# Impact of reduced flooding on herpetofauna in a TPWD bottomland

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*Abstract*: Floodplain forests are among the most threatened habitats in North America. We used the species richness, ranked abundance, and diversity of amphibians and reptiles to assess the effects of flood suppression at the Old Sabine Bottom Wildlife Management Area (OSBWMA) in Smith County, Texas, USA. Amphibians and reptiles were surveyed using visual surveys, cover boards, and with minnow traps at ephemeral pools: in undisturbed bottomland forest, in maintained openings, and a bottomland hardwood regeneration site (Baker Tract). We observed a total of 3343 amphibians and reptiles representing 45 species in 2007 through 2009 (sample period two) whereas 2280 records of 42 species were made in 1998 and 1999 (sample period one). Species diversity indices and rarefaction adjusted richness were not different between years of sample period one (1998-1999) and years of sample period two (2007-2009) but

community comparison indices indicated that changes occurred for some species. The ranked abundance of each species was compared to their ranking in the datasets of each sample period. The number of southern leopard frogs increased and the number of small-mouthed salamanders decreased during sample period one. Turtles and lizards did not vary much between sampling periods. Terrestrial snake species such as king snakes and earth snakes became more abundant in the later period. We used GIS to assess how collections of amphibians and reptiles differed in a year with reduced (less winter) flooding to one with a more normal (winter) flood pattern. Overall, the presence of amphibians varied according to the flooding patterns and these animals were restricted to more permanent water if the floods were reduced. The change in the herpetofaunal communities suggests that changes in flooding have a measurable affect on the surveyed makeup of amphibians and reptiles in this floodplain. One caveat, however, is that during the same period, hog activity increased dramatically and may have had impacts on the same fauna in ways that cannot be interpreted with this data.

## INTRODUCTION

Bottomland hardwood forests are among the most important ecosystems in the southeastern United States due to their high biodiversity and productivity, yet are also one of the most threatened habitats (Junk et al. 1989; Bayley, 1995; Tockner and Stanford, 2002). These ecosystems are important as habitats for a variety of plants and animals due to the episodic disturbances of flood pulses (Sparks et al. 1998; Tockner et al. 2006). The high resource availability of deposited nutrients provides an energy base that serves as a resource for a wide variety of organisms adapted to the cyclic disturbances (Swanson et al. 1998; Ostfeld and Kessing 2000; Kozlowski, 2002). Reservoir development have caused this forest type to suffer the greatest losses of any wetland habitat in the United States (Bayley, 1991; Ozesmi and Bouer, 2002). In Texas, it is estimated that 60% of the original bottomland hardwood habitat has been lost (Graham *et al*., 1997; Stallins, et al., 2010). Direct losses of habitat are often due to reservoir construction, which flood the sites, but additionally, downstream flood suppression can alter the floodplain ecosystem such that it no longer functions naturally (Graf, 2006; Hampton and Ford, 2007).

The construction of dams and the regulation of river flows alter or reduce flooding regimes and cause significant negative effects to bottomland floral and faunal communities (Brinson, 1993; Nilsson and Berggren, 2000; Graf, 2006). The periodic flooding associated with bottomland hardwood forests normally deposits a large nutrient subsidy in the form of organic material which then translates into a high biotic production (Bayley, 1995; Ostfeld and Keesing, 2000). The flooding also increases the diversity of flora and fauna in this habitat due to the intermediate disturbance phenomenon which creates niches that would otherwise not exist (Kozlowski, 2002; Sparks, 1995). The nutrient input therefore translates into significant prey availability for bottomland carnivores including herons, raccoons, bobcats, amphibians, turtles and aquatic snakes (Finger, *et. al*., 1987; Hampton and Ford, 2007). This is a bottomup ecosystem control mechanism that allows more trophic levels to exist. Therefore floodplains have both high biomass and also high diversity.

One of the most unique and complex aspects of the ecology of bottomland hardwood floodplains is the adaptation of the species to the variable nature of the flood pulses (Benke, et al., 2000; Osfield and Keesing, 2000). The timing and duration of floods are unpredictable and therefore the animals living there have evolved the ability to adjust to the variation in nutrient availability (Poff et. al, 1997). The absence of floods can decrease the organic material deposited in the ecosystems changing plant growth and reducing species that feed on the detritus such as macroinvertebrates (Hupp, 1990; Graf, 2006). The suppression of floods can therefore decrease biodiversity indirectly up the food webs (Krebs 1985; Brawn et al. 2001; Elderd 2006; Marston et al. 2005). Consequently, a conservation concern for this ecosystem is the impact of flood suppression and alteration of flood regimes caused by reservoirs constructed upstream of bottomlands (Sparks, et al., 1998, Tockner et al., 2006). These artificial lakes act as sinks for nutrients and have also altered the dynamic processes in which the floodplain habitats have evolved. Intermediate size, short-duration and seasonalfloods have been replaced with fewer but sometimes larger scale flood events especially during periods of climatic extremes (Figure 1). How the change in flood pulses have impacted the ecology of organisms of bottomland forests has rarely been examined.

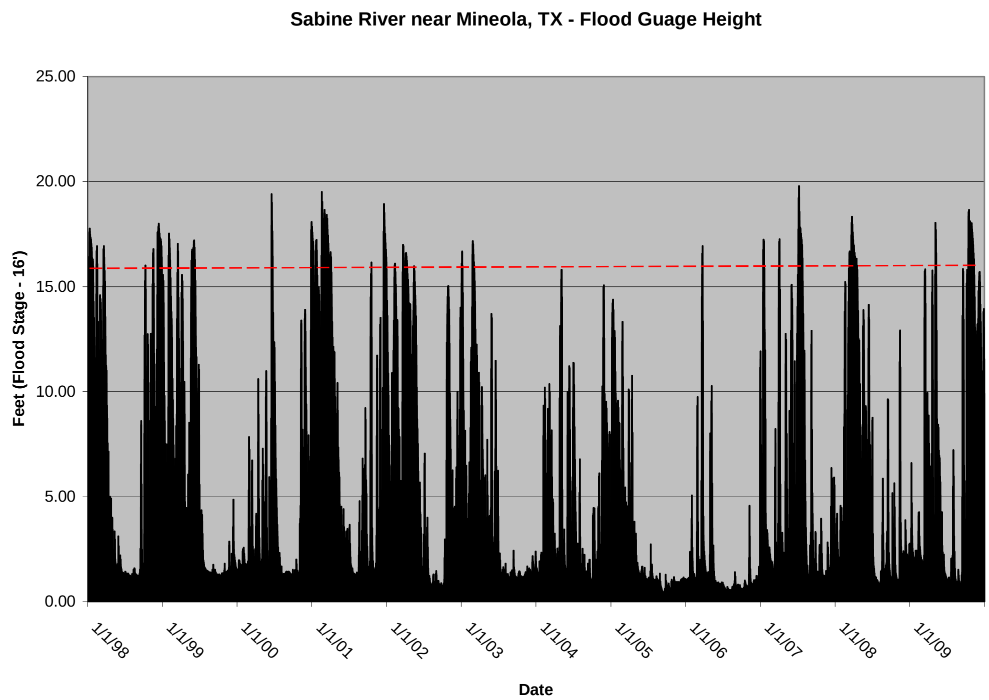



Figure 1. Flood characteristics as recorded at a gage on the Sabine River near Mineola just above the OSBWMA. Note multiple floods in the winters of 1998 and 1999; the drought in 2004 to 2006 and the smaller duration floods of 2007 and 2009.

Due to their complex and environmentally driven life histories, amphibians and reptiles are often studied as indicators of wetland health (Christy and Dickman, 2002; Conant and Collins, 1998). Reptiles and amphibians may also constitute much of the biomass in bottomlands and are important members of those communities (Duellman and Trueb, 1986; Zug et al., 2001, Tockner et al., 2006). The herpetofaunal assemblage is therefore a major factor in ecosystem structure and function, and studying changes in dviersity and abundance of amphibians and reptiles can lead to conclusions about how outside factors have modified these habitats. Globally, amphibian and reptile populations have been declining for several decades (Stuart et al., 2004). The loss of bottomland floodplain habitat is one of many factors that is believed to be a cause of those declines (Tockner et al., 2006).

This project investigated how the variations in flood pulses (Figure 1) that have occurred in the last decade at the Old Sabine Bottom Wildlife Management Area (OSBWMA) have affected the diversity and abundance of amphibians and reptiles there. This WMA is a 5727 acre (2318 ha) bottomland hardwood forest in Smith County that is part one of the largest bottomland forest tracts remaining in east Texas. It is characterized by periodic flooding from the upper Sabine River and Lake Fork Creek and two associated large reservoirs upstream, Lake Tawakoni and Lake Fork (Figure 2). The water levels at Lake Fork (403 msl) are regulated in order to prevent flooding of lakefront property via five tainer floodgates and spillway that can release up to 81,900 cfs, whereas the Iron Bridge Dam at Lake Tawakoni (437.5 msl) has an uncontrolled spillway of 480 feet that has a maximum designed release of 50,000 cfs.

Intensive surveys were conducted by the PI in 1998 through 2000 in which normal seasonal flood pulses (5 or 6 floods per winter) occurred (Ford, 1998; 1999). From 2004 to 2006 flooding of the management area was severely reduced (1 short event) because of drought conditions and the subsequent altered releases of water from Lake Tawakoni and Lake Fork. One of these two reservoirs (Lake Tawakoni) currently supply water for municipal use and water consumption is predicted to increase dramatically in the next decade. The other reservoir (Lake Fork) is expected to come online over the next five years. A comparison of the current herpetofaunal makeup to that which occurred in the first surveys (sample period one) should give insight into how reduced flooding has impacted the species of this bottomland (sample period two) and suggest what future change may occur due to reduction in flooding. Specifically, this study will indicate changes in the makeup of the amphibian and reptile community by determining which have declined or disappeared and which have increased in number.

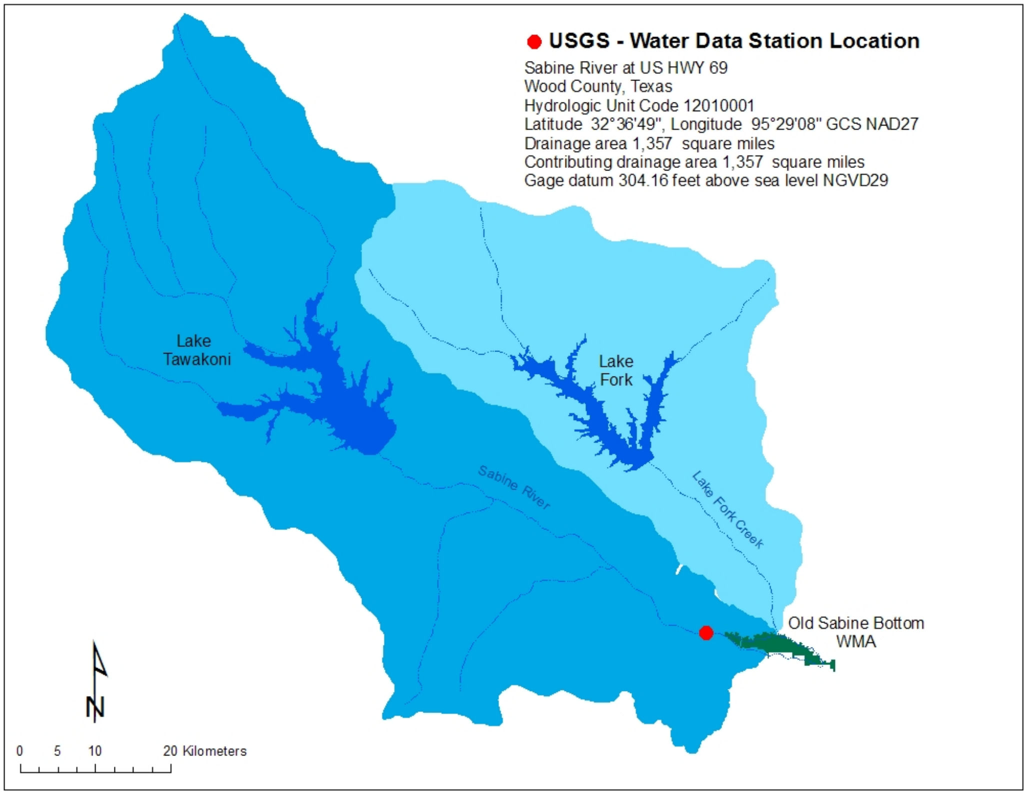



Figure 2. The upper Sabine River basin and Lake Fork Creek watersheds. Includes the locations of Lake Tawakoni and Lake Fork in relation to the OSBWMA and the USGS gauging station where flood data was taken.

## BACKGROUND

Natural floodplains are dynamic ecosystems with flood regimes as the primary agent of control. Their high species diversity and landscape-corridor function place the conservation of floodplains as high priority. As with other natural habitats, modifications in bottomland forests, such as a change in flooding pattern, can reduce fauna richness and abundance of terrestrial vertebrates (Clawson *et al*., 1997; McLeod and Gates, 1998;

Harrison and Kilgo, 2004; Heltzel and Leberg, 2006). On the other hand, such alterations may not affect or may even benefit some species. Since species may respond differently to various habitat changes, it is important for management practices to evaluate which strategies are advantageous or detrimental to species of concern. In addition, because of varying species' responses to alterations, evaluation of taxa that cover a broad physiological and ecological spectrum can help determine more accurately the status of the habitat. Because changes to natural habitat can alter the species abundance within a community, the health of an ecosystem is commonly assessed by evaluating assemblages (Harrison and Whitfield, 2004; Arand *et al.*, 2005). Amphibians and reptiles are ideal indicators of habitat quality because many of their physiological functions are dependent upon various aspects of their environment (Burton and Likens, 1975; Stevenson *et al*., 1985; Vitt *et al*., 1990; Wake, 1991). Further, these species represent a significant proportion of biodiversity and are often reported at very high densities (Burton and Likens, 1975), allowing detectable changes in density during comparative studies.

The purpose of this study was to investigate impacts of reduced (altered) flood regimes in a bottomland hardwood forest by assessing the amphibian and reptile communities in this floodplain. This project will investigate how the changes in flood pulses that have occurred between the two study periods at the Old Sabine Bottom Wildlife Management Area (OSBWMA) has affected the diversity and abundance of amphibians and reptiles there. A comparison of the herpetofauna currently present should give insight into how a lack of flooding impact the species of this wetland. Specifically, this study will indicate which amphibians and reptiles have declined or disappeared and which have increased in number.

The formation of ephemeral pools in floodplains serves as a high yield but variable resource patch for many species of herpetofauna. The pools left by the receding floodwaters are nursery areas for invertebrates, fish and larval amphibians. Some species of snakes often gorge themselves at drying pools with as much food as they can consume. Because temporal aspects of this resource are dependent on the timing of flood pulses, the variability in that process produces variation in the timing and types of food for amphibians and reptiles each year (Hampton and Ford, 2007). For example, in a year with early flooding, frog tadpoles and salamander larva may do extremely well. In a normal year (Figure 3) in which spring rains are high, other species of amphibian do well in the pools. Those differences also influence the success of snakes that forage on aquatic prey. Understanding how the individual species of amphibians and reptiles respond to different levels of flooding will help us understand how wildlife in bottomland forests, such as the OSBWMA, will be changed due to the impact of reduced yearly flood regimes.

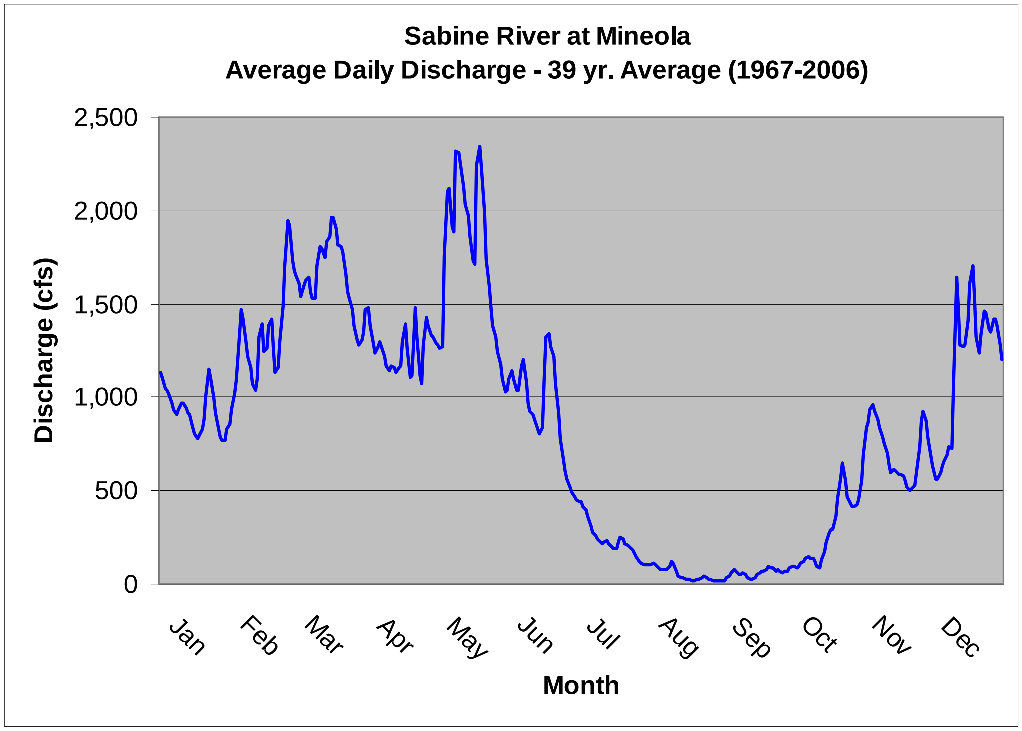



Figure 3. Season flooding on the Sabine River at Mineola above the OSBWMA based on average daily flow in cubic feet per second from 1967 to 2006. Note the seasonally dry summer and early fall from July to September and the wet winter and spring from November to June. April and May represent the highest flood potential based on this 39 year average.

WILDLIFE PRIORITIES

The piney woods ecoregion is listed in the Tier II of priority in the Texas Comprehensive Wildlife Conservation Strategy Wildlife Action Plan. In particular, the rapid growth of the human population of the area is seen as a problem. Bottomlands in the area have low conservation protection both because they are rare and the high likelihood of them being impacted by floodplain alteration including clear cuts, channelization, levee construction and the building of reservoirs. Several species of amphibian and reptile found at the OSBWMA are listed as state threatened (Timber rattlesnake, *Crotalus horridus* and alligator snapping turtle, *Macroclemys temmincki*) or species of concern (Gulf coast waterdog, *Necturus beyeri*).

MANAGEMENT IMPLICATIONS

Texas Parks and Wildlife management areas are holistically managed for wildlife restoration but studies on the effects of alteration of habitats on non-game species are rare. Changes in the non-game species may be important to understand both from the point of conservation of specific nongame species but also because they may have impacts on other species and total species diversity. The sloughs, oxbows, ponds and temporary pools at the Old Sabine Bottom WMA are an essential resource for much of the terrestrial fauna that occur there including salamanders, frogs, snakes, and other vertebrates (Doles, 2000; Hampton and Ford, 2007). The surrounding terrestrial habitats are also dependent on large influxes of organic material during flooding events. The survival of these habitats is influenced by the variable flooding patterns related to seasonal rainfall in the basins and the timing of water release from upstream reservoirs. The unpredictable nature of ephemeral pools and streams is a natural part of the bottomland forest and how the animals at the OSBWMA change in response to reduced flooding is important to understand to determine how management practices might help species dependent on habitats maintained by flooding. For example, wood ducks are often protected from predators like rat snakes during flood events in floodplains (Carfagno and Weatherhead, 2009, Roy Neilsen and Gates, 2007). For many aquatic and terrestrial vertebrates, some of which are of conservation concern, bottomland hardwood forests are essential sites for mating, oviposition, and offspring growth (Pashley and Barrow, 1993; Semlitsch *et al*. 1996). Investigation of non-game species may be helpful in evaluating the effects of habitat alteration on less conspicuous communities.

# METHODS

STUDY SITE

The Old Sabine Bottom Wildlife Management Area (OSBWMA) consists of 5,727 acres (2318 ha) and is located approximately 5 km northeast of Lindale, Smith County, Texas (Figure 4). The northern border of the study area is defined by the Sabine River, which runs through 21 counties in northeast Texas and ultimately drains into the Gulf of Mexico. The Old Sabine Bottom WMA is part of one of the largest contiguous hardwood forest tracts remaining in Texas. Bottomland hardwood forests make up only 1.1% of the land in the state of Texas (Benforado 1985). The majority of the OSBWMA has not been altered since 1940. Dominant tree species include: water elm (*Planera aquatica*), several oak (*Quercus*) and hickory (*Carya*) species, green ash (*Fraxinus Pennsylvanica*), sugarberry (*Celtis laevigat*)*)*, and cedar elm (*Ulmas crassifolia*). (Alden, 1998). Approximately 795 acres (321.7 ha) of the study area exists in an early successional bottomland or grassland / shrub vegetative state with 228 acres (92.3 ha) being managed and maintained in an early state of succession. Approximately 71 % of the successional/grassland habitat was acquired in 2003 when TPWD (Texas Parks and Wildlife Department) obtained ownership of a 568.7 acre (230.1 ha) tract of land on the west side of Farm to Market Road 1804 in Smith County, Texas (Ford et al., 2005). This tract of land (Baker Tract) was acquired by the Department as part of a carbon sequestration project and reforested with bottomland hardwood seedlings in February of 2003. Prior to TPWD acquisition and subsequent restoration project, the historical use of the tract included hay production and livestock grazing. Prominent vegetative species on the tract included a mixture of exotic improved pasture grasses, coastal Bermuda grass

*(Cynodon dactylon)* and bahiagrass *(Paspalum notatum)*. Within two years several native plant species were observed on the tract including greenbriar *(Smilax sp.)*, dewberry *(Rubus trivialis)*, blackberry *(Rubus sp.)*, giant ragweed *(Ambrosia trifida)*, golden aster *(Heterotheca sp.)*, *Eupatorium sp.*, bluestem *(Andropogon sp.)*, goldenrod *(Solidago sp.)*, foxtail grass *(Setaria sp.)*, smartweed *(Polygonum sp.)*, buttonbush *(Cephalanthus occidentalis)*, elm *(Ulmus sp.)*, and common persimmon *(Diospyros virginiana).* Several large pools occur in this area and several species of amphibians utilize these for breeding. This Baker Tract is very similar in stage to the 1804 Grassland site, east of Farm to Market Road 1804, as surveyed in the 1998 and 1999 study period. That area is now in thick shrubs and vegetation and no longer comparable in habitat.

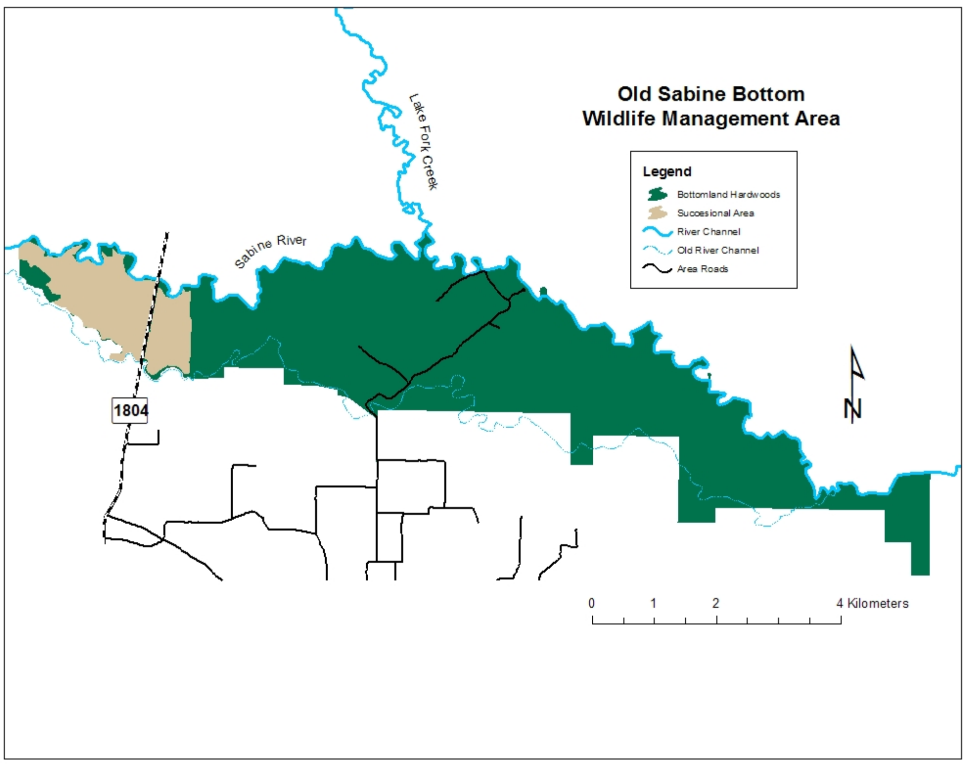



Figure 4. Map of the Old Sabine Wildlife management area. The Baker Tract, west of FM 1804, was substituted for comparison to the 1804 Grassland area, east of FM 1804 for the 2007-2009 study period.

Therefore the Baker Tract was added to the study area and the 1804 Grassland area was deleted from this study second study period (Figure 4).

Within the forested area of the OSBWMA are a number of reclaimed oil pads, which are now maintained in early successional vegetation by annual mowing and disking (Hampton, 2004). Some species of amphibians and reptiles are common in these sites. The sites have strong transitional edges from the mowed habitat to mature forest. There are also three active oil pumps within the forested area of the OSBWMA (Hampton, 2004). Some natural ephemeral pools occur in each of these sites and breeding amphibians and semi-aquatic snakes use these pools (Doles, 2000). The edges of these pads are more gradual with some scrubs and smaller trees phasing into the main forest.

As a result of heavy rainfall, watershed runoff, and overbanking with influence from the opening of floodgates, and spillway overflow, this bottomland forest experiences seasonal flooding from the Sabine River during the winter and spring months (Fig. 3). In general, the pools in the bottomland contain water from mid-December to early June (Hampton, 2004; Hampton, 2007). However, as the frequency of the floods decline the pools still fill with rainwater, but they do not receive the organic material that the floods would bring. In addition, because the surrounding vegetation would normally be suppressed by the standing water, which now is present only for shorter periods of time, a dramatic increase in grasses and shrubby vegetation occurs (Nilsson and Berggren, 2000).

Figure 5. Flood waters at the OSBWMA. These normally occurred in the winter but rare summer floods occurred in 2007.

## Evaluation of flooding patterns: 1998-99 and 2007-2009

The Old Sabine WMA often floods several times each winter if the watershed experiences seasonally normal rainfall (Figure 5). Both water from upstream (the Sabine River from Lake Tawakoni) and from Lake Fork Creek, which enters in the center of the WMA have influence on the extent of flooding (Fig. 2). This flooding is important because several species of the amphibians breed in the pools that form. These pools are full of detritus, which is the nutrient base for both tadpoles of the winter breeding frogs and for invertebrates, which are the food for the larva of winter breeding salamanders. For amphibians, this pattern can influence the numbers that metamorphosis later and therefore affect the numbers of adult amphibians for the next year or several years. This delay in effect on adult populations makes it difficult to look at abundance in particular years as recruitment of metamorphic frogs and salamanders may not occur but the number of adults remain high. Therefore evaluation of changes in numbers over several wet years or after droughts are important to examine. Changes that occur in species or abundance can give insight into longer term effects influenced by variations in flood period, duration, and intensity (Figure 6).

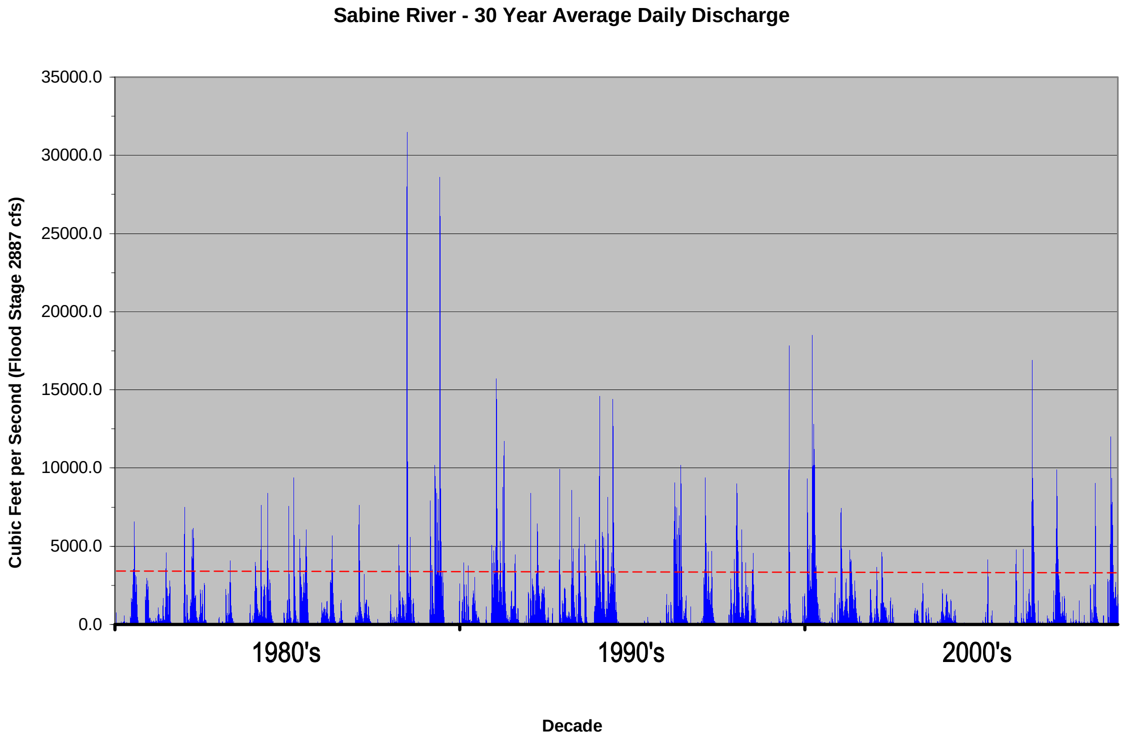
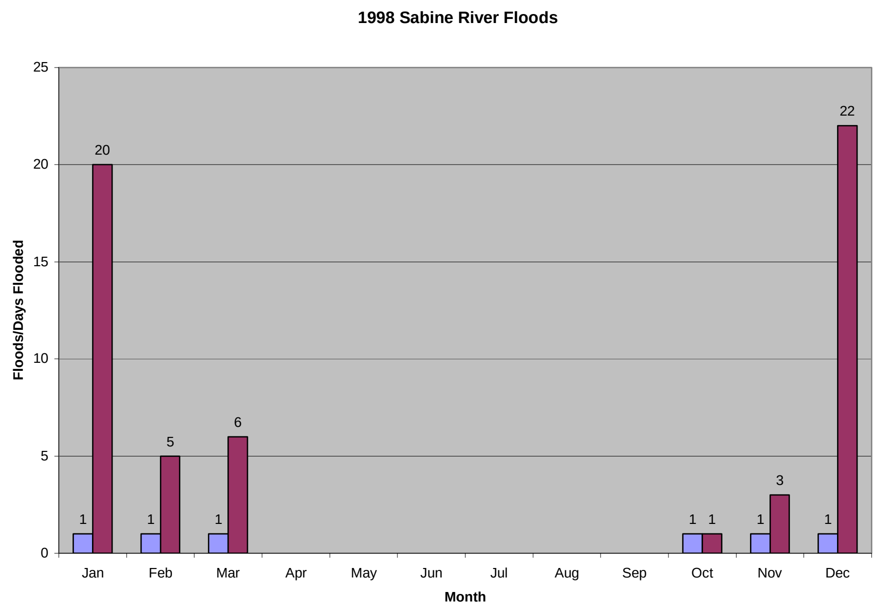



Figure 6. Flooding pattern (average daily discharge at Mineola gage) at the OSBWMA in the 1980's though 2009. The dashed red line is the flood stage for the OSBWMA.

## Sample period one/normal flooding (1998 -1999)

In 1998 the flooding pattern was seasonally normal but high in duration during the winter months and a dry spring (Figure 7). The flooding of the OSBWMA occurred in the late fall and winter which is the normal pattern (Fig. 3). In 1999 the pattern shifted with less rain in the fall thus less winter flooding occurred. A seasonally wet spring also occurred in 1999 causing normal spring floods and more in the late early summer. The overall duration and intensity of the flooding was less but was seasonal in period of occurrence.



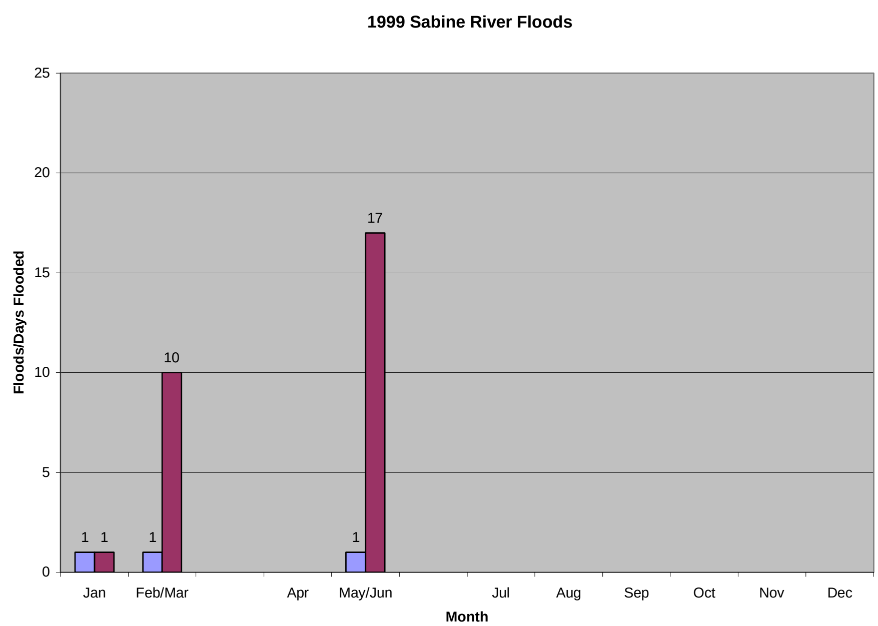




Figure 7. Seasonal flooding patterns at the OSBWMA in sample period one (1998-1999) of this study. Note flooding is in fall and winter the first year and then spring the second.

## Years prior to second sample period

From 2004 to 2006 the East Texas area suffered a prolonged drought of several years and the flooding at the OSBWMA was significantly reduced (Figures 8 and 9). This lack of flooding allowed encroachment of vegetation into areas that normally would have been inundated by water and would have suppressed or killed the vegetation.

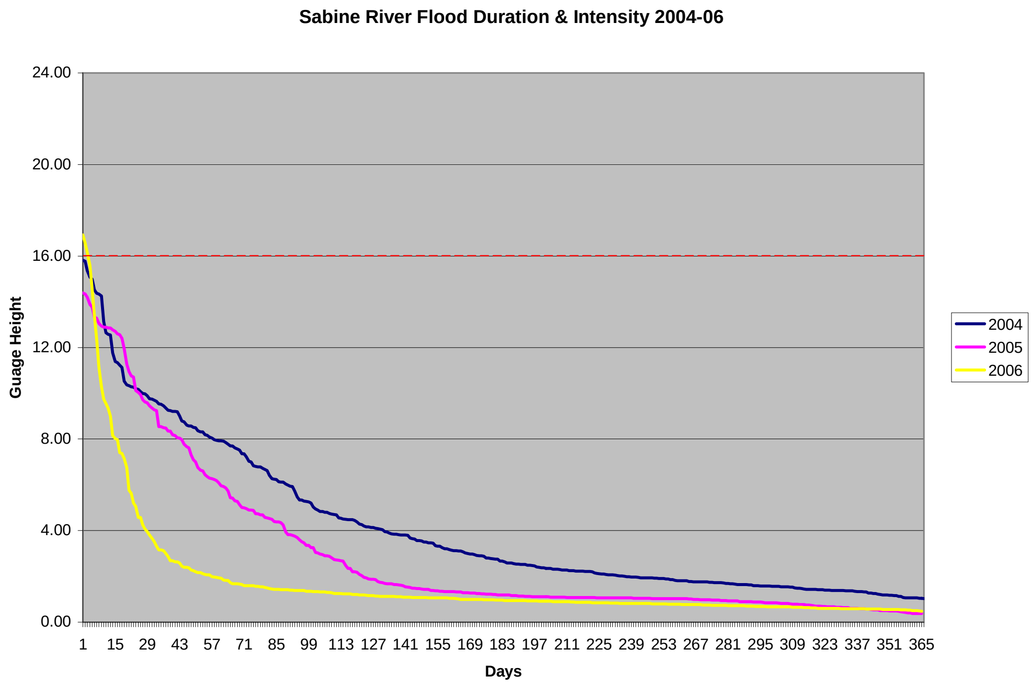



Figure 8. Seasonal flood characteristics at the OSBWMA in the drought years before the second sample period (2007-2009) of this study. The dashed red line is the flood stage for the OSBWMA. Note there were only a few days when floods occurred over the three year period.

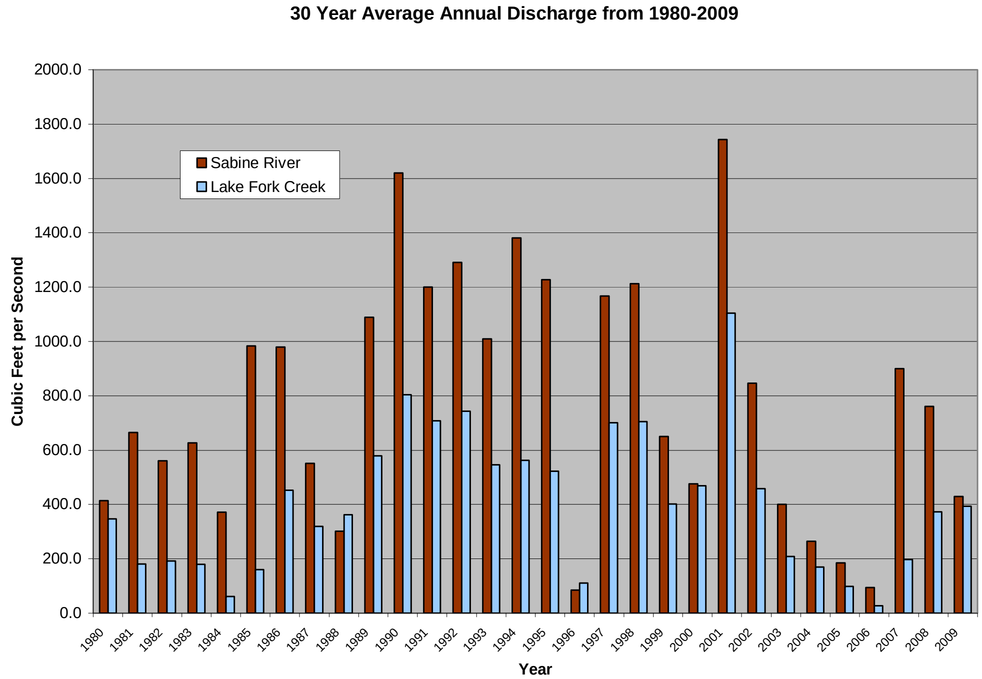



Figure 9. Annual discharge for the two watersheds influencing the OSBWMA. Note the very low discharges levels for 2004-2006. This was the drought prior to the second sample period. Also note the relatively normal levels that occurred in 1997 through the summer of 1999.

## Sample period two/reduced flooding (2007-2009)

During the study years of 2007-2009 the rainfall was quite variable. Falls were drier than usual so less winter flooding occurred. Some of the delay was due to the drought of previous years. However, the spring rains were high which allowed for very unusual summer flooding when high summer rains occurred (Figure 10). These floods caused very different situations for the amphibians as summer breeding species were able to reproduce in large numbers.

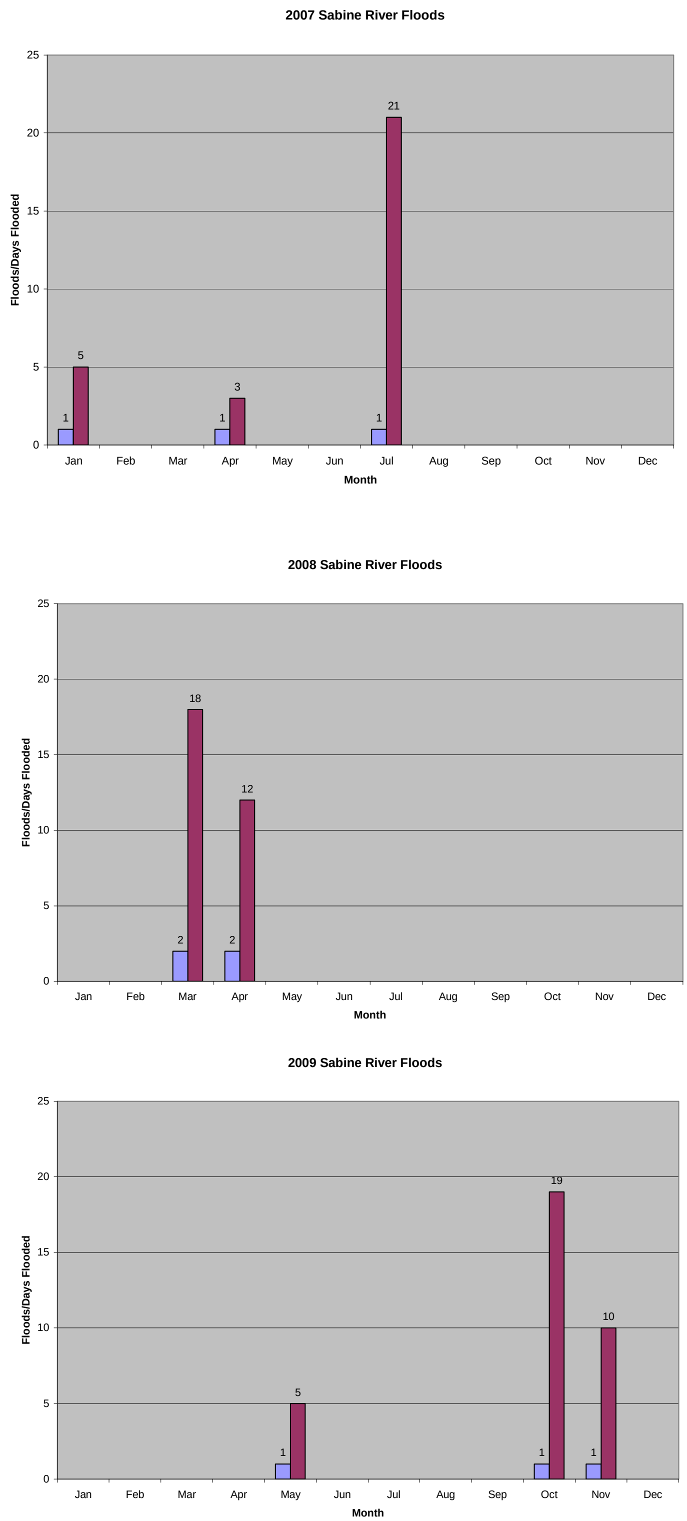



Figure 10. Seasonal flooding patterns at the OSBWMA in the last 3 years (reduced flooding) of this study. Note the seasonal variability; the rare summer flood in 2007 and only flooding in the spring in 2008. One spring and two fall floods occurred in 2009.

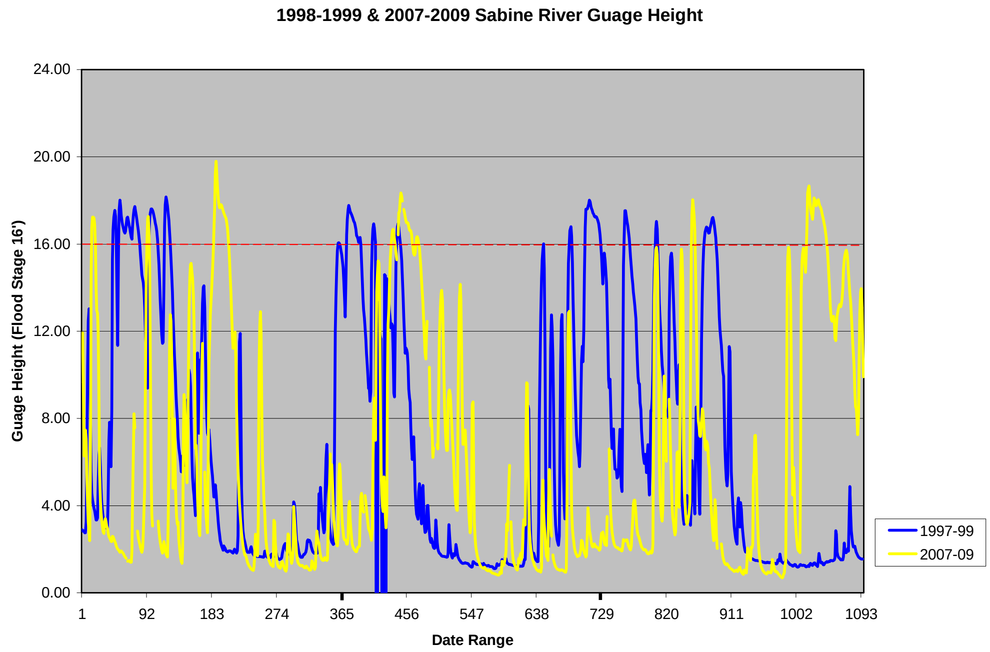



Figure 11. Seasonal flooding pattern at the OSBWMA during the two sampling periods. The blue line is the seasonally normal pattern of 1997-99 and the yellow line shows the highly variable and reduced flooding of 2007-09.

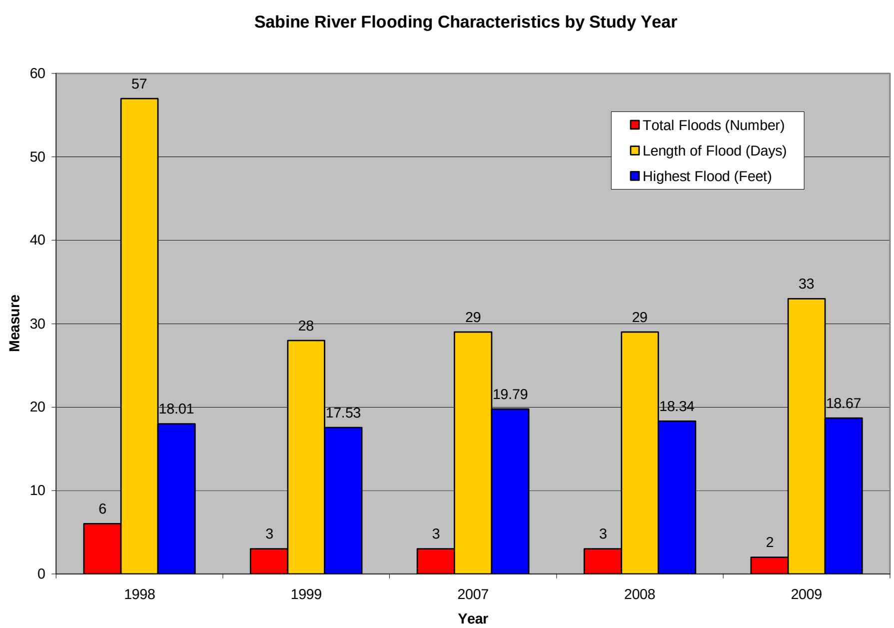



Figure 12. Overall flooding characteristics at the OSBWMA in the 5 years of this study.

## Comparison of two sample periods, 1998-1999 to 2007-2009

We felt that sample period one, the years of 1998 and 1999, had characteristics of years of high to normal rainfall patterns with the periods of flooding falling within the seasonal patterns over the last few decades (Figure 6). We suggest that the drought conditions from 2004-2006 would be similar to the effects of floods suppression as expected to occur with the increased demands on surface water in the upper Sabine River and Lake Fork Creek watersheds. Even though normal rainfall occurred in 2008 and 2009 the release of water from manmade impoundments did not occur until the fall rains had replenished them, changing the nature of the flooding regime making them highly variable (Figure 12). We believe the pattern represented will be occurring more and more often. We therefore considered 1998-1999 to represent a period of normal flooding and 2007-2009 to represent a period of reduced flooding following an extended drought and associated with lower reservoir levels. To determine how the amphibian and reptile populations were responding to these periods of normal flooding and to periods of reduced flooding, we compared species and abundance in the combined years of 1998 and 1999 to the years 2007 to 2009.

# OBJECTIVES

Examine changes in community structure of the herpetofauna - The periodic flooding of the OSBWMA creates multiple ephemeral pools that persist for various amounts of time. However, most of them dry by late July or early August. These pools provide amphibians such as frogs and salamanders with ample food resources and suitable breeding habitats (Petranka, 1998). In addition, various species of fish move into the pools during the floods and many reproduce there. Amphibians (larval, sub-adult, and adult) and fish are commonly utilized prey of various semi-aquatic species of snakes, egrets, herons, owls, raccoons and other carnivorous mammals. In particular, water snakes (*Nerodia sp*.), western cottonmouths (*Agkistrodon piscivorus*), and western ribbon snakes (*Thamnophis proximus*) can be found in large numbers in the vicinities of these pools. Although some amphibian and reptile species are found in the most interior parts of the forest, many of the lizard species of east Texas are edge species that utilize open habitat to thermoregulate. Some species of snakes also utilize edges such as the Texas rat snake (*Pantherophis obsoleta*), which forages on eggs and nestling birds in such habitat. Flooding is known to reduce the ability of this species to predate wood duck eggs. To examine the impact of the change in the habitat due to reduced flooding regimes on the amphibians and reptiles at the OSBWMA, we compared:

1. The species diversity of the amphibians and reptiles from surveys in 1998 and 1999 to those in 2007-2009 substituting the newly acquired Baker tract which had been pasture until February of 2004, for the 1804 grassland area used in the earlier surveys.
2. The ranked abundance of amphibians and reptiles from those same time periods. This will allow examining the change in species community composition as it relates to the different flooding regimes that have occurred recently in the OSBWMA.
3. Examining the change in individual species as it relates to the two periods of flooding patterns in the OSBWMA.
4. GPS location data for the occurrence of the amphibians and reptiles both during years of reduced and normal flood periods in the OSBWMA. This data

will be overlaid on topographic maps of the area to give spatial insight into how the flooding might affect the presence or absence of these organisms.

We assume amphibian and reptile community will have changed both due to the increased vegetation and the lower organic material for their prey and thus any differences will be related to this reduced flooding regime.

# METHODS

Several techniques were employed in the first surveys for reptiles and amphibians and in general they were followed in the current surveys (Ryan *et al*., 2002; Ford and Hampton, 2005).

Cover boards - Cover boards are an effective method for surveying cryptic amphibians and reptiles (Fitch 1992; Grant et al, 1992). Cover boards were placed in all areas and consisted of wooden and metal cover objects (91 x 91 cm) placed around pools, along trails in the forest and in the Baker Tract in lines near the ATV trails (Figure 13). Boards were tied to adjacent shrubs and trees in order to prevent them from floating away during flooding. These cover objects were sampled periodically based on our presence in an area and records of any amphibian and reptile were taken.

Figure 13. Cover boards placed near ephemeral pool at the OSBWMA. Note the large amount of vegetation in this year of reduced flooding.

Aquatic trapping - When sufficient water was present in aquatic habitats in the forest, maintained openings and Baker Tract unbaited minnow traps were placed in the water (not submerged), and covered with vegetation to prevent overheating of animals (Figure 14). When present these traps were checked daily. Hoop and catfish traps were used to collect turtles in both the Old Channel and in the main portion of the Sabine River.

Figure 14. Minnow trap in pool at the OSBWMA.

Visual and time constrained searches - Visual searches were made while checking cover boards, tin, and minnow traps in areas that are either in the pool or on the shore surrounding the pool (Figure 15). We also dip-netted pools that held water to determine presence of amphibian larva and aquatic salamanders.

Figure 15. Visual searching for amphibians and reptiles at the OSBWMA.

Nocturnal surveys - The main road into the WMA plus the side roads 7.3 miles (11.7 km) were driven during appropriate weather and temperatures. Speed was maintained at 15 miles per hour (24 kph) and stops were made to listen for frog calls. Periodically, spotlight surveys of the shores and water of selected pools in the OSBWMA were conducted in order to locate snakes and amphibians that were present. To determine the presence of rare anurans "Frog Loggers" (automated call recorders) were used several times around several pools. However, this equipment was not reliable and so discontinued.

If an animal was collected by any method, we identified it to species and took measurements appropriate for the animal (generally sex, length, and mass). For species that were likely to be recaptured (i.e. snakes and turtles) it was marked for recapture identification (toe-clipped, scale-clipped, or PIT-tagged (Passive Integrative

Transponder). Recaptured animals were only counted once in data analysis. Animals were returned to the place of capture. Because of the morphological similarity and difficulty of capturing each individual lizard (*Eumeces* spp.) during the warmest months, similar sized individuals seen every week under the same cover object were considered recaptures. We estimated the abundance of *Eumeces* spp. by using the number of positively identified (captured) *E. fasciata* and *E. laticeps* from each treatment applied to the total number of observed *Eumeces*, both captured and escaped individuals.

Analysis of Communities - Several methods were used to analyze whether the amphibian and reptile community in the years with normal/seasonal floods was different from the years with reduced/variable floods. Year-to-year fluctuation in amphibians and reptiles abundances makes comparison of annual samples directly inappropriate, therefore we grouped 1998 and 1999 since that was a seasonally normal flood period and 2007 -2009 since that was representative of a variable reduced flood period. In addition, although effort was relatively equal, it was not used in evaluation of the communities because one collection method alone does not provide accurate assessment of richness and diversity for amphibians and reptiles (Ryan *et al*., 2002; Ford and Hampton, 2005). Instead, change in structure of the amphibian and reptile communities, not density, was the emphasis of this study. Such issues as changes in species richness (#s) and changes in dominant species (most abundant) within groups as reflected in species-importance curves were examined. However, species richness is impacted by sample size, therefore we used species diversity analyses that were more appropriate for the data collected in this study. We also used a Rarefaction method to adjust species richness to whichever year had the lower sample size for the group (Smith, 2001). This analysis produces a richness for the larger sample as if it had only the lower number of records therefore they could be directly compared. We also compared species diversity in each of the different periods by calculating Simpson's Diversity Index. Simpson's index is not biased by sample size and is therefore more appropriate for comparison of communities with different species numbers (Lande, 1996; Lande *et al*., 2000). We created a 95% confidence limit for each community's index by Bootstrapping with 5000 iterations.

We then compared the communities of amphibians and reptiles collected in the period of normal flooding to reduced flooding by a Jaccard's community comparison and by a percent similarity community comparison index. These methods are recommended when the data consist of presence or absence of species and express relative similarities between communities (Brower et. al, 1998; Gotelli and Colwell, 2001). The values in Jaccard's community comparison range from 0 (when no species are found in both communities) to 1 (when all species are in common). The values in percent similarity community comparison give the proportion of species in the first community that are in the second community.

Three community comparison indices that take species abundances into account were also used to examine the different years. These were Canberra metric, which gives a comparison from 0 to 1 reflecting vastly difference or identical species composition and abundance. Morisita's index of community similarity, which is based on Simpson's index of dominance, also ranges from 0 to 1. Morisita's has the desirable characteristic of being little affected by sample size. Horn's index of community overlap is based on information theory and ranges from 0 to 1 also.

We used a single factor analysis of variance to determine if the overall species diversity was different in the years of 1998-1999 and 2007-2009 (Sokal and Rohlf, 1981). Rarefaction adjusted data was used in this analysis. We also produced Rank Abundance curves to examine changes in the structure of species in the communities (Williamson and Gaston, 2005). These were not done with raw numbers as those would be dependent upon effort but were rather produced by dividing the numbers collected of each species over the total capture for that period and then ranking the species from highest to lowest. Recaptures were not used in any analyses.

To determine if the rank abundance patterns followed the expected lognormal distribution for species, we compared expected numbers to the observed for terrestrial reptiles (lizards and snakes) and for amphibians (anurans and salamanders) (Smith, 1981). We did not test the turtles against the expected lognormal distribution, as the number of species was too small to produce enough species in each octave. We produced species curves for both normal and reduced flooding periods.

<u>GIS analysis and habitat changes</u> - We utilized GIS and GPS technology to analyze both tabular and spatial datasets in order to better understand the occurrence of amphibians and reptiles relative to the number and duration of flooding events at the OSBWMA. Tabular data included both historical and recent water data from USGS for the Sabine River and Lake Fork Creek, the primary drainages that influence the WMA. The spatial data includes 2004, 2005, and 2009 digital orthographic quadrangles for Lindale and Crow TX, 10M DEM and the corresponding elevation data which includes a four-foot contour interval. Locations of individual amphibians and reptiles in 2007-2009 were taken with a handheld GPS unit. Utilizing this data the occurrence of amphibians

and reptile in a years with reduced flooding (2007) was compared to the locations where these organisms were found in a year with more seasonal flooding (2008). GPS location were not available from 1998 or 1999 but this comparison of later periods should give some general insight into how these animals respond to variable/reduced flooding regimes. The locations for both years were mapped and spatially analyzed using ArcGIS to determine which sites sampled were commonly associated with amphibians or reptiles. This spatial data along with species changes from the rank abundance data were then used to hypothesize what factors, related to vegetation, occurrence of pools, etc. that have changed, are influencing the current distribution of those species.

## RESULTS

In 1998 and 1999 (sample period one), the years with normal seasonal flooding, we captured 2280 animals representing 15 amphibian species, 26 reptile species and alligators. In 2007 to 2009 (sample period two), the years after reduced variable flooding, we captured 3343 animals representing 15 amphibian species and 30 reptile species. The normal flooding years had fewer overall records of each group except for the salamanders and lizards, which were more abundant in reduced flooding years (Table 1).

Amphibian diversity.

Eleven total species of anurans were collected in both normal and reduced flood years (Table 1). Almost a thousand more records were made in the later years, however, Simpson's diversity and evenness was lower in those reduced flood years. Rarefaction analysis indicated the species richness was equivalent. Community similarity indices varied from 0.46 to 0.82 so some of the methods indicated the species composition was somewhat different (Table 2). Frog logging equipment produced some additional data on the common species but did not produce any species that were not recorded by visual surveys or nighttime call surveys. Abundances of the treefrogs (*Hyla*) and several other species went down significantly whereas there was a dramatic rise in the numbers of leopard frogs (*Rana sphenocephala*). The northern chorus frog (*Pseudacris triseriata*) was only present in 1998, whereas the pickerel frog (*Rana palustris*) was only recorded in 2008.

Table 1. Numbers of anurans collected at the OSBWMA during normal years and those with reduced flooding.

| | 1998 | 1999 | Normal Floods | 2007 | 2008 | 2009 | Reduced Floods |
|---|---|---|---|---|---|---|---|
| *A. crepitans* | 57 | 179 | 236 | 62 | 30 | 2 | 94 |
| *B. velatus* | 14 | 345 | 359 | 14 | 2 | 120 | 136 |
| *G. carolinensis* | 1 | 38 | 39 | 4 | 3 | 12 | 19 |
| *H. cinereus* | 70 | 174 | 244 | 0 | 20 | 24 | 44 |
| *H. versicolor /chyrsoscelis* | 17 | 121 | 138 | 0 | 9 | 40 | 49 |
| *P. crucifer* | 30 | 0 | 30 | 0 | 24 | 36 | 60 |
| *P. triseriata* | 5 | 0 | 5 | 0 | 0 | 0 | 0 |
| *R. catesbiena* | 8 | 35 | 43 | 11 | 40 | 4 | 55 |
| *R. clamitans* | 11 | 41 | 52 | 2 | 115 | 7 | 124 |
| *R. palustris* | 0 | 0 | 0 | 0 | 8 | 0 | 8 |
| *R. sphenocephala* | 24 | 343 | 367 | 4 | 507 | 1190 | 1701 |
| *Total* | | | 1513 | | | | 2290 |
| *Species richness* | | | 10 | | | | 10 |
| *Rarefaction adjusted richness* | | | | | | | 9.99 ± 0.013 |
| *Simpson's diversity* | | | 0.82 (0.817-0.829 | | | | 0.44 (0.417-0.459) |
| *Simpson's evenness* | | | 0.91 | | | | 0.49 |

Table 2. Community comparisons for anurans collected at the OSBWMA during period after normal flooding and after reduced flooding.

| | |
|---|---|
| Jaccard's coefficient of community | 0.82 |
| Percent of similarity | 0.47 |
| Canberra's metric | 0.46 |
| Morista's index of community similarity | 0.57 |
| Horn's index of community overlap | 0.76 |

Seven total species of salamanders were collected in both normal and reduced flood years (Table 3). Fewer records were made in the later years. However, Simpson's diversity and evenness was identical in both periods. Rarefaction adjustment to the smaller sample size only reduced the richness in the earlier years a small amount. However, community similarity indices ranged from 0.26 to 0.77, which indicates the species composition was different (Table 4). A single two-toed amphiuma (*Amphiuma means*) was recorded in the earlier samples and one Gulf Coast waterdog, (*Necturus beyeri*) in the later years.

Table 3. Salamanders collected at the OSBWMA during years of normal floods and reduced flooding.

| | 1998 | 1999 | Normal Floods | 2007 | 2008 | 2009 | Reduced Floods |
|---|---|---|---|---|---|---|---|
| *A. opacum* | 9 | 1 | 10 | 0 | 2 | 1 | 3 |
| *A. texanum* | 31 | 64 | 95 | 0 | 29 | 4 | 33 |
| *A. maculatum* | 1 | 4 | 5 | 0 | 1 | 0 | 1 |
| *Siren intermedia* | 0 | 14 | 14 | 1 | 39 | 17 | 57 |
| *A. means* | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| *N. viridescens* | 0 | 20 | 20 | 0 | 1 | 1 | 2 |
| *N. beyeri* | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Total* | | | 145 | | | | 97 |
| *Species richness* | | | 6 | | | | 6 |
| *Rarefaction adjusted richness* | | | 5.67 ± 0.474 | | | | |
| *Simpson's index* | | | 0.53 (0.456 - 0.606 | | | | 0.53 (0.460 - 0.582) |
| *Evenness* | | | 0.64 | | | | 0.64 |

Table 4. Community comparisons for salamanders collected at the OSBWMA during period after normal flooding and after reduced flooding.

| | |
|---|---|
| Jaccard's coefficient of community | 0.71 |
| Percent of similarity | 0.50 |
| Canberra's metric | 0.26 |
| Morista's index of community similarity | 0.67 |
| Horn's index of community overlap | 0.77 |

Reptile diversity.

Eleven total species of turtles were collected in both normal and reduced flood years (Table 5). Eight species were found in the first period and 10 in the second. Almost 100 more records were made in the second period, and after correction for the larger sample size, species richness was still higher in that sampling period. However, Simpson's diversity and evenness was lower in the reduced flooding periods although the confidence limits suggest these diversity indices are not different. Community similarity indices indicated the species composition was different in the different periods (Table 6). The biggest change evident was a shift from Mississippi mud turtles (*Kinosternum subrubrum*) to the two musk turtles (*Sternotherus oderatus* and *S. carinatus*).

Table 5. Turtles collected during normal flooding years and in years with reduced floods.

| | 1998 | 1999 | Normal Floods | 2008 | 2009 | Reduced Floods |
|---|---|---|---|---|---|---|
| *Apalone spinifera* | 6 | 7 | 13 | 34 | 0 | 34 |
| *Chelydra serpentina* | 1 | 13 | 14 | 10 | 2 | 12 |
| *Graptemys kohnii* | 0 | 1 | 1 | 11 | 0 | 11 |
| *Graptemys ouachitensis* | 15 | 13 | 28 | 16 | 0 | 16 |
| *Kinosternum subrubrum* | 3 | 0 | 3 | 0 | 0 | 0 |
| *Macrochelys temmickii* | 0 | 0 | 0 | 1 | 0 | 1 |
| *Pseudemys concinna* | 13 | 6 | 19 | 6 | 0 | 6 |
| *Sternotherus carinatus* | 6 | 6 | 12 | 113 | 0 | 113 |
| *Sternotherus odoratus* | 0 | 0 | 0 | 12 | 0 | 12 |
| *Terrepene carolina* | 0 | 0 | 0 | 0 | 1 | 1 |
| *Trachemys scripta* | 10 | 32 | 42 | 18 | 3 | 21 |
| Total collected | | | 132 | | | 227 |
| Richness | | | 8 | | | 10 |
| Rarefaction adjusted richness | | | | | | 9.16 ± 0.699 |
| Simpson's diversity | | | 0.81 (0.771 - 0.831) | | | 0.71 (0.656 - 0.750) |
| Evenness | | | 0.92 | | | 0.79 |

Table 6. Community comparisons for turtles collected at the OSBWMA during periods after normal flooding and after reduced flooding.

| | |
|---|---|
| Jaccard's coefficient of community | 0.64 |
| Percent of similarity | 0.44 |
| Canberra's metric | 0.34 |
| Morista's index of community similarity | 0.48 |
| Horn's index of community overlap | 0.72 |

Four total species of lizards were collected in both normal and reduced flood years (Table 7). Fewer records were made in the later years, and one fewer species was collected. However, Simpson's diversity and evenness was higher in the reduced flooding periods although the confidence intervals for diversity overlap. Community similarity indices indicated the lizard species composition was fairly similar (Table 8) but the green anole (*Anolis carolinensis*) was only recorded in the earlier period.

Table 7. Lizards collected at the OSBWMA during years of normal floods and during reduced flooding.

| | 1998 | 1999 | Normal Floods | 2007 | 2008 | 2009 | Reduced Floods |
|---|---|---|---|---|---|---|---|
| A. carolinensis | 6 | 7 | 13 | 0 | 0 | 0 | 0 |
| E. fasciata | 6 | 13 | 19 | 5 | 13 | 11 | 29 |
| E. laticeps | 4 | 8 | 12 | 3 | 12 | 1 | 16 |
| S. lateralae | 64 | 56 | 120 | 11 | 36 | 28 | 75 |
| Total | | | 164 | | | | 120 |
| Species Richness | | | 4 | | | | 3 |
| Rarefaction adjusted richness | | | 4.0 $\pm$ 0.002 | | | | |
| Simpson's | | | 0.44 (0.365-0.516) | | | | 0.54 (0.462-0.599) |
| Evenness | | | 0.59 | | | | 0.80 |

Table 8. Community comparisons for lizards collected at the OSBWMA during period after normal flooding and after reduced flooding.

| | |
|---|---|
| Jaccard's coefficient of community | 0.75 |
| Percent of similarity | 0.81 |
| Canberra's metric | 0.60 |
| Morista's index of community similarity | 0.97 |
| Horn's index of community overlap | 0.94 |

A total of 18 species of snake were collected in both normal (first period) and reduced flood years (second period) (Table 9). More animals were recorded in the later years, and 3 more species were collected. Increased species diversity occurs with increasing sample size but even after rarefaction adjustment for this larger sample size the species richness was higher (almost 16 versus 14). However, Simpson's diversity and evenness were very similar in both periods. Community similarity indices generally indicated the species composition was fairly similar although the Canberra Metric suggested some significant differences in the communities.

Table 9. Snakes collected at the OSBWMA in years with normal floods and with reduced flooding.

| | 1999 | 1998 | Normal Floods | 2007 | 2008 | 2009 | Reduced Floods |
|---|---|---|---|---|---|---|---|
| *A contortrix* | 21 | 12 | 33 | 2 | 9 | 5 | 16 |
| *A. piscivorus* | 40 | 20 | 60 | 67 | 97 | 27 | 191 |
| *C. horridus* | 0 | 2 | 2 | 4 | 1 | 1 | 6 |
| *F. abacura* | 1 | 1 | 2 | 2 | 3 | 0 | 5 |
| *L. calligaster* | 1 | 0 | 1 | 7 | 7 | 0 | 14 |
| *L. getula* | 7 | 2 | 9 | 11 | 13 | 3 | 27 |
| *L. triangulum* | 0 | 0 | 0 | 5 | 3 | 0 | 8 |
| *M. flagellum* | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *N. erthrogaster* | 64 | 9 | 73 | 30 | 13 | 38 | 81 |
| *N. fasciata* | 17 | 10 | 27 | 11 | 18 | 22 | 51 |
| *N. rhombifer* | 17 | 0 | 17 | 3 | 9 | 0 | 12 |
| *O. aestivus* | 7 | 0 | 7 | 3 | 6 | 0 | 9 |
| *P. obsoleta* | 3 | 5 | 8 | 6 | 8 | 2 | 16 |
| *R. rigida* | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *S. dekayi* | 17 | 1 | 18 | 0 | 2 | 2 | 4 |
| *S. occipitomaculata* | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| *T. proximus* | 54 | 8 | 62 | 39 | 54 | 69 | 162 |
| *V. striatula* | 0 | 0 | 0 | 0 | 3 | 2 | 5 |
| *Total Collected* | | | 320 | | | | 609 |
| *Species richness* | | | 14 | | | | 17 |
| *Rarefaction adjusted richness* | | | | | | | 15.94 $\pm$ 0.777 |
| *Simpson's index (95% conf. intervals)* | | | 0.85 (0.835-0.863) | | | | 0.80 (0.785 -0.817) |
| *Evenness* | | | 0.91 | | | | 0.85 |

Table 10. Community comparisons for snakes collected at the OSBWMA during period after normal flooding and after reduced flooding.

| | |
|---|---|
| Jaccard's coefficient of community | 0.72 |
| Percent of similarity | 0.73 |
| Canberra's metric | 0.43 |
| Morista's index of community similarity | 0.89 |
| Horn's index of community overlap | 0.91 |

Alligators were also recorded in both normal flooding years and in the years of reduced floods.

Overall species richness was not significantly different from the years after normal flooding and in years after a prolonged drought (Figure 16; F = 0.03; df = 1,8; P = 0.87).

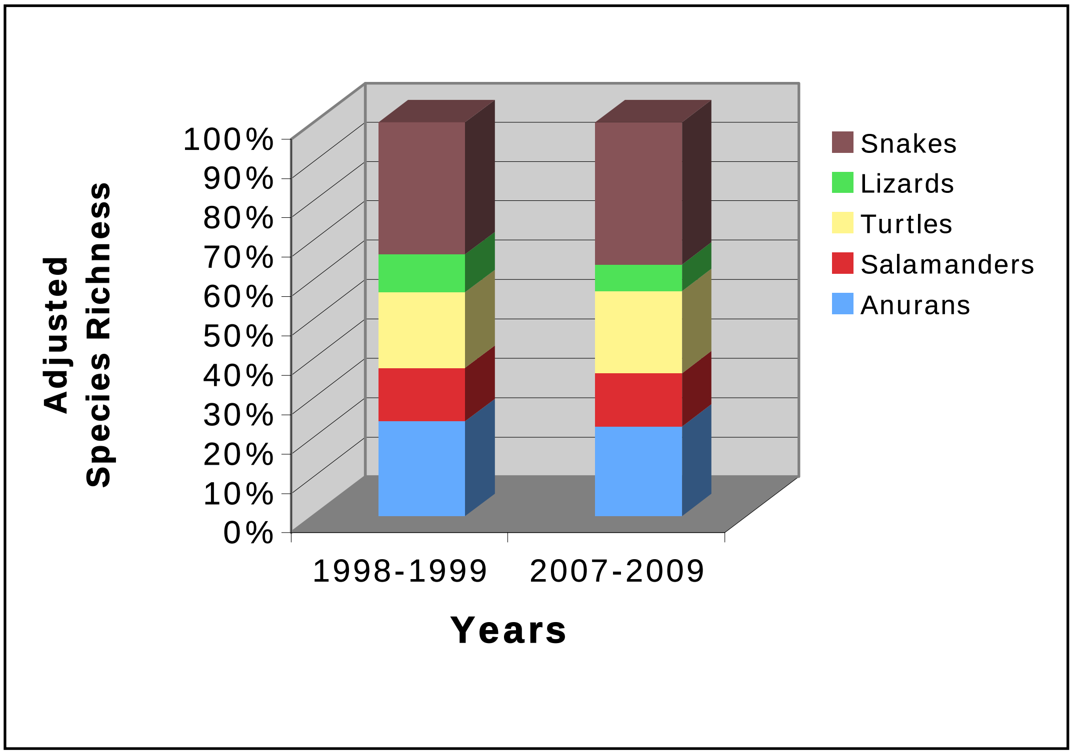



Figure 16. Changes in species richness (Rarefaction adjusted) of amphibians and reptiles at the OSBWMA in years after a normal flooding period (1998 - 1999) and a period of reduced flooding (2007 - 2009).

## COMMUNITY ASSEMBLAGE STRUCTURE

Amphibians

The anuran assemblage, as represented by the Ranked Abundance curves, appeared to be more dominated by the southern Leopard Frog (*Rana sphenocephala*) in the reduced flooding period (Figure 17). The normal years show a much more even distribution of abundance among the species with 5 relatively common species. In both periods about 5 species were infrequently recorded.

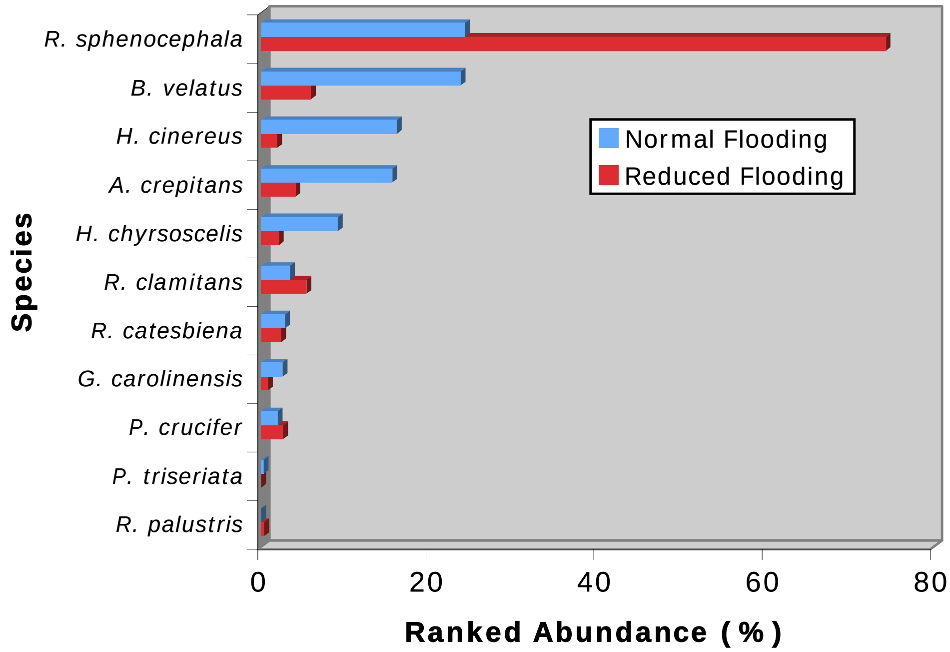



Figure 17. Frog and toads collected at the OSBWMA during years with normal floods and with reduced flooding.

The salamander assemblage appeared to change between the normal flooding and reduced flooding years (Figure *18)*. The normal years show a much more even distribution of abundance among the species with the small mouthed salamander (*Ambystoma texanum*) being a very common species. In the reduced flood period the aquatic salamander, the siren (*Siren intermedia*), became the dominant species in the records. In both periods 4 other species were relatively less common but two of the other *Ambystoma* seem to have also become more rare in the reduced flooding periods.

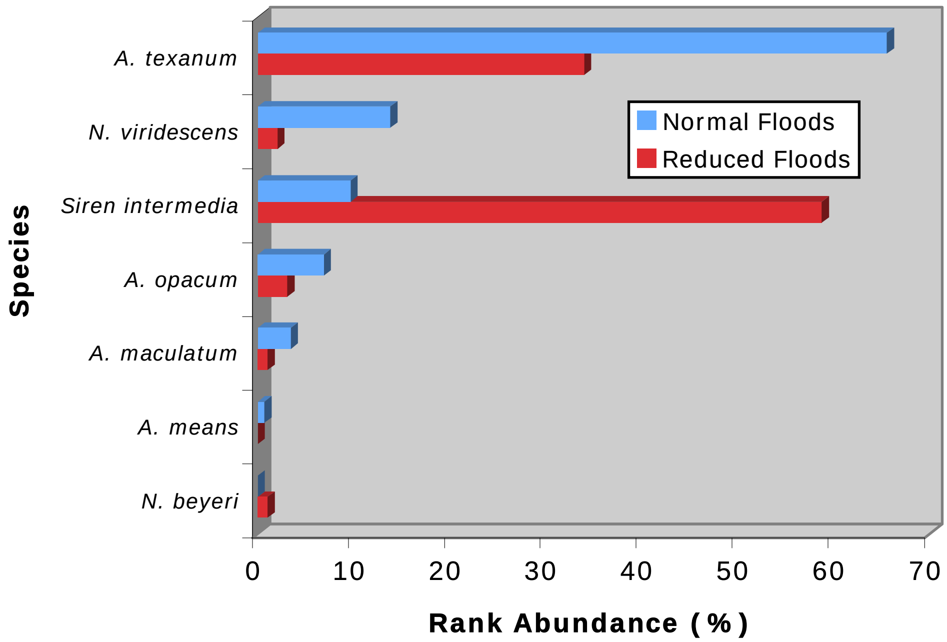



Figure 18. Salamanders collected at the OSBWMA during years with normal floods and with reduced flooding.

Reptiles.

The turtle assemblage appeared to be very similar between the normal flooding and reduced flooding years (Figure 19). The only obvious difference was that the razorback musk turtle (*Sternotherus carinatus*) increased in capture rate in the later period.

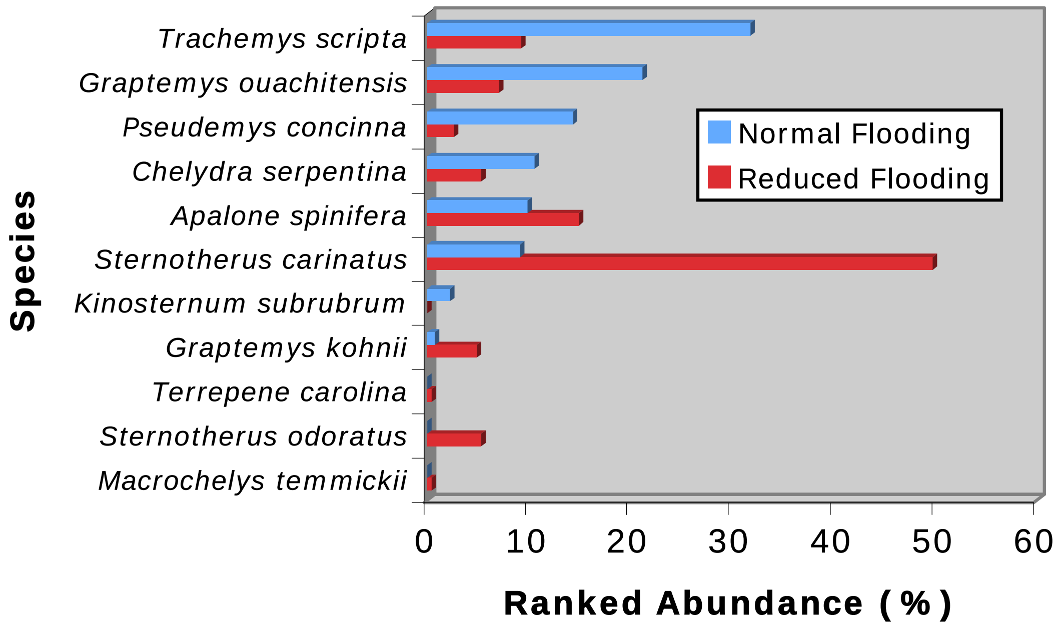



Figure 19. Turtles collected at the OSBWMA during years with normal floods and with reduced flooding.

The lizard assemblage between the normal flooding and reduced flooding years did not appear to have changed significantly (Figure 20). The ground skink (*Scincella lateralae*) was dominant in both periods. However, the rarely encountered Green Anole (*Anolis carolinensis*) was not collected in the years with reduced flooding.

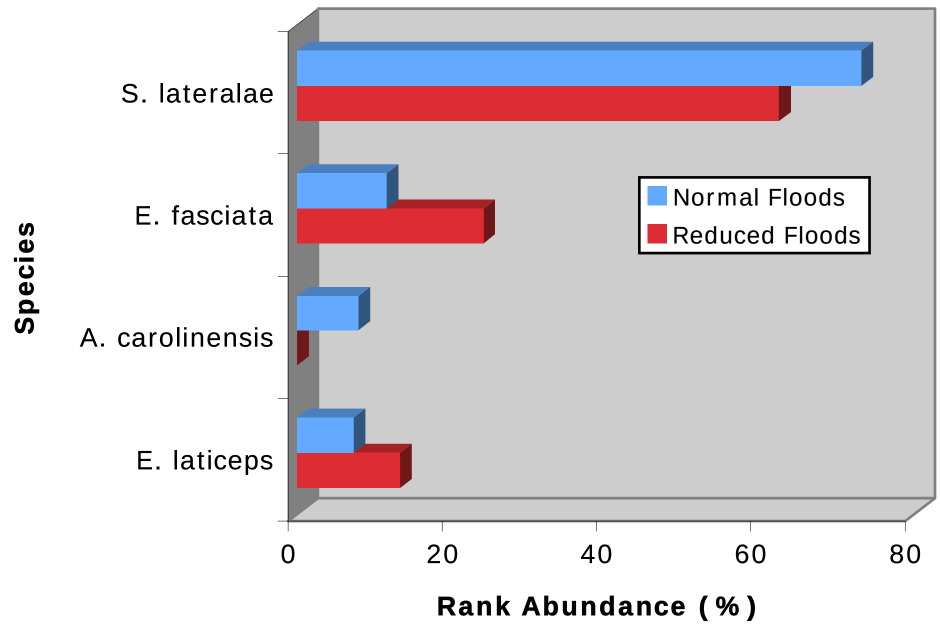



Figure 20. Lizards collected at the OSBWMA during years with normal floods and with reduced flooding.

The snake assemblage appears to have the same structure between the normal flooding and reduced flooding years but has changed in species composition (Figure 21). In both periods 3 species were dominant with a number of intermediately abundant species. However, in the normal years the dominant species was the yellowed-bellied water snake (*Nerodia erythrogaster*). In the reduced flood period the western cottonmouth (*Agkistrodon piscivorus*) became the dominant species in the records. Also in the later periods the king snakes (*Lampropeltis getula, L. triangulum* and *L. calligaster*) increased in collection rate in both the grassland area and the main forested sites. The southern copperhead (*A. contortrix*) and the Texas Brown snake (*Storeia dekayi*) also declined in abundance in the reduced flooding period.

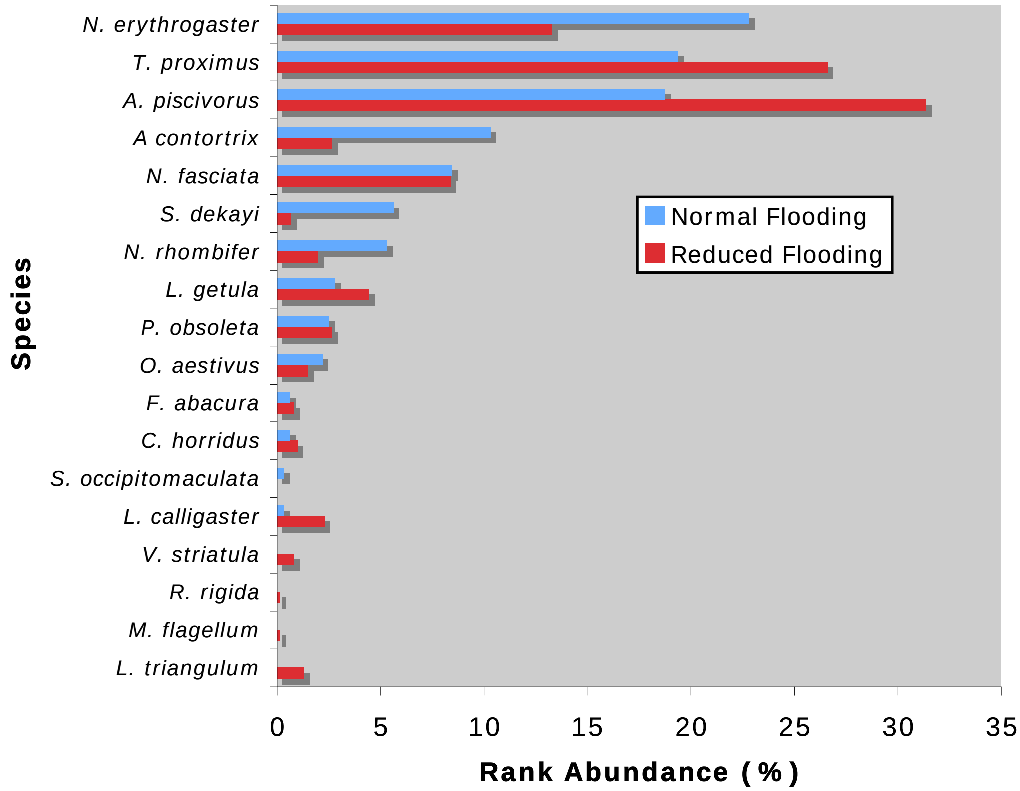
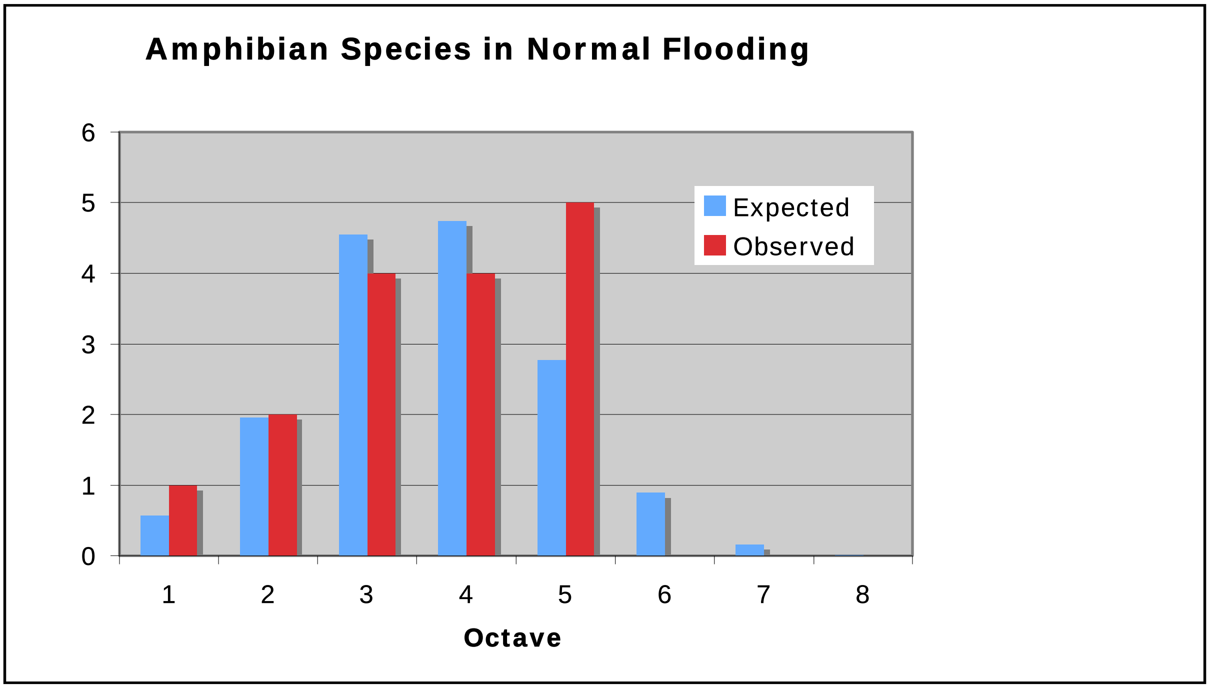



Figure 21. Snakes collected at the OSBWMA during years with normal floods and with reduced flooding.

The number of individuals in each species in communities generally follows a lognormal distribution with a few species having high abundances and several having intermediate abundances but most being relatively rare. The expected number of amphibian species plotted with the observed number for both normal and reduced flooding periods is shown in Figure 22.



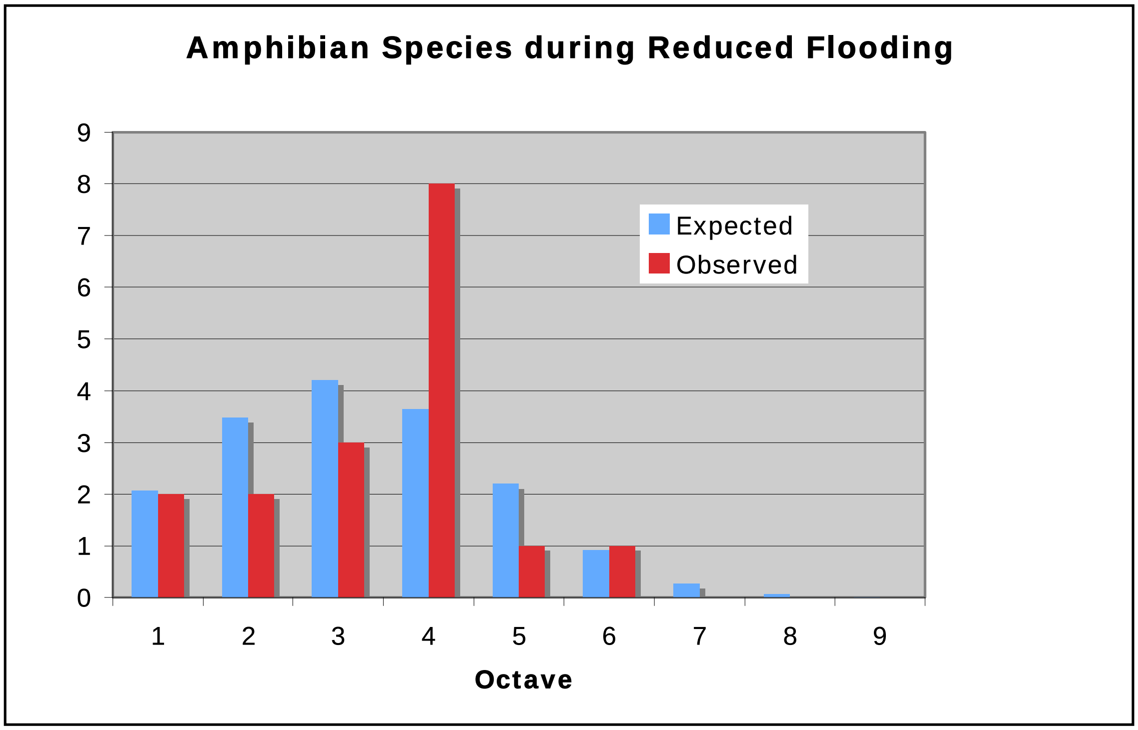
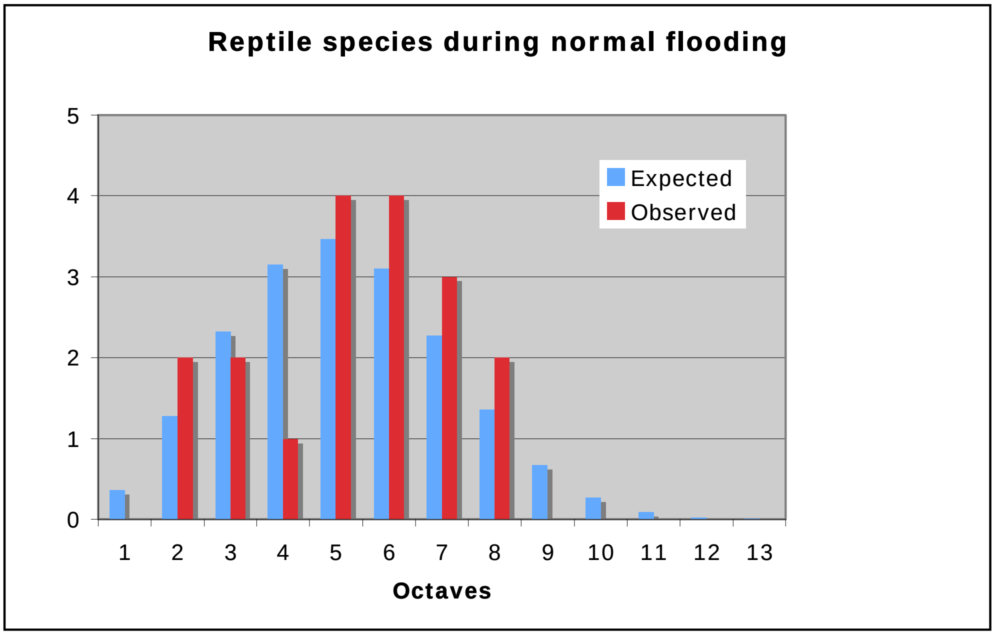




Figure 22. The number of amphibian species in abundance ranks (most to least) found at the OSBWMA during years of normal flooding and reduced flooding. The expected numbers match a lognormal distribution.

The expected number of terrestrial reptile species plotted with the observed number for both normal and reduced flooding periods is shown in Figure 23. Note number of species in each abundance group is similar to the expected.



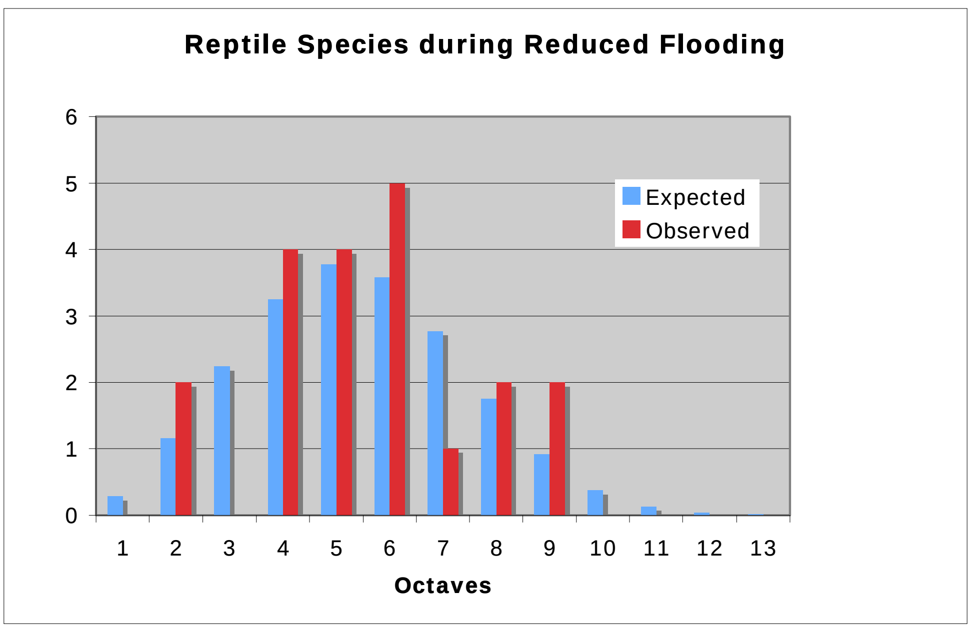




Figure 23. The number of reptile species in abundance ranks (most to least) found at the OSBWMA during years of normal flooding and reduced flooding. The expected numbers match a lognormal distribution.

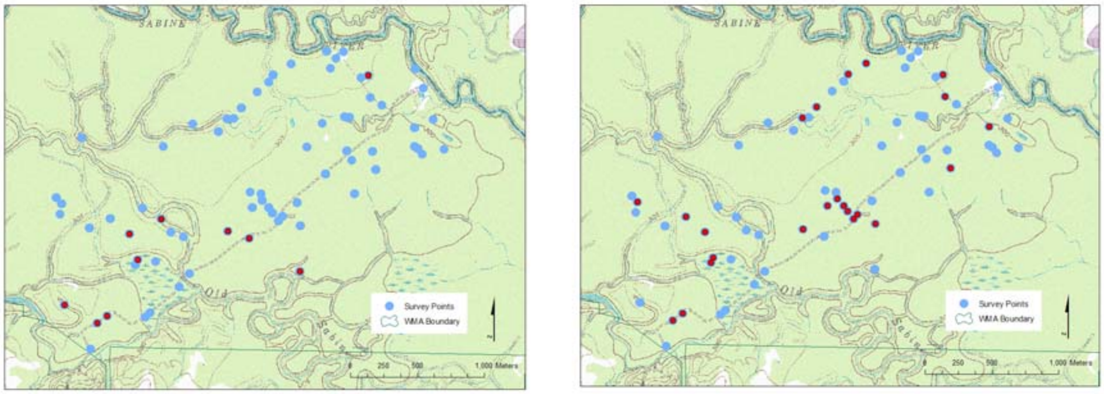
Overall, the 5 amphibians and reptiles were lost from the reduced flooding years in the latter surveys (Table 11). Most of these were rare in the earlier studies so their lack of occurrence in the later period may be just a random event. However, the lack of green anoles seems to be a significant change. Nine species not recorded in the earlier surveys were found in the reduced flooding years. Again some of these were rare and their occurrence might just be due to the greater sampling. However, the musk turtle and the coachwhip were found in some numbers in the second period.

Table 11. Changes in species of amphibians and reptiles collected at the OSBWMA during periods after normal flooding and after reduced flooding. Numbers reflect a species occurring in that period that was not recorded in the other period.

| | Anurans | Salamanders | Turtles | Lizards | Snakes | Total |
|---|---|---|---|---|---|---|
| Normal flooding period | 1 | 1 | 1 | 1 | 1 | 5 |
| Reduced flooding period | 1 | 1 | 3 | 0 | 4 | 9 |

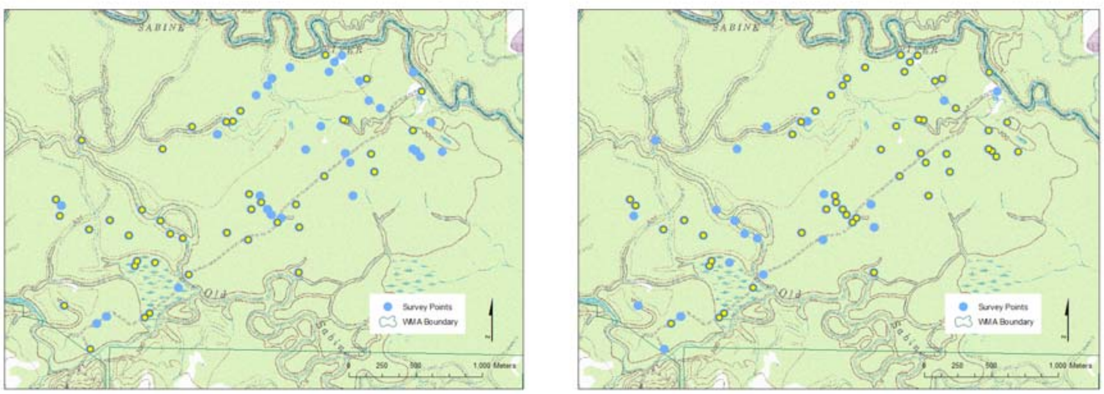
## GPS MAPPING

In a year after several years of reduced flooding (2007) amphibians were restricted to areas with more permanent water, such as the oxbow at the Old Channel (Figure 24). In a year in which a substantial amount of rain in the spring produced some flooding in the late spring and summer (2008) the amphibians were recorded throughout the bottomland. The reptiles (lizards and snakes) although more terrestrial showed some of the same pattern but were more scattered throughout the OSBWMA even during the reduced flooding year than were the amphibians (Figure 25).




2007 2008

Figure 24. Locations (red dots) where amphibians were found in a year with reduced flooding (2007) and a year with spring and summer floods (2008). Locations where animals were collected in all years are shown in blue, whereas locations during those specific years are shown in red.




2007 2008

Figure 25. Locations (yellow dots)where reptiles were found in a year with reduced flooding (2007) and in a year with spring and summer floods (2008). Locations where animals were collected in all years are shown in blue, whereas locations during those specific years are shown in yellow.

## DISCUSSION

Flooding patterns.

Our overall objective was to compare the herpetofaunal community during years of relatively normal flooding regimes for a bottomland hardwood floodplain to the community found during a period of reduced flooding. Normal flooding regimes for the Sabine River (5 or 6 flood pulses in the winter and spring) occurred before and during the first sample period (1998 and 1999) of amphibians and reptiles that were conducted at the OSBWMA.

From 2004 to 2006 flooding at the OSBWMA was severely reduced (only 1 minor event in that period) and continued during the first year of the study (2007). Grasses and other vegetation (understory shrubs) became thick throughout the WMA because of the lowered hydroperiods (Ford, pers. obs.). Normally, water remaining on these plants would suppress or kill species not adapted to floodplains. Because of thick plant growth in the reduced flooding period it was actually difficult to visually survey amphibians and reptiles as compared to this method in the earlier years of normal floods.

However, in 2007 abundant fall and winter rainfall slowly filled most reservoirs that had been low from the drought of 2004-2006 resulting in lower water releases. With an occurrence of a late spring rain event, the higher water in the reservoirs contributed to a rare summer flood. This was an abnormal pattern for the WMA. In 2008 a few normal spring floods occurred and in 2009 some higher than normal fall flooding occurred. Both of these flooding periods were somewhat variable but the water remained in the area long enough to kill back some of the vegetation. In addition, the nutrient subsidy that normally would occur due to floods in the winters occurred in these flooding events also. Therefore, in some ways the processes that occurred in 1998 and 1999 returned in 2008 and 2009 just during different seasonal periods. However, the species changes that occurred over the drought years appeared to have remained during this second sample period. In addition, the fact that the floods were at a very different time of year made a change in the amphibian and reptile communities.

## General Herpetofauna of the OSBWMA

Because of the flood-produced nutrient subsidy, the bottomland hardwood forests of the southeastern United States accommodate numerous and diverse species of amphibian and reptiles (Moseley *et al*., 2003; Goldstein *et al*., 2005). The OSBWMA in the years with normal flooding patterns has a diverse and extremely abundant amphibian fauna. Tadpoles of a variety of frogs and toads eat the vegetation and detritus that is found in the ephemeral pools. Huge numbers of these larva occur in years with flooding and adequate rainfall. The reproductive period of different species of amphibians vary seasonally and so year-to-year variation in success of each species occurs because of variation in the timing of rainfall. Over the long term, each species succeeds in recruiting new individuals but only a few species like the leopard frog are abundant in each year. Salamanders also are very dependent on the cycles of rainfall but are carnivores. They feed on the invertebrates and also tadpoles that are eating the debris washed into the pools by the floods. However, in years with floods the pools also fill with fish, which use these pools as spawning areas. The fish feed on the tadpoles and salamander larva and so these species numbers are lower in any pools with fish. In years with several winter floods most of the pools receive adult fish, which breed there, and this influences the abundance and species composition of amphibians in those years (Ford and Hampton, 2007).

Reptiles are also very dependent on the pulsed resources of floods. Some species of turtles like sliders eat vegetation (algae), fish, and invertebrates (Ernst and Lovish 2009).

However, most turtles in this habitat, like the abundant razorback musk turtle, eat invertebrates and fish. The species in the river itself eat both live and dead fish, mussels, snails, and a variety of other organisms. Some are specialists but most are generalist feeders. The lizards are mostly ground dwellers like skinks and eat the abundant terrestrial invertebrates. Snakes are the most diverse assemblage with the dominant species feeding on the huge numbers of fish and amphibians (Ford and Lancaster, 2006). A large group of intermediately abundant snake species are also present that eat specific prey (e.g. bird eggs, other snakes, crayfish, and insects). Some species are only occasionally found in the area and may be impacted by the floods (washed away) so that they are only present in certain areas (higher ground) or in specific periods (after droughts).

## Changes in the herpetofauna during reduced flooding

Amphibians.

Because of the cyclic nature of most amphibian reproduction any conclusions about changes in numbers must be made cautiously. Overall diversity did not seem to be changed in the reduced flooding years with 2 species lost but 2 different species gained (Table 11). In addition, the number of species in each abundance group followed the lognormal distribution (with slightly fewer rare species) in both normal and reduced flooding periods. However, community comparison indices indicated some differences in the community had occurred (Tables 3 and 5).

The changes in rank abundance of particular species in the community may be indicative of the impact of change in the habitat on some species. At the OSBWMA during 2007 and early 2008 species of frogs and toads dependent on rainfall to breed were reduced in number and the overall species diversity went down (Table 1). Amphibians became more restricted to the permanent water sources such as the Old Channel and larger ponds (Figure 21). Only species like cricket frogs that breed on the riverbanks were not reduced in number. However, when rainfall increased in 2008 and 2009, the leopard frog's reproduction increased dramatically (Figure 16). Fish were not present in the pools but there was enough late spring rain to keep the pools full until the larva could metamorphose.

Reduced flooding therefore increased the number of sites where successful breeding of amphibians could occur (Kats and Sih 1992; Binckley and Resetarits 2003; Turner et al., 1994). However, competition for the algae between tadpoles of different species for the algae could increase. So timing of rainfall might also influence which species was most successful (Toft, 1985). Large numbers of leopard frog and bullfrog froglets were present everywhere in the area in 2008 and then later metamorphs were abundant. Some other species also did well in that year but nowhere near as well as the leopard frogs (Figure 16, Table 1). In addition, metamorphosis did not always result in adult frogs. For example, bullfrog recruitment occurred in the summer of 2008 but numbers declined rapidly and no adults were seen in later years. This species is not as successful in forested bottomlands. The salamanders in general did better in terms of reproduction in the years of reduced flooding. If the pools filled with rainfall and no fish were washed in by floods, then salamander larva were very abundant. However, the adults and the young leaving the pools were impacted by another problem in this period.

Feral hogs became much more evident in the later period. In particular, they would feed around the edges of ephemeral pools turning the sphagnum moss over and created a very inhospitable environment for metamorphosing salamanders (Figure 26). During 2008 and 2009 the edges of nearly every pool in the whole WMA were damaged extensively by hogs such that very little habitat for terrestrial salamanders like the small-mouthed salamander was left. In 1998-1999 nearly all fallen logs would have salamanders under them. In the second sample period very few logs had not been turned over by hogs and few terrestrial salamanders were present (Figure 17). Therefore, it is difficult to say if reduced flooding has caused a decline in their numbers. However, in conjunction with the increased numbers of hogs and their tendency to feed near ephemeral pools, the future of this group of amphibians is questionable at best. The fact that aquatic salamanders such as the siren became dominant in the later years (Table 3) supports the need to monitor the terrestrial salamanders in particular.

Figure 26. Hog damage near ephemeral pools at the OSBWMA in periods of reduced flooding.

Reptiles.

The composition of the turtle assemblage did not appear to change dramatically in the reduced flooding years (Figure 18). This may be a reflection of their slow recruitment or their tendency to occur more in the river and large creeks than in the ephemeral pools. Therefore, they may be less impacted by the changes in periodicity of flooding. The only obvious difference was the abundance of the razorback musk turtle in later years. Whether this is due to some life history difference in this species or is an artifact of trapping bias for this species is unknown but some authors have indicated it is difficult to trap (Tinkle, 1958).

The terrestrial reptile (lizards and snakes) community did not change in terms of richness or diversity and the number of species in each abundance group followed the lognormal distribution in both normal and reduced flooding periods (Ford and Lancaster, 2006). A few species are abundant with several intermediately abundant species and lots of rare species (Figure 20). The dominant species in the OSBWMA are aquatic predators feeding on amphibians and fish, although the cottonmouth also eats other prey. The intermediate species of snakes are of all sizes and shapes and eat a variety of types of food.

The species composition of lizards and snakes was different in the two periods. The lizard fauna at the OSBWMA was not diverse, only consisting of 4 species. The skinks were the most observed and the arboreal anole was rare. Therefore, it is difficult to document change occurring in this group. However, our perception was that all the skinks were less abundant after the drought. The ground skink, in particular was very abundant throughout the area in the earlier years. It feeds upon small terrestrial invertebrates and is prey itself for a wide variety of predators. It probably forms the largest terrestrial vertebrate biomass on the site. Skinks are the prey for several species of snakes such as copperheads and fewer of this species were recorded in the second period. Fewer worms might also explain the decline in Texas brown snakes since they are their primary prey. However, the only species change that can be directly related to reduced flooding is the decline in yellow-bellied water snake. It eats predominately fish and that prey item became less available (Mushinsky and Lotz 1980; Mushinsky et al. 1982). The ribbon snake, which eats fish also eats frogs (Gibbons and Dorcas 2004; Rossman et al. 1996), so switched in its ranking with the water snake. However, there was a shift away from juveniles to adults, suggesting its reproduction may have been reduced. The other abundant snake, the cottonmouth, is a generalist and even eats other snakes (Vincent et al., 2004) so seemed less affected by the change in flooding. It was difficult to ascertain whether any particular pattern to their numbers had occurred. Some of the rare snakes are small species like earth snakes that might be washed away by the periodic flooding or more terrestrial species like coachwhips (*Masticophis flagellum)*. Earth snakes did have a slight increase in numbers, as did the coachwhips, which might be explained by the reduced flooding. Another abundance change in snakes during the second period was an increase in speckled king snakes. They increased in number both in the main forested area and in the grassland but a specific explanation is not evident for this change.

The overall conclusion from examination of the ranking of species in their assemblage is that there were some changes in the makeup of each group. Five species occurred in the early years that did not in the later period and 9 species occurred in later years only. Pulsed resources can reduce the intensity of species interactions and allow for increased diversity (Ostfeld and Kessing 2000; Stapp and Polis 2003). Periodic disturbances influence trophic interactions (Elderd 2006), affecting primary vegetation and top predators, the two ends in the food web (Doyle 2006). As a result of changes in flooding regimes (frequency, duration, and intensity), the base of resources may be decreased or eliminated; this in turn can modify competitive interactions between species.

In particular, the top predators that may have reduced competition often decrease in number. The increase in competition tends to reduce diversity with only the most successful species remaining.

The changing of flooding regimes has caused fewer inundations of pools of the OSBWMA. The implications of the lack of nutrients in the ecosystems are likely a reduction in available resources for invertebrates and the larva of frogs and salamanders. In addition, slackwater fish are less likely to be trapped in the pools (Bayley 1991; Swanson et al. 1998). These species were a large biomass available for secondary level predators like the snakes. Amphibians and reptiles are difficult to sample without bias across species and so interpreting the change in their assemblages must be done with caution. However, because they are diverse and feed on a wide variety of prey, changes in their community can give insight into how complex processes such as flood suppression can affect a bottomland habitat. The decline in fish eating species and those eating aquatic macroinvertebrates is likely due to the reduced floods but why other species abundances are changing is less obvious. For example, small species like the brown snake, which might be expected to wash away in normal flood periods declined instead of increased in the reduced flood period. Most likely, their lower abundance is also related to a reduction in prey availability.

Finally, the increase in hog activity makes any strong statement of the impact of flood suppression less secure. They likely have major impacts on the herpetofauna both directly through predation on some species, but also indirectly by the damage they are doing to the habitat near ephemeral pools. The damage to the pools increased during periods of reduced flooding as the hogs increased foraging in those areas due to dryer conditions. It is possible that during normal flooding years, wetter conditions will disperse this increased population of hogs and they will have less severe impacts on the herpetofauna populations.

In conclusion, the natural regime of flooding in the OSBWMA has changed due to human impacts on the watershed and how this has changed the seasonal flooding. Flood suppression seems to be occurring during and after drought years. The reduction in water levels of reservoirs has resulted in less water release through dams into the Sabine River during low water periods. Therefore, the WMA has increased variability in flooding regimes and extremes are now experienced outside the seasonal norms. When the floods are lacking there is increased vegetation in the bottomland and also reduced nutrient input into the area. The composition of the amphibians and reptiles does change but in somewhat unexplained ways. Modification (such as increased surface water use) to normal flood regimes can impede natural processes and decrease the diversity of floodplain vegetation. Because fauna are dependent upon particular plants for food, nesting sites, and predator refuges, changes in plant communities can influence animal presence and abundance (Brawn et al. 2001; Marston et al. 2005). Persistence of this valuable ecosystem is dependent upon the periodic inundation and natural flood regimes. Continued investigations and a better understanding of the importance of flooding is important to be able to implement effective management strategies and river regulations. Due to the endangered nature of bottomland hardwood forest any change in flooding pattern is a serious threat to this ecosystem.

Whether the OSBWMA will remain a functional natural floodplain habitat is unknown but some changes are likely inevitable and how they will impact this area is unknown.  Continued monitoring of the amphibians and reptiles is advisable with the recommendation that particular species that have changed in this study might be good model organisms to track.

Periodic floods in bottomland hardwood forests create a unique and biologically diverse ecosystem.  Yet, few studies have investigated floodplains and fewer have addressed management concerns of amphibians and reptiles within this threatened habitat.  This study represents the first to investigate how changes in the flooding pattern have affected amphibian and reptiles communities. Additional and more detailed studies, particularly including changes in the plant community and invertebrate prey availability, would further explain why these communities are changing.

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## Management Implications

Several issues relative to management of the OSBWMA occur relative to the results of this study.

Hog management

An increase in the impact of feral hogs on the OSBWMA was evident from the first study in 1998 and 1999 to the current research.  Some of this may just be the result of an increased population of feral hogs on the WMA.   In addition, hunters have increased success during flooding, as the hogs are restricted to higher ground during that time.  However, it also appeared that during reduced flood years, hogs were concentrating foraging around ephemeral pools and the edges of creeks and streams due to dryer conditions. This may be a result of the reduced flooding in that the interior sites were dryer than in the years with flooding. Turning the vegetation around pools where the ground is softer appeared to be a foraging strategy that hogs were employing in this area. Therefore the impact of the hogs on amphibians and other animals living near ephemeral pools was acerbated by the reduction in flood regimes.

Wood duck recruitment

Wood duck predation in bottomland hardwood is reduced during floods. Predators such as Texas rat snakes appear to have difficulty locating nests when a floodplain is inundated by water (Carfagno and Weatherhead, 2009, Roy Neilsen and Gates, 2007). Since duck reproduction is often in the spring when the flooding is normally occurring, a reduction in flooding periodicity or duration could have an impact on the ability of wood duck populations to recruit young of the year. Monitoring wood duck boxes in years with normal flood patterns and those of reduced frequency would be an important project for this WMA. It is also likely that predation on other cavity nesting species, like Eastern Grey Squirrels, might be impacted by reduced flooding and should be monitored also.

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