ASSIGNMENT OF GLOBAL INFORMATION SYSTEM COORDINATES TO CLASSICAL MUSEUM LOCALITIES FOR RELATIONAL DATABASE ANALYSES

by

OLEKSIY KNYAZHNITSKIY, B.S.

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CHAPTER I

INTRODUCTION

Many decisions are made based on information concerning the flora and fauna of the world. With the development of a large number of technological breakthroughs, such as computers, DNA sequencers, satellite imagery, and image analyzers, etc., the volume of knowledge available concerning plants and animals is rapidly expanding and has grown beyond our ability to examine each study and data set in the classically employed "hands on" analyses. To more effectively share and interrogate data sets, a new field of science has evolved called bioinformatics. At the heart of bioinformatics is the ability to use computers to examine massive data files in a critical synthesis. These syntheses employ relational databases to examine the geographical and temporal relationships compared to other data sets.

The Museum of Texas Tech University has been archiving biological specimens as a source of information on biocomplexity, disease, affects of agriculture, etc. These collections of biological voucher specimens are a valuable source of information that may be explored in a relational format. A new Relational Database Management System was designed to perform operations and increase the purpose of the electronic database (Monk, 1998). The Natural Science Research Lab's (NSRL) current collection was constructed to meet the needs of scientists and biologists, and increase the potential of the collection using the ongoing technological development of computer software and hardware (Baker et al., 1996). A problem to such use is that the data have to be in a format that is compatible with computer analysis. For example, a location such as *10 MI S LUBBOCK* cannot be recognized in a geographical context without assistance and extra computer time. Two types of locality data, Universal Transverse Mercator coordinates (UTM) and longitude and latitude, can be easily utilized by computer software. UTM coordinates are numerical data that depict exact geographical locations on a map. A world map is divided into 60 zones. To assign UTM coordinates for a specific location, the position within defined zones is established. For instance, the state of Texas is situated in zones thirteen, fourteen and fifteen (see Figure 1.1). Units express UTM coordinates in meters, so that the accuracy of a geographical location is no more than one meter.

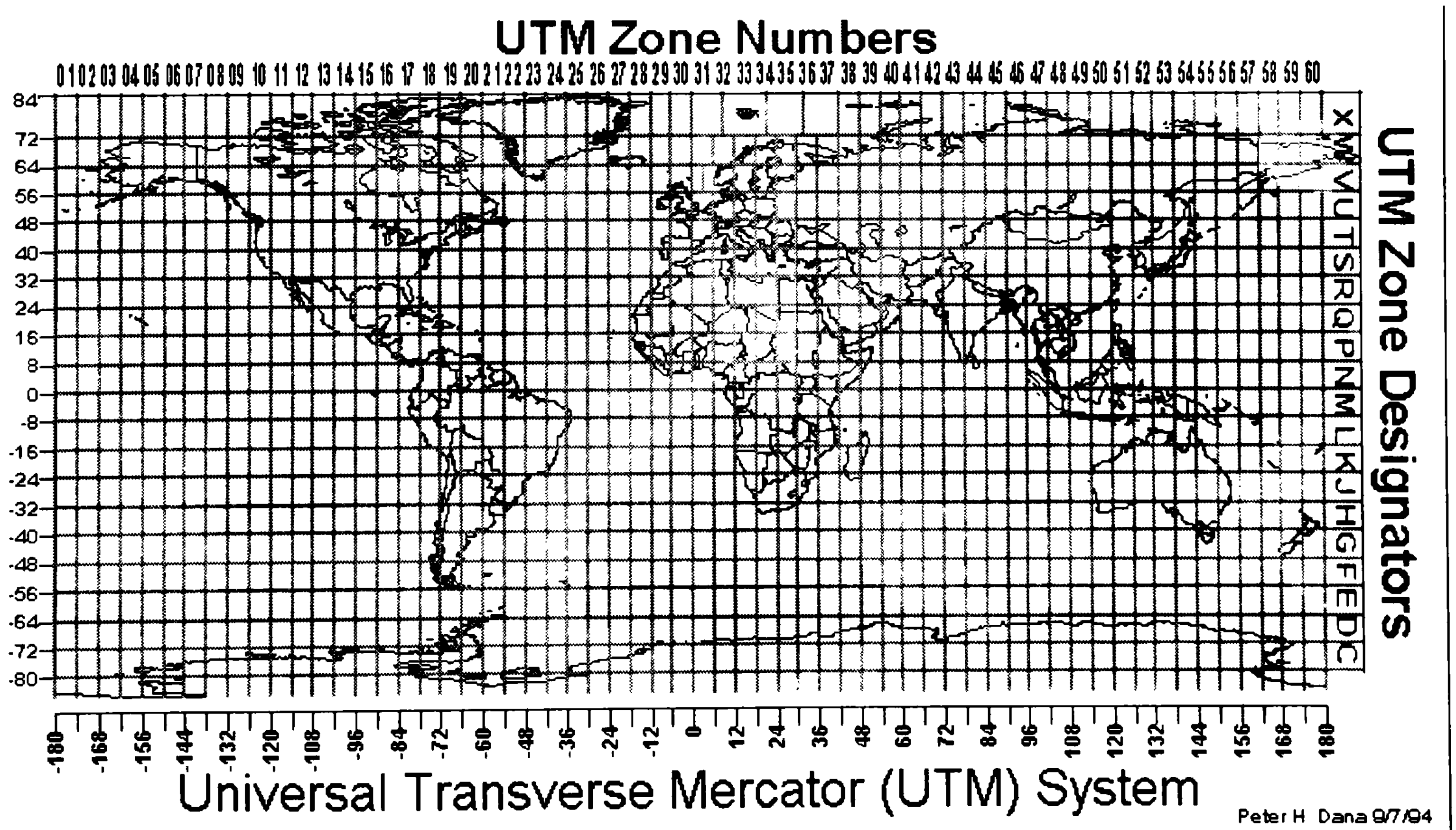

Figure 1.1. Map of UTM zones of the world created by Peter H. Dana at http:// www.utexas.edu/ftp/depts/grg/gcraft/test/corecoor/gif/utmzones.gif.

Generally, specimens collected and archived prior to 1990 were assigned geographical locations that were not computer compatible. This project was to convert geographical locations of the mammals of Texas such as *1 MI N, 10 MI E LUBBOCK*, *5 MI E ODESSA*, or *DALLAS* to UTM coordinates. The ultimate goal was to have UTM coordinates for all voucher specimens of mammals in the museum and in the USA so that these collections can be interrogated using compatible, relational databases.

Several problems are encountered in transcribing classical museum localities to computer compatible coordinates. First, not all localities recorded on tags of specimens contain equal accuracy. Therefore it was necessary to document the level of accuracy for each locality. The precision index (precindex) identified the accuracy of UTM coordinates (see Appendix). Precindex 1.1 represented coordinates that had been obtained by the collector using Global Position System (GPS) technology. If precindex was 3.0, then the location was computerized from relative distance data. If a record had only the name of a county, the precindex was 4.0 indicating that the accuracy was about thirty miles. To get better accuracy was not easy. For example, using the record *1 MI N, 10 MI E LUBBOCK*, it was impossible to identify from which exact place in Lubbock the collector had orientation. Some of the records contain directions from parks, creeks, or counties and most of them have precindex four. A second problem was encountered when the tag did not describe a location that was identifiable to a current map such as *5 MI FROM SALDINE*. The program to be developed had to handle records in a metadata context.

CHAPTER II

METHODS AND MATERIALS

I used Visual FoxPro 5.0 to assign UTM coordinates in a database file format for localities on museum tags. I recorded the UTM coordinates of the cities and towns of Texas using the digitizing system of ArcView Geographic Information System (GIS) to update the original data dictionary. Using the map of Texas on the digital computer table. I established the coordinates of the cities in zone fourteen for all three zones. Moreover. I designed software identified as *UTM convertor* that analyzed geographical locations and assigned UTM coordinates using the dictionary. The software deals with any number of records and can analyze the types of records commonly found in museum files. The working time of the software directly depends on the number of records in two tables. There are main functions that I ran step by step. The software characteristics were created because after several functions. it was useful to examine other records that did not contain a point that could be mapped and assigned a specific UTM location (Table 2.2). However, all records could be used in the subsequence steps.

The *UTM convertor* has nine options as follows:

1. Select table,
2. Select dictionary.
3. Add columns,
4. Drop columns.
5. Browse table,

6. Separate table,
7. Assign UTM,
8. Report,
9. Exit.

In the *Select table* and *Select dictionary* options, the user specifies a table and the appropriate dictionary. To analyze the table, it should contain five additional fields such as direction 1 (*dir1)*, digital data 1 (*dig1)*, direction 2 (*dir2)*, digital data 2(*dig2)*, and *city*. The option *Add columns* is used to make these fields. The next step of the program is to separate the records. For example, records

1. *7.5 MI NW NOTREES*
2. *1.0 MI N, 9.0 MI W WELLINGTON*

will be separated using *Separate table* option this way (Table 2.1).

Table 2.1. Separation of records.

DIG1	DIR1	DIG2	DIR2	CITY
7.5	*NW*			*NOTREES*
1.0	*N*	*9.0*	*W*	*WELLINGTON*

Many records have comments together with the names of cities. So that if there is the locality such as *1.0 MI N, 9.0 MI W WELLINGTON, NEAR COUNTRY BLACK ROAD* in the table, the field *city* is not compatible with the *UTM convertor* program (Table 2.2).

Table 2.2. An example of a record that is not compatible with the *UTM convertor*.

DIG1	DIR1	DIG2	DIR2	CITY
1.0	*N*	*9.0*	*W*	*WELLINGTON, NEAR COUNTRY BLACK ROAD*

It is essential to look through the table and cut such comments to prepare the field *CITY* (Table 2.3) for UTM assignment. The option *Browse table* was designed to open and work with the table.

Table 2.3. An example of *UTM convertor* compatible record.

DIG1	DIR1	DIG2	DIR2	CITY
1.0	*N*	*9.0*	*W*	*WELLINGTON*

Using *Assign UTM*, the program creates UTM coordinates and updates the precindex field. It uses the main table and the dictionary database file (Table 2.4).

Table 2.4. Assigned UTM coordinates to records.

DIG1	DIR1	DIG2	DIR2	CITY	EASTING	NORTHING
7.5	*NW*			*NOTREES*	*136362*	*3546991*
1.0	*N*	*9.0*	*W*	*WELLINGTON*	*374393*	*3859381*

The option *Report* was created to check how many records were assigned. At the end of the program you can use the *Drop columns* option to delete those fields such as direction 1 *(dir1)*, digital data 1 *(dig1)*, direction 2 *(dir2)*, digital data 2*(dig2)*, and *city*. The *UTM convertor* is available at http://nsrlmap.musm.ttu.edu/utm/project.htm.

CHAPTER III

RESULTS

I worked with 15,220 locality records for mammal voucher specimens collected from Texas. UTM coordinates were successfully assigned to 96.2% of the records, where 86% of the records were assigned by the software and 10.2% of the records were assigned manually. Moreover, UTM dictionaries were created for fifty states and Puerto Rico as appropriate for the zones in these states using the original database from US Census Bureau (<http://ftp.census.gov/ftp/pub/tiger/tms/gazetteer/places.zip>). Therefore, using *UTM convertor* and dictionaries (see http://nsrlmap.musm.ttu.edu/utm/project.htm), UTM coordinates can be assigned to localities for mammal voucher specimens from all of the USA for specific geographical locations. Geographical representation of the Texas records is available at http://nsrlmap.musm.ttu.edu/map1/texas.html. The assigned UTM records are easily analyzed by GIS software, for example, to develop maps shown in the following discussion I used ArcView GIS 3.1. This is an example of a Java client interaction with a server to produce dynamic maps (see Figure 3.1).

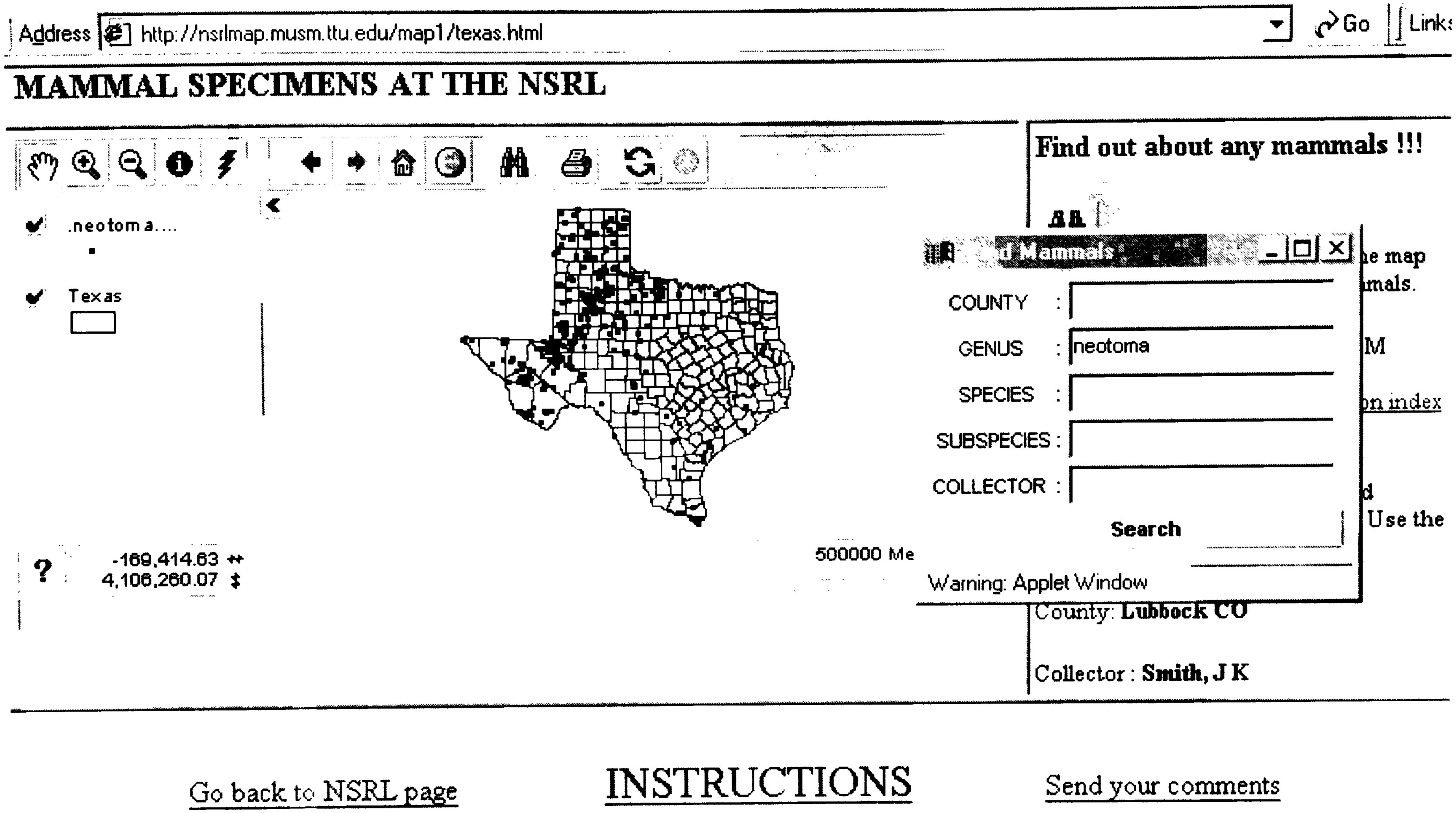

Figure 3.1. Interactive Map Café applet that produces dynamic maps.

CHAPTER IV

DISCUSSION

The *UTM convertor* assigned coordinates to about 86% of the 15,220 locality records. After several stages of assigning records, it was necessary to correct spelling mistakes of localities, add some cities to the dictionary, and edit comments in the specific field of the main table. Following is an example of some localities to which UTM coordinates were assigned by the *UTM convertor* program:

1. *0.5 MI N, 0.5 MI W WHITEFACE,*
2. *1 MI SW GANADO,*
3. *1.5 MI W PLAINVIEW ON DONALD LEE TURRELL FARM,*
4. *2.25 MI N, 7.5 MI E QUANAH,*
5. *1 MI N, 1.5 MI W LUBBOCK.*

Furthermore, 10.2% of the records were assigned manually. These records contained data in a non-traditional format, for instance:

1. *4 MI S, 7 MI E JCT 84 AND LOOP 289,*
2. *3.1 MI E JCT TEX 59 AND FR 1758 ON 1758,*
3. *GUADALUPE MTS NATL PARK, UPPER DOG CANYON, RANGER STA.*

I searched for these locations on the maps and calculate their UTM coordinates.

Finally, I was unable to assign UTM coordinates to 3.8% of the records because these localities could not be identified on the map. The locality description did not contain enough information to accurately locate them. The following are examples of localities that could not be assigned UTM coordinates:

1. *3 MI S OF I 40 ON CARBON BLACK ROAD,*
2. *5 MI FROM SALDINE,*
3. *3 MI ? ODESSA,*
4. *1 MI E, 1 MI S THE CITY DUMP,*
5. *DOUBLE U RANCH.*

The accuracy of records varied tremendously as show by the following:

1. *4TH AND QUAKER AVE, LUBBOCK,*
2. *HOUSTON AREA,*
3. *1.25 MI N, 3 MI W WINK,*
4. *LUBBOCK CO.*

The first record is more accurate than the other records, hence more exact coordinates could be assigned to this area. Furthermore, the third record is second in line of accuracy. We do not know from which point in the city of Wink the collector traveled north and west, but we do know that Wink is a small town. Finally, *Lubbock Co* is very large about 30 x 30 mi, so an accurate location cannot be assigned. At least, it is reasonable to assume that the specimen was collected within the 30 by 30 mile area. The locality *HOUSTON AREA* is even more difficult, because it is impossible to determine if the locality is in the city of Houston or the surrounding suburbs. The accuracy of each locality was documented using a precision index (see Appendix): (1) *4TH AND QUAKER*

AVE, LUBBOCK (precindex 3.0), (2) *HOUSTON AREA* (precindex 5.0), (3) *1.25 MI N, 3 MI W WINK* (precindex 3.0), (4) *LUBBOCK CO* (precindex 4.0).

After assigning UTM coordinates, it was possible to use GIS software to better interrogate and understand mammal zoogeography. Applications of the GIS for mammals included several examples as follows: a demonstration of maps depicting UTM locations assigned to sites where field biologists collected archived specimens. Localities can be analyzed through software by such fields as dates, collectors, species, genus etc. These are some of the ways that the distributions of voucher specimens of Texas mammals can be studied. Voucher specimens housed in the NSRL (Figure 4.1) have been collected throughout the state but most intensively in west Texas. Collections (Figure 4.2) from other museums (Table 4.1) excluding the NSRL have been made throughout the state but are most intensive in north Texas. When these two data sets were combined (Figure 4.3) it is apparent that most area, the state have been heavily studied than others.

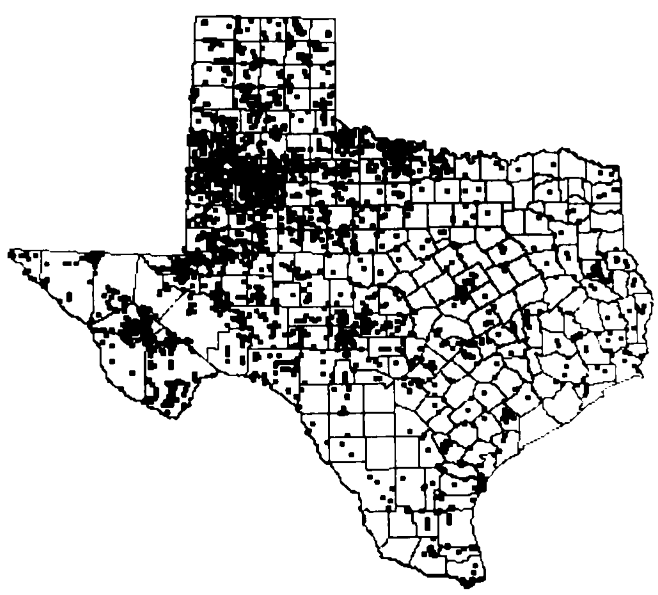

Figure 4.1. Distribution of all localities of mammal voucher specimens housed at the Natural Science Research Laboratory (up to 1998).

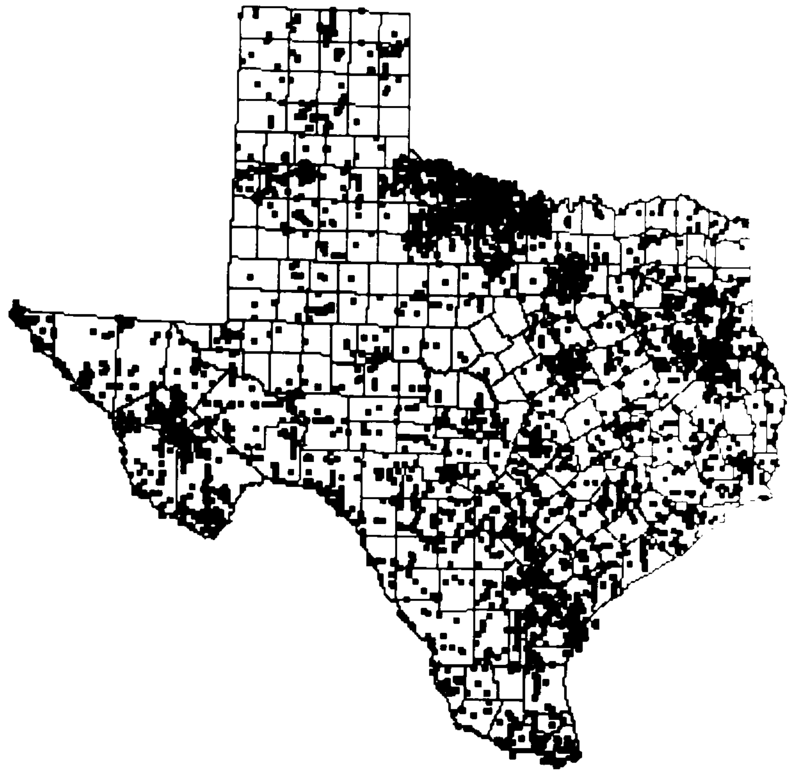

Figure 4.2. Distribution of all localities of mammal voucher specimens housed at other collections represented in Table 4.1 up to 1991 (Dr. Schmidly's database, Texas Tech University).

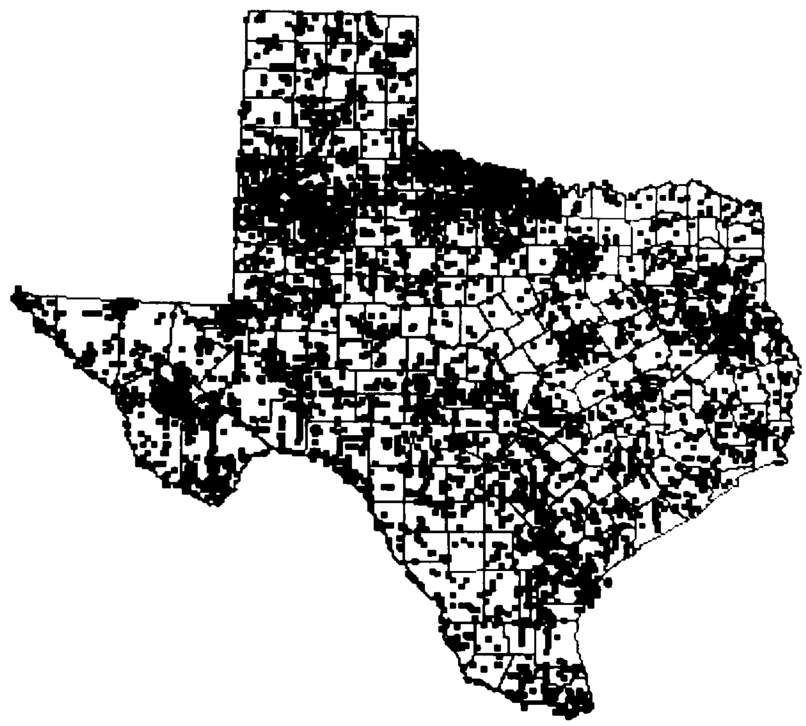

Figure 4.3. Localities of all mammal specimens in all collections represented in Table 4.1 and the Natural Science Research Laboratory studied by Dr. David Schmidly for the Mammals of Texas (Davis & Schmidly. 1994).

Table 4.1. Collections represented in Dr. Schmidly's database (*Condor*). Acronym fields are represented in accordance with The American Society of Mammalogists (ASM) (Yates et al.. 1987), or as the *Condor* database acronym (DB Acronym).

Collection	DB Acronym	ASM Acronym
American Museum of Natural History, New York	AMNH	AMNH
Angelo State University, Vertebrate Research Collection	ASUVC	ASVRC
Big Bend Natural History Association, Big Bend National Park	BBNP	BBNHA
Baylor University, Strecker Museum	BUSM	SM
Corpus Christy State University Vertebrate Collection	CCSU	--------
Carnegie Museum of Natural History, Pittsburgh	CMNH	CM
Dallas Museum of Natural History	DMNH	DMNH3
Field Museum of Natural History	FMNH	FMNH
Fort Worth Museum of Science and History	FWMSH	FWMSH
University of Kansas Museum of Natural History	KU	KU
Los Angeles County Museum of Natural History	LACM	LACM
Louisiana State University Museum of Zoology	LSUMZ	LSUMZ
University of Texas at El Paso, Mammal Div., Lab. for Env. Biology	MALB	UTEP
Museum of Southwestern Biology, University of New Mexico	MSBUN	MSB
Michigan State University	MSU	MSU
Museum of Vertebrate Zoology, University of California at Berkeley	MVZ	MVZ
Midwestern State University Collection of Recent Mammals, Wichita Falls	MWU	MWSU
Philadelphia Academy of Science	PAS	ANSP
Stephen F. Austin University, Department of Biology, Nacogdoches	SFAVC	SFASU
Sul Ross State University, Vertebrate Collection, Alpine	SRSU	SRSU
Southwest Texas State	SWTS	--------
Texas A&I University (now Texas A&M University at Kingsville)	TAIU	TAIU
Texas Natural History Collection, University of Texas at Austin	TNHC	UTLPA
Texas Wesleyan College, Museum of Zoology, Fort Worth	TWC	TWC
University of Illinois Museum of Natural History	UIMNH	UIMNH
University of Michigan Museum of Zoology	UMMZ	UMMZ
U.S. National Museum	USNM	USNM
University of Texas at Arlington Collection of Vertebrates	UTAVC	UTACV
Witte Memorial Museum, San Antonio	WMSA	WMM

A center of mammal research (Figure 4.2) can be seen around Wichita Falls where Dr. Stangl's research effects are well documented. Once placed in a GIS the distributions of species such as *Mus musculus* (Figure 4.4, Figure 4.5). *Dipodomys ordii* (Figure 4.6, Figure 4.7), *Dipodomys merriami* (Figure 4.8, Figure 4.9), *Felis* and *Lynx* (Figure 4.10, Figure 4.11), and *Neotoma micropus* (Figure 4.12, Figure 4.13) can be easily depicted.

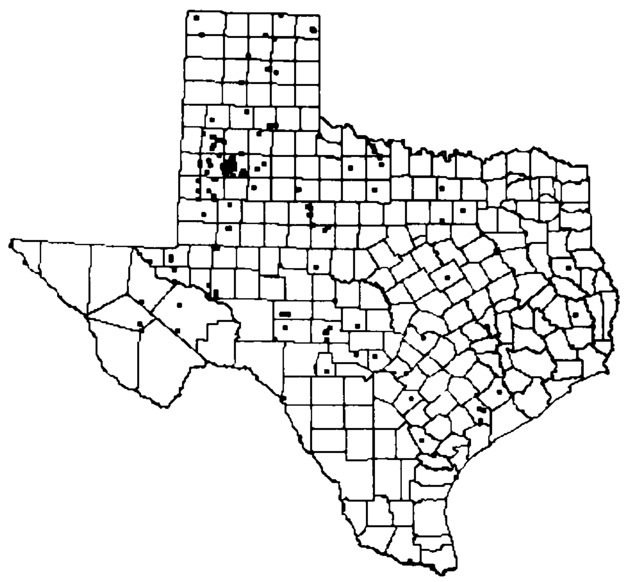

Figure 4.4. Distribution of localities where voucher specimens of *Mus musculus* have been collected and stored at the Natural Science Research Laboratory.

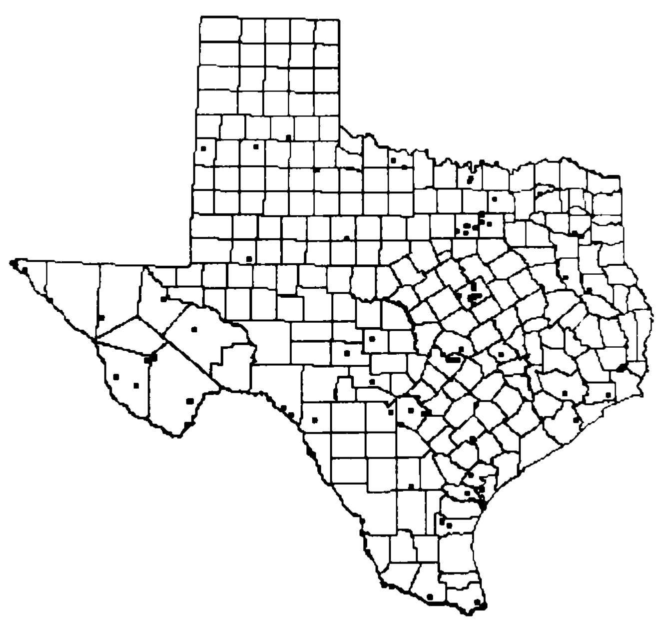

Figure 4.5. Distribution of specimens of *Mus musculus* archived at other locations represented in Table 4.1 excluding the Natural Science Research Laboratory.

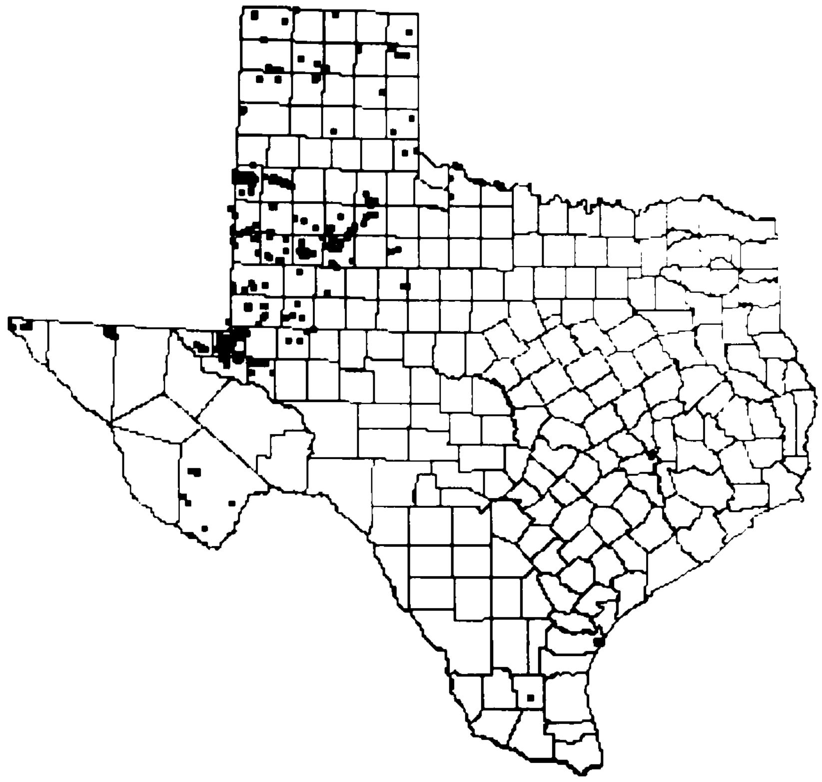

Figure 4.6. Distribution of localities where voucher specimens of *Dipodomys ordii* have been collected and stored at the Natural Science Research Laboratory.

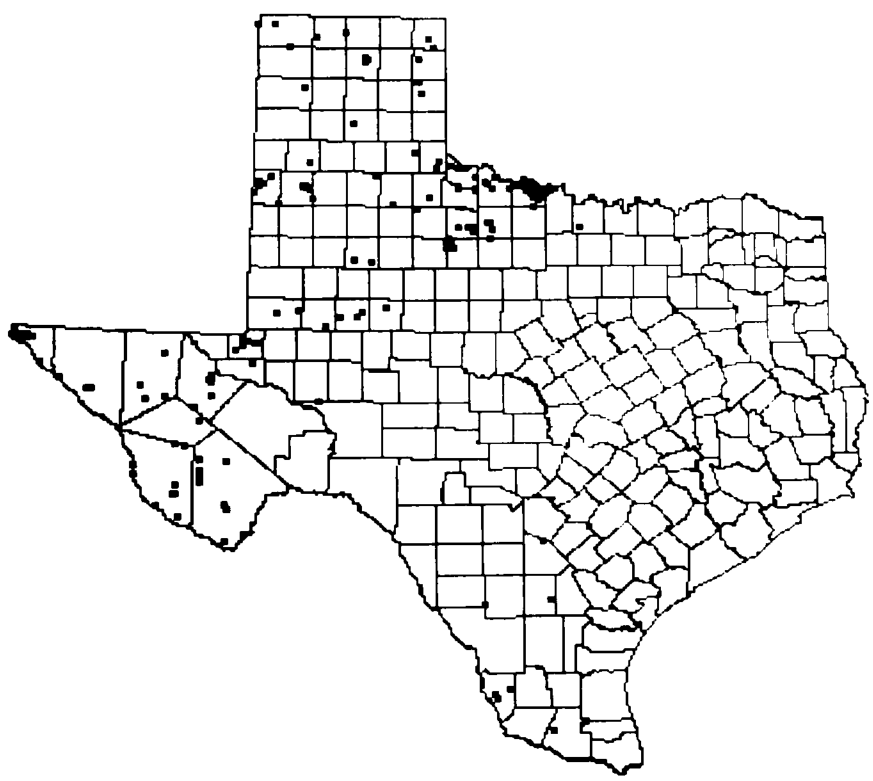

Figure 4.7. Distribution of specimens of *Dipodomys ordii* archived at other locations represented in Table 4.1 excluding the Natural Science Research Laboratory.

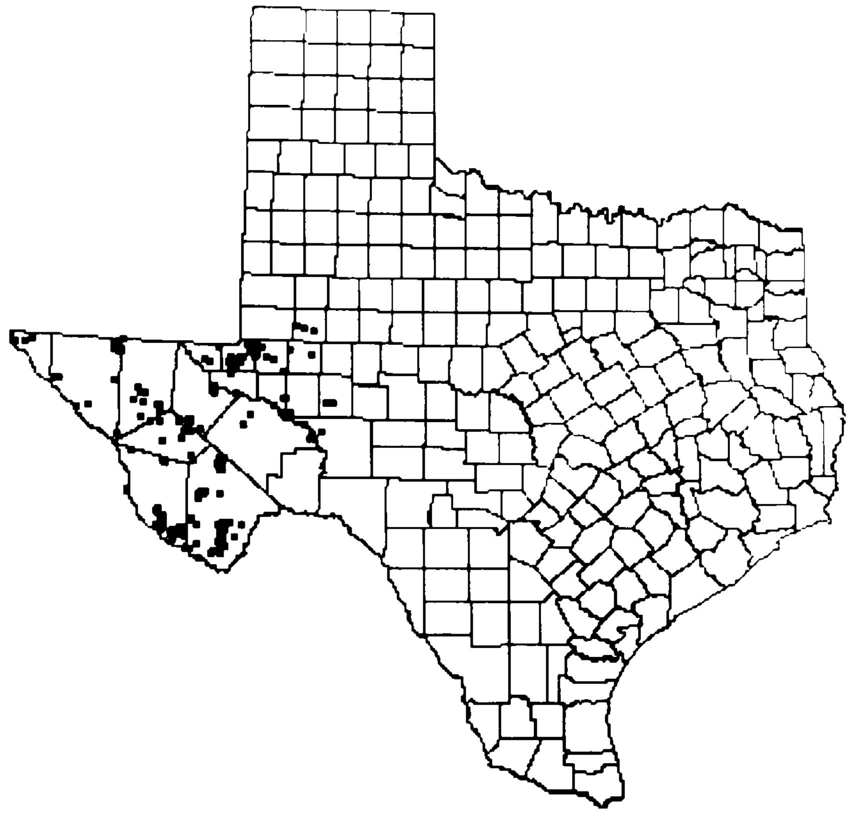

Figure 4.8. Distribution of localities where voucher specimens of *Dipodomys merriami* have been collected and stored at the Natural Science Research Laboratory.

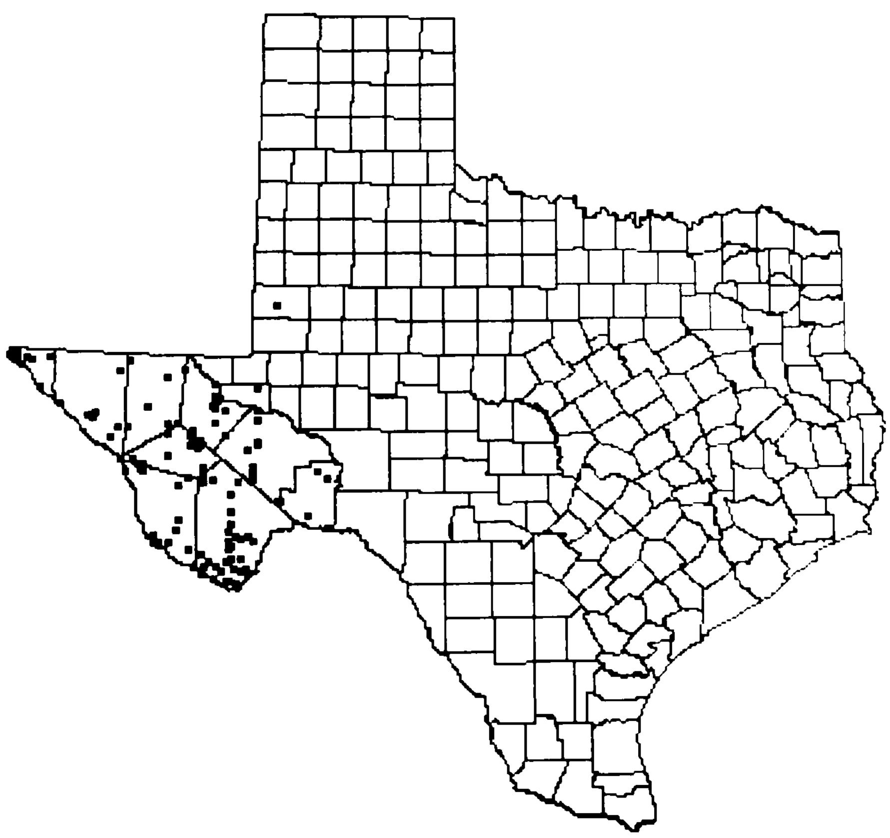

Figure 4.9. Distribution of specimens of *Dipodomys merriami* archived at other locations represented in Table 4.1 excluding the Natural Science Research Laboratory.

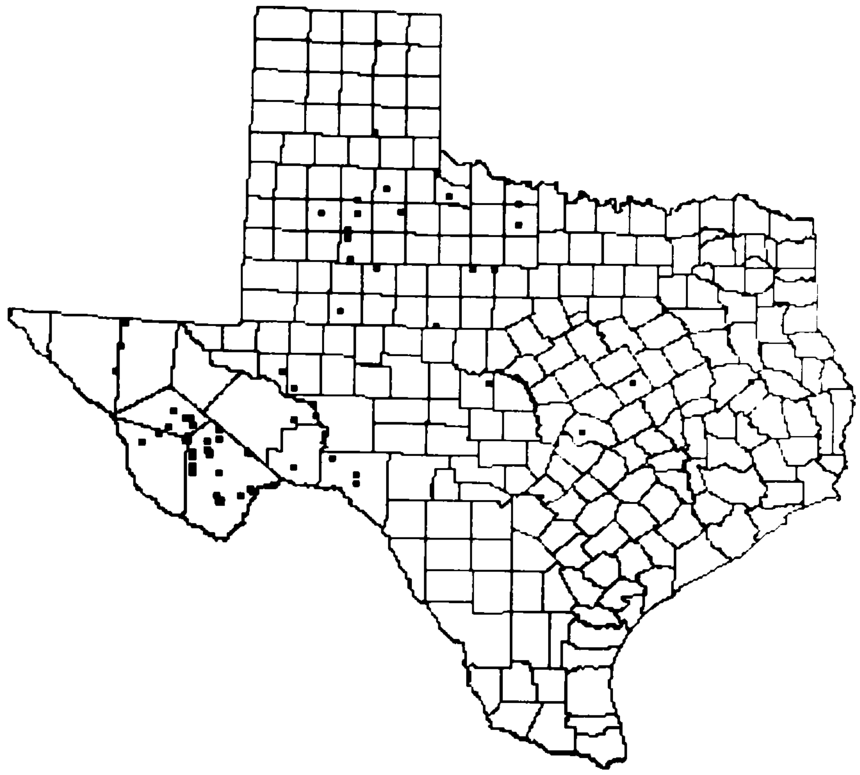

Figure 4.10. Distribution of localities where voucher specimens of *Felis* and *Lynx* have been collected and stored at the Natural Science Research Laboratory.

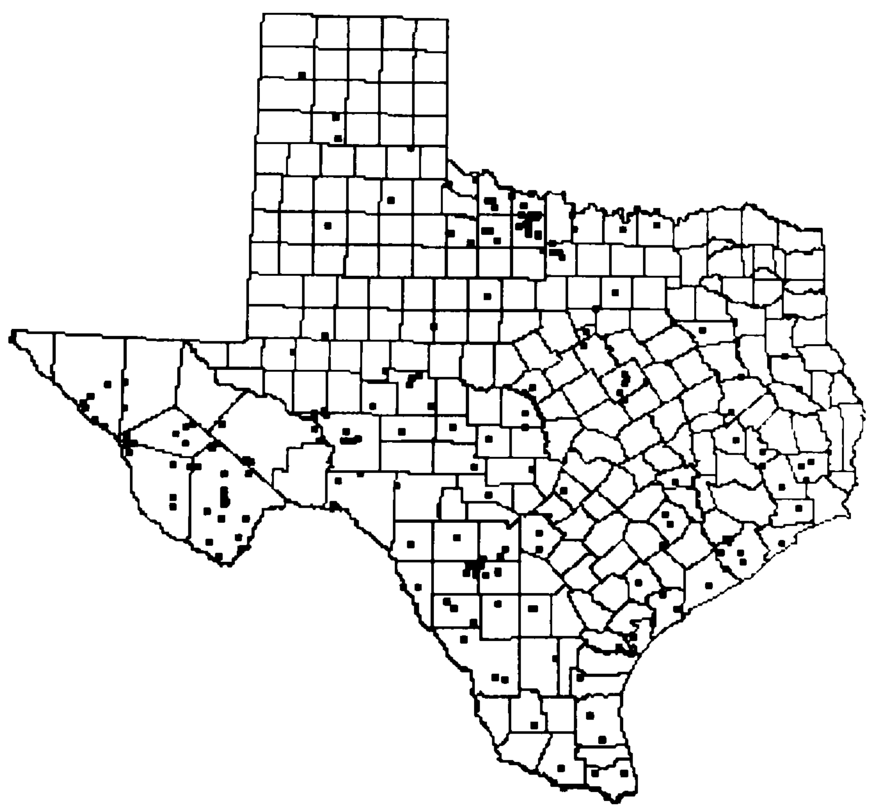

Figure 4.11. Distribution of specimens of *Felis* and *Lynx* archived at other locations represented in Table 4.1 excluding the Natural Science Research Laboratory.

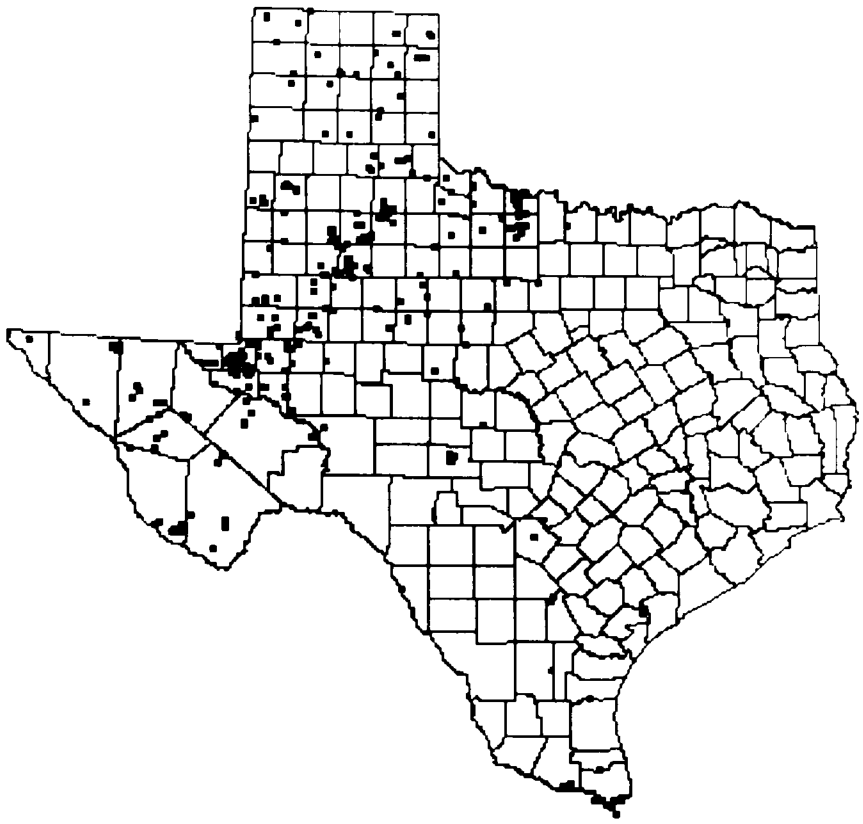

Figure 4.12. Distribution of localities where voucher specimens of *Neotoma micropus* have been collected and stored at the Natural Science Research Laboratory.

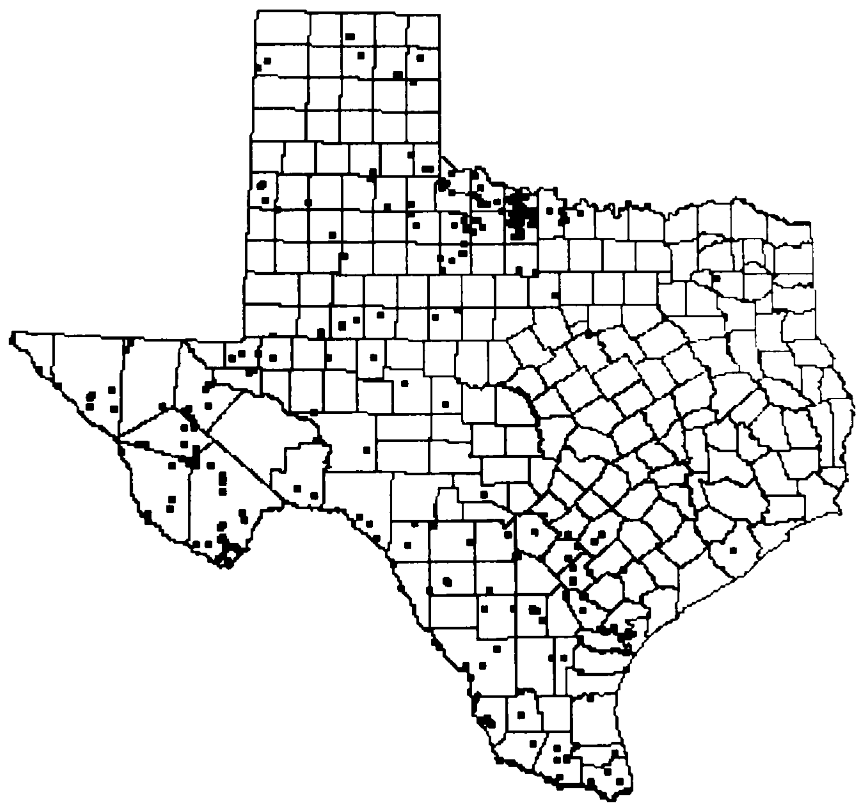

Figure 4.13. Distribution of specimens of *Neotoma micropus* archived at other locations represented in Table 4.1 excluding the Natural Science Research Laboratory.

The history of mammal and specimen collection can be visualized by examining the collection localities over time. Prior to 1959, Texas Tech did not have an active program in mammalogy (Figure 4.14, Figure 4.15).

Figure 4.14. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected prior to 1949.

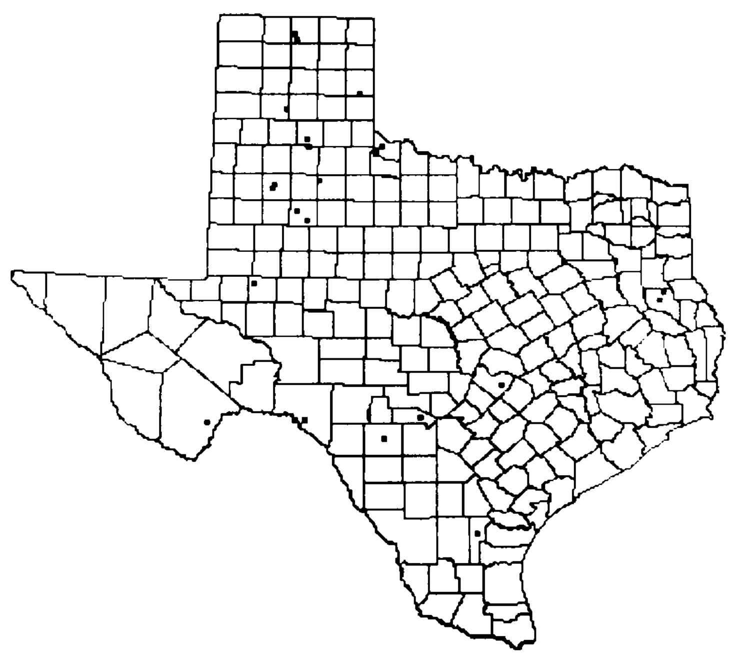

Figure 4.15. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected after 1 Jan 1950 and before 1 Jan 1960.

In the sixties, Dr Packard developed a strong mammalogy program as indicated by the number of localities in the Figure 4.16. Dr. Packard had many graduate students, including David Schmidly, etc. The collection was expanded in the 1960's as these students completed master theses and doctors' dissertations (figure 4.16). In 1967 Dr. Robert J. Baker joined the Tech faculty; he and his students also contributed significantly to the collection during the 1970's (Figure 4.17), the 1980's (Figure 4.18), and the 1990's (Figure 4.19)

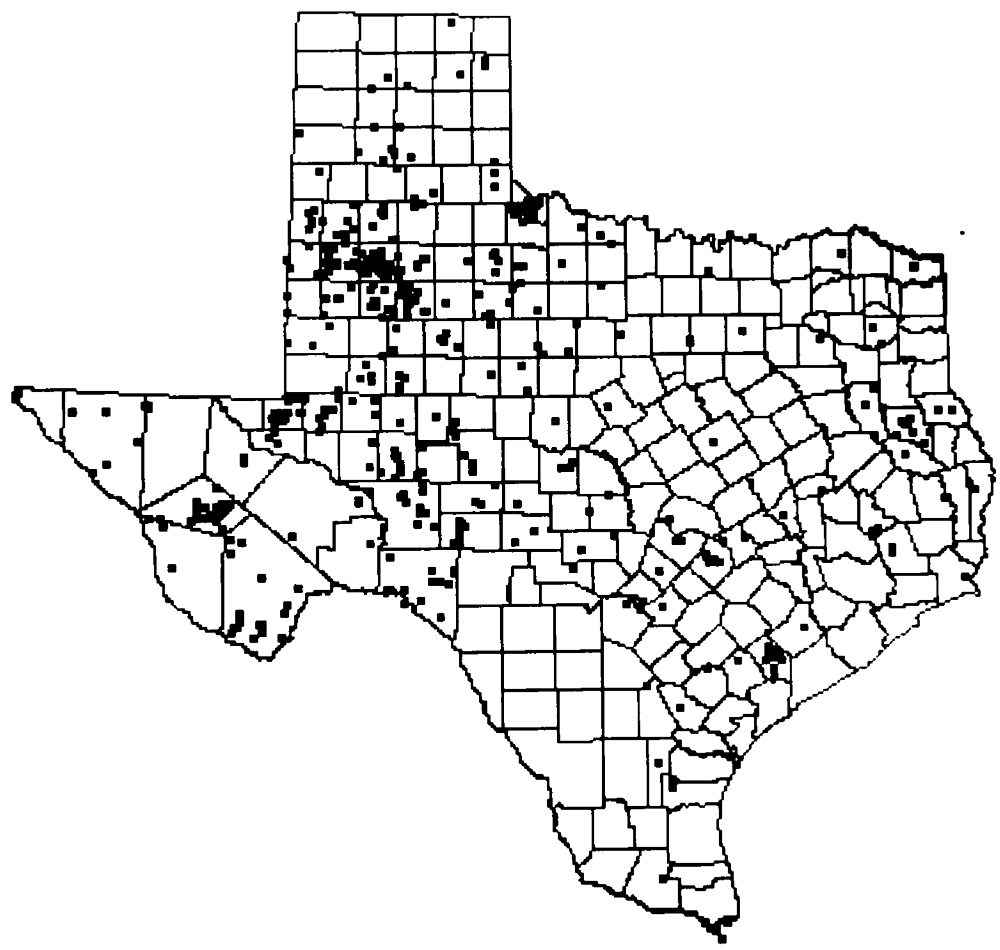

Figure 4.16. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected after 1 Jan 1960 and before 1 Jan 1970.

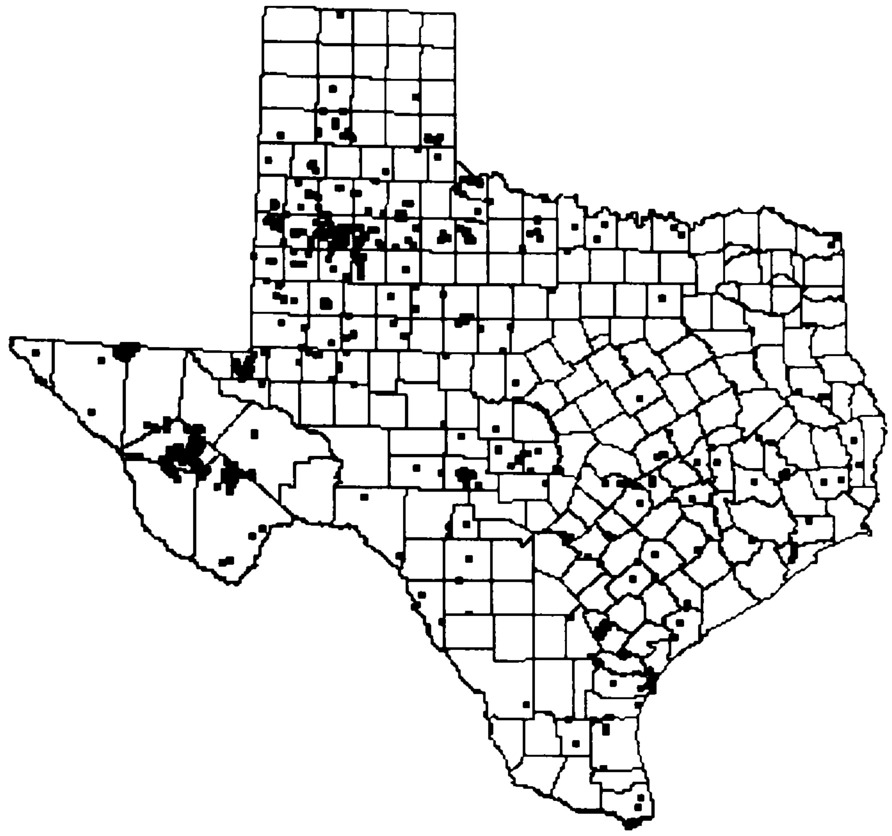

Figure 4.17. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected after 1 Jan 1970 and before 1 Jan 1980.

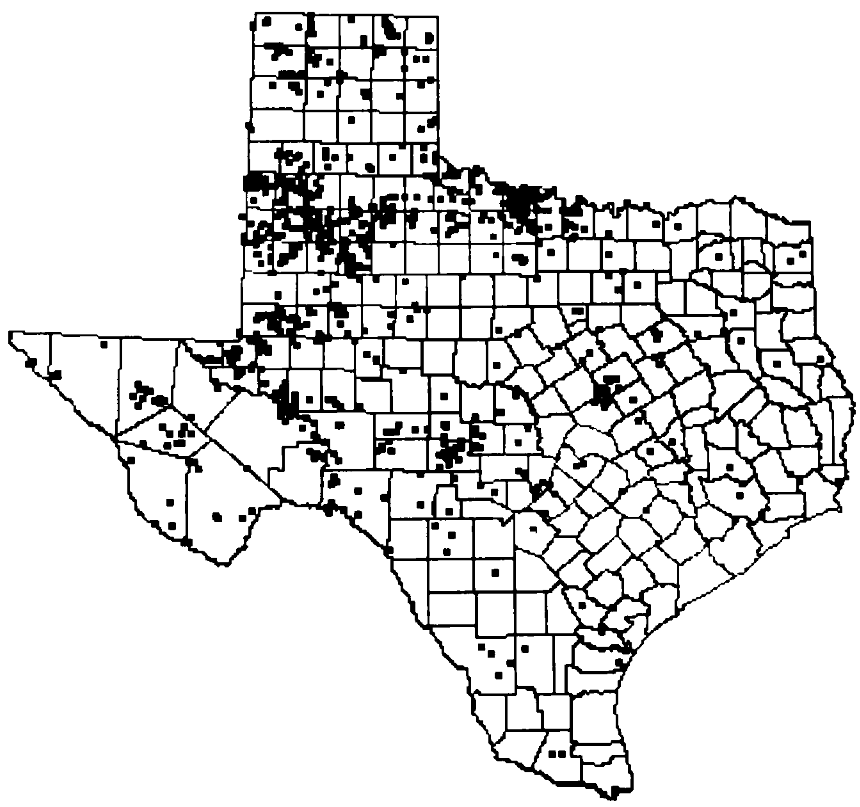

Figure 4.18. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected after 1 Jan 1980 and before 1 Jan 1990.

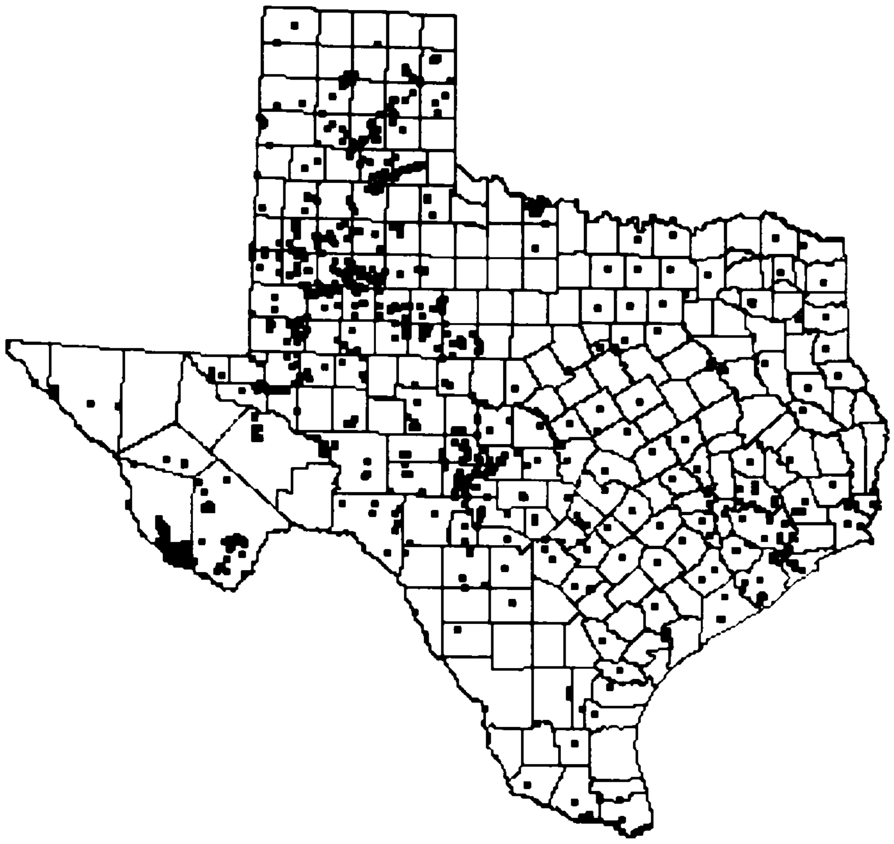

Figure 4.19. Localities of mammal specimens housed at the Natural Science Research Laboratory that were collected after 1 Jan 1990 and before 1 Jan 1999.

During the 1990's, as Global Position System receivers became readily available, location of collections were recorded in the field using UTM coordinates (Figure 4.20).

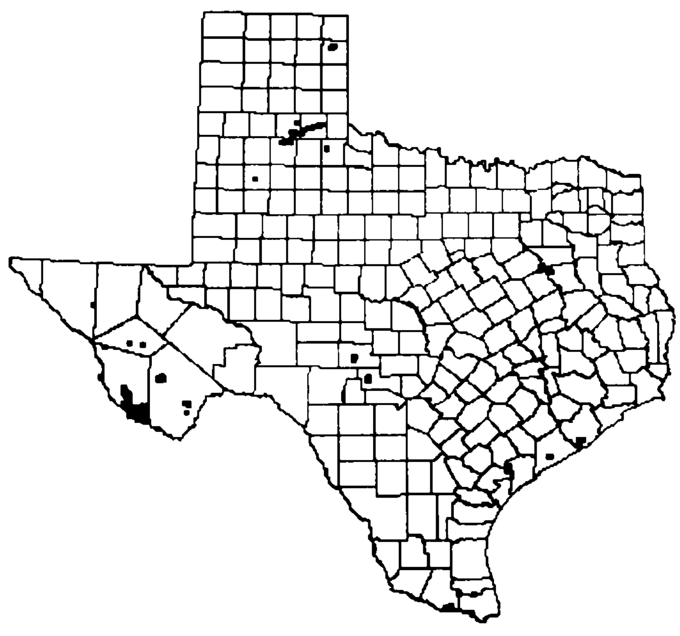

Figure 4.20. Localities of mammal specimens housed at the Natural Science Research Laboratory that have primary data (precision index 1.1).

Once UTM coordinates have been assigned to voucher specimens. These specimens become much more valuable and can be used to analyze and predict distribution of vertebrates. For instance, there are approximately two hundred sixty-seven records of *Peromyscus boylii* depicted on the Figure 4.21 and Figure 4.22

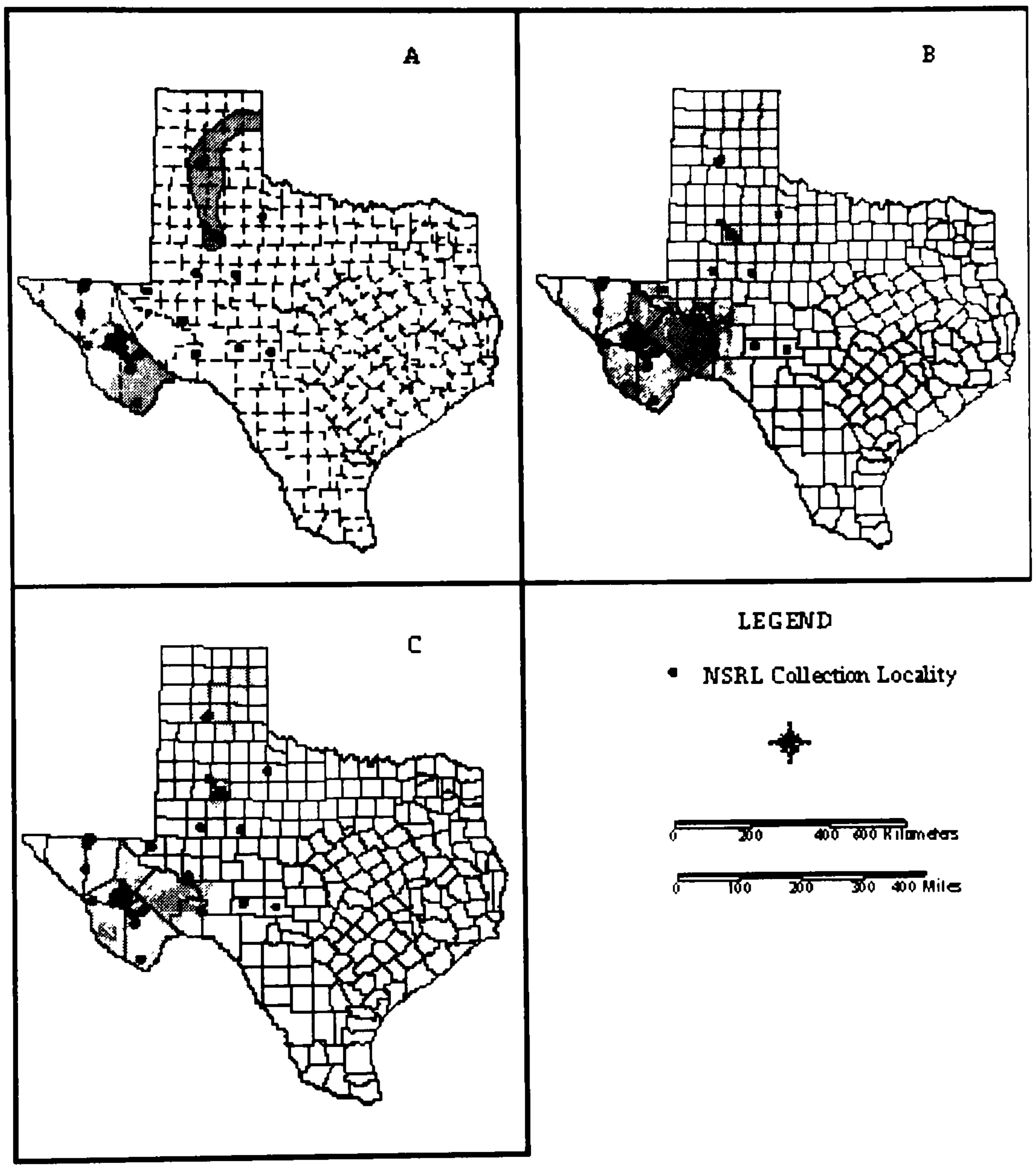

Figure 4.21. An example of Kelly Allen's dissertation work (Texas Tech University) depicting distribution of the brush mouse (*Peromyscus boylii*). The documented range extent (A) represents the range extent as defined within Davis and Schmidly (1994). Predicted habitat (B) was modeled using GIS and includes all possible habitat while the distribution model (C) reflects the predicted habitat as defined by the known range extent and collection localities.

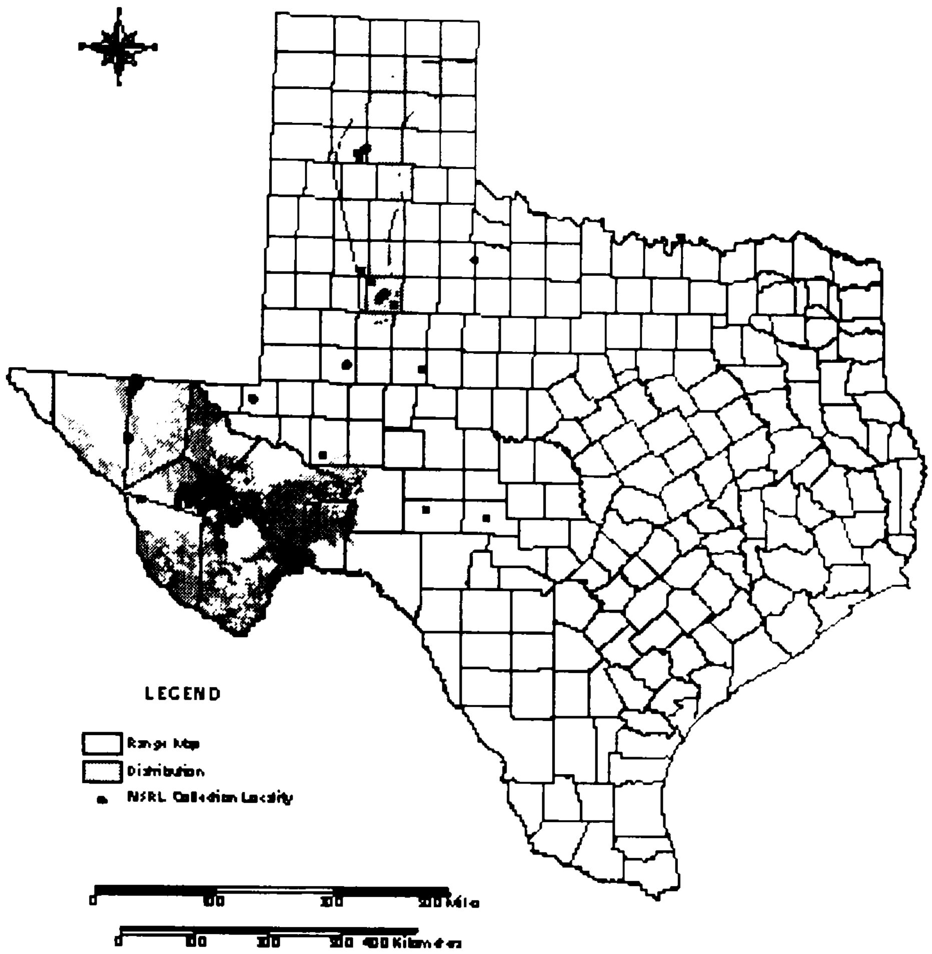

Figure 4.22. Second example of Kelly Allen's dissertation work (Texas Tech University) where distribution of the brush mouse (*Peromyscus boylii*). Light gray areas represent the range extent as published in Davis and Schmidly (1994) while the dark gray areas represent predicted habitat modeled using a GIS. Collection localities indicate voucher specimens labeled as *Peromyscus boylii* and housed in the Natural Science Research Laboratory.

By developing information systems, humankind has more and more ability to comprehend data that surrounds us. Regardless of the discipline, decisions based on a huge amount of data cannot be made without information systems. Bioinformatics opens the new way of decision making in biology. It includes "the delivery of the data and its synthesis to potential users" (Parker et al., 1998, p. 1). The museum data compatible with computer analysis now are a source of information to do research on different varieties of biological aspects. Artificial intelligence is the key to produce analyses of data and provide results using specific biological methods. For instance, scientists can visualize the distribution of specimens by genus or species all around the world in conjunction with diseases that occurred twenty years ago. Decisions of bioinformatics will be impacted and limited by information processing, accuracy, reliability, and detail of information where benefits to society can be invaluable in developing a new knowledge of data (Baker et al., 1998).

CHAPTER V

CONCLUSION

The *UTM convertor* is designed to assign GIS coordinates for relational database analyses. It is only a matter of time and size of tables. The *UTM convertor* has the ability to analyze traditional reference point locality data and to automatically assign UTM coordinates. It also records a precision index value for each locality to which coordinates were assigned.

It is possible to include different types of localities for analysis of museum collections by the *UTM convertor* or to make the *UTM convertor* teach itself to study records in the future. Assigned UTM records are immediately available for analysis and are much more valuable than records without GIS compatible locations. Biologists can obtain data searched by many fields such as genus, species, dates, counties, collectors etc. The examples of species distributions, NSRL history distributions, and other GIS applications are to demonstrate the importance of GIS compatible coordinates.

LITERATURE CITED

Baker, R. J., Phillips, C. J., Bradley, R. D., Burns, J. M., Cooke, D., Edson, G. F., Haragan, D. R., Jones, C., Monk, R. R., Montford, J. T., Schmidly, D. J., and Parker, N. C., 1998. Bioinformatics, Museums and Society: Integrating Biological Data for Knowledge-Based Decisions. Occasional Papers, Museum of Texas Tech University, 187:i+1-4.

Baker, R. J., Albin, B., Bradley, R. D., Bull, J. J., Burns, J., Clark, K. A., Edson, G., Estrada, R. E., Farley, E., Fedler, C.B., Gharaibeh, B. M., Hammer, R. L., Jones, C., Monk, R. R., Montford, J. T., Moore, G., Parker, N. C., Rawlings, J., Sansom, A., Schmidly, D. J., Sims, R. W., Wichman, H., and Yancey, F. D., 1997. Natural Science Database: Resource Management and Public Health. Pp 10-20 *in* Collaboration: The "Key" to Success: Proceedings of the 4th Annual Conference, Organization of Fish and Wildlife Information Managers, July 1996. (M. Shaughnessy, ed.,) 1-96 pp.

Davis, W. B., and Schmidly, D. J., 1994. The Mammals of Texas. Austin: Texas Parks and Wildlife. 1-338 pp.

Monk, R. R., 1998. Bar Code use in the Mammal Collection at the Museum of Texas Tech University. Museology, 8:1-8.

Parker, N. C., Bradley, R. D., Burns, J. M., Edson, G. F., Haragan, D. R., Jones, C., Monk, R. R., Montford, J. T., Phillips, C. J., Schmidly, D. J., and Baker, R. J., 1998. Bioinformatics: A Multidisciplinary Approach for the Life Science. Occasional Papers, Museum of Texas Tech University, 186:i+1-8.

Yates, T. L., Barber, W. R., and Armstrong, D. M., 1987. Survey of North American Collections of Recent Mammals. American Society of Mammalogists, supplement, 68(2), 1-55.

APPENDIX

COORDINATE PRECISION INDEX VALUES

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(Documentation Standards for Automatic Data Processing in

Mammalogy, Version 2.0, McLaren et al., 1996, page iv-15)

DESCRIPTION: This category is used to indicate the reliability of the coordinates that have been applied to a given collecting locality.

1.1 Designates coordinate data as entered by the collector and accurate to ±10 meters; e.g., data obtained using GPS technology.

1.2 Designates coordinate data as entered by the collector and accurate to ±100 meters; e.g., data extrapolated using 1:24,000 topographic map.

1.3 Designates coordinate data as entered by the collector and accurate to ±1 kilometer; e.g., data extrapolated using ≥ 1:100,000 scale map.

2.0 Designates coordinate data which has been looked up in tables listing coordinates for various place names on the globe. Precision: Collection site within 3 miles of coordinates given.

3.0 Designates coordinate data which have been computerized from relative distance data. It would also include center coordinates for small islands and other small geographic features.

4.0 Designates center coordinates for larger geographic features given in the collector's data where no precise information is given. This would cover most US counties and larger islands. Precision: Collection site within 30 miles of coordinates given.

5.0 Designates center coordinates for even larger geographic features such as larger US counties, small states and countries, and very large islands. Precision: Collection site within 100 miles of coordinates given.

6.0 Designates larger US counties, small states and countries, and very large islands. Precision: Collection site within 300 miles of coordinates given.

7.0 Designates center coordinates for very large geographic features such as "AFRICA" or "AUSTRALIA." Precision: Collection site > 300 miles from coordinates given. Although of marginal value, this value indicates that some LOCALITY information is known.

8.X Designates an interim value, based on one of the above values of precision but where the data have the potential of more precision. This marks them for future reference when the coordinates for this place name may be found. The "X" represents the current precision level used.

9.0 Designates that no LOCALITY data are available. This flags any data in the coordinate fields as garbage.

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Agree (Permission is granted.)

Disagree (Permission is not granted.)

Student's Signature   Date