# The *Thomomys mazama* Pocket Gopher in Washington Prairies: A Contemporary View for Management

**By**

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ABSTRACT

# The *Thomomys mazama* Pocket Gopher in Washington Prairies: A Contemporary View for Management

Cynthia J. Knudsen

One species living in western Washington prairies is the pocket gopher, *(Thomomys mazama)*, a vital component in the maintenance of Washington state prairie ecosystems**.** The burrowing activities of the *T.mazama* gophers contribute to the maintenance of the diversity of plant species in prairies.

Washington State has experienced population growth that has resulted in development of prairie regions. This development creates interruptions in the pocket gopher's habitat that resulting in the creation of edge effects that contribute to habitat fragmentation and possibly to species extinction. Extinction rates for species residing specifically in prairie landscapes are highest for the species that are rare, or that require large patches of unbroken habitat and have short distances between those patches, or for species that have limited dispersal distances. All these conditions may apply to the *T.mazama* gopher in Western Washington prairies.

Immediate research should be conducted to determine how the *T.mazama* is affected by habitat fragmentation and to preserve this species valuable place in prairie ecosystems. There are many modeling programs available to estimate possible impacts to the gopher's habitat. Although these modeling projections are useful, they cannot provide complete solutions, because little data currently exists on the *T.mazama* gopher to use in these models.

A population survey should be conducted for the presence of *T.mazama* gophers in Washington prairies. Once species identification is complete for the *T.mazama*, this information may then simultaneously be incorporated within a landscape ecology approach that addresses prairie ecosystem maintenance on large landscape scales and small scales of biologic and habitat requirements. This approach addresses a multi-scale systems perspective that must be incorporated within policy decisions in order to provide maximum protection for the *T.mazama* habitat and the larger ecosystem functions.

It is only by these methods that adequate policy can be created to identify and protect the *T.mazama* from extirpation. Once accurate gopher inventory data is adapted to modeling programs, it will be possible to create informed wildlife and land development policy so Washington prairies may be preserved and priority habitat may protected for the *T.mazama*..

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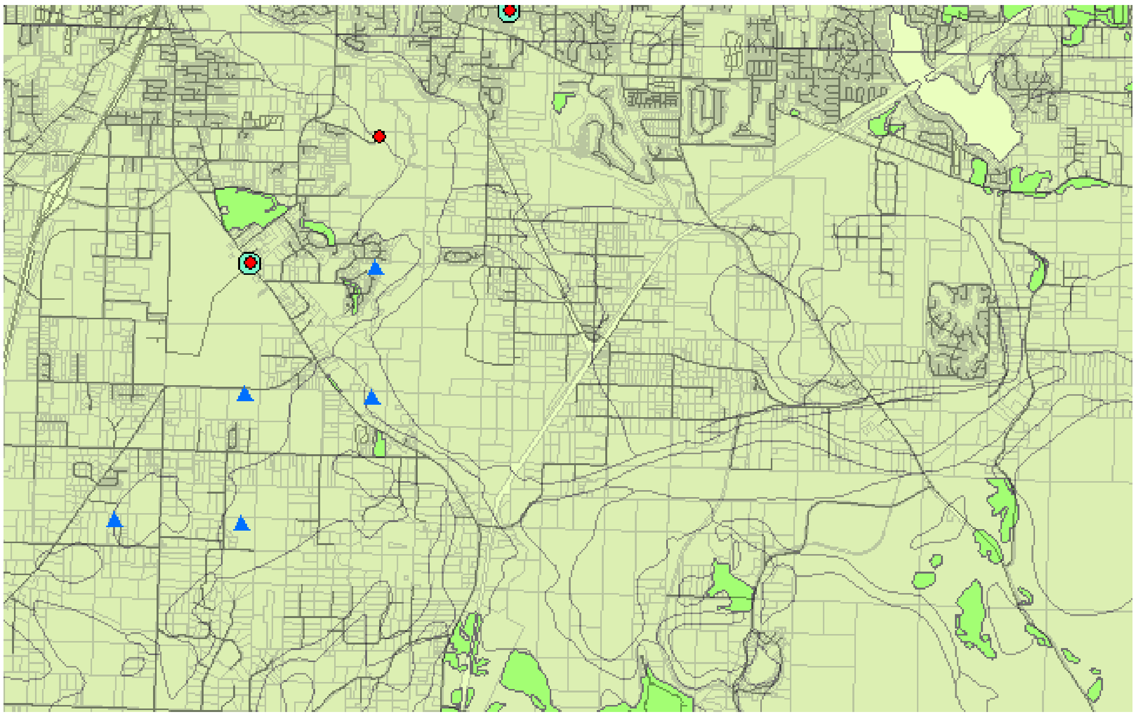


## Figure 1. Olympia Washington Airport

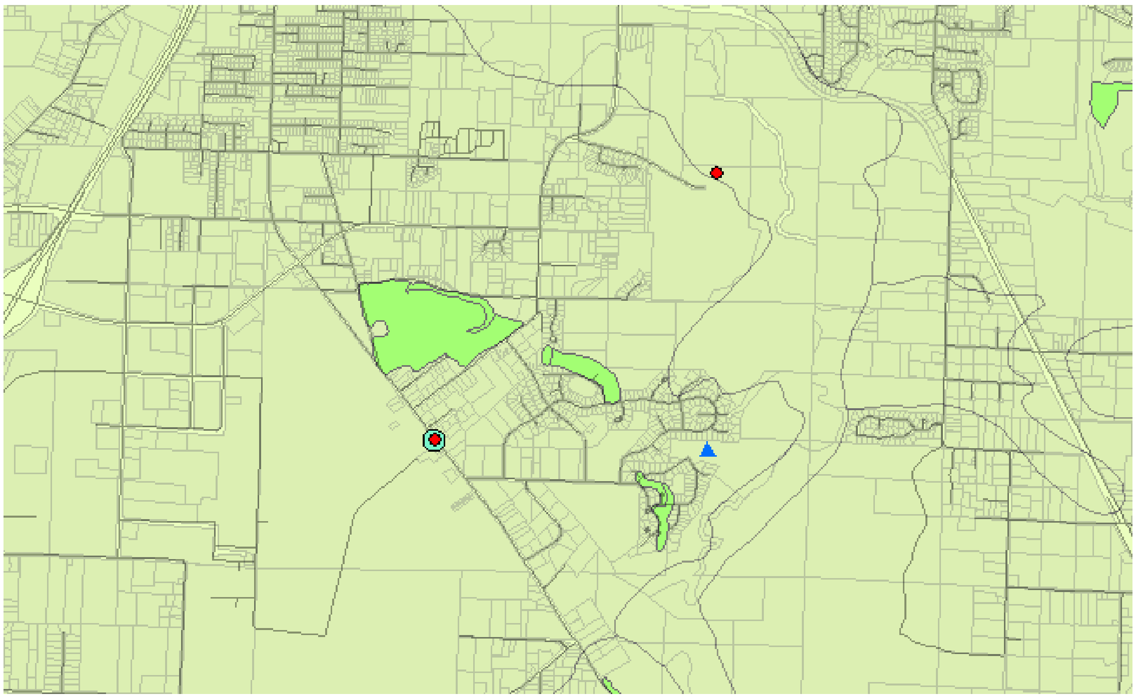
This figure illustrates historic Bush Prairie habitat locations for the *T.mazama*, impacts from development activities to current prairie regions, and current locations of gopher captures (Dalquest 1944; Steinberg 1999).

Capture locations are illustrated for the *T.mazama* from 1944 and 1999, in this region that is now been severely affected by urban development as evidenced by the density of roads in the area. Locations of historic gopher capture are indicated by the triangular shapes where captures occurred in 1944 (Dalquest 1944). Current capture locations from 1999 are illustrated by small circles on the Olympia Airport grounds in the left quadrant and also in the upper left regions where a capture occurred on private land.

Prairie remnants defined by Washington State Department of Natural Resources, are displayed in this illustration as irregularly shaped shaded areas, towards the bottom right of the map, and a few in the upper left region. These shaded areas may provide locations of possible optimum habitat for the *T.mazama*, although no recorded captures of gophers were made in these prairie remnant regions.

This habitat region has *T.mazama* populations that are not currently protected by any conservation measures although the area is greatly affected by urban development.

**Figure 2.**



## Figure 2. Detail of the Olympia Airport Area.

This habitat map indicates current and historic habitat locations for the *T.mazama*. Washington State current prairie regions as defined by Washington State Department of Natural Resources, are shown as dark shaded areas, present right on the Olympia Airport grounds. Current capture locations are indicated as the small dot in the upper right region on private land, and on the grounds of the Olympia Airport from 1999.

A historic capture location is referenced by the triangle shape where a capture was recorded in 1944. Note the habitat locations on private land as a small circle to the top right portion of the illustration. This indicates the importance of protecting habitat regions on public and private land (Dalquest 1944; Steinberg 1999).

# Figure 3.

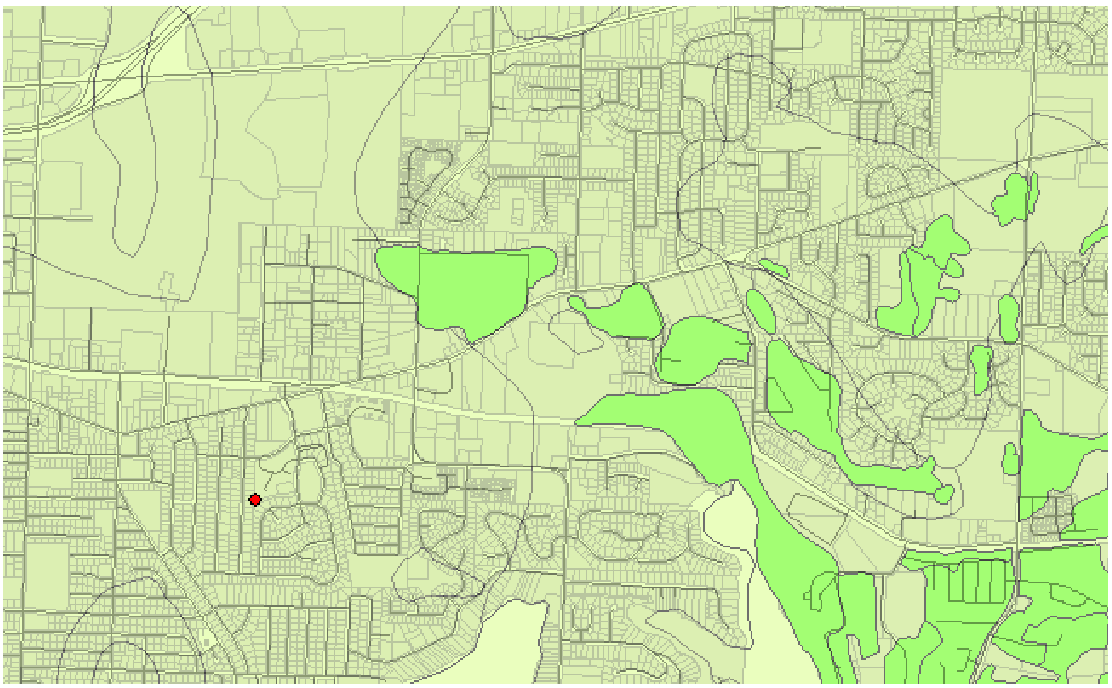


**Figure 3. Habitat location of *T.mazama* gopher in Lacey, Washington**

(Steinberg 1999)

This illustration indicates the location of a gopher in Lacey, Washington, near the intersection of College Street and SR 507. Existing prairie remnants are shown as irregular shaded shapes to the right of the small circle that indicates the capture of a *T.mazama* in this urban area.

Since pocket gophers have little aboveground motility, they can become isolated in urban areas such as illustrated in the habitat map shown above. This illustration clearly indicates that the *T.mazama* is capable of living in densely populated urban areas outside of land that is currently classified as natural, gharry oak, and shrub land prairie areas by Washington State Department of Natural Resources. Protection for this species must also include public and private land policy if they are to survive.

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## Table 1.

Benefits to Plants from Gophers (Huntly 1988 p. 789).

**Ecosystem Processes Affected by Burrowing Activity in Gopher Habitat**

| 1 WEEK, 1M ² | 1 YEAR, 100M ² | 50 YEARS |
|---|---|---|
| Increased light penetration | Increased resource heterogeneity | Altered soil fertility |
| Altered soil resources | Increased topographic heterogeneity | Altered rate of succession |
| Decreased plant biomass | Increased plant species richness | Altered Path of Succession |
| Increased available resources | Increased variability in plant biomass | Altered topography |
| New colonization sites | More microhabitats for consumers | |

As the table illustrates, burrowing activities of pocket gophers create increase soil mixing, enhanced water permeation and soil aeration although these observations are general (Hansen 1968; Huntly 1988). These general observations are only partially useful for prairie environments because additional various components of species diversity need to be included within a complete analysis of the landscape. Detailed quantative studies will need to include more parameters in individual environments such as; the number of species present, (species richness) abundance of different species (species evenness), species that are present (species composition), interactions between species (nonadditive effects) that include temporal and spatial variation (Symstad 2003).

## Table 2.

Western Washington State Prairies as listed by Dalquist (1944)

| Prairie Name | Gopher Subspecies | Location and Soil Depth of Prairies |
|---|---|---|
| BUSH PRAIRIE | *pugetensis* | 4 miles South of the Puget Sound soil five foot deep (including the Olympia Airport and fields west of the Olympia airport |
| VAIL PRAIRIE | *yelmensis* | 1 mile W. Vail, Thurston County 3 feet or less in soil |
| GRAND MOUND PRAIRIE | *yelmensis* | 2 miles south Tenino, Thurston County soil 3 feet deep |
| ROY PRAIRIE | *glacialis* | 2 miles South of Roy, Pierce County 4 feet deep soil |
| ROCKY PRAIRIE | *tumuli* | 5 miles N. Tenino, Thurston County |
| ROCHESTER PRAIRIE | *yelmensis* | 2 miles N. Rochester, Thurston County soil 3 feet deep |
| SCOTTS PRAIRIE | *couchi* | 4 Miles north of Shelton Mason County soil 9 inches thick and stony |
| LOST LAKE PRAIRIE | *couchi* | 15 miles NNE Satsop, Mason County |
| STEILACOOM DELTA | *tacomensis* | 2 miles NW Steilacoom, Pierce County |

## Table 3.

## **Processing of Natural Resource Data** (Nelson 1988 et.al.)

### ABC Resource Survey Process of Data Management

| | |
|---|---|
| **LEVEL 1** | **Raw Data**:<br>Presented on two sets of maps:<br>one set with structural information,<br>the other with functional maps<br>These maps delineate selected features of<br>the area where ecological processes occur |
| **LEVEL 2** | **Interpretation of Environmental Significance and Constraints**.<br>Environmental Significance includes:<br>comparing cultural and natural<br>resource values within the region,<br>derived from ecological theory.<br>Includes past and present land use<br>transportation and wildlife corridors, and spatial and<br>temporal land use from literature searches,<br>interviews and using topographical imagery.<br>Constraints: This uses an index<br>to evaluate significant features of<br>management considerations such as:<br>replaceability and compatibility |
| **LEVEL 3** | **Synthesis**<br>(Summary Maps) These maps focus on<br>summarizing constraints within the area<br>evaluating maps developed at level 2. |
| **LEVEL 4** | **Boundaries and Institutional Arrangements**<br>This is an actual management proposal<br>for an Environmentally sensitive area,<br>indicating boundary delineations, desirable buffer areas,<br>appropriate zoning proposals |

## Acknowledgements:

Thanks to John Means. Ken Tabbutt. Deep appreciation to my reader Ralph Murphy for taking this project on, Lars, Justin Knudsen, John Perkins, Fran Collins, and Anna Schmidt. I am thankful for the Evergreen Foundation Grant(s), and other financial assistance from the MES program. Special thanks to crazy Sue Sanders who bought me a book when I was broke and helped keep me in school, and Suzanne Cravey who brought me a pillow and a beer at different times. Deepest appreciation for Dr. Marilyn Gage, nurse Karen and Pamela Paley, M.D. extraordinaire, who literally saved my life in summer 2002.

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I give thanks for all the hard times that have made the success of this degree especially sweet.

Dedication:

This is for you Daniel. Love Mom.

Daniel Ryan Knudsen
17 years 2 months
8-16-1984 - 10-20-2001

**"LOAFING AGAIN," says the Pocket gopher. "You are woefully lacking in will power. Your work times are brief. Your loafing times are long." Reproof is vain in his voice, that gruff grumble-burred scratching in his throat that somehow shapes itself into words. Irritable by nature, he is trying to irritate me. Afflicted with a work ethic, he has no appreciation of quiet repose. A lifelong underground miner, he would undermine my enjoyment of drowsy rest. No matter. I am armored against him by my curiosity about him.**[1]

[1] From *Conservations with a Pocket gopher* by Jack Schaefer as found in Steinberg, E. K. (1999). Diversification of Genes, Populations and Species: Evolutionary Genetics of Real and Virtual Pocket Gophers (Thomomys). Department of Zoology. Seattle, WA., University of Washington: 157p.

# Chapter 1

## Introduction

> “The gophers of Puget Sound are doomed to extinction, perhaps within a century” (Dalquest 1944).

One species living in western Washington prairies is the pocket gopher, *(Thomomys mazama)*, a vital component in the maintenance of Washington state prairie ecosystems. By the process of burrowing, they provide aeration to prairie soils combined with the resultant introduction of new soil to the surface. These contributions assist in the valuable function of maintaining diversity of plant species in prairies and additional beneficial effects to plant and insect species.

Conserving ecological diversity in the natural environment is imperative when creating policy to protect ecosystem functions. Currently prairies in Washington State experience degradation from construction, burn suppression, and Douglas fir encroachment. Protecting and maintaining Washington prairie environments is critical for maintenance of healthy ecosystems. Will the *T.mazama* pocket gopher have adequate management to preserve its valuable place in prairie ecosystems?

Specific information regarding the *T. mazama* is difficult to find, as well as locating quantative studies involving specific estimates of damage created by *T.mazama* gophers to agricultural crops and tree plantations (Barnes 1973; Kruckeburg

1991; Steinberg 1995; Steinberg 1996; Witmer 1996; Verts 1998; Steinberg 1999). Although all species were identified as *T.mazama* in the Witmer study in a 1996 South Puget Sound study, the gophers differed in physical characteristics enough so Witmer believed that "considerably more research may be required to resolve taxonomic issues of isolated gopher populations in the Puget Sound Region" (Witmer 1996). This lack of data and recently expressed concern regarding definitive taxonomic identification of the *T.mazama* species represents an urgent need for research, because of the *T.mazama's* current listing status as a *species of concern* by both Washington State and Federal Fish and Wildlife Agencies.

Many general studies regarding pocket gophers (*Thomomys sp.*) have investigated gopher's relationship to habitat, biology parameters, population structures, discontinuous habitat patches, and habitat congruity. Other studies have outlined detailed research needs for conducting biological surveys, but the vast majority of studies have emphasized population control measures. The lack of current data regarding the *T.mazama* confirm the need for collecting additional data that will provide a comprehensive examination of this species biologic parameters, and provide current detailed information that will assist in creating protection measures.

Washington State has experienced population growth that has resulted in human development of prairie regions. This development creates interruptions in the pocket gopher's habitat that results in the creation of edge effects that contribute to habitat fragmentation and possibly to species extinction. Extinction rates for species residing specifically in prairie landscapes are highest for the species that are rare, or that require large patches of unbroken habitat and have short distances between those patches, or for species that have limited dispersal distances. It is also possible that small mammals move differently in crossing unfamiliar habitat with different compositions of patch structure and densities of wildlife, (Szacki 1991; Leach 1996). These habitat constraints regarding movements of small mammals are especially true for fossorial mammals[1]. Research findings regarding small mammals in fragmented prairie habitat may have direct application to the *T.mazama* in Washington prairies. Immediate research should be conducted to determine how the *T.mazama* is affected by habitat fragmentation. These research findings regarding impacts to habitat should be included in species management plans. Pocket gophers are a plastic species, capable of forming subspecies easily. They are located primarily in regions with soil types capable of providing adequate gas permeability and supporting a variety of forage. In general, the genetic structure of gopher populations provides clear illustrations of genetic drift and selection in determining general genetic population structures (Steinberg 1999). Because of these particular biologic circumstances, gophers are also used in computer modeling programs as examples illustrating controversial theoretical questions pertaining to the genetic structure and origins of various populations, and for experimentation with speciation theories within the discipline of evolutionary biology. These modeling studies suggest gopher populations may be changing over time. These studies may also indicate a need for additional research into the current genetic status of this species in Washington because of the gopher's inherent ability to form subspecies

Many general wildlife simulations seek to provide projections for management that can be used in policy decisions. These models may seek to resolve habitat

[1] Personal Communication: Rex E. Marsh. Specialist in Vertebrate Ecology Emeritus, University of California, Davis.

fragmentation that has been created due to societal goals, predicting distinct movement routes of wildlife, or gaining predictive power for management decisions, but they are often using incomplete information regarding movements of wildlife. Models are also created specifically featuring *virtual gophers* that are used to demonstrate benefits to their surrounding environment regarding tunnel construction and seed germination effects (Seabloom 2001).  Although these projections are useful, they cannot provide complete solutions (Pulliam 1988; Cornell 1992; Davidson 1998; Rapport 1998; Bain 2000; Ebenbach 2000; Ney-Nifle 2000; Abrams 2002; Frid 2002; Kokkoris 2002). Modeled projections involving environmental conditions, movement of wildlife species and population parameters often use data that also does not accurately reflect dynamically changing environmental conditions which can lead to inaccurate projections (Landres 1988; Hansen 1999; Steinberg 1999; Holmes 2001; Ludwig 2001). In general, gophers are popular for virtual modeling and academic theorizing but studies focusing on the actual biology, dispersal, habitat requirements, and the resultant benefits to plants and soils in Washington prairies from the *T.mazama* gophers have largely been ignored (Witmer 1996; Steinberg 1999).

Research must be conducted primarily concentrated on definitive biological and genetic parameters of the *T.mazama* species. In the process of identifying the *T.mazama* species, other sub-species will also be identified that will assist in prioritizing management goals for the *T.mazama* species. When subspecies of gophers are genetically identified, and this data is confirmed with standard skeletal measurements, populations may be located, and inventories may be conducted. These methods for gopher identification must be applied to all gopher populations in western Washington to confirm the existence of the exact locations of the *T.mazama* species and to identify and inventory all gopher populations starting with the known historic population locations.

Collecting accurate data will involve a complete inventory of pocket gopher populations, a complete mapping of gopher habitat, genetic identification of species and sub-species, identifying diet and confirming physical habitat requirements. In addition, this data must be incorporated into a management plan that addresses landscape and habitat parameters on several different scales.

Once this accurate gopher inventory data is adapted to modeling programs, it will be possible to create informed wildlife and land development policy so Washington State prairies may be preserved and priority habitat may protected for the *T.mazama.* In addition, once species identification is complete for the *T.mazama*, this information may then simultaneously be incorporated within a landscape ecology approach that addresses prairie ecosystem maintenance on large landscape scales and small scales of biologic and habitat requirements. This landscape ecology approach addresses a small-scale and large-scale systems perspective that must be incorporated within policy decisions in order to provide maximum protection for the *T.mazama* habitat and the larger ecosystem functions. It is only by these methods that adequate policy can be created to identify and protect the *T.mazama* from extirpation.

Although there is limited initial data available on the *T.mazama*, this thesis will as closely as possible, provide detailed biologic and habitat requirements of the *T.mazama,* along with providing a complete discussion of genetic, environmental conditions, social constraints, political concerns, and other factors that may limit the gopher's habitat and survival in Washington prairies.

# Chapter 2

## The *Thomomys mazama* in Washington prairies

### Subspecies in Washington

Historically, more than 300 species and subspecies of pocket gophers have been described starting in 1891 (Bailey 1915; Johnson 1960; Hall 1981), with several sub-species of *T.mazama* initially located in Western Washington. Historically the *T.mazama* underwent more than twenty-two revisions from 1891 through 1954 and they are among the most taxonomically diverse animals (Johnson 1960; Steinberg 1999).

Subspecies in Washington were listed as ; *melanops, yelmensis, tacomensis, couchi, glacialis, pugetensis, tumului, and louiei* as late as 1996 (Dalquest 1944; Witmer 1996). There is also evidence regarding gene flow between *Yelmensis, pugetensis and glacialis,* with populations of pocket gophers persisting through a process of extinction and subsequent recolonization, providing evidence of the durability of this species (Steinberg 1999).

The *T.mazama* subspecies have a very close similarity to *T. talpoides,* the northern pocket gopher that lives in higher altitudes and in the eastern portion of Washington, that generally prefers sub-alpine habitat in Western Washington (MacMahon 1989).

*T.mazama* gophers in the Puget Sound region of Washington State are restricted to specific habitats primarily within the glacial outwash regions of prairies. Dalquest believed that they did not occur in the woody areas or the openings on the sides of prairies, however due to recent habitat fragmentations recent studies have noted their presence in tree farms causing some concern among agricultural providers (Dalquest 1948; Witmer 1996).

Additional data representing gopher populations on several scales, and human demographic data needs to be incorporated into management policy with the objective of refining general understanding of the species, to a finer level of understanding that is focused on preserving prairie habitat and the *T.mazama* species. With enhanced biological and genetic data for the *T.mazama* and the incorporation of human population demographics, surrounding Washington State prairies, management strategies may be evaluated for the gopher species that are at risk of extirpation, and alternative management strategies and landscape settings for prairie preservation may be devised.

## Habitat Locations of *T.mazama*

The *T.mazama* species is located in western Washington, western Oregon, and northern California (Johnson 1960; Barnes and United States. Bureau of Sport Fisheries and Wildlife. 1973; Verts 1998). They are primarily located in lowland prairie regions that have their glacial origins from the Puget lobe of the Continental Vashon Glacier. Washington prairies have experienced impacts due to grazing, agriculture, military activities, and fire suppression that has resulted in the subsequent growth of forests, dividing them into several numerous isolated prairies.  This has resulted in the formation of isolated habitats that has contributed to the creation of several pocket gopher subspecies (Dalquest 1942; Del Moral 1976; Drake 1998).

*T.mazama* gophers may be threatened with extinction as the prairies are reclaimed by forests and as Washington State population and development activities increase. Population growth has resulted in burn suppression in prairie regions.[2] Lack of wildfire may also be interrupting the landscape-scale biodiversity in prairie ecosystems (Dalquest 1948; Kruckeburg 1991; Leach 1996).

[2] Contemporary urban prairie environments experiencing wildfire may result in loss of homes and other personal property that may inspire volunteer restoration efforts. House, F. (2001). "On Behalf of the Wild: A Conversation with Gary Snyder." Ecological Restoration **19**(4): 227-234.

# Chapter 3

## *T.mazama* Biology

### Biological Parameters

For most species of pocket gophers, the young are generally born hairless with the teeth not yet erupted, possessing short limbs. The early studies conducted on T.mazama by Scheffler in 1938 lists the pocket gopher litter size as an average of five young for the *T.mazama* in Olympia, Washington Puget Sound region (Hill 1934; Scheffer 1938; Schram 1961; Marsh 1992).

Male *T.mazama* pocket gophers express dimorphism, where males are larger than females. In general, the size of gophers is directly related to the local habitat where the forage availability also determines population density (Steinberg 1999).

Ratios between sexes were nearly 1 to 1 in a 1996 study in lower Puget Sound. It is known that low density populations have unitary sex ratios but this bias is positively related to population density and with population increases, the ratio can be increased to 4 : 1 with a bias toward females (Patton and Smith 1990 in Witmer 1996;

Steinberg 1999). This ratio may be a bias introduced by trapping techniques[3]. Gestation of the *T.mazama* is thought to be 28 days, with the average number of embryos equal to five (Scheffer in Dalquest 1948).

The pelage of *T.mazama* is rich in color, ranging from all black to yellowish hazel on the dorsum with whitish tail and feet, although pelage is not sufficient to identify differences in species (Verts 1998).

General mortality rates of *T.mazama* populations are high (between 50% and 80% annually). Maximum lifespan of gophers is 5 years although average lifespan is 1 to 1.5 years with mortality caused by weather conditions, predation, diseases and parasites (Nevo 1979; Marsh 1992).

Young gophers disperse above ground, under cover of snow, or underground at approximately 8 weeks. They can live temporarily in vegetation growing above ground in tunnels made in the snow that provide considerable forage in winter (Ingles 1949; Vaughan 1963; Barnes 1973; Nevo 1979; Marsh 1992). Dispersal distances for gophers in similar environments to Washington prairies are noted as 900 feet for *T.bottae;* and 785 and 2590 feet for *T.talpoides*. Dispersal has been documented as up to 100 feet in snow tunnels for winter foraging for *Thomomys monticola* (Ingles 1949; Aldous 1951; Vaughan 1963), but no specific recent estimates are available *for T.mazama.*

The *T.mazama* has exclusive territories. During the yearly breeding season or when the females are rearing young is the only time gophers interact with each other. Plural occupancy of gophers is rare, with each gopher constructing a burrow just big

[3] Personal Communication from Rex E. Marsh, Specialist in Vertebrate Ecology Emeritus, University of California, Davis. May 6, 2003

enough for their size, although adults may share a common nesting site. Breeding season is during the winter, possibly extending through spring, at low elevations. After dispersal of the young, territories remain stable and the gophers live alone until the next breeding season (Barnes 1973; Nevo 1979; Witmer 1996; Steinberg 1999).

Because the general biology of pocket gophers, it is possible to use this information to assist in the formation of potential population estimates. However, these estimates could possibly be inaccurate due to changing habitat conditions and other factors regarding forage conditions, weather, disease, or predation.

## Adaptation to Subterrian Niche, Speciation

Pocket gophers have no overlap in the fossorial (underground) niche that they occupy, either between different individuals of the same gopher species, of between different species of gophers in the same region. These factors result in fixation of chromosomes, over time, which starts the process of speciation. Small habitat ranges lead to competition for food for each individual and the species as whole. Limited food resources will also produce small, subdivided populations that are semi-isolated and territorially structured, with sex ratio thought to be density dependent. These established territories, according to Nevo, become optimal areas of habitat, providing population stabilization. Fluctuations in these established populations are regulated by predation, parasites, disease or random factors (Nevo 1979; Reichman 1982).

Reichman observed that pocket gophers utilize a method of geometric spacing much like constructing burrows out of building blocks, with burrows of males larger than burrows of the females. Equal distances between branching points in the burrows are generally used. Burrow construction requires tremendous energetic investment.

Pocket gopher will alter burrow length rather than alter spacing between spaces between their neighbors, and seem to have a very sensitive awareness of spatial distances, with burrows of males larger than that of females. Gopher burrows that are vacated are rapidly reoccupied. Depth of burrows vary with temperature conditions, with burrows deeper in hotter climates where the gophers adjust for an optimal temperature regime (Nevo 1979; Reichmann 1982).

Pocket gophers have unique adaptations to soil conditions. Since the burrows are sealed habitats, gophers must adapt to limited permeability to gasses such as oxygen and carbon dioxide within the soil barrier, and the gophers own physiological conditions involving facilitation of gas transport in their blood and tissues.

Gophers actively defend their burrow from intruders, although some species are known to live compatibly with gophers in their burrows such as; deer mice, pocket mice, kangaroo rats, voles, ground squirrels, although when two adults pocket gophers are placed together they are known to fight viciously. Amphibian species such as the Tiger salamander have also been found in pocket gopher burrows (Vaughan 1961; Vaughan 1963; Barnes 1973; Hall 1981; Marsh 1992; Klaas 1998).

## Limiting Factors

Because gophers are entirely dependent on environmental conditions of soil permeability and forage availability, and they possess inherent territorially and limited mobility they are vulnerable to extirpation. These territory parameters, and quality and quantity of food sources, all determine carrying capacities of gophers. These specific biological limiting factors for the *T.mazama* gophers are critical for managers to incorporate in conservation policy specifically for prairie habitat.

Often relocation of pocket gophers appears to be a possible solution when habitat becomes irreparable because of construction activities or gophers are causing damage to agricultural crops and trees, but the process of relocation can create survival problems for the species. Gophers expend a large energetic investment when creating new burrows and during the process of constructing burrows, gophers are exposed to increased predation and disease. There may also be potential difficulties of introducing inherently territorial gophers to new habitat, because gophers are known to fight aggressively when placed in close proximity. They also have poor thermoregulation properties and may suffer impacts from temperature extremes. Pocket gophers have evolved and developed sub-species adapted to specific soil conditions that possess acceptable gas permeability characteristics in the soil and forage conditions. There is a lack of knowledge regarding successful translocations of fossorial species, and when all the specific biological limiting factors for this species of concern are evaluated, relocation of gophers will not be a viable consideration.

# Chapter 4

# Genetics

## Creation of Subspecies

Historically, gopher subspecies were thought to be caused by depth of prairie soil, size of prairie stones, and small divisions in soil and vegetation. This has since been verified by several  recent studies (Dalquest 1944; Cox 1990; Steinberg 1999).

In 1944, Dalquist thought that the origins of the T.mazama were the results of migrations of the *T.mazama* from the south and east areas of Washington, and that they formed isolated populations based on habitat and soil conditions (Dalquest 1944).  E.K. Steinberg's work identifying the genetic code of the *T. mazama* has revealed vital information regarding this species in 1999,  but until then the original work in 1944 from Dalquist was the most recent biological study of the species (Dalquest 1944; Witmer 1996; Verts 1998; Steinberg 1999).  This recent discovery of the genetic origins of *T.mazama* revealed true origins of this species as being through population introductions from the northern expansion of the Pleistocene glaciations in the Olympic Mountains. This resulted in establishment of colonizations of *T.mazama* in the glacial outwash prairies (Steinberg 1999).

Pocket gophers of the genus Thomomys comprise one of the most plastic groups of North American mammals (Dalquest 1944; Hall 1981; Smith 1988; Steinberg

1999). Until 1998, according to Land Mammals of Oregon, it was commonly believed that “disjunct populations (of *T.mazama*) were even found in the Olympic mountains” (Verts 1998) but recent taxonomic revision from Steinberg’s work using DNA from the mitochondrial portion of the cell. This specific method of genetic identification processing is referred to as MtDNA processing. The recent taxonomic identification of the gopher has reclassified the *T.mazama* species as having its genetic origins in California, from the *T. Bottae* group (Steinberg 1999). MtDNA studies have been very effective for determining the origins of animal populations. The Steinberg study also confirms that the Olympic Mountain region species is a distinct species, not originating from *T.mazama*, but from *T. melanops*, a species that survived local glaciation (Steinberg 1999).

The origins of the *T.mazama* species are an important discovery, illustrating the ability of this species to adapt to its environment and its need for maintaining this specific habitat in the glacial outwash lowland prairies on Washington for its survival. In general, it is thought that gophers adapt to their individual habitat by continually genetically evolving, responding to specific environments by incorporating thermoregulation properties that in part, involves increased circulation to their feet and tails (McNab 1966).

## Western Washington Populations

The Shelton Washington pocket gopher populations observed by Scheffler in 1938 appeared to have combinations of cranial features that are different from other species in the region, and as appearing only on the "…open lowland prairie area in the vicinity of the type locality bordering inlets of Puget Sound and of Hood Canal…." A specific location of this population was also published in 1955 as "…four miles north of Shelton, Mason County, Washington…" in The Survey of North American Recent Mammals by the United States National museum (Miller 1955). The unique genetic differences of this population in Shelton, Washington were later confirmed by Steinberg's 1999 genetic analysis (Scheffer 1938; Steinberg 1999).

Techniques are available for identifying the *T.mazama* to species and advanced genetic techniques are available for identifying populations. These tools should be used in Washington prairies where they can assist in positive identification of the *T.mazama* species. These genetically confirmed populations within Western Washington would undoubtedly confirm habitat locations and affirm the need for specific habitat protection within different prairie regions of Western Washington. This data will also assist in habitat protection by identifying populations that should receive priority conservation consideration.

The *T.mazama* pocket gophers of Washington have experienced geographical isolation due to their habitat on glacial outwash prairies, contributing to a large number of subspecies. This has caused subjective speculation and adds controversy regarding which of these species should be recognized nomenclaturally (Hall 1981). Adding to this controversy, genetic tests may be necessary to identify the *T.mazama* because species identification of the *T.mazama* and the *T.talpoides* are largely indistinguishable from external characteristics (Barnes 1973).

## Genetic Identification of Subpopulations

Translocated genes in the *T.mazama* species reveal a single mitochondrial to nuclear translocation event occurred before *T.talpoides* and *T.mazama* split into separate lineages. (Steinberg 1999). The cytochrome *b* process of genetic processing is a technique especially useful in identifying rodent populations (Maulk 1999; Spradling 2001). Three major subspecies in Washington have been recently identified by identifying Cytochrome *b* genetic analysis of allele characteristics. This discovery replaces the six classifications that were originally based on morphological features that were thought to occur (Dalquest 1944; Steinberg 1999).

Genetic studies are especially useful in determining aspects of spatial structure and variation in gopher populations. This is because gophers do not disperse over long distances; they occupy fixed positions in space, and occupy defined home ranges that occur in resident populations of varying density and size due to frequently dividing populations, with added characteristics of territoriality and low vagility (Nevo 1979; Steinberg 1999).

Technology exists for identifying the genetic origins of gopher populations and for identifying sub-populations. These tools should be incorporated into management strategies as a partial solution. These analyses will provide technical data that will assist in insuring conservation of this species. Confirming these genetic studies for all gopher populations in Washington prairie habitats is imperative to identify sub-species for management purposes.

# Chapter 5

## *T.mazama* Skeletal Identification

General identification of rodent species involves skeletal measurements, specifically the skull (Dalquest 1944; Tryon 1951; Johnson 1960; Livezy 1979; Hall 1981; Rensberger 1983; Brylski 1985; Smith 1988). Members of the *Thomomys* group can be positively identified by their slender cranial rostrums where the bases of the skull are not as divergent as other species and the base of the rostrum is broader on the dorsal surface and different in function and spatial organization from other species (Thaeler 1980; Hall 1981). Skull differences are in many cases more similar for *T.mazama* and *T.talpoides* than other subspecies of gophers (Johnson 1960). Identification of the *T.mazama* species is made by observing a lack of a sphenoidal fissure in the cranium, and a wider flange extending posteriorly and ventrally at the angle of the mandible. These differences now separate them from other species where they were included for many years (Johnson 1960; Verts 1998).

Ageing of the *T.mazama* is conducted by cross sectioning teeth (mandibles) that have been stained with Papanicoloau (Harris) Hematoxylin .and imbedded in paraffin blocks where adhesion lines, or darkly stained lines in the bone may be detected with microscopic examination (Livezy 1979).

A longer thinner baculum (penis bone) measuring 22 to 31mm has also been determined as a feature of the *T.mazama* used to definitely identify this species, including the identification of juveniles from other species (Johnson 1960; Livezy 1979; Hall 1981; Witmer 1996; Verts 1998).

These identification methods for gopher populations involving skeletal identification procedures should be used in conjunction with genetic testing to confirm gopher subspecies and to construct population estimations for conservation of the species.

# Chapter 6

## Habitat

The *T.mazama* appears above ground for brief periods for tunnel construction and grazing outside their tunnel openings. Larger areas mostly found in deeper burrows are used for nest and food storage areas. Tailings from the burrow systems of pocket gophers are “fan shaped” piles of earth instead of the more conical shaped mounds produced by moles. Side tunnels off the main runways, are used as exits off the main runways and for soil depositaries, debris storage, and excess food storage (Scheffer 1938; Miller 1948; Aldous 1951; Barnes and United States. Bureau of Sport Fisheries and Wildlife. 1973; Marsh 1992; Marsh 1992; "Inventory Methods for Moles and Pocket Gophers" 2001).

The depth of gopher burrows range from a few inches to more than 5 or 6 feet. It is common to find several nest chambers where they forage and store food, and deposit waste. In a study of gopher damage to forested areas in Washington,  they were found at depths of 4 to 18 inches below the ground (Barnes 1973; "Inventory Methods for Moles and Pocket Gophers" 2001).

Gophers may have natural fluctuations in populations and seasonal periods of inactivity with no visual sign of burrow construction (Aldous 1957; Laycock 1957). Local abundance of *T.mazama* is limited to the size of soil patches and to available food resources (Dalquest 1944; Steinberg 1995; Steinberg 1996; Steinberg 1999).

Gophers live in a closed microhabitat underground where soil porosity is critical to the gopher habitat (Barnes 1973). All requirements regarding diffusion of gases must be met within a closed burrow system. Gophers are thought to be limited in their distribution in soils with high clay content because of their limited ability to allow gas diffusion of oxygen and carbon dioxide. Larger gopher species require more sandy soil and avoid heat by digging deeper burrows, where smaller species are located in marginal shallower soils. Sizes in gophers are a direct adaptation to the soil types in their environment (McNab 1966). These discoveries confirm the importance of maintaining specific habitat conditions for gophers.

In general, the geographic range of gophers is affected by characteristics of the physical environment, although different species of gophers have an apparent tolerance to higher moisture content in soils, possessing the ability to adapt to edaphic conditions (Kennerly 1959). The way a gopher adapts to rocks in the soil depends on soil moisture conditions. If the soil is dry, gophers will avoid large rocks more than they will in moist soil conditions (Hansen 1968). The gopher may provide little above ground evidence of mounding activity when the soil is dry, however they still may be present. Increased soil temperature and decreased soil moisture, results in soil being deposited in unused upper tunnels and not being brought to the surface (Laycock 1957).

No research exists for specific limitations that *T.mazama* populations may have for gas exchange properties. Without existing research into gas exchange and moisture requirements of the *T.mazama* habitat, successful translocation of this species may be in doubt.

# Chapter 7

## Diet of the *T.mazama*

The *T.mazama* gopher prefers to live in cleared areas with no overstory cover where in general, they seem to adapt its dietary needs to the environment. In shrub-grasslands, soils occupied by pocket gophers appear to contain fewer rocks, usually where forbs are found (Hansen 1968). Gophers prefer grasses and forbs[4] in the spring and summer, preferentially choosing them when they are the most succulent (Myers 1964; Burton 1978; Cox 1989). In general, pocket gophers are root feeders. They will also feed on the cambium layer of roots, and generally not on grasses, although there are exceptions[5] . A 1998 study indicates that gophers will leave sites where there is a reduced dicot[6] availability, indicating that there is a level of dicot intake necessary for optimal reproduction and fitness, although more study should be conducted to

[4] FORB: broad-leaved herbaceous plant: any broad-leaved herbaceous plant that is not a grass, especially one that grows in a prairie or meadow
as defined by MSN dictionary on the World Wide Web at:
http://encarta.msn.com/encnet/features/dictionary/DictionaryResults.aspx?search=forbs

[5] Personal Communication: Rex E. Marsh, Specialist in Vertebrate Ecology Emeritus, University of California, Davis, May 6,2003

[6] **DICOT:** plant with two leaves at germination**:** a flowering plant that produces two seed leaves (cotyledons) when it germinates and whose subsequent leaves have a network of veins. Most herbaceous plants, trees, and shrubs are dicotyledons. Subclass *Dicotyledonae*. *Also called* dicot Reference MSN Dictionary:
http://encarta.msn.com/encnet/features/dictionary/DictionaryResults.aspx?search=dicot

determine the actual mechanism by which the population wide density is altered (Rezsutek 1998).

The *T.mazama* in south central Oregon has included ponderosa pine (P*inus ponderosa*) as a minor component of its diet. Diet preferences may also change with seasonal fluctuations, with gophers generally preferring the most succulent foods available (Burton 1978). This may indicate that as the natural prairie habitat of the *T.mazama* in Washington prairies is slowly eliminated and they are forced into marginal regions, their diet may also include roots of trees. This situation has the potential of placing gophers in direct conflict with humans who consider the gopher's pests when they cause damage to tree nurseries and home gardens.

In a 1996 study near the Olympia airport, all the gophers in two sites identified as *T.mazama* were feeding in the (*Tsuga hererophyll*a) vegetation zone (Franklin and Dryness 1973 in Witmer 1996), where the most common tree species is the Douglas Fir (*Pseudosuga*). The sampling sites in this study were on the Olympia Airport grounds and a nearby tree orchard. The actual adaptability of the diet of the *T.mazama* in Washington prairies requires research to identify how susceptible this species is to extirpation and how adaptable they are to dietary constraints.

# Chapter 8

## Damage to Crops

Along with research indicating beneficial effects to plants, there has been extensive research conducted on controlling gopher populations. Pocket gophers are considered a major pest due to damaging agricultural crops, trees, and field machinery (Dalquest 1948; Barnes 1973; Marsh 1992; Whitmer 1999).

Several studies in Washington have been conducted regarding damage control, gopher monitoring and trapping techniques of the *T.mazama* and the *T. Talpoides* species in timber plantations, because of the damage these species has caused to timber crops (Marsh 1984; Hartwell 1988; Engleman 1999; Engleman 1999). Poisoning with toxic baits and trapping are the favored methods of gopher population control. Specifically strychnine is used, although it has been shown that the *T.mazama,* and other gopher species can acquire a high tolerance to strychnine poisoning (Barnes 1973; Lee 1990; Marsh 1992; Marsh 2001).

Pocket gophers in general, are a major hindrance to reforestation in the Western United States, probably injuring more conifer seedlings than all other animals combined (Witmer 1996). Herbicides (2-4-D) have been used in experiments for gopher control, by eliminating their major food sources. These experiments have shown some success, but have been largely inconclusive. Adequate methods within these studies were not used to demonstrate if the cause of death was herbicide poisoning, or starvation due to reduced forage (Keith 1959; Tietjen 1967). Later studies confirmed that specific behavior factors of the gopher combined with vegetative control may also adversely affect the gopher's diet, and decreased populations are likely to result (Burton 1978; Tunberg 1984). Some experiments have been conducted by applying strategically timed applications of herbicide that were thought to ultimately increase Ponderosa pine seedling (*Pinus ponderosa*) and decrease northern gopher populations (Engeman 1998). But overall, when herbicides are used, gopher habitats are not eliminated, they are only effectively modified. Attempts at controlling gophers by using herbicides effect the entire ecological community (Marsh 1984).

Alternative biologic control or integrated pest control methods such as increasing the presence of owls has not been effective for controlling pocket gopher populations. Current research has identified several possible solutions for gopher population control representing non-lethal methods of population and damage control where they still may provide benefit soils and plants within prairie regions (Marsh 1998; Whitmer 1999).

Successful research has been conducted in controlling fertility in mammals with the use of chemical fertility suppressants, such as the wild horses in the Prior Range. Research may also possibly be indicated regarding use of chemosterilants or antifertility chemical agents for rodent control (Marsh 1986; "Wildlife Fertility Control: Fact & Fancy" 2000; "Decision Record and Finding of No Significant Impact for the Pryor Mountain Wild Horse Range" 2002).

Another method of maintaining populations where they are needed for prairie maintenance may involve genetic research into the specific types of trees that are resistant to pocket gopher damage control. Methods may also be developed regarding barrier control methods such as impermeable fencing, to protect desired agriculture areas and tree plantations (Marsh 1984; Salmon 1990; Marsh 1991).

Alternative methods exist for controlling gopher populations rather than fatally poisoning with strychnine. Ultimately the most effective way to control gopher species is by basing control measures on ecological principles (Barnes 1973). To maintain the positive effects that gophers provide to prairie environments, more research is indicated regarding developing alternative methods. These alternative methods may consist of applying chemosterilants and research into the genetic engineering of plant species and investigating methods of barrier control.

# Chapter 9

## Methods of Trapping Gophers – and Alternatives

Researching gopher populations will require acquiring expertise in applying live trapping methods to gain adequate population estimates. Primary methods for performing census counts of gophers include presence/absence methodologies and relative abundance direct observance methods. For absolute abundance studies, mark-recapture is conducted ("Inventory Methods for Moles and Pocket Gophers" 2001; Glennon 2002).

Detecting gophers in natural habitat may be conducted by creating holes that open up the gophers burrow above suspected tunnels. Openings created in these tunnels may be closed within a few minutes to 48 hours providing possible population estimations (Barnes 1973; Marsh 1992; Witmer 1996).

Alternative trapping methods include track tubes, which indicate presence of the animal by indicating footprints left on a track surface inside the tube, reducing handling of gophers (Glennon 2002). Live trapping is not without risk, it is possible for pocket gophers to perish in cold weather in live traps if not provided with a food and warmth source because of gophers poor thermoregulation properties (Howard 1951; Nevo 1979).

## Translocation of the *T.mazama*

Suggested methods of *T.mazama* control may include moving populations artificially. The only study located regarding reintroducing rodents to new habitat involved one successful translocation of ground squirrels. This method allowed time for them to acclimatize in one cage to their the new environment (Salmon 1981). These methods have not been used for pocket gopher translocation and it doubtful that this method used for translocating squirrels will be useful for pocket gophers. In general, the *T.mazama* prefers a constant solitary environment. They have a poor tendency to regulate temperature and there are unknown factors surrounding actual biologic requirements regarding soil conditions and forage opportunities that are needed for the *T.mazama.* The *T.mazama* species is listed as a threatened species and should not be possibly further threatened by translocation activities, and they may have a tendency to fight when placed together. Although new construction does threaten *T.mazama* habitat, such as may be now being experienced by the *T.mazama* population at the Olympia airport, protecting original habitat in Washington prairies is a preferred option over translocating the *T.mazama*. To date, there has been no research on translocating the T.mazama gopher. Research is indicated regarding translocation of gophers when their habitat is irreparably damaged from human construction and development activities.

# Chapter 10

## Benefits to the Ecosystem from Gophers

Historically, early scientific findings regarding mound building by gophers indicated that it was the primary cause of soil erosion, but additional research indicated that the true cause of erosion was partially caused by overgrazing, and not entirely attributed to gopher mounds (Scheffer 1938; Ellison 1946; Hansen 1968). Pocket gophers live underground almost exclusively, appearing above ground occasionally. The claws and forefeet and occasionally the incisor teeth conduct digging of tunnels that appear geometrically spaced in straight paths and equidistant from its neighbors (Hall 1981; Hafner 1982; Reichmann 1982).

Although mound sizes are different within various gopher species, the gross shape of the mounds is the same consisting of a fan shaped or conical mound with plugs to the side of the main opening or an unplugged opening. In regions of rocky soil gophers create beds in circular patterns that have a higher proportion of perennials when compared to the overall landscape (Hafner 1982; Cox 1989).

Pocket gophers create beneficial impacts to affect ecosystem processes over a variety of spatial and temporal scales. Table 1 shows a general description of the effects to plants caused by pocket gophers in short and long term periods in prairie ecosystems. Backfilling and soil deposits from gopher burrowing activities may also affect ecosystem structure as much as surface mound building. Most digging activity occurs in the late fall and early winter when rains have softened soil that stimulate the germination of annual plants (Miller 1948; Richens 1966; Mielke 1977; Anderson 1987; Cox 1990; Huntly 1991).

Pocket gophers influence the plant community in two ways; consumption of selected dicots and forbs, or by altering the aboveground production of biomass or abundance of several plant species (Spencer 1985; Huntly 1991; Rogers 2001). Gophers also generate small scale edge effects as well as short-term and long term effects to plant communities within prairies, that create beneficial effects for the entire plant community (Vaughan 1961; Reichman 1982; Williams 1986; Huntly 1991; Rezsutek 2000).

Edge effects to plant communities are explained in a study by Reichman who illustrates this concept by providing an example of trees by the edge of a clearing. The trees at the edge of the clearing grow tall in response to continuous sunlight but their neighbors experience a shortened stature due to a shading effect which provides trees farther in the forest as with additional sunlight, providing for increased growth. This creates as Reichman describes a "…competition-induced wave of biomass…." Pocket gophers provide this effect to prairie ecosystems systems by creating a sharp edge effect from their soil deposits above ground. The effect directly over a 10cm burrow has an effect at least 1m wide (0.5 on each side of the burrow). This creates positive affects on prairie soils, because in the gopher's process of mound building, stable aggregates in prairie soils that retard mineralization rates are enhanced (Reichman 1993; Klaas 1998).

Small patches of soil exposed by gophers create a small microhabitat that is different in soil content and biomass from the surrounding areas. This can affect patterns of plants and animals in the ecosystem by providing a greater range of sites for seed germination and growth. These effects are similar to features found in long-term development of mima mounding in prairies. A well accepted theory is that the mima mound soil formations are caused by gophers (Nikiforoff 1941; Scheffer 1947; Price 1949; Scheffer 1966; Del Moral 1976; Mielke 1977; Cox 1984; Cox 1989; Inouye 1997). However, there has also been some doubt regarding whether gophers actually did cause mima mounds phenomenon (Nikiforoff 1941; Scheffer 1947; Scheffer 1966; Del Moral 1976).

During a recent study of a tallgrass prairie in Iowa that measured the effects of gopher burrow building over time, it was determined that concentrated effects to prairie ecosystems were less than 8m, in 1 to 2 weeks. After 3 to 4 weeks, this effect shifts in location, resulting in clustered patterns of disturbance that measure less than 20 meters over two years. Pocket gopher mounds within fields with established plant communities often provide germination opportunities for new plant growth where even this small scale disturbance to grassland prairies effects grassland communities through its effects to individual plant species (Hobbs 1987; Gibson 1989; Davis 1995; Klaas 2000; Rezsutek 2000; Rogers 2001; Ostrow 2002).

Initial research regarding gopher mounding activity on serpentine grassland communities have indicated that some grasses are dominant over other grassland species on gopher mounds, due to lower micronutrients in the soil. As these elevated levels of micronutrients decrease, the likelihood of potential invasive species is thought to be decreased. Additional research indicates that survival of plants have similar survival potential on or off a gopher mound, but shoots on the gopher mounds that did survive grew larger and created many more seeds than control plants in control plots (Koide 1987; Reichman 1988). The soil from gopher mound tailings differ in nutrient content from the top layer of prairie soil, providing a higher total nutrient for plants around gopher mounds, where gopher mound soil forms aggregates which assist soil condition in less than two years (Spencer 1985).

More research is needed regarding the short-term and long-term effects to plant species in Washington State prairies that are generated from gopher's activities. Research topics that could be considered include how reproduction and food habits may be interpreted by soil conditions and precipitation rates. Competitive exclusion, niche packing, and competitive exclusion are also important research considerations. Observations must also be performed on a large-scale with long-term studies, which include latitude and gradient, site fertility, climate, and not solely in comparing species diversity which may introduce faulty indices (Bandoli 1981; Hobbs 1987; Koide 1987; Huntly 1988; Huntly 1991; Clark 1998; Symstad 2003 et al.).

To date, no such study of the *T.mazama* habitat has been completed at these scales, but one long-range study of cultivation and grazing had been conducted in California indicated that in nitrogen rich soils where gophers are present, there is a long-term improvement in increases of grass species and forbs providing food for the gopher populations (Stromberg 1996).

Research indicates that gophers provide valuable benefits to soil conditions and for maintaining prairie environments. Accurate data for the *T.mazama* regarding small-scale habitat parameters of diet, habitat and dispersal parameters, as well as data representing long-term changes over time to gopher habitat are critical for this species at risk.

It is possible to predict soil disturbance rates with the only constraints being soil condition, and the size of the gopher. Soil deposition rates may be calculated if the size of the gopher and the energy efficiency in the soil is known (Andersen 1982; Anderson 1987; Cox 1990; Cox 1991). These calculations are based on above ground soil deposits from gophers, although significant soil deposits occur belowground (Andersen 1982; Cox 1990).

In summation, gophers are proven effective agents assisting seed germination, and soil aeration. They are invaluable in maintaining the diversity of prairie environments. Their presence in prairies should be maintained and their species protected. Biological data involving the *T.mazama* and the prairie environment should be collected, monitored, and used within predictive models. The data collected for habitat protection should be long-range for local prairies on a small scale. For prairie conservation in the entire region, a larger scale of data should be collected that will involve protection of general biodiversity. To maintain prairie environment, long-term research should be conducted on Washington prairies to determine the actual contribution of the *T.mazama* gopher's effects to soil, and large and small landscape effects to plants. These effects should be given priority consideration for inclusion in conservation policies for protecting habitat for the *T.mazama.*

# Chapter 11

## Gophers and the Benefits to Soil

Previous studies regarding tunneling energetics (or amount of energy expended by pocket gophers to create a tunnel) are referenced to a single point in time, with little predictive ability to infer connections between system dynamics and relationships to environmental conditions. However there may be a pattern linking geometric features of tunnel construction regarding length between mounding activity, with food resource levels and the length of tunnels (Reichmann 1982; Anderson 1987; Thorne 1990). Tunneling energetics in pocket gophers is high. The timing of burrow construction may be associated with activities that make movement easier in the tunnel system, coinciding with periods when optimal soil moisture levels increase soil friability that reduce the energy required for tunnel construction or at times when foraging activities are at an optimum (Miller 1948; Bandoli 1981). No data is available on the effect of food habits or reproduction on burrowing activity in pocket gophers (Bandoli 1981).

It may be imperative to apply findings of these specific burrow energetic studies when conducting research into *T.mazama* habitat, or if habitat is damaged and research is conducted into translocation of gophers.

Little literature exists on the soil movement capability of *T.mazama*, but the closest relative of *T.mazama* is a prodigious soil mover. After the eruption of Mt. St.

Helens, the Northern pocket gopher *T.talpoides* had covered 2% of the tephra[7] surface with old soil, providing soil for recolonization of damaged habitat for other species  All samples from the Mt. St. Helens study were obtained above the 1000m in the Pacific silver fir and Mountain Hemlock zones (Anderson 1987; Crisafuli 2003).

It has been shown that meadow voles avoid areas with soil disturbances with resulting increased opportunity for seedling germination. This may result in enhanced biomass, leading to distinct changes in the plant community especially in communities where perennial grasses may limit availability of sunlight. This is important to the prairie habitat because the voles tendency to avoid soil disturbance will ultimately enhance species richness, abundance and plant community heterogeneity (Klaas 1998).

Pocket gophers also create an indirect effect on the above ground insect populations because they affect the overhead plant cover that attracts insects. In a 2002 study it was determined that gophers selectively removed plants. When above ground areas were sprayed with insecticide the gophers fed disproportionately in areas of non-aphid insects (Ostrow 2002).

Uniform or clumped distribution of gopher burrows may provide variation to the core species on the prairie, providing  soil for secondary vegetation, primarily for annuals, and they also may be the origin of North American prairie soils (Mielke 1977; Spencer 1985; Reichman 1993).  The overall effect to the plant community depends on the rate of mound formation, the rate of the succession process and the types of plants present (Spencer 1985).  Gopher mounds have also been found to increase approximately 5.5% in overall primary production in shortgrass prairies where the

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Tephra definition:[7] volcanic fragments**:** solid material ejected explosively from a volcano, for example, ash, dust, and boulders, Reference: http://encarta.msn.com/encnet/features/dictionary/DictionaryResults.aspx?search=tephra increased production more than offsets the newly exposed areas (Grant et.al 1980 in Huntly 1988). Yearly rainfall variance has a significant effect on plant species within the prairies, and this also affects movements of gophers on the prairies (Hobbs 1991).

# Chapter 12

# Prairie Habitat and the Pocket Gopher

## The *T.mazama* Pocket Gopher in Washington Prairies

Although extensive research has been conducted regarding effects of gophers to soils in prairie environment, more research is indicated in Washington prairies specifically aimed at tunneling energetics of gophers and obtain appropriate forage and soil rate deposition with resultant effects to plants and animal species. The beneficial effects from gophers to soil and to prairie regions cannot be disputed. Research should be conducted on Washington prairies to measure specific effects from the *T.mazama* to plants and species and this research should be monitored on a long-term basis. Incorporating this data analysis into a long term planning agenda is imperative when estimating impacts to the natural prairie landscapes. This method will greatly assist in planning conservation measures for maintaining the prairie environments

## Historic Habitat of the *T.mazama*

The first complete inventory of all pocket gopher subspecies in Washington State prairies was conducted in 1915 by the United States Biological Survey (Bailey 1915). The nationwide gopher habitat study conducted is still reasonably accurate to this day because of the consistent soil conditions within prairie environments that Washington prairies provide, and the remarkable detailed observations made regarding gopher biology and habitat. Unfortunately, there have been severe impacts to original *T.mazama* habitat since the 1915 studies were conducted.

Dalquist and Scheffler conducted the next comprehensive pocket gopher study in 1944. They listed the Prairies of Washington and sub-species of pocket gophers living in the prairies. A comprehensive listing of Washington prairies are listed found in Table 2.

A new subspecies of gopher was added to Dalquist's previous list of subspecies named in 1949 as *Thomomys talpoides louiei*, named by Albert Moore of Portland Oregon (Branch of Wildlife Research office of the United States Fish and Wildlife Service), after the Chairman of the Board of Directors of the Crown-Zellerbach Corporation; Mr. Louis Bloch. These pocket gophers resided in the Crown Zellerbach tree farm 12 miles NNE of Cathlamet at an altitude on 2,500 feet in Wahkiakum County, Washington (Gardner 1949). Subsequent studies such as the Smithsonian Institutions North American Recent Mammals, built upon work from Bailey and Dalquist (Miller 1955; Steinberg 1995; Steinberg 1996; Steinberg 1999).

Genetic studies conducted by Steinberg in 1999 would ultimately update the taxonomy into three major subspecies of the pocket gopher in western Washington State, and reveal the origins of the sub-species using genetic processes that also ultimately confirms skull measurements of the *T.mazama* species (Smith 1988; Steinberg 1999).

Historic and contemporary regional data is available to identify possible habitat regions of the *T.mazama* and other gopher subspecies in Washington State. More research should be conducted to inventory the *T.mazama* and other specific subspecies in Washington to determine population dynamics and other beneficial effects to the environment and to surrounding prairie regions.

To date no specific scientific studies regarding biotic or population parameters had been conducted on the gopher species *Thomomys talpoides louiei* in SW Washington. Historically since 1915, this species was known as a separate subspecies as identified though direct observation and skeletal identification. Recently Steinberg has confirmed the genetic characteristics of this subspecies a separate species of pocket gopher. This is a clear indication that it is possible to use current technology and skeletal identification techniques together to positively identify gophers to subspecies (Steinberg 1999). These findings should be used together regionally to confirm positive identification of all gopher species. This genetic-skeletal process will provide data that will be incorporated in the creation of a accurate conservation policy.

In summary, the *T.mazama* historical taxonomy and habitat requirements have been studied in detail since 1915 although some studies may have been conducted in the region earlier (Bailey 1915; Dalquest 1942; Miller 1955). In 1955, Miller and

Kellog determined that species in the Puget Sound region of Washington existed only in *specific regions* in Washington, as far as they could determine. Steinberg and Witmer verified these findings and confirmed these habitat locations in recent *T.mazama* species (Steinberg 1996; Witmer 1996; Steinberg 1999).

# Chapter 13

## Current Habitat Studies

### Washington State Department of Fish and Wildlife Habitat Studies

Washington State Fish and Wildlife (WDFW) have preliminary data indicating the habitat of the *T.mazama* species through its <u>Location Data and Predicted Distributions</u> study that utilized LANDSAT satellite data. This study conducted in 1997 found no *T.mazama* species on islands in Washington State, and listed current habitat locations primarily the same as indicated in previous Dalquist and Scheffler studies. The *T.mazama* gopher data in the Washington State Location Data study admits that populations may be overestimated because of local exterminations, and that clear-cuts that were included in the maps may be unsuitable or inaccessible to pocket gophers. Accurate resolution of habitat at this scale is difficult, and some of the data indicated as optimum habitat may be too shrubby or have unsuitable soil types. According to this study, non-forested cover (except shrubland) was good habitat. When the study was conducted, the satellite data used did not have adequate resolution to reliably distinguish the "preferred native prairie" conditions from unsuitable non-forested habitat. Optimum low elevation habitat was indicated as being within open undisturbed tracts of meadows or prairies without conifer encroachment that included substantial forage and loose soil adequate for burrowing. Ecoregions listed as core habitat include the Puget Sound Douglas fir zones, Woodland/Prairie complex and Cowlitz River zones, with the Western Hemlock zone as peripheral. The data indicates that non-disturbed land with no evidence of heavy cutting, grazing, or burning may have optimum habitat for the *T.mazama* pocket gopher (Johnson 1997).

To create accurate maps, the landscape scale to be considered should guide the method of collection of and data processing. Numerous scales need to be addressed when mapping biodiversity and creating habitat maps, because maps are two or three-dimensional representation of features that may vary over time. One habitat feature may appear inconsequential at one scale for a species, but disastrous at another scale. It is possible to delineate accurate habitat ranges using GIS software that assimilates available landscape and biological data to create accurate habitat ranges for ecologically sound land management or LANDSAT imagery remote sensing applications. Once this data is obtained, it is possible to use it to represent an unending number of spatial resolutions (Muchoki 1988; <u>Mapping the Diversity of Nature</u> 1994; Hansen 1999).

Since this initial data was generated for pocket gophers in Washington State, multi-scale data approaches have been applied to landscape management issues and to environmental conditions as they change. It is imperative that investigations within the data structure are also incorporated into landscape patterns to indicate changes that can be measured over time for specific measurements (Frohn 1998). These measurements may be used for delineating specific habitat locations of a species with limited dispersal activity. In general, habitat locations for the *T.mazama* are currently located in prairie regions of marginal habitat quality representing a variety of habitat locations in developed urban areas and undeveloped areas where vast prairies once occurred (Kruckeburg 1991).

## GIS and the *T.mazama* in Washington

In order to observe *T.mazama* habitat on a smaller scale habitat than was used at WDFW in 1997, and to accurately pinpoint habitat locations,. Habitat maps for the *T.mazama* were then created using Geographic Information Systems software (GIS) to determine if *T.mazama* species were residing only in the current prairie locations, or if they were living in urban areas. Data for these illustrations were collected from readily available on-line sources and from Washington State Department of Natural Resources, Natural Heritage section. Geographical Information Systems (GIS) ArcView software was used to portray these local prairie regions. Data was collected from previously published scientific documents regarding the origins of the *T.mazama.* Township, Range and Section data obtained from Dalquist, Steinberg, and the Burke Museum in Seattle Washington (Dalquest 1944; Steinberg 1996) were obtained to provide capture locations of the *T.mazama* that represented historic habitat. Habitat maps were then created for the *T.mazama in* Southern Puget Sound. They are illustrated in Appendix 1-3 Township Range and Section location data was converted to latitude and longitude coordinates and reprojected through GIS [8] to create habitat points represented historic, current and museum trapping locations. Current prairie and oak grassland land cover regions as defined by Washington State Department of Natural Resources (DNR), Natural Heritage Program were then overlaid on Thurston County shape and plot maps to create current and historic geographic habitat representations.

Overall, capture locations of the *T.mazama* in Western Washington indicate that the gopher's habitat is located within wide-ranging historic habitat boundaries. Land that has been classified as existing Prairie fragments by the State of Washington DNR does not represent historic or current capture locations for the *T.mazama*. Currently capture locations as indicated by historic and current capture locations indicate that the habitat for the *T.mazama* may occur in residential locations, and within urban areas, and not within the land currently classified as prairie remnants. These initial habitat maps provide detailed illustrations of past and present habitat locations that clearly indicate that the *T.mazama* does not live in the mandated prairie locations as defined by Washington State Department of Natural Resources. Instead, they seem to live in areas of unbroken land primarily found in prairie regions, such as airports, prison grounds, bulb farms, tree plantations, and large stretches of unbroken private land. Shrinking available habitat and the absolute requirement for acceptable soils for the *T.mazama* brings them in direct conflict with human populations, prescribed land use practices and local, regional, Federal, and State government regulations and political pressures. These constraints may directly threaten their existence because of continued human development in Washington State prairie regions.

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[8] A Township Range Section on-line converter was used to convert original data to latitude and longitude coordinates. This data converter is located at: http://www.esg.montana.edu/gl/trs-data.html .
State Plane 1927 coordinates were then selected for viewing the reprojected data.

Further research is indicated to accurately identify these actual populations to subspecies. Data should then be incorporated into the *actual* habitat locations within a multi-scale planning regime that also incorporates environmental concerns and parameters that indicate change over time for environmental modeling purposes. This may assist in providing protection for this *species of concern*. These initial findings indicate that due to impacts to Western Washington prairie habitat, protection measures are indicated for the *T.mazama*. For additional information, refer to Appendix 1 through Appendix 3.

# Chapter 14

## Field Observations - The Olympia Washington Airport

Anchor Environmental, L.L.C., recently conducted a survey of gopher habitat, at the Olympia Washington airport at the request of the Port of Olympia, to determine if suitable habitat would be present for gophers on the airport grounds if construction of a new runway, called the Delta taxiway, and a new Helipad was built. The survey was conducted June 29, July 2 and 3, 2002, with results indicating high frequency of gophers in areas with soft soils and the presence of numerous herbaceous plants, with an average of mounds at approximately two per square meter.

The survey indicated that there was *some indication* that gopher mounds may stop where compacted soil areas begin, but that gopher mounds were still present on airport grounds in areas with a higher density of gravel. Overall, the survey did not discourage construction activity of a new runway or a helipad, but indicated that with removal of an old road bed, loosening compacted soil, and adequate habitat restoration in areas of construction, there would be adequate gopher habitat with moderate colonization ("Pocket Gopher Survey, Olympia Airport" 2002).

This survey of gophers did not address biological realities of *T.mazama* requirements that may be encountered by gophers during construction activities. There was no provision as to *how* the *T.mazama* gophers would colonize the proposed new areas or how many gophers may be threatened by construction activities. Airport runway construction may compact the gophers underground burrows and force the *T.mazama* aboveground. This would expose them to predation, interruption of seasonal dispersal activities, and limit their underground foraging activities as they attempt to build new burrows. Establishing new gopher colonies may require extensive tunneling activity which may severely stress the gophers as they attempt to establish new burrows.

Visual inspections of the Olympia Airport by A. Schmidt and C. Knudsen during an on-site visit February, 2003 indicated that gophers were present on the grounds at the west end. Airport personnel assisted these observations of gopher habitat. New mounding activity to any extent was not noted at that time. When leaving the site, there were additional observations of large frequent gopher mounds outside the Olympia Airport grounds, indicating the possible presence of gophers in surrounding State office grounds and industrial areas.

Occasionally, the *T.mazama* feed just within a short distance of the entrance of their tunnel openings when they are above ground, or seasonally, possibly during dispersing activities by the young once a year. At these times they are susceptible to predators such as: weasels , coyotes (C*anis latrans)*, bobcats (*Lynx rufus)*, badgers (*Taxidae taxus)*, great horned owls (*Bubo virginianus)*, great grey owls (*Strix robulosa*), barn owls (*Tyro alba*), hawks (*Buteo spp.*) and snakes (Tryon 1942; Howard 1951; Moore and Reid Elbert 1951; Barnes, United States. Bureau of Sport Fisheries and Wildlife. et al. 1973; Nevo 1979). Predation for gophers by the above predators has been highest at times of subadult dispersal, usually occurring at limited distances when the gophers are one to two months after birth, occurring shortly after weaning. (Nevo 1979).

The Optimal dispersal theory assumes that maximum fitness is achieved during dispersal activities and is evidenced in short-term survival, and contributes to survivorship of the gophers in the long run. The optimum proportion of young-of-the-year dispersers to new habitat areas is ultimately related to available habitat, local carrying capacity, and optimal foraging range of the habitat (Nevo 1979). This theory assumes that there is established habitat nearby for the young of the year dispersers.

It may be imperative that biological factors regarding predation and dispersal are adequately addressed, when recommendations are made regarding habitat. Destroying a colony of gophers by construction activities and then providing new nearby habitat, may not allow for natural survival mechanisms of the species, or guarantee that the gophers will be able to migrate successfully to utilize the new habitat.

Generally, suitable gopher habitat is defined primarily by soil type and food availability. Once territory has been established, most gophers remain sedentary throughout their lives with only small boundary changes where their burrows may be used continuously for up to three years (Nevo 1979).

New habitat for gophers may be expressed as a ratio of habitat generation time to the time the habitat provides adequate food for harvesting (Nevo 1979). No provision is indicated in the Olympia Airport study as to how new sources of food would be supplied or what those sources would be, but a recommendation was made regarding restoring the Olympia Airport grounds by "… seeding with prairie species…"

Some plant species naturally found on the Airport grounds are listed in the report, but it is unclear which of these species would be seeded to restore gopher habitat. The Pocket Gopher survey report states only that the newly restored habitat could be colonized by gophers when the habitat was restored ("Pocket Gopher Survey, Olympia Airport" 2002). This newly seeded restored area may provide adequate habitat for pocket gophers, although until food sources are established, this area may instead consist of a population sink that contributes to the formation of metapopulations, which may further threaten the *T.mazama* species.

Destroying habitat is unfortunate for gophers with possibly lethal consequences. Habitat is difficult to replace because of spatial limitations in urban areas, and other biological limitations such as territorial considerations, forage availability during construction activities, and problems with predation.

It is imperative that for realistic protection of this species, policy must allow for the gopher's biological constraints and habitat requirements. In this example regarding the Olympia Airport, difficulties may be experienced by all the *T.mazama* populations in prairie regions in Washington that are undergoing environmental change due to population expansion, burn suppression and construction activities. In addition, on airport grounds, there are Federal rules specifically requiring clear runway areas that may require chemical removal of forage items necessary for maintaining the *T.mazama* populations. These Federal property mandates may come in direct conflict with Washington State attempting to protect this *species of concern*, from the harmful effects of herbicides.

# Chapter 15

# Prairie Restoration in Washington State

## Sustaining Grassland Prairies

When considering habitat restoration for the *T.mazama*, the issue of available forage is critical. Historically, burning prairies was performed by Native Americans to preserve the natural grasses and maintain the prairies. Prescribed burns are invaluable tools in protecting prairie habitat, and they should be conducted yearly or bi-yearly at appropriate times to maintain the prairie ecosystem (Howe 1994; Howe 1995; Leach 1996; Howe 1999). It is also thought that pocket gophers may have relatively low mortality to fire because of their burrowing capacities (Marsh 1984).

Generally, a few species of grasses dominate prairie landscapes. When the prairie experiences a burn, new species are encouraged to grow, primarily new shoots and forbs which is a vital food for the pocket gopher (Antos 1983). Burning prairie environments may increase the possibility that the rate that seeds are trapped near gopher mounds. As a result, this may increase the likelihood that gopher mounds act as colonies for seed germination (Spencer 1985). Sustaining grassland prairie environments also depends on successful introduction of alien plant species, or plants that are not dominant in the landscape (Karl 1999).

The Nature Conservancy assists prairie conservation efforts by enlisting extensive volunteer assistance regarding seed germination techniques. These techniques require a majority of plant species for germination and conventional stratification techniques, although some of these seeds have been difficult to germinate and the techniques require refinement (Drake 1998).

Simulation modeling has been developed specifically to estimate gopher population dynamics, effects to plant communities, and population parameters for the *T.mazama* within fragmented habitats (Andersen 1982; Hobbs 1987; Steinberg 1999; Seabloom 2001). There are also modeling techniques for effects to ecosystems specifically created by gophers including spatio-temporal patterns of gopher mound production measuring change over time within tall grass prairie ecosystems. These techniques may be useful in measuring impacts occurring within Washington State lowland prairie environments (Klaas 2000).

Within Washington State Department of Natural Resources Natural Heritage program, information regarding rare plants and other rare species is available that may provide information for conservation planning protection for prairie landscapes. This Natural Heritage Data is compiled from public and privately owned land, and it is used primarily for local land use planning. It may serve as a major comprehensive source of information for biodiversity conservation strategies that provides coverage across many jurisdictions. State planning departments may use Natural Heritage data but if little attention is given to biodiversity at a systems level, the Natural Heritage data may be underutilized (Cort 1996). This data could be combined with modeling programs to estimate future impact of prairie environments. This approach, along with conserving gopher habitat and enlisting the assistance of volunteers, may indicate the best combination of factors necessary for prairie conservation.

## Multi-Scale Prairie Restoration Strategy

Management objectives generally focus on evaluating current knowledge and evaluating competing values and interests between public and private objectives in prairie environments. When managers take an ecosystem approach to define a geographic space that focuses on ecosystem processes it takes the emphasis off of biota and on to a systems approach (Yaffee 1999). Biota is an important consideration in prairie ecosystems but a complete survey of biological and biogeographical resources on a larger scale should also be conducted. This includes environmentally sensitive areas, local scale, biotic, abiotic, geomorphic, hydrologic, wildlife, and cultural factors. These larger scale environmental functions focus on regions of prairie landscape environments. This large-scale approach is imperative in assisting in conservation planning. In this way, landscape features may be evaluated on a larger scale, and also linked to regional land use goals. This approach may be one good way to maintain sustainable resource use. The ABC approach is explained in Table 3. It recognizes four levels of analysis and mapping that are important in categorizing the steps in conducting a large scale approach to landscape studies based on Geographic Information Systems (GIS) using analysis of environmentally sensitive areas (ESA) to create a sustainable approach to development (Nelson 1988 et.al.).

GIS is valuable method for creating maps that define habitat boundaries. It also is an invaluable tool in communicating with the public and a potential tool for involving all stakeholders by providing a visual representation to habitat parameters. Spatial modeling of critical habitat, land development patterns, and alternative development scenarios may be presented in a format easily understood by all stakeholders. Often, when the public is dependent on a natural resource, they will often ignore science based policy unless the policy is based on local knowledge of resource use (Weeks 1997; Shindler 1999). GIS provides a visual aid that may assist in obtaining local knowledge.

A modeling approach similar to the ABC approach was applied on several scales for Summit County, Colorado that also used available information to create landscape management forecasting predictions, including public and private land (Theobald 2002). Additional recent studies approach a landscape ecology by also using small-scale and a large-scale approaches that provide for maximum benefits to biodiversity near nature reserves (Hansen 1999).

These examples of comprehensive approaches to land use policy incorporates a large scale view for management that includes land boundaries for public and private lands and also creates a detailed view of landscapes where land-planning decisions may be made where all significant small scale habitat factors can be included. In prairie environments, this large-scale approach would undoubtedly include large prairie regions that prioritize regions of available habitat for the pocket gopher.

Traditionally, edge habitat includes greater habitat variability for wildlife, leading to greater vegetative complexity. There are also many negative consequences with edge habitats. They can lead to patchy habitat and isolation of wildlife. They are difficult to predict and can result in dire consequences for the pocket gophers depending on a optimum habitat consisting of unbroken prairie (Yahner 1988). Using a large-scale approach and combining this approach with GIS, assists as a visual aid in identifying habitat protection goals by identifying edge habitat.

Public policy in State and Federal agencies will include rare and endangered species protection, which may also have direct relevance for species of concern. These species protection goals may be achieved by land acquision, land trusts, investigating land use patterns for conservation opportunities, and shifting funding priorities to take advantage of rare species protection opportunities. However, land acquision also needs to match the range sizes of the species, and the agency capacity that is necessary to manage endangered species (Press 1996; Tenenbaum 2000; Ludwig 2001).

# Chapter 16

# Recommendations for Conserving Washington State Prairies And Assisting in Protection of the *T.mazama*

## Ecosystems Approach to Landscape Management

Mammal species are more vulnerable to extinction than birds (Soule and Wilcox, 1980 in Muchoki 1988) and the potential for extinction of species on grasslands is a serious concern. Once prairies damage has occurred, restoration may take centuries (Schramm 1990 in Sampson 1994).

The *T.mazama* is a component of a larger ecosystem. Ignoring surrounding ecological implications of the gopher's central place in the prairie ecosystem will weaken ecosystems, continue environmental degradation, and create permanent extirpation of many species as well as the gopher.

Unless management adapts a multi-level approach applying available data representing public and private land, and including biologic requirements of the *T.mazama* and edge effects to this species in Washington prairie environments, extirpation is a possibility. The *niche* management approach, or management with the primary focus on managing ecosystem biota must be replaced with data from multi-levels that include ecosystem processes (Samson 1994; Brown 1996).

Effective environmental managers must now possess skills in several disciplines such as geography, economics, and political science. These changes in environmental policy represent evolving social and environmental conditions that represent recent developments in ecological and biological understanding. Changes in scientific knowledge and within society have influenced the way policy is created. Policy is increasingly being informed with applications from several disciplines such as economics, ecology, and with applications from new technologies. Environmental policy changes also are influenced by global change, different stakeholder value systems, equity and social justice issues that may represent difficult management goals. All these factors considered together emphasize the need for multi-scale management (Mangel et.al. in Salwasser 1992; Beattie 1996; Ludwig 2001) Multi-scale management objectives may be the best solution for the protection of prairie ecosystems and for the subsequent protection of the T.mazama, as these regions continue to experience impacts from human development activities.

## Evaluating policy

When using a multi- scale approach to land management, it is important to evaluate critically the data that is used. For example, many studies have contributed extensive knowledge to species conservation, but when creating environmental policy conservation specialists should thoroughly understand the specific applications of the data being included in policy. For example, there are three factors to include when considering genetic information.

1. Estimation: Because large errors can be associated with subsampling populations and because inherent variability of random effects (i.e. genetic drift), simple measures of genetic structure can not be applied at "face value".
2. Interpretation: There are many alternative possible causes for any estimated genetic structure (i.e. limited dispersal, historic population bottlenecks, and high variation in population size). Therefore, using statistics of population genetic structure (particularly statistics that assume equilibrium conditions) to determined specific ecological details about species or populations is problematical.
3. Application: Even if we have good estimates of genetic structure, it is not immediately obvious how they can be practically applied (Steinberg, 1999).

Correctly identifying genetic population structures are aids in identifying gopher populations and are an invaluable aid in conservation strategies although they in themselves not the only tool that should be utilized by conservation managers. Without the addition of accurate demographic data for *T.mazama* populations, understanding the genetic structure of the species may only reveal partial insight that may not include all parameters needed for conservation.

Obstacles to applying a landscape ecology approach for decision making within State and Federal agencies may include conflicting permit regulations that specifically pertain to air and water issues. There may also be a lack of understanding how to apply regulations with public and regulatory agencies. Equally challenging is the process of defining *ecosystem management* and *watershed management* (Brown 1996; Yaffee 1999). There are different interpretations of the terms *environmentally sensitive multiple use*, *an approach to resource management*, and *eco-regional management"*. Each of these approaches may emphasize different values, knowledge, and focus. The environmentally sensitive multiple use approach, may observe an anthropocentric perspective, the ecosystem approach could emphasize a biocentric view, and the ecoregional management could place priority on an ecocentric view. These three different views may represent a paradigm shift that may indicating change within management policy (Kessler 1992, and Kimmins 1995 in Yaffee 1999). Awareness of these different approaches may be important in evaluating a multi-scale approach to Washington prairie landscapes and for the protection of the *T.mazama*.

Adding to the different approaches in evaluating environmental policy, there are two main types of ecosystem classifications that define geographical data that are used, namely, the Omernik, and Bailey systems that are used in many government applications. These methodologies have an unintended negative effect of creating disunity because they do not address ecosystem processes that cause change over time. They primarily focus on mapping geographical space and the objects on that space in that time, and do not allow for dynamic climatic conditions in the ecosystem. This results in different kinds of ecosystem classifications in the same management category (Lugo 1999). Major errors may occur if managers reach land management policy decisions based on reaching a consensus by averaging different scientific positions without understanding data classification systems (Ludwig 2001).

Another ecosystem classifications system currently being used is the Holdridge Life Zone System, which includes data precipitation, and mean annual temperature depicting climatic conditions for ecosystem function. This system has received some criticism regarding life zone names that do not always coincide with observed vegetation, its data classification does not consider the seasonality of the climatic data parameters, and its' classification systems are thought to classify only tropical systems, however, this data classification may be a step in the right direction (Lugo 1999).

By becoming aware of different approaches to policy and data classification, and using accurate landscape scales that include accurate landscape parameters, and incorporating habitat boundaries and species, change may be possible on a local level that offers protection to the *T.mazama* and its place in the Washington prairies. It then may be possible to move along a continuum, and ultimately reach consensus by acting conservatively and managing adaptively (Sampson 1994; Flather 1998; Shindler 1999; Yaffee 1999).

## Research Requirements

The *T.mazama* is a valuable species in Washington lowland prairies, causing positive effects with plant and insect communities as well as contributing to the origin of prairie soils. They affect plant communities in positive ways, allowing for the germination of annuals and assist in gas transport and drainage in soils, necessary for maintenance of prairie environments. Conservation plans should be created to protect the *T.mazama*, because of the invaluable service they provide to the prairie environment.

The habitat and dynamics of pocket gopher populations make them vulnerable to extinction. Maintaining western Washington State prairie habitat and protecting the *T.mazama* is an important goal for environmental managers. It is imperative that data is collected on small and large scales representing short-term and long-term events in prairie landscapes. Biological data must be collected regarding the life history and limiting factors for the *T.mazama*. This data can be used to create a landscape systems analysis that can be used within a GIS mapping format to compliment existing data within Government agencies to delineate management areas that protect and conserve the Washington lowland prairies.

It is thought that populations of pocket gophers persist through a process of extinction and subsequent recolonization. Prairies in Washington are undergoing destruction due to construction activities. Conducting the process of redefining managements units within prairie regions could be critical to pocket gophers survival. Genetic identification of gopher populations is important to identify the scale at which genetic differentiation is manifested. These findings will reveal an accurate scale for direct management efforts. These genetic findings may also have practical implications for management by establishing or disproving that distinct populations are found in different regions. Discovering the genetic origins of pocket gophers may also support the findings that species should ***not*** be moved within regions, as is common with fish populations (Steinberg, 1999). Without accurate demographic and natural history information regarding the *T.mazama*, adequate management may never be attained.

The extent that translocating gophers to new habitat will be successful depends on individuals passing alleles to the new neighbors, which cannot be successfully estimated because of the potential of disease or parasite infestations caused by moving *T.mazama* from one location to another. The success or failure of translocation remains unknown.

Previous research regarding the habitat of the *T.mazama*, utilized methodology that had inadequate resolution to delineate between appropriate and inappropriate habitat. Although data collected by the WDFW indicates non-disturbed land with no evidence of cutting, heavy grazing or burning may be optimum habitat for *T.mazama* it may not account for soil conditions or forage availability on a small enough scale.

To create accurate data for the *T.mazama*, a Western Washington inventory should be conducted that includes mark-recapture, live trapping, or using track tubes. Techniques such as GIS and habitat mapping can be utilized, to create habitat maps after a complete habitat inventory has been performed. Since gopher mounds are visible above ground, opening tunnels may assist for gopher location and possible enumeration.

Research should also be collected regarding thin prairie soils including soil depletion rates over time and soil conditions that relate to specific gopher burrows. Research is also indicated regarding specific sizes of gopher burrows and linking food habits of the gopher over existing soil conditions that relate to precipitation, and other long-term effects to soil. Soil depletion rates also may be calculated if sizes of gophers and energy use efficiency are known. This valuable data should be incorporated into management strategies to assist in prairie restoration.

Data and biological samples may be collected during the *T.mazama* statewide inventory process that can assist in clarifying taxonomic issues by providing more samples for MtDNA analysis. If there are trapping mortalities when using live trapping techniques, specimens should be collected for ageing purposes, and for skeletal confirmation of species.

Since herbicide use affects energetics of the whole ecosystem with inconclusive results regarding gopher control, research should be conducted for damage control the pocket gopher initiates, by researching genetically modified trees that may resist damage, chemosterilants, gopher fencing, and research into placing trees in gopher proof tubes before planting.

## Recommendation against translocation of *T.mazama*

The *T.mazama* is adaptable to some degree with diet, and due to unknown reasons, they may leave areas of reduced dicot availability, which may indicate flexibility in acquiring new habitat, and they can adapt their sizes to environmental conditions in the soil. However, these factors are not adequate to consider relocating gophers without extensive research.

Translocation of gophers without conducting adequate prior research may cause mortality. Gophers have over time adapted to soil conditions and to the variety of available forage in the specific isolated prairies where they live. If they are relocated to new areas, with too much clay in the soil or inadequate gas diffusion properties, they may become hypothermic or unable to adapt to new forage. Tunneling energetics are known to be high for gophers, and wet soil will limit gas diffusion properties.

Transporting gophers may be difficult because they have poor thermoregulation properties, have been known to die in live traps due to hypothermia. They are territorial and have been known to fight viciously when placed together. Little is known about tunneling energetics for the *T.mazama*, because previous studies are referenced from a single habitat area, with no references to other soil types. No specific literature exists for translocation of *T.mazama* gophers. If translocation of gophers is attempted, intensive research should be conducted before the gophers are moved. This will reduce incidental occurrences of gophers that may perish attempting to tunnel in impervious soils or suffer effects from predation or hypothermia, or translocation to inadequate habitat.

## Conclusions

Maintaining the habitat for the *T.mazama* pocket gopher is a vital component of prairie restoration in Washington State. Gophers are invaluable restorative agents on the prairies due to the gopher's soil mining and aeration functions on the prairies, leading to gas transport within fragile prairie soils, and soil-mounding activities during burrowing that introduce soil to the prairie surface offering opportunities for germination of non-dominant plant species. Additionally, gophers maintain habitats occasionally near the edges of prairies, assisting in preventing invasive vegetative encroachment.

There are opportunities for prairie restoration that apply a landscape ecology approach to mapping, prioritizing habitat, and creation of policy, including protection of the native plant and animal species and restoration of native seeds (Drake 1998; Weber 1999). These approaches, along with recruiting and using volunteers to restoring prairie habitat through prescribed burns is effective in several regions across the United States (Sampson 1994; Kurtz 2000). However, work that is far more intensive than the current efforts needs to be accomplished to restore the prairies in Washington, to assist in landscape recovery, and to protect habitat for the *T.mazama,* a *species of concern.*

Without more research, these limiting factors relating to the geographical conditions and biological needs of the *T.mazama* will make relocation of gophers risky.

Although it may be possible to identify current and historic habitat locations by examining easily obtained available data, this data needs strategic applications to a cohesive management strategy that combines several landscape scales. This approach will assist in preserving the unique remaining prairie habitat, and the *T.mazama* populations. This approach will be a benefit to the maintenance of the prairie ecosystem, and insure continued enjoyment of the prairies for future generations.

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