x 8 sites x 9 total sampling events over the course of the proposed research, the total cost is $14,400. These charges are fair and reasonable as TIAER, a state of Texas public university, is not allowed to profit or incur monetary losses for analyses performed. Costs of these analyses will be charged to the Bureau of Reclamation.

Environmental and Regulatory Compliance Costs

- No Environmental and Regulatory Compliance Costs or Contingency Costs will be incurred with the proposed research.

Reporting

- No additional reporting costs will be incurred with the proposed research.

Other

TTU match

- Tuition and fees: the actual amount of tuition and fees for M. VanLandeghem (PhD student) is $6,136 for each year for a total of $12,272.

BR funds

- Tuition and fees: the estimated amount of tuition and fees for M.S. student is $7,086 (FY12) and $7,440 (FY13) for a total of $14,526.
- Postage: this budget item is to cover cost of overnight shipping of samples from sampling sites on the Pecos River to TIAER. It is estimated at a total of $3,600 for the two years.

Indirect Costs

TTU match

- Indirect costs charges for this project are assessed at 10% of total direct costs. Texas Tech is thus matching an amount of $4,501 for each year of the project.

BR funds

- The Bureau of Reclamation will provide $4,402 in FY12 and $4,403 in FY13 as indirect cost charges (at 10%).

Contingency Costs

- No Contingency Costs will be incurred with the proposed research.

Total Cost

TTU cost

- FY12: $49,508
- FY13: $49,508
- Total: $99,016

BR cost

- FY12: $48,426
- FY13: $48,430
- Total: $96,856

Combined cost

- FY12: $97,934
- FY13: $97,937
- Total: $195,871

The non-federal contribution is slightly higher than the federal cost