8-2018

Evaluating Climate Change Policy Through the Endangered Species Act

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Evaluating Climate Change Policy Through the Endangered Species Act

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Environmental Dynamics

by

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August 2018
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This dissertation is approved for recommendation to the Graduate Council.

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Abstract

This research sets out to address a growing knowledge gap of climate change science in regards to the state of Arkansas. Within the coming chapters, the goal of this research is to examine climate data and to identify if any evidence of climate change can be detected and what are the policies in place to adapt to these potential changes. Furthermore, the scope of this research will be narrowed to a few counties over the southwest Arkansas, and a specific endangered species, the Leopard Darter. Upon examination of previous environmental and ecological climate change related research it became clear that the general focus was placed on regional bodies of the U.S., instead of state and county specifically targeted research. Additionally, attempts to create policies to mitigate harms associated with climate change have been addressed nationally but not within Arkansas. With illustrations showing that climate change is indeed happening in Arkansas and in southwest Arkansas, this research highlights the importance of mitigation and addresses the lack of policies in regards to climate change with endangered species.

Acknowledgement

An Infinite Thank You

There are no words in any language that I could ever type which would truly give the proper amount of gratitude I feel towards the University of Arkansas, the Environmental Dynamics program, my committee, Dr. Mike Hayes & J.D. Sara Gosman, my friends, Ms. Chang Liu & Mr. Rob Fernandez, my family, and my committee chair Dr. Song Feng. With their truly limitless help and abundance of support I have managed to do what I previously thought impossible; I will complete a PhD in a field I truly have grown to love. Let me end this with this simple example: if I were given $1 for every time someone helped me over the past four years with this dissertation, I would be easily a millionaire.

Dedication

To the Future Generations

I will be the first to admit that I am far from the most intelligent, strongest, attractive, or charming person alive; I am is a just a mere person. A person who is trying to make this planet into something beyond my grandest imagination for you. Know that I have, and will continue every day to try make your life as glorious as possible; may my path and the paths before me lay the foundation for you to dream and achieve the impossible.

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Introduction: Climate Change and Climate Policy Implications Review on Endangered Species

1. Introduction

The climate in the United States is exhibiting a slow warming trend in recent decades. This shifting climate has a wide range of impacts which can be felt rippling throughout both the natural and economic realms. One specific sector that these climate change related impacts are felt in is the fishery world. While often overlooked within the gigantic agricultural world, and the global fish trade, fisheries contribute to a multi-billion dollar industry in the United States alone (USDC, 2016). While the warming trend might be welcome to some areas for fisheries in general the overall harms outweigh the minimal gains. Despite agriculture, and fisheries, being a multi-billion dollar industry national climate policies are seemingly absent in the US. From our research, the only current plausible way to address climate change on a federal level is through recovery plans tied to endangered species.

In this chapter, I review the current progress on climate change and its impact on fisheries, look at the potential of change to an Arkansas climate, examine climate change related polices, and look into drought plans being a potential work around for climate policy. Some of these topics will need a further in-depth analysis due to their expanding nature, and these issues will be addressed in the coming chapters. Finally, this chapter will conclude by outlining the knowledge gaps and research plan within this dissertation.

2. The changing climate

2.1 Global climate change

When addressing climate change, there is virtually a limitless pool of topics that can be viewed for evidence. However, for this research we narrowed the scope to topics that could potentially do severe harm to the agricultural sectors of Arkansas to two: 1) increasing severity of extreme weather events, 2) disruption of ecosystems, and stress upon livestock and crops. While these topics are not limited to Arkansas, much can be gathered from other regions and sectors encountering these similar issues.

The IPCC, NWS, NCA, and National Academies of Science (NAS) are just a few of the major scientific bodies that have stated the potential for stronger storms is increasing due to climate change (IPCC, 2013; NWS, 2007; NCA, 2014; NAS, 2016). To illustrate this better, there is a projected increase to favorable environmental days in the U.S. for F2+ tornadoes thanks to climate change (Lee, 2012). For Arkansas, which already sees a fair share of tornadoes, this increase only spells the potential for more harm.

Continuing along this trend is the unfortunate disruption and even destruction of ecosystems. While droughts and extreme precipitation events are straightforward and quick in regards to a changing ecosystem, the idea of a slow disruption from climate change can be easily overlooked. A relatively straightforward and slow disrupter, already being recognized in both stream and terrestrial areas from climate change, is through the alteration of both water and air temperature (Hill et al., 2014). This potential minute alteration of temperature makes certain species unable to thrive and sometimes even live within the affected area. A recent study in the Journal of the Arkansas Academy of Science found that these often overlooked impacts can wreak havoc to Arkansas farmers and sustainably lower their yields (Magugu et. al., 2016). Compounding this problem can be the incoming of invasive species that can now live within this area and overtake their rivals on the food chain. At some point in the future, farmers could be presented with a critical choice for their livelihood, ranging from shifting their crops, increasing the use of fertilizers and pesticides, or simply giving up. For Arkansas and its strong dependency on agriculture, this presents a critical future dilemma.

These are just two of the growing potential harms from climate change that can happen to Arkansas. Mixing these previous two examples with droughts, will lay the foundation for an understanding as to how stresses upon the agricultural field will grow in the coming years.

2.2 Temperature, precipitation, and drought

A common metric monitored to evaluate if the climate is indeed changing is through temperature fluctuations: max, minimum, diurnal, mean, etc. These metrics can be viewed, for the U.S., for over a century to help visualize these changes. Should these metrics be varying, and at what rate they are changing could potentially point towards a shifting climate. Additional metrics we looked at to see if the Arkansas climate is indeed changing was through precipitation, heatwaves, droughts, and frost day frequency. If these metrics are in fact changing, then likelihood of a series of environmental events are due to happen.

After addressing temperature it becomes important to see if precipitation is becoming effected, and if so, how is it changing? Are the precipitation events becoming stronger, or are there more frequent but less violent responses to precipitation? Nearly always, when looking back decades and taking into account climate change the precipitation events are becoming stronger and more frequent, as predicted by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2012; IPCC, 2013). However, annual precipitation totals fluctuate from region to region due to a variety of factors. If a region is indeed roughly having the same amount of precipitation and having more extreme events then this leaves bigger gaps between rainfall events. This gap becomes an excellent foundation for the formation of a drought.

Droughts are continuous and slow-moving natural disasters that create major problems on many levels for people all throughout the world. Accordingly, it is important to understand the many different definitions of a drought in order to make appropriate recovery plans associated with this environmental hazard. A generally accepted definition of drought is an extended period of time during which there is very little to no precipitation, especially when compared to the average amount of precipitation that same area customarily receives. This multifaceted interchange between natural precipitation deficiency, i.e., excessive evaporation, and the demands of human and environmental water use are the factors that primarily lead to drought (American Meteorological Society, 2013).

The Food and Agriculture Organization of the United Nations (FAO) has estimated that droughts are the world's costliest natural disaster, accounting for $6-8 billion U.S. dollars annually, and effect more people than any other form of natural disaster. Moreover, droughts have caused death and displacement of more people than cyclones, floods, and earthquakes combined, making them the world's most destructive natural hazard (FAO, 2013). Since 1900, over 11 million people have died as a result of droughts, and 2 billion people have been affected by drought in some way. The FAO states that the frequency, intensity, and duration of droughts are expected to rise as a result of climate change, taking an increasing toll on human lives and the economy (FAO, 2013). Throughout history, drought has been directly related to human development and migration and continues to affect these human-environmental interactions today.

While the drought in California has received a large portion of U.S. media attention, there are many other intense droughts taking place globally. In Brazil, the 2015 drought has been called the worst drought in 80 years (BBC, 2015). This drought has had devastating effects such as crop failure, forcing migration, and wildfires throughout the areas of São Paulo, Rio de Janeiro, and Minas Gerais, where water is not only used for agricultural and residential purposes, but also electricity generation. Alarmingly, with over 75% of Brazil's electricity generation coming from hydroelectricity, this drought is currently affecting the country in several ways (U.S. EIA, 2014). With lower power generation in Brazil from the failing hydroelectricity plants Brazil is now forced to look into less environmentally friendly electricity generation. Furthermore, expect roaming blackouts in major metropolitan areas of Brazil, and expect a lower tourism turnout in the foreseeable future. It should be noted that currently Brazil is in the recovery process and many of these issues have or are presently being addressed.

Additionally, drought policy in India has been a hotspot only for a little over a century despite drought being tied back to cultural heritage for ages. Between the late 18th and early 20th centuries, India was overwhelmed with severe droughts and famine time and time again. The Great Bengal Famine of 1769-1770 resulted in 10 million deaths, spanning several territories (Raychaudhui et al., 1983). Following this drought, in the early 1790s the Doji Bara famine took an additional 11 million lives (Grove, 2007). After this, in the 1870's, the India Meteorological Department (IMD) was created and is now responsible for drought information such as water resource management, predictions, and warnings (IMD, 2015). Despite the fact that the IMD has been around for over a century and is geared to help alleviate drought in India, many drought policies are still lacking in cooperation across administrative and political boundaries and have failed to become integrated into drought management. India, like many other countries, has historically relied on a reactive crisis based approach to drought relief instead of a more proactive risk management approach. This difference led to the creation of the 2010 National Disaster Management Authority (NDMA) who created the "National Guidelines for Drought Management" (NDMA, 2010). This document is arguably the most integral approach to drought management in India's history and looks at drought with a scientific mindset by relating drought impacts to policy makers. Furthermore, this document began to shift the former way of combatting droughts into the more modern approach of prevention, preparedness, and mitigation. In addition to this shift, a better understanding to the citizens of India came about that droughts are not only a function of lower rainfall totals, but also poor management of water resources.

Continuing on the drought related difficulties in Asia, it has been predicted that South Korea will experience more frequent and more intense droughts due to the changing global climate (Kim et al., 2016). In 2015, a modeling system was created to project potential climate change impacts associated with hydrological droughts in the Weihe River basin (WRB) in North China. The model showed that while there is a chance that the frequency of droughts might decrease, their intensity and duration will increase (Fei et al., 2015). The idea that droughts are spreading and can become both common has been recognized by the Intergovernmental Panel on Climate Change (IPCC) which notes that droughts are going to likely increase in many regions (IPCC, 2013). The current drought situation in Cape Town presents itself as a prime example of this issue.

Finally, despite the more apparent global effects of drought such as lower crop yield and unsanitary water conditions, there are also some less apparent consequences of drought such as the transmission of epidemic typhus. This disease is caused by the bacterium Rickettsia Prowazekii and is transmitted by body lice. This disease thrives when conditions become unsanitary and crowded, especially during a mass migration in times of drought. Specifically, this was the case during the major droughts in Mexico during 1655-1918, in which there was evidence found for 22 of these large epidemics outbreaks of typhus via tree ring data in association with these typhus outbreak dates (Burns et al., 2014). Basically, the drought was forcing people to live closer and in less clean environments when compared to non-drought years. Once these living conditions happened due to drought the spread of typhus via bacterium followed. The overarching message of these locations and problems is that it appears that no region is immune from drought and that drought carries several risks often over looked.

2.3 U.S. drought

A prime example of climate change devastation in the U.S. was the recent multi-year drought throughout California (Seager et al., 2015). Water levels plummeted as the drought took place and to counteract this more groundwater was taken up at an alarming rate, in addition to changing land-use patterns (NOAA, 2016). The hope of salvaging the land through the pumping of water from local aquifers is only a temporary fix, this act of water pumping is actually causing the ground to sink leading to a new set of problems. This sinking creates more stress on the land and further means that there will be new infrastructure needs to alleviate these compounding problems (Robinson & Vahedifard, 2016).

With this in mind, it is important to consider the climate of North America and how already drought affects more North Americans than any other natural hazard (Kansas Drought Watch, 2015). Feng et al. (2011) described several drought periods during the past century including the 1930s, 1950s, and a period from 1998 to 2005. Within the last five years, there have been intense droughts across North America, further showing the power of drought despite efforts to combat them. The key takeaway is that the race between droughts getting worse because of climate change and whether society can address droughts through proactive drought management strategies. Finally, it should be stated that droughts carry the ability to strike virtually anywhere with little warning and can last for decades.

2.4 Climate change within Arkansas

The question of whether or not the climate is changing in Arkansas is something that needs to be addressed first and if so, how is it changing? Furthermore, does this change blanket the entire state or vary region to region? Currently there is a climate change research knowledge gap for Arkansas despite wide global acceptance of climate change science. A recent analysis of heavy rainfall events in Arkansas Red River Basin from the Journal of Advances in Meteorology in regards to climate change looked into this very knowledge gap; they found there is an uncertainty in regards to an exact precipitation forecast when looking into the future dealing with climate change (McCorkle et al., 2016). This finding was only further confirmed the following year from researchers in Journal of Applied Meteorology and Climatology through advanced GIS modeling (Qiao et al., 2017). A somewhat straightforward conclusion from these two groups of researchers as to why this is a difficult region to predict climate change impacts upon, is that this river basin varies greatly from east to west.

Instead of using advanced GIS modeling techniques to address climate change in Arkansas, we instead address this knowledge gap through the examination of historical information and future climatic projections through a range of extreme weather events and temperature related metrics. Furthermore, to understand the impact of climate changes on endangered species, we are eventually narrowing down this research into a region of a few counties in Southwest Arkansas.

2.5 Natural disasters

Alongside drought are several other natural disasters that carry with them the probability to increase in severity and frequency thanks to climate change, i.e. hurricanes, flash floods, forest fires, tornadoes, etc. These changes and intensities associated with weather will be impacted due to climate change (IPCC, 2013). A prime example of this can be the recent hurricanes such as Irma and Harvey, which demonstrated devastating powers that were previously unheard of. While Arkansas might be immune from the direct impacts of hurricanes, and the indirect impacts from the remnants of hurricanes, it remains quite susceptible to flash floods, tornadoes, drought, and heatwaves. Mitigative efforts against disasters continue scattered throughout Arkansas, but these efforts are usually only discussed when fresh on the mind of policy makers and citizens. At some point unless there is a shift in thinking, this process appears to only moderately prepare Arkansas against the threats of previous natural disaster powers.

2.6 Heavy precipitation events

The flipside of a drought is an immense precipitation event. The IPCC has reported that these events will be increasing in severity, and potentially in frequency due to climate change (IPCC, 2007). These disasters carry with them a whole new set of obstacles and mitigative efforts that will need to be uniquely addressed for each specific region. Taking this into consideration, at what point do endangered species get addressed? While it is understandable to place one's life ahead of another species in a split decision, within what timeframe does this thinking switch? Often hurricanes can fall within this grey area due to a multi-day forecast - however, flash floods present the opposite. With climate change these flash floods and extreme precipitation events are projected to rise, this leads to a gap in endangered species recovery knowledge planning (IPCC, 2013).

3. Impact of climate changes

3.1. Overall impact of climate changes on agriculture

In addition to land-use patterns, human beings are currently altering the environment in unparalleled ways never seen before in human history. These alterations often lead to negative environmental outcomes such as climate change, land degradation, and water and air pollution; of which all propel the magnitude and frequency of droughts (Shew, 2016). This idea of human beings adding negative environmental impacts that increase the frequency of drought has been known and outlined by the Brundtland Commission (WCED, 1987). Furthermore, it is only growing more complex with new contributing factors being discovered every day. Some of these new and upcoming negative factors from humanity include new land management practices, farming practices, damming of natural waterways, excessive use of aquifers, and environmental destruction.

3.2. Impact of climate changes on fisheries and fish

When dealing with virtually any environmental topic, water should almost always be a primary focus point due to its need to sustain life. Taking this into consideration water temperature should be addressed when dealing with rising temperatures and drought. When dealing with heatwaves and elevated temperatures several environmental impacts can start to take place; 1) water sources become more limited, 2) potential cyanobacterial blooms can form, 3) dissolved oxygen within the water become lethal to local water creatures, and 4) habitat loss can take place (AghaKouchak, 2015; Matthews & Zimmerman, 1990; McGowan et al., 2017; Tramer, 1977).

Freshwater fisheries have already started taking adaptation strategies against many of these climate change related issues without really knowing they were. Commercial fisheries now include monitors for dissolved oxygen which activate air pumps when needed, additionally they have a controlled water source which maintains a healthy fresh water supply essentially limiting both habitat loss and cyanobacteria blooms. After coming to this realization that commercial fisheries are already preparing for climate change, we turned to natural fisheries which are not being managed within a closed computer monitored environment.

Research directly related to climate change impacts upon the fishery industry is lacking due to their natural structure which allows full control over their environment. Despite shifting this focus a minute amount to natural fisheries the knowledge gap only shrinks a little at best. This gap is only further compounded when narrowing down the scope to Arkansas. A critical hiccup in this gap is how little in comparison water temperature is monitored versus that of air temperature. The workaround for this within this research was to focus on climate related metrics such as thermal tolerance for a fish species, changing air temperatures, and how these metrics relates to various fish species. Fortunately, shallow fresh water temperature can be closely estimated to ambient air temperature (Mohseni et al., 1998). Taking this idea into consideration, within the shallow waters of southwest Arkansas lies a perfect home for our research which happens to be the home of the endangered Leopard Darter. This small fresh water fish can only be found in the Little River drainage area of southwest Arkansas and nearby parts of Oklahoma.

When considering this location a minute fluctuation of temperature might seem innocent at first, however several minnow species closely related to the Leopard Darter only have a thermal tolerance up to 38.4^{o}C. Should this temperature barrier be broken, then equilibrium loss takes place, leading to death (Beitinger & Bennett, 2000). Despite how simple some of these related environmental issues are to drought in regards to water health, they can often be overlooked. A key to addressing climate change in this area, and for this species, is through environmental policy built to protect the Leopard Darter. Unfortunately, for the Leopard Darter this is quite lacking.

4. Climate change policy

4.1 Global acceptance of climate change and related policies

One of the most recent international recognition of accepting climate change science was confirmed with global acceptance in 2015 of the United Nations Framework Convention on Climate Change (UNFCC) in Paris, where the Paris Climate Accord was created (UNFCC, 2015). Despite this global acceptance of climate science the current U.S. administration refuses to accept and promote both the science as well as the voluntary terms put in place to counter the potential hazards of climate change. It should be noted that while the argument over economics of this accord can be approached from a variety of different views, it will not be approached within our research. We instead focused on what this withdrawal means for climate change policy in the U.S.

4.2 Vanishing support for U.S. climate change policy

With the lack of a national climate change policy there is little that can be done to mitigate climate change from a policy side. Within the past few decades both major political parties have attempted to address climate change and both have been shut down. A prime example of this can be viewed from the 2003 Climate Stewardship Acts, which were introduced to the U.S. Senate by Senators John McCain and Joseph Lieberman only to fail (U.S. Senate, 2003). However, these acts, and further bills and committees have demonstrated that climate change is an idea that needs to be tackled and with the modern recusal of the United States from the Paris accord, it only demonstrates further how far America is falling behind.

A final thought to conclude on this is that the common location thought to best address climate change policy in the U.S. is through the Clean Air Act and the Clean Water Act. However, these two acts are shackled against making changes in regards to climate change despite the overwhelming support of scientific evidence. This might appear morally wrong knowing that the air and water we use every day is impacted by the climate; which is changing. Despite these limitations there appears to be a semi-work around through the Endangered Species Act, which allows loosely associated policy steps with climate change to be accounted for and adapted. This is of course assuming they are written into the species' recovery plan and approved. This very action of working with a knowledge of climate change in a national policy is presently going through multiple legal hurdles and faces uncertainty. Should climate change indeed be happening within this region of Arkansas, and it appears that it is, then a pathway towards climate change policy can start to take place through the Endangered Species Act. Again, this might not seem like the most logical approach; but, progress in any form, is still progress.

5. Climate change planning

5.1 U.S. drought policies

A workaround to addressing climate change policy for U.S. currently is to instead focus on climate change recovery and mitigation; this idea can be viewed through the creation drought plans in the U.S. While drought plans are scattered throughout the world, ranging from small city plans to state or province-level plans in the United States, there are currently only three states without drought plans (Figure 1) (NDMC, 2016).

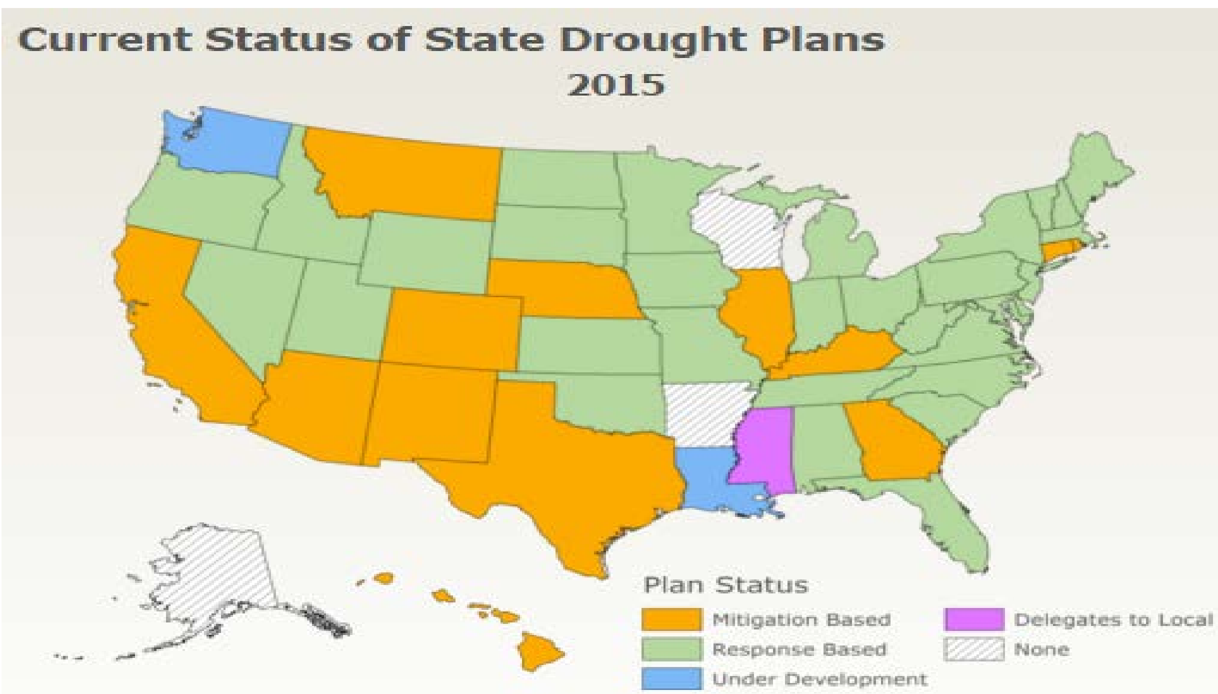

Figure 1. A current map of the U.S. state drought plans (NDMC, 2016)

While there are a variety of different styles of drought plans throughout the world, in the United States there are basically two types. To illustrate from Figure 1, there are 13 states that have mitigation plans and 32 states that have response-style drought plans, excluding the Mississippi approach of delegation to a local level. This process means that the drought affected area will activate its own drought plan instead of a statewide drought plan becoming activated. To define further, a response plan is more geared towards the short term with actions or guidelines of how to lower the immediate threat associated with drought. Common elements with a response plan might include provisions for drought monitoring, agency responsibility, potential impacts expected during a drought, and triggers that initiate the response-drought plan during a drought (NDMC, 2016). Comparatively, a mitigation-based drought plan focuses more on limiting drought risks before a drought occurs, while still focusing on reducing the impacts of a drought. This style of plan identifies short and long-term actions, programs, and policies to best promote preparedness, while at the same time promoting the development of mitigation activities, identifying parties responsible for risk reduction, listing specific actions to help mitigation, and finally drought impact and assessment monitoring (NDMC, 2016).

Accordingly, it is important for each area considering a new drought plan to take into consideration the drought history associated within the land. If a specific area is under constant drought with a long history of drought, a mitigation based plan might be the best option. Conversely, if a specific area rarely experiences drought and has a short history of it, then a response plan is probably sufficient. An example of this could be establishing a drought response plan over a rainforest. While each of these two plans carries their own unique perspective on how to lessen the damage on drought, it is ultimately up to each location’s legislature when they choose to implement a certain plan.

Taking this wide spread acceptance of drought plans into consideration, should drought plans start to incorporate climate change science, then potentially all of these states could start moving towards mitigation. While not all drought policies can switch over freely to another state due to a variety of factors like river or state borders, soil types, zoning, and government bodies, many of the key features in one plan can be molded to create another policy or plan. Additionally, this potential acceptance and push towards climate change mitigation can make financial since too. On the unfortunate event of a drought happening, should a drought plan already be in place then the initial process of creating a drought plan, excess water pumping, and many discomforts could be avoided.

5.2 Financial Logic for a drought plan

An example that demonstrates the value of a drought plan would be to look at the U.S. and how it generates a vast amount of its GDP from agriculture and agricultural services. If the U.S. not have drought plans in place throughout the states its GDP could suffer greatly in a drought. In 2014, the United States Department of Agriculture (USDA) showed that this $835 billion dollar industry accounts for a 4.8 percent share of the entire U.S. GDP (USDA, 2016). Furthermore, the food manufacturing sector employed about 1.5 million people in 2014, which is 14 percent of the manufacturing jobs in the U.S., as well as being just over one percent of the total U.S. population (USDA, 2016). In light of this, if a megadrought occurred in the U.S., the consequences would be felt in many other countries because the U.S. is a leader in the exportation of agricultural goods. Consequently, a vast majority of drought plans and policies in the United States are written to help mitigate harm to farmers and farming communities. For this reason, more drought plans are written in this manner in the U.S. when compared to others around the world.

5.3 Endangered species recovery plans

Another way the U.S. is currently working around the gap in accepted climate change science is through the creation of recovery plans written for endangered species. A recovery plan is as straight forward as it sounds in regards to endangered species; it is a plan that is written for the endangered species to recover to a self-sustainable status. Logically, the climate for a species is something that has to be monitored and kept in an acceptable range for the species to recover. Despite the seemingly obvious knowledge that climate change is effecting a magnitude of environmental issues, agencies writing recovery plans are somewhat handicapped when addressing climate change. While creating a modern and effective recovery plan might seem relatively simple, there are a virtually limitless set of obstacles to these plans such as a species cannot be listed as endangered with its primary reason being from climate change. Another issue where the plan is written often is effected by local environmental ideology towards climate change. In California, Colorado, and Oregon for example several plans are updated to reflect climate change and newer plans are being written with this in mind – however, in Arkansas this is far from the case. Meaning that an endangered species in Arkansas will most likely not have the most modern and effective thinking to support its recovery plan, essentially limiting the potential recovery of the species.

An additional hang-up with recovery plans is that their renewal or update process is voluntary by the agencies responsible. Furthermore, the timeline to update a plan falls roughly every five to seven years depending on the status and location of the written recovery plan. The Endangered Species Act relatively gained popularity in the latter part of the previous century and many of the plans written then have not been updated since. While extreme events associated with climate change continue to grow in power and frequency, many creatures with older written recovery plans are left behind. With just some of the issues listed above it becomes apparent that the effectiveness of a recovery plan can be limited.

6 Summary

6.1. Knowledge gaps

Based on our current research and finding associated with climate change in the U.S., I identify the following knowledge gaps. 1) There is a void of climate change related research in Arkansas especially in the fishery sector 2) Specific issues related to climate change and its impacts to Arkansas, especially southwest Arkansas, are not being addressed. 3) Currently within the U.S. there simply is no policies in place to properly address climate change and Arkansas appears to be continuing this trend.

6.2 Outline

I am researching the following questions over the next few chapters. First, how is climate change appearing in Arkansas? What is the evidence? We look into the various metrics associated with climate change and address these one by one to see if there is indeed a changing climate in Arkansas. Next, we will look to see if these potential impacts associated with climate change being addressed in Arkansas. Specifically, we focused on the potential impacts of climate change on Leopard Darter, an endangered minnow fish in Southwest Arkansas. Finally, what is the current status of climate change policy in Arkansas? Given these, how can Arkansas learn from the these lessons and adapt to climate change?

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Observed and projected changes in climate and extreme events in Arkansas

Abstract

Climate change appears to be rewriting our expectations of expected climate situations are across the planet. This chapter investigates the data to see if Arkansas is immune to these oncoming changes or to see if climate change is already having a noticeable impact. Through the analyzation of historical climate data with key observable metrics, we investigated the idea of a changing Arkansas climate through analyzing numerous historical climate related metrics e.g., temperature, precipitation, frost day frequency, etc. Initial results have shown that the climate is changing primarily through extreme weather events; additionally, Arkansans appear to be in the early phases of a growing season climate shift. Furthermore, some results showed that the frost days are starting to decline primarily due to a minimum nightly temperature higher than in the previous cold seasons within Arkansas.

Continuing our study from our initial findings, we approached what the projected future impacts to Arkansas will be from multiple metrics working alongside IPCC Representative Concentration Pathways. The significance of these results shows that indeed the climate is changing presently and appears to be in a growing rate of change for Arkansas. There is a seemingly endless set of topics that will need to be addressed with these changes should life wish to continue in a gratifying manner within the state of Arkansas.

1. Introduction

Climate in a given region can be defined by fundamental weather conditions such as temperature, air pressure, precipitation, etc., throughout the year, averaged over a series of multiple years for this selected area. Climate change is encroaching upon these conditions and noticing a change in long-term averages in that defined region, which in this study is Arkansas (NASA, 2011). Changing climate in Arkansas could include warming, cooling, and changes between temperatures. These climatic changes can occur both naturally and anthropologically alongside having various time scales. Two of the key metrics we looked into for this research were temperature and precipitation based upon their potential for change.

Climate change can bring several issues to environmental realms including droughts and extreme precipitation events, both of which can become more punishing due to the effects of climate change (Semenza & Menne, 2009; Pachauri & Reisinger, 2007; Füssel, 2000; Feng et al., 2017). Additionally, these two polarizing events are being forecasted to increase globally (Karl et al., 1995; Dai et al., 1998; Solomon et al., 2007; Knapp et al., 2002). These two unwelcoming intertwined responses to climate change each require their own unique set of plans to mitigate their impacts.

On the opposite end of the spectrum associated with droughts are extreme precipitation events; these extreme events are a constant reminder of how the opposite of a drought, major flooding, can devastate an area. Texas recently experienced this firsthand with Hurricane Harvey producing over four feet of precipitation causing the city to flood, millions in infrastructure damage, and citizens to have both mental and physical health consequences (Shah et al., 2018; Shultz & Galea, 2017).

The United States has become a divided nation on the topic of climate change. However, climate change science remains impartial to whomever chooses to direct one's gaze upon it. And when one looks, it will be seen that 2016 was the hottest year in over a century with 2015 and 2017 not far behind (Kennedy et al., 2017; NOAA, 2017; NOAA, 2018). The implications of a warming planet can be catastrophic on a virtually limitless set of topics and Arkansas appears to be trending in the same direction of warming when looked at from a national view point. Furthermore, temperature is critical and a straight forward issue when addressing hazards associated with climate change. One important consequence of a rising yearly temperature is a shift in growing season days.

A warmer or longer growing season can have implications on agriculture productivity, distribution of crops, and soil implications (Ruane et al., 2013; Wienhold et al., 2018). Arkansas from 1980 – 2017 roughly averaged between $250 and $500 million dollars in annual damage from climate related disasters as shown below in Figure 1 from NOAA - with Arkansas identified by the arrow (NOAA, 2018). Should climate change impact Arkansas, then its effects could be felt throughout the state’s economy.

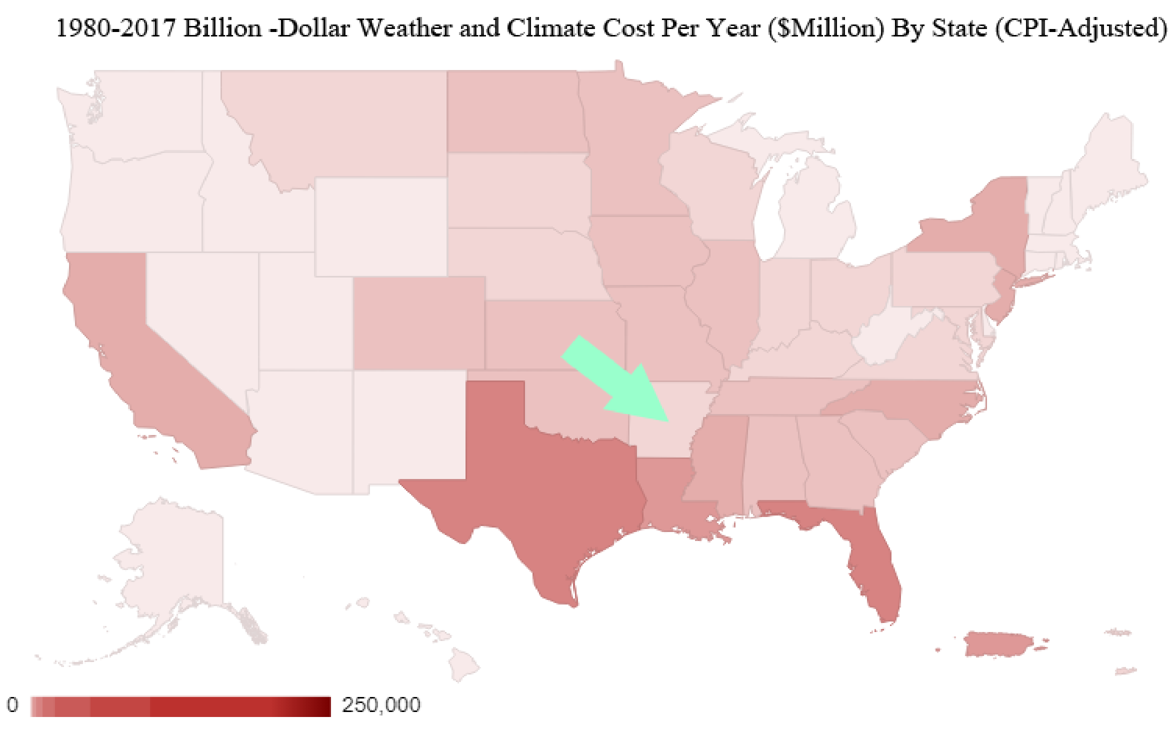

Figure 1. Disaster costs from climate per year by state. By NOAA, 2018.

When stepping back and looking globally there are multiple climate change scenarios in place that will likely result in a changing planet. However, an in-depth modern analysis of the climate in Arkansas was not present at the time of this writing. We are seeking to fill this knowledge gap of what has, is currently, and what could be happening to Arkansas's climate in order to open the door towards future climate related research concerning Arkansas specifically.

Our overall goal and objectives of this study is to investigate the data and see if the climate in Arkansas is changing. If the climate is indeed changing, at what rate is this change happening? Finally, we plan on addressing Arkansas's future climate projections based upon historical data and future national and regional climatic projections.

2. Data and methods

This research will attempt to gain insight about whether Arkansas is in fact changing climatically. This will be done by using climatic data from all sources. We will analyze temperature and precipitation related events from these sources in Arkansas. From this we will look ahead to see if and what factors these stresses could create within Arkansas. In order to expand on these individual metrics, we will follow the hypothesis that climatic trends will continue as they are currently going.

2.1 Observational and paleo data

When addressing a topic such as climate change, temperature is a metric toward which many people can relate. However, data from the high-resolution Climatic Research Unit (CRU) and Palmer Drought Severity Index (PDSI) becomes more difficult to relate. While this data might appear complex, the idea of drought strength and frequency can be garnered and understood on a basic level.

While addressing climate change we focused on these factors: 1) monthly precipitation, 2) monthly average daily minimum temperature (Tmin; °C), 3) monthly average daily maximum temperature (Tmax; °C), 4) daily mean temperature (Tmp; °C), 5) frost day frequency (days), and 6) diurnal temperature range (DTR; °C). The indicators used are from 1901-2016 and obtained from the high-resolution CRU gridded climate dataset CRU TS V4.01 (Harris et al., 2014). The spatial resolution of the CRU dataset is 0.5° in longitude and latitude.

Besides the monthly temperature and precipitation, the variations of hydroclimate are also critical for agricultural and water resources management. The monthly Palmer Drought Severity Index (PDSI) is calculated using the CRU dataset (Schrier et al., 2013; Osborn et al., 2016; Osborn et al., 2017). Additionally, the reconstructed warm season (June-August, JJA) PDSI spanning the last two millenniums was obtained from Living Blended Drought Atlas (LBDA) (Cook et al., 2010). The LBDA is a new, tree ring-based paleoclimate reconstruction at half-degree grid point over North America for the last 2,000 years. PDSI integrated changes in moisture supply (precipitation) and demand (evapotranspiration) over multiple seasons. Cook et al., (2010) demonstrated good agreement between the reconstructed and instrumental PDSI records. The LBDA has been used to assess the frequency and spatial distribution of droughts over the past millennia (e.g., Cook et al., 2013). In this study, the reconstructed PDSI from 900-2000AD in Arkansas was analyzed. There are no reconstructed PDSI in AR before 900AD, mainly because long-term tree chronologies are not available in the focal state.

Additionally, the daily maximum temperature, minimum temperature, and precipitation at 0.25-degree resolution from 1901 to 2014, derived from Global Land Data Assimilation System Version 2 (hereafter, GLDAS) are also used to examine the changes of extreme weather events (e.g., Li et al.,2018). The GLDAS is a new generation of reanalysis developed jointly by the

National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC), and the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP).

2.2 Future projected data

To understand the projected future climate change within Arkansas, the monthly temperature, precipitation, and PDSI from dozens of global climate models participating in the inter-comparison project phase 5 (CMIP5, Taylor et al., 2012) are analyzed. These models are listed in Table 1. The simulations covered 1850-2005 (historical run) and from 2006 to 2100 with proposed changes in anthropogenic aerosols and greenhouse gases following the IPCC Representative Concentration Pathways 4.5 (RCP4.5) and 8.5 (RCP8.5). IPCC RCP's are projections used for climate modeling that vary based upon how much greenhouse gases (predominately CO_2) are emitted. The RCP4.5 states that CO_2 will peak around 2040 whereas RCP8.5 is a continuation of our current CO_2 output rate (IPCC, 2014). The monthly temperature and precipitation were statistically downscaled to half degree resolution (Feng & Fu, 2013; Feng et al., 2014). The statistically downscaled data were subsequently used to calculate the PDSI that spanning the 1850-2100 under different scenarios (Feng et al., 2017).

Table 1. CMIP5 Models

	Model name	PDSI	Tmax	Tmin	Precipitation	Origin
1	ACCESS1.0	√	√	√	√	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
2	ACCESS1.3	√				
3	BCC-CSM1.1	√	√	√	√	Beijing Climate Center, China Meteorological Administration
4	BNU-ESM		√	√	√	College of Global and Earth System Science, Beijing Normal University
5	CanESM2	√	√	√	√	Canadian Centre for Climate Modelling and Analysis
6	CCSM4	√	√	√	√	National Center for Atmospheric Research
7	CESM1_BGC	√	√	√	√	
8	CESM1_CAM5	√	√	√	√	
9	CMCC-CM	√				Centro Euro-Mediterraneo per I Cambiamenti Climatici
10	CMCC-CMS	√				
11	CNRM-CM5	√				Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique

Table 1. CMIP5 Models (Cont)						
12	CSIRO-Mk3.6	√	√	√	√	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence
13	FGOALS-g2	√				LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University
14	GFDL-CM3	√	√	√	√	Geophysical Fluid Dynamics Laboratory
15	GFDL-ESM2G	√	√	√	√	Geophysical Fluid Dynamics Laboratory
16	GFDL-ESM2M	√	√	√	√	
17	GISS-E2-H	√				NASA Goddard Institute for Space Studies
18	GISS-ER	√				
19	HadGEM2-CC	√				Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
20	HadGEM2-ES	√				
21	INMCM4	√	√	√	√	Institute for Numerical Mathematics
22	IPSL-CM5A-LR	√	√	√	√	Institut Pierre-Simon Laplace
23	IPSL-CM5A-MR	√	√	√	√	
24	IPSL-CM5B-LR	√				

Table 1. CMIP5 Models (Cont)						
25	MIROC-ESM	√	√	√	√	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
26	MIROC-ESM-CHEM	√	√	√	√	
27	MIROC5	√	√	√	√	
28	MPI-ESM-LR	√	√	√	√	Max Planck Institute for Meteorology (MPI-M)
29	MPI-ESM-MR		√	√	√	
30	MRI-CGCM3	√	√	√	√	Meteorological Research Institute
31	NorESM1-M	√	√	√	√	Norwegian Climate Centre
32	NorESM1-ME	√				

Note. A list of CMIP5 models used in this study with a brief description. Historical runs (1850-2005) and two future scenarios (RCP4.5 and RCP8.5) runs (2006-2100) in individual models are used. For models with multiple ensemble runs, the first ensemble member was used.

Besides the modeled monthly temperature, precipitation and PDSI, the daily maximum temperature (Tmax), minimum temperature (Tmin), and precipitation during 1950-2100 from 21 CMIP5 models (see Table 1) were downscaled to 0.25-degree resolutions. We obtained these daily downscaled climate variables from NASA.

All datasets listed in Table 1 cover the global land areas. This study only focused on the variations of these quantities and the derived indices in Arkansas. Because these datasets have different spatial resolutions, the LBDA, GLDAS, and CMIP5 dataset were interpolated to the same grids as the CRU, which allows us to analyze the climate variations at the same level.

2.3 Methods

The climatic data we used for this research was retrieved from historical records, CRU, and GLDAS. Furthermore, the CMIP5 model simulations were used for future projections. In order to make unbiased comparisons of this data and how it has impacted Arkansas, we focused solely on results and not cultural impacts. By doing this, we obtained measurements such as frost day frequency and were able to give a simple, straight-forward figure to demonstrate that this is, in fact, changing. The usefulness to this approach allows each acting party to understand how these results might impact each person, government agency, or company. It is up to the individual to choose how to respond of their own volition to these findings.

We focused on the warm and cool seasons for a variety of reasons. The first reason being that Arkansas is a state heavily focused on agriculture which needs a stable warm season for harvests. Additionally, people can relate to the extremes of hot and cold temperatures; these extreme events most often occur in warm and cool seasons, e.g. there are not many freezing days in July for Arkansas. Alongside the seasonal changes, the extreme weather events were also analyzed. There are two common groups of criteria which are often used to define extreme weather events: the relative and the absolute thresholds. The relative threshold is largely applicable for broad regions with large climatic differences, whereas the absolute threshold is more precise and often easier to follow for a smaller selected area (Vavrus et al., 2015). Because we only focus on Arkansas, the extreme events within our findings are based on the absolute threshold. According to multiple previous studies about the thresholds adopted within the United States, hot days are defined to have a daily maximum temperature of at least 90^{o}F (32.2°C) (Maloney et al., 2014; Patz et al., 2014), extreme cold days have a daily minimum temperature of 0^{o}F (-17.8°C) or lower (Vavrus & Van Dorn, 2010), and heavy precipitation days are defined to have a daily precipitation of at least 2 inches (50.8mm) of rainfall, or liquid-equivalent snowfall (Groisman et al., 2004; Vavrous & Behnke, 2014). Additionally, temperature thresholds are critical when looking into species such as the Leopard Darter due to their inability to cope with extreme heat and cold.

3. Reconstructed and observed climate changes in Arkansas

3.1 Changes in seasonal temperature and precipitation

We looked at maximum temperature (Tmax) during cool and warm seasons within Arkansas from 1901-2016, as shown below in Figure 2. The Tmax did not show a significant trend in cool seasons or warm seasons, instead showing decadal variability. While this might seem to be hopeful against the idea of oncoming climate change in Arkansas, it should be remembered that these are daily maximum temperatures and they are not a sole reflection of overall temperature norms. A change in Tmax might seem minute on a grand scale of climate, however for Arkansas, which is a heavily focused agricultural state, plants haves a maximum heat tolerance in addition to having several climatic variabilities associated with temperature that should be addressed before a concrete conclusion can be extrapolated. Should the daily Tmax get too hot, Arkansas could potentially lose valuable cropland of which consequences could ripple throughout the state's economy, leading into a potential abundance of concerns.

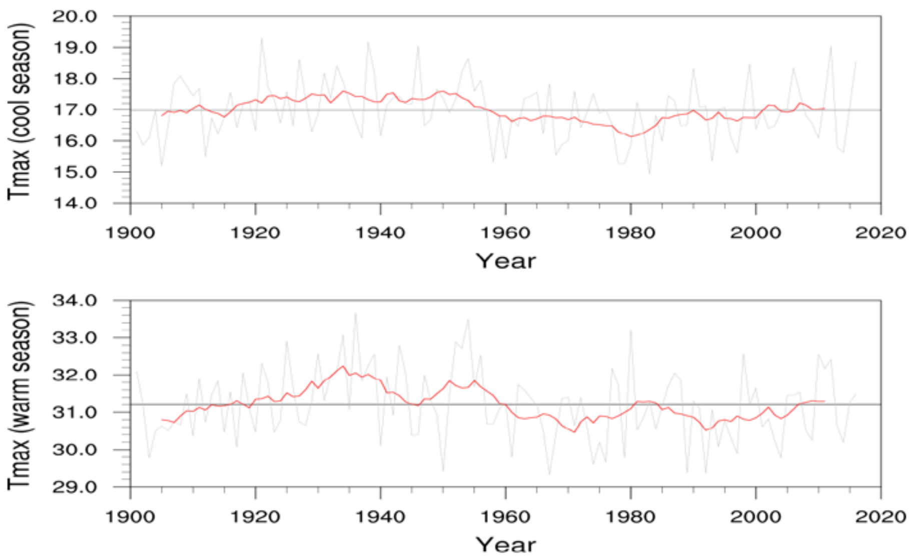

Figure 2. Temporal variations of warm and cool season daily maximum temperature (Tmax) from 1901-2016.

The minimum temperature (Tmin), however, showed an increase from the 1970s onward, especially during the warm season as viewed below in Figure 3. These results showed that Arkansas might be having a shift in overall temperatures when measured with a diurnal temperature range. Taking this into consideration, we measured diurnal temperature range (DTR) alongside daily mean temperature (tmp) within Arkansas as shown below in Figures 4 & 5. Additionally, these temperature changes can lead to new problems for Arkansas ranging from an acceleration of pest development to a variation in bird migration (Merrill & Peairs, 2017; Zaifman et al., 2017).

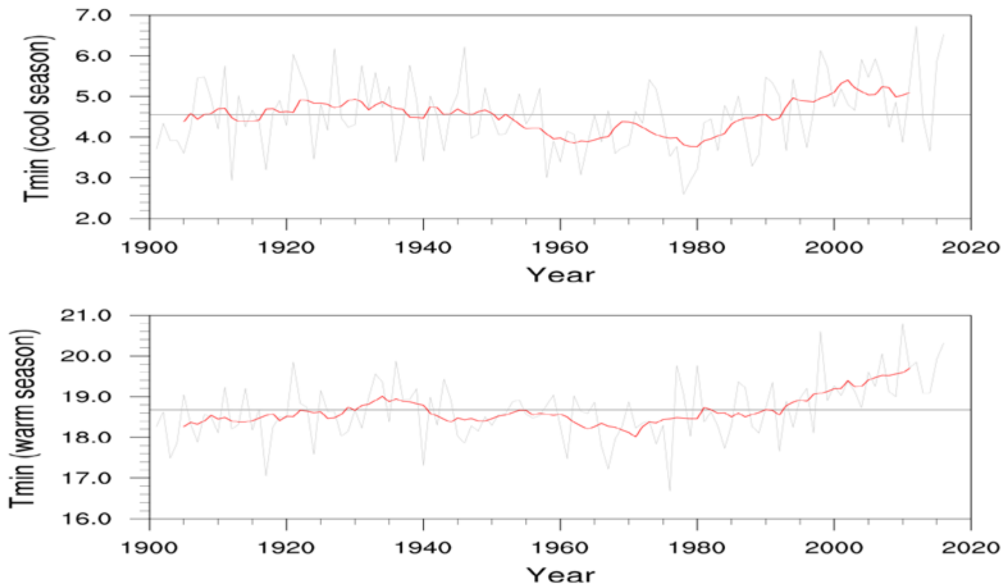

Figure 3. Minimum temperature variables (Tmin) within Arkansas during warm and cool seasons from 1901-2016

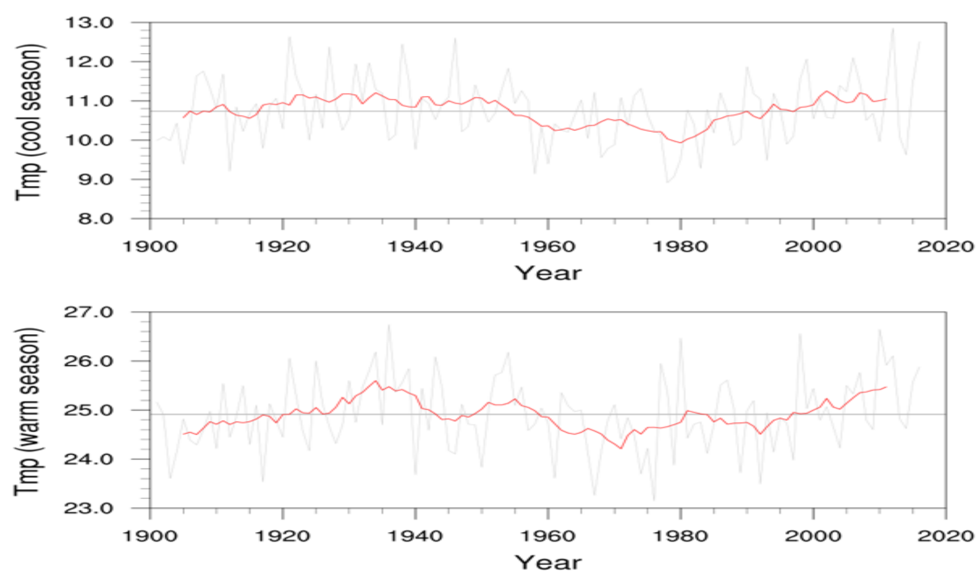

Figure 4. Daily mean temperatures (Tmp) within Arkansas during warm and cool seasons from 1901-2016

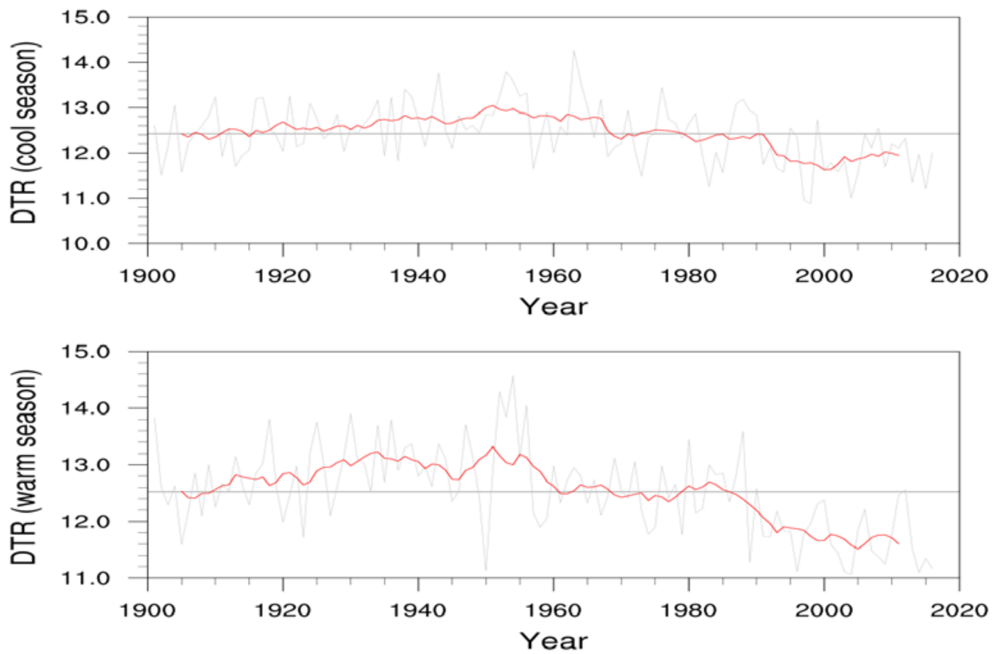

Figure 5. Diurnal temperature ranges (DTR) within Arkansas during warm and cool seasons from 1901-2016

These temperature changes during the cool season opened up a new avenue of thought we decided to pursue. Noticing the shift during the cool season, we researched the frequency of frost days in Arkansas as shown below in Figure 6. The logic behind this specific metric was to see if there was a noticeable visual reference point associated with this research to which everyone could relate. Frost has powerful impacts upon a region's environments e.g., ecological distribution of some tree species, shifting of spring water melt, precipitation changes, etc. (Charrier et al., 2015; Jykama & Sykes, 2007; Eckhardt & Ulbrich, 2003). In fact, Arkansas has witnessed a shift in less frost frequency, meaning these impacts could happen consequently. This finding of a lower frequency in frost days builds upon the work in eastern Arkansas by the Journal of Water and Land Development (Magugu et al., 2018). Their conclusion of this impact upon the agriculture industry, along with these other new potential impacts within this paper might not seem dramatic at first – however, once the tipping point has been crossed it will become exceedingly difficult to restore the previous normality. Additionally, once some of these impacts start impacting Arkansas they will only multiply the difficulties and burdens placed upon the land.

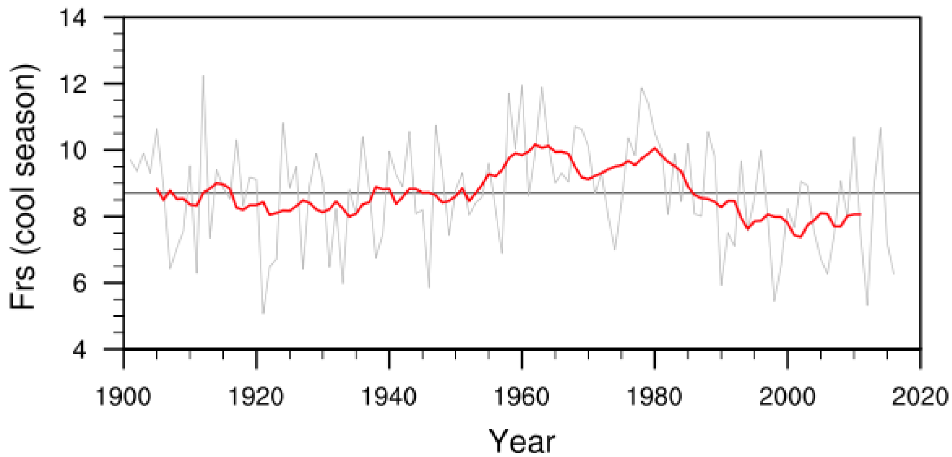

Figure 6. Frequency of frost days (Frs) within Arkansas during cool seasons from 1901-2016

3.2 Changes in drought variability

The PDSI is a recognized drought index due to its reliability and modern accuracy with Arkansas, and was chosen for these very reasons (Liu & Hwang, 2015). The temporal variation of reconstructed PDSI from LBDA indicated that the medieval warm period (MWP) has been climatically drier than the subsequent little ice age within Arkansas (Figure 7). Six megadroughts were not evenly distributed in time, clustering during the MWP and the centuries immediately thereafter (Figure 8). The results from the PDSI within Arkansas for present day show that we have a relatively wetter cool season in comparison to the warm season, which can be seen below with Figure 9. Furthermore, the precipitation totals are actually higher in the cold season than expected when compared with regional trends. The moderate fluctuations are quite expected and reflect no real need to separate these to research more in depth when associated with this specific research. Additionally, fluctuation of PDSI (Figure 10) showed severe droughts during 1930-1945 (the Dust Bowl), 1950-1960, and 1962-1970, respectively.

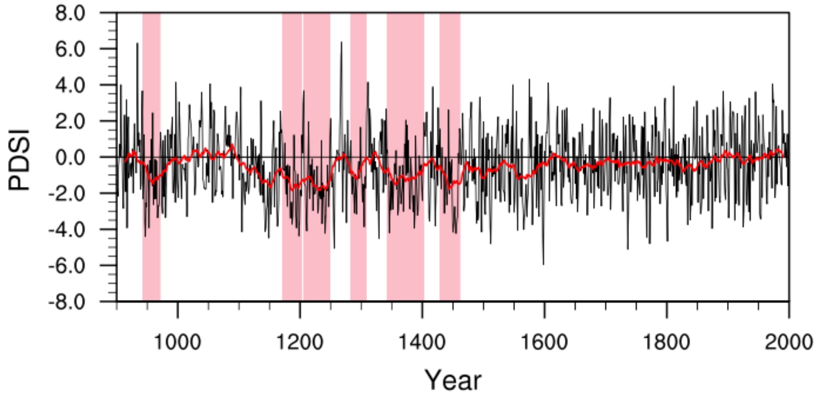

Figure 7. PDSI variation of Arkansas during warm and cold seasons, the red shadings are megadrought events.

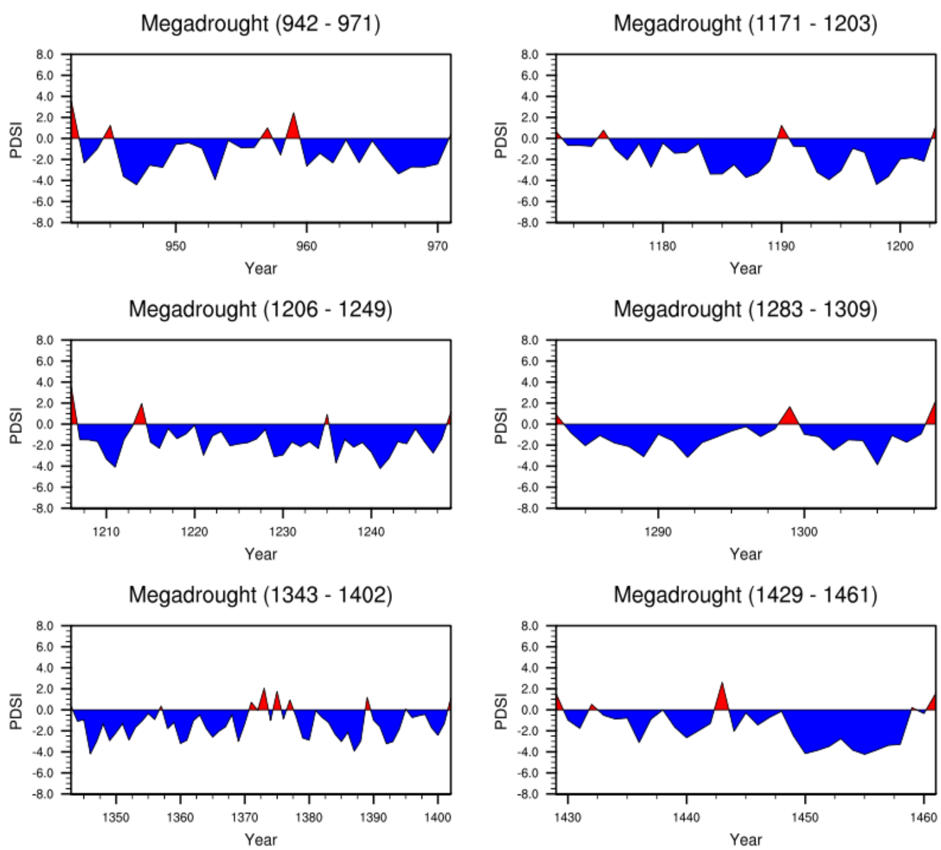

Figure 8. The specific temporal variation of the PDSI for the six megadrought periods

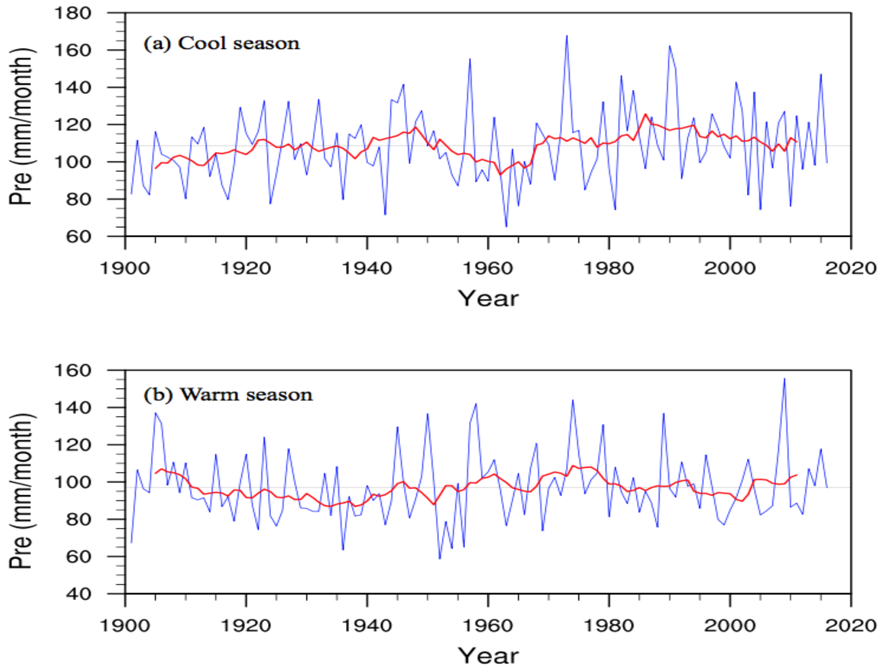

Figure 9. Precipitation (Pre) within Arkansas during warm and cool seasons.

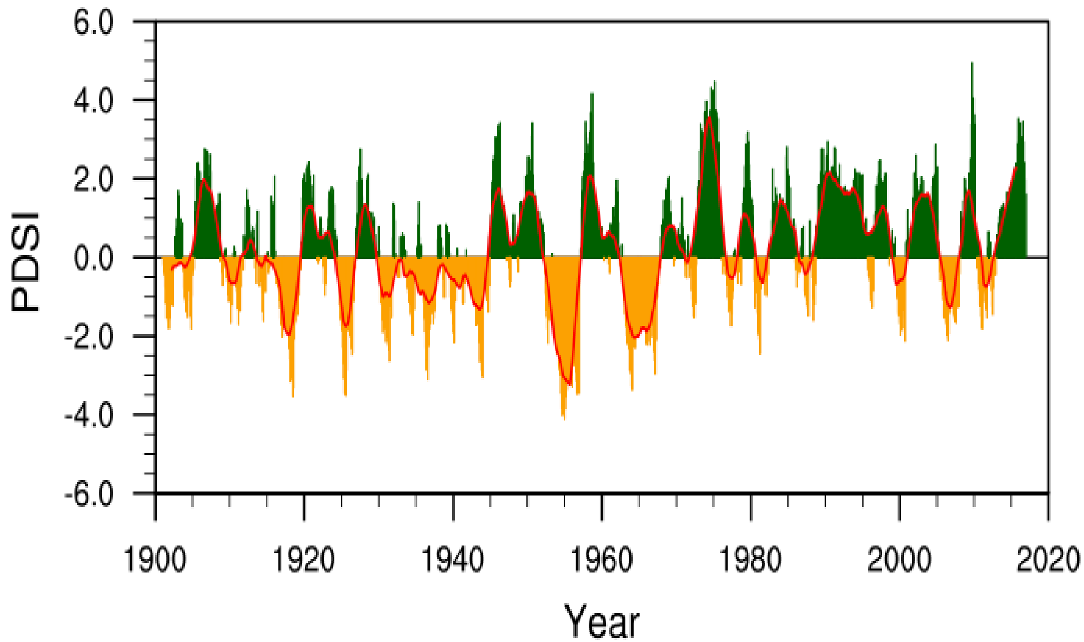

Figure 10. PDSI of Arkansas monthly.

While these historical records do not show an uptick in drought frequency, it should be noted that droughts and mega droughts can still happen with relatively no major warning. When taking into account all of the various metrics associated with climate change that are currently known, the environmental conditions for drought is shown to be present here in Arkansas for the future. Some of them can be seen with the longer warm seasons and the increase in warmer nighttime temperatures. Taking just these two indices into account, it becomes apparent that most likely more water will be needed for the agriculture industry, essentially straining the already depleting aquifers.

3.3 Changes in weather extremes

Changes in weather extremes carry the potential to become more common and more extreme in regards to climate change (Konisky et al., 2016; Wang et al., 2015). These changes, while appearing minor, e.g. a warmer average with nighttime temperatures, can have serious environmental repercussions such as more violent thunder storms. We took the historical data alongside our projected data to address this very topic.

The basic climate of Arkansas can be described as warm and humid, so the frequency of extreme cold is relatively low (Figure 11). Additionally, the temporal variation of extreme heat and extreme precipitation have not showed significant trends, while both indicated strong decadal variations as shown in Figures 12 and 13. Despite not showing red flags currently, extreme weather events still carry the potential to happen randomly without much warning. Taking this into consideration when looking ahead for Arkansas, this is something that should be continued to be researched when considering the impacts of extreme weather. A prime example of this can be the effects of hurricane Harvey from the nearby state of Texas just last year (2017).

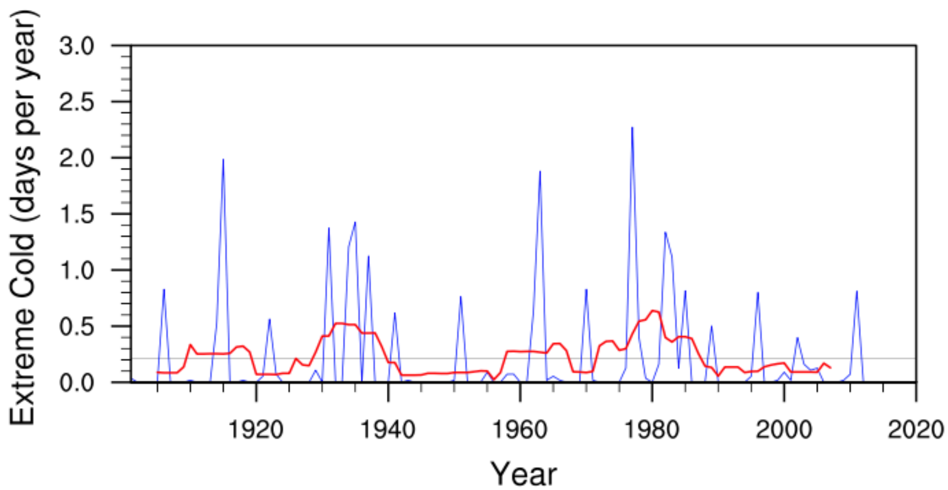

Figure 11. The temporal variation of extreme cold days

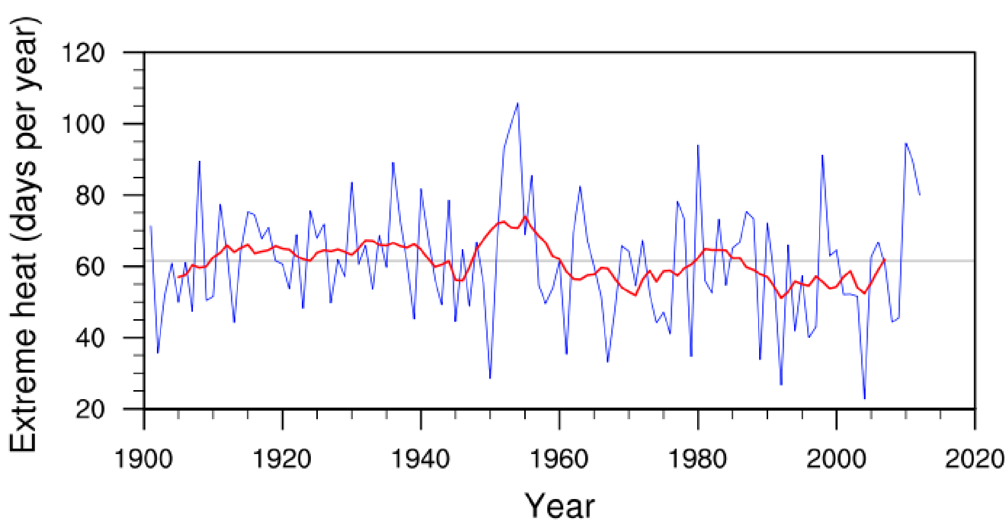

Figure 12. The temporal variation of extreme heat days

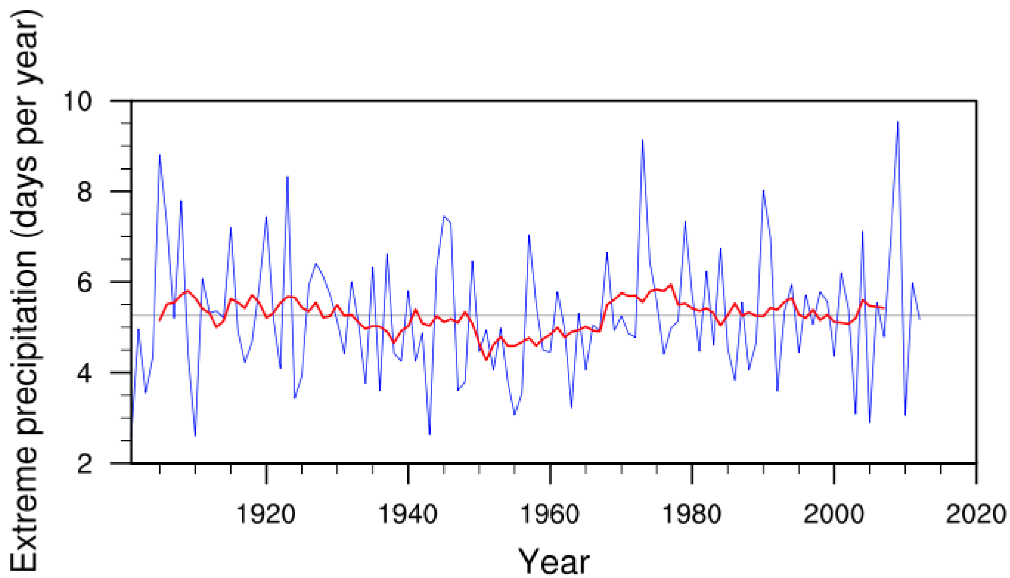

Figure 13. The temporal variation of extreme precipitation days

4. Projected changes in Arkansas

4.1 Projected changes in temperature, precipitation, and drought

Looking ahead to the future is key for the sustainability of Arkansas and agriculture in general within in the state. We approached this topic and looked at future climatic models and trends primarily using the IPCC RCP's to look at future trends within Arkansas. RCP4.5 and RCP8.5 scenarios were the ones selected due to their climatic goals and business as usual commonly associated with climate change. The goal of this future gazing was to determine if these climatic trends continue, then we might know what mitigation efforts should be taken for Arkansas.

We followed our previous work and modeled the warm and cool seasons. Furthermore, we continued to look into both maximum temperature, minimum temperature, precipitation, and PDSI. Compared to the observations during 1950-2005, the models did a reasonable job in simulating the low frequency changes in temperature, precipitation and PDSI (Figures 14-17).

Specifically, the results suggested that both maximum temperature and minimum temperature are projected to increase in the future, and the increasing amplitude of RCP8.5 is obviously greater than that of RCP4.5 (Figures 14 & 15). It should be noted that the extent of the increase is more significant in warm season. For the precipitation, our results do not show a significant changing trend (Figure 16). However, even though the precipitation results don't show an obviously decreasing trend, it is not all good news. This is because both the warming and the PDSI increased indicating a drying trend in the future despite precipitation remaining roughly the same (Figure 17). The drying trend is mainly caused by increasing evaporation associated with the projected warming (Feng et al., 2017). Additionally, the precipitation will arrive in fewer sessions and with more intensity (see section 4.2), suggesting less rainy days and more prolong droughts.

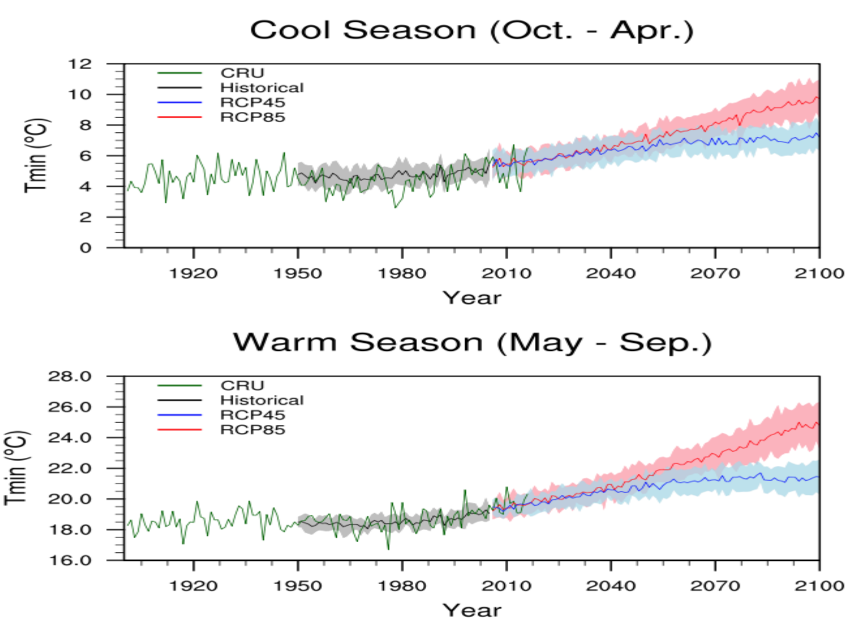

Figure 14. The temporal variation of Tmin in the future for Arkansas, the shading denotes 1 standard deviation of the models

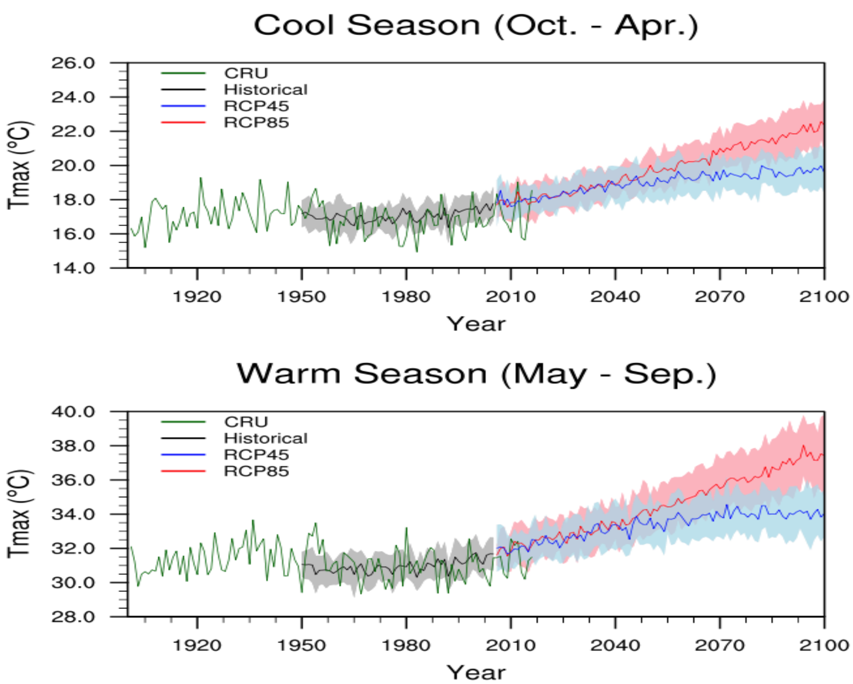

Figure 15. The temporal variation of Tmax in the future for Arkansas, the shading denotes 1 standard deviation of the models

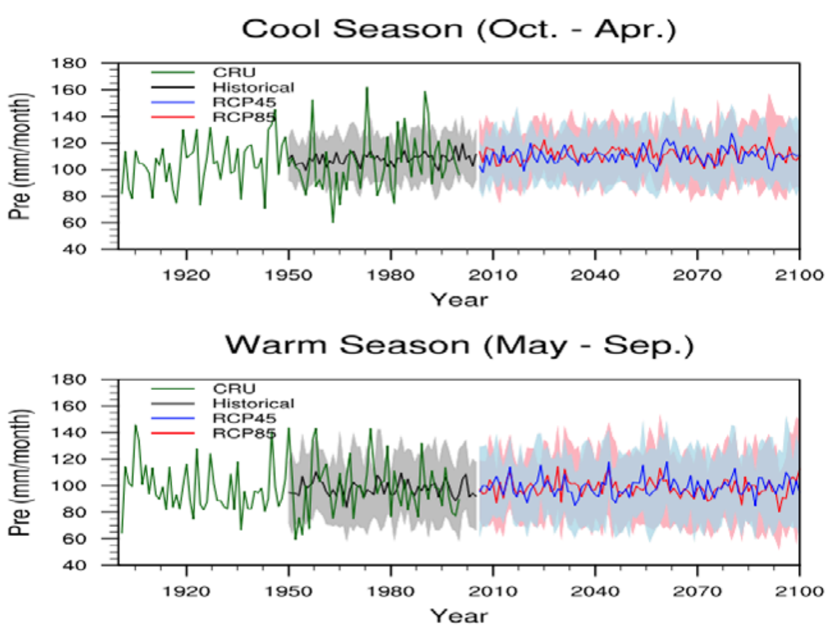

Figure 16. The temporal variation of precipitation (Pre) in the future for Arkansas, the shading denotes 1 standard deviation of the models

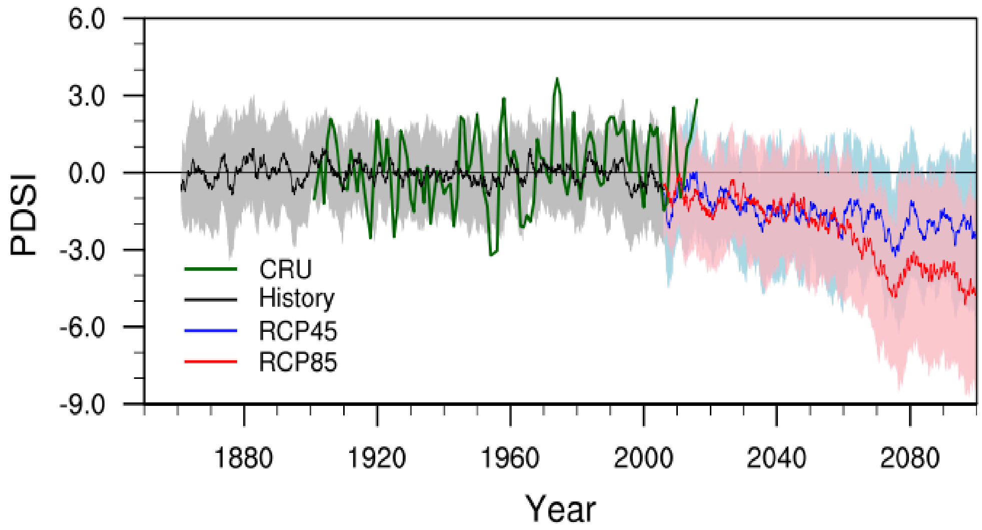

Figure 17. The temporal variation of the PDSI in the future for Arkansas, the shading denotes 1 standard deviation of the models

4.2 Projected changes in weather extremes

We investigated extreme precipitation events which are defined as daily precipitation totals above 50mm (Groisman, 2005). We also looked into both extreme heat and cold days, where the maximum temperature is above 32.2°C or below -17.8°C. The temperature marks were chosen specifically due to previously accepted and peer reviewed works in similar fields who all marked these temperatures as the start of extreme temperature days (Karl & Trenberth, 2003; Maloney et al., 2014; Patz et al., 2014). This absolute threshold is often easier to understand and can be relevant for certain impacts for anyone to relate.

The severity of extreme heat days, a daily maximum temperature of at least 32.2°C, can be felt throughout many industries even if they are only indirectly related to temperature. Epidemiological studies have confirmed time and time again that heatwaves may result in excess morbidity and mortality within the general population (Hansen et al., 2008a, 2008b; Nitschke et al., 2007; Ye et al., 2012). While human experiences can simply justify this as an increase in fatigue and stress placed upon the human body and escape to advanced shelter, nature cannot turn on the air conditioning to escape the extreme heat. Compounding this with the harms that extreme heat can cause upon the agricultural world, it becomes apparent that this is a risk that should be mitigated against.

Using these core ideas, we approached this topic using both historical data and GLDAS data from Arkansas, modeled using both RCP4.5 and RCP8.5 as shown below in Figure 18. As many would assume judging solely from recent historical trends, Arkansas is indeed on track for more extreme heat days. Should the RCP8.5 come to fruition, then the sheer number of extreme heat days for Arkansas will have doubled in a little over a century from 1950.

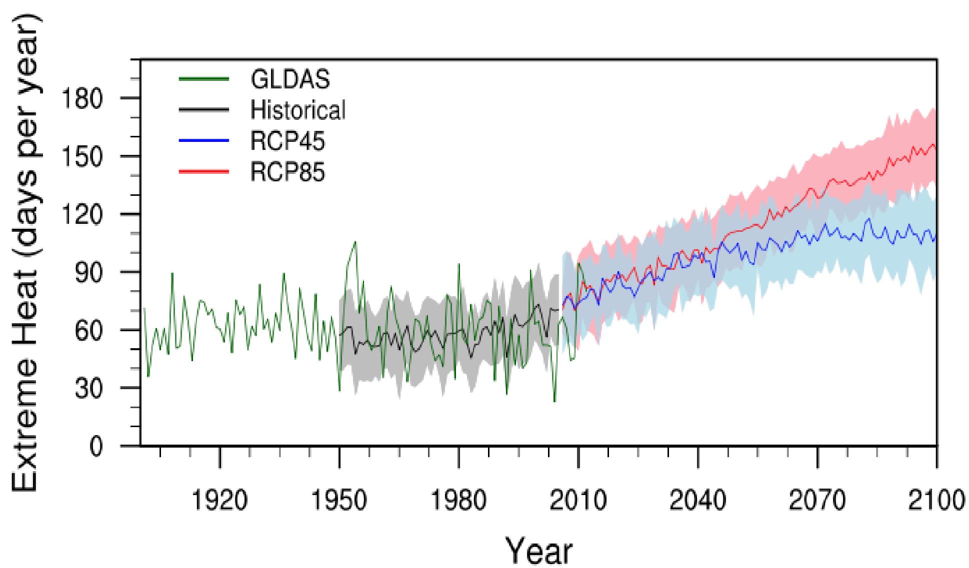

Figure 18. The projected extreme heat days within Arkansas, the shading denotes 1 standard deviation of the models

Taking the knowledge that we gained from the extreme heat forecasts, we turned to the opposite of extreme cold, a daily minimum temperature of -17.8 C or lower. Again, we used historical and GLDAS data while modeling with the IPCC's RCP4.5 and RCP8.5 projections.

The projected days of extreme cold basically disappear in the future within Arkansas as shown below in Figure 19.

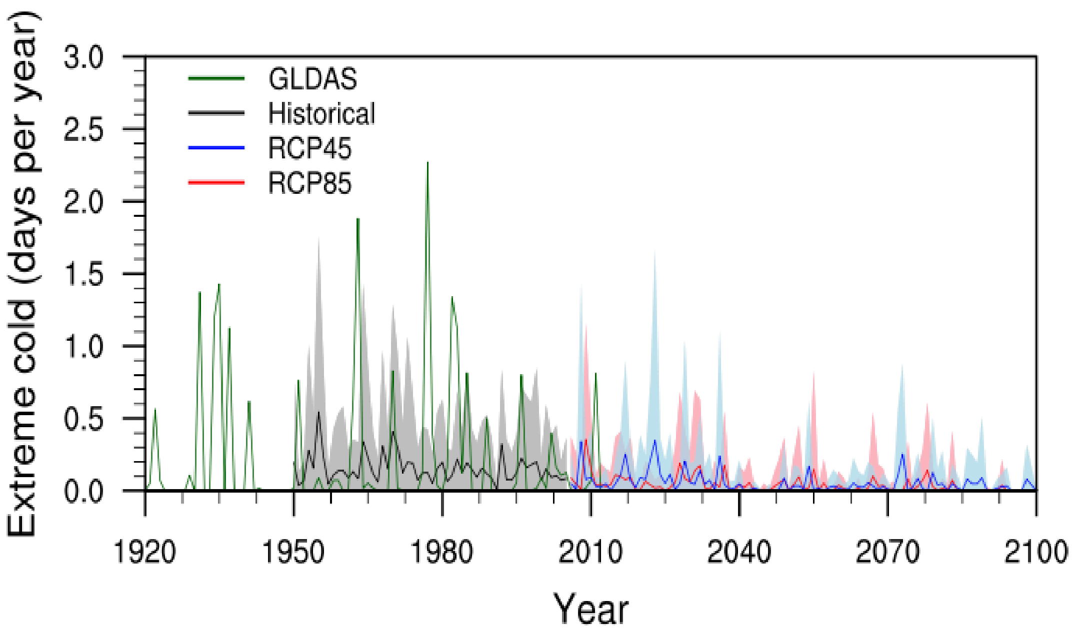

Figure 19. The projected extreme cold days within Arkansas, the shading denotes 1 standard deviation of the models

Precipitation, while being a basic necessity for life, can quickly turn into hazard depending on the amount falling as well as when it falls, after an extended drought for example. If Arkansas maintains a roughly average amount of rain annually while being mixed with more extreme heat days as we've seen projected above than the amount of rainfall days, then it will most likely be limited in scope. This means when Arkansas does receive rain, it will receive it in abundance. We approached this idea of extreme precipitation, a daily precipitation with at least 50.8 mm, and modeled it into the future again using the IPCC RCP4.5 and RCP8.5 projections; our results are shown below in Figure 19. Comparing to the mean temperature, precipitation, PDSI and temperature-based extremes (Figures 14-18), the models did a poor job in simulating the number of extreme precipitations. This is because the models are usually better at simulating the mean climate variables than the extreme events. Additionally, the extreme precipitation (e.g., 2in/day) usually affected local regions. The models, however, have a course resolution (e.g., more than 100 km), which cannot simulate the local extremes. Despite this limitation, the modeled precipitation extremes showed a slowly increasing trend during 1950-2005, which is consistent with the observations (Figure 20). The extreme precipitation is projected to further increase in the future, especially under the RCP8.5 scenario.

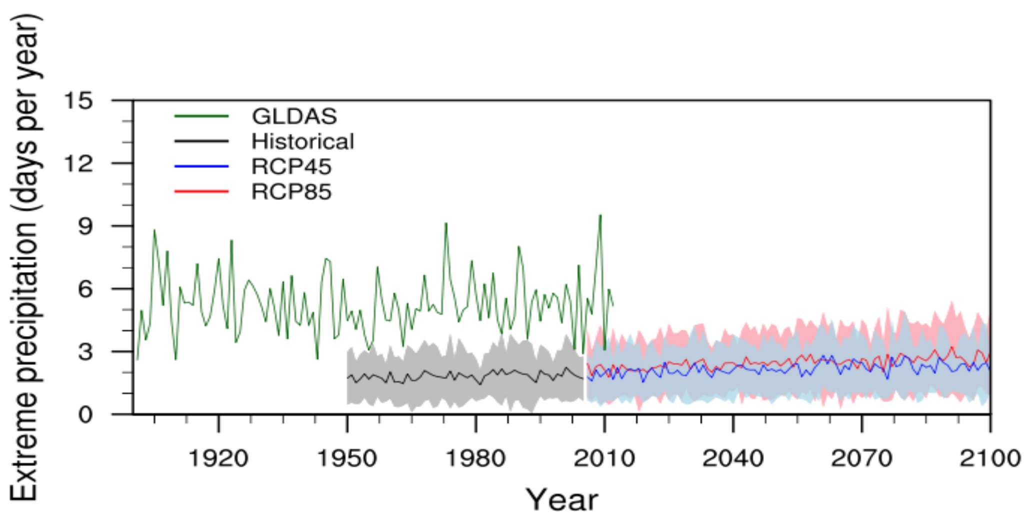

Figure 20. The projected extreme precipitation days within Arkansas, the shading denotes 1 standard deviation of the models

5. Discussion

This study investigated a set of corresponding historical, environmental factors associated with the climate in Arkansas. Figures were created to identify historical trends and look into the question of whether or not Arkansas's climate is changing. Arkansas appears to be following the global trend of climate change through a route containing more extreme precipitation and warmer temperatures. While there are several other metrics that can be explored from this data, the key takeaway for us was that Arkansas does not appear to be immune to climate change.

These results led us to wonder about certain regions within Arkansas as well as climate change policies within the state. While a longer warm season and a weaker winter might sound appealing at first due to the possibility of additional harvests, there are issues associated with both of these that needs to mitigated against should Arkansas wish to continue with life as normal as it can be, such as pest migration, new invasive species, or extinction of local species (e.g., Leopard Darter), etc.

5.1 Links between climate change and weather extremes

Studies have shown multiple impacts to a region due to a warmer warm season e.g., increased fir seedling mortality, potential decrease in rice production, or a variation in hydrologic response to a warming season (Shen et al., 2014; Yu et al., 2014; Christiansen et al., 2011). Additionally, a warmer winter can lead towards an incoming migration of invasive species which can wreak havoc upon an environment through biodiversity loss and impacts upon food security (Bebber et al., 2013; Butchart et al., 2010). Arkansas should take note of these oncoming forces and look into measures that can be used to ease these burdens. While all concerns associated with climate change can realistically not be prevented, others however can work towards being addressed through current projects and government agencies. The United States Fish and Wildlife Service (USFWS) is an example of one agency that could focus on preserving endangered species against climate change. While their efforts of restoring endangered species is admirable, they are handicapped with a limited budget for such an undertaking. Additionally the USFWS has no standard federal climate change policy to work from. With the proper foundation through legislature in place, Arkansas can seemingly stay potentially one step ahead of several needs in the coming battle for climate change policies.

The forecasts from the IPCC (IPCC 2007; IPCC 2012; IPCC 2014) range in severity of climate related changes from region to region, and, judging from our research, it appears Arkansas will also be affected from climate change. It would appear that Arkansas is continuing along the roads of surrounding areas in that it will also have a warming uptick, e.g. in diurnal temperatures, less frost days, etc. However, where the exact boundary is to where these upticks start to scale down appears to be a moving target currently.

5.2 Implications of results

Plants and animals respond drastically differently to temperature fluctuation. These potential responses depend greatly on environmental triggers which are largely influenced by temperatures and drought (Botterill & Hayes, 2012). Drought is the typical thought when addressing water shortage for understandable reasons. When water becomes limiting, plant water uptake and plant transpiration is reduced (Bartholomeus et al., 2011). The animal kingdom is also forced to respond to limiting water by delaying migration, avoiding cyanobacteria blooms, and producing less offspring (Tottrup et al., 2012; Brasil et al., 2016; Currinder et al., 2014).

Water should always be paramount upon the mind of all species, and this holds quite true during extreme weather events or natural disasters. However, drinking water is what is often thought of when associating water with extreme weather. Two groups that are often overlooked which are in dire need of water during these events are that of endangered species and fisheries. While doing this research it was extremely difficult, if not impossible, to find any related studies, research, peer-reviewed articles, etc. associated with endangered species and fisheries during an extreme weather event. Understandably, any species will focus on its own survival first – however, oftentimes humans are the shepherds that must bare this responsibility or these endangered creatures could simply vanish. With this being said, we should look into this topic in greater detail as time is not working in favor of endangered species.

6. Conclusion

The significance of this research should not be overlooked because it demonstrates what is expected: Arkansas is not immune to climate change. Instead this research should be used to help current policy makers, farmers looking years ahead at potential crops, or start to show the climatic trends that future generations of research can be built upon. This research only further validates what the scientific community e.g., NASA, NOAA, IPCC, USFWS, etc., and the planet is currently telling us: it’s getting warmer and more extreme weather is on the horizon.

While this study addressed climate change and some implications from it specifically to Arkansas, there are simply too many issues associated with climate change to be addressed within this research. Furthermore, the variability of climate change impacts throughout Arkansas might vary from region to region inside the state borders. Future research should focus on an in-depth analysis of a select region or multiple regions, as it could potentially solve this limiting factor to this research.

If there is a positive takeaway from this research it is a warning. This warning hopefully will not fall upon deaf ears and instead be used as a wakeup call that Arkansas needs to act upon before it becomes too late. Yes, Arkansas is warming and showing an unwelcoming growth towards extreme weather events alongside drought, and it appears to be continuing down this path. We should remember that there will hopefully be generations of humans to come and we should feel an obligation to make this planet, and Arkansas, as amazing as it possibly can be. This research shows that we need to act and the sooner the better. Knowing what we know, if roles were reversed, we would ask this of our grandparents. For, if we cannot fix this now, it should not be we who are to condemn the unborn.

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Impacts of Climate Change upon Endangered Species in Arkansas: Case Study for Leopard Darter

Abstract

Climate is a powerful influence upon all species throughout the world, and its impacts on endangered species are only magnified more so. Already in limited numbers for various reasons, endangered species must overcome the same changes from climate change as other species, but in a handicapped manner. Within this research we examine the links between climate change, e.g. changes in temperature, precipitation, and natural disasters, as well as its potential impacts upon endangered species in Arkansas. Specifically, within this research we analyze these climatic variables and relate them to the Leopard Darter, *percina pantherina.* These results show that the changes in annual temperature and precipitation should be tolerable for this species in the immediate future – however, the increase in natural disasters, rising temperature, and higher chances for extreme weather events could cause severe issues long term. Overall, the outlook for endangered species in Arkansas does not improve with climate change despite the typical associations of temperature and precipitation staying close to the local averages.

Key words: ***Climate change, drought, Leopard Darter, drought, extremes***

1. Introduction

The United States recently had its 20th consecutive year where the annual average temperature exceeded the average, and 2016 was the hottest year in 122 years; furthermore, 2017 was closely followed as the third hottest year, behind 2016 and 2015 (NOAA, 2017; NOAA, 2018). To compound the climbing temperature average is the realization that natural disasters are on the rise as well within and throughout the United States (IPCC, 2007). Despite the possibility of overall weather events either decreasing or staying roughly the same, there is the realization that the intensity and frequency of extreme weather events will in actuality increase due to climate change (Smith & Katz, 2017; EOS, 2018). These incoming realities create additional stresses upon all creatures and carry potentially devastation to endangered species despite having various protected areas and policies in place.

Climate change impacts magnify the risks to all creatures through fluctuations in streamflow, precipitation, pH levels, average temperature, etc. (IPCC, 2013; Carpenter et al., 2008; Thomas et al., 2004). These associated risks carry a greater challenge to the health of endangered species primarily due to: 1) limited available land (Ando et al., 1998; Kerr & Deguise, 2004), 2) limited numbers and breeding populations (Land, 1988; Synder et al., 1996), and 3) mistimed or new incoming predator migration (Robinson et al., 2009). A prime example of these risks can be shown with elevated temperatures in water sources due to heatwaves or typical water pools used by fish to escape environmental hazards through migration thereby facing more abiotic factors in part due to a drought (AghaKouchak, 2015; Matthews & Zimmerman, 1990; McGowan et al., 2017; Tramer, 1977). Furthermore, when a drought effects streams or rivers and causes the water to run dry oftentimes endangered fish do not have an escape route. Also, a healthy fish species population could withstand the loss of a single habitat and move on as a whole whereas this habitat loss to an endangered species could spell its doom with little to no other places available. Should a fish, solitary or numbered, be able to escape these environmental hazards to either new water sources, depths, or habitats there remains even more additional risks which are growing in part due to climate change. With human expansion and water control i.e. building dams, reservoirs, irrigation projects, etc. there comes a whole new set of obstacles to conquer. To be brief, an example of this could be that a previous cool water retreat might now be completely gone or instead harbor predator species.

To complicate measures even more is the fact that not all of the consequences associated with climate change carry a negative impact, and each region and species will face different changes (IPCC, 2007). A longer summer might be positive for some species due to more incoming food sources or a longer breading window – however, this carries with it the heightened risks of having cyanobacteria blooms, droughts, changes in migration patterns, potential new predators, etc. This means that one generic approach to a region, state, or county may not work unilaterally when trying to protect a species. Also, the surrounding areas and how they are impacted from these changes will need to be considered due to the potential of these changes to bring new issues upon this protected area.

When approaching a species with such a limited area, it is critical to consider every element in play. The endangered cave crayfish, *cambarus zophonastes*, is only known to exist within two counties in Arkansas and is an excellent example of climate change impact potential (USFWS, 2017). Should a natural disaster such as a drought, flood, or heatwave hit this area implications could be direr upon this already endangered species. The potential solutions seem straightforward enough – create a customizable recovery plan for each species in the United States and adapt accordingly for each species. Unfortunately, there are over 2,000 threatened or endangered species in the United States, and this number is growing (Jacobson, 2013). Also, the current total of species being delisted due to a recovery in a sustainable number is a mere 56 of over 2,000 (Jacobson, 2013). This means that the current plans we have are not appearing to be working at a high success rate when compared against a full recovery. Additionally, the time and resources needed to create, update, monitor, and regulate a current or new recovery plan simply are not available to the United States Fish and Wildlife Service (USFWS) at the present rate.

For this study the endangered Leopard Darter, *percina pantherina*, was chosen. This is due to: 1) having a critically low genetic effective population (AGFC, 2015), 2) being at a heightened risk of extinction due to temperature changes (AGFC, 2015), 3) having a relatively modern recovery plan, and 4) access to available and recent data in regards to the species. Beforehand, this endangered species could migrate or escape to lower water levels within a cooler thermal refuge – however, now in its limited area of six counties in Arkansas and three isolated populations in the Little River watershed in Oklahoma these options are not always available (ODWC, 2017). Because of its limited refuge, the Leopard Darter is at a heightened risk of extinction when compared against another endangered species. Therefore, it is necessary to evaluate the potentially changing climate in the Leopard Darter regions alongside its recovery plan.

2. Material and methods

2.1 Study region

The overarching study areas within this work consisted of six counties (Polk, Sevier, Howard, Pike, Hempstead, and Miller counties) in southwestern Arkansas (Figure 1). The primary study site within this work on the Leopard Darter was completed in Howard county Arkansas, specifically within the Cossatot River and Cow Creek areas. The primary reason for this area being chosen is because research or work with endangered species takes a noticeable amount of time to setup, and, unfortunately, this was not available at the time of this writing. Additionally, there are two counties listed as critical for the Leopard Darter, as they are house some of the few remaining locations left where this creature survives. This study did not dive into the differences between critical habitat and normal lands due to the fact that those distinctions are primarily a difference in public policy. The policies about endangered species will be evaluated in the following chapter.

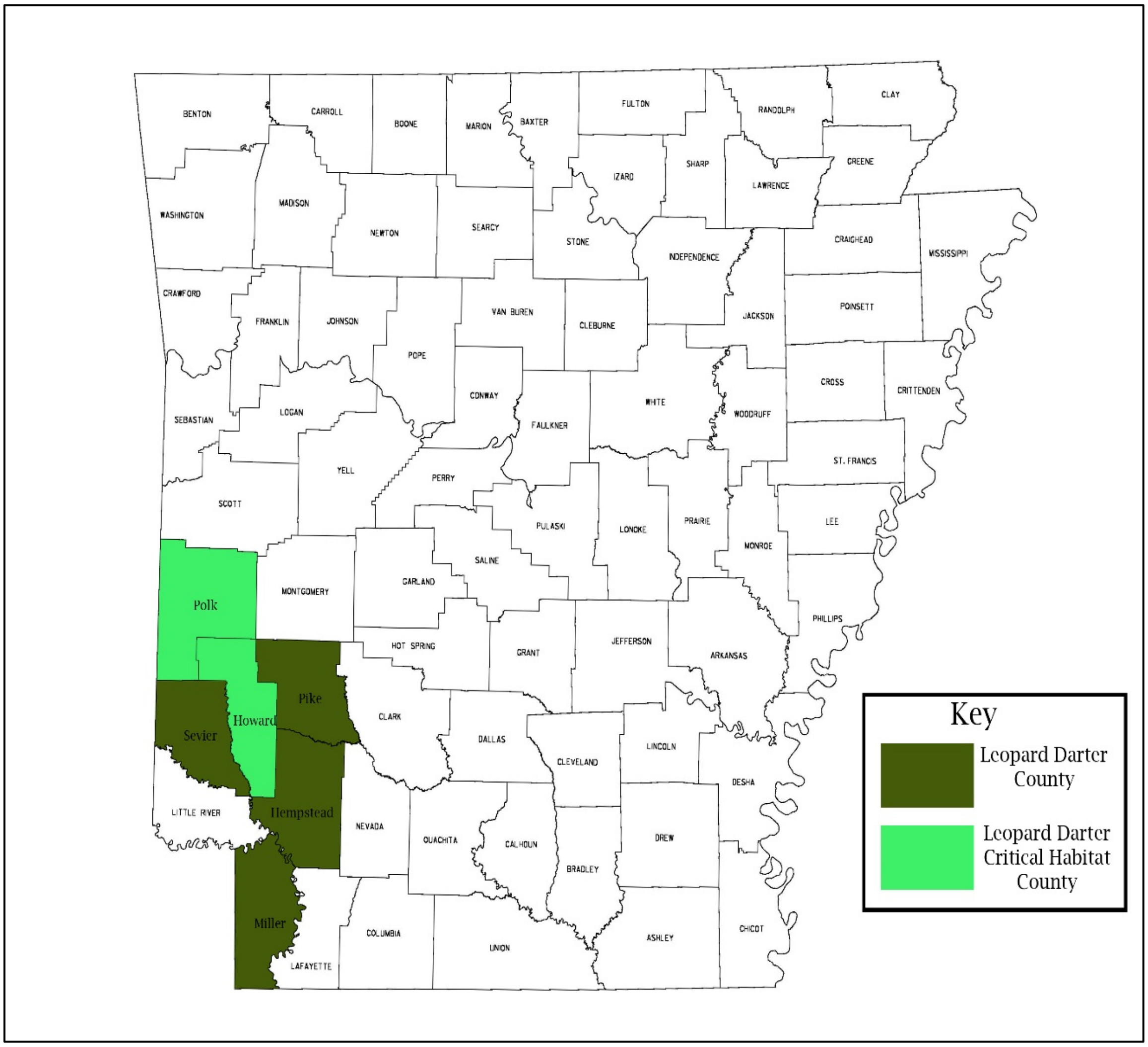

Figure 1. The study area in Southwest Arkansas

2.2 Climate data and extreme indices

The monthly mean daily maximum, minimum, and mean temperature alongside the monthly total precipitation (ppt) from the six county regions from 1895 to 2015 were obtained from the PRISM climate group (PRISM Climate Group, 2017). To examine the changes in climate extremes, the daily temperature and precipitation in the six counties during 1981-2015 were also obtained from PRISM. All climatic data was screened for potential outliers to confirm the normality of data distribution.

The annual mean temperature and annual total precipitation in individual counties were calculated to examine the long-term climate changes in the six counties. The next variables we analyzed were the number of days with extreme (ppt>100mm/day) and zero rainfall events using the daily precipitation data within this region. These two indexes were analyzed because temperature, zero precipitation, or large rainfall events can harm aquatic life (Marino et al., 2017).

Besides the precipitation indices, maximum daily water temperatures are quite a limiting factor for fish in rivers (Cassie et al., 2001). The Leopard Darter is quite susceptible to temperature fluctuation and needs a relatively moderate water temperature for optimal survival. Several similar minnow species within these shallow streams are acclimated to water temperatures of 25^{o}C and can have a water thermal tolerance up to 34.5^{o}C with the nearby Great Plains minnows being able to tolerate temperatures up to 38.4^{o}C (Matthews & Zimmerman, 1990). Five species in the nearby genus of *Etheostoma* can withstand upper temperatures of 38.4^{o}C before death due to a loss of equilibrium takes place (Beitinger & Bennett, 2000). Currently, the thermal tolerance and intolerances of the Leopard Darter in the genus *Percina* is unknown. However, the similarities of the nearby minnows and the Great Plains minnow allow us to set a target for a critical temperature the Leopard Darter should avoid if possible (38^{o}C). The long-term daily water temperature data in the study regions is not available, which make it impossible to monitor the changes of this extreme water temperature seamlessly.

Daily water temperature, however, can be estimated from daily air temperature. A previous study (Mohseni et al., 1998) suggested that the relationship between air temperature and stream temperature is non-linear at the high and low temperatures for multiple reasons, with evaporation being a major culprit. There are several statistical models using either non-linear, linear, regression, or non-parametric methods to obtain the exact relationship between air and water temperature (Letcher et al., 2016). However, depending upon the river type and time scale, it is possible to quantify the relationship between the air to water temperature using linear or logistic functions (Gu et al., 2014; Mohseni & Stefan, 1999; Naresh & Rehana, 2017). The time lag ranges from only a few hours to days depending on the depths of the water body. For a steam less than two ft. deep, the lag time of this reflection in change is usually in the order of hours (Preud'homme & Heinz, 1992). The basic important take away from these studies is that the shallower the water, the quicker it changes to reflect air temperature.

Much of the habitat of the Leopard Darter is within streams which are quite shallow, suggesting that the lag time between water temperature and air temperature should be within hours. To further examine the links between water temperature and air temperature in the study region, we plotted the measured air and water temperatures in our study region that are currently available (Figure 2).

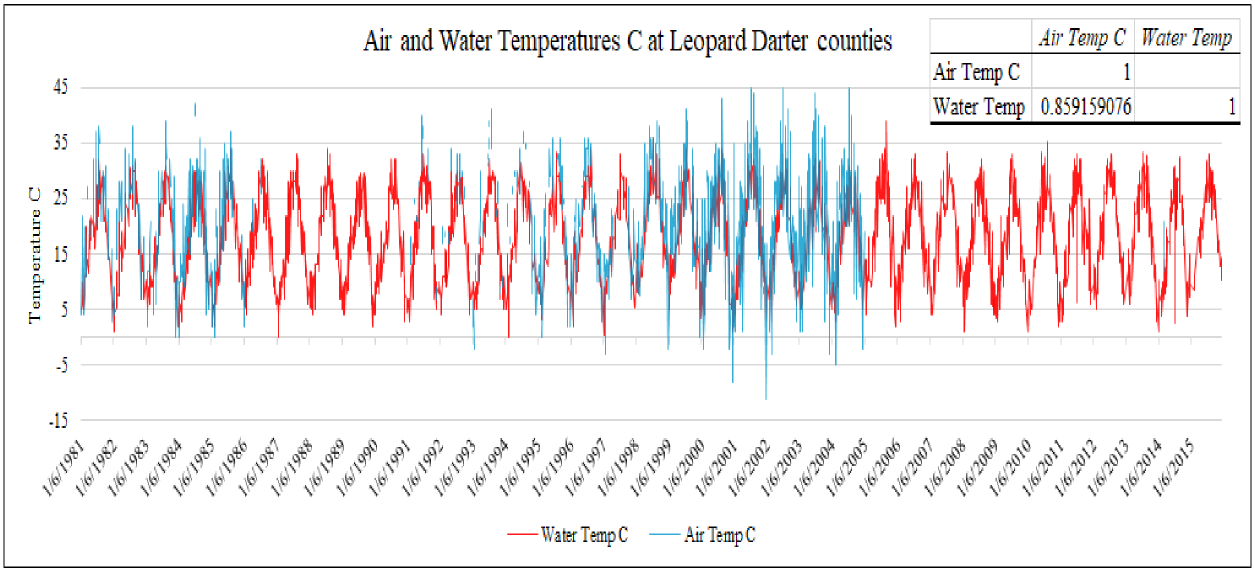

Figure 2. Historical temperature correlation for Leopard Darter counties.

This mixture of data was gathered from the USGS and USFWS. The irregularity and lack of consistency was due to a variety of issues 1) new sensors are constantly being installed, 2) these sensors usually only have a maximum lifespan of 1-2 years, and 3) some of these sensors require manual recordings of data without digital backups or reporting. Despite these setbacks in our study region, it still showed that the variations of water and air temperature closely match each other. The correlation between the two timeservers is 0.859. The strong relationship between water and air temperature in our study region (Figure 1) and the short time lag (e.g., a few hours) between the two temperatures suggesting that it should be good enough to use the extreme air temperature to evaluate the impact of extreme water temperature on Leopard Darter. Therefore, the annual number of days with daily maximum air temperature hotter than 38°C are analyzed. More hot days suggest higher risks of the hot water temperature, and hence heat stress on Leopard Darter.

2.3 Natural disasters in the study region

Natural disaster data was obtained from FEMA dating back to the 1950s for each of the Leopard Darter counties. This data was then filtered, removing all non-climatic natural disasters e.g. earthquakes. Also, it should be noted that many various, minor climatic events such as cold weather snaps or heatwaves were not included in this analysis. This is because they did not cause enough monetary damage to be declared a disaster by FEMA. However, these minor climatic events can still wreak havoc upon the natural environment.

3. Results

3.1 Changes in annual mean temperature and total precipitation

Our calculations of precipitation and mean temperature within this region showed fluctuations – however, there were no dramatic trend changes as shown in Figures 3-6. This was expected when taking into account the overarching reports of the region from various IPCC reports (IPCC, 2012; IPCC, 2013; NCA, 2014). However, Arkansas as a whole is moving in a warmer direction as shown in the previous chapter, this area appears to be a pocket that has not followed along so far. There have been a few years which have shown spikes in temperature or rainfall due to extreme weather events, quite similar when compared with the state as a whole. However, the precipitation and temperature climate has stayed roughly the same over the past century. This idea of these climate metrics staying eerily similar is a key reason why we decided to look back at the previous few decades to see if this was a constant factor; it appears that this is not always the case. That being said, should more droughts and extreme weather events continue, then its impacts upon Leopard Darter within this area could be affected.

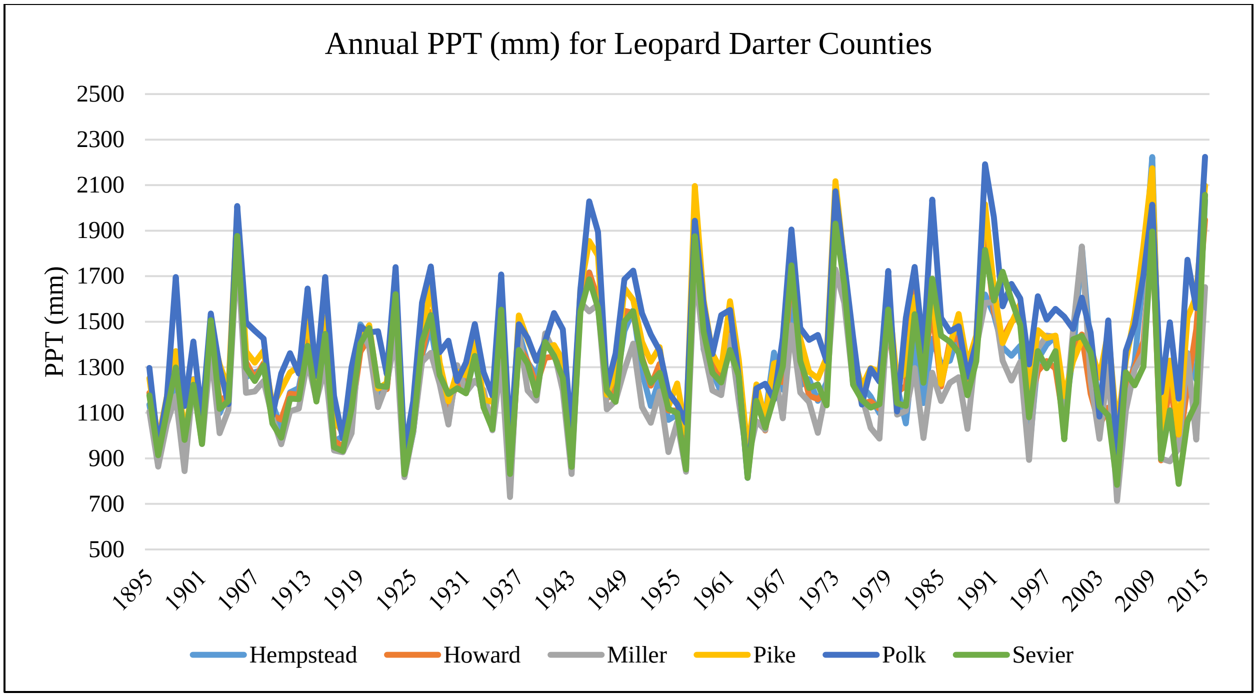

Figure 3. Annual precipitation (PPT) in individual Leopard Darter counties during 1895-2016.

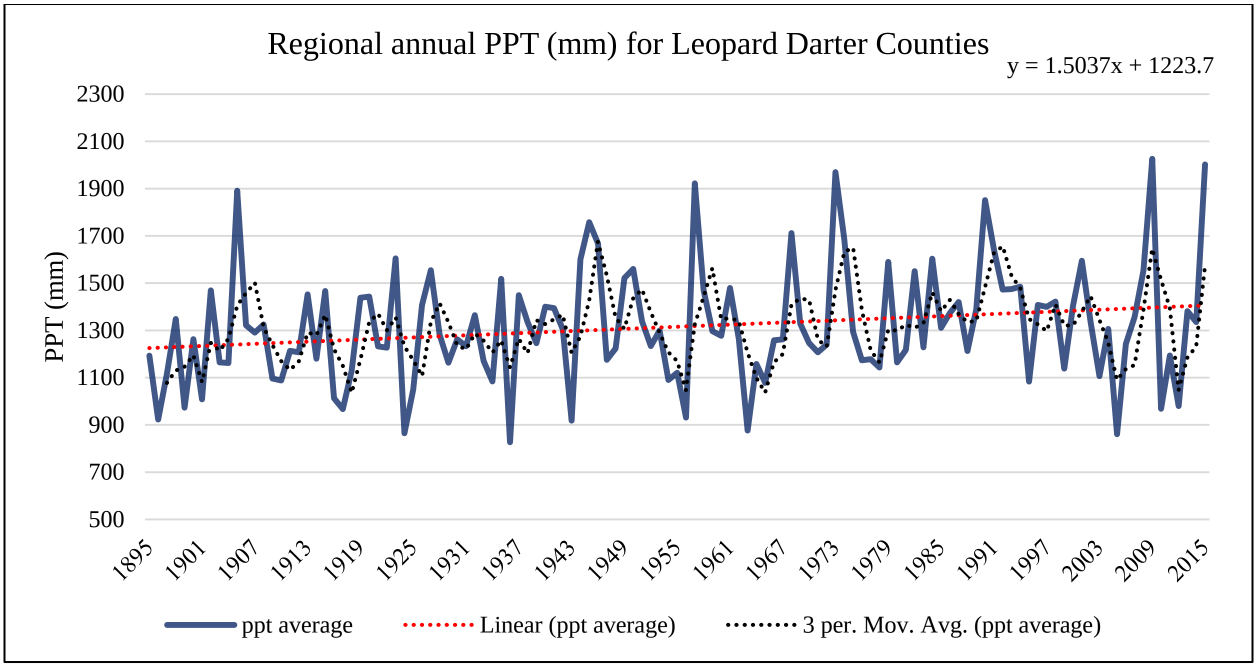

Figure 4. Temporal variations of regional averaged PPT in the Leopard Darter region during 1895-2016.

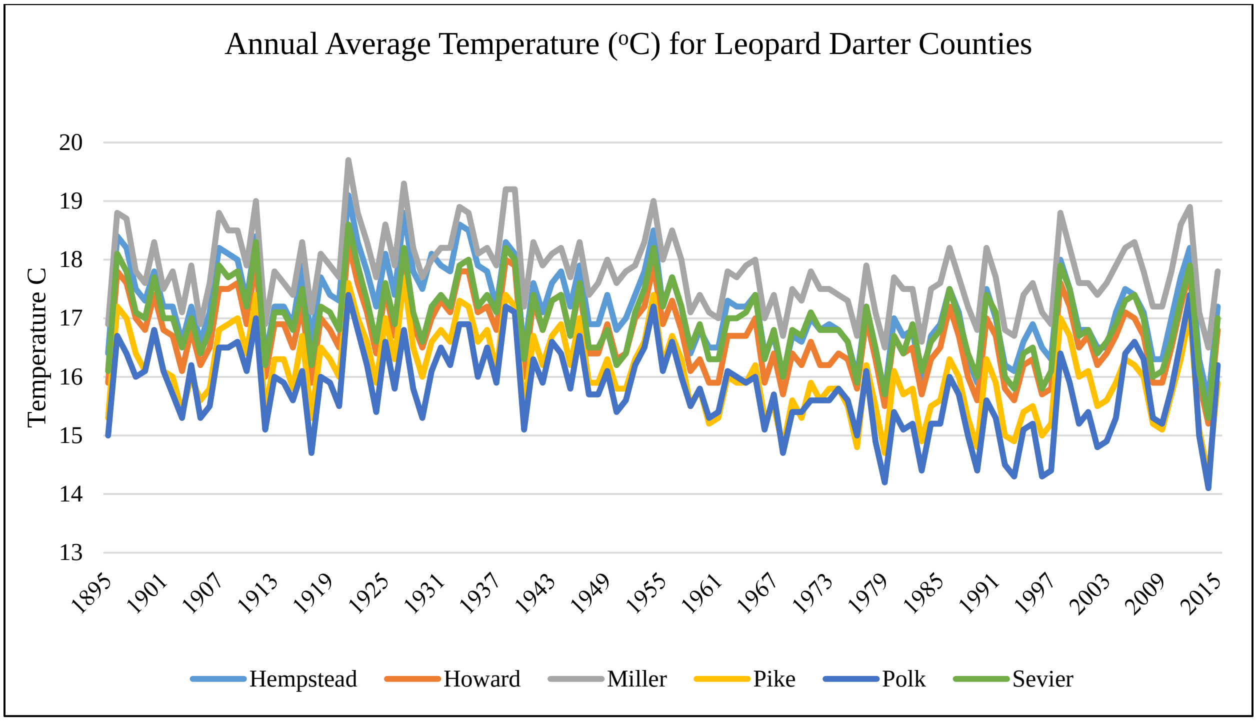

Figure 5. Temporal variations of annual temperature °C in individual Leopard Darter counties during 1895-2016.

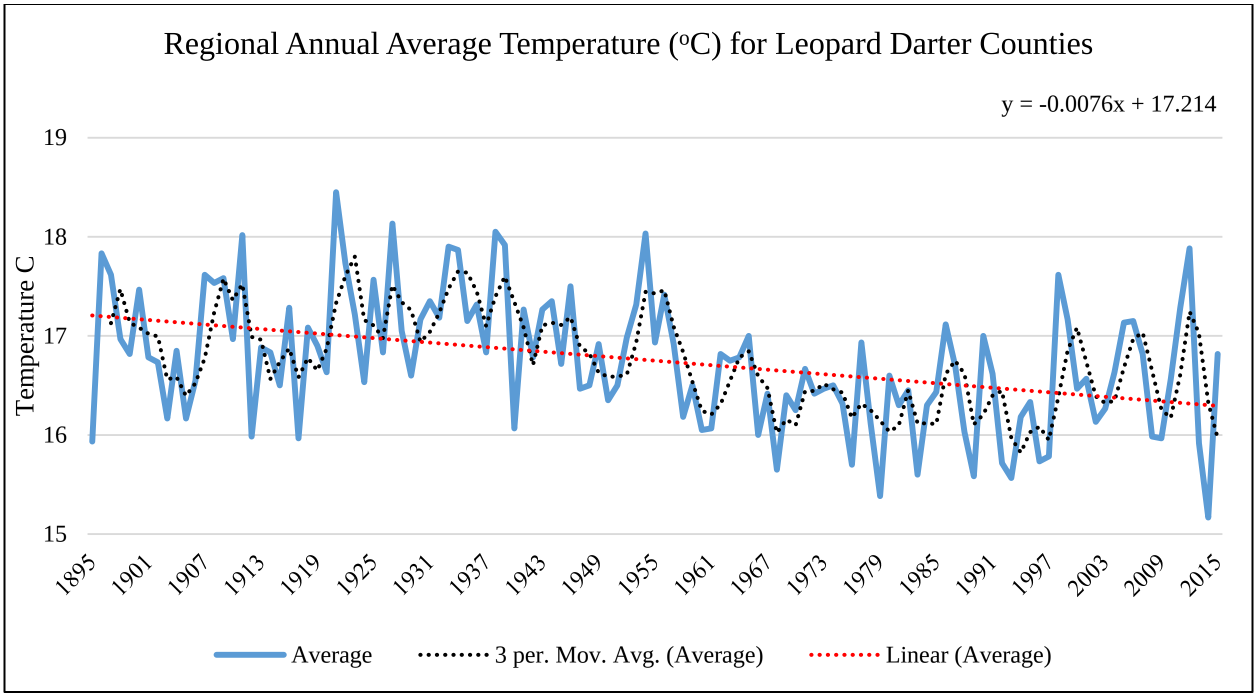

Figure 6. Temporal variations of annual temperature °C within the Leopard Darter region during 1895-2016.

In regards to air temperature, the trends in the past century versus those of the previous 35 years (1981-2015) can reflect quite different results (Figures 7). Over the past few decades the trend is steadily going up starting from 16.3°C in the 1980s to 16.6°C during the 2010s. Also, the rate of increase per decade has been going up constantly with no decadal average being lower than any of the decades before it during this span. On the flip side of this is how Arkansas as a state during this same time span is actually rising, though at a much slower and inconsistent rate (Figure 8); there has been a 0.23°C temperature rise for Arkansas versus 0.31°C in the region of the Leopard Darter. If this rising trend continues as the past 35 years have shown, then the potential environmental impacts listed earlier upon the Leopard Darter will only grow in correspondence.

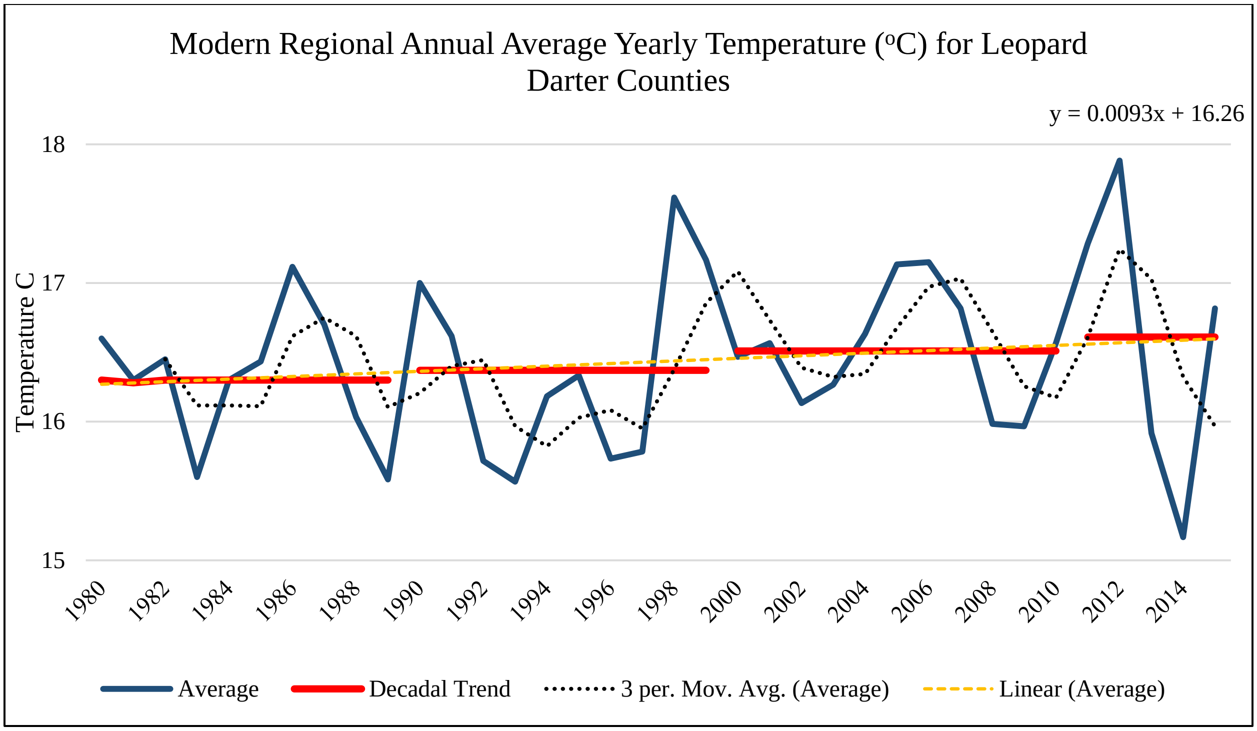

Figure 7. Temporal variations of annual temperature ºC within the Leopard Darter region during 1981-2016.

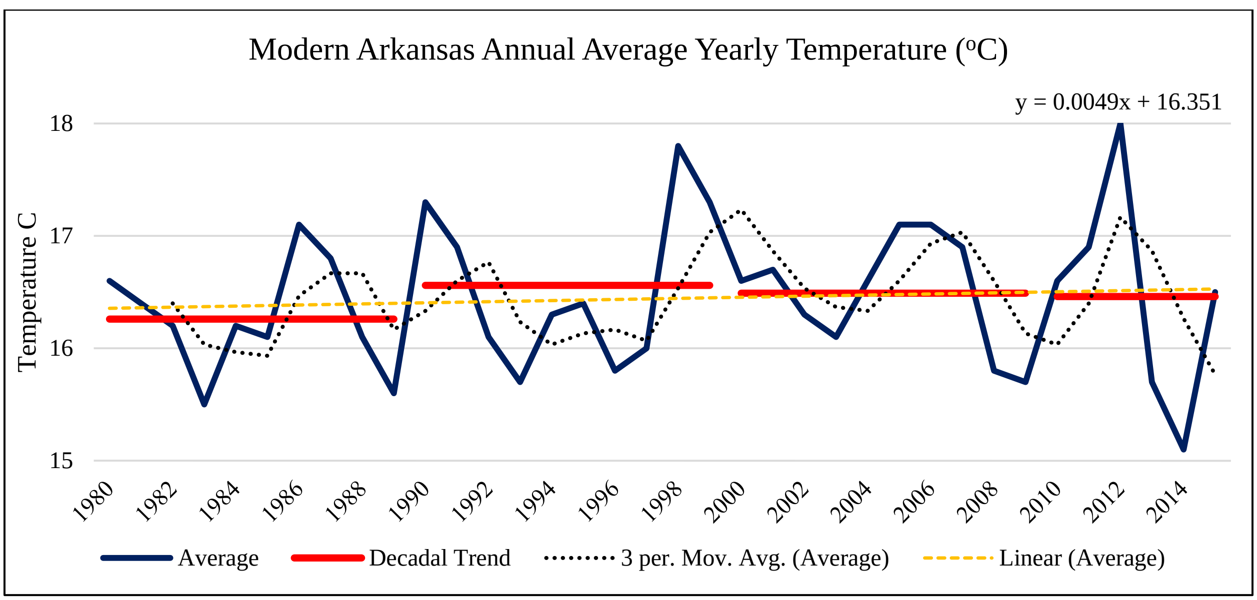

Figure 8. Modern temporal variations of annual temperature ºC for the state of Arkansas during 1981-2016

Precipitation has not been following the rising path of change in this region alongside temperature for recent years (Figure 9). When comparing this to Arkansas (Figure 10), it's the opposite. In fact, this region is starting to get less precipitation. Over the past few decades within the Leopard Darter region the trend has gradually been declining in precipitation to a total of -36mm compared to a 134.8mm rise for the state as a whole. A prime recipe for a drought is less precipitation and higher temperatures, which this region is striding towards.

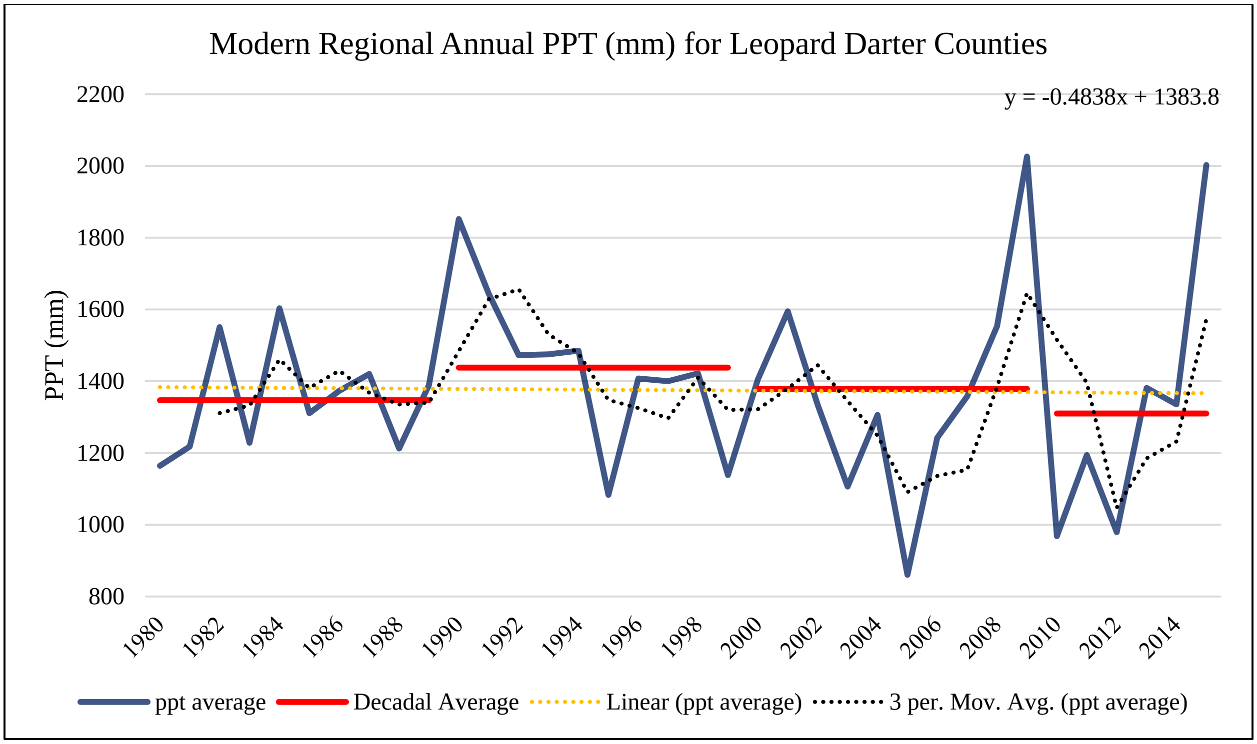

Figure 9. Annual precipitation variations within the Leopard Darter region during 1981-2016.

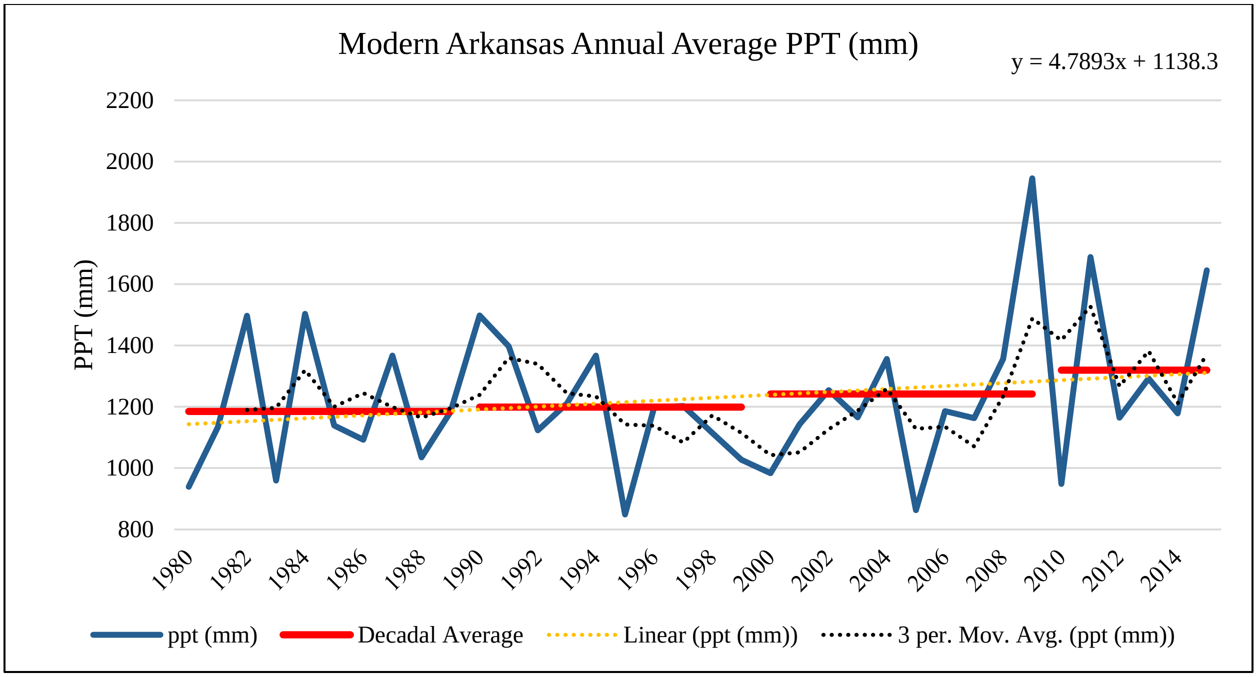

Figure 10. Annual precipitation variations within the Leopard Darter region during 1981-2016.

A key reason as to why these environmental factors are important in regards to the Leopard Darter is that when a massive drought hits, similar to the one in 2011 for Arkansas, this species is more susceptable to evironmental harms. Droughts often bring higher temperatures, a lowered water table, potential cyanobacteria blooms, and a variation from normal dissolved oxygen levels a drought which all can lead to large die-offs of the Leopard Darter population. Should these droughts potentially come more often due to shifting climatic conditions within the region, then the Leopard Darter recovery plans need to adapt beforehand.

3.2 Hot day changes in Leopard Darter counties

While Arkansas might appear to be relatively the same climatically compared over the past century, it is the extreme events that can wreack havoc upon most species. As mentioned earlier, 38^{o}C is the estimated the thermal tolerance of the Leopard Darter. We looked into how often these days were hitting that limit within the region.

There was a noticeable spike in events where the air temperatures rose to or above 38°C as shown below in Figure 11. Also, when looking back at 2011 and 2012, there was a large spike in entries above 38°C, and it should be noted that this was during the drought in this region. Assuming the previous trends of warming temperature and less rain continues within this region, then should another drought hit it is likely that additional extreme heat days could occur. Should climatic model projections hold true as they appear currently, then it seems fairly probable that this trend of days above 38°C will continue upwards, creating more potential havoc upon the Leopard Darter population.

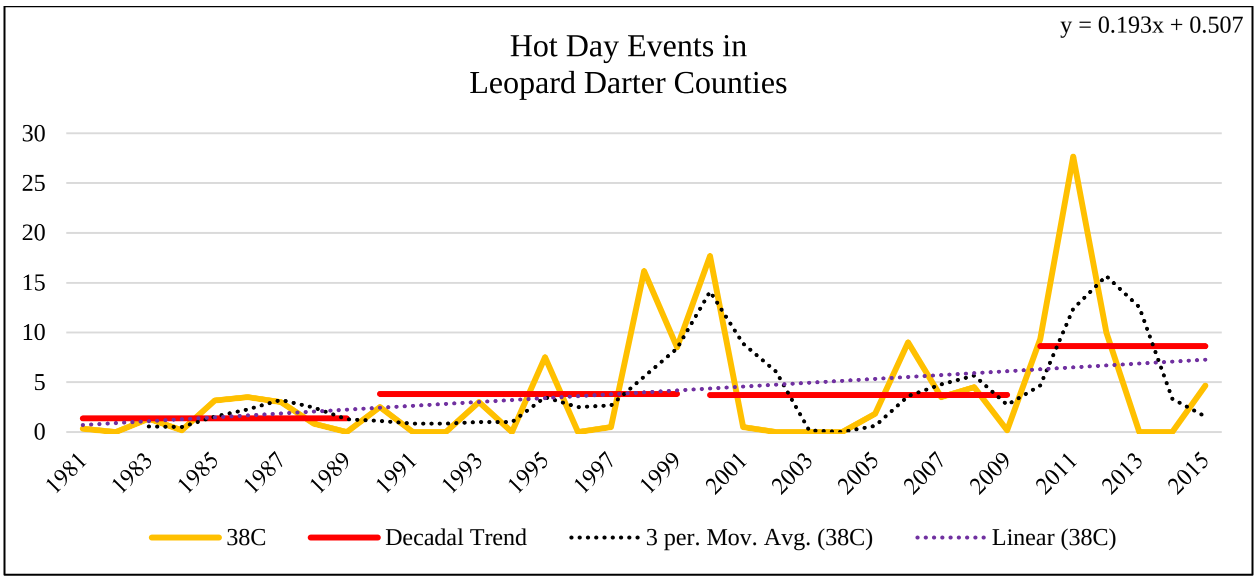

Figure 11. Shows the averages of the trend of warmer days in Leopard Darter counties.

Taking this regional view we decided to look at each county within this region to see if there were any noticeable trends or outliers (Figure 12). As we expected, the trends were relatively balanced with each other. However, it appeared that Polk County seemed to be a bit more immune to these 38°C events. These less frequent events could largely be due to a variety of reasons; 1) being higher in latitude, 2) averaging multiple hundreds of meters above the other counties, or 3) that Polk County has multiple rivers, Ouachita and Cossatot, running throughout the county instead of being reliant upon one river or lake.

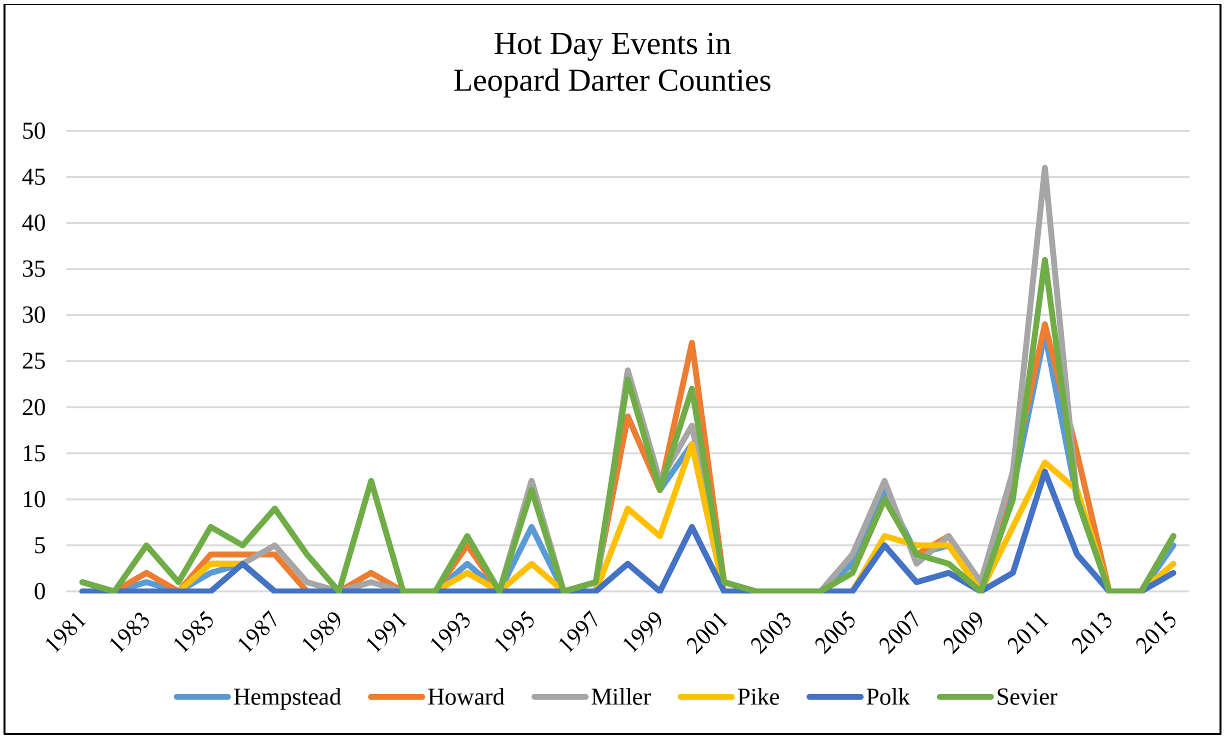

Figure 12. Shows warmer days over the past years in Leopard Darter counties.

Furthermore once looking at these historical records we decided to look directly to see if there was a relationship between these events and the gradual rising temperature within this region. Once we looked back at the lowering precipitation and rising temperatures, this rise in extreme heat events made sense.

3.3 Changes in extreme events

Taking this previous results over a changing climate we decided to dive into this a bit more. We focused on climatic events above 100mm (ppt), and 0mm (ppt) from 1981-2015 as shown below. These enabled us to view another way that this region was in fact starting to become effected by climate change.

When dealing with extreme rainfall events such as 100mm of precipitation there are several issues that tie into the health of the Leopard Darter. These rushing waters bring new predators, changing habitats, and pollutants into the already limited area that Leopard Darters call home. The trend in this region actually shows that these events are happening more frequently despite having less precipitation total in the region (Figure 13). Flooding can lead to habitat issues throughout the river despite potentially having less precipitation in one area than a nearby region due to many of these counties having the same rivers flowing through them. If a river floods upstream, then the flood will continue onwards essentially effecting multiple counties throughout the Leopard Darter region.

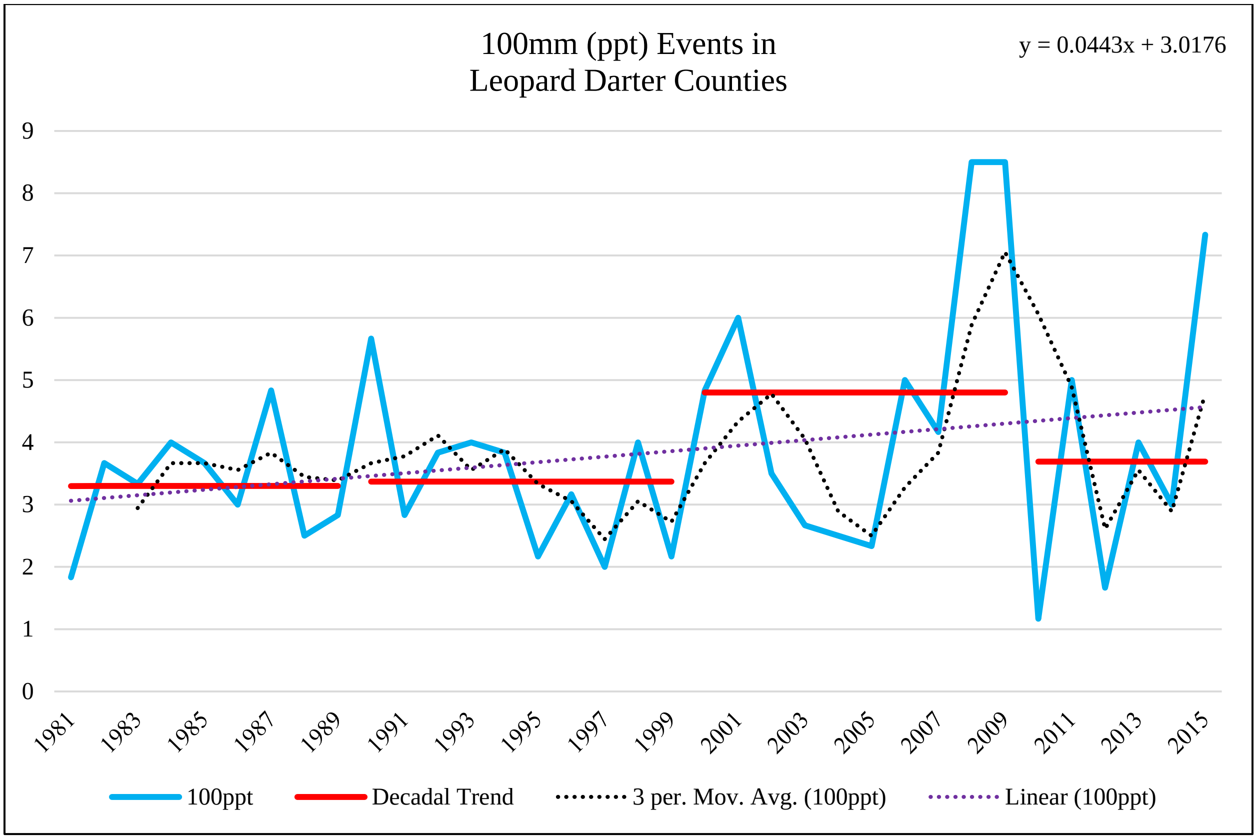

Figure 13. Shows the averages of the heavy precipitation events in Leopard Darter counties.

Taking this knowledge into account, we looked to see if one particular county was more or less susceptible to these events (Figure 14). While Miller County appeared to be affected a bit lower, potentially from having a lower latitude or having the lowest elevation, it was still far from immune from harm in regards to these extreme precipitation events.

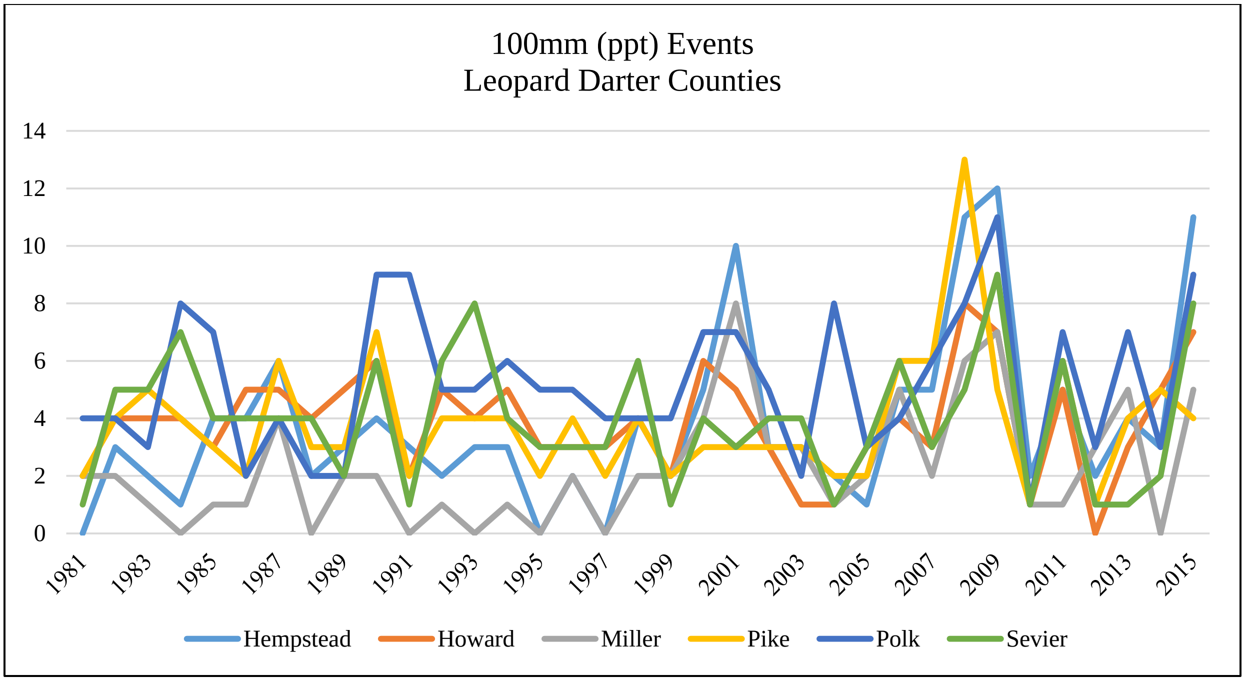

Figure 14. Shows heavy precipitation events over the past years in Leopard Darter counties.

On the flip side of these heavy precipitation events are the zero precipitation days. The simple reason for looking into this metric was that as a fish the Leopard Darter needs incoming water to survive. We started again by taking a regional approach (Figures 15) and then looked at each individual county (Figure 16) to see if there any interesting results. As it turns out, the rate of days without any precipitation is increasing. With both the annual and decadal averages trending towards more zero precipitation days, this further enhanced our thoughts of this area being more prone to a potential drought than previously expected.

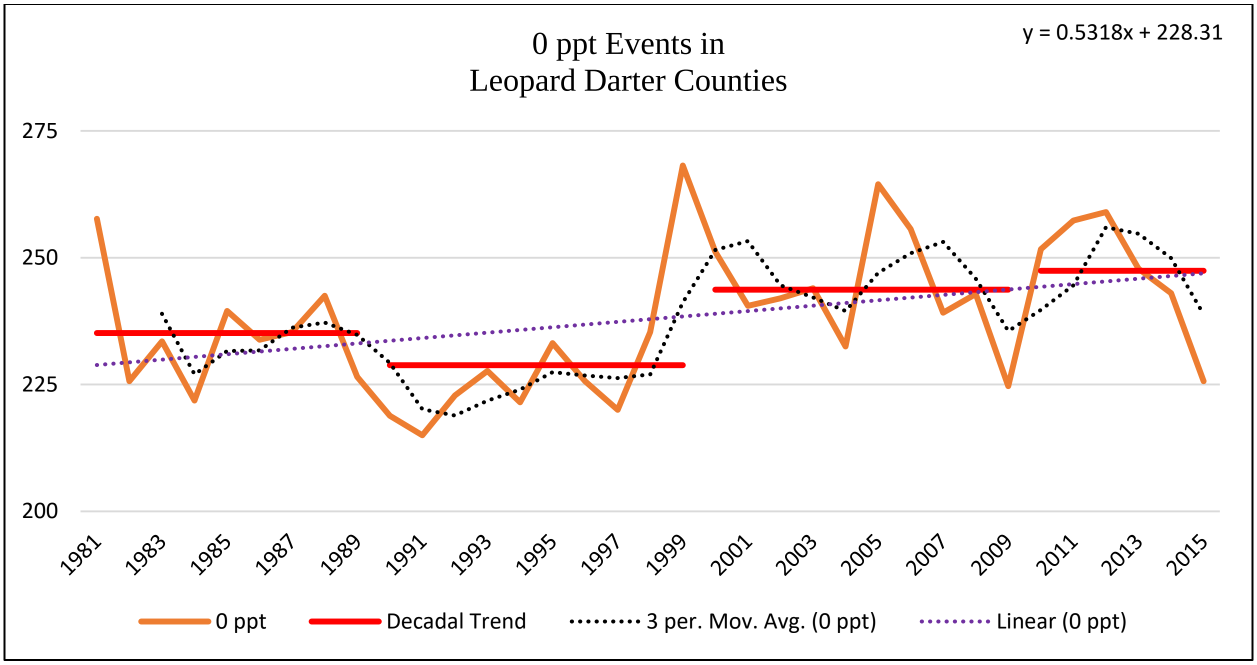

Figure 15. Shows the averages of the zero precipitation events in Leopard Darter counties.

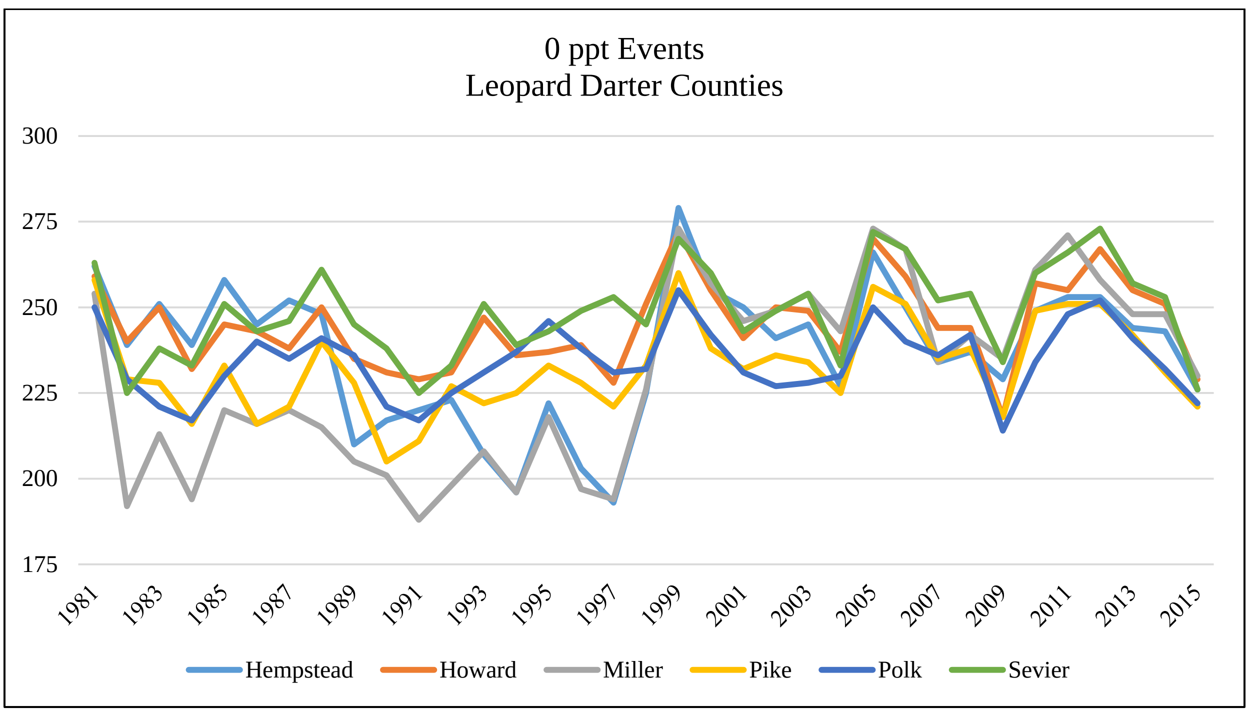

Figure 16. Shows zero precipitation events over the past years in Leopard Darter counties.

3.3 Changes in natural disasters

Despite the relative overall stability in temperature and precipitation over the past century, the amount of disasters within this region rose noticeably (Figure 17). FEMA data from this area roughly shows almost one natural disaster per year within these counties currently, since 2000. Comparatively, the norm just 30 years ago for natural disasters was roughly one every five years. While this might seem to be an alarming idea to some, it should be noted that this was also projected in multiple IPCC reports and seems to be coming to fruition at an escalated rate.

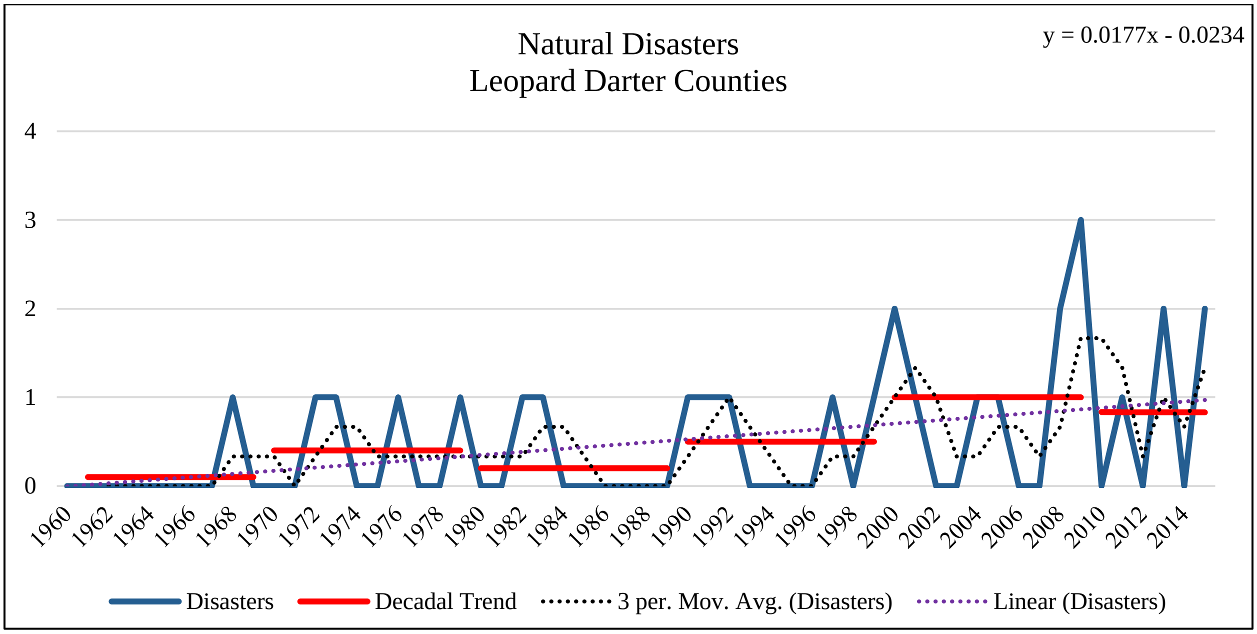

Figure 17. Shows the total number of natural disasters for Leopard Darter counties.

Despite heatwaves not being included in this FEMA disaster data, it does match with the IPCC projections to help explain this increase in natural disasters while not having a major climatic temperature shift. Oftentimes droughts and heat waves are not reported as natural disasters until the rain returns, despite droughts potentially being more costly than other natural disasters (EPA, 2018). These delays can also alter dates as to when drought disasters impact a given area, meaning that direct correlations between some drought related disasters are difficult to match with a precise timeline to extreme heat events.

As an increase of natural disasters recognized by FEMA within this area rise and the rate at which they are occurring is also rising, this entails another burden upon endangered species in this region. This assumption of a rising disaster probability goes with the general trend in the severity of natural disasters becoming stronger as predicted from the IPCC (IPCC, 2012; IPCC, 2013). Additionally, this falls hand in hand with an increase of hazardous events over the past few decades having been noted by major insurance companies (Munich, 2012) and international disaster databases (EM-DAT, 2011). Also, this increase in climate events within this region does not show an increase of non-climatic events such as earthquakes.

While not being counted as a disaster to FEMA this part of Arkansas is not immune from the cold days decreasing and the warm days and nights increasing. Heat waves have been shown to have an increase in frequency, and an increase in heavy precipitation events have also been detected in this region (IPCC, 2013; National Climate Assessment, 2017).

4. Discussion

As mentioned earlier, a great tool to mitigate incoming harm to an endangered species is a recovery plan. While there are hundreds of recovery plans throughout the U.S., there is no current model or baseline example for a standard that deals with climate change. Also, anything to do with climate change policy in the U.S. is a tricky subject to say the least (Kukkonen et al., 2017: USCSCEPW, 2016). There currently is no federal policy directly relating to climate change despite relatively high numbers of the U.S. population believing in the existence of climate change (Leiserowitz et al., 2009; Nisbet & Myers, 2007). Also, the links between any form of climate change policy and endangered species are quite thin (Wang et al., 2015). Should there be a linkage or further development into this topic, then the possibility to save more species would only rise.

Although our data seems to overlap with current climatic trends, it serves to amplify the validity of this research alongside previous work in this subject. The overall arching trend in this area is that the climatic factors, i.e. mean temperature and precipitation, have roughly stayed the same as a whole over the past century. However, when looking at changes over the recent years and decades, a changing trend starts to become noticeably visible in less precipitation and more extreme weather events. The lack of major increase or decrease in temperature is something that could be looked into in future detail when compared against other regional areas of similar natural structure, latitude, elevation, and layout.

While there is no exact forecast for multiple years in regards to climate, we can start to mitigate against these incoming potential extremes. One might expect the population of the Leopard Darter to start to reflect a decline from these points in the coming years. However, the data we have presently does not show an exact population of the species, and forecasting a population trend with this many potential factors poses a challenge and is not currently viable.

Should the Leopard Darter somehow survive these potential oncoming climate anomalies, this will most likely only mark the beginning of a struggle to stay alive. Why should future generations be hindered for the environmental situations that we are producing and have known about for decades? When dealing with an extinction rate such as we are due to the wide array of global issues, it only seems logical to have a contingency plan in place. A final suggestion to this research would be that testing needs to be done with this species to understand its exact thermal tolerance as well as updating the recovery plan associated with it to help mitigate these potentially more numerous hazards.

5. Conclusion

This study was carried out to explore the relationship between climate change and endangered species within Arkansas, as it focused primarily on the Leopard Darter. Currently, there is no direct immediate threat of climate change related issues hampering this species. However, should the severity of stronger extreme weather events due to climate change continue alongside rising temperatures, then these impacts will lead to serious issues for this species. This is due to the species' limited numbers and lack of a strong genetic effective population.

Analyzing this climatic data further within Leopard Darter counties enabled us to recognize that this region is gradually changing. Previous findings with climate change continue to show: 1) extremes weather events are rising, 2) temperatures are continuing to rise (NASA, 2017; NOAA, 2018), and 3) species are becoming extinct at a higher rate (Harley, 2011; Seney et al., 2013). These points and this research only further demonstrate that the Leopard Darter will most likely need more help to recover.

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The Gaping Void within U.S. Climate Policy: An Evaluation of Climate Change Policy and its Rippling Effects through Arkansas and the Endangered Species Act

Abstract

Numerous ideas and opinions have crossed the U.S. political realm in regards to climate change – virtually none of these however, have become adopted. When investigating climate change policy for addressing oncoming climate hazards we noticed there was a major knowledge gap in this field. We examined the various attempts, ideal paths, and viable routes to address climate change in the U.S. and found no real support to mitigate against the impacts of climate change. Initial results led us into the understanding that neither the Clean Air Act nor the Clean Water Act can be used to address climate change despite the basic principle of these two acts being created to improve health and the environment. Additionally after scouring current environmental laws and polices we discovered that the Endangered Species Act (ESA) of 1973 is one of the very few already established routes to address climate change policy. In Arkansas working through the ESA was the only accepted route we found to address climate change policy. Even this route is having to fight a gargantuan uphill battle despite having a seemingly limitless supply of peer-reviewed science to justify itself. The significance of this finding paints a relatively grim picture; however, that can hopefully be addressed in future environmental policies.

Key words: Climate change, climate policy, Endangered Species Act, Arkansas

1. Introduction

The forthcoming wave of climate change related hazards is already upon us (Mechler & Bouwer, 2014). The National Oceanic and Atmospheric Administration (NOAA) has shown that billion dollar disasters are happening across the U.S., as shown in Figure 1. These disasters demonstrated that all states within the U.S. are at risk despite their geographic location and mitigation practices. Furthermore, the rate at which these intense events are happening is also increasing, as shown below in Figure 2. It should be noted that these disasters range from wildfires, tornadoes, hurricanes, droughts, etc... This means that there is a variety to these disasters impacting the U.S. and should the U.S. wish to plan for this, then it will have to adapt to an increasing amount and potential strengthening of disasters if it wishes to continue life as usual. To complicate this notion further is that climate models have projected the continuation of the more intense and higher frequency disasters in the U.S. (Melillo et al., 2014). Finally, the increasing frequency and intensity of these disasters is likely linked to human induced climate change; this means the longer we continue life as usual, the more likely we are to increase these disasters in both rate and severity (Peterson et al., 2013; Smith & Katz, 2013).

When addressing the multiple avenues related to climate change disasters it becomes imperative to have a strong legal foothold to build climate change protection and adaption policies upon. Currently, this is far from the case in the U.S. and especially in Arkansas. While not located on a coastline, Arkansas is still susceptible to climate change through rising temperature, additional stress on electricity demand, heavy precipitation events, weaker winters, etc. (McCorkle et al., 2016; McFarland et al., 2015). As shown previously, the frequency of disasters is rising and Arkansas is far from removed of this. The goal of this study is to address these oncoming issues with a review of historical climate change policy in the United States, especially the state of Arkansas, identify the gaps within climate change policy, and outline procedures on how to address these issues.

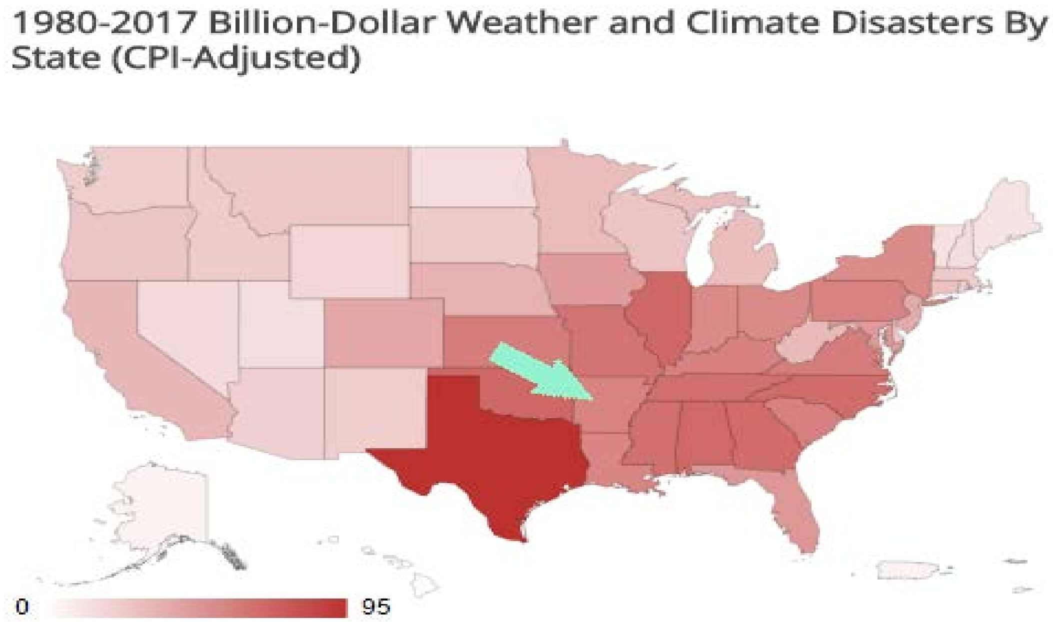

Figure 1. Billion-dollar disasters in the U.S. The arrow shows the state of Arkansas. By NOAA, 2018.

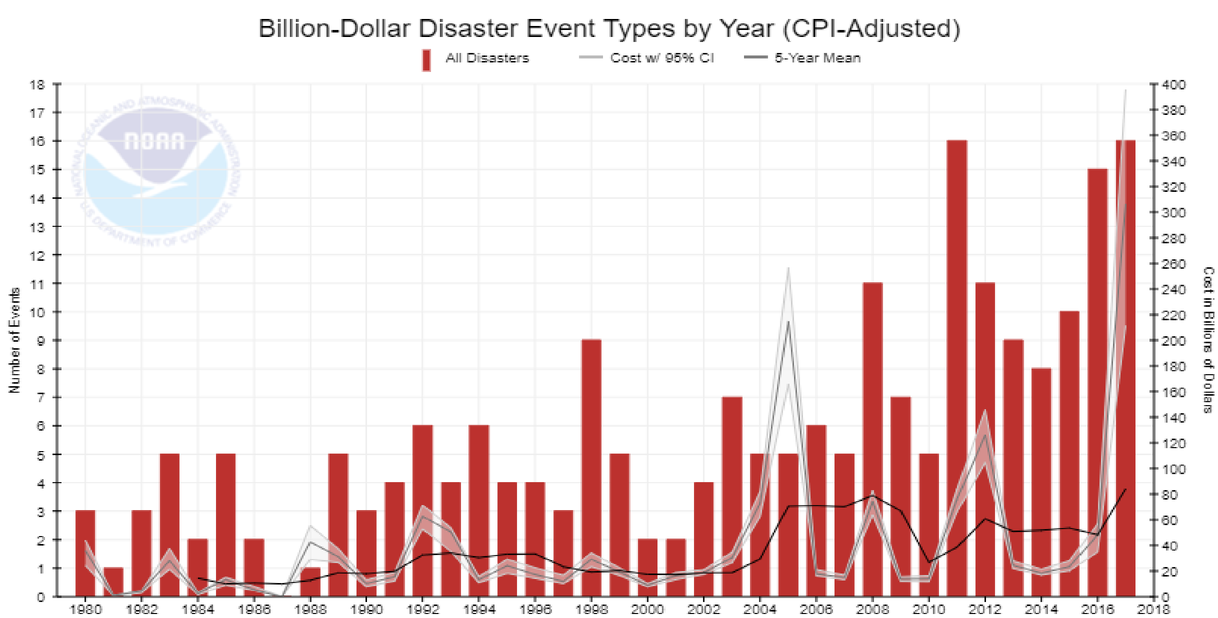

Figure 2. Increasing rate of billion-dollar disasters in the continental U.S. By NOAA, 2018.

2. Recognition of climate change policy problems

It appears that the policy making process with climate change in the U.S. is constantly dancing on the edge of a well-crafted blade. On one side of the ledger the desires for climate change policy are having to be crafted from already existing policies. While on the other side new legal policies are facing an ever climbing upwards battle for acceptance. In regards to the policies surrounding endangered species and climate change there is currently no true nationally accepted policy in place which unifies the two. The responsibility of the recovery of an endangered species falls upon the federal government which should take into account all environmental issues associated with an endangered species, including climate change. The Endangered Species Act (ESA) designates a species as “endangered” when it “is in danger of extinction throughout all or a significant portion of its range.” This existence may be endangered due to a variety of reasons including natural or manmade factors affecting its existence (16 U.S. Code § 1533(a)(1)(E), 2018). This is the approach being taken now addressing climate change using the best scientific and commercial data available. Once a creature is placed under the protection of the ESA it falls under the protection of the federal government and a recovery plan is created. In Arkansas all current recovery plans looked at with this writing show that there are only four recovery plans that address climate change. While four might appear to be a step in the right direction it should be noted that this is only 14.8% of all recovery plans in the state.

Climate change is a global and national problem; it is happening as shown from a virtually limitless amount of studies constantly being produced and having impacts in multiple fields (IPCC, 2014; ISAB, 2007; Schuur, 2005; WWF, 2003). Despite opposition from various local sources in business and politics, climate change continues to be acknowledged throughout the world as a current and upcoming global problem. This recognition was demonstrated earlier and renewed with global acceptance in 2015 with the United Nations Framework Convention on Climate Change (UNFCC) in Paris, where the Paris Climate Accord was created (UNFCC, 2015). Despite having the 20th consecutive year where the annual average temperature exceeded the average and 2016 being the second warmest year in 122 years the U.S. still appears to be behind the world's recognition of climate change (NOAA, 2016). This has become even more apparent now as the current administration has chosen to withdraw from the voluntary Paris Climate Accord.

Understanding how climate change impacts multiple fields becomes quite tricky. Consider sea level rise which could affect agriculture through a potential loss of land or sea water intrusion into an aquifer for example. NASA has established that the rate of change in sea level rise is 3.2 mm per year and this rate is continuing to climb (NASA, 2017). While this might not seem like a massive increase with sea level rise, in Miami this becomes huge as the cost of preventing these damages associated with water rising is in the hundreds of millions. Even short term solutions here can make a huge difference in the long term trend of rising sea level (Zickfield, 2017). Unless changes are made the National Resources Defense Council (NRDC) has stated that by the end of this century the homes of upwards of 13.1 million Americans could be inundated by rising sea levels (NRDC, 2017).

Knowing this is coming is excellent, however there is no national policy or agency in place to mitigate these impacts. A start for fixing this could be to address which agency has the direct responsibility to address climate change. Also, which method should that agency approach climate change from, e.g. updating building codes, creating environmental land policies, etc. For climate change we would give a monetary value to the problem by addressing which government acts to use, the resources the agencies need to address climate change, and address which policies being currently used. This hiccup is rippling down the policy chain and seemingly magnifying its impacts along each link.

2.1 Historical climate change policy problems

There is currently no natural climate change law in place within the U.S. and judging from the past attempts at this, the road ahead will be difficult. The past few decades within the U.S. have not been immune to approaches by both major political parties on measures to address climate change. However, these acts, bills, and committees have failed for numerous reasons. Furthermore, the globally accepted climate change policies of Kyoto and Paris have either not been ratified or been pulled out from after initial acceptance. This constant denial and removal from globally accepted science is creating issues with current and potentially future climate policy making. When creating policy in regards to climate change there needs to be a base federal foundation in place which could also enable the states to enhance policy is desired.

In 2003 the Climate Stewardship Acts, a series of three acts, were slowly introduced to the U.S. Senate by Senators John McCain and Joseph Lieberman with several co-sponsors. The primary goal of these acts was to introduce federal funding for research with climate change and create a mandatory cap and trade system for greenhouse gases against anthropogenic climate change. The first of these acts failed by a vote of 43 to 55 on October 30, 2003 (U.S. Senate, 2003). The subsequent following acts failed to gain enough votes to pass through the Senate too. Unfortunately, for climate science this would be the start of a failing trend of acceptance of the science.

Following these attempts was the introduction of the Global Warming Pollution Reduction Act of 2007 which can easily be confused with the Waxman-Markey Bill. The primary target of this was to amend the Clean Air Act to reduce carbon dioxide (CO_2). This would be completed by the introduction of increased performance standards for electric and motor vehicles with the option of a cap and trade system. This cap would begin in 2010 and eventually end the increments by 83 percent by 2050. Furthermore, this act would provide funding for research and design on geologic sequestration of CO_2. Subsequently, it would help set emission standards and work with renewable fuel requirements for gasoline starting in 2016. Finally, this act would establish energy efficiency and renewable portfolio standards. To validate this massive progress there would be periodic evaluations by the National Academy of Science (U.S. Congress, 2007). However, this bill would fail in committee and never make it to a vote continuing the denial of policy creation against climate change.

From a global perspective it appears that the U.S. also is lagging behind acceptance in climate change policy. The Kyoto Protocol was a key starting point for this global viewpoint. Despite U.S. President Bill Clinton signing the protocol in November of 1998, it required the approval of the U.S. Senate and it never went to a vote (Samuelsohn, 2014). To compound this effort is the current political view from the U.S. President Donald Trump, who started the process to make U.S. pull out from the Paris Accord (Shear, 2017). While this withdrawal won't start until 2020 the public opinion and view to the U.S. has already been impacted. This continues to show the lack of support from U.S. policy makers despite other countries recognizing climate change as a real threat.

3. Climate change and its relationship to the Endangered Species Act

Addressing the topic of climate change policy for this research we had initially thought the Environmental Protection Agency (EPA) would have the legal rights needed to both improve endangered population numbers and at minimum maintain current numbers in regards to combatting climate change. However, this is not the case in regards to climate change for two key reasons: 1) climate research has only recently been introduced into the political community to institute change with the already established EPA, 2) the legal issues and concerns with climate change have yet to be completely established. These reasons created challenge that must be to overcome in regards to climate change if the EPA is to be the head agency.

The next step we took was to look into the Clean Water Act (CWA) and see if this could be used as a viable protection route against climate change. Again, this proved not to be a suitable route as previous attempts through this avenue have failed with the same idea. The CWA regulates discharges of pollutants into water, not air emissions (Craig, 2010; Jones, 2015). This regulation of discharges are from "point sources", i.e. discrete conveyances that are created from man-made alterations of natural lands, e.g. discharge pipes, in addition to "nonpoint sources" which are not regulated directly, e.g. more spread out areas of land where the pollutants cannot be singled out quickly such as a farm or parking lot (Jones, 2015). The ability to tie each pollutant to its source, e.g. the exact source of CO_2 from an exact location, is currently not available in mass quantity, essentially this renders these sources as a blur instead of a specific target which could be addressed. While in the coming future generations this might be a viable window with relatively quickly and low cost – however, it simply remains an unviable window right now.

This, finally led us to the ESA of 1973 and how climate change is being addressed through it. When looking how climate change could be addressed within the boundaries of Endangered Species Act there are minute opportunities (Chen, 2015). Imagine climate change and its encompassing web of issues as factors in the sustainability of a species. While it might seem obvious at first to think of how rising temperatures, droughts, and increase in severe weather impact endangered species it is now possible to address how these issues are rising due to climate change within the ESA (McClure et al., 2015). One of these options to address climate change is through Section 4(a)(1) of the Act which establishes how a species is determined endangered or threatened. Of the five factors, (E) presents "Other natural or manmade factors affecting its continued existence" (Federal Register, 2006). It might appear that having to deal with a massive issue such as climate change that going through recovery plans created for endangered species is unusual. However, that is main avenue of addressing climate change currently.

In 1973 when the ESA was signed into law there was limited knowledge of climate change. Taking this into account when the act was written there was no true need in writing adaptive policies in regards to severe weather frequencies, vanishing coastlines, and rising temperatures now commonly associated with climate change. This has become quite the conundrum for already written plans, which lack the ability to adapt to change without a major rewrite. In fact only 10.3% of 1209 recovery plans written as of 2008 feature any mention of climate change listed as a threat (Povilitis & Suckling, 2009). Of those 124 recovery plans just mentioned, only 117 of those recovery plans listed specific concerns (Povilitis & Suckling, 2009). Continuing on this trend is the fact that only 29 species had recovery plans that indicated anthropogenic reasons for climate change and a single multispecies recovery plan in Hawaii accounted for 18 of these species (USFWS, 2006; Povilitis & Suckling, 2009).

While newer recovery plans have the benefit of having up to date research, older recovery plans have yet to be able to update to list climate change e.g. melting ice waters, rising sea levels, new migration patterns, loss of food source as a source of risk to a species primarily due to the slow voluntary update process. While this might not seem like the most direct avenue to address climate change in policy from an outside perspective it does however allow this problem to be recognized within established government policy. Almost all the seemingly straightforward avenues to pursue climate change policy are handcuffed, making it quite challenging to approach climate change in any other manner.

Next we needed to determine which agency is primarily responsible for the Endangered Species Act (ESA). As it currently stands the Fish and Wildlife Service (USFWS) appears to the most responsible. The tasks of recovery plan creation and updating associated with the ESA task primarily falls to the USFWS alongside the NOAA fisheries. Listed in the USFWS website it states the second function of this agency is to "Protect endangered species" (USFWS, 2016). These agencies are in charge of monitoring and creating new plans to best keep the species going within these protected habitats. This seemingly creates a lack of incentive to maintain and update these plans to the fullest. So far the USFWS has proposed two species to be directly threatened due to climate change: the polar bear and the wolverine (Blumm & Marienfeld, 2014). For the polar bear this was created through the use of the "best scientific and commercial information available" to determine that the loss of sea ice would cause the polar bear species to become endangered. A similar route was taken for the wolverine, in which it was determined that with the loss of habitat due to climate change would directly impact it (81 Fed. Reg. 47,522, 2014; 73 Fed. Reg. 28,212, 2008). For the polar bear this worked and minor changes have been made. On the flip side for the wolverine, the science was deemed inconclusive and the listing decision for this case was closed in 2014 (Horan, 2016). This case was reopened by the USFWS in 2016 for comments and the final results from this case are currently pending (Horan, 2016). If the wolverine be named endangered solely due to the direct impacts from climate change upon habitat loss, it will become the first species to do so.

What little changes that are made in regards to climate change within recovery plans are usually only introduced as potential changes when the review process of each recovery plan is updated and discussed. To complicate this topic is the fact that neither agency is 100 percent responsible for these species overall recovery, meaning if the recovery plan fails or if there is no update in the next few decades then no one is at fault. The USFWS agency is figuratively handcuffed against making major adaptive changes for climate change because these policies typically must be written and adopted by the EPA (Besinger, 2016). This process only happens every five to eight years at best on recovery plans that are lucky enough to be selected from the hundreds of recovery plans that could use updating. This could open the door for many other species and could potentially lead towards a climate change shift with endangered species policy making.

4. Climate change and Arkansas's endangered species consequences

Thinking of climate change it is critically important to remember that these changes take place over decades and not mere years or months. These changes in climate can have direct or indirect effects on species being positive, neutral, or negative depending on the species and its relationships to the variables in place (Fortini & Dye, 2017; IPCC, 2007). Additionally, the intensity and frequency of extreme weather events can rise due to these slow changes (Huber & Gulledge, 2011). This could be how the severity and frequency of droughts in the coming years to Arkansas (Qiao et al., 2017). In addition to these potential quick and dramatic changes is the ever changing climate which can lead to longer warm seasons (IPCC, 2014) and more heat waves (Huber & Gulledge, 2011; Meehl & Tebaldi, 2004). With species that are already endangered or threated these consequences from climate change can paint a drastically grimmer situation. While climate change might open an avenue for a species that was previously unavailable it quite often closes the gate on another. Fire ants can be best thought of here as they are now able to live in more northern latitudes thanks in part to climate change but at the expense of previous native ant and insect species (Allen et al., 2004).

Within the state boundaries of Arkansas there has not been a shift of more than 2^{o}C in annual temperatures during the past 123 years (PRISM, 2017). However, the effects of climate change have been noticed through the increasing frequency of extreme weather events and natural disasters. This was expected and warned against in multiple climate articles including those from the IPCC (IPCC, 2012). The climate for Arkansas is influenced by factors all over the region; just because Arkansas is remaining slightly steady in temperature, it does not mean that Arkansas will remain steady in other factors influenced by regional climate, e.g. heat waves and extreme precipitation. As shown in Figure 3, the number of hot days (maximum temperature >= 32.2^{o}C) and extreme precipitation days (daily total precipitation >= 50.8 mm) appear roughly the same. However, when climate change is taken into consideration and these metrics are projected into the future (see Chapter 2) a noticeable increase starts to take place. These changes together with changes in other climate extremes (see Chapter 1) can directly impact endangered species through lowered water levels, pH fluctuation, dissolved oxygen fluctuation, cyanobacteria blooms, and seasonal length changes which, changes food sources and breeding timelines. The IPCC has verified these risks to both terrestrial and marine ecosystems with both a medium to high confidence to attribution in climate change throughout North America (IPCC, 2014).

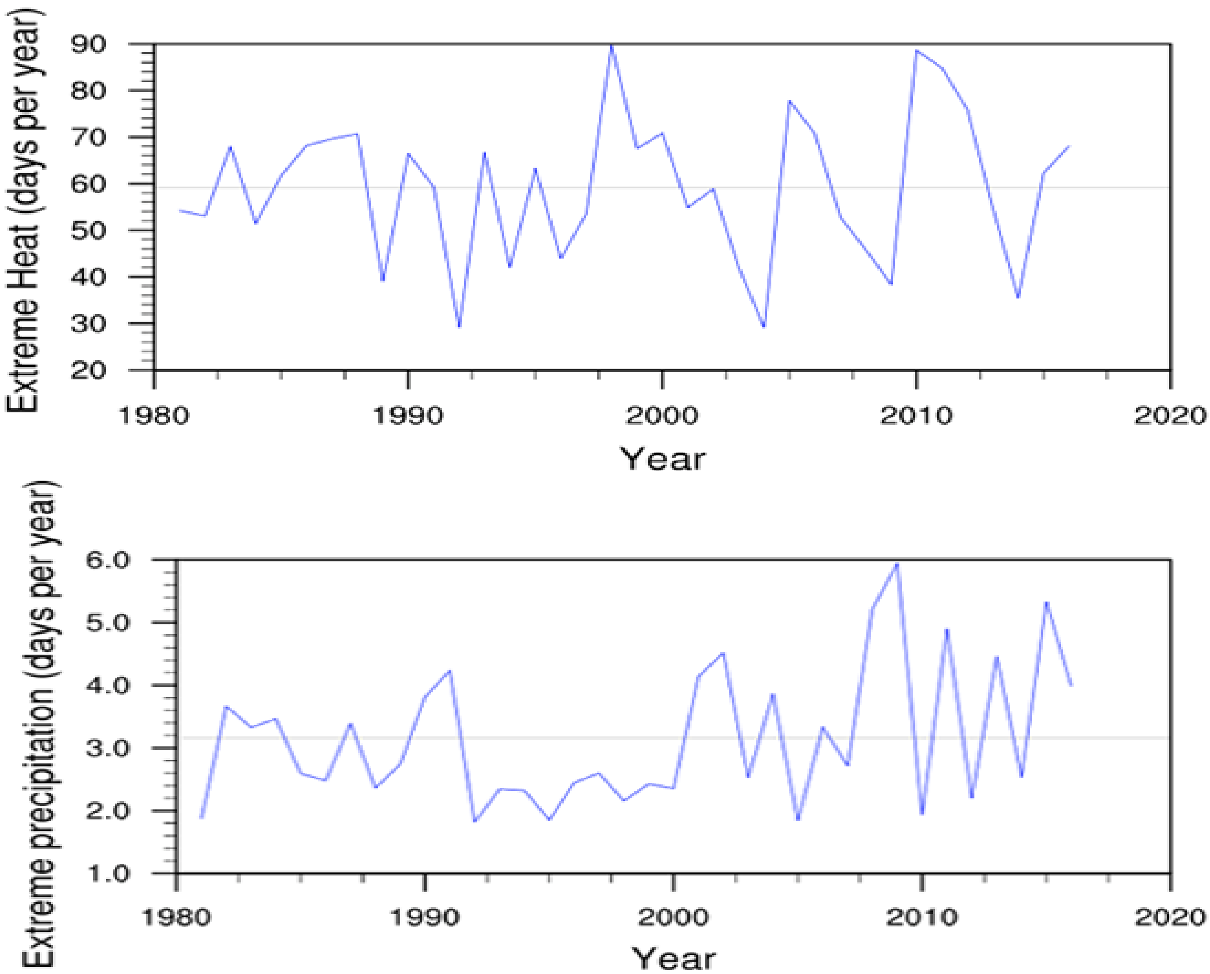

Figure 3. Temporal variations of the number of extreme hot and precipitation days in Arkansas.

In the case of many fish species within Arkansas the window for breeding is only a few weeks and requires a precise range of temperature, dissolved oxygen, and pH levels to take place. If these variables not align, the chances for new offspring diminish quickly if not completely evaporate and climate change is bringing rising stream temperatures along with several other issues (Ficklin et al., 2013; Kaushal et al., 2010). In a large portion of recovery plans looked at, severe weather and the frequency of severe weather events are completely overlooked. It is understandable that not every single potential issue could be addressed in recovery planning, it seems though that general effects from climate change and extreme weather events should probably be considered due to their increasing frequency. The key takeaway here for climate change policy throughout the U.S., not just Arkansas, is knowing that climate change influences several more factors than just temperature and those factors can have substantial impacts.

4.1 Arkansas recovery plans

Taking the lack of recognition of climate change into account, when looking at the 35 listings of endangered and threatened species in Arkansas, only 12 of the recovery plans or federal regulation documents mention climate change. These regulation documents can range from reviews of current plans, determination of threatened status, or proposed threatened status. Eight species still do not even have a recovery plan in place. Narrowing this further down is that only four of the 12 species, listed earlier, mention climate change specifically in their recovery plan. It should be noted that going back two decades there was no mention of climate change in any of the species regulation documents or recovery plans within Arkansas. When dealing with endangered species it should be of constant importance to recall that these species are endangered for a reason. These endangered species cannot seemingly quickly rebound or recover from an issue or they would most likely not be endangered in the first place. Climate change is magnifying the intensity of several elements that often drive these species into becoming endangered in the first place.

As mentioned above the recognition of climate change within Arkansas recovery plans, for endangered or threatened species that even have an accepted or in place recovery plan, is a mere 14.8%. Three of the four recovery plans that have climate change mentioned have been written since 2014, with the Indiana bat (Myotis sodalist) being revised on 2007 being the outlier. While the 14.8% recovery plan recognition might not demonstrate a level of concern for climate change as a whole, it does however show that plans are being updated with current scientific research and planning species recovery with climate change as a factor now. The idea that climate change is just starting to become recognized in Arkansas recovery plans is illustrated below in Figure 4. While this might to start to show a trend towards recognition it should be noted that only half of new recovery plans since 2007 have included climate change. 50 percent is far from widespread acceptance and despite research into the matter of why only 50 percent at the time of this writing, summer 2017, it is currently unknown. This further demonstrates the need for either new policies or updating current plans when dealing with climate change related issues.

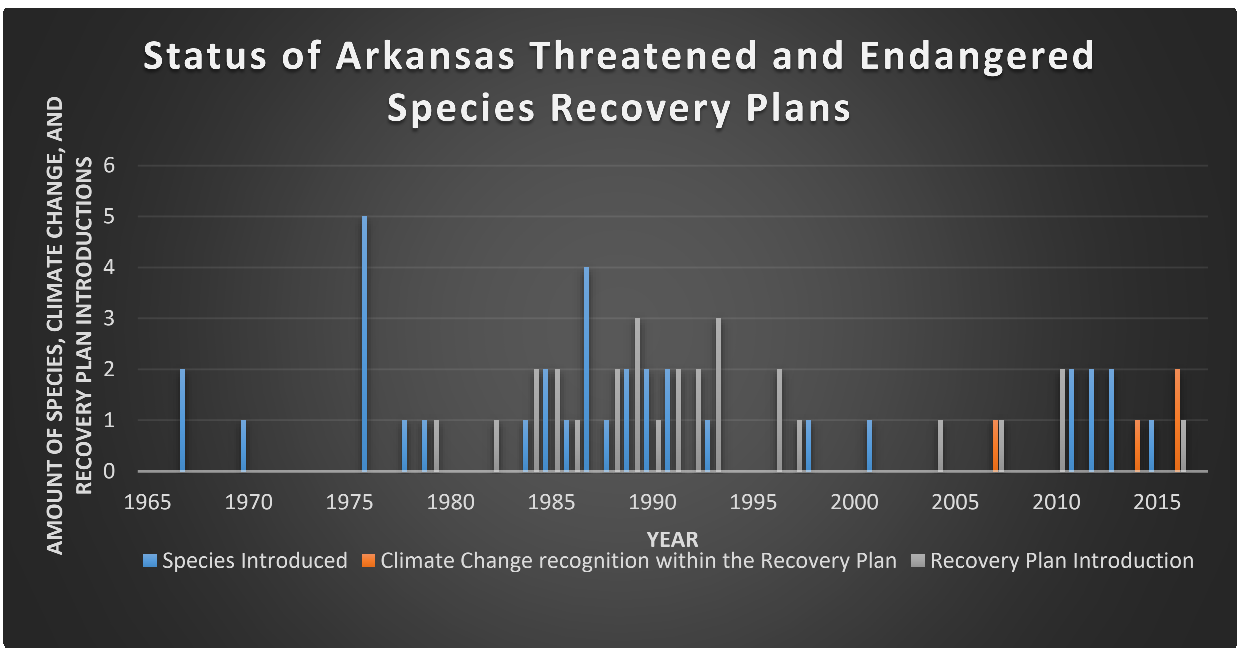

Figure 4. Status of Arkansas Threatened and Endangered Species Recovery Plans.

Many endangered species are trapped within a finite space and lack the ability to migrate or adapt without some form of outside assistance. One prime example of this in Arkansas is the cave crayfish, *cambarus zophonastes*, which is only known to exist within two counties in Arkansas (USFWS, 2017). There are several species (e.g., Leopard Darter) that are similar in this way which makes recovery planning far simpler. While this might seem like a positive value for a species it also has a grimmer setting as well. If the recovery plan not be adaptable or not written adequately then this species will have a slimmer chance to recover due to its limited range. Having looked into manmade mass species migration as a solution to this problem it seems virtually impossible to achieve and extremely cost intensive, making this an unlikely scenario should this recovery plan fail.

The Pallid Sturgeon (Scaphirhynchus albus) recovery plan, accepted in 2014, demonstrates how climate change is both a threat to the species and establishes a recognized scientific understanding process that could be considered with future policies. Later in this recovery plan the USFWS use expert judgement to weigh relevant information on uncertainty in their considerations in regards to climate change. They specifically note the IPCC and the U.S. Global Change Research Program results on the trends of climate change with: 1) changing climate trends with this region getting warmer, and 2) the average temperature in the U.S. is at least 1.1^{o}C higher than they were 50 years ago (USFWS, 2014). Additionally, this recovery plan notes how climate change will directly impact this species through runoff pattern shifts, late season river flow reduction, and water temperature rising (IPCC, 2007). Finally, in the summary of the impacts of climate change section it notes that it is difficult to evaluate long-term effects from climate change as there are many anthropogenic influences within this species habitat (USFWS, 2014). This made us wonder if all recovery plans should require expert judgement in regards to climate change, e.g. what biological risks the effects of severe drought could carry to a species versus that of an exceptional drought. Also this idea of having the “best scientific and commercial information available” is already in place, which makes us wonder why explaining the need for expert judgement was needed in the first place.

While Arkansas recovery plans might not be the most perfect route to consider when dealing with climate change policy, they do show an acceptance of the science (USFWS, 2014). Even within these recovery plans the authors note that assessing the relationship with climate change and these recovery plans will be difficult without cautious consideration of other already confounding factors (USFWS, 2014). Logical reasoning implies to us that when a recovery plan author makes the case that despite its potential confusing spectrum of problems, climate change still needs to be investigated for the best possible recovery plan.

4.2 Other recovery plans

For a comparison in recovery plans we looked at diverse plans from varying states in the U.S. to see how the differences are explored and how recovery planning methods vary in regards to climate change. Some of the best examples of states that openly demonstrated preparation for climate change in their updated recovery plans were that of Colorado, Oregon, and California. Prime examples of this could be through the state recovery plans from Colorado on the Mexican Spotted Owl (USFWS, 2012), the Sei Whale recovery plan (NOAA, 2011), and the Bull Trout plan from Oregon (USFWS, 2015). These recovery plans showed numerous methods and techniques in mitigating potential threats due to climate change while simultaneously appearing not to address climate change as a primary factor in endangerment.

The recovery plan for the Mexican Spotted Owl first demonstrates that climate change is a threat to the species by addressing it over 100 times within 414 pages of recovery planning content (USFWS, 2012). This is shown quickly by listing climate change to this species and by this recovery plan has a section on recommendations specifically on how to counter climate change damages. It continues further to list how factors from climate change such as a shift in the species' range may occur and this is validated by referencing scientific models that predict hotter and drier conditions in the southwestern U.S. for future decades (USFWS, 2012). For validation many of these models used have been created and tested to forecast against climate change by NASA, NOAA, and the IPCC.

Additionally, within this document it notes that a scientific panel was enlisted to review the status and threats of the Mexican Spotted Owl. This panel was unanimous in regarding the West Nile Virus as a threat to the species (Courtney et al., 2004). West Nile has been shown to be migrating due to climate change and the migration various avian species with data from the EPA (Dusek et al., 2009; EPA, 2016; Maidana & Yang, 2013). Again, climate change is not the primary issue against the recovery of this species – nevertheless, it's still influencing this species through a varying factor. This demonstrates a method to tie climate change into a recovery plan. This is just one example of how scientific climatic modeling and expert advice from varying agencies can be merged with a recovery plan to create the best recovery plan for the endangered species at hand.

The recovery plan for the sei whale provides two interesting approaches that can be demonstrated in regards to climate change policy making in Arkansas, despite never having a chance of existing in Arkansas: 1) it was created by NOAA working with international agencies demonstrating a collaborative goal, and 2) the location of these whales can actually range from the Pacific to the Atlantic Oceans meaning this recovery plan had to be created and organized for multiple varying climates (NOAA, 2011). Arkansas despite being a landlocked state still can benefit from multi-agency collaboration and the understanding of varying climatic conditions for a species that might migrate throughout the state and region.

Climate change was recognized by the International Whaling Commission (IWC) and they placed a moratorium on commercial whaling in 1986 (NOAA, 2011). Compounding this more is the growing concern about global warming and the recognition of shifts within the natural climatic oscillations such as El Niño or La Niña. The evidence for this potential threat suggests that productivity in the North Pacific and other oceans could be affected by changes in the environment from climate change (Mackas et al., 1989; Quinn & Niebauer, 1995). All of this translates into the acceptance of climate change being a key factor and multiple nations agreeing to protect these species. If multiple nations with several barriers such as language, heritage, and reasoning for whaling are able to come to acceptance on the protection of a species; it seems logical that a few agencies could do so similarly.

While there are massive unknowns to exact future forecasts with climate due to climate change, there is a key point in the sei whale recovery plan that could be used in Arkansas recovery plans. Climate change is listed as a strong hampering factor against the recovery of the sei whale. This is due to the increase in global temperatures associated with climate change and how these alterations are expected to have profound effects on artic and sub-arctic ecosystems. Furthermore, these climatic impacts are projected to accelerate within this century (Arctic Climate Impact Assessment, 2004; Anisimov et al., 2007). These impacts are expected to create a change with sei whales due to the alteration of habitat availability and food availability, additionally climate change is already showing signs of shifting in copepod distribution in the north Atlantic (NOAA, 2011; Hays et al., 2005). Due to climate change this example of food scarcity from climate change should be considered within Arkansas recovery plans – however, it simply is not within the majority of Arkansas recovery plans. With several Arkansas species potentially losing habitat and food availability due to the unknown changes associated with climate change in this oncoming century it seems natural to list climate change as a potential culprit for this reason. While this might not be the homerun in climate change policy that is needed, it does however allow climate change to be widely accepted within the Arkansas recovery policy making process.

In North America, climate change is starting to take effect through increasing temperatures alongside the severity and increasing amount of severe weather events (IPCC, 2014). This finally leads to the bull trout recovery plan, which is a prime example of how a rival state recovery plan could be adapted to Arkansas's recovery plans. The bull trout recovery plan details how climate change is an influencing factor on food sources similar to the Sei Whale and goes into more details on the need for species migration due to climate change (USFWS, 2015). If these waters are not available or inhabitable due to climate change or extreme weather events there needs to be remedies in place. For Arkansas an example of this could be the installation of water pumps in certain areas to help combat dissolved oxygen drops. Also, extreme droughts associated with climate change create potential cyanobacterial blooms and these only further validate this idea for potential installation. The cost for water pump installation is minor on the cost scale when compared to the potential loss of a species or the cost of relocating a species to a new land. A primary reason for this is that acquiring and maintaining a large enough population of the species to succeed is far lower in already established habitat. Compound this with the acquisition of new lands, and removal of potential predator species that impact the incoming species within a new habitat only magnifies the cost even more. Finally, this is assuming that nature agrees with the move and does not introduce an unforeseen element into this equation, in which case more costs would be needed to offset this.

5. Discussion

Presently, in 2017, there is no direct policy manner currently which addresses climate change and its coming consequences head on in the U.S. The manner that we found through this research in best addressing this topic is through the updating and creation of new recovery plans tied to the Endangered Species Act. This might not seem like the most prominent route, but it does however appear to have the least amount of obstacles and is already in play.

While the U.S. might have no national policy on climate change, each state seemingly has the opposite and approaches it quite differently. Within the ESA in Section 6(c)(1), it discusses how a cooperative agreement can be entered into with any state on the maintenance for conserving the endangered or threatened species (USFWS, 2013). The views and recovery plan creation recognition difference addressed on climate change vary greatly from California to Florida for example and this does not equal out to the same level of treatment for each species. Legal issues to an epic problem such as climate change can make it exceedingly difficult to have one state's view taken above those of the other states should resistance be present, e.g. how droughts will be combatted in fear of wildfires in states ranging from California to Oregon with water rights and usage for example. These issues continue onwards with the protection of endangered and threatened species which is already far from 100% perfect. If a species is migratory such as a bird that ranges from Washington to Texas, should Texas be able to use water from another state and its potential endangered species even if both are in a drought to preserve this species? If the scientific recognition of climate change have any input in the recovery plan at all, or should the recovery plan be solely built upon current climate conditions and federal laws? These are just some questions that seemingly have no concrete answer in recovery plan creation. Until there is a uniform recognition or defiance of climate change in policy creation, certain species will have an advantage over others despite being federally protected.

This means that during the creation and updating of recovery plans there should be a solution in place that overrides county, state, and national boundaries when trying to protect endangered species such as an interstate agreement. Federal agencies can only do as much as they are allowed to do, separate authority over multiple agencies only complicates this measure further. While sometimes this is the case with cooperation, there appears to be no universal mandatory agreement on when this should happen. If variables change over the coming years (i.e. extreme weather, droughts, natural disasters, etc.), is the same recovery plan methodology viable? Unless this is addressed in the recovery plan it would appear most unlikely. It's understandable to forget an endangered species during a natural disaster – however, in the recovery phase of a disaster this really should not be overlooked. Imagine what is presently happening, fall 2017, in Puerto Rico after hurricane Irma with regards to endangered species. Are there agencies looking after these endangered species? If not, at what point will they be addressed again? The protection of our own species is understandable – however, as current natural champions of the food chain we are responsible for the countless species below us as well.

5.1 Suggestions and conclusion

Presently, there is no direct national policy that addresses climate change. This led us to into thinking outside of the box and grasping towards new approaches. Currently, as of this writing, the federal success rate of a bill being passed with anything associated climate change in it is quite low. While there is a strong federal presence within the recovery planning methodology, there seems to be a strong delay on any updates to a recovery plan once it is created. Should this task fall to a new team after a few years? Or maybe let the local needs and wants become managed on a state-by-state level with federal approval? After researching this topic and reading through hundreds of recovery planning documents we can say there really is no one size fits all solution here. If a metric were created based upon the recovery of multiple species and techniques used then perhaps a more streamlined planning document and process could be developed. However, the creation of a solid piece of climate change policy that could lay the framework for creating recovery plans and let each region adapt from this plan could save time enabling the boundaries and agents to know their determined role, money, and potentially the species as well. The bottom line is that despite a slow increase in climate change acceptance and planning recognition in recovery planning, we need to address this topic with more haste and consistently throughout the United States before these endangered species potentially become extinct.

Taking this into account there still is a noticeable difference in recovery plans written 30 years ago versus those written in the past few years. If a standard is established that requires scientific expert advice and modeling with each species' needs taken into account, it seems only logical that the survival rate would increase. An example of this could be in likely areas of drought within a recovery plan, a scientific team could be brought in to help further develop this recovery plan with multiple scenarios in place to help this species combat the effects of that drought. Currently, the revisions and updates to recovery plans are voluntary – would it be beneficial to make revisions mandatory every decade? This is another place where the creation of a solid climate change policy could step in and take the old plans' groundwork and build it back into a modern recovery plan. At some point for endangered species to have the maximum chance for survival climate change, its effects need to be accounted for.

Unfortunately, for the Leopard Darter the current recovery plan simply does not address climate change at all. The current recovery plan was originally written in 1984, then revised in

1993. Within the document it states that the goal is to have this species delisted in 2003, however that simply has not happened. Taking into account the findings from this research in both the Leopard Darters home habitat in addition to Arkansas as a whole - the overall impacts of climate change upon this species could become greater within the coming years/decades.

While, there are mentions of a desire to update the current revised recovery plan in the "5-Year Review of 25 Southwestern Species" of 2006 (USFWS, 2016). These revisions have yet to take place. Furthermore, there appears to no overall system to determine which species takes priority over the other in regards to updating and creating new recovery plans. This only muddies the notion of climate change being introduced into the Leopard Darter plan more.

With plenty of resounding scientific evidence showing that climate change effects are already starting to take place (IPCC, 2014; NASA, 2017; WWF, 2003), it is just a matter of time before climate change effects ripple down through the natural cycle. Species that can adapt and have massive numbers should have the advantage over those that do not. This is simply due to numbers and larger migration options. The flip side to this is that endangered species do not have these two options and are forced to adapt within their own region, if it is possible at all. The simple solution from my perspective would be to allow climate science and its findings to be incorporated in policy making at all steps needed, or at least make it universal in recovery planning. As it stands now there are few positives working in favor of endangered species and the weaknesses of recovery plans is well recognized in the scientific community (Foin et al., 1993; Schemske et al., 1994; Tear et al., 1993). This system that is currently in place with having to work through ESA is making minimal progress towards climate change policy making and is only hampering recovery plans.

Our time is not infinite and we only have to look back to the dinosaurs to see how quickly a planet can change. Currently, the rate of a creature being delisted from endangered species protections due to a recovery in sustainable numbers is a mere 56 out of over 2,000 (Jacobson, 2013). While addressing climate change in recovery plans might not appear to be a viable solution to this epic problem, it at least opens the door towards finding a potential solution. With hope there is a chance; we alone created this problem, and we have the power to solve it if we act with haste.

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Conclusion: The End Game

1. Conclusion

1.1 The balance of climate

Climate shapes the world around us in a limitless amount of ways and despite Arkansas being a relatively small area on the surface of the planet it has many different local climates. If any part of this climate balancing act changes throughout the world, it can create a rippling effect that can be felt throughout several realms, including Arkansas. This is the basic idea of climate change and we approached it looking into precipitation, temperature, and environmental policies geared towards it within Arkansas, and specifically Southwest Arkansas.

1.2 Warmer nights in Arkansas

Several key metrics that are changing in Arkansas which we discovered are: 1) the daily minimum temperature in Arkansas during the warm season is on the rise, 2) the difference in diurnal temperatures is shrinking, 3) the number of frost days are declining, 4) the mean overall temperature is on the rise, 5) precipitation is relatively staying the same overall despite showing larger gaps between precipitation events, and 6) extreme weather events and droughts appear to be on the rise. While all of these are closely related, they can shape so much more than just “it is warmer”, i.e. seedling mortality increasing, cyanobacteria blooms, decrease in rice production, etc. (Shen et al., 2014; Yu et al., 2014; Christiansen et al., 2011). The future appears to show troubling climate related issues for Arkansas. Should these measures start to be addressed and mitigated against though, the severity of these issues can be somewhat restrained.

With Arkansas having a major focus on agriculture as a primary source of income alongside the consumption of grown foods, should these changes continue to grow as they are then the results of this could impact multiple sectors of everyday life in Arkansas. The idea of having less food and lower income creates a recipe for despair. Furthermore, the idea of having a shift in growing seasons might sound appealing, but there are several new factors that need to be addressed or the change could present an enormous obstacle for farmers to overcome (Ruane et al., 2013; Wienhold et al., 2018). As addressed in the previous chapters, an increase of new pests and invasive species alongside combatting longer periods without precipitation places more burdens upon the agricultural sector of Arkansas. Furthermore, these warmer nights and increased temperatures could lead to more water pumping; this could essentially drain the lowered aquifers, raise energy need for farms, and place a higher electricity cost upon farmers. At what point does this water pumping simply stop and farmers give up either due to lack of water or income? Another issue from climate change to this sector is what do farmers do when the opposite happens and massive extreme precipitation events happen and happen more frequently? It is quite difficult to prepare against one type of disaster, trying to prepare for multiple type's only places a greater burden upon this sector. Imagine finally completing the installation of retaining ponds to combat flooding and the next year a massive drought hits. Again, climate change is presenting multiple new problems which will hopefully be addressed before the tipping point has passed.

1.2 Southwest Arkansas

As we approached Southwest Arkansas with the knowledge that Arkansas has many varying climates, the results of climate change becoming stronger in so many ways within this region relatively caught us off guard. Going against the fluctuating decadal temperatures for Arkansas and overall warming trends are the temperatures of Southwest Arkansas, which have been rising consistently over the past few decades. Carrying this idea of a warming climate further is the trend that heavy precipitation (100mm), zero precipitation, and hot day events (above 38°C) are all on the rise within this region, and when working with the idea of protecting the Leopard Darter and Arkansas fisheries in general, all of these impacts carry grave weight. How do these naturally endangered tiny fish counter multiple hot day events when in a drought and shrinking water pool? How do these fish escape migrating new predators? It's exceedingly difficult for a species to overcome and recover once becoming endangered, after all they are endangered for one reason or another. Should we not protect these fish then their future appears quite grim.

Taking these increasing climate change related elements into consideration we next looked at natural disasters within this region. Almost as predicted from the IPCC (IPCC, 2012), the amount of natural disasters are on the rise too. While this might create the illusion of doom and gloom it could also be a wakeup call to the region on starting to install mitigation-based techniques to the various industries in play here.

1.3 Climate change policy

The lack of any overarching federal climate change policy creates a web of uncertainty when dealing with measures to prevent future harms associated with climate change. Despite the general trend in the severity of natural disasters becoming stronger as predicted from the IPCC it seems the United States is choosing to ignore overwhelming scientific warnings (IPCC, 2012; IPCC, 2013). As it presently stands the only major piece of federal policy that can address climate change does not reside in either the Clean Air or Clean Water Act; instead it falls into a tiny section within the Endangered Species Act. Seeing how climate impacts both air and water this seems quite unusual and this oddity has been approached before by the government to no avail and judging from all of the failed measures attempting to address climate change, from both major parties, it seems very little will be done before the harsh realities of climate change set in. Currently, (2018) there are multiple lawsuits being filed against major oil companies on the topic of them hiding their knowledge of these climatic harms. While this might seem like a step in the right direction, it should be noted that in similar cases against major tobacco companies that these cases took decades to resolve. Should these climate change lawsuits follow in the same manner at what point do we cross the tipping point before we can recover with climatic harm?

1.4 Filling the knowledge gap

When we started this research we looked at a few key points to see how we could fill the knowledge gap of potential climate changes in Arkansas. First, is there evidence that the climate of Arkansas is changing with climate change? Yes, these findings of a warmer Arkansas, especially a warmer Southwest Arkansas, are quite apparent. Next, this led us into the avenue of seeing if there is are viable climate change policies that can be used to address climate change. Unfortunately, there simply is no real viable federal legislation to deal with climate change in the United States. This also holds true for Arkansas climate policy. What does all of this mean for the filling these knowledge gaps? This means that the knowledge that Arkansas is indeed warming and there can still be measures put into place through policy to address these oncoming issues is still possible. However, judging from the noticeable changes happening to the climate in Arkansas already, these changes need to happen with some haste.

1.5 Final thoughts

We took the basic understanding of climate effecting all forms of life and focused on precipitation, temperature, and the mixture of these two to see if the climate in Arkansas was changing. As it turns out, Arkansas right now is experiencing some shifts in minute manners which unless halted, will start to cascade throughout the plant and animal kingdom of Arkansas.

Luckily, we have taken the already accepted knowledge of the planet and region getting warmer from the IPCC (IPCC, 2007; IPCC, 2012; IPCC, 2013). Should policy makers or local officials wish to have a reference point or guideline of potential climatic changes in Arkansas, this option is now available via this research. However, unless these findings lead towards actions than these simple changes when paired with a species that is already endangered only creates a recipe for failure. As it presently stands the Leopard Darter will need help to combat climate change and unless climate change polices are updated or created on both a federal and state level, this ‘canary in the coal mine’ situation will simply drift pass us leading towards more environmental harms.

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