

DRIVERS OF WATERFOWL VARIABILITY IN THE ARKANSAS MISSISSIPPI
ALLUVIAL VALLEY

by

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of

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in

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ABSTRACT

Wintering waterfowl populations in the Arkansas Mississippi Alluvial Valley (ARMAV) are influenced by a combination of habitat availability and climate variability, but the relative importance of these factors at a regional scale remains unclear. Therefore, my study evaluated the influence of wetland cover, rice agriculture, and seasonal climate variables on Mallard (*Anas platyrhynchos*) and total duck abundance across 11 watersheds in Arkansas from 2012 to 2024. I obtained waterfowl survey data from standardized aerial counts, and derived land-cover data from United States Geological Survey and United States Department of Agriculture datasets and processed them using QGIS. I obtained climate variables, including temperature and precipitation, from National Oceanic Atmospheric Administration stations and analyzed them for both winter (November–February) and summer (June–August) seasons. I conducted linear and multiple regression analyses to assess relationships among environmental variables and waterfowl abundance at the watershed scale. My results indicated an overall decline in waterfowl populations across the ARMAV, with notable spatial variability among watersheds. Rice cover increased substantially across all watersheds but showed no significant relationship with waterfowl abundance. In contrast, wetland cover exhibited moderate to strong relationships with duck and Mallard populations in several watersheds, although the direction and strength of these relationships varied spatially. Multiple regression models demonstrated that land cover variables explained a significant proportion of variation in select watersheds but not across the entire region. Climate variables showed limited correlation with wintering waterfowl abundance, with no significant relationships observed for winter temperature or precipitation. However, summer temperature exhibited moderate correlations with Mallard abundance in some regions, suggesting potential indirect effects. Overall, my study highlights the importance of wetlands as a key driver of waterfowl abundance in the ARMAV and emphasizes the spatial differences of habitat relationships. My findings suggest that habitat management, particularly wetland conservation and hydrologic management, may be more effective than reliance on agricultural extent alone.

CHAPTER ONE

INTRODUCTION

Ecological and Economic Importance of Waterfowl in the Mississippi Alluvial Valley

Waterfowl, such as ducks and geese, are often important indicators of ecological health. Declining populations can indicate habitat loss and unstable ecosystems while increased or stable populations may indicate robust ecosystem functions and good water quality (Hale, 2023). Waterfowl are particularly important when studying wetland habitats, which have a complex mix of terrestrial and aquatic traits that are dynamic and often temporally variable. Studying waterfowl's changing populations is vital to conserving habitats, preserving ecosystem services, and monitoring climate stress.

In addition to the ecological importance of waterfowl populations, they are also important economically. In the United States, \$2.5 billion is spent in bird-hunting expenses each year, including tags, stamps, and equipment (Freeman, 2024). The Mississippi Alluvial Valley (MAV) is one of the most important wintering grounds for waterfowl in North America. The MAV provides extensive floodplain wetlands and agricultural habitats used by wintering ducks. Arkansas, located centrally within the MAV, provides resources for millions of migratory waterfowl each year due to its extensive wetlands and abundance of agricultural land. The state is also in the top three states for migratory bird-hunting expenditures. Arkansas generates approximately \$4 million per day during the 72-day waterfowl hunting season making it the second biggest industry in the state, behind agriculture (Freeman, 2024). Waterfowl populations

are ecologically, economically, and culturally important components of Arkansas's natural resources, supporting ecosystem functions, recreational hunting, and regional economies.

Mallard ducks (*Anas platyrhynchos*) are an ideal focal species for examining wintering waterfowl population dynamics due to their ecological importance, abundance, and management relevance. Among waterfowl species, the Mallard is the most harvested and heavily managed, making their population trends of concern to hunters, conservationists, and wildlife managers. Other dabbling ducks largely follow the population trends of Mallards, making Mallard research applicable to other species of waterfowl (Herbert et al, 2021). Mallard's body condition is influenced by food availability. Wintering Mallard body mass in the Lower Mississippi Alluvial Valley varied substantially among years and was related to climate and habitat conditions, with greater Mallard body mass following periods of increased rainfall or flooding, which are indicators of food availability for waterfowl (Veon et al., 2023).

Climate and Habitat Influences

Wintering waterfowl populations in Arkansas, including Mallard ducks, have exhibited increasing interannual variability, creating uncertainty for wildlife managers and conservation planners (Zhao et al., 2016). Wintering waterfowl distribution and abundance are linked to habitat conditions and environmental variability with variables such as surface water amounts, wetland availability, rice agriculture, and weather conditions having the strongest influence in the MAV (Herbert et al., 2021). Land cover conditions are important predictors of relative wintering waterfowl abundance across flyways, yet the influence of regional scale land-use change remains poorly understood. Most studies focus on a broader flyway or ecosystem,

leaving very few studies evaluating how winter temperature and precipitation influence waterfowl abundance specifically within the Arkansas Mississippi Alluvial Valley (ARMAV), leaving a gap in our understanding of how climate variability may directly affect wintering waterfowl numbers in this key region (Cox et al. 2023; Herbert et al. 2021; Pearse et al. 2023; Zhao et al. 2016).

Waterfowl in North America rely on a complex matrix of interconnected public and private lands for their habitat needs. The habitat values for waterfowl species are heavily influenced by geography and weather. After assigning habitat marginal values to each region of the United States, the habitat in the Southeastern region, including the ARMAV, had the highest positive contribution to waterfowl survival (Burner et al., 2023). Therefore, this region is critical for further study to inform conservation decision making. Waterfowl are “short-stopping” during their migrations (Cox et al., 2023), meaning they are not traveling as far south as they once did to escape the intense cold. Flyway use is also changing. More Mallards are occurring in the Pacific Flyway, suggesting that their migratory patterns are changing. These changes are likely caused by climate change and are of concern for the future of waterfowl species (Zhao et al., 2016). If migratory patterns are changing, this can lead to ducks spending seasons in regions that have a negative effect on survival, such as the Midwest (Burner et al., 2023). This should also inform adaptive management of duck harvest practices and habitat modifications. When migratory timing changes, this can alter the use of wetlands and agricultural habitats by waterfowl and leads to a mismatch between the hunting seasons and established monitoring programs (Pearse et al., 2023).

Research Focus

My study seeks to quantify the relative influence of climate and habitat variables on wintering waterfowl populations in the ARMAV using watersheds as the spatial units. By taking long-term survey data and integrating them with climate and land cover data, my study aims to define the relative roles of climate and habitat in shaping wintering waterfowl population dynamics at a regional scale. Specifically, my study addresses the questions “Does the availability of rice agriculture and wetland habitat within ARMAV survey watersheds correlate with Mallard and total duck abundance during winter, and are regional climate data correlated with population trends?”

The ARMAV is a landscape that plays a critical role in supporting migratory waterfowl. By examining the relative influence of climate variability and habitat availability on Mallard and duck abundance, I hope to contribute to a more specific understanding of how environmental drivers shape these populations. Because Mallards and other dabbling ducks support substantial recreational harvest and economic activity in Arkansas, improved insight into these drivers could support adaptive harvest management and season structure decisions. Habitat planning and improvement efforts that strategically align flooding practices and agricultural practices with anticipated climate conditions may also help maintain long-term population sustainability while maintaining hunting opportunities. My study tests the hypothesis that variability in wintering waterfowl populations in the ARMAV is jointly influenced by regional winter climate conditions and habitat availability, with winter temperature, precipitation, rice agriculture, and wetland availability serving as key indicators of Mallard and total duck abundance at the

watershed scale. I hypothesize that the climate variables will have stronger correlations to waterfowl abundance in the more northern watersheds and that habitat variables will have stronger correlations to waterfowl abundance in southern portions of the ARMAV.

CHAPTER TWO

METHODS

Study Area

Waterfowl migrations in North America are broken down into four flyways, the Atlantic, the Mississippi, the Central and the Pacific. My study takes place in the Mississippi Flyway (Figure 1). Within that flyway, the Arkansas Mississippi Alluvial Valley is broken down into 13 unique watersheds. I only included watersheds that are sampled by the Arkansas Game and Fish duck surveys in my analysis, leaving 11 watersheds with varied land cover (Figure 2). To analyze climate data, I chose three study sites based on differing latitudes and availability of data. Jonesboro, Arkansas, located in the Cache watershed, Stuttgart, Arkansas, located in the Bayou Meto watershed, and Monticello, Arkansas, located in the Bayou Bartholomew watershed. The Cache watershed is almost entirely comprised of wetlands and cultivated crop land. The Bayou Meto watershed is majority cultivated crop land and wetlands but with a significant section of pastureland in the Northwest corner. Bayou Bartholomew is mostly evergreen forest and cultivated crop land.

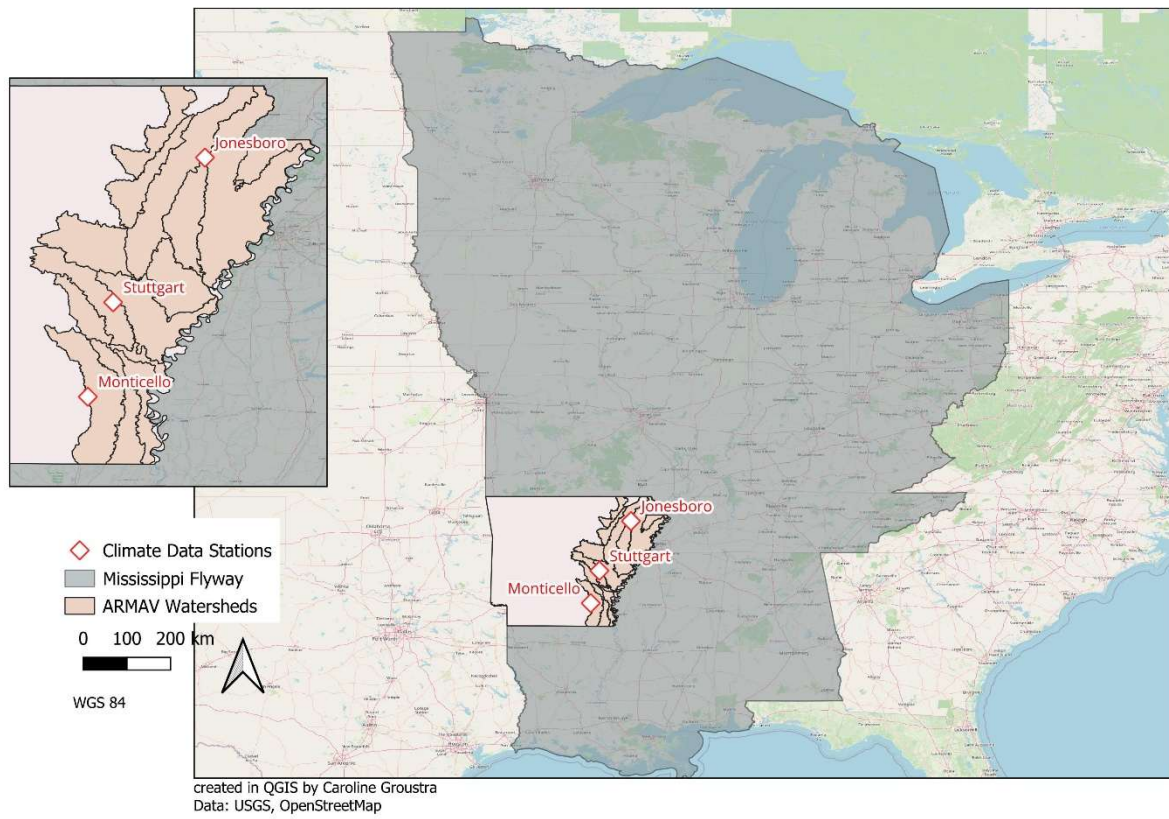


Figure 1: The Arkansas Mississippi Alluvial Valley location within the Mississippi Flyway. The inset map indicates the location of the study sites.

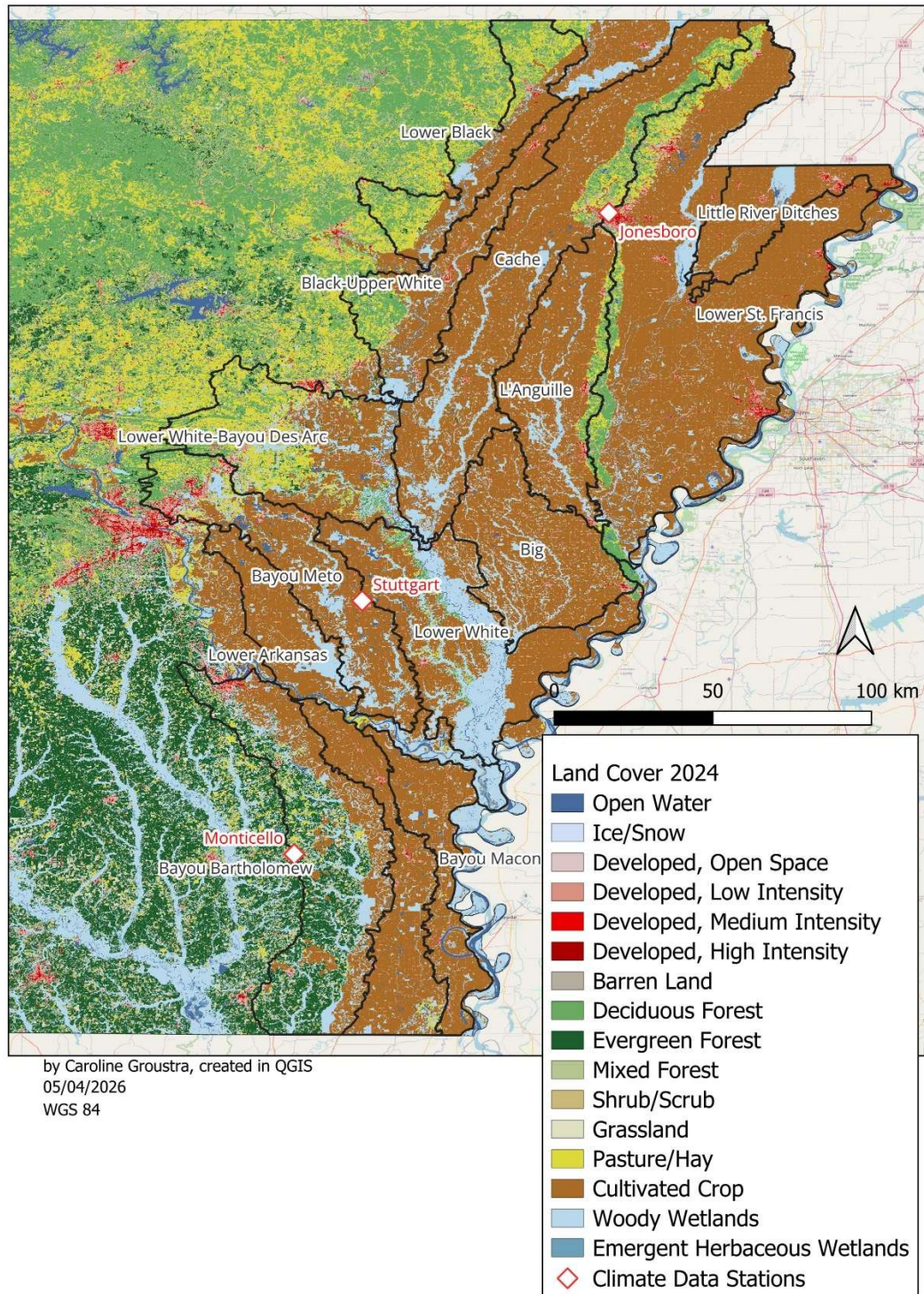


Figure 2: Land Cover classes for Arkansas in 2024 overlaid with study watersheds and climate data stations.

Analysis

I obtained waterfowl population data for the Mississippi Alluvial Valley (MAV) from 2012–2024 from standardized survey counts of Mallard (*Anas platyrhynchos*) and total duck species within designated watershed survey areas conducted by the Arkansas Game and Fish commission. Aerial surveys of 250-m transects were randomly selected in each watershed during each season (Arkansas Game and Fish Commission, 2025). I imported data into R for processing and analysis. For each ARMAV watershed, I calculated the percentage change in population over the study period separately for Mallards and total ducks. Because each watershed varies greatly by size, I decided not to measure land cover by area but instead by percentage change to make the watersheds comparable. For visualization, I generated a horizontal bar chart using base R plotting functions. I plotted side-by-side bars to compare Mallard and total duck percentage changes within each watershed.

I then conducted spatial analyses to quantify changes in wetland and rice agricultural land cover across watersheds within the study region. I obtained watershed boundaries as polygon shapefiles representing eleven hydrologic units within the study area. I obtained land cover data as 30-m raster datasets representing conditions from 2012 to 2024 (USGS, 2024). I processed these datasets to identify wetland and rice agricultural areas during different years. I defined wetland classes using land cover codes corresponding to woody wetlands (90) and emergent herbaceous wetlands (95). I identified rice agriculture using crop classification codes from cropland datasets obtained from the USDA Cropland Data layer (2023). I conducted all spatial analyses using QGIS version 3.40.7. I performed raster processing and geospatial calculations

using tools available in the QGIS Processing Toolbox, including Raster Calculator and Zonal Statistics (See Appendix A).

To evaluate the correlation between environmental variables and waterfowl abundance, I developed linear regression models using Mallard count and total duck count as response variables. I obtained predictor variables for climate data from the National Oceanic and Atmospheric Administration (NOAA) weather stations located within the study region. I calculated annual average temperature (°F) and total precipitation (cm) from monthly observations during the winter duck season (November-February) and the preceding summer season (June-August). I evaluated statistical significance of each regression model using the F-statistic and associated probability values ($\alpha = 0.05$). I visualized waterfowl responses to summer temperature using base R, plotting summer temperature (°F) on the x-axis, and species-specific counts (Mallard and Duck) on the y-axis. I generated smoothed trend lines for both groups using locally weighted regression to show general trends. I separated data by watershed, specifically Cache, Bayou Bartholomew, and Bayou Meto - Lower Arkansas.

I conducted statistical analyses in R to evaluate relationships between wetland area, rice cover area and waterfowl abundance across Arkansas watersheds. I compiled annual counts of total ducks and Mallards for each watershed with estimates of wetland area and rice area derived from land cover datasets. I evaluated the strength and significance of the relationship between land cover and waterfowl abundance using Pearson correlation coefficients (r), coefficients of determination (R^2), and associated p-values. I conducted analyses independently for each watershed to account for potential spatial differences in habitat availability, landscape composition, and waterfowl use.

Finally, I created a multiple regression model for the three study sites (Jonesboro, Monticello, and Stuttgart) with waterfowl population numbers versus the variables of summer climate and wetland cover. I compiled the results into a table for comparison including the associated p-values and R^2 .

CHAPTER THREE

RESULTS

Waterfowl Populations

Mallard and other duck species declined in population across the ARMAV, but some specific watersheds increased in populations between 2012 and 2024 (Figure 4).

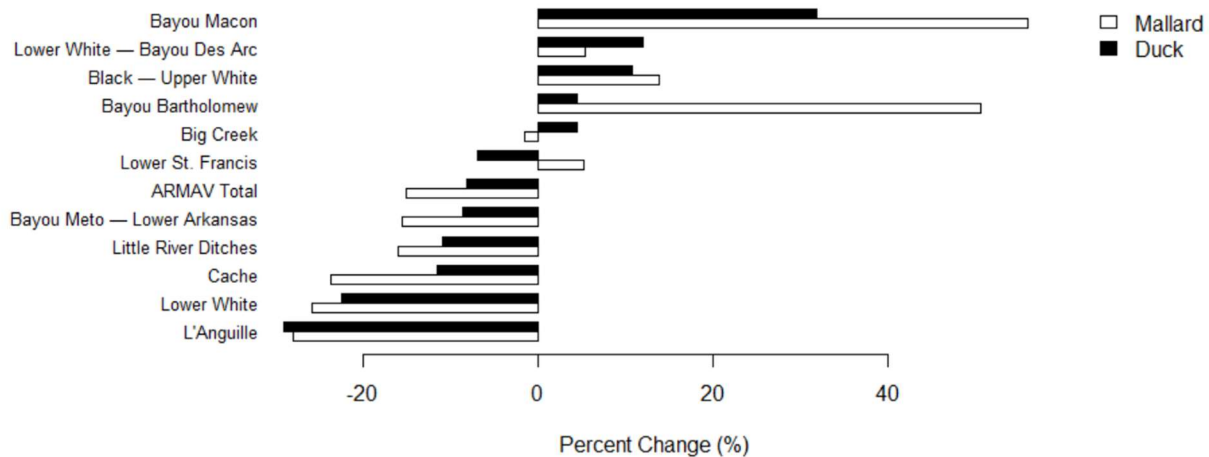


Figure 3: The percentage change in duck and Mallard populations between 2012 and 2024, separated by watershed. The results were sorted by level of duck decline.

Bayou Macon and Bayou Bartholomew had the largest increases in Mallards between 2012 and 2024, and L'Anguille, Lower White and Cache had the largest decreases. Overall duck populations showed a similar pattern with Bayou Macon, Lower White-Bayou Des Arc, and Black-Upper White having the largest increases and L'Anguille, Lower White and Cache having the largest decreases. This suggests that some watershed areas are attracting waterfowl while others are deterring waterfowl, but overall, the ARMAV duck populations are generally declining.

Land Cover Variables

Over the 12-year study period, there were many changes in land cover. Wetland cover remained consistent overall with small losses in Lower White-Bayou Des Arc and Little River Ditches, and substantial gains in Bayou Bartholomew and Black-Upper White watersheds (Figure 5, Table 1). Rice cover on the other hand had large increases over the 12 years of the study (Figure 6, Table 1). Bayou Bartholomew had a very large 1744% increase and every other watershed also increased in rice cover.

Table 1: Percentage Change in Land Cover from 2012 to 2024 by Watershed.

Area	% Change Wetland Cover	% Change Rice Cover
Bayou Bartholomew	29%	1744%
Bayou Macon	1%	489%
Bayou Meto — Lower Arkansas	5%	193%
Big Creek	1%	226%
Black — Upper White	44%	229%
Cache	2%	212%
L'Anguille	1%	237%
Little River Ditches	0%	734%
Lower St. Francis	1%	285%
Lower White	0%	210%
Lower White — Bayou Des Arc	-4%	181%

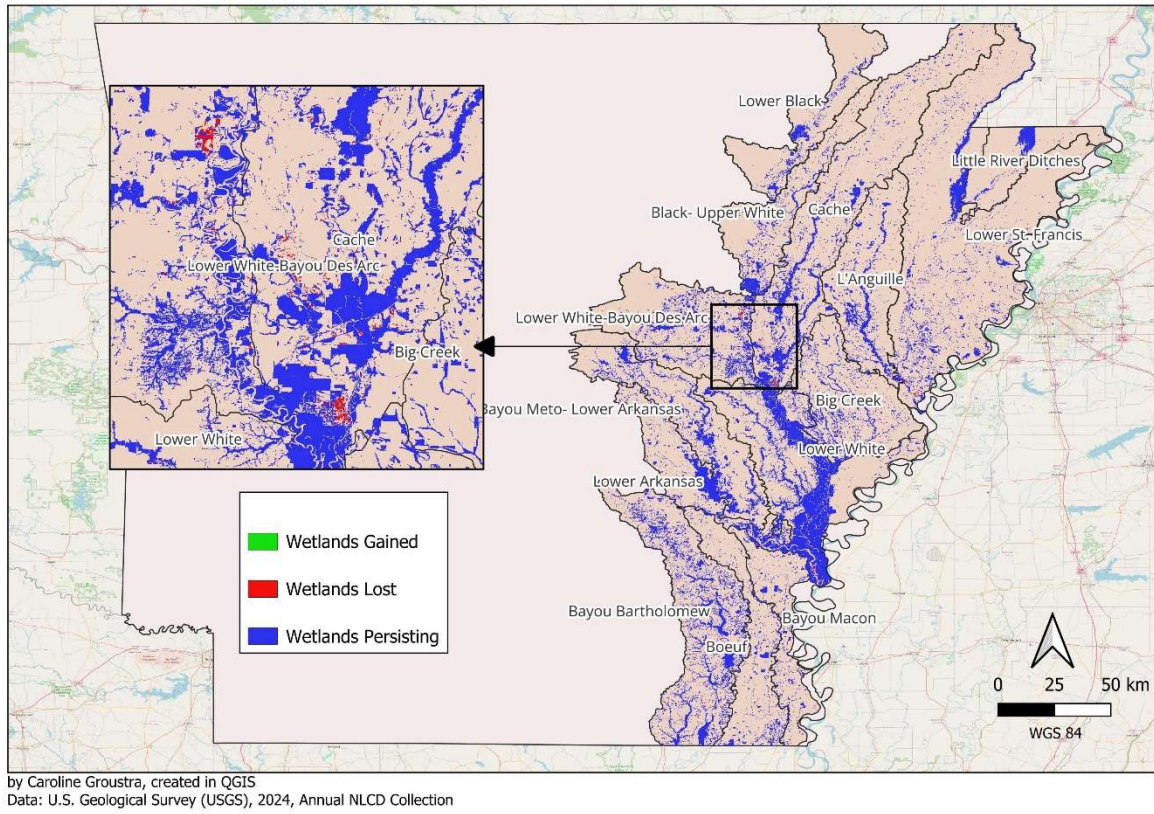


Figure 4: Changes in wetland cover from 2012 to 2024 in the Arkansas Mississippi Alluvial Valley.

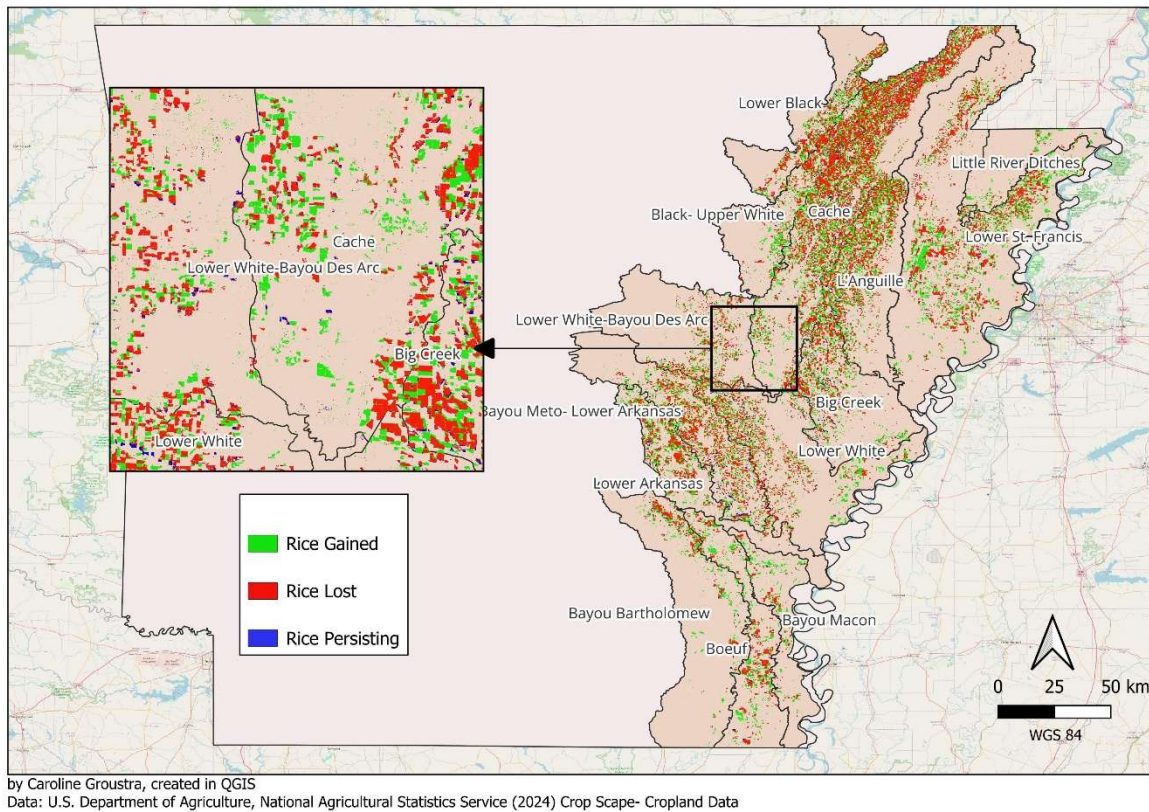


Figure 5: Changes in rice cover from 2012 to 2024 in the Arkansas Mississippi Alluvial Valley.

Based on the regression model, the strength of the relationship between annual rice area and waterfowl abundance was non-significant across all watersheds (Table 2). For total duck counts, correlation coefficients (r) ranged from -0.48 to 0.15 , with corresponding R^2 values between 0.0008 and 0.23 . None of the duck regressions were statistically significant at $\alpha = 0.05$, with p -values ranging from 0.34 to 0.96 . Similarly, Mallard-specific models showed no significant correlations, ranging from -0.44 to 0.16 , with R^2 values between 0.001 and 0.19 , and all p -values exceeding 0.38 . These results indicate that, for the study period, rice area was not correlated with waterfowl abundance.

Table 2: Regression Statistics by Watershed for Rice cover & Waterfowl Statistics.

Watershed	Duck Correlation	Duck P Value	Duck R²	Mallard Correlation	Mallard P Value	Mallard R²
Bayou Bartholomew	-0.29	0.58	0.08	0.03	0.95	0.00
Bayou Macon	-0.18	0.73	0.03	-0.25	0.63	0.06
Bayou Meto - Lower Arkansas	-0.48	0.34	0.23	-0.44	0.38	0.19
Big Creek	-0.16	0.77	0.02	-0.41	0.42	0.17
Black- Upper White	0.15	0.78	0.02	0.16	0.76	0.03
Cache	-0.31	0.55	0.10	-0.27	0.61	0.07
L'Anguille	-0.27	0.61	0.07	-0.28	0.59	0.08
Little River Ditches	-0.38	0.46	0.14	-0.39	0.44	0.16
Lower St. Francis	-0.46	0.36	0.21	-0.29	0.58	0.08
Lower White	-0.28	0.59	0.08	-0.28	0.59	0.08
Lower White - Bayou Des Arc	-0.03	0.96	0.00	-0.18	0.73	0.03

The strength and direction of the relationship between wetland area and waterfowl abundance varied across watersheds (Table 3). For total duck counts, correlation coefficients ranged from -0.92 to 0.87 , with R^2 values from 0.046 to 0.86 . Significant positive relationships were observed in Black - Upper White ($r = 0.87$, $p = 0.0001$) and significant negative relationships in Cache ($r = -0.70$, $p = 0.01$). Mallard specific correlations were similarly variable, ranging from -0.73 to 0.90 , with R^2 values between 0.04 and 0.80 . Significant relationships were observed in Black - Upper White ($r = 0.90$, $p = 0.00004$) and Cache ($r = -0.74$, $p = 0.004$). At Lower White — Bayou Des Arc, wetland area was strongly negatively associated with total duck abundance ($r = -0.92$, $p = 0.00001$), explaining 86% of the variation in duck counts, whereas the relationship with Mallard abundance was not statistically significant ($r = -0.66$, $p = 0.014$, $R^2 = 0.44$). Wetland area explained a much greater proportion of variation in waterfowl abundance compared to rice area, with several watersheds showing moderately

strong to strong relationships. These results indicate that wetland extent is more strongly associated with waterfowl abundance than rice cover within Arkansas watersheds during the study period.

Table 3: Regression Statistics by Watershed for Wetland cover vs Waterfowl Statistics. Significant values are highlighted.

Area	Duck Correlation	Duck P Value	Duck R ²	Mallard Correlation	Mallard P Value	Mallard R ²
Bayou Bartholomew	-0.26	0.38	0.07	-0.14	0.66	0.02
Bayou Macon	-0.22	0.48	0.05	-0.26	0.39	0.07
Bayou Meto - Lower Arkansas	-0.28	0.35	0.08	-0.31	0.30	0.10
Big Creek	-0.34	0.26	0.11	-0.58	0.04	0.33
Black - Upper White	0.87	0.00004	0.76	0.89	0.001	0.80
Cache	-0.70	0.01	0.48	-0.74	0.004	0.54
L'Anguille	-0.40	0.18	0.16	-0.44	0.13	0.19
Little River Ditches	-0.24	0.44	0.06	-0.19	0.53	0.04
Lower St. Francis	-0.66	0.01	0.44	-0.59	0.03	0.35
Lower White	-0.58	0.05	0.34	-0.66	0.02	0.44
Lower White - Bayou Des Arc	-0.92	0.001	0.86	-0.66	0.01	0.44

The results of the multiple linear regression indicate that wetland cover in conjunction with rice cover does not have a consistently strong link to waterfowl populations across all watersheds but does influence some regions (Table 4). The strongest, most statistically significant relationships were found in the Cache, Black-Upper White and Lower White-Bayou Des Arc watersheds. In the Cache watershed, both Mallard and duck populations were correlated with land cover. The model indicates that for ducks, land cover explained 96% of their population variation and 88% of the Mallard population numbers. In the Black-Upper White region, only Mallards showed a significant relationship with land cover and in the Lower White-Bayou Des Arc watershed only ducks showed a significant relationship with land cover. This suggests that land cover variables are associated with waterfowl abundance in select watersheds

but not across the whole of the ARMAV. There is a high spatial variability in land cover/waterfowl relationships.

Table 4: Multiple Regression Statistics for Wetland Cover & Rice Cover vs Waterfowl Populations. Significant values are highlighted.

Watershed	Duck R²	Duck P Value	Mallard R²	Mallard P Value
Bayou Bartholomew	0.11	0.85	0.07	0.90
Bayou Macon	0.03	0.95	0.06	0.91
Bayou Meto — Lower Arkansas	0.72	0.15	0.50	0.35
Big Creek	0.06	0.91	0.53	0.32
Black — Upper White	0.84	0.07	0.88	0.04
Cache	0.96	0.01	0.88	0.04
L'Anguille	0.41	0.46	0.42	0.45
Little River Ditches	0.15	0.79	0.17	0.75
Lower St. Francis	0.58	0.27	0.20	0.72
Lower White	0.42	0.44	0.43	0.44
Lower White — Bayou Des Arc	0.90	0.03	0.53	0.32

Climate Variables

In the northernmost watershed, the Cache, there was no correlation between waterfowl population numbers and winter climate data (Table 5). However, Mallard numbers and summer temperature were correlated. As summer temperature increased, so did Mallard population numbers.

In the Bartholomew watershed, I found the same pattern. No significant relationship in the winter data, but a moderate relationship between Mallards and summer temperature. However, in this area when temperature increased, Mallard abundance decreased. In the Bayou Meto Watershed (Table 5), the southernmost study site, I found no relationship between climate and waterfowl abundance for either season. There is no indication that winter climate is a strong

indicator of waterfowl populations in any watershed, but there could be a slight influence from summer temperature, especially on Mallard numbers. In the Cache watershed, waterfowl abundance increased when average summer temperatures exceeded 81.5°F (Figure 6). In contrast, Bayou Bartholomew decreased when temperatures rose above this threshold. Bayou Meto showed no response.

Table 5: Cache watershed climate data from a station located in Jonesboro, AR. Regression statistics between Mallard and Ducks vs Temperature and Precipitation are included for the summer season (June-August) and winter season (November-February). Significant values highlighted.

	Winter		Summer	
	correlation	P value	correlation	P value
Mallard vs Temp	-0.09	0.76	0.58	0.04
Duck vs Temp	-0.08	0.78	0.42	0.15
Mallard vs Precip.	-0.26	0.39	-0.53	0.06
Duck vs Precip	-0.21	0.49	-0.41	0.17

Table 6: Bartholomew watershed climate data from a station located in Monticello, AR. Regression statistics between Mallard and Ducks vs Temperature and Precipitation are included for the summer season (June-August) and winter season (November-February). Significant values highlighted.

	Winter		Summer	
	correlation	P value	correlation	P value
Mallard vs Temp	-0.31	0.30	-0.56	0.05
Duck vs Temp	-0.32	0.29	-0.33	0.27
Mallard vs Precip.	0.25	0.40	0.03	0.92
Duck vs Precip	0.27	0.38	-0.24	0.43

Table 7: Bayou Meto watershed climate data from a station located in Stuttgart, AR. Regression statistics between Mallard and Ducks vs Temperature and Precipitation are included for the summer season (June-August) and winter season (November-February).

	Winter		Summer	
	correlation	P value	correlation	P value
Mallard vs Temp	-0.01	0.98	0.40	0.18
Duck vs Temp	-0.03	0.93	0.17	0.57
Mallard vs Precip.	-0.05	0.87	-0.39	0.19
Duck vs Precip	-0.12	0.69	-0.44	0.13

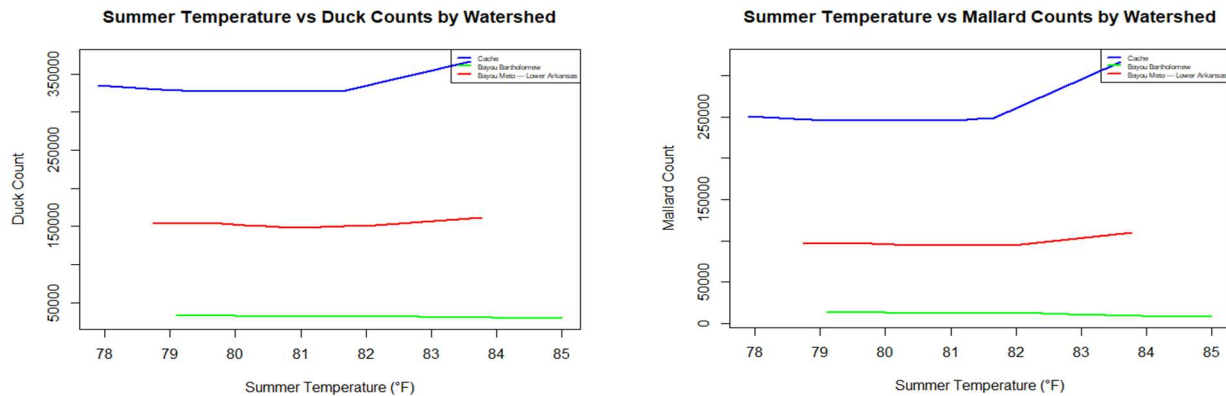


Figure 6: The relationship between summer temperature and waterfowl abundance. Duck population on the left and mallard population on the right.

Mixed Variables: Climate and Land Cover

I chose the two variables with the highest correlation in previous models, summer temperature and wetland cover, and regressed them against waterfowl population numbers (Table 8). As expected, the Cache watershed was the only study site that showed a significant correlation but notably is explaining 15% more of the population changes in Mallards than in ducks based on the R^2 values.

Table 8: Multiple Regression statistics for Summer Temperature + Wetlands vs Waterfowl Populations. Significant p values are highlighted.

Watershed	Duck R^2	Duck P Value	Mallard R^2	Mallard P Value
Bayou Bartholomew	0.15	0.44	0.31	0.16
Bayou Meto — Lower Arkansas	0.15	0.45	0.34	0.13
Cache	0.54	0.22	0.69	0.003

CHAPTER FOUR DISCUSSION

Regional Declines and Spatial Redistribution

Overall, there was a decline in waterfowl populations in the ARMAV for both Mallards and other duck species. However, certain watersheds exhibited growth in waterfowl numbers. This indicates that some waterfowl choose to change locations during their winter migration. My research shows that birds are wintering further north at the landscape level, but here at the regional level, this is not the case within the ARMAV. The watersheds that are showing growth in waterfowl numbers are not necessarily the watersheds that are farther north. The southernmost watersheds, Bayou Bartholomew and Mayou Macon, show the largest increases in waterfowl numbers along with a few watersheds in the northeast. The spatial redistribution of waterfowl in the ARMAV cannot be directly tied to direction alone.

Limited Role of Rice Agriculture

My correlational study showed little influence from rice agriculture on waterfowl distribution. There was no correlation for any watershed within the ARMAV, even with large increases in rice land cover in watersheds such as Bayou Bartholomew. This was an unexpected outcome because rice is known as an important source of winter foraging for waterfowl. I hypothesized that there would be a large correlation with waterfowl numbers. My findings contrast with the findings from other studies that identify rice land cover as an important component of wintering waterfowl habitat at broad spatial scales (Herbert et al., 2021; Williams et al., 2014). My outcome suggests that annual rice availability does not necessarily equal habitat

suitability. The influence of rice cover is dependent on other geographical and hydrological variables that my study does not consider, especially at the watershed scale.

My study relied on an annual average of rice land cover from the USDA cropland data. It compiles data from the entire growing season; it does not show rice land cover during winter migration periods alone. My study did not take agricultural practices into consideration such as leaving leftover rice untouched in fields after harvest or flooding fields to create areas that mimic natural wetlands, creating habitat for waterfowl. These are actions that Arkansas Game and Fish encourage to manage duck populations (AGFC, 2026). However, rice land cover is valuable in increasing waterfowl populations only as a replacement for missing wetlands (Vest et al. 2023).

Variable Influence of Wetlands

I found a strong, if variable, wetland influence on waterfowl populations for both Mallards and ducks. What is interesting is that most watersheds showed strong negative relationships, but one showed a strong positive relationship, the Black-Upper White watershed. In five of the wetlands, there was no correlation, in five of the watersheds there was a negative relationship and in one watershed there was a positive relationship. My results contradict my original hypothesis that wetland cover would be a key variable in all watersheds, and that southern watersheds would have a more significant relationship between land cover and waterfowl abundance. The southernmost watersheds provided no indication of a correlation to wetlands.

Wetlands are important habitats for waterfowl, but my results suggest that habitat quality may play a large role in the patterns observed in populations in the ARMAV. Ducks prefer

shallow, food rich wetland areas to winter near. Wetlands taking up more space in the region does not mean that the wetlands are attractive to waterfowl. If the wetlands are too deep during the migration period, for example, this may cause waterfowl to redistribute to a different area. Food availability, visibility, and types of vegetation could also play a part. The Black-Upper White watershed showed the opposite. The pattern here is that as wetlands increase, waterfowl populations increase. Perhaps the wetlands that are increasing in the region are also good quality habitat for migrating birds. Wetland quantity alone is not enough to correlate all watersheds to waterfowl populations.

Combined Effects of Land Cover

When wetland cover and rice cover were evaluated together there was evidence for strong explanatory power, but the result was highly variable. The Cache watershed had the highest R^2 , showing that 96.4% of the duck population variability was explained by those two land cover variables. The relationship between Mallards and land cover was also strong but 8.4% lower than for ducks in general. The Black-Upper White showed a strong correlation for Mallards and the Lower White- Bayou Des Arc had a strong correlation for ducks. All three of these watersheds were in the northwest section of the ARMAV. These findings were consistent with previous work demonstrating the importance of wetlands and agricultural land cover in shaping waterfowl distribution (Herbert et al., 2021; Williams et al., 2014). The combined land cover variables had no correlation with waterfowl in any other watershed. Differences in landscape configuration change the relationship (Masto et al., 2024). In the Cache watershed, wetlands alone were strongly and negatively related to waterfowl, while rice alone had no effect. However, when rice and wetlands were analyzed together, a strong association to waterfowl

abundance was clear, suggesting that ducks respond to the combination of habitats rather than either one individually. Agriculture and wetlands are known waterfowl limiting factors and are used to estimate the spatial energy capacity of a region, but it is extremely difficult to obtain sufficient data for the models to work at the regional scale (Williams et al., 2014).

Weak Influence of Winter Climate

Contrary to my expectations, there were no significant relationships between waterfowl and winter temperature or precipitation in any watershed. This differs from broader spatial studies done at the flyway level (Zhao et al., 2016). This could indicate a few things. One possibility is that the ARMAV is relatively stable when it comes to climate. There are few extremes during the winter, making these variables non-explanatory. Another possibility is that there could be a lack of data with only three study sites selected. If I had analyzed more sites within each watershed or more sites within different watersheds perhaps a correlation could have been found.

Influence of Summer Climate

Although winter climate showed little effect on waterfowl abundance, summer temperature exhibited a moderate relationship with Mallard abundance in two of the three study sites. Interestingly, the direction of this relationship differed between watersheds, with a positive correlation in the Cache watershed and a negative correlation in Bayou Bartholomew. In the Cache watershed, higher summer temperatures were associated with increased Mallard abundance. In Bayou Bartholomew, higher summer temperatures corresponded to decreased Mallard abundance.

What these results potentially indicate is that Mallards are “short-stopping”. Migratory practices of waterfowl are highly influenced by temperature; when summer temperatures are increased this leads to Mallards not going any farther south (Cox et al., 2023). The Cache watershed is in the northern part of the ARMAV. Bayou Bartholomew is in the southernmost part of the ARMAV. Elevated temperatures may reduce the extent of southward migration, resulting in fewer Mallards reaching more southern portions of the flyway. This means that abundance increases in northern areas while declining in southern regions, producing a positive relationship with temperature in the north and a negative relationship in the south. The Bayou Meto- Lower Arkansas watershed seems to be insulated from the summer climate variables, showing no correlation for ducks or Mallards.

Implications for Management

The results of my study have several important implications for waterfowl management in the ARMAV. First, the strong and consistent influence of wetlands highlights the importance of wetland conservation, restoration, and management as primary tools for supporting waterfowl populations. Successful wetland restoration can take 50-100 years in the ARMAV, but it has been shown to be successful in two study sites in Bayou Bartholomew (Sheldon et al., 2016). Its importance in waterfowl abundance suggests that more programs for increasing wetland areas that have been lost to cropland should be a central focus for organizations working to improve future population numbers. However, wetland area alone is not enough. Efforts should focus not only on increasing wetland area but also on improving hydrologic management and habitat quality.

Second, the lack of a strong relationship between rice cover and waterfowl abundance suggests that agricultural practices alone may not sustain populations without proper water management. Programs that incentivize flooding of rice fields during winter may be more effective than expansion of rice acreage alone. Arkansas Game and Fish currently pays farmers not to till their rice fields in the fall and to flood them with surface water, citing that flooded rice fields provide 11% of the food energy mallards receive from the area. When rice fields are tilled, the leftover waste rice is buried and made unavailable to migrating waterfowl (AGFC, 2026). My findings support the expansion of this new program.

Last, the spatial variability in the correlations between all the analyzed variables is important. There is not a one size fits all program for waterfowl conservation. At the regional level, individual watersheds must be managed differently based on their distinct habitats and microclimates. More research needs to be done, especially in the watersheds where I found no correlation between waterfowl abundance and land cover or climate variables (Figure 8).

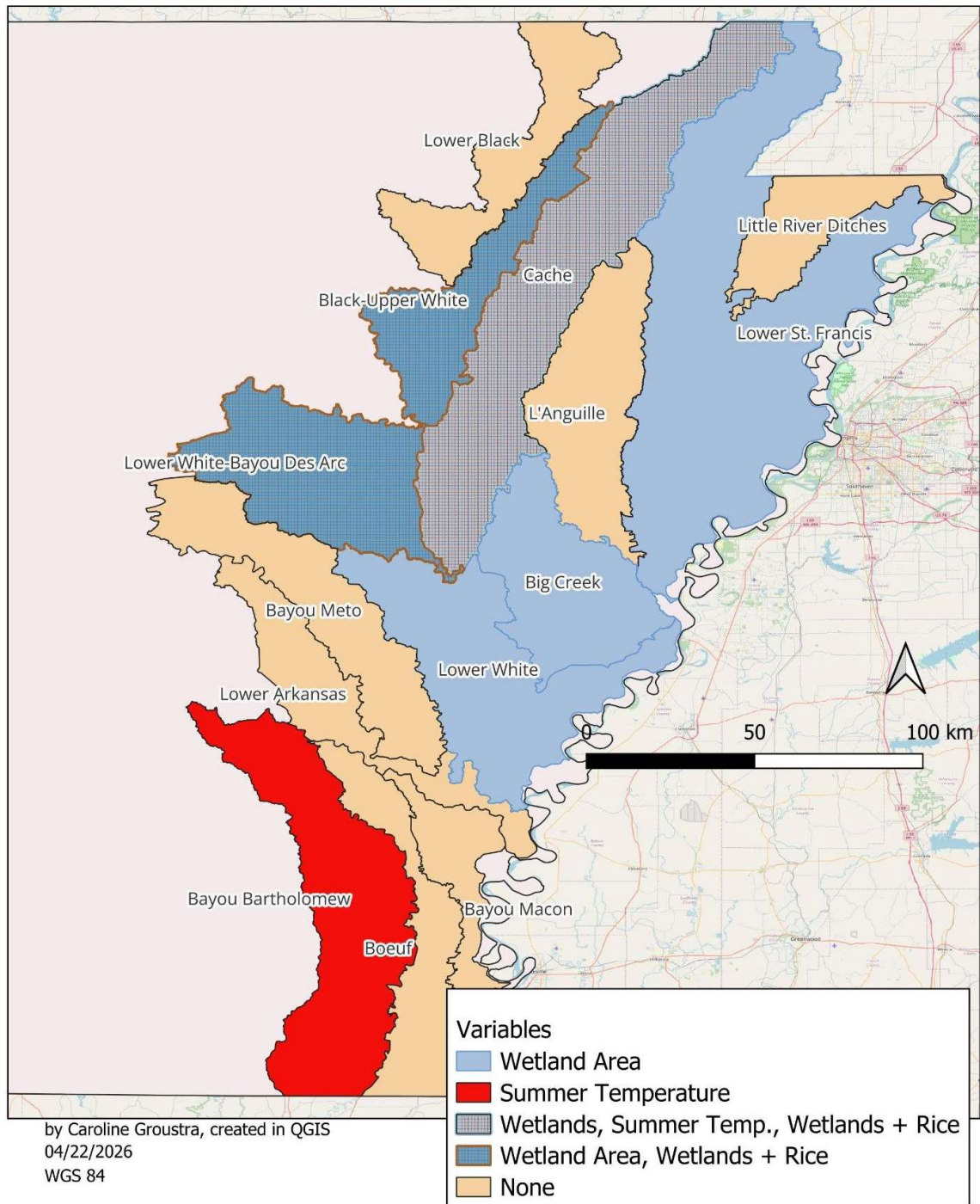


Figure 7: Map of variables that were found to show evidence of correlation within each watershed.

Limitations and Future Research

The Arkansas Game and Fish Commission has only been surveying waterfowl populations for 12 years. The relatively short study period (2012–2024) may not capture longer-term climate trends or population cycles. Also, the use of watershed-scale averages may obscure fine-scale habitat use and local variability. Watersheds have very different sizes and shapes that could include various microclimates. Future research should incorporate higher-resolution habitat data, including flooding regimes and wetland quality metrics, as well as longer time periods to better assess climate effects. Expanding analyses to include additional environmental variables such as habitat disturbance, hunting pressure, and water availability could further improve understanding of waterfowl population dynamics.

CHAPTER FIVE

CONCLUSION

I examined the relationships between rice land cover, wetland land cover and climate variables to wintering waterfowl abundance across the ARMAV. My results indicate that population numbers for all waterfowl declined in the ARMAV during the 2012 to 2024 study period, although some watersheds showed increases in population numbers. This points to spatial redistribution of wintering waterfowl. Wetland cover showed the strongest and most consistent association to waterfowl across the ARMAV, though the strength and direction of the relationships changed based on watershed. This variation suggests that wetland cover alone is not the only driver of waterfowl populations in the ARMAV. Rice land cover showed no correlation to waterfowl abundance even with large increases in every watershed over the 12 years of the study. However, the existence of rice fields is not a good indicator of waterfowl populations because my study did not include any data on planting seasons and field flooding practices. I urge further research into these relationships. Climate variables exhibited limited association to waterfowl abundance, showing a correlation for Mallards and summer temperature only. This result potentially signifies that short stopping is occurring in Arkansas. Mallards are not migrating as far south based on temperature.

Overall, my results demonstrate that relationships between environmental variables and waterfowl abundance in the ARMAV are spatially variable across watersheds. No single variable explained the patterns of abundance across the study area. Future research should include more nuanced predictor variables, longer periods of time and finer scaled habitat data to clarify these relationships.

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APPENDICES

APPENDIX A

QGIS Workflow for extracting Wetland Area Analysis

I used the following steps to derive wetland area estimates within the Arkansas Mississippi Alluvial Valley (ARMAV) study extent using National Land Cover Dataset (NLCD) data and spatial analysis tools.

1. NLCD Data Acquisition: The National Land Cover Dataset (NLCD) for the selected study year was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium.
2. Study Area Clipping: The NLCD raster was clipped to the ARMAV study boundary using a spatial mask to ensure analyses were restricted to the study boundary.
3. Wetland Classification Extraction: Wetland land cover classes were extracted using the raster calculator. NLCD classes 90 (Woody Wetlands) and 95 (Emergent Herbaceous Wetlands) were selected and combined into a single wetland layer.
4. Zonal Statistics by Watershed: Zonal statistics were calculated using 8-digit Hydrologic Unit Code (HUC-8) watershed boundaries. Wetland area was summarized within each watershed and extracted to a spreadsheet for analysis.

Reference for Dataset: U.S. Geological Survey. (n.d.). National Land Cover Database (NLCD). Multi-Resolution Land Characteristics Consortium. <https://www.usgs.gov/>