

Texas Cooperative Fish and Wildlife Research Unit

ESTABLISHED IN 1988



What we do

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.

<https://www1.usgs.gov/coopunits/unit>AboutUs/Texas>



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Research Highlights

Names of investigators, funding source and amount, and project periods can be found in the FY19-20 Financial Report. Please use project number for cross reference.

Processing Hydroacoustic Telemetry Data using High-throughput Computing (RWO101, 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



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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.

Understanding the Ecology of Lesser Prairie Chickens in Conservation Reserve Program Dominated Landscapes with Implications Toward Lesser Prairie-Chicken Management in Texas (TPW34, Completed)

The decline in population size and range of the lesser prairie-chicken throughout its distribution has led to substantive conservation concern. Conservation Reserve Program lands are known to provide habitat for the species at the northern extent of its distribution, but different grass species and weather patterns at the southern extent of the distribution may not

provide the same habitat benefits.

Although substantial effort has been invested in understanding the lesser prairie-chicken life history and the effects of some management practices on its ecology, information was lacking regarding the species use or avoidance of Conservation Reserve Program fields in the Southern High Plains of Texas. We conducted research in collaboration with personnel from the Texas Parks and Wildlife Department, US Fish and Wildlife Service, and Texas Tech University to fill in this knowledge gap. We assessed habitat selection by lesser prairie-chickens within Conservation Reserve Program fields, native grassland, and row-crop agriculture in Texas at the second order of selection (home range placement within the landscape) and at the third order (individual study animal locations within the home range). At the second order of selection, lesser prairie-chickens selected Conservation Reserve Program fields seeded in nonnative grasses and native grasses and forbs year-round. Within our study area, we found row-crop agriculture and native grassland were avoided. Native grass Conservation Reserve Program fields were used in proportion to their availability year-round. Only Conservation Reserve Program fields seeded in native grasses and forbs were selected at the third order of selection. Based on our results, Conservation



Reserve Program fields provide habitat for lesser prairie-chickens, and as such, may be both beneficial to persistence of the species on the High Plains of Texas and provide additional management options and opportunities for state, federal, and private land and wildlife management entities.

Towards a Better Understanding of Blue Suckers: Validation of Age Determination Methods & Estimating the Influence of Temperature on Aerobic Scope (TPW37, Completed)

Blue suckers are generally listed as threatened or as species of greatest conservation need. In addition to habitat fragmentation and habitat degradation, reasons for blue sucker population declines may include their sensitivity to streamflow alteration. Blue suckers are highly *potadromous* and undertake long-distance upstream migrations to spawning habitat. Recent studies have suggested that adult Blue Sucker (*C. elongatus*) are associated with high current velocity, and migratory behavior in the Colorado River shows interannual variation associated not only with streamflow but also temperature. Little information is available, however, about their swimming performance and the influence of temperature. In addition, conservation strategies for fisheries stocks typically rely on age and growth analysis. While most ageing techniques are based on otoliths, this requires sacrificing the study organism and runs counter to conservation goals for rare and imperiled species. This project aims to provide information on two aspects of the biology of blue suckers in order to inform the development of effective

conservation and management plans: (1) evaluation of the influence of temperature and current velocity on swimming performance, and (2) validation of age estimation methods, specifically for fin rays.

Results using a swim tunnel indicated that current speed influenced behavior and therefore may affect accessibility to spawning habitat; the thermal limits for swimming performance, however, were broader than the temperatures observed during spawning migration and spawning. Additional information will be needed to understand the effects of current speed on migratory behavior of blue suckers. Cross-sections of otoliths and fin rays from OTC-marked fish were observed under ultraviolet light. Age estimates at time of harvest were between 2-32 years and were similar for fin rays and otoliths; based on time since OTC injections, percent accuracy of age estimates were 85% and 89% using fin rays and otoliths, respectively. Thus, fin rays can provide an adequate alternative to otoliths for age estimation in Blue Sucker.



Developing an Automated System for Screening Wildlife Trail Camera Imagery (TPW42, Completed)

Trail cameras are common tool for surveillance and monitoring of wildlife. Trail cameras often are activated by motion of vegetation due to wind or other factors when an animal is not actually present. Thus, manual screening of trail camera imagery is necessary but time consuming. We pursued development of a software

tool that could automate or semi-automate screening of camera-trap images for the presence of animals. The goal of the project was to reduce the cost and to increase the accuracy associated with manual inspection that is presently done by human observers. We developed approach that had high accuracy in separating images that had animals present from those that did not during both diurnal and nocturnal periods and take into account shadow movements and cloud cover. We are in the process of refining this tool.

Influence of Environmental Variables on Growth of Toxigenic Golden Alga (*Prymnesium parvum*): A Laboratory Test of Field-Generated Hypotheses (OA79, 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 and sometimes unexpected information concerning environmental variables associated with golden alga presence and abundance in inland waters of the USA. Three 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.

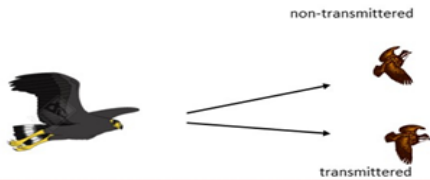
Golden alga blooms occur in eutrophic/hypereutrophic waters, but the role of organic nutrient fractions is not fully understood. This study focused on nitrogen. Organic and inorganic fractions were varied while keeping total nitrogen concentration constant. The results showed that growth occurs in the presence of inorganic or organic nitrogen, but that optimal growth occurs when both fractions are present, and the organic fraction is predominant. Follow up studies are needed to better understand the role of organic nitrogen in the distribution and growth of golden alga.

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 the 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.



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Impacts of Transmitter Weight and Attachment on Raptor Agility and Survival (OA85, Completed)



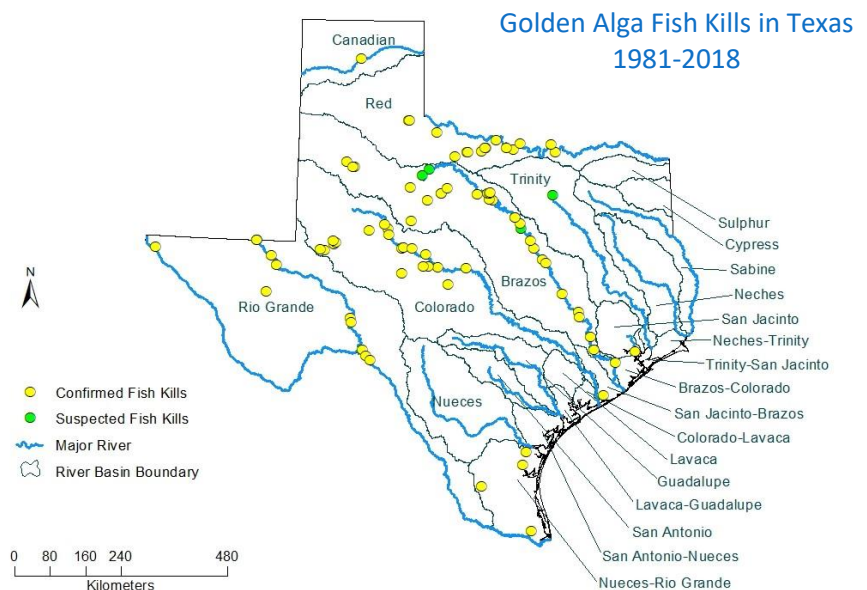
Radio and GPS transmitters are a common, if not critical, tool in current use for wildlife research. However, the potential influence of transmitters, in context of weight and attachment methods, has received little critical evaluation as to influence on predatory bird hunting effort and capture success, or for the influences they may pose in terms of handicapping prey. We combined multiple studies to investigate the influence of wildlife location transmitters on avian behavior. First, we studied the alterations in direct and curvilinear flight paths of raptors subjected to different weight loaded transmitter attachments. Second, we indirectly investigated transmitter impacts by analyzing nest behavior and prey provisioning at Swainson's hawk nests with and without adults that had transmitters attached. We then switched the perspective to study transmitter impacts on avian prey species by studying Harris's hawk selection of quail when presented with the choice of a transmitted or non-transmitted northern bobwhite in paired trials. We found that transmitters weighing up to 5% of a hawk's body weight do influence straight and curvilinear flights, with stronger influences on curvilinear flight; the impact appears minimal in test trials, but the influences could be

substantively magnified in natural settings and foraging attempts. Additionally, it appears transmitters did lead to capture of smaller prey animals based on our prey provisioning study. Finally, we found selection of prey was not random, with hawks pursuing radio-tagged bobwhite during 64% of our paired trials. Our data will provide a clearer understanding that attaching radio-transmitters is not without negative influence to both predator and prey, and that prey survival estimate derived from radio-telemetry studies may be biased in predisposing the study animals to predation.

Salinity adaptation in the harmful alga, *Prymnesium parvum* (OA89, Completed)

Golden alga (*Prymnesium parvum*) is a toxin-producing, euryhaline species responsible for fish-kills worldwide. Although thought to have originated in high-salinity habitats, *P. parvum* abundance in U.S. inland waters and its growth potential in the laboratory

show a biphasic association with salinity, with peak abundance near 10-15 psu. It is unclear, however, if *P. parvum* can adapt to long-term exposure to high salinity regarding its growth potential. This information is necessary to understand the spatial distribution of golden alga blooms and especially their absence from Texas coastal habitats. A Texas strain of *P. parvum* maintained for ~3 years at 5 psu in modified artificial seawater medium (ASM) was subjected to the following treatments over 5 continuous batch cultures: modified ASM at 5 psu (ASM-5), modified ASM with gradually increasing salinity to 30 psu (increased by 5 psu/batch with NaCl), modified ASM at 30 psu increased with NaCl (ASM-30), and Instant Ocean®, a more complex salt mixture, at 30 psu (IO-30). Treatments were conducted in triplicate and each replicate served as inoculum for subsequent cultures. Exponential growth rate (r) and maximum abundance were determined. Growth rate was reduced when salinity abruptly increased from 5



to 30 psu in ASM but compensation occurred during the second culture round. Gradual adjustment in ASM did not influence this outcome, as inhibition of *r* was still observed during the last cycle when salinity was increased from 25 to 30 psu. Inhibition of maximum abundance was consistently observed in ASM-30 after direct transfer or gradual adjustment. Growth rate and maximum abundance in IO-30 and ASM-5 were generally similar.

In conclusion, adaptation to high salinity in ASM was observed for *r* but not maximum abundance, and relatively complex salt mixtures (IO) can compensate for the inhibitory effect of increased salinity. These findings provide insight on *P. parvum*'s ability to disperse into new environments of varying salinity.

**Guana Island
Ornithology/Hurricane Research
(OA92, Completed)**

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. Comparing population density estimates between previous survey years and 2019 suggested a dramatic decrease in Bananaquits from an average of 144 individuals in the sampled area 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 surveyed 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 to 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.



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

The Jim Bertram Lake System (JBLS) consists of several stream impoundments within the City of Lubbock, Texas (USA). Baseflow in the upstream reach is dominated by nitrogen-rich treated wastewater. Toxic blooms of *Prymnesium parvum* in the system occur irregularly in fall or winter-spring, but little is known about water quality variables that facilitate these blooms or about the alga's spatiotemporal distribution. This information would be useful to the design of control methods for the study area and other places impacted by *P. parvum*, as adequate field methods are presently unavailable. This study covered the JBLS and a larger lake ~25 river-kilometers from the upstream reach. Water quality assessments were conducted over a 1-year period. Total phosphorus was largely below detection limit (<0.04 mg l⁻¹), indicating the system is phosphorus-limited. Algal abundance was low and associations were determined using multiple logistic regression. *Prymnesium parvum* incidence was negatively associated with temperature and positively with organic nitrogen and calcium hardness. These findings conform with prior reports but the positive associations of *P. parvum* with the latter two variables are notable because they have not been widely confirmed. Spatiotemporal distribution was evaluated in fall and winter-spring of three years. *Prymnesium parvum* incidence was much higher in the upper than the lower reach, and in the lower reach was detected only after a dense bloom developed in the upper reach contemporaneously with stormwater runoff-associated flooding events. Thus, a major source of propagules for the



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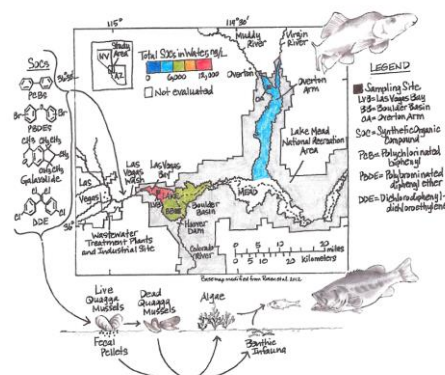
system seems to be the upstream reach and their dispersion vector is hydraulic flushing. Because nitrogen: phosphorus ratios in urban runoff are far lower than those prevailing in the upper reach, what triggered the bloom may have been relief from phosphorus limitation. This study provided geographic, water quality, and weather indices that may inform the development of control methods for *P. parvum*.



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)

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 food web, trophic magnification factors (TMF) indicated statistically significant biomagnification

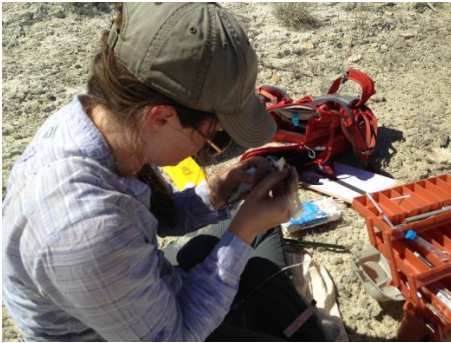
for nine and biodilution for two of 22 SOC's examined. The highest value recorded was for PCB 118 (TMF, 5.14), and biomagnification of methyl triclosan (3.85) was also apparent. Biodilution was observed for Tonalide® (0.06) and Galaxolide® (0.38). Total SOC concentration in quagga mussels was higher 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 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, 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 SOC's and other processes in the food web of Lake Mead.



Structure and Connectivity of Mid-Continental Snowy Plovers (RWO98, Active)

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.



Changes in Avian and Plant Community Composition and Structure Following Prescribed Thinning in Pinyon-Juniper Woodlands (RWO100, 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 - 2020 at a site in Lincoln County, NM and 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. Our final season is currently underway, and analysis is pending. We anticipate our data will provide important insights that will improve resource managers ability to strategically plan and implement prescribed thinning programs to meet multiple objectives.



Assessing Distribution and Occupancy Patterns of Riparian Avifauna in the Trans Pecos Region of Texas (TPW40, 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 general. 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 management agencies with data to make informed decisions for identification of priority areas for conservation and restoration.

Influence of Woody Vegetation Patterns on Scaled Quail Demographics (TPW41, Active)

Scaled quail (*Callipepla squamata*) populations have declined precipitously over the past four decades, with several factors including habitat loss and fragmentation, increased predation, and disease believed to explain the decline. However, the underlying mechanisms driving this decline are still poorly understood. Scaled quail demographics are influenced by extreme variations in annual weather observed in semi-arid ecoregions such as the Rolling Plains of Texas. Scaled quail follow predictable seasonal routines within their home range from morning feedings, loafing, evening feedings, to roosting. Consequently, negotiating similar routes and knowing where important resources are located is essential to quail survival, especially during unfavorable weather. Likewise fragmentation has severe implications on scaled quail populations due to increases in edge habitats which allow predators more efficiency to locate prey at higher densities in fragmented landscapes. To understand the influence of density independent and dependent factors on scaled quail demographics we evaluated the winter

survival rates of scaled quail within the Rolling Plains and High Plains of Texas. We radio-marked and GPS tagged 82 scaled quail during the 2018-2019 winter field season and 79 scaled quail for the 2019-2020 winter field season on 2 study sites with stable populations and 2 study sites with intermittent populations. Data analyses are currently ongoing but will lead to a better understanding overwinter survival rates of scaled quail among stable and intermittent population. This will provide critical information for long term conservation and management, as well as aid our understanding of the factors associated with decline of scaled quail.



Distribution and Habitat use of Kisatchie Painted Crayfish in Northeast Texas with Investigation of Multi-scale Environmental Influences on Crayfish Community Structure (TPW43, Active)

The Kisatchie Painted Crayfish, *Orconectes 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. In addition to its distribution, little is known about the

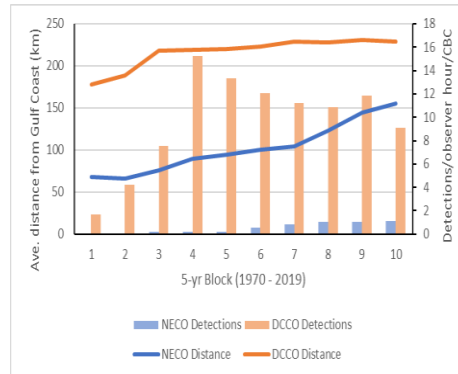
habitat use or population structure of *O. maletae* in the state. Local habitat variables such as substrate size, water depth, conductivity, and temperature have been shown to be important predictors of occurrence for other species of *Orconectes* crayfish, but it is unknown how such relationships apply to *O. maletae*. Furthermore, sedimentation, fragmentation, and other habitat alterations represent potentially serious threats to the species, but a lack of information on the ecology and distribution of the species impedes assessments of the extent of such threats. Patterns of co-occurrence and environmental influences on structure of 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. Preservation of tissues for molecular genetic analyses is needed to assess population genetic structure and phylogenetic status of *O. maletae* and other native crayfish species to support their management. Therefore, 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.

Pilot Study - Understanding the Distribution and Relative Abundance of Cormorants in Texas (TPW44, Active)

There is concern 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 are assessing 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 derived estimates of distribution change based on the average distance from the Gulf Coast at which each species was detected at Christmas Bird Count (CBC) surveys over the last 50 years, and estimates of abundance based on average number of detections/observer hour/CBC count (#/obs.hr./CBC). We found no statistical evidence of an expansion of double-crested cormorants in Texas. Across the 50-year period, the species was detected at an average of 178 – 230 km (depending on the 5-year block) from the Gulf Coast. However, there was a significant but non-linear increase in abundance across 5-year blocks. Double-crested cormorants increased from an average 1.7/obs.hr./CBC in 1970-74 to a peak of 15.2/obs.hr./CBC in 1985-89, but have since leveled off to between 9.1 and 11.2/obs.hr./CBC over the last 20 years. In contrast, we found evidence of significant increases in both range and abundance of *neotropic cormorants*. The average distance the species was detected from the Gulf Coast increased linearly from 67.8 km in 1970-74 to 155.7 km in 2015-19. Additionally, the average detection rate progressively increased each 5-year block from an average of 0.1/obs.hr./CBC in 1970-74 to 1.1/obs.hr./CBC in 2015-19. Our next tasks include using archived data to assess distributional and abundance patterns during summer months, and to conduct in field cormorant surveys at

water bodies with and without fish stocking programs.



Interactions of Juvenile Swainson's Hawks with Wind Energy Facilities During Dispersal and Migration (OA87, Active)

Swainson's hawks (*Buteo swainsoni*) are migratory raptors that breed in North America and overwinter in central Argentina. While we know much about Swainson's hawk behaviors on the breeding range, little is known about migration and wintering behaviors, and even less is understood about the juvenile period between fledging and recruitment. We set out to study juvenile behaviors, survival, and dispersal using satellite transmitters; we attached solar-powered platform transmitter terminals (PTT) on a backpack-style harness to 17 hawks in good body condition and with mass > 650 g (transmitter and harness < 4% bodyweight). Survival was low, with 24% of hawks surviving to their second year, 12% to their third year, and 6% (1 hawk) surviving into the fourth year of life (we are still tracking this bird). We tagged two hawks from the same nest six times, and we found that siblings, and presumably family groups, break up after a 45-day post-fledging period. Juveniles explore the breeding landscape while staging for migration,

presumably fattening up and joining migratory flocks, similar to adult hawks. We collected data on 12 juveniles that initiated their first migration; hawks often went off track and perished, but otherwise migratory behaviors were similar to adults we tracked in a related study. Several hawks spent their first winter in a location north of the primary wintering grounds for adults. Juveniles took longer to return to breeding grounds than adults, and spent summers exploring nomadically, rarely visiting natal nest locations. We found no evidence of recruitment among tracked hawks and therefore only speculate on natal dispersal.



Avian Community Response to Brush Control on the Welder Wildlife Refuge - Phase II (OA90, Active)

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 are partnering 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 are using 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 is 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 have used avian and vegetation surveys conducted annually

among control and treatment plots to identify temporal patterns of community level changes in the avian community and the success of brush control efforts. We are using VHF transmitters to determine breeding season home range size and estimate habitat use for roadrunners tagged and monitored each summer in 2018 - 2020. The final season of this project is currently underway, and analysis is ongoing with expected completion in December 2020. Our results will provide insights as to the success of different brush control methods to restore prairie, whether or not natural avian communities can be restored, and if so, what the lag periods for avian community restoration may be.

NWI SWiFT Environmental Assessment and Monitoring Study (OA91, Active)

Technological advances have facilitated the use of wind to provide a carbon free source of energy. These advances are not without ecological cost, however, in terms of habitat displacement and direct mortality of some wildlife species. The Scaled Wind Farm Technology 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 of raptor species abundance, community indices of diversity, richness, and overlap among years, and assessing these in context on seasonal weather patterns. These data will be useful in examining patterns of association with trends in prey species populations, such as *Lagamorphs*, cotton rats (*Sigmodon hispidus*), and northern bobwhite (*Colinus virginianus*).



Burrowing Owls and Wind Energy Development (OA93, Active)

Burrowing owls 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 are partnering with Consolidated Nuclear Security, LLC through the Department of Energy, and with the Idaho Cooperative Fish and Wildlife Research Unit, 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. Our study will allow assessments of burrowing use or avoidance of wind energy facilities and evaluate the potential direct and indirect influence of the structures on the species ecology. This will provide important data with which to understand and evaluate risks and determine the need for burrowing owl conservation actions in context of renewable energy development.



Ecology of Devils River Minnow *Dionda Diaboli* in an Invaded Stream-riparian Ecosystem (TPW45, New)

Streams often face multiple stressors that simultaneously erode the quality and quantity of freshwater habitats to the detriment of sensitive aquatic species (Revenga et al. 2005; Strayer & Dudgeon 2010). 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 (USFWS 2005; TPWD unpublished data), 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 currently interest by partners to address these concerns and restore riparian habitats along San Felipe Creek (San Felipe Creek Master Plan, Vol. 1); however, the science to understand impacts of 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 fish removals, 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 (Recovery Action 1.1.3; USFWS 2005). Food web dynamics will be compared between stream reaches of varying land management practices and levels of riparian degradation. Data will be used to assess the extent (i.e., direct, indirect effects) of the threat that invasive fishes and invasive riparian vegetation poses to the DRM and other native fishes of conservation concern (Recovery Action 1.2.1 and 1.3.5).

Dimensions of diversity in urban fisheries: Examining habitat, fish, and anglers to inform the management of Texas Community Fishing Lakes (TPW46, 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. The proposed study will examine 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 will be studied to quantify the availability and quality of littoral and shoreline habitats and the diversity of fish assemblages. Concurrently, recreational anglers will be 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 will be 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.

Nest Site Selection and Nest Survival of Avian Communities in Pinyon-Juniper Woodlands Undergoing Thinning Prescriptions (OA95, New)

Pinyon-juniper woodlands are an extensive and biologically important vegetation community across the western United States. This vegetation community type has 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. A key issue is that many obligate and semi-obligate pinyon-juniper associated bird species show declining populations, 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 initiating a study to understand changes in nest 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.

Development of Environmentally Friendly Methods to Control Harmful Algal Blooms (OA96, New)

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 golden alga.

Giant reed (*Arundo donax*) is a harmful invasive plant in the USA. A previous study 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 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 their growth effects.

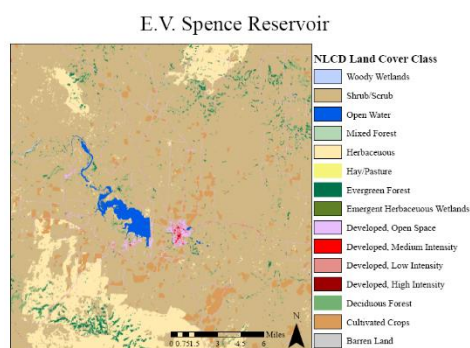
Preliminary observations showed vigorous bacterial growth in cultures of golden alga in the presence of giant reed. This finding suggests the presence of algicidal bacteria in the cultures. Therefore, another objective of this study is to determine the growth effects of bacterial strains isolated from the cultures and their mechanisms. This information may inform the development of probiotic treatments to prevent or control harmful blooms.



Associations Between Land Cover use and Incidence of Toxic Blooms of *Prymnesium parvum* in Reservoirs of the Colorado and Brazos River basins (OA97, New)

Prymnesium parvum is a harmful alga responsible for numerous fish-kill events across the United States. Factors such as salinity, temperature, and nutrient concentrations can influence growth of this species. Human activities can change the landscape around water bodies and alter their physicochemical characteristics, which in turn can influence harmful algal bloom formation. A previous study modeled the relationship of *P. parvum* with land cover, soil erosion, precipitation, temperature, and lake elevation; however, only one lake was evaluated, and other potentially important variables were not considered. The present study will evaluate four lakes and include additional variables such as pesticide usage over the watershed, water chemistry, and lake discharge. In addition, the evaluation will be based on drainage area (hydrologic units). A better understanding of the relationship between anthropogenic alterations of aquatic habitats and *P. parvum* would be helpful for mitigation and management purposes, and to prevent further spread. The objectives of this study are to 1) determine what changes in land cover types or other landscape variables are associated with the massive spread of *P. parvum* since 2001, and 2) determine which land cover types and other landscape variables are associated with the incidence of toxic blooms. The study will focus on four Texas lakes, one impacted and one non-impacted in each of two river basins: in the Brazos River, Possum Kingdom Lake

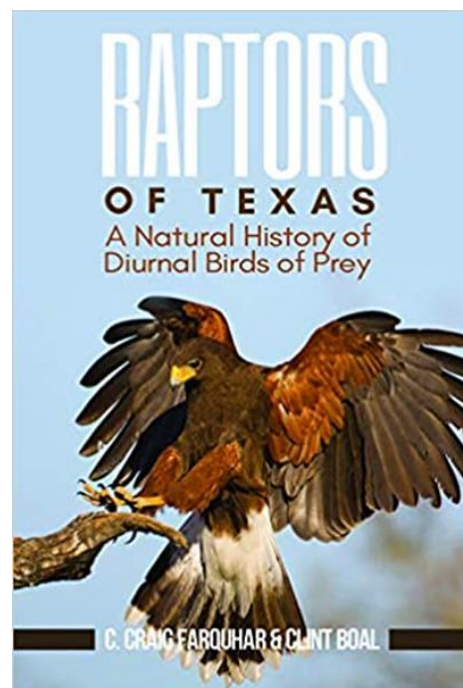
(impacted) and Waco Reservoir (non-impacted); and in the Colorado River, E.V. Spence Reservoir (impacted) and Twin Buttes Reservoir (non-impacted). For the first objective, principal component analysis (PCA) will be used to examine patterns in environmental data collected since 1992 using different grouping factors (pre-/post-2001; impacted/non-impacted; river basin; other). For the second objective, a logistic approach to multiple regression will be applied using the period from 2001 to the present; depending on PCA results, PC regression may also be performed.



Raptors of Texas – a natural history of diurnal birds of prey (Unassigned Project)

Diurnal raptors—birds of prey that hunt during the day—include easily recognizable birds like eagles, hawks, or falcons. They may be seen perched on highway signs, electrical poles, or soaring overhead in urban and rural spaces across North America. Here, avian ecology and raptor experts C. Craig Farquhar and Clint W. Boal present the first comprehensive volume on these birds of prey in Texas. Given the state's size, location, and biodiversity, it is not surprising that Texas leads other states in the documented number of raptor species. The introductory chapters provide

information on raptor ecology, evolution, behavior, morphology, and the unique conservation challenges raptors face in Texas and elsewhere. Detailed species descriptions of Texas' regularly occurring diurnal raptors come next, illustrated with life-like graphite drawings and accompanied by unique, up-to-date range maps. Additionally, shorter entries for rare raptors sighted in the state are provided. This reference is a must-have for serious birders, ornithologists, avian ecologists, and wildlife professionals who want to know more about these birds of prey and the important roles they play in our urban and rural environments alike.



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 personnel.

Terrestrial

Assessing Texas Kangaroo Rat Monitoring Protocols, Habitat Management, and Population Connectivity - proposal submitted.

Assessing Breeding Range Expansion and Negative Influences on Livestock Production by Crested Caracara in Texas - proposal in development in collaboration with USFWS and Texas AgriLife.

Use of Passive Auditory Recorders to Assess Expanding Distribution and Habitat Association of Small Owls - proposal in development with Angelo State University and Unit College.

Breeding Abundance and Distribution of Aplomado Falcons in Southern Mexico – partial funding obtained in collaboration with Oregon State University and the Peregrine Fund.

Aquatic

NRT – HDR: Convergence Research of Wildlife, Environmental, and Computational Science and Engineering – proposal submitted (specific focus of proposal is harmful algae).

Low cost Natural Biosorbents to Remediate Municipal Wastewater for Reuse – proposal submitted (specific focus of proposal is aquaculture).

Publications FY 2018-2020

Barnes, M.A. and 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. 2018. Estimates of Abundance and Longevity of Bridled Quail-Doves (*Geotrygon mystacea*) on Guana Island, British Virgin Islands. *Wilson Journal of Ornithology* 130:981-987.

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*.

Dabney, B., Patiño, R. 2018. Low-dose stimulation of growth of the harmful alga, *Prymnesium parvum*, by glyphosate and glyphosate-based herbicides. *Harmful Algae* 80, 130-139

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.

Eric Lonsdorf, Carol A. Sanders-Reed, Clint Boal, and Taber D. Allison. 2018. Modeling Golden Eagle - Vehicle Collisions to Design Mitigation Strategies. *Journal of Wildlife Management* 82:1633-1644.

Faquhar, C.C., and C.W. Boal. In press. The Raptors of Texas. 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*.

Harryman, S.W.H., B.A. Grisham, C.W. Boal, S.S. Kahl, R.R. Martin, and C.A. Hagen. 2019. Multiscale habitat selection of lesser prairie-chickens in an agriculture/conservation reserve program land matrix. *Journal of Fish and Wildlife Management* 10:126-136.

Haukos, D.A., C.W. Boal, S. Carleton, and B. Grisham. 2018. Roles of Cooperative Research Units in contemporary conservation of natural resources. *Transactions of the North American Wildlife and Natural Resources Conference* 80:124-132.

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. Chapter 10 in *Case studies in decision analysis for natural resource management* (M.C. Runge, S.J. Converse, J.E. Lyons, and D.R. Smith, eds.). Johns Hopkins University Press, Baltimore, MD.

Mitchell, N.R., C.W. Boal, and B.R. Skipper. In press. Distribution, density, and land cover associations of wintering golden eagles in the southern Great Plains.

Patiño, R. 2019. Sex determination, gonadal sex differentiation, and sex control in Channel Catfish. Pages 477-494 in *Sex Control in Aquaculture* (H. Wang, F. Piferrer, S. Chen and Z. Shen, eds.), Wiley-Blackwell. <https://doi.org/10.1002/9781119127291.ch23>

Perkins, R., C.W. Boal, and C.B. Dabbert. 2018. Raptor selection of captive rear and release

galliform birds. *Wildlife Society Bulletin* 43:713-715.

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.

Rashel, R.H. and Patiño, R. 2019. Growth response of the ichthyotoxic haptophyte, *Prymnesium parvum* Carter, to changes in sulfate and fluoride concentrations. *PLoS One* 14(9): e0223266.

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. In press. The American Kestrel Genoscape (*Falco sparverius*): Implications for Monitoring, Management, and Subspecies Boundaries. *The Auk*.

Skipper, B.R., and C.W. Boal. 2019. Nest-defense Behavior of Mississippi Kites in Urban and Exurban Areas. *Human-Wildlife Interactions* 13:142-149.

Taylor, C.M., Miyazono, S., Cheek, C.A., Edwards, R.J., Patiño, R. 2018. The spatial scale of homogenisation and differentiation in Chihuahuan Desert fish assemblages. *Freshwater Biology* 64, 222-232. <https://doi.org/10.1111/fwb.13211>

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.

Welch-Acosta, B., B.R. Skipper, and C.W. Boal. 2019. Comparative breeding ecology of Mississippi Kites in urban and exurban areas of west Texas. *Journal of Field Ornithology* 90:248-257

Yamamoto, Y., Hattori, R.S., Patiño, R., Strüßmann, C.A., 2019. Environmental regulation of sex determination in fishes: Insights from atheriniformes. In, *Current Topics in Developmental Biology* (Capel, B., editor), chapter 9. Academic Press.

Presentations FY 2019-2020

Unit staff and students made 49 presentations at the following conferences:

12th NWCC Wind Wildlife Research Meeting, St. Paul, Minnesota.



Texas Cooperative Fish & Wildlife Research Unit

Annual Meeting of the American Ornithological Society, Anchorage, Alaska.

Annual Meeting of the Texas Chapter of The Wildlife Society, Montgomery, Texas.

Annual Meeting of the Texas Colonial Waterbird Society, Austin, Texas.

ASLO Aquatic Sciences Meeting, San Juan, Puerto Rico.

Chihuahuan Desert Conference, El Paso, Texas.

Joint Annual Meeting of the AZ/NM Chapters of the Wildlife Society, Albuquerque, New Mexico.

Meeting of The Raptor Research Foundation, Fort Collins, Colorado.

Meeting of the Texas Chapter of the Wildlife Society, Corpus Christi, Texas.

Meeting of The Wildlife Society, Reno, Nevada.

North American Ornithological Conference VII, San Juan, Puerto Rico.

Texas Chapter of the American Fisheries Society, Waco, Texas.

Texas Harmful Algal Bloom Work Group Subcommittee, Port Aransas, Texas.

U.S. Geological Survey, Ecosystem Mission Area, Webinar.

Annual Texas Tech Biological Sciences Symposium.

Texas Tech University Annual Graduate Student Research Poster Competition.



Recognition for Excellence in Research, Scholarship, or Creative Activity (Award II; Appointments, Fellowships, and Other Honors), Texas Tech University (November 7, 2019).

Elective Membership Status, American Ornithological Society (June 28, 2019).

Outstanding Faculty, Texas Tech Chapter of The Wildlife Society (April 10, 2019).

Wildlife Publication Award - Edited Book, The Wildlife Society (October 8, 2018).

Emily Richardson (graduate student)

Best Student Poster Award, Texas Chapter of the American Fisheries Society, College Station, Texas, 2018.

Caroline Skidmore (graduate student)

First place graduate student poster. Annual Meeting of the Texas Chapter of The Wildlife Society, Montgomery, TX (February 22, 2019).

Jennifer Harris (graduate student)

Second place graduate student poster.

Annual Meeting of the Texas Chapter of The Wildlife Society, Montgomery, TX (February 22, 2019).

Jonathan Bentley (undergraduate student)

First place undergraduate student poster. Annual Meeting of the Texas Chapter of The Wildlife Society, Montgomery, TX (February 22, 2019).

Olivia Gray (undergraduate assistant)

Second place undergraduate student poster. Meeting of the Texas Chapter of the Wildlife Society, Corpus Christi, TX (February 14, 2020).

Awards 2018-2020

Clint Boal

Fran and Frederick Hamerstrom Award, Raptor Research Foundation (November 9, 2019).

Recognition for Excellence in Research, Scholarship, or Creative Activity (Award I; National/International Recognition), Texas Tech University (November 7, 2019).

