I. INTRODUCTION

Feral hogs (*Sus* scrofa) are non-indigenous hogs that have escaped or been released into the wild. Research on the hog consists of a wide variety of issues concerning their status, damage and management in Texas, however little research has concentrated on the economic influence these invasive animals are capable of. It is understood that feral hogs represent both a significant financial liability and a potential economic asset to many landowners in Texas (Bach 1997). Feral hogs can cause considerable amounts of damage to property, crops and animals by rooting, wallowing and depredation, resulting in substantial financial losses. The state of Texas claims that hogs annually wreak $52 million in property damage across the state (Lynn 2008). The fact remains that feral swine are a rapidly rising nuisance species that cause escalating amounts of damage (Taylor 1998). It is accepted that as their populations continue to expand, so will their damage. Therefore, it is vitally important to quantify economic damages by the hog in order to effectively monitor their spatial distribution and assist subsequent management efforts.

Due to the numerous problems associated with hogs, the state of Texas allotted one million dollars toward feral hog control programs in 2008 (Lynn 2008). An analysis of the economic damage caused by the feral hog is extremely useful considering the amount of effort put into funding, management and control of these troublesome creatures. This research, survey information and economic assessment will be helpful in determining the impact feral hogs have in the North Texas region, which is newly expanded territory. It will also be effective as a future tool in establishing whether any particular region significantly differs from population estimates; thus identifying areas of significant economic damages that should warrant further attention to control in order to curb future losses. Until we recognize the amount of economic damage the hog is capable of inflicting and assess their prospective benefit, we will not know how to minimize their destructive nature while maximizing their potential.

By analyzing the extent of hog damage in North Texas and detailing potential concerns, wildlife managers, the public and the state can come together in evaluating implications, deliberating solutions and further addressing the consideration of whether additional management efforts should be focused toward the North Texas region as a result.

II. BACKGROUND AND AIMS

Much of the previous research conducted on the feral hog ranges from current and historical status, population dynamics, disease and parasitology to various control and management techniques. (Adams et al. 1995; Tolleson et al. 1995; Rollo et al. 2007; Davis 1995; Littauer 1997) Noted wildlife biologists Richard Taylor, Mark Mapston and Dale Rollins have written extensively about the feral hog in Texas, explaining in detail their history, current status and other general information (Taylor 1997, 1998; Mapston 1914; Rollins 1997, 2007). In 1999, Fort Worth hosted the First National Feral Swine Conference with lengthy reports from eleven central U.S. states, which was considered the first major step in identifying and addressing the numerous problems associated with the hog (REF). Robert Beach has studied depredation problems involving feral hogs for the Texas Animal Damage Control Service. He maintains the assertion that hogs have become too prolific, too destructive, and too widespread for wildlife managers to remain complacent about their future in the state, insisting that they require proper management to ensure the well being of native plant and wildlife species (Beach 1992). Landowners are certainly considered at risk as well by continuing to face incessant amounts of property loss and other forms of economic damages.

Just how many are there? In terms of population dynamics, Texas is home to an estimated two million feral hogs, which is about half of the entire populace in the United States (Rollins 1997). This number is sure to have grown. The feral hog has expanded in population and increased its range dramatically over

the years due in part to a high reproductive rate, impressive adaptability and a propensity for survival. Relocation, disease control among domestic animals, rangeland management, and habitat improvements have also helped them explode in population (Taylor 1991). Taylor has also examined the reproduction of hogs in Southern Texas, alleging their ability to double population size in four months (Taylor 1998). In 1993, feral hogs had very low or no populations in North Texas, however reports had started to suggest that populations had begun to expand and increase in these areas. This fact alone is important in the context of understanding the importance of studying the effects of the hog in an expansion range. Many biologists consider them the most prolific large, wild mammal in North America, and with good reason (Adams et al. 2005; Gipson et al. 1998; Mayer et al. 1991). The hog's drastic population increase is a great cause for alarm as it subsequently means their damage is also increasing as a direct result.

Yet, because of the difficulty associated with obtaining accurate estimates of hog numbers, other methods must be used. A model for predicting spatial density based on ecological data was developed by researchers at Texas A&M (Rollo et al. 2007). This model used social structure, behavior and ecological landscape variables such as suitable riparian habitat, forage availability, and drainage data. The model proved to be an effective improvement over daysmetric mapping, but is still not a totally reliable method of population estimation. Passive tracking indexes, distance sampling and mark-resight are other methods that have been used recently in an attempt to accurately obtain hog numbers (Engeman et al. 2001; Focardi et al. 1999). There remains a great need in wildlife management for a way to index populations of feral swine (Engeman et al. 2001). The economic assessment model outlined in this article is considered another partial method that can be used as an indicator of population size. However, until a reliable method is established, evaluating spatial density will continue to be an inconsistent area of research.

A fair amount of research has focused on the extent of feral hog damage, mainly within the environmental and ecological realm. Analysis suggests that the activities of rooting, wallowing and depredation enhance erosion and destroy habitat. (Mapston 1914). Since they are omnivores, hogs will eat almost anything they find, thus competing directly with wildlife and livestock for food as well as habitat. Rooting activity in a holly-oak grove was observed with the conclusion that the wild boar may exploit hoards of acorns collected by small mammals by actively searching for buried acorns due to above ground scarcity (Focardi et al. 1999). An additional study confirms the potential for inter-specific resource competition between white-tailed deer and feral hogs (Yarrow 1988). These studies have agricultural implications as wildlife look toward alternative sources of food and habitat.

The spread of disease has been studied at length, highlighting the elevated incidence rate of brucellosis, pseudorabies and cholera as three diseases in particular that have been fairly well documented because of ongoing federal eradication programs (Davis 1995). Therefore, there is an inherent risk for wildlife-transmitted infectious disease on livestock and domesticated animals, posing another area of concern for landowners and cattle ranchers. Humans are not excluded as is the case with the recent swine flu outbreak of spring 2009. Back in 1970 it was stated that the potential for these animals to become infected with avian or human influenza, and vice versa, was more than a distinct possibility (Hall 1970).

What can be done? Wild hogs are classified as feral livestock according to state law (Texas Legal Code 1993). Attempts to define property rights and a better definition of ownership for these animals are needed, with ownership of the hogs being established within Texas law (Bach 1997). It is noted that the obvious choices are to designate ownership to either those whose land they live upon or to the state. The current situation only agitates the problem, increasing the amount of damage that hogs impose upon resources (Bach 1997). The establishment of legal liability for damages caused by the hogs is

considered very important to the discovery of future solutions. As a result, taxing and zoning laws have been thought of as part of future solutions.

Management and control techniques are another area of considerable interest that have been examined rather extensively, for due reason. It is estimated that the average cost for hog control over the lifetime ownership of land was $2,631.00 (Adams et al. 2005). Extent and rate of reduction have been measured in feral hog abundance at two sites where they were poisoned with the anticoagulant warfarin (Choquenot et al. 1990). However, any potential implications have been quieted by a study evaluating the efficiency of baiting delivery systems. Taking into account the high rate of ingestion by non-target animals, baits are determined to be unsuitable for any pharmacological applications in their current form (Campbell et al. 2006). The effectiveness of several major methods to reduce damage were examined claiming that only hunting was effective, thus stressing the idea that funding be reconsidered to put more emphasis on the development and introduction of new harvest models (Geisser et al. 2004). Texas Animal Damage Control Service confirms this assertion by describing the minimal efficiency of hog-proof fences, electrical fences, snares, cages and traps (Littauer 1997). Hunting remains the most effective form of control with aerial helicopter shooting being perceived as the most cost-effective option in controlling feral hog populations (Choquenot et al. 1999).

However, little research has centered on the economic effects which define the current problems in these management efforts, with the exception of a few key articles. Agricultural producers, farmers, cattle ranchers and landowners experience financial losses because of feral hogs rooting and eating vegetation intended for livestock feed, promoting the growth of undesirable plants, muddying ponds and streams, and damaging fences, feeders, food plots and other property (Taylor 1998). The state of Texas claims that hogs annually wreak $52 million in property damage across the state (Lynn 2008). It is proposed that the average economic loss due to hog damage is estimated at $7,515.00 per landowner

per year (Adams et al. 2005). This valuable estimate was calculated using purposive sampling and a self-administered mail-out questionnaire similar to the one proposed in this article. It will be used as population data for relative comparison as outlined in the methodology and analyses.

In 2007, the Texas Department of Agriculture funded a pilot project through the Texas Cooperative Extension to study and measure the economic impact of managing feral hogs within agricultural enterprises (Gillum 2007). This particular project was designed to cover three different eco-regions within South Texas: Blackland Prairie, Postoak Savannah/Piney Woods, and Coastal Prairie. These regions included Hill, Navarro, Camp, Titus and Matagorda counties. The Extension's Agricultural Economics unit provided assistance in developing an agricultural producer/landowner survey to determine the economic value of previous feral hog damage and evidence of change in that damage following the project's management efforts, which included extensive trapping. This project proved to be a fitting example of economic research for feral hog damage but this area is still very minimal. This article plans to build on this limited area of research.

An analysis of the negative impacts and harvestable benefits is an undeniable necessity given the nature of the current situation. Revenues lost due to property loss and other economic damages are known to vary, but to what extent? The goal of this research is to expand upon this limited area of research and to determine the extent of influence the feral hog currently has on economics in North Texas. This goal will be accomplished by providing and utilizing an economic damage model that will be effective in determining whether a region has been subjected to significant hog damage. An additional objective would be to answer the question regarding whether feral hogs are an economic liability or an under-utilized asset, which will further assist management efforts. Education is another function of this project. Landowners will benefit from the educational efforts of the research presented; keeping everyone informed of the progress, findings and success of ongoing feral hog management procedures.

III. METHODOLOGY

According to Taylor's historical population estimates, feral hogs had bare to modest numbers in North Texas up to the year 1993 (Figure 1). This research plans to fill in the gap for newly expanded territory.

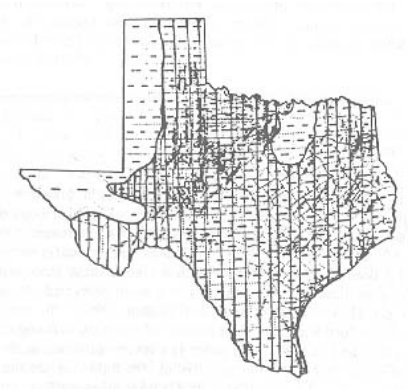

Figure 1 - 1993 Feral Hog Distribution (Taylor 1998)

The proposed target area in North Texas being studied is a defined region surrounding Ray Roberts Lake, a 30,000 acre reservoir north of Denton, TX. This target area was chosen because feral hogs prefer habitat rich in dense vegetation located in moist bottomlands commonly found in riparian areas or drainage basins, which is characteristic of land around a lake.

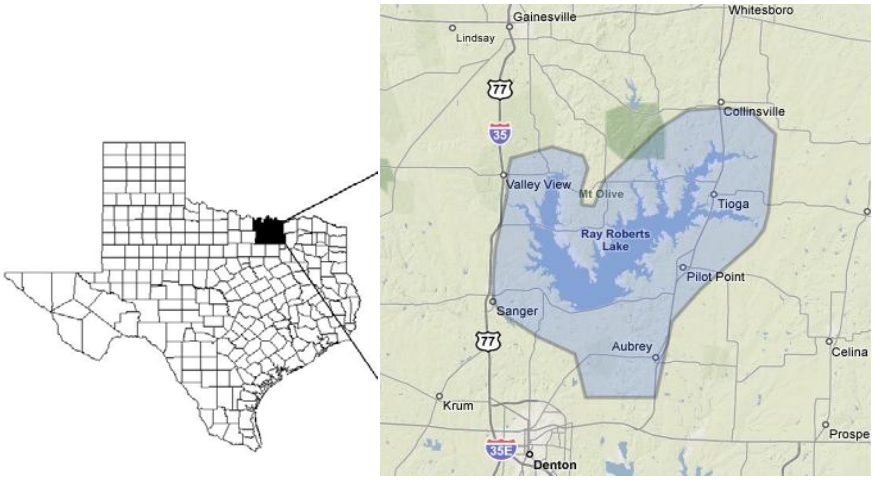

Figure 2 – Proposed target area: Buffer zone around Ray Roberts Lake.

The region will be established using a buffer zone approximately three miles wide surrounding the perimeter of the lake with an added three by five mile extension on the southern end where the Greenbelt Corridor (Elm Fork of the Trinity River) makes its way to Lake Lewisville (Figure 2). Notable towns being included within this buffer zone are Sanger, Aubrey, Pilot Point, Tioga, Collinsville and Valley View. These towns and their respective zip codes will be useful in determining the spatial patterning of economic damages as explained later. It is accepted that economic damages will generally be the highest closer to the lake where preferred habitat is located, and will gradually diminish moving away from it. Therefore, a three mile buffer zone is being used because it is expected to produce the most respectable sample size with representative data. A one to two mile buffer zone would be too small of a sample and five or more miles would be too large of a sample.

One of the most common methods of estimating wildlife damage is to survey randomly sampled landowners and request their estimates of damage for a given season and property type (Yoder 2002).

In order to determine the extent of economic damage, data will be collected by administering a mail-out questionnaire. Foremost, details of the questionnaire will include specific questions about damages: property losses, agricultural losses, and/or ranching losses. Establishing these three types of economic damages are essential for analyses. Furthermore, additional questions will detail total property acreage, acreage damaged, leasing practices, hog presence and attitudes/opinions. Acreage questions will be important in figuring out the total percent acreage affected by hog damage. Lastly, by analyzing the number of landowners utilizing leasing practices and the hunting industry versus landowners who are not, one can better gauge the effectiveness of using feral hogs as an economic asset. Any economic profits attributed to leasing practices, hunting or sales will be noted. The hunting of feral hogs has grown in popularity recently and by improving the promotion of leasing and hunting practices, it is

feasible that landowners make a profit off these pesky animals. The remaining questions will be useful in determining the general consensus of the hog by outlining presence, opinions, concerns and suggestions.

The survey questionnaire will be mailed to all landowners falling within the established buffer zone, as well as Extension agencies in Collin, Cooke, Denton and Grayson counties, and natural resource personnel at Texas Parks & Wildlife Region III. This way both the private and public land owner will be included and those who decide to participate in the questionnaire will make up the sampling frame (n).

After data are collected, it will then be analyzed using three separate damage models which are summed into total aggregate damage. These three damage models are defined as property losses, agricultural losses, and ranching losses.

Damage due to property losses will be calculated simply by averaging total property losses per individual per year. D_P = net property losses

In order to analyze agricultural losses, an econometric model of damage rates developed by Jonathan Yoder will be utilized. This model provides consistent estimates of not only agricultural wildlife damage, but also the impact of land-use characteristics on expected damage and claims, and abatement recommendations based on damage rates (Yoder 2002).

Agricultural wildlife inflicted damage is defined as: $D_A = PAY\partial$ or $D_A = R\partial$

Where P is the market price per unit of crop in the field, A is the number of acres in the field, and Y is the average yield per acre on undamaged acres (bushels or tons). R is the potential revenue and the product of the previous three variables. ∂ is the damage rate for the field defined as: ∂ = yield loss/potential field yield. Estimates of agricultural damage will be generated by multiplying predicted values of ∂ by county level production and price data from USDA for each crop identified in the survey.

Damage due to ranching losses will be calculated using: $D_R = Pn$

Where P is the market price per unit of livestock animal lost and n is the number of livestock animals lost.

These three models will then be used to generate a total aggregate damage estimate (TD) for the established target area in North Texas for 2009: $TD = D_P + D_A + D_R$

This estimate will not only be useful in evaluating the representativeness of survey estimates, but also determining whether hog damage falls within the range of previously published estimates for Texas ($7,515.00 per individual per year). This allows for a comparison to be made on whether these findings are significant enough to warrant further attention to management and control in the region.

To do this comparison, a test of difference will be utilized. A one-sample t-test will be calculated comparing the difference between in-sample aggregate damage and state-wide estimates.

$t_{n-1} = (\bar{x} - \mu) / (s/\sqrt{n})$ Where $\bar{x}$ = mean aggregate damage and $\mu = 7{,}515.00$

If the t-statistic falls within the rejection region ($p < .05$), in-sample aggregate damage is considered significantly different than state-wide damage estimates.

Finally, total acreage affected by hog damage will be calculated by dividing total acreage into acreage affected by damage. The percent total acreage damaged by hogs will be determined as a result.

After data are analyzed, it will then be summarized using descriptive statistics in SPSS (Table 1). n=???

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
Property Loss (D_P)	$1,522.00	$519.00	$0.00	$1,888.00	$3,382.00
Agricultural Loss (D_A)	$5,305.00	$1,125.00	$0.00	$5,100.00	$14,400.00
Ranching Loss (D_R)	$1,695.00	$1,215.00	$0.00	$2,008.00	$7,826.00
Total Damage (TD)	$8,611.00	$2,101.00	$0.00	$6,500.00	$20,999.00
Acreage Damaged	1.25	0.55	0	1.50	6.50

Table 1 – Descriptive Statistics of Economic Hog Damage and Acreage Damaged (**Hypothetical)

Furthermore, data for total damage and acreage damaged will then be geo-coded into a database for the established target area using ArcGIS (NAD 1983). Total damage estimates and acreage affected will be mapped according to zip code by city in order to determine areas most affected and to analyze the percent of potential habitat being destroyed. In order to further visualize any areas of particular concern or detriment, a boundary will be placed around any "high risk" areas indicating zones of significant economic damage. These "high risk" areas will serve as red flags to any potential future farming or ranching enterprises. By using GIS, one can better understand the factors influencing the economic data by picturing and analyzing the results in a geospatial environment.

Limitations of the research may include a sampling frame that would not be representative of the population due to a low response rate or bias because only those negatively affected by feral hogs responded to the questionnaire. Therefore the data are prone to suffer from systematic sample-selection bias. Because landowners who suffer high damage rates are more likely to submit exaggerated claims than landowners who suffer low damage rates, in-sample damage rates may tend to be higher on average than population damage rates.

Finally, surveys are largely applicable for estimating wildlife damage in general, but are costly to process.

Future considerations include analyzing field characteristics of damaged and undamaged properties, and developing a suitable habitat model to compare this interaction with damages. Considering data on the proximity of suitable habitat to damaged versus undamaged fields will improve future estimates and aid in the discussion of future solutions. Further research would also implement repeated sampling to further analyze economic damages in relation to time.

V. CONCLUSION

It has been established that feral hogs are a nuisance and have numerous associated problems; populations are rising dramatically, they harbor and transmit diseases, and they cause impressive amounts of ecological damage by destroying habitat and competing for resources with other wildlife. However, it has yet to be established how much economic damage the feral hog is capable of inflicting. Not to mention the complete lack of research on the feral hog in its newly expanded region of North Texas. By analyzing the data collected from a mail-out questionnaire around Ray Roberts Lake by using three models recognized in this paper, economic damage has been quantified for the region and the results are up for discussion.

Are feral hogs an economic burden or an under-utilized asset? They are undoubtedly an economic burden however the latter represents a vas margin for improvement through leasing practices. The state of Texas, the Cooperative Extension, Texas Parks & Wildlife and numerous wildlife managers and resource personnel across the state have shown increased awareness and efforts to fund, manage and control these invasive animals; however signs point toward an uncontainable dilemma. What steps must be taken now continue to be up for debate, however until a solution is found and regions of high economic risk are identified, native plants and wildlife species are still at risk, and the farmers, ranchers and landowners of Texas will continue to face escalating amounts of property loss and economic damages.

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