Texas Cooperative Fish and Wildlife Research Unit

ESTABLISHED IN 1988

What We Do

The Texas Cooperative Fish and Wildlife Research Unit is part of the National Cooperative Research Units Program that resides within the U.S. Geological Survey. The Texas Unit was established in 1988 and first staffed in 1989. Our mission is to conduct and facilitate research, train graduate students, and provide technical service on natural resource issues of interest to cooperators and the public. Natural resources targeted by our research range from endangered species to invasive species to game species. Our research utilizes concepts and approaches from the fields of animal ecology, physiology, toxicology, conservation and environmental science, and structured decision-making.

Unit activities are guided by a coordinating committee consisting of Texas Tech University, Texas Parks and Wildlife Department, The Wildlife Management Institute, U.S. Fish and Wildlife Service, and U.S. Geological Survey.

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https://www1.usgs.gov/coopunits/unitAboutUs/Texas

Project Highlights

Names of investigators, funding sources and amounts, and project periods can be found in the FY20-21 Financial Report. Please use project number for cross reference.

RWO 98: Structure and Connectivity of Mid-Continental Snowy Plovers (Completed)

Negative population trends of snowy plovers *(Charadrius nivosus)* have been documented for the Southern Great Plains (SGP). However, there is a paucity of data concerning population connectivity of snowy plovers on the SGP, where breeding habitat can be spatially disjunct; ranging from 10-600 km apart. Such breeding habitat distribution, coupled with precipitation stochasticity and low snowy plover abundance at sites in Texas and New Mexico, may elevate risks of regional extirpation, and population persistence probability may be quite low. We used the Motus Wildlife Tracking Network to track snowy plover movements across 6 sites on the SGP of Texas, New Mexico, and

Oklahoma in 2017 and 2018.We also performed breeding season surveys in Texas and used 20-year survey data from 2 National Wildlife Refuges (NWR; one in New Mexico, one in Oklahoma) to assess current population trends, relative abundances, and detection probability across the SGP landscape. Trend data from Salt Plains NWR in Oklahoma indicate a stable population of ~4500 plovers during the past decade. However, this stability at Salt Plains NWR contrasts with long term declines of breeding snowy plovers on the SGP of Texas (44%) and at Bitter Lake NWR in New Mexico (63%). Within breeding season movements of snowy plovers during 2017 and 2018 suggest that Salt Plains NWR is not connected to Texas saline lakes nor Bitter Lake NWR populations. Furthermore, only 2 individuals moved from Bitter Lake NWR to Texas, revealing these populations are weakly linked and that some degree of isolation exists. Relatively frequent movements of plovers to one of the study site saline lakes in the SGP of Texas may be indicative of higher-quality breeding and foraging habitat for regional snowy plovers due to the occurrence of consistent freshwater artesian springs at that site. Overall, such potentially low population connectivity may warrant further investigation into the genetic underpinning of small, isolated and potentially threatened subpopulations.

RWO 100: Changes in Avian and Plant Community Composition and Structure Following Prescribed Thinning in Pinyon-Juniper Woodlands (Active)

Pinyon-juniper woodlands are an extensive vegetation community found throughout the western United States, where climate and land use practices have significantly altered woodland range and density. This expansion has created federal and state agency interest in tree removal and thinning with the goals of reducing fuel loads and restoring historic stand structure. Conversely, the high proportion of avian pinyon-juniper specialists included on national and state lists of concern has created a need to balance thinning targets with conservation of these woodland-obligate bird species. We have partnered with the U.S. Bureau of Land Management and the U.S. Fish and Wildlife Service to study how avian community composition and structure changes in concert with vegetation community change following thinning prescriptions at two geographically distinct pinyon-juniper woodlands in central New Mexico. We stratified our random sampling into thinned and unthinned plots and conducted point count surveys during the breeding seasons of 2018 - 2021 at a site in Lincoln County, NM and in 2018 – 2020 at a site in Socorro County, NM. We observed 90 species across both sites, with over half determined as moderate or high conservation concern in the State of North America's Birds 2016. This project is ongoing as the first component of a longer study to understand time-lags associated with both avian and vegetation response to landscape level management actions.

RWO 101: Processing Hydroacustic Telemetry Data using High-throughput Computing (Completed)

The intent of this project is to develop numerical methods and to implement these methods in an open-source Python software package that will allow scientists to process telemetry data rapidly using high-throughput computing. The Levenberg-Marquardt algorithm implemented to resolve the spatial locations of the signals is not producing reliable positions. We have a number of proposed options solve the problem. In our implementation of Levenberg-Marquardt, we are using signals received at exactly four hydrophones to resolve the spatial location of the signal. We now believe that using four hydrophones is not sufficient given the noisy nature of the data. We expect that using a larger number of hydrophones for each optimization run

would improve the spatial resolution. However, this would require significant changes to the current software. At each iteration, the algorithm needs values for the Mean Squared Error (MSE), its gradient vector, and its Hessian matrix. Our software to calculate these values was written assuming that we were using exactly four hydrophones. Updating the MSE function to use an arbitrary number of hydrophones is relatively straightforward. However, updating the software to calculate the gradient vector and Hessian matrix given an arbitrary number of hydrophones would be daunting. Another option, given the difficulties in obtaining gradient and Hessian information for an arbitrary number of hydrophones, is using approximations to the gradient and Hessian, or changing to an optimization algorithm that is not gradient-based.

RWO 102: Development of an Effective Survey Methodology for Detection and Monitoring of Texas Kangaroo Rats (New)

The Texas kangaroo *rat (Dipodomys elator;* TKR) is endemic to the East Central Texas Plains and Southwest Tablelands ecoregions in north-central Texas (Texas Conservation Action Plan 2012). It is a rare, nocturnal rodent, making it an especially challenging species to obtain data for reliable estimates of population size or change. Existing surveys have primarily been by spotlight along roads; however, this presents a very biased interpretation of presence and habitat use and has not been sufficient to allow reliable estimates of density. Other density estimates, such as those derived from burrow counts are valuable as an index only; researchers have found individual TKRs may be associated with as many as 6 burrows. There is an urgent need to develop a reliable, repeatable survey method based on detection probabilities. This will require innovation in approaches but is foundational to developing a method that allows reliable estimates of population sizes and how they respond to management actions. We are initiating a study that, through experimentation and field test trials, will allow us to assess novel approaches to surveying for the Texas kangaroo rat. If successful, it will result in a new approach/method that will be suitable for nocturnal application, reliable, repeatable, and based on detection probabilities so that population abundances may be estimated. Developing such a method is incredibly important for assessing population trends and effectiveness of conservation efforts. We anticipate testing and comparing the following established (as baseline) and new methods for surveys: driving spotlight surveys, walking burrow surveys, walking spotlight surveys, walking surveys using thermal imaging monoculars, and transect flights by a UAV (drone) equipped with a thermal camera. All methods will be based on detection probabilities and estimates of abundance based on DISTANCE sampling. This project will start in January 2022.

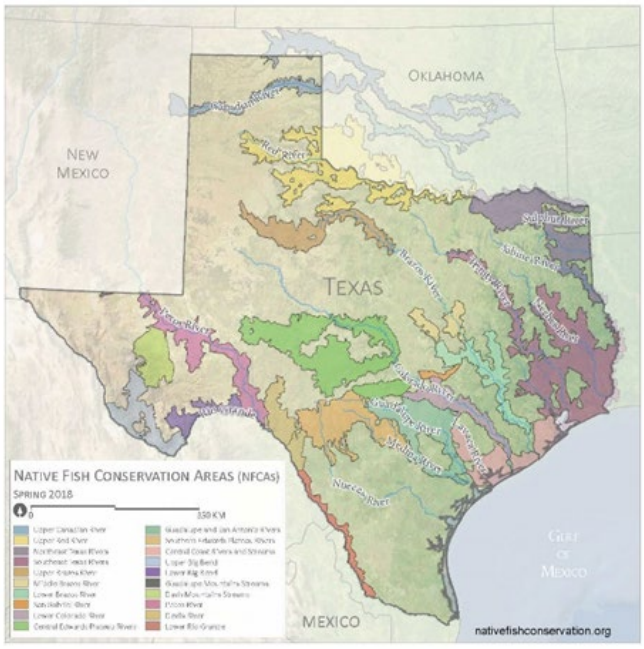
RWO 103: Assessing Risk for Westward Expansion of Zebra Mussels to Guide EDRR Strategies (New)

Early detection to help contain and prevent the spread of zebra mussels westward continues to be a high national priority for the Aquatic Nuisance Species Task Force. Zebra mussels are representative of nonindigenous aquatic species (NAS) with devastating economic, recreational, and environmental impacts that are under watch as a problematic species across the U.S. and in Texas. Targeting dispersal pathways is likely the most efficient means of controlling their spread further west. Thus, there is a need for risk assessment to guide prevention campaigns and monitoring efforts to detect and report new sightings of zebra mussels and other NAS. We will develop a risk assessment of waterbodies that are most likely to be hubs for the spread of nonindigenous aquatic species and forecast potential spread from hubs to other suitable waterbodies. Our specific objectives are to assess the risk of waterbodies to act as potential hubs based on transportation routes and estimates of recreational use, identify uninfested waterbodies with suitable habitat for zebra mussels to establish, forecast potential spread of zebra mussels from hubs to other suitable waterbodies in west Texas and eastern New Mexico, and validate network and model predictions of high-risk waterbodies with existing data on zebra mussel invasions and historical patterns of spread. By providing data and decision support tools on invasion risk our goal is to facilitate early detection and

mitigation strategies that may ultimately lower the cost associated with zebra mussel impacts.

RWO 104: Species Distribution Modeling and Native Fish Conservation Area Prioritization to Guide Landscape-level Conservation (New)

Conservation networks are a primary tool in multi-species stream conservation at large spatial scales. Recent efforts by TPWD have led to the development of statewide Native Fish Conservation Areas (NFCAs) focused on landscape-level conservation planning. These priority geographic areas are department-wide focal landscapes for technical and financial resources and will be integrated into comprehensive revisions of the Texas Conservation Action Plan (i.e., State Wildlife Action Plan of Texas). Although initial inception of NFCAs has been successful for project planning and implementation, development of this effort highlighted geographic areas that were undersampled or required baseline ecosystem assessments of habitat, water quality, and fish and mussel communities. Over the past 7 years, work on filling these information gaps with fish community field surveys, detailed biodiversity assessments (i.e., Bioblitzes), and citizen-based monitoring have been conducted in collaborative efforts between University of Texas and TPWD to provide additional data through the Fishes of Texas project biodiversity database and support management and conservation recommendations. Thus, there is a need to update predicted occurrences of species, and refine hierarchical prioritization within NFCAs, especially for Species of Greatest Conservation Need (SGCN). In collaboration with TPWD and the Fishes of Texas Project, we will develop new species distribution models and further evaluate areas of greatest conservation value within and outside of the existing NFCA network. Research during the development of these models will address what environmental factors best predict the occurrence of fishes in Texas streams, which modeling approach provides the most accurate and appropriate predictions for species-environment relationships in a conservation framework, and how various conservation objectives (e.g., protect or restore habitat condition, maintain dispersal corridors, etc.) affect the ranking and selection of geographic priorities. This will add a critical step in aligning conservation planning objectives and priority projects within NFCAs to the distributions of species.



TPW 40: Assessing Distribution and Occupancy Patterns of Riparian Avifauna in the Trans Pecos Region of Texas (Active)

Riparian areas in the Chihuahuan Desert Ecoregion are identified as a priority for conservation in the Trans Pecos region of Texas. It is also an objective of the Texas Parks and Wildlife Department to work toward the recovery of threatened, endangered, and high-priority species associated with riparian systems. In the Chihuahuan riparian zones this includes the federally threatened western yellow-billed cuckoos (*Coccyzus americanus occidentalis*) and the state threatened common black-hawk *(Buteogallus anthracinus)*, gray hawk *(Buteo plagiatus)*, and zone-tailed hawk *(Buteo albonotatus)*. However, little quantitative data are available for riparian obligate birds in the region. In 2018 and 2019 we studied the distribution, relative abundance, and community structure of avifauna among 8 riparian systems of the Trans Pecos region, and estimate nesting abundance and productivity of diurnal raptor species. Larger riparian woodlands had greatest bird diversity, and cavity nesting species tended to be absent from smaller woodlands. Tree sizes, heights, and density also substantively influenced species gradients. Consistent with this, we found substantive differences in height and DBH of nest trees and grove density used by different raptor species, suggesting the species we studied are selecting

riparian woodlands with different characteristic. This suggests even age riparian systems are not adequate for occupancy of this suite of raptor species; rather a mixed-age and structure of riparian woodlands is important for continued presence of these raptors, and larger woodlands increase avifaunal diversity and abundance. These results will provide management agencies with data to make informed decisions for identification of priority areas for conservation and restoration. We are currently collecting pre-scheduled passive audio recordings in additional riparian areas of the Trans Pecos to further determine species distribution patterns in the region.

TPW 41: Influence of Woody Vegetation Patterns on Scaled Quail Demographics (Active)

Semi-arid landscapes, including those in the Texas Rolling Plains, have undergone shifts in vegetation structure over the past century, resulting in irregular, dense stands of woody vegetation in areas that were once predominantly mixed grasslands. While there has been a growing body of literature and interest in scaled quail, more research was needed to understand if scaled quail population declines in the Texas Rolling Plains were correlated to changes in woody species encroachment and habitat fragmentation. We captured 187 scaled quail and deployed 43 GPS-transmitters that gathered location data. We calculated home range size of 27 scaled quail and collected 4,560 drone images to estimate habitat selection. The overall accuracy of the drone images being classified as the correct vegetation community based on ground truthing was 85.65%; average home range size was 91 acres. Grassland comprised the largest percentage of landcover type within home ranges at an average of 54% followed by succulents (12%), bare ground (10%), and woody vegetation (8%). Scaled quail selected similar habitat among ranches and temperature was a better predictor of habitat selection in winter compared to vegetation. Scaled quail were flexible and used various types of cover in winter. Vegetation and microclimate did influence one another, and areas that were composed of more bare ground and woody vegetation were warmer. However, our results indicated woody vegetation and bare ground within the home range both negatively influenced overwinter survival (~57%), but fine scale vegetation and microclimate did not. Our findings support previous assessments that suggest the woody vegetation encroachment phenomenon is contributing to the decline of scaled quail in the Texas Rolling Plains, and management designed to reduce woody vegetation and increase native warm season bunchgrasses will be beneficial for scaled quail, grassland songbirds, and other native wildlife on the Texas Rolling Plains.

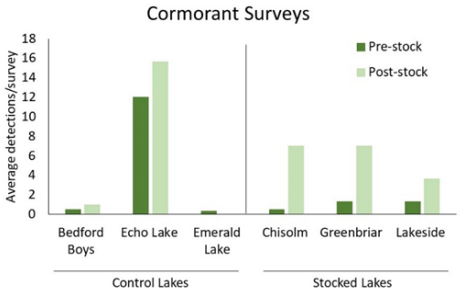
TPW 43: Distribution and Habitat Use of Kisatchie Painted Crayfish in Northeast Texas with Investigation of Multi-scale Environmental Influences on Crayfish Community Structure (Active)

The Kisatchie Painted Crayfish, *Faxonius maletae*, lacks sufficient information for the development of a conservation and management plan. The species is known to occur in only a few localities in the Big Cypress Creek drainages of northeast Texas, but it is possible that more intense, systematic survey efforts would expand the known distribution in Texas. Furthermore, patterns of co-occurrence and environmental influences on the structure of overall crayfish assemblages have not been studied in streams of northeast Texas. Finally, because crayfish surveys have been rarely carried out in Texas, few specimens are available in natural history collections for researchers and managers in the state. To address this need, comprehensive surveys across northeast Texas (beyond limited, historic collection sites), with a

systematic assessment of habitat associations and patterns of co-occurrence with other crayfish species, are badly needed to develop a conservation plan for the species. Therefore, we surveyed 74 sites across 11 counties (i.e., Camp, Cass, Franklin, Gregg, Harrison Hopkins, Marion Morris, Titus, Upshur, and Wood) with a combination of seine netting, D-netting, and trapping. To date, we have collected and vouchered 12 crayfish species, including our target *F. maletae*, plus *Cambarellus puer, Cambarus diogenes, Faxonella clypeatus, Faxonius palmeri, Procambarus clarkii, P. curdi, P. dupratzi, P. kensleyi, P. natchitochae*, and *P. zonangulus*, as well as a few specimens that remain to be identified through laboratory inspection and DNA barcoding. Focal species *F. maletae* has been collected at five sites spanning four counties (i.e., Franklin, Titus, Camp, and Marion), including one collection outside of the historically known range.

TPW 44: Pilot Study – Understanding the Distribution and Relative Abundance of Cormorants in Texas (Completed)

Over the last decades, there has been an increasing conflict between conservation of cormorants and perceived and real predatory impacts they pose to managed fisheries. This has been exacerbated by increases in cormorant populations across North America. Continentally, the majority of these conflicts have been in the northern Great Lakes states and in the southeastern United States. More recently there is a common perception that populations of double-crested (*Phalacrocorax auritus*) and neotropic (*Phalacrocorax brasilianus*) cormorants are increasing in Texas and creating a conflict with fish stocking and fishery management in public waters. We assessed the historic and current distributions of cormorants in Texas, seasonality of presence, and if relative abundance of cormorants at water bodies is related to stocking schedules. We used Christmas Bird Count data to assess population changes in Texas over the last 50 years. We found no statistical evidence of an expansion of double-crested cormorants in Texas but there was a significant but non-linear increase in abundance across 5-year blocks. In contrast, we found evidence of significant increases in both range and abundance of neotropic cormorants. We used before and after surveys to assess cormorant presence at neighborhood fishing lakes that were and were not stocked. We found no change in presence of cormorants at non-stocked lakes but a significant and rapid change in presence following stocking at stocked lakes.



TPW 45: Ecology of Devils River Minnow *Dionda diaboli* in an Invaded Stream-riparian Ecosystem (Active)

Streams often face multiple stressors that simultaneously erode the quality and quantity of freshwater habitats to the detriment of sensitive aquatic species. Groundwater dominated streams in semi-arid and arid landscapes face additional threats such as water extraction, altered flow regimes, encroachment of invasive species, and reduced water quality (e.g., salinity, pollution, turbidity), which collectively alter aquatic environments in ways that stress populations of native fishes and the food resources they rely upon. San Felipe Creek, which is listed as critical habitat for Devils River Minnow (DRM) *Dionda diaboli* and is one of only three known remaining populations in Texas, has been degraded by many of these stressors including the presence of invasive fishes (e.g., armored catfish *Hypostomus* sp.) and riparian vegetation (e.g., Giant reed *Arundo donax*). There is interest by partners to address these concerns and restore riparian habitats along San Felipe Creek. However, the impacts of these invasive species on food web dynamics as they relate to priority species such as DRM is lacking. Findings from this project will be used to inform efforts to prioritize the management of riparian vegetation, invasive fishes, as well as to

identify locations on public and private lands for effective habitat enhancement or restoration projects. This study will address key information gaps laid out in the recovery plan concerning the ecology of federally threatened DRM by quantifying the diet habits of the fish assemblage and availability of basal food resources in the designated critical habitat of San Felipe Creek. Food web dynamics will be compared between stream reaches of varying land management practices and levels of riparian degradation. Sampling began in the spring of 2021. Samples are currently being processed and findings will be reported later.

TPW 46: Dimensions of Diversity in Urban Fisheries: Examining Habitat, Fish, and Anglers to Inform the Management of Texas Community Fishing Lakes (New)

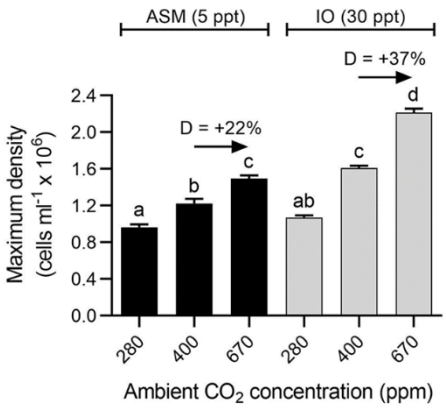
Urban fishing programs have been developed as a strategic approach to manage underserved fisheries and to engage and recruit new recreational anglers. Effective management of these urban fisheries requires a basic understanding of both ecological and human dimensions, which entails integrative study approaches. Traditional fisheries approaches (aquatic biology of freshwater systems) coupled with human dimensions methodologies provide a means of holistically examining and weighing the importance of catch and non-catch related factors that are important to urban anglers and those interested in recreational angling. This study is examining multiple dimensions of diversity within urban fisheries of Texas to better understand the interactions of anglers with their fishery. Community Fishing Lakes (CFLs) in Lubbock and DFW metroplex are being sampled to quantify the availability and quality of littoral and shoreline habitats and the diversity of fish assemblages. Concurrently, recreational anglers are being interviewed at each lake to quantify the quality of angling experiences, fishing tendencies (i.e., harvest, catch-release, fishing effort), and angler demographics. In addition, non-fishing individuals at the same parks are being interviewed to assess attitudes towards fishing (e.g., do you go fishing? why not?) and their perception of nearby urban fisheries. Collectively, assessments of habitat, fish, and people (anglers, potential anglers) will address knowledge gaps concerning Texas urban fisheries. Findings will aid in identifying best approaches (maximize benefit; cost-effectiveness) for enhancing underserved urban fisheries and indirectly benefit broader initiatives aimed at recruiting new recreational anglers. The project began collecting data during spring of 2021. Findings will be reported at a later date.

TPW 47: Assessing Texas Kangaroo Rat Habitat Connectivity, Management and Monitoring Protocols (New)

The Texas kangaroo rat *(Dipodomys elator*) is a rare species endemic to the Central Great Plains and Southwest Tablelands ecoregions in north-central Texas. Due to substantial reduction in distribution and suspected population declines, the species has been petitioned for federal protection under the Endangered Species Act and is ranked as a G2 - imperiled (global ranking) and S1 – critically imperiled (state ranking) species. We propose a study addressing three important steps in the effort to conserve the species. First is to conduct experimental vegetation manipulations to determine feasibility and effectiveness of restoring/enhancing/creating usable habitat for Texas kangaroo rats. Second is to use GPS data loggers to assess movement patterns and dispersal of Texas kangaroo rats, especially the success of getting dispersal of individuals into restored areas from proximal occupied areas. Third is to model connectivity and environmental resistance to dispersal of Texas kangaroo rats within and among the known occupied clusters. Using such a model would allow targeted application of habitat restoration/creation knowledge from objective 1. This project has been delayed and is just starting July 2021.

OA 79: Influence of Environmental Variables on Growth of Toxigenic Golden Alga *(Prymnesium parvum)*: A Laboratory Test of Field-Generated Hypotheses (Completed)

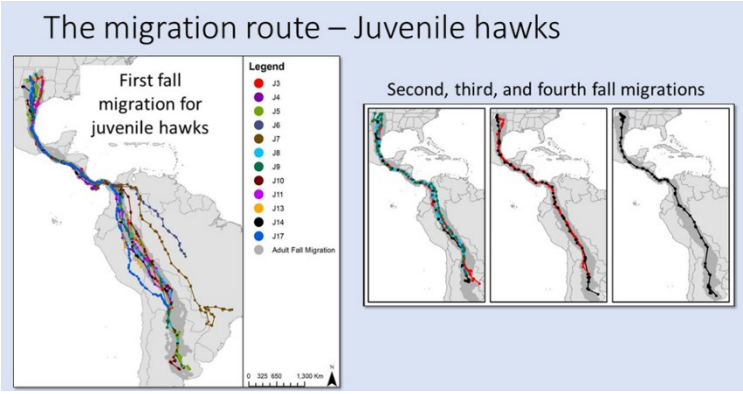
The environmental regulation of golden alga *(Prymnesium parvum)* growth has been intensively researched and, in recent years, our laboratory and others have gathered new information concerning environmental variables associated with golden alga presence and abundance in inland waters of the USA.



Notable examples include the biphasic association between golden alga abundance and salinity, the positive association with sulfate concentration, and the positive association with organic nitrogen concentrations. The purpose of this study was to determine if these associations are spurious or linked in a cause-effect manner under controlled laboratory conditions. This study reported a clear biphasic growth pattern with increasing salinity; namely, golden alga growth seemed to be positively associated with salinity from 5 to 10–15 psu, but negatively associated at higher levels (>15 psu). This observation confirms the biphasic growth pattern observed by field studies and strengthens the conclusion that high salinity presents a barrier for the expansion of golden alga in inland brackish waters. This study also showed that sulfate positively influences golden alga growth independently of salinity, thus suggesting that waters with high sulfate concentrations may have a higher risk of golden alga establishment and bloom formation. Golden alga blooms occur in eutrophic/hypereutrophic waters, but the role of organic nutrient fractions is not fully understood. IN this study, organic and inorganic fractions were varied while keeping total nitrogen concentration constant. Results showed that growth occurs in the presence of inorganic or organic nitrogen, but that optimal growth occurs when both fractions are present and the organic fraction is predominant. Lastly, this study examined the working hypothesis that rising air CO2 levels can stimulate golden alga growth and abundance. Past (280 ppm), present (400 ppm), and projected levels (670 ppm) of air CO2 were tested for their growth effects. The results obtained confirmed this hypothesis, thus suggesting that golden alga growth in the field might have already been affected by current levels of air CO2 compared to pre-industrial conditions and, if the trend of increasing CO2 continues, the intensity of blooms may also continue to rise.

OA 87: Interactions of Juvenile Swainson's Hawks with Wind Energy Facilities During Dispersal and Migration (Completed)

Swainson's Hawks *(Buteo swainsoni)* are migratory raptors that breed in western North America and winter in the Pampas of Argentina. Most research on this species has focused on reproduction, habitats, foraging, and populations, with relatively little research on migration or wintering ecology, and, importantly, there is a lack of information about the juvenile and subadult period which lasts three to five years. We equipped 17 fledgling hawks with satellite transmitters to describe ecology and survival during their first years of life. We observed a post-fledging-dependence period of 19 to 79 days. After gaining independence, hawks spent time wandering the breeding range until migration. Young hawks migrated south at the same time as adults, and first migration attempts showed high variability in routes; most juvenile hawks that deviated from the primary route perished before reaching the wintering grounds. Some first-wintering periods were spent at a location northwest of the primary wintering grounds of adult hawks. Hawks that survived the first winter used expected pathways and had lower mortality during future migrations. Young hawks left for the northward migration later and arrived on the summering grounds later than adults, possibly because they were not intending on breeding upon return. On summering grounds, hawks wandered and explored; one hawk appeared to establish a home range in third and fourth summers but did not nest. Survival was lowest immediately following fledging, and first migrations were another common period for mortality. We never observed a breeding attempt among this sample, and therefore could not establish natal philopatry or dispersal.



OA 90: Avian Community Response to Brush Control on the Welder Wildlife Refuge - Phase II (Completed)

Grassland obligate birds are experiencing widespread population declines across North America, largely due to loss of prairie grasslands. This has led to widespread prairie restoration effort. The Texas coastal prairie has experienced extensive brushland encroachment and efforts to restore coastal prairie grasslands and the natural avian communities has been given little attention compared to other regions. We partnered with the Welder Wildlife Foundation to assess coastal prairie restoration efforts on the Welder Wildlife Refuge, in San Patricio County, Texas. Our study is a before-after control-impact investigation of the temporal patterns of avian communities change in relation to chemical and prescribed fire brush control. Additionally, we used greater roadrunners *(Geococcyx californianus)* as a focal species for more specific habitat use assessment. Roadrunners requires a combination of open areas for foraging and brush for perches and nesting, but little quantitative data are available for roadrunner habitat selection, especially at the interface of prairies and brushlands of the Gulf Coast. Our goal was to understand how prairie restoration efforts can contribute toward grassland bird community recovery, while also accounting for species, such as the roadrunner, that require a mixture of vegetation communities. We conducted vegetation sampling along a 30-meter transect in June-July of 2018, 2019, and 2020 at 29 sample sites each within both the control and treatment plots. We found that woody vegetation canopy communities varied by plot and herbaceous cover community was most impacted by the application of prescribed fire. We found that herbicide application in conjunction with prescribed fire can be a successful in reducing woody vegetation canopy cover while increasing native graminoid cover. When assessing the avian communities between a control plot and an herbicide and prescribed fire treated plot, we found alpha diversity was highest within the control plot. Detections of birds in the scrub habitat guild was highest in the control plot in contrast to the treatment plot where the grassland habitat guild had the highest number of detections. Avian community structure varied in response to woody vegetation canopy cover and graminoid cover. When focusing on our roadrunner habitat study, we found roadrunners selected for bare ground and avoided riparian and water landcover types at the 1st order. At the 2nd order, roadrunners selected for bare ground and avoided riparian and water land cover types. For the 3rd order they used all land cover types proportionally with the exception of the water land cover type which they avoided. The removal of woody vegetation may benefit roadrunners on the Welder Wildlife Refuge considering that at the first and second order roadrunners are selecting for bare ground. Overall, the reduction in brush cover comes with an increase in forage production. Increased forage production will allow for higher stocking rates and ultimately a larger profit if the land manager decides to stock cattle. However, for long term management plans, finding a balance between conservation goals, restoration efforts, and financial gain by both ecotourism and cattle production, will require cost-benefit analysis by landowners.

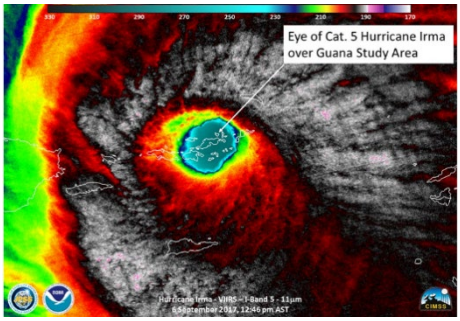
OA 91: NWI SWIFT Environmental Assessment and Monitoring Study (Active)

The Scaled Wind Farm Technology (SWiFT) program at the Reese Technology Center (RTC) is a research facility for research and development of improved wind energy generation. As part of their compliance program, we have been conducting several lines of research based on monthly surveys of avian species on and adjacent to the RTC, and species-specific studies at the RTC. One example of research results includes a long-term study of American kestrels *(Falco sparverius)* populations and factors that influence nesting success and productivity. We have found that kestrels in our study area have some of the highest nest success and productivity rates reported in North America, and that approximately 25-35% of pairs produce a second brood of nestlings. Additionally, there was no meaningful difference in nest success rates between a nest box program (83.2%) and those using 'natural' nests (89.5%). Another

example is an assessment of seasonal and annual variations in abundance of birds in different guilds. This will facilitate long term assessment of abundance, diversity, richness, and overlap among years, and assessing these in context on variance in weather patterns (e.g., drought, extreme cold).

OA 92: Guana Island Ornithology/Hurricane Research (Active)

The Caribbean region is considered a biodiversity hotspot and a priority for ecological conservation efforts. The Caribbean is also recognized as a region that will likely undergo substantive environmental changes over the next century. Contemporary modeling suggests the Caribbean will become more prone to protracted periods of drought and experience fewer but stronger hurricanes. In 2017, Guana Island, British Virgin Islands experienced a direct strike from Hurricane Irma and a subsequent hit from Hurricane Maria. In October 2019 we returned to Guana to conduct assessments of the avian and iguana populations and compare them to data we had collected annually on the island from 2003 – 2015. We detected a dramatic decrease in Bananaquits from an average of 144 individuals in the sampled area pre-hurricane to only 16 in 2019, a decrease of Black-faced Grassquits from an average 33 individuals to an estimated 19, and an increase of the opportunistic generalist Pearly-eyed Thrashers from an estimated average of 55 in the sample area to 74 individuals in 2019. The population of the Bridled Quail Doves, a species of conservation concern, was so low that we could not calculate density estimations as was made in previous years. However, raw detection rates of 0.37 - 0.40/100m in 2014 and 2015 dropped to only 0.18/100m surveyed in 2019. In contrast to the avian community, the endangered rock iguanas appeared to have benefited from hurricanes opening up the forest; occupancy of sampling plots was 94.4% compared too only 17.2% in 2009 surveys. Our results indicate some species recover quickly and may even benefit from the forest changes caused by severe storms, whereas others have protracted recovery periods. We have been prevented from returning in 2020 or 2021 due to the COVID-19 pandemic, but anticipate revisiting and repeating surveys when travel is again allowed to the study site.



OA 93: Burrowing Owls and Wind Energy Development (Completed)

Burrowing owls *(Athene cunicularia)* are a small owl species that is of substantial conservation concern across their breeding distribution in the prairies and steppes of North America. Burrowing owls not only nest in, but seasonally migrate the length of, the Great Plains. These landscapes have become areas of rapid wind energy development, and there are cases in which wind turbines have resulted in direct mortality of burrowing owls. Of avian species experiencing mortality due to collision with wind turbines, raptors, such as burrowing owls, appear to be the most vulnerable and may experience proportionally greater population level influences through direct mortality or habitat loss associated with wind energy development. We partnered with Consolidated Nuclear Security, LLC through the Department of Energy, and with the Idaho Cooperative Fish and Wildlife Research Unit, to attempt to understand burrowing owl habitat use and movement patterns in context of wind energy development on breeding areas in Texas, and migratory pathways across the Great Plains. We deployed 4 transmitters in 2020, are deploying 3 more in 2021, and are pooling our data with that from Idaho to assess similarities or departures in migration associated with latitude of origin.

OA 95: Nest Site Selection and Nest Survival of Avian Communities in Pinyon-Juniper Woodlands Undergoing Thinning Prescriptions (Active)

Pinyon-juniper woodlands are an extensive and biologically important vegetation community across the western United States and have been found to have the highest diversity of wildlife, highest density of nesting birds, and the highest number of bird species throughout the year compared to other upland habitats in the West. However, due to land-use patterns, pinyon- juniper woodlands have expanded beyond their historical distribution. In response, land management agencies have enacted removal or thinning actions to restore landscapes. A key issue is that many obligate and semi-obligate pinyon-juniper associated bird species show declining population trends, and many are included on lists of conservation concern maintained by various agencies and groups. There is a clear need to better understand how prescribed treatment of pinyon-juniper woodlands influences the local avifauna and attempt to balance competing management objectives of grassland restoration and pinyon-juniper bird conservation. We are studying changes in nesting density, site selection, nest survival, and estimates of productivity among the avian community in treated and untreated pinyon-juniper woodlands. The resulting data will better inform land and wildlife managers on what level of thinning and removal provide the maximum benefit for avian communities and meet the broader objectives to restore grass and woodland habitats in New Mexico and across this habitat type in the Southwest United States.

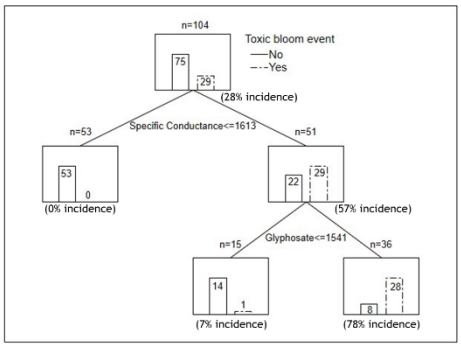
OA 96: Development of Environmentally Friendly Methods to Control Harmful Algal Blooms (Active)

Golden alga *(Prymnesium parvum)* is a euryhaline haptophyte that produces compounds highly toxic to fishes and other gill-breathing aquatic organisms. In the USA, harmful blooms of golden alga were first reported in 1985 in the Pecos River, and they have now spread through most of Texas and the sunbelt states. The ecological impacts of toxic blooms have been severe; unfortunately, effective field control methods are presently unavailable. The goal of this research is to develop effective and environmentally friendly methods to control harmful blooms of *P. parvum.* Giant reed *(Arundo donax)* is a harmful invasive plant in the USA. A previous study by our laboratory showed that extracts from giant reed and two of its known constituents, gramine and skatole, inhibit growth of golden alga and suggested this plant is a potential source of natural products for controlling blooms. Extract are relatively difficult to prepare, however, and may not be a viable option for field application. Also, the two allelochemicals previously tested were less potent than the extracts thus indicating the existence of additional, more potent allelochemicals. The objectives of this research are to determine if giant reed chips or their aqueous leachate can effectively inhibit golden alga growth and to screen other known giant reed constituents for growth effects. Results showed that dried chips and leachate from giant reed are potent inhibitors of *P. parvum* growth. In addition, the indole alkaloid ellipticine, which is present in relatively high concentration in giant reed leachate, was found to be among the most potent natural algicides identified to date for any harmful algae. These observations confirm the existence of highly potent anti-*P. parvum* allelochemicals in giant reed and demonstrate potential for using products derived from this plant in the development of natural, environmentally friendly methods to control harmful algal blooms. Current experiments are addressing the species-specificity and mechanisms of action of giant reed leachate and allelochemicals.

Test chemical	IC_{50} (mg L^{-1})	
	Day 3	Day 9
Gramine	2.78[a]	1.83[a]
1 H-Indole	2.10[a]	1.01[b]
2,4,6-Trimethyl-benzonitrile	2.28[a]	0.84[b]
5,6-Dichlorogramine	0.54[b]	0.22[c]
Ellipticine	0.012[c]	0.007[d]

OA 97: Long-term Trends in Land, Water Quality/Quantity, and Air Variables and their Association with the Harmful Alga *Prymnesium parvum* in Watersheds of the Southern Great Plains, USA (Completed)

Total environmental associations with harmful algal bloom incidences are seldom examined. This study evaluated the association of thirty-three land, water quality/quantity, and air variables with the annual incidence of toxic blooms of *Prymnesium parvum* in reservoirs of the Brazos River and Colorado River, Texas (USA). One highly impacted and one reference reservoir were selected for each basin. Land cover and pesticide use were estimated for a 0.5-km zone on either side of streams within respective reservoir watersheds. All variables were expressed in annual values. Objectives were to 1) determine major environmental differences in impacted reservoirs before and after their first bloom occurrence in 2001 (period of record, 1992-2017), 2) identify conditions unique to impacted reservoirs since the onset of blooms (2001-2017, all reservoirs), and 3) identify new potential drivers of bloom occurrence (1992-2017, all reservoirs). Principal component analysis was used to address objectives 1 and 2. Use of the herbicide glyphosate greatly increased in all watersheds since 1992 (or 2001) while use of other pesticides generally declined. Compared to reference reservoirs/watersheds, impacted reservoirs/watersheds had higher levels of specific conductance, lower wetland area, and higher levels of glyphosate use. Classification tree analysis was used to address objective 3 using non-redundant environmental variables as explanatory factors. The risk of toxic blooms increased when specific conductance was >1613 µS/cm, and this risk further increased when glyphosate use was >1541 kg/year. Replacing specific conductance with wetland area (redundant variables) yielded similar results; namely, the first and second splitting variables were wetland area and glyphosate. This study confirmed the importance of salinity as explanatory variable for the distribution of *P. parvum* blooms at the landscape scale and suggested a possible mitigating role for wetlands. The positive association of glyphosate with bloom occurrence is notable because glyphosate at environmentally relevant concentrations can stimulate *P. parvum* growth.

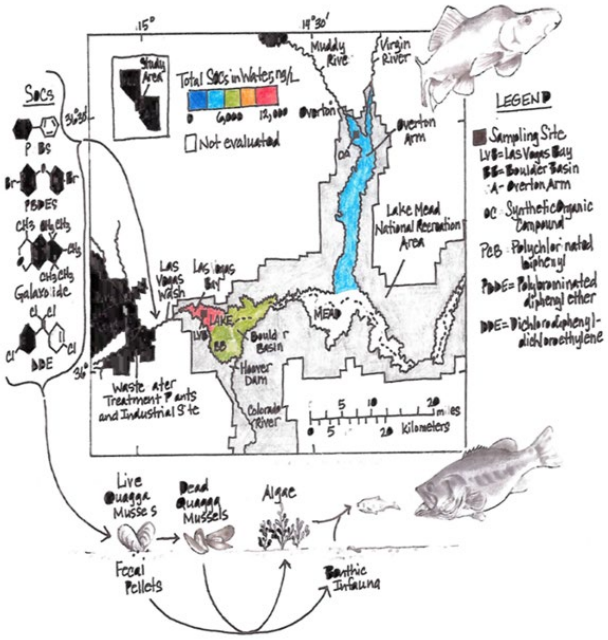


OA 98: Pilot Project – Home Range and Habitat Use of Zone-tailed Hawks (Active)

The zone-tailed hawk *(Buteo albonotatus)* is a medium sized bird of prey with a broad yet patchy distribution across the southwestern United States, where it is purported (but not confirmed) to be migratory, through parts of Mexico and Central America where it is considered resident. Zone-tailed Hawks are known to occupy a diversity of land cover types and elevations, found from low desert riparian zones to high elevation pine forests. Ecologically, they are one of the least understood and studied raptor species occurring in North American. In Texas they are protected as a threatened species, but this listing is largely based on a lack of quantitative data, perceptions of small populations, and risk of habitat loss due to degradation and loss of riparian woodlands. However, little quantitative data are available regarding the species breeding density and reproductive success across its distribution in the southwestern United States. The lack of information regarding its population size, nesting ecology, success, and habitat selection hampers identification of conservation needs and management actions. We deployed GPS transmitters on two male zone-tailed hawks in the Trans Pecos in June of 2021 and are already obtaining previously unknown ecological information regarding their breeding season home range sizes and movements. We plan to deploy an additional 5 GPS transmitters during the breeding season of 2022. These will be the first quantitative data obtained on home range size, movements, and habitat use for the species, and will serve to better inform management and conservation actions in the Big Bend country of Texas.

Unassigned Project #1: Movement of Synthetic Organic Compounds in the Food Web after the Introduction of Invasive Quagga Mussels *(Dreissena bugensis)* in Lake Mead, Nevada and Arizona, USA (Unassigned #, Completed/Published)

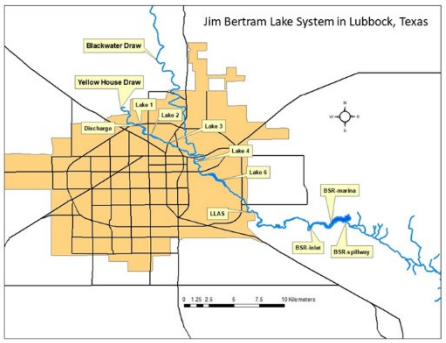
Introductions of *dreissenid mussels* in North America have been a significant concern over the last few decades. This study assessed the distribution of synthetic organic compounds (SOCs) in the food web of Lake Mead, Nevada/Arizona, USA and how this distribution was influenced by the introduction of invasive quagga mussels. A clear spatial gradient of SOC concentrations in water was observed between lake basins downstream of populated areas and more rural areas. Within the foodweb, trophic magnification factors (TMF) indicated statistically significant biomagnification for nine, and biodilution for two, of 22 SOCs examined. The highest value recorded was for PCB 118 (TMF, 5.14), and biomagnification of methyl triclosan (TMF, 3.85) was also apparent. Biodilution was observed for Tonalide® (0.06) and Galaxolide® (0.38). Total SOC concentration in quagga mussels was higher than in three pelagic fishes. Also, 19 of 20 SOC examined in Largemouth Bass *(Micropterus salmoides)* had substantially lower concentrations in 2013, when quagga mussels had become well established, than in 2007/08, soon after quagga mussels were introduced. Estimates of SOC concentrations in the water column and quagga mussels suggest that a considerable portion (~10.5%) of the SOC mass in the lake has shifted from the pelagic to the benthic environments due to quagga mussel growth. These observations suggest that benthic species, such as the endangered Razorback Sucker *(Xyrauchen texanus)*, may be experiencing increased risk of SOC exposure. In addition, stable isotope analysis (carbon and nitrogen) indicated a decrease in the nutritional value of zooplankton to consumers (e.g., Razorback Sucker larvae) since quagga mussels became established. These changes could affect Razorback Sucker larval survival and recruitment. Results from this study strongly suggest that the introduction of quagga mussels has greatly altered the dynamics of SOCs and other processes in the food web of Lake Mead.



Unassigned Project #2: Water Quality Associations and Spatiotemporal Distribution of the Harmful Alga *Prymnesium parvum* in an Impounded Urban Stream System (Unassigned #, Completed/Published)

The Jim Bertram Lake System consists of several stream impoundments within the City of Lubbock, Texas (USA). Baseflow in the upstream reach is dominated by nitrogen-rich-treated wastewater. While toxic blooms of *Prymnesium parvum* have occurred in this system for ~2 decades during fall or winter-spring, little is known about water quality variables that facilitate blooms or the alga's spatiotemporal distribution. Water quality associations were examined monthly over a 1-year period. Total phosphorus was largely below the detection limit, suggesting that the system is phosphorus limited. Algal abundance was low during the assessment period and associations were determined using multiple logistic regression. Algal incidence was negatively associated with temperature and positively with organic nitrogen and calcium hardness. These findings conform with earlier reports but positive associations with the latter two variables are noteworthy because they have not been widely confirmed. Spatiotemporal distribution was evaluated in fall and winter-spring of three consecutive years. *Prymnesium parvum* incidence was higher in the upper than in the lower reach, and detections in the lower reach occurred only after a dense bloom developed in the upper reach contemporaneously with stormwater runoff-associated

flooding. Thus, the upstream reach is a major source of propagules for downstream sites. Because urban runoff is a source of phosphorus and its nitrogen: phosphorus ratio is lower than prevailing ratios in the upper reach, what triggered the bloom was likely relief from phosphorus limitation. This study provided water quality, geographic and hydrological indices that may inform prevention and control methods for harmful algae in nitrogen-enriched urban systems.



Unassigned Project #3 – Raptors of Texas: A natural History of Diurnal Birds of Prey (Completed)

This is a book originally scheduled for publication in May 2020 but delayed by Texas A&M Press due to the COVID-19 pandemic.

Proposed Projects

We are responsive and opportunistic in conducting research and providing technical support of relevance to unit cooperators within the research expertise of unit scientists. The list below includes specific or general projects being considered for FY22.

Terrestrial projects

Building climate resiliency for lesser prairie-chickens among West Texas rangelands – proposal in development (Boal)

Crested caracara breeding range expansion and association with livestock production – proposals submitted and in development in collaboration with USFWS and Texas AgriLife (Boal)

Breeding abundance and distribution of aplomado falcons in Southern Mexico – partial funding obtained in collaboration with Oregon State University and the Peregrine Fund (Boal)

Wildlife Friendly Lubbock: a community outreach program for urban wildlife education – project development starting with local Lubbock entities (Boal)

Aquatic projects

NRT – HDR: Convergence research of wildlife, environmental, and computational science and engineering – proposal submitted to The National Science Foundation; specific focus of proposal is harmful algae (Patiño)

Influence of surface water alkalinity on growth of *Prymnesium parvum* – new MS student project (Patiño)

Association between the carbonate system status and isotopic niche variability in lake biota – proposal being considered for submission to The National Science Foundation (Patiño and Rogosch)

Evaluating resilience and vulnerability of fish assemblage structure to intermittent flow (Rogosch)

Food habits of SGCN fishes to inform habitat assessment and restoration in the Red River basin (Collins, Durham, Rogosch)

Assessment of *Gila pandora* in Little Aguja Creek (Davis Mountains), Texas (Collins, Rogosch)

Publications FY2020-2021

Barnes, M.A. and R. Patiño, R. 2020. Predicting suitable habitat for dreissenid mussel invasion in Texas based on climatic and lake physical characteristics. Management of Biological Invasions 11:63-79.

Boal, C.W. 2019. Urban nesting by a broad-winged hawk pair in the southern High Plains of Texas. Bulletin of the Texas Ornithological Society 52:54-58.

Boal, C.W., B.D. Bibles, and J.M. Tomacek. In Press. Predator-prey relationships and management. In Wildlife management and conservation: contemporary principles and practices, second edition (P.R. Krausman and J.W. Cain, III, editors). Johns Hopkins University Press, Baltimore, MD.

Boal, C.W., MA. Thornley, and S.D. Mullican. In Press. Food habits of American kestrels in a nest box program: unintended consequences of a conservation action. Journal of Raptor Research 55:00-00.

Clayton, J.B., R. Patiño, R.H. Rashel, and S. Tábora-Sarmiento. 2021. Water quality associations and spatiotemporal distribution of the harmful alga *Prymnesium parvum* in an impounded urban stream system. Journal of Urban Ecology 7:1-13.

Dwyer, J.F., R.K. Murphy, D.W. Stahlecker, A.M. Dwyer, and C.W. Boal. 2020. Golden eagle perch site use in the U.S. southern plains: reducing mortality risk uncertainty. Journal of Raptor Research 54:126-135.

Farquhar, C.C., and C.W. Boal. In Press. The Raptors of Texas: a natural history of birds of prey. Texas A&M Publ., College Station, TX.

Gicklhorn, T.S., C.W. Boal, and P.K. Borsdorf. In Press. Lesser prairie-chicken use of man-made water sources. Southwestern Naturalist 00:00-00

Goodbred S., M.R. Rosen, R. Patiño, D. Alvarez, K. Echols, K. King, and J. Umek. 2021. Movement of synthetic organic compounds in the food web after the introduction of invasive quagga mussels (*Dreissema bugensis*) in Lake Mead, Nevada and Arizona, USA. Science of the Total Environment 752: 141845.

Haralson-Strobel, C.L., C.W. Boal, and C.C. Farquhar. 2020. Nest site selection of white-tailed hawks (*Geranoaetus albicaudatus*) on Texas barrier islands. Wilson Journal of Ornithology 132:668-677.

Heath, K.M., W.C. Conway, C.W. Boal, D.P., Collins, G. Hensley, W.P. Johnson, and P.M. Schmidt. 2021. Detectability and abundance of snowy plovers at the Salt Plains National Wildlife Refuge, Oklahoma. Journal of Fish and Wildlife Management 12:50-60.

López-Altarriba, E., R. Patiño, M.L. Vázquez-Sauceda, R. Pérez-Castañeda, L.U. Arellano-Méndez, R. Ventura, and L. Heyer. 2020. Water quality and ecological risk assessment of intermittent streamflow through mining and urban areas of San Marcos River sub-basin, Mexico. Environmental Nanotechnology, Monitoring and Management 14:100369.

Lyons, J.E., K.S. Kalasz, G. Breese, and C.W. Boal. 2020. Resource allocation for coastal wetland management: confronting uncertainty about sea level rise. Pages 108-123 in Case studies in decision analysis for natural resource management (M.C. Runge, S.J. Converse, J.E. Lyons, and D.R. Smith, editors.). Johns Hopkins University Press, Baltimore, MD.

Mather, M.E., J.M. Smith, K.M. Gerber, R.B Taylor, C.G. Kennedy, S.M. Hitchman, J.S. Rogosch, and H.M. Frank. In Press. Solving persistent fisheries and aquatic conservation problems by quantifying the spatial distribution of mobile organisms within aquatic landscapes. Fisheries https://doi.org/10.1002/fsh.10645.

Mitchell, N.R., C.W. Boal, and B.R. Skipper. 2020. Distribution, density, and land cover associations of wintering golden eagles in the southern Great Plains. Western North American Naturalist 80:452-461.

Perry, G., C.W. Boal, R. Verble, and M.C. Wallace. 2020. "Good' and 'bad' urban wildlife. Pages 141-170 in Problematic Wildlife Vol. 2: New conservation and management challenges in the human-wildlife interactions (F.M. Angelici and L. Rossi, editors). Springer International Publishing, Switzerland.

Richardson, E.T. and R. Patiño. 2021. Growth of the harmful alga, *Prymnesium parvum* (Prymnesiophyceae), after gradual and abrupt increases in salinity. Journal of Phycology 57:1335–1344.

Rogosch, J.S., and J.D. Olden. 2020. Invaders induce coordinated isotopic niche shifts in native fish species. Canadian Journal of Fisheries and Aquatic Sciences. 77:1348-1358.

Ruegg, K.C. Ruegg, M. Brinkmeyer, C.M. Bossu, R. Bay, E.C. Anderson, C.W. Boal, R.D. Dawson, A. Eschenbauch, C.J.W. McClure, K.E. Miller, L. Morrow, J. Morrow, M.D. Oleyar, B. Ralph, S. Schulwitz, T. Swem, J.F. Therrien, T.B. Smith, J.A. Heath. 2021.The American kestrel genoscape (*Falco sparverius*): Implications for monitoring, management, and subspecies boundaries. Ornithology 138:1-14.

Tonkin, J.D., J.D. Olden, D.M. Merritt, L.V. Reynolds, J.S. Rogosch, and D.A. Lytle. 2021. Designing flow regimes to support entire river ecosystems. Frontiers in Ecology and the Environment 19:326-333.

Watson, K.A., D.U. Greene, and C.W. Boal. 2019. Breeding and diet of white-tailed kites (*Elanus leucurus*) in the Texas panhandle. Wilson Journal of Ornithology 131:844-849.

Presentations FY2020-2021

Unit staff and students made 40 presentations at 12 state, national, and international meetings including -

Birding the Border Festival, Del Rio TX. Apr. 2021.

Chihuahuan Desert Conference, El Paso, Texas. Nov. 2019.

Missouri Natural Resources Conference, Virtual Meeting. Feb. 2021.

New Mexico Ornithological Society Annual Meeting, Virtual Meeting, Mar. 2021.

North American Ornithological Conference VII. Virtual Meeting. Aug. 2020.

Raptor Research Foundation Annual Meeting, Fort Collins, CO. Nov. 2019.

Texas Chapter of the American Fisheries Society, Waco, TX. Jan. 2020.

Texas Chapter of the American Fisheries Society, Virtual Meeting. Feb. 2021.

Texas Chapter of the Wildlife Society Annual Meeting, Virtual Meeting, Feb. 2021.

Texas Chapter of the Wildlife Society Annual Meeting, Corpus Christi, TX. Feb. 2020.

Texas Colonial Waterbird Society Annual Meeting, Austin, TX. Nov. 2019.

Wildlife Society Annual Meeting, Reno, NV. Oct. 2019.

Awards FY2020-2021

Staff

Clint Boal

2020 USGS Excellence in Science Award, USGS Cooperative Research Units Program, Apr. 2021.

President's Award, Raptor Research Foundation, December 2020.

Dean's Research Grant Award, College of Agriculture Science and Natural Resources, Texas Tech University, Nov. 2020.

W.L. McAtee and G.V. Burger Award, The Wildlife Society, Sep. 2020.

Fran and Frederick Hamerstrom Award, Raptor Research Foundation, Nov. 2019.

Recognition for Excellence in Research, Scholarship, or Creative Activity, Texas Tech University, Nov. 2019.

Reynaldo Patiño

Special Thanks for Achieving Results (STAR) Award, USGS Cooperative Research Units Program, Apr. 2021.

Students

Olivia Gray

Second place, Undergraduate Research Poster, Texas Chapter of the Wildlife Society, Feb. 2020.

Meghan Mahurin

Third place, Graduate Research Poster, Texas Chapter of The Wildlife Society, Feb. 2021.

Derek Malone

Graduate Student Fellowship, Welder Wildlife Foundation, 2019-2021.

Pendleton Scholarship, Department of Natural Resources Management, Texas Tech University, May 2021.

Sophie Morris

Christopher Rodriguez Research Presenter Award, CISER: Center for the Integration of STEM Education and Research, Texas Tech University, Apr. 2021.

Outstanding Presenter, Undergraduate Research Conference, Texas Tech University, Apr. 2021.

Collin Caruthers Memorial Scholarship, Texas Chapter of The Wildlife Society, Feb. 2021.

Ariana Rivera

Texas Tech University Outstanding Student in Wildlife, Texas Chapter of the Wildlife Society, Feb. 2021.

Shisbeth Tábora-Sarmiento

Distinguished Graduate Student Assistantship, Texas Tech University Graduate School, Sep. 2021.