LAND USE IMPACTS AND HABITAT PRESERVATION IN THE GRASSLANDS OF WESTERN MERCED COUNTY, CALIFORNIA

Prepared for:

GRASSLAND WATER DISTRICT

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EXECUTIVE SUMMARY

The Grasslands in western Merced County were once part of an extensive, pristine wetland system that covered at least 4 million acres in the Central Valley of California. At that time the landscape was teeming with abundant wildlife. Large herbivores were common, and wetland birds were so numerous that they blackened the skies. Beginning over 150 years ago, the onset of grazing and then farming gradually changed the landscape. Native perennial plant communities were replaced by exotic annuals before 1850, and large predators and grazing animals disappeared. As early settlers discovered the rich soils on the valley floor, development of a huge agricultural industry began. Key to the success of agriculture was an irrigation system to supply water for crop production, coupled with an effective system for draining the irrigation water from fields.

As the landscape changed from a pristine setting to an agricultural system, native ecosystems were fragmented and the size of the remaining natural habitats gradually decreased. Conversion of the native systems to agricultural production accounted for much of the loss in size, but establishment of transportation and irrigation systems further fragmented the environment and disrupted migration corridors and movements of animals among remnant habitats. These same corridors allowed the rapid dispersal of exotic plants. Effective use of irrigation waters required land leveling and drainage systems to prevent salt concentration. These modifications further impacted the already greatly modified hydrology associated with the establishment of water storage and distribution facilities. Other changes associated with agriculture further impacted the quality and function of natural environments. The use of pesticides, herbicides, and fertilizers degraded water quality. Intensive soil manipulations increased sedimentation, and irrigation water moving through some soils concentrated elements such as selenium that disrupted biological processes.

Because changes associated with agriculture had a profound effect on the size, distribution, and quality of remnant natural habitats, many practices and habitats associated with agriculture became important for some wildlife. Grazing lands were used extensively by geese, cranes, and some shorebirds. Waste grains such as corn, wheat, barley, and rice provided important sources of high energy foods readily consumed and digested by waterfowl and other granivorous birds. Nesting birds made use of agricultural fields such as alfalfa and wheat before harvest. Sites considered as waste areas by the agricultural community also were important for some wildlife. Sump areas for drain water and drainage ditches sometimes had borders of wetland vegetation that supported diverse wildlife aggregations.

Although the extensive disruption caused by agriculture reduced the numbers and changed the distribution of wild populations, the Central Valley continues to be one of the most important habitats for waterfowl on the North American continent even though habitats now cover less than 300,000 acres. About 60% of the wintering waterfowl in the Pacific Flyway use Central Valley habitats and about 65% of the North American pintail population use these wetland habitats. The largest contiguous block of remaining wetland habitat in the Central Valley is the San Joaquin Valley Grasslands. Of the remaining wetlands in the Central Valley, about 33% are clustered in the Grasslands between Merced and Los Banos along the San Joaquin River. This sizable area is of considerable importance because the variety of habitats are important to the maintenance of biodiversity on a national and international scale. Such habitat diversity is driven by differences in soils and hydrology between the East and West Grasslands. Thus, wetland habitats within the Grasslands represent many different hydrologies ranging from vernal pools to permanently flooded wetlands.

Central Valley habitats increasingly are being impacted by urban expansion. Cheaper land and housing in the Valley compared to the Bay area have attracted many people that are willing to commute long distances for employment. The population of Merced County is expected to grow from 180,000 in 1990 to 260,000 in the year 2000. As this population grows there will be multifaceted impacts that will further degrade both agricultural and remnant natural systems. As urbanization progresses, open space will continually disappear, fragmentation will increase, and a host of factors with high potential to disrupt and degrade the functions and values of the Grasslands ecosystem will be imminent. Expansion of transportation corridors in number and size will bring more fragmentation and increased air pollution. As areas of impermeable surfaces such as roofs, highways, and parking lots increase, runoff will be more rapid and of greater volume. Stormwater carries sediments and pollutants of many types. Free roaming pets are always in abundance near urbanized areas; their activities disrupt wildlife life history strategies and can result in direct mortality to wildlife. The juxtaposition of urban areas adjacent to natural environments has an insidious impact that gradually reduces the quality and functional area of these habitats. Such changes have been commonplace across the United States. The decrease in open space and associated fragmentation in conjunction with the effects of transportation, recreation, reduction in air and water quality, and general disturbance gradually modifies plant and animal communities. Monotypic plant communities will be more common. Exotic plant and animal species may increase while native populations disappear.

The Grasslands ecosystem is a significant remnant of our natural heritage. Not only is this a unique parcel of a diminishing resource in the Central Valley and the state of California, but these wetland habitats are critical to the survival of migratory species that move across the North American continent and among continents during their annual cycle. Thus, further loss and degradation of this largest remnant wetland habitat in the Central Valley not only will have an important negative impact on local resident wildlife and plant communities, but also will negatively impact migrant animals that move to distant countries during their annual travels. For this reason, protection and appropriate management of this unique ecosystem is essential to assure preservation and to maintain productivity of this important natural heritage. Preservation of this system requires that fragmentation must stop and the area not decrease in size. Some agricultural land use practices will continue to provide important open space as well as important foods or habitats for wildlife. Protection of these agricultural lands from conversion to other uses should be an integral part of strategies aimed at protection of this important system.

Changes in land use require management to emulate historic water regimes that are tied to wetland productivity and life cycle events of wetland wildlife. Careful and timely manipulation of soil and water assure productivity and the biodiversity associated with diverse wetland systems.

This land use study has identified the perturbations that have affected this wetland ecosystem for the past 200 years. Available information clearly demonstrates the importance of strengthening the protection of the Grasslands Wildlife Management Area to assure the long-term integrity of this important and unique habitat. Adequate open space must continue to exist in the future as part of protective measures that are essential to maintain the functions and values of this system for wildlife and humans. Additional information and a better understanding of interactions among perturbations must be generated before additional encroachments compromise the viability of this system forever.

INTRODUCTION

Man's first impact in the San Joaquin Valley dates back about 10,000 years to the arrival of immigrants that crossed the land bridge from Asia. At that time California had a rich fauna of wildlife that exploited diverse habitats in the mountains and valleys. The geomorphology of the Central Valley floor had a profound influence on the location, general topography, structure, and function of these diverse habitats. The distribution, diversity, and abundance of plants and animals reflected the size and distribution of different habitats. The distribution of habitats in turn influenced the location of Native American populations. The extent Native Americans impacted wildlife populations is not fully known, but many suspect that their hunting skills were adequate to influence the distribution and size of large mammal populations (Burney 1993). However, Native Americans differed from subsequent settlers because their way of life had little impact on the landforms or hydrologic regimes that controlled the dynamics of wetland habitats within the San Joaquin River floodplain.

When the Spanish arrived in the San Joaquin Valley in the 1700's, a wonderfully diverse and largely untouched ecosystem composed of interspersed wetland and upland habitats existed between the Coast Range and the Sierra Nevada. As an increasing number of settlers reached California in the 1800's, the potential for agriculture in the Valley was recognized and the first steps were taken to divert water for agricultural purposes.

Agricultural development reached a peak by the middle of the twentieth century. The modifications required for successful agriculture in this semiarid region had a dramatic influence on the landscape. Foremost among these changes were developments required to ensure a more consistent water supply across large portions of the Valley. Reservoirs were constructed to store water, and extensive canal systems were built to transport water to farms. Such developments drastically affected the hydrology and water quality within the Valley. In addition, a transportation infrastructure that interconnected farms and communities was required to move equipment, supplies, and commodities, which further altered ecosystem function. As human populations continued to grow, more perturbations impacted an increasingly fragmented landscape. Open space decreased as the demands for housing, recreation, wastewater treatment and other essential developments associated with urban and industrial expansion required more land. Continued growth and shifts in the human population in California remain an important influence on current land use. Projections for population growth within the Central Valley suggest a huge increase as more and more people seek affordable land and housing. These demands for living space and associated developments will continue to change the character of Merced County.

Collectively, these factors have had a profound influence on the size, distribution, and function of pristine habitats that once provided wildlife populations with the seasonal necessities required for survival and reproduction. Some impacts are subtle and difficult to quantify (e.g., minor disruptions in landform) whereas others, such as changes in land use practices, have obvious results. This report documents the changes in land use in western Merced County extending back more than 200 years. The implications of these impacts are described in relation to the location and types of activities associated with land use in the County and the potential or documented consequences to natural resource elements. The focus of the study identifies factors associated with the most recent changes in land use related to urban expansion, which will continue to occur in the Central Valley and specifically in western Merced County. The purpose of this document is not to promote the ideology that natural resource concerns be considered and preserved at the expense of economic growth and community development. Such a concept is no longer a viable option in today's society. Rather, the intent is to provide a factual basis that identifies the importance of the Grasslands as an integral component of a much larger landscape that is in imminent danger of being fragmented and disrupted to a greater extent. Further, it is imperative that all individuals and organizations be aware that irreparable damage to the land base likely will have devastating consequences to human populations. Thus, strategies must be implemented to assure that the value and function of natural systems remain viable in order to provide societal benefits and to protect open space for future generations to enjoy.

STUDY AREA

The focus of this report is on the land use impacts within an area described as the Grasslands Wildlife Management Area and surrounding lands within 2 miles of the management boundary (Fig. 1). This area, which encompasses 179,463 acres (Merced Data Special Services, Inc. 1993), includes the largest contiguous block of wetlands remaining in the Central Valley of California. A major wintering ground for migratory waterfowl and shorebirds of the Pacific Flyway, the Grasslands also provide habitat for a number of threatened and endangered species. The U.S. Fish and Wildlife Service recognizes the Central Valley (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986, U.S. Fish and Wildlife Service 1978, 1987) as one of the most important wintering areas for waterfowl in the nation, and the Western Hemisphere Shorebird Reserve Network has designated the Grasslands as an international reserve for migrant and wintering shorebirds. These important wetlands are the remnants of a wetland complex that historically extended throughout the Central Valley and

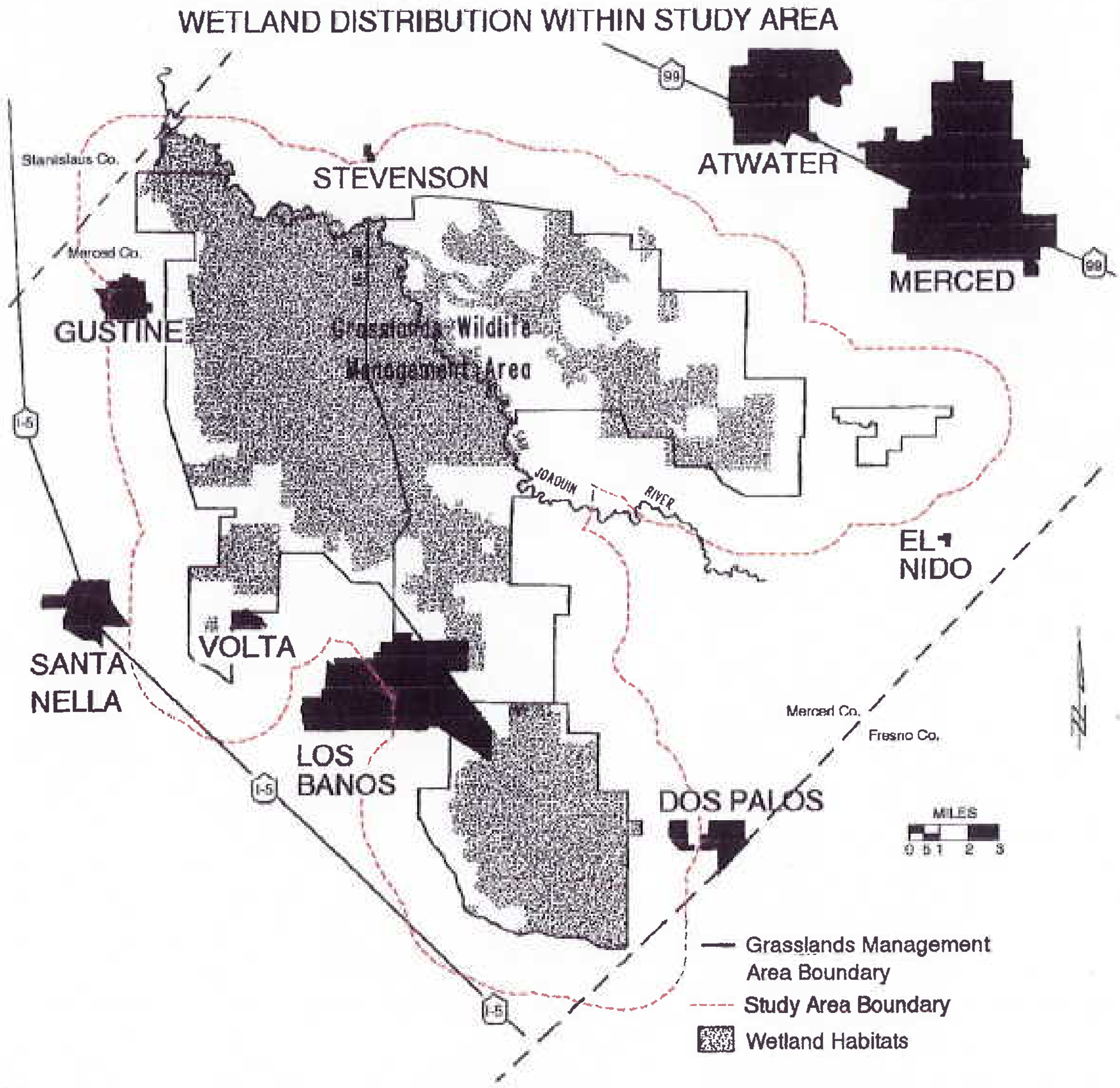

Fig. 1. Grasslands Study Area including a 2-mile perimeter surrounding the Grasslands Wildlife Management Area.

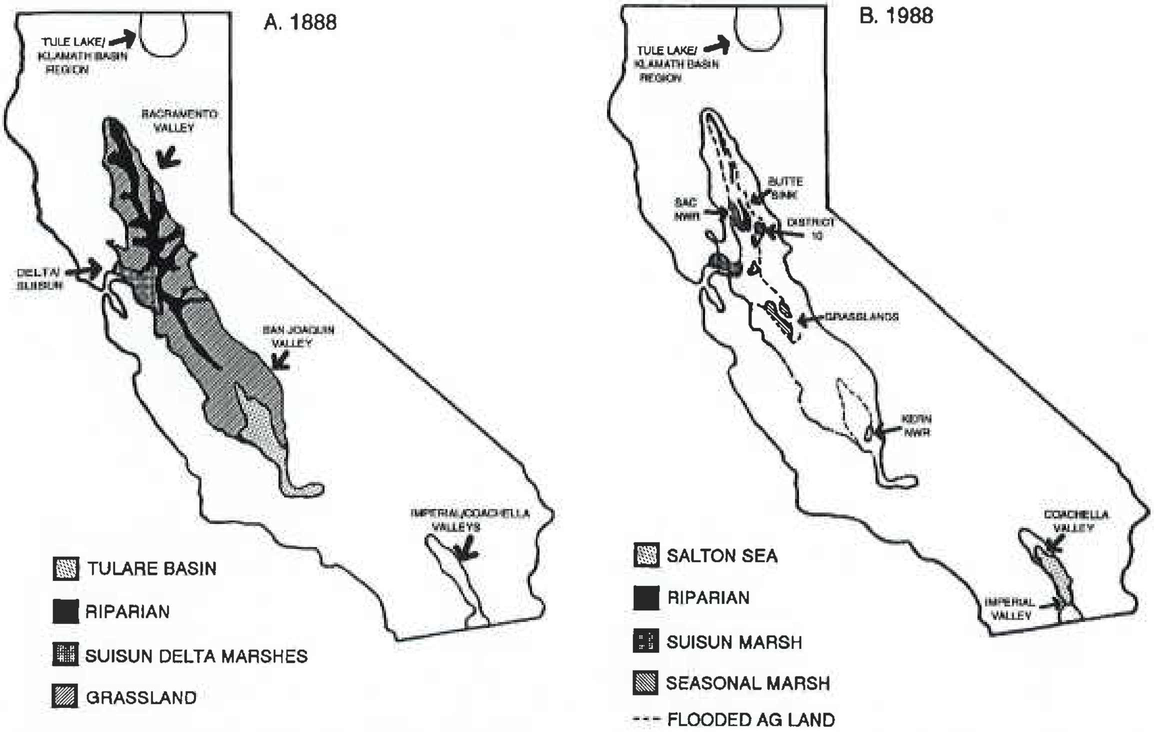

Fig. 2. Location and distribution of general habitat types in the Central Valley of California in 1888 (A) and the fragmentation of these contiguous habitats by 1988 (B).

composed part of a 4 million acre wetland system (U.S. Fish and Wildlife Service 1978; Fig. 2). Currently, only about 281,000 acres of wetland habitat remain in the entire Central Valley (U.S. Fish and Wildlife Service 1987). Land ownership within the Grasslands Study Area is varied, consisting of federal, state, and private entities (Fig. 3). Habitat types also are diverse, including semipermanent and seasonal wetlands, vernal pools, riparian corridors, native grasslands, and developed agricultural lands. Published reports provide variable estimates of wetland habitats. Merced Data Special Services, Inc. (1993) provided an estimate of 116,509 acres of wetland habitat in the study area. Other estimates, including those from the San Joaquin Valley Drainage Program, include areas of seasonal and permanent wetlands. These estimates sum to 91,465 acres but do not include the habitats in the East Grasslands (Table 1). Earlier reports (Table 1) suggest that over 90% of wetland habitats exhibit seasonal hydrology. This complex of wetland habitats is of special significance because the size, juxtaposition, and connectivity of the different wetland types provide a unique opportunity to sustain native migratory and resident wildlife populations. The associated uplands surround-

Table 1. Estimated area of wetland habitat (San Joaquin Valley Drainage Program 1990) within the Grasslands Study Area.

	Wetland type	Acre
Grassland Water District	Seasonal	32,000
	Permanent	6,400
	Total	38,400
San Luis National Wildlife Refuge	Seasonal	2,665
	Permanent	40
	Total	2,705
Merced National Wildlife Refuge	Seasonal	725
	Permanent	21
	Total	746
Volta Wildlife Area	Seasonal	2,400
	Permanent	300
	Total	2,700
Los Banos Wildlife Area	Seasonal	3,060
	Permanent	760
	Total	3,820
Duck Clubs outside Grassland Water District	Seasonal	11,144
	Permanent	0
	Total	11,144
TOTAL	Seasonal	83,944
	Permanent	7,521
	Total	91,465

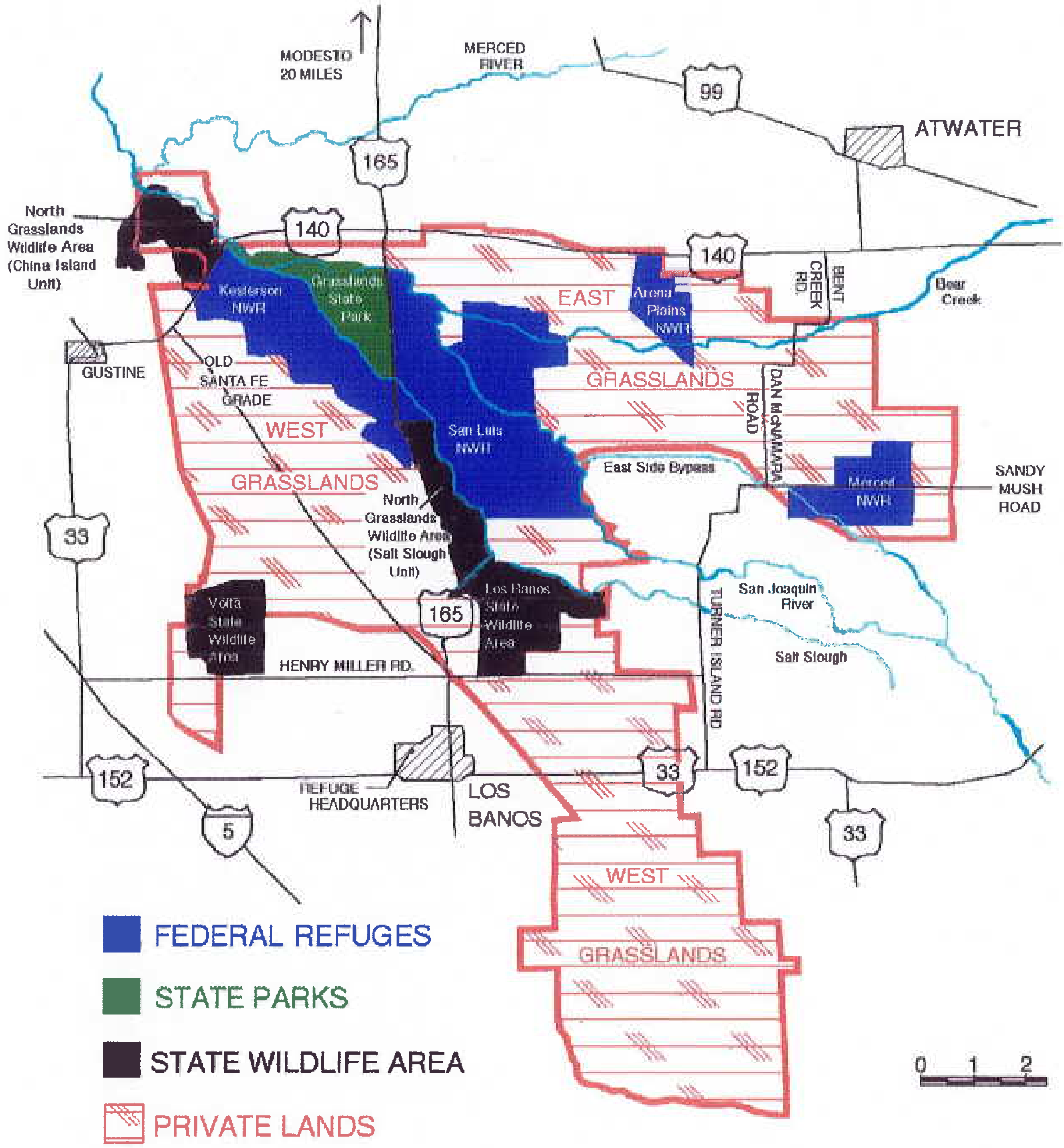

Fig. 3. Federal, State, and private owned lands in the Grasslands area.

ing the semipermanent wetlands also are of special importance because they provide nesting areas for waterbirds, important food sources for grazers such as geese, and essential habitat for endangered species as well as numerous upland wildlife.

The Grasslands are bounded by numerous towns and cities (Fig. 1). The largest population centers are Merced to the east and Los Banos to the west, with 1990 populations of 50,000 and 13,500, respectively. Smaller communities include Volta, Santa Nella, and Gustine to the

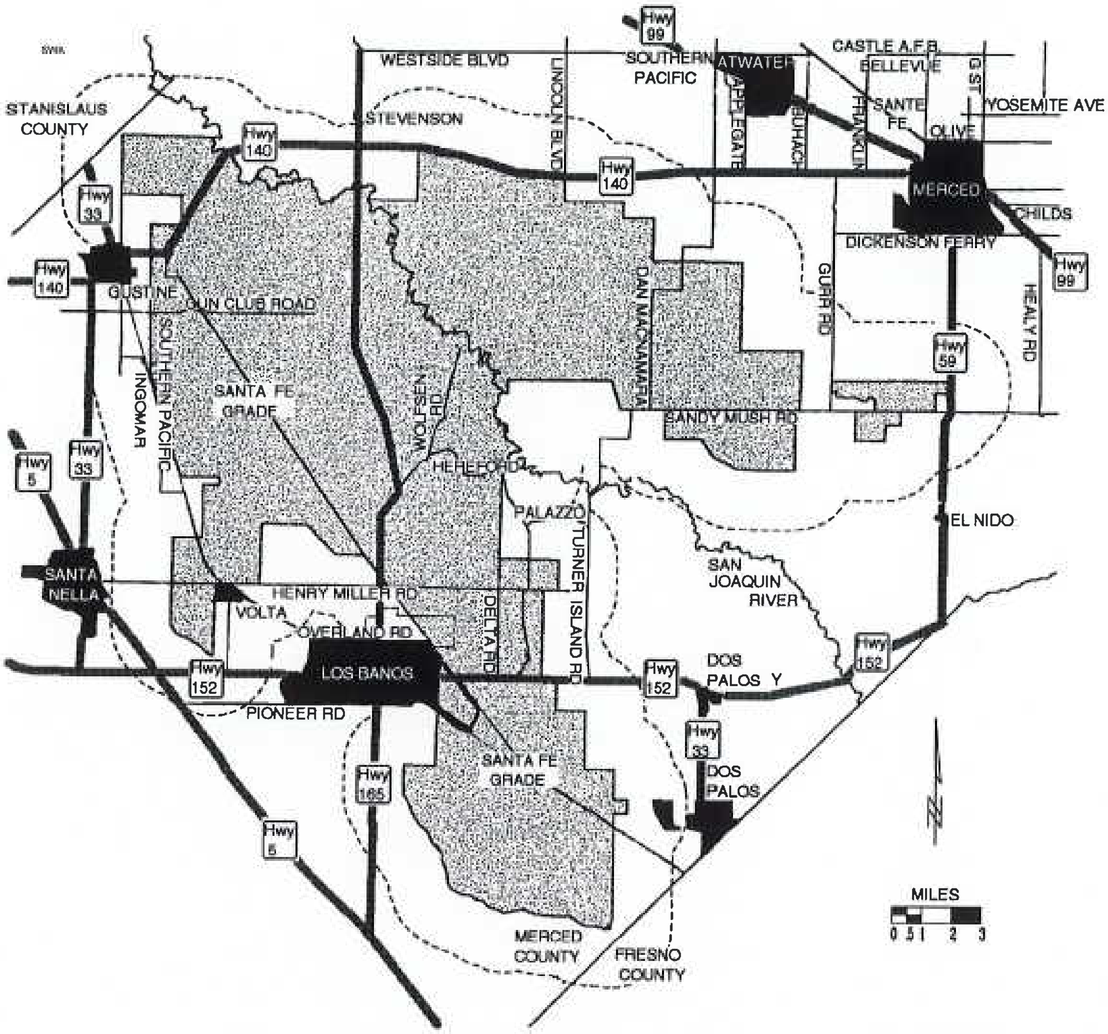

Fig. 4. The location of major roads and highways within the Grassland Study Area of western Merced County.

west, Stevenson to the north, and El Nido, Dos Palos, and South Dos Palos to the east. The 1990 population of Merced County was 178,403 (Wright 1993) with a projected growth to 264,000 by 2005 (Association of Bay Area Governments 1991). Population projections by the Department of Finance suggest that Merced County will have a population of 626,900 by 2040 (State of California 1993).

Other important features in relation to land use are roads and highways (Fig. 4). Four-lane highways are Interstate 5 to the west, California 99 to the east, and California 152 that runs through Los Banos and bisects the Grasslands into areas described as the North and South Grasslands. Other major state highways impacting the study area include California 140 to the north, California 165 that bisects the area north of Los Banos, and California 33 to the west. Other transportation corridors such as Henry Miller Road also support a considerable amount of local traffic within the study area.

Developments for water transport are key components that influence habitat type, hydrology, and land use in the Grasslands. The area is laced with canals that transport irrigation water or collect irrigation drain water. Starting at I-5 and moving east, the primary water conveyance systems within the study area include the California Aqueduct, Delta-Mendota Canal, Outside Canal, and Main Canal. Salt Slough, San Joaquin River, and Eastside Bypass handle drain water. These systems including Bear Creek and Merced River handle riparian flow

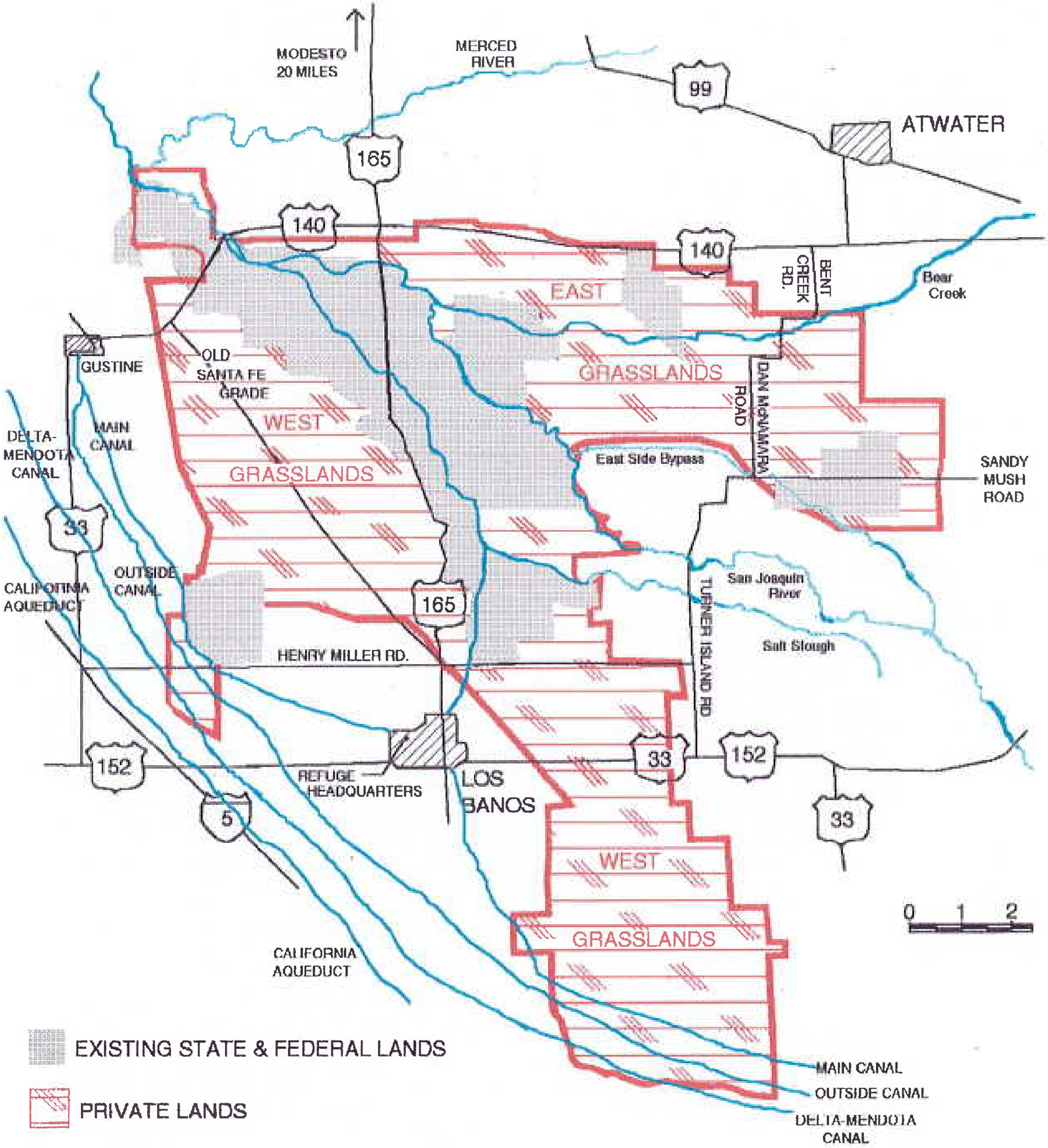

Fig. 5. Location of major water conveyance components affecting the Grasslands Wildlife Management Area.

(Fig. 5). There are a large number of smaller canals that move water within and adjacent to the study area (Figs. 6A and B). In addition, two natural drainages (Mud Slough and Salt Slough) also are used to transport water. These canals have an important influence on the hydrology of the area and, especially for some terrestrial species, represent obstacles for movement.

CLIMATE

The climate of the study area is described as Mediterranean. Distinctly semiarid, the high mountains that enclose the Valley to the east,

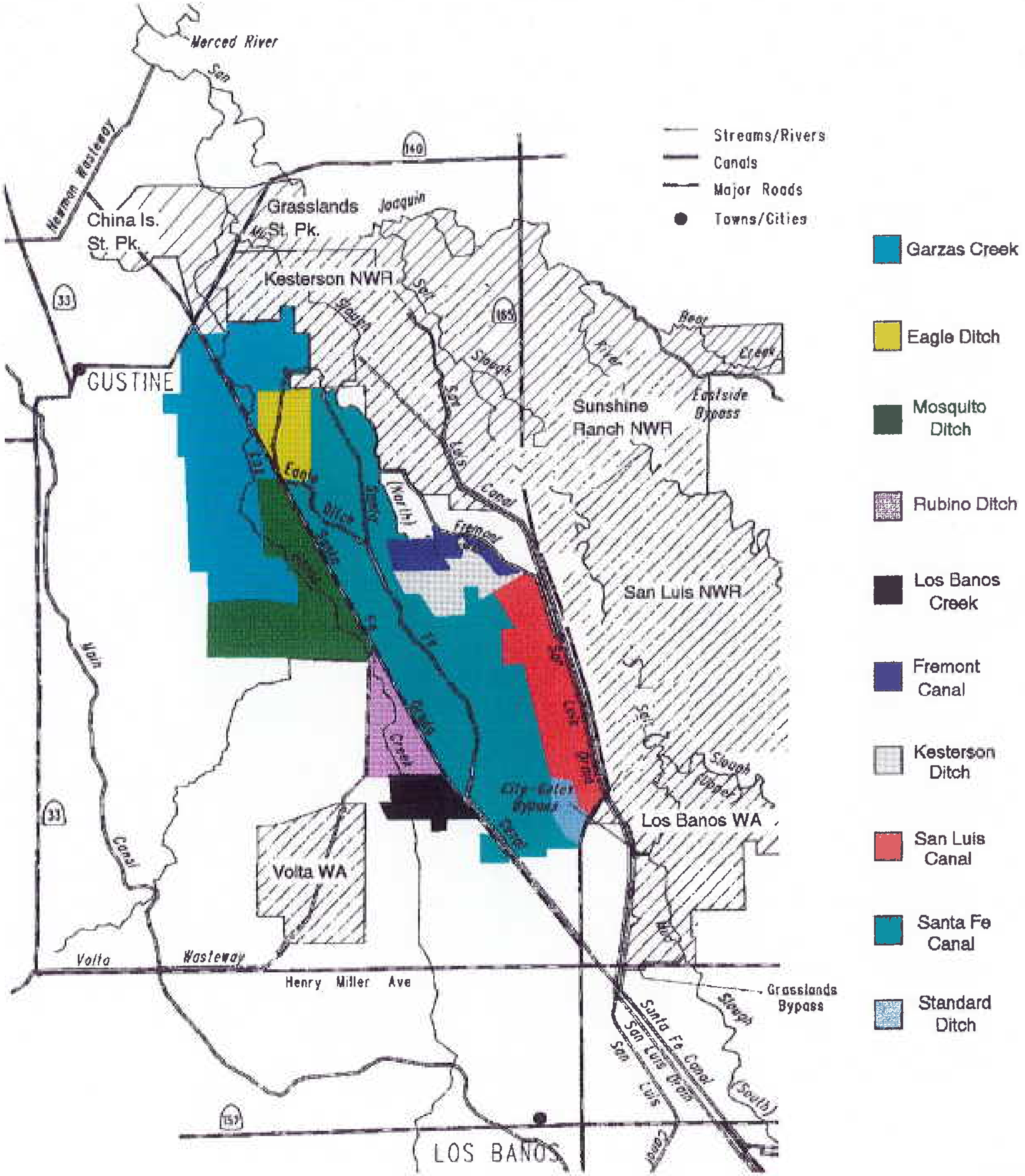

Fig. 6A. Location of water transport canals within the North Grasslands and the areas they supply.

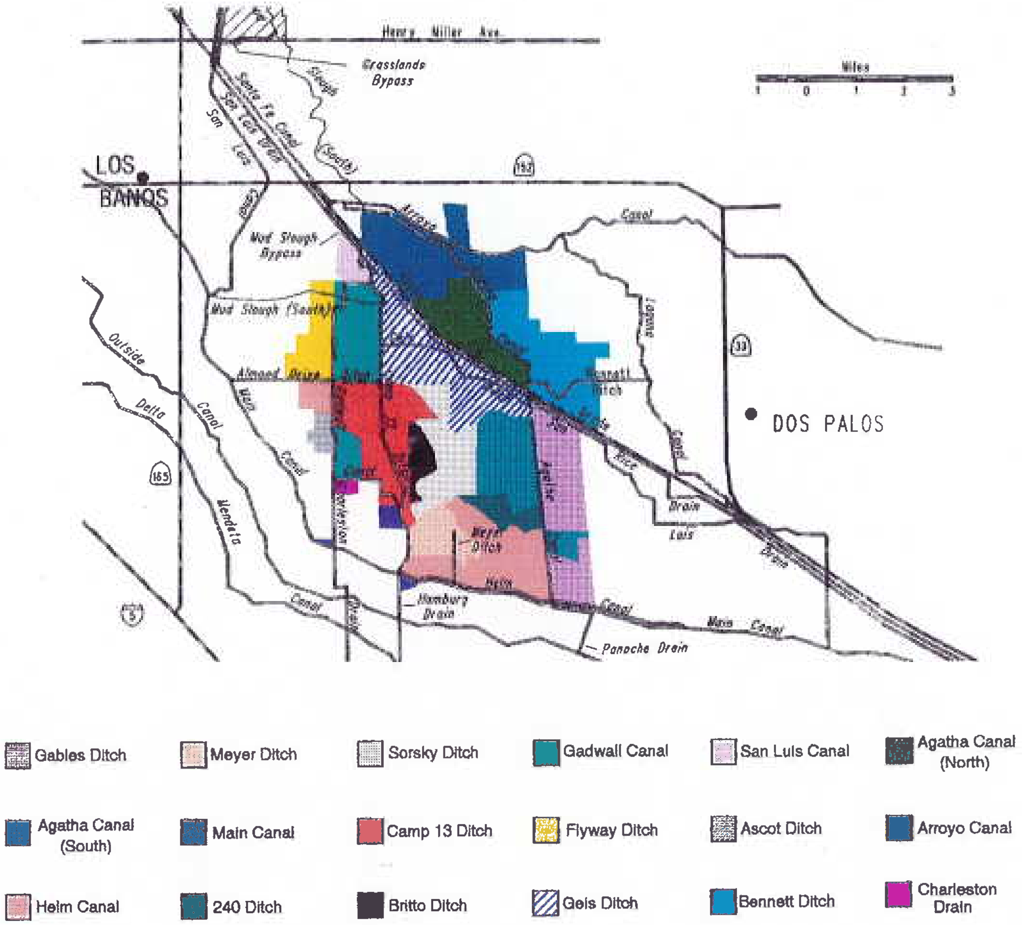

Fig. 6B. Location of water transport canals within the South Grasslands and the areas they supply.

west, and south, buffer the area from oceanic and continental influences (U.S. Department of Agriculture 1941, Association of Bay Governments 1991). Summers are long, dry, and hot with low relative humidity. During some years the summers are extremely hot. For example, midday temperatures can range from 100 to 110° F, with peaks of 117° F recorded (Nazar 1990). The hottest months are July and August, but clear skies and dry air allow rapid radiation. Thus, night temperatures are frequently 40° F cooler than during the day. This daily variation results in an average summer temperature of only 79° F. Prevailing winds are from the northwest; March is the windiest month. The number of frost free days varies within the study area, ranging from 260 to about 320 days (Nazar 1990).

In contrast, winters are cool and periods of gentle rain, ground fog, and clear frosty weather are common. Winter temperatures average 47.5° F from December through February and the relative humidity is high. Damp, foggy days are interspersed with mild, clear, sunny periods.

Average annual rainfall varies from 8 to 11 inches, depending on location within the study area. However, annual rainfall patterns are erratic and yearly variations of 3-24 inches are not uncommon. The rainy period extends from November through April; January is the month of maximum rainfall. Some showers occur in May and in the latter part of September, but little rain falls from June through mid-September.

GEOLOGY OF THE REGION

The current topography and soils in the Central Valley result from processes that began about 150 million years ago when the site was covered by a shallow sea. The North American Plate began to move westward at a faster rate and collided with the diving Pacific Plate. Surface material on the ocean floor was scraped off onto the leading edge of the North American Plate, then folded and pushed upward, possibly as high as 15,000 feet to form what would become the Sierra Nevada mountain range (Whitney 1979). The enormous heat and pressure of these processes changed the sedimentary rock to metamorphic rock present in the Sierra Nevada today. Magma formed along the diving plate and either erupted from onshore volcanoes or cooled within the earth. These processes formed the granitic core of the pre-Sierra Nevada. Activity subsided in the region as the North American Continent pushed the Pacific Plate boundary farther westward. The pre-Sierra Nevada mountains then went through an erosional phase in which they were reduced to a gently rolling topography. The granitic core, as well as portions of the metamorphic formations, was exposed on the surface (Ogden 1988). The current Valley floor was originally the site of deposition for chemical precipitates and clastic materials from the ocean. This depositional phase was followed by a downwarping of the ocean floor. Subsequently, thousands of ft. of sand, gravel, and volcanic materials were deposited in the structural trough that is now the Central Valley floor.

Different geologic processes at different locations in the Valley largely determine present day topographic and soil characteristics. On the west side of the Valley, marine shales were deposited. The Coast Range sediments formed when these deposits were uplifted. The erosion from this uplift created landforms such as the Panoche Pan. Materials from these marine deposits contributed salts, selenium, and other potentially toxic substances to the Valley floor (U.S. Department of the Interior and California Resources Agency 1990).

The dominant landform on the east side of the Valley is the Sierra Nevada mountains. The eroded material from these mountains is much different from the Coast Range because of the supply of metamorphic and granitic materials throughout the Sierra Nevada. On the east side of the San Joaquin River about 85 % of the parent material in the Merced area is alluvial material washed from the Sierra Nevada (Arkley 1990). The alluvium varies considerably in mineral composition and in manner of deposition. Some are fresh, unweathered deposits whereas other soils have been developing for thousands of years. Fine silt and clay are dominant in the lower basin area and some soils are strongly alkaline.

SOILS

Soils in the West Grasslands, including the basin, on the basin rim, and on alluvial fans consist of the following: Edminster-Dospalos-Kesterson nearest the river in the northern part of the Grasslands, Bolfor-Dospalos-Alros along the river to the south, Triangle-Turlock-Britto at the next highest elevation along the river, and finally a bit farther from the river are Pedcot-Marcuse-Volta soils (Nazar 1990; Fig. 7). Soils on alluvial fans of the San Joaquin Valley are Dosamigos-Deldota-Chateau, and Woo-Stanislaus, but only small areas of these soil types occur within the study area. All of these soils are very poorly drained or poorly drained except for the Woo-Stanislaus soils (Table 2).

Soils in the East Grasslands are very different from those in the West Grasslands largely because of differences in parent material (Fig. 8). These soils fall into two distinct groups and include soils of alluvial fans and floodplains (Merced-Temple-Columbia immediately adjacent to the river and Hilmar-Delhi-Dello along Highway 140 in the north). Poorly drained soils of the saline-alkali basin are Rossi-Waukena, Lewis-Landlow-Burchell, and Fresno-Traver (Fig. 8).

HYDROLOGY

Historically the hydrology of wetlands associated with the Grasslands of western Merced County was dynamic, being driven by local and regional precipitation fluxes (Ogden 1988, San Joaquin Valley Drainage Program 1990). Local precipitation occurred as rainfall, which directly influenced wetland hydrology. In contrast, regional precipitation patterns primarily were determined by precipitation events in the surrounding mountains. Melt waters from snow in the Sierra Nevada were particularly important. Regional precipitation patterns influenced the hydrology of the San Joaquin River and its tributaries, which in turn influenced the hydrology in the floodplain by surface flooding or regulation of the water table (Ogden 1988). Thus, both local and regional precipitation patterns interacted to determine the timing, depth, and duration of seasonal flooding that created

Table 2. General characteristics of Grasslands soils.

Soil	Location	Description
WEST GRASSLANDS SOILS		
Edminster-Dospalos-Kesterson	West of and immediately adjacent to San Joaquin River; In the valley basin	Very deep, nearly level, poorly drained soils that have hummocky microrelief
Bolfor-Dospalos-Alros	West of and immmediately adjacent to San Joaquin River in the valley basin	Very deep, nearly level, very poorly drained soils
Triangle-Turlock-Britto	High zones along west side of San Joaquin River in the valley basin or on the valley basin rim	Very deep, nearly level, very poorly drained soils
Pedcat-Marcuse-Volta	Higher zones away from the west side of the San Joaquin River alluvial rim fans and the valley basin	Deep and very deep, nearly level, poorly drained soils
Dosamigos-Deldota-Chateau	On higher zones away from the west side of the San Joaquin River on low alluvial fans	Very deep, nearly level, poorly drained and somewhat poorly drained soils that are partially drained.
Woo-Stanislaus	On higher zones away from the west side of the San Joaquin River in alluvial fans	Very deep, nearly level, well drained soils
EAST GRASSLANDS SOILS		
Merced-Temple-Columbia	Immediately adjacent to east side of San Joaquin River on alluvial fans and floodplains, including natural river levees	Parent material is primarily granitic, water table is near surface; Historically these soils frequently were flooded in early summer for extended periods; Poorly drained
Hilmar-Delhi-Dello	Along Highway 140 east of San Joaquin River on alluvial fans and floodplains	Parent material is granitic alluvial; modified by wind and water level to undulating topography; Permeable to poorly drained
Rossi-Waukena	To East of San Joaquin on higher ground in poorly drained saline-alkali basins	Nearly level soils just above flood level; Parent material is primarily granitic; Poorly drained
Lewis-Landlow-Burchell	East of San Joaquin River on higher ground in poorly drained saline-alkali basin	Parent material is igneous rock nearly level with poor drainage
Fresno-Traver	East of San Joaquin River on higher ground in poorly drained saline-alkali basins	Parent material is granitic; generally level with mounds; Poorly drained

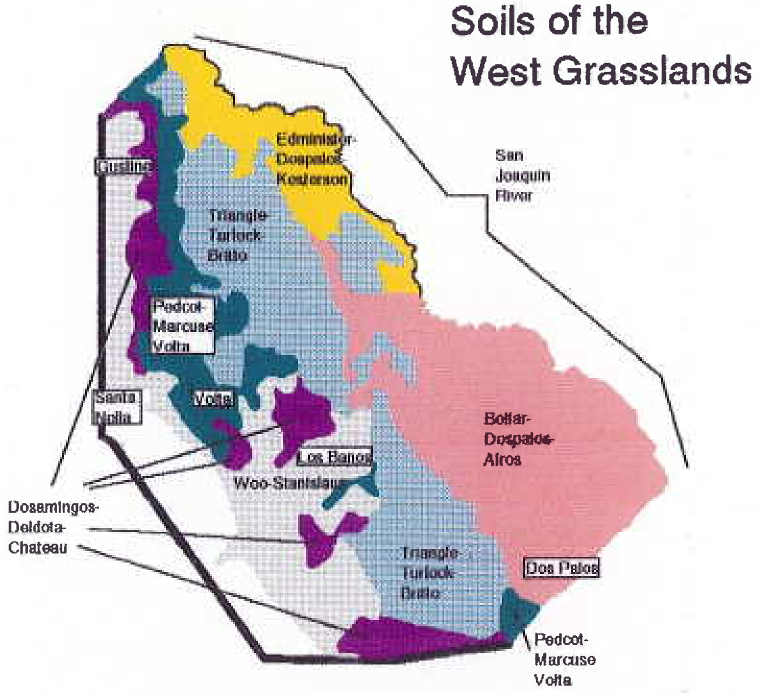

Fig. 7. Soils of the Grasslands Study Area, west of the San Joaquin River.

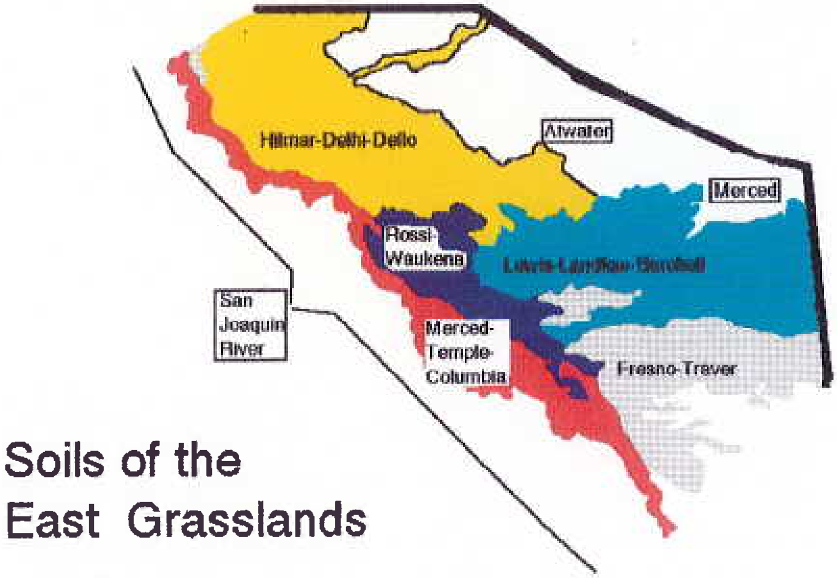

Fig. 8. Soils of the Grasslands Study Area, east of the San Joaquin River.

and nourished wetland habitats and provided a haven for myriad wildlife species. Some of the most extensive flooding in the San Joaquin River system occurred when high flows into the Tulare Basin reached levels that caused water to flow northward from this closed basin (Ogden 1988). The natural ridge along the Kings River is at an elevation of 210 ft. msl. Thus, water flows northward when surface water increases above this elevation. Such high flows were recorded in 1862 when Tulare Lake was at 220 ft. msl and likely covered over 500,000 acres with depths up to 40 ft. The normal pattern of precipitation is erratic but the rainy season consistently occurs during winter (November-April). January is the wettest month. This precipitation provides the water supply for the extensive area of vernal pools and seasonal wetlands within the study area. Historically, the tule marshes within the floodplain were replenished with water during the high flows normally associated with melt water from the mountains in spring and early summer. These variable patterns of precipitation and melt water created a dynamic wetland complex with great seasonal and among-year variation in number of basins flooded, area of wetlands flooded, and amount and types of foods produced (Ogden 1988). The topography and soils, wetland size, wetland depth, and interconnections with sloughs produced a multitude of different wetland habitats that largely have been disrupted by human activities.

Historically, the value of this wetland system to wildlife was enhanced by its direct connection to other important wetland habitats within the Central Valley of California, including the Delta Region of the San Joaquin and Sacramento rivers, the Sacramento Valley to the north, and the Tulare Basin to the south (Fig. 2). Thus, the Grasslands originally were part of a continuum of wetland habitats extending from the northern sections of the Sacramento Valley to the Tulare Basin. This vast complex of habitats provided myriad opportunities for wildlife to meet life history requirements.

Today, the surface hydrology is driven by flows through man-made canals (Figs. 5 and 6). The water supply primarily enters the Grasslands through a complex water distribution infrastructure. During periods of heavy precipitation and high flows in canals, there is some uncontrolled flooding. The remnant wetlands are flooded during the winter but some areas are flooded in fall to attract early migrant waterbirds. This consistent pattern of early fall flooding of some habitats differs from the historic hydrology of natural flooding during the wet winter period.

Little is known about the historic subsurface hydrology. Currently, the subsurface hydrology reflects the impacts related to water projects and water use by agriculture, municipalities, and industry. Undoubtedly, the timing and amount of natural flow in streams of all sizes has influenced discharge and recharge and thus, the current ground water levels. Extraction of groundwater for various uses further impacts the groundwater reserves. The drainage systems associated with agriculture also have an important influence because water must be transported away from the root zone and these drain waters often carry toxic materials that influence the overall quality of groundwater.

HISTORY OF THE GRASSLAND WATER DISTRICT

Much of the current land use in the Grasslands can be traced to the vision of Henry Miller who arrived in the San Joaquin Valley in 1864. Miller's dream was of irrigation (Winton 1962). He saw the potential to capture the annual seasonal flows of the San Joaquin River and use these waters during the dry season to improve agricultural opportunities, including the ability to increase forage production for cattle. Miller and Lux formed a company, Miller and Lux, Incorporated, that was to have a profound influence on wetland and grassland habitats in Merced County. Construction of the first irrigation canal began in 1871 and continued until 1878. Evidence of these early developments designed to irrigate semiarid pastureland is still seen in the Grasslands, and marks the beginning of human efforts to divert water from the western slopes of the Sierra Nevada mountains. Gradually waters from the Kern, Little Kern, Tule, Kaweah, Kings, Fresno, and Chowchilla rivers, as well as run-off from the Coast Range, were captured for agricultural purposes.

Other entrepreneurs, including James Ben-Haggin and Lloyd Tevis also had an important influence on more southern San Joaquin Valley habitats (Winton 1962). These two men established the Kern Land and Cattle Company that encompassed a large land base, including two-thirds control of the water flow in the Kern River. As Miller and Lux expanded their operations to the south, conflicts developed with the Kern Land and Cattle Company. These conflicts led to the establishment of Buena Vista Lake in the late 1880's.

A dam was built across the San Joaquin River near Mendota to permit diversion of water to the Grasslands region in Merced County. Dikes and levees were constructed at strategic points to allow excess irrigation water from Miller and Lux croplands to be used to flood the Grasslands during periods of adequate water availability. When such diversion occurred in summer and fall, this water provided waterfowl with excellent habitats. Excess water for hunting lands also was furnished by Miller and Lux, but the amount depended on water availability in the San Joaquin and Kings rivers. In dry years, no water was furnished. Miller and Lux, Inc., claimed much of the water the Federal Government needed for development of the Central Valley Project. The legal battle for water was resolved when the law of riparian rights became the water law of the state of California.

In 1926, Miller and Lux liquidated 98,234 acres in the area now known as the Grasslands (Leach 1960). Lands adjacent to the San Joaquin River were sold to cattlemen, dairymen, and duck clubs. When the land was sold, Miller and Lux retained title to the water rights appurtenant to those lands, whether riparian, prescriptive, or appropriative. These water rights were essentially the rights to the San Joaquin River flood waters when the flow of the river exceeded the requirements of the croplands served by Miller and Lux. Even though land owners did not have water rights during this time, excess water was made available to land owners to flood wetlands and grazing lands.

By the 1930's the Federal Government took control of the natural resources of the Central Valley and foremost among these resources was water. The U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, along with other state and federal agencies, established control of the water, but use for fish and wildlife was not identified until the Central Valley Project was reauthorized in the 1950's.

In 1939, Miller and Lux sold the water rights to the 98,234 acres serviced by San Joaquin River water. The Federal Government paid $2.45 million for these rights and agreed to protect the water right by continued diversion of the water until the United States was ready to use the water elsewhere in the Central Valley. Provision to store these waters was possible with the construction of Friant Dam on the upper reaches of the San Joaquin River. Friant Dam was completed in 1944, but transfer of this water was not possible until completion of the Delta-Mendota Canal in 1952. Various land owners in the Grasslands realized their water supply was about to be cut off following completion of Friant Dam. This stimulated the organization of several livestock and duck hunter associations. On 2 August 1944, all such associations were merged into the Grassland Water Association and incorporated under state laws as a nonprofit mutual water association. The original area serviced by the Grassland Water Association was 61,370 acres. Of this area, 53,747 acres either were controlled or owned by 139 duck clubs or livestock companies. Although the primary incentive of livestock companies was beef production, most of these lands were flooded for waterfowl at some time during the year. The number of clubs or livestock companies has varied over the years, but the majority of the land within the Grassland Water District continues to be wetlands that are flooded seasonally each year.

Some important changes also have occurred in the management of Grasslands habitats in the past decade. Originally, grazing was an integral part of duck club operations. Grazing for prolonged periods by domestic stock year after year led to some conflicts between beef production and maintaining high quality wetlands for waterfowl and other waterbirds. A dependable water supply always has been a major concern for wetland managers in the Grasslands. As important is the timing of the supply in relation to wildlife need. Recently, legislation (1992 Central Valley Project Improvement Act) has identified the importance of a reliable water supply for maintaining wetland values in the Grasslands. Deliveries of these waters was initiated in 1993. Since then, additional conflicts have developed over the rights to these waters in response to the 1992 legislation.

RATIONALE FOR PRESENTATION OF THIS REPORT

The history of the Grasslands is complex and well-documented, yet confusing to many who have not taken the opportunity to peruse available information. Such confusion results because much of the information is anecdotal or qualitative, rather than quantitative. Thus, there often are discrepancies among published reports concerning the *exact* timing of specific events that have had great significance in understanding the current status of the Grasslands from a natural resources viewpoint. As a result, it is difficult to synthesize this wealth of knowledge in an enlightening manner. This particularly is true when an attempt is made to integrate historical information regarding the main topics of interest, which include: (1) the impact that habitat changes have exerted on wildlife populations, (2) the causes of habitat change, and (3) how future changes in the Grasslands ecosystem may further impact plant and animal communities. Fortunately, however, the *chronology* of events relating to a specific topic are consistent. For example, the chronology of habitat change in the Grasslands are equable among documents, although specific dates of important events may not coincide exactly. Therefore, it remains possible to use past information to gain valuable insight concerning potential impacts that may result if the Grasslands continue to be modified. The difficulty resides in attempting to combine information relative to human demographics, land use changes, habitat alteration, and wildlife populations into a format that can be understood by individuals with various professional backgrounds and, more importantly, can be used to arrive at decisions that will protect the existing integrity of the Grasslands.

To solve this dilemma, we have taken an approach whereby information for a specific topic will be presented separately at varying scopes. Thus, the history of habitat loss/change will be presented for the Pacific Flyway and continent, the state of California or the Central Valley, and finally the San Joaquin Valley and Grasslands Study Area. A similar tact will be used to present information on changes in population levels of species. Organization of the information in this format hopefully will serve to identify the importance of scale when evaluating the value of an area. Benefits often are integrally linked to other areas or ecosystems, thereby forcing considerations of the whole (e.g., Pacific Flyway) rather than component parts (e.g., Grasslands). Additionally, valuable insights can be gained by incorporating information or facts from other sources. Although the Grasslands is unique in many ways, some impacts that currently threaten this area have become a reality in other regions of the country. We would be remiss if such lessons were not taken into account. Subsequently, biological information will be presented to more specifically identify the causal agents involved in ecosystem functions and the importance of temporal and spatial aspects of habitats in determining the reproductive success and survival of wildlife.

LEGISLATION OF IMPORTANCE TO LAND USE IMPACTS IN THE GRASSLANDS

A large number of legislative actions dating back to the early 1800's have had important implications for land use activities in the Grasslands (Table 3). Among the earlier acts of

Table 3. Selected events in wetland and land use legislation with implications for grassland habitats.

1802	U. S. Army Corps of Engineers created for military and civilian construction works, including navigation.
1849	Swamp Lands Act passed to allow settlement of swamp lands with agreement to clear land.
1862	Homestead Act passed to open up western lands to settlement and development.
1877	Desert Lands Act passed to open southwest for settlement.
1886	Green Act permits levee construction along natural drains for reclamation of federal land in the floodplain
1902	Reclamation Act passed giving authority to the U.S. Bureau of Reclamation to develop water supplies for land reclamation and irrigation.
1903	President Roosevelt designates the first national wildlife refuge at Pelican Island, Florida, as a bird sanctuary.
1936	Flood Control Act passed following an earlier version passed in 1927 giving the Army Corps authority for flood control efforts on major streams and appropriating funds for public flood control works.
1948	Water Pollution Act establishes study program and grants for waste treatment.
1950	Dingell-Johnson Act authorizes federal aid for restoration of freshwater fish.
1950	President's Water Resources Policy Commission.
1954	Watershed Protection and Flood Prevention Act establishes technical and financial aid to local organizations for watershed work plans.
1954	Public Law 674 authorizes the use of Central Valley Project water for fish and wildlife purposes.
1964	Wilderness Act authorizes reservation of federal lands as wilderness areas.
1968	Wild and Scenic Rivers authorizes reservation of river reaches for preservation.
1969	National Environmental Policy Act requires federal agencies to prepare environmental impact statements on projects and develop mitigation plans with public participation.
1972	Clean Water Act authorizes the Environmental Protection Agency to create and enforce water quality standards and guidelines for permitting draining and filling of wetlands (administered by the Army Corps).
1973	Endangered Species Act authorizes the Fish and Wildlife Service to list threatened and endangered species, to designate critical habitat areas, and to develop recovery plans.
1977	Executive Order 11990 mandates that all federal agencies work to minimize impacts on wetlands.
1978	Fish and Wildlife Improvement Act authorizes water to be made available for Grassland Water District on a nonreimbursable basis.
1985	Food Security Act establishes the Wetlands Reserve Program administered by the U.S. Department of Agriculture's Soil Conservation Service to provide funds to farmers who keep wetlands out of production.
1986	Emergency Wetlands Resources Act.
1988	The National Wetlands Policy Forum sets a goal of "no net loss" for wetlands and Presidential candidate George Bush endorses the goal.
1990	Water Resources Development Act passed.
1990	Truckee-Carson Water Rights Settlement Act passed authorizing water-rights acquisitions from a Bureau of Reclamation project for purposes of restoring the Stillwater National Wildlife Refuge wetlands.
1990	Coastal Wetlands Protection, Planning, and Restoration Act authorizes $35 million for wetlands restoration in coastal Louisiana.
1991	National debate erupts over Vice-President Quayle's attempt to change the definition of wetlands used in the 1989 federal wetlands delineation manual thereby potentially excluding from federal protection 50% of the nation's remaining wetlands.
1992	Central Valley Project Improvement Act sets aside 800,000 acre-ft. of water for fish and wildlife protection and an additional 430,000 acre-ft. of water specifically for wetland use. Also establishes a Restoration Fund with an initial $35 million.

importance were the establishment of the U.S. Army Corps of Engineers, Desert Lands Act, and Reclamation Act which set the stage for changes in natural ecosystems to an agricultural environment. These acts and others also set in motion major changes that led to the destruction and degradation of wetlands, loss of natural habitats and open space, loss of animal populations and plant communities, and changes in hydrology of the San Joaquin Valley.

As natural systems have been lost and degraded there has been a gradual shift in attitudes and legislation to counter earlier programs that exploited systems without consideration for environmental issues (Table 4). Public concern for ecosystems dates back to 1891 with the Forest Resources Act which was stimulated by exploitation of timberlands. Water resources were not identified in Federal legislation until 1968 when the Wild and Scenic Rivers Act was passed. Thereafter coastal areas were protected under the Marine Protection and Sanctuaries Act of 1972. Most recently wetlands have been identified as systems holding high public value and legislation such as the Emergency Wetlands Resources Act of 1986 and Coastal Wetlands Protection, Planning, and Restoration Act of 1990 (which protect Louisiana coastal habitats) have been important. Among the most important acts affecting the San Joaquin Valley, including the Grasslands Study Area, is the 1992 Central Valley Project Improvement Act which set aside 430,000 acre-ft. of water for Central Valley wetlands protection and established a Restoration Fund with an initial $35 million. Some ecosystem protection also is apparent in some legislation, including the swamp buster provision of the 1985 Food Security Act (Table 3).

Table 4. Evolution of concern for ecosystems in the United States.

Ecosystem	Act
Timberlands	Forest Resources 1891
Grazing Lands	Taylor Grazing 1934
Wildlife Sanctuaries	Fish and Game Sanctuary 1934
Wilderness	Wilderness 1964
Rivers	Wild and Scenic Rivers 1964
Coastal Areas	Marine Protection and Sanctuaries 1972
Forest Lands	National Forest Management 1976
Rangelands	Federal Land Management and Policy 1976
Wetlands	Emergency Wetlands Resources 1986
	Coastal Wetlands Protection, Planning, and Restoration 1990
All Ecosystems	National Biological Diversity Conservation and Environmental Research 1990

Although the purpose of legislation is to establish standards and guidelines for the protection, regulation, and management of natural resources, the types of legislation approved also reflects public attitudes and perceptions regarding wildlife landscapes. In colonial times, some states established game laws in the 1700's to set seasons that provided some annual protection for game species whether they were fish, birds, or mammals (Table 5). The Lacey Act of 1900 was the first federal legislation to protect wild animals. The most all-inclusive legislation that protects ecosystems as well as individual species is the National Biological Diversity Conservation and Environmental Research Act of 1990. The passage of such legislation indicates laypersons are becoming increasingly aware that destruction and modification of landscapes may be potentially deleterious to all living organisms, including humans.

Table 5. Evolution of concern for species groups in the United States.

Species group	Act
Large (Huntable) Mammals	Early State Game Protection
Birds, Fish	Laws (1700's)
Wild Animals	Lacey 1900
Wild Birds	Migratory Bird Treaty 1918
Fish	Fish Restoration and Management 1950
Plants, Animals	Endangered Species 1973
All Species	National Biological Diversity Conservation and Environmental Research 1990

OVERVIEW OF HABITAT LOSS AND CHANGE

GRASSLANDS PLANT COMMUNITIES

The pristine area of western Merced County was part of a grassland and wetland ecosystem sometimes described as California Prairie and Tule Marsh habitats (Fig. 9; Burcham 1957, Munz and Keck 1959). The grassy portion of the region was dominated by perennial grasses that were excellent pasture. Unfortunately, changes in vegetative composition and distribution in the Valley following arrival of the Spanish in California never were documented (Heady 1988). Nevertheless certain conditions likely occurred and are generally agreed upon by experts. *Stipa pulchra*, a perennial bunchgrass, probably dominated the Valley grassland, particularly at higher elevations that were drier. Interspersed among the bunch grasses were annuals, especially at lower elevations immediately adjacent to wetland habitats in Merced County. The grassland type characteristic of the region occurred on a wide variety of soils with some authors identifying the distribution on as many as 195 soil series (Barry 1972). Broadleafed plants, especially perennials with bulbs, were interspersed among the grasses. Herbaceous annuals were dominated by members of the Caryophyllaceae, Compositae, Cruciferae, Labiatea, Leguminosae, and Umbelliferae (Stebbins 1965).

The seeds of alien species were present in the adobe of the earliest Spanish missions, providing evidence that the first changes in grassland plant composition in California preceded extensive settlement by Europeans (Hendry 1931). However, the timing and extent of these early changes in plant communities is poorly documented. Undoubtedly, some changes in the grassland community probably preceded the period of intensive grazing that began after the mid--1800's. Records indicate that introduced species such as wild oats (*Avena fatua*) and *Brassica nigra* were abundant before livestock overgrazed the area. Certainly, additional changes in the pristine grassland occurred as more

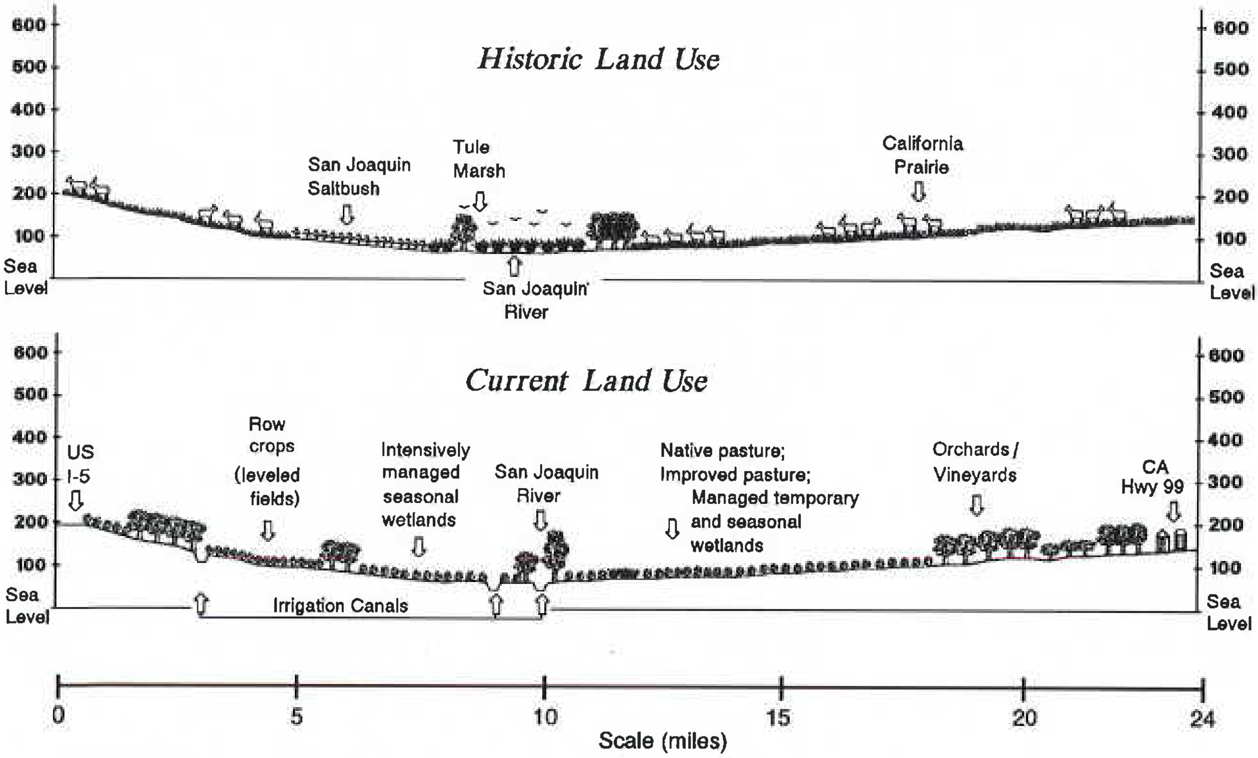

Fig. 9. Comparison of the distribution and type of vegetation communities in the study area before and after agricultural development.

and more settlers arrived in the Valley (Burcham 1957). There is disagreement over the relative importance of how different factors altered the pristine California Prairie (Heady 1988) but at least four factors commonly are associated with changes in the prairie community: (1) invasion by alien plant species, (2) changes in the kinds of animals and their grazing patterns, (3) cultivation, and (4) fire, as well as the complicated interactions among these factors (Heady 1988). A major change in the Grasslands was associated with the introduction of domestic livestock. Likewise, the arrival of many alien seeds, bulbs, and cuttings with miners in the 1850's provided another source of plant material that compromised native plant communities. Extensive areas also were converted to dry-land farming with grains and forage as the principal crops (Heady 1988). Those areas that were farmed and have reverted to grassland continue to be dominated by annuals rather than perennials. The role of fire in pristine grasslands is not documented, but fire likely was a part of the evolutionary history of the California Prairie (Heady 1972). Thus, as is the case with any changes in pristine environments, many different factors interacted in combination to result in the demise of the original grassland community in western Merced County.

Historic and current information suggests that the general macroscale distribution of native plant communities has not been influenced by land use changes. Thus, the current distribution of wooded riparian forests, grasslands, marshlands, and shrublands is similar to the distribution during the past several hundred years (Heady 1988). However, the species composition of these communities has changed. The pristine perennial grassland community was dominated by *Stipa pulchra* in association with other perennials including *Aristida hamulosa, Elymus glaucus, E. triticoides, Festuca idahoensis, Koeleria cristate, Melica californica, M. imperfecta,* and *Poa scabrella.* Some annuals were present and included *Aristida oligantha, Descampsia danthonioides, Festuca megalura, F. pacifica,* and *Orcutti* spp. The replacement annual grasslands have a composition that is highly variable (McNaughton 1968), but common species include *Bromis mollis, B. rigidus, B. rubens, Erodium botrys, E. cicutarium,* and *Avena fatua.*

WETLAND COMMUNITIES

Status of Continental Wetlands

To understand the importance of Grassland habitats, understanding the status of wetlands on a larger scale is necessary. Nationwide, wetlands have received considerable attention since 1985 because of the North American Waterfowl Management Plan and the 1985 Food Security Act. Although exact estimates of the original acreage of wetlands in the 48 coterminous states were never made, experts suggest there were about 220 million acres of wetlands in colonial America (Dahl 1990). Wetland loss has been excessive during the past 200 years and today less than 100 million acres remain (Dahl and Johnson 1991). Historically, wetland losses primarily have been associated with conversion of native habitats for agricultural purposes. For example, from the mid-1950's to the mid-1970's, 87% of wetland loss was related to agriculture (Frayer et al. 1983). Although this rate has declined to 54% from the mid-1970's to the mid-1980's, agriculture continues to have an important impact on wetland losses. In contrast, urban land uses accounted for about 5% of wetland losses during the 30-year period beginning in the mid-1950's (Tiner 1984).

The total loss of wetlands has been devastating to wildlife populations and has disrupted many wetland values and functions that subsequently compromise economic benefits to society (Odum 1979). Factors such as fragmentation, changes in hydrology, disruption of functions, excessive losses of ephemeral and temporary wetlands, increased sedimentation, and excessive nutrient or toxic chemical loads all have major impacts on remaining wetland habitats or influence the type and duration of use by wildlife (Table 6). Fragmentation of wetland corridors and wetland systems is a national problem and is well-represented by the current discontinuous distribution of remnant wetlands in California.

Status of California Wetlands

California had an estimated 5 million acres of wetlands in the mid-1800's (California Department of Fish and Game 1983). The majority of these wetlands were in the Central Valley, but other sites such as the Klamath

Table 6. Examples of ecological implications resulting from wetland loss, degradation, and modified hydrology.

Perturbation	Ecological implication	
	Habitat	Wildlife
Wetland drainage	Loss of habitat	Populations reduced
Wetland complexes disrupted by highways, farming organization, etc.	Habitat quality decreases	Fewer species present; Resources for some life cycle events eliminated or reduced
Upstream reservoirs	Changed hydrology results in changes of plant species composition and productivity	Some species eliminated; Resources available for lesser number of animals
Nonpoint pollution	Sediments and pollutants accumulate in wetlands; Undesirable plant monocultures become more common	Certain species and/or age classes are impacted; Food production declines

Basin were of great importance to the waterfowl resource (Heitmeyer et al. 1989). Unfortunately more than 95% of these historic wetlands have been destroyed or modified (Frayer et al. 1989, Gilmer et al. 1982). Remnant wetland habitats primarily are within the Central Valley where about 287,000 acres remain. Few if any of these remnant wetlands remain in pristine condition because man has impacted each wetland directly or indirectly. Changes in volume and flow patterns of water, groundwater levels and sedimentation rates are just a few examples of the widespread modifications to wetlands resulting from man's activity. Privately owned and operated duck clubs are particularly important because they account for two-thirds, or over 170,000 acres, of these wetland habitats. The remaining one-third is divided between state and federal ownership and managed as wildlife areas. Nearly all of these remnant habitats are managed intensively for the benefit of waterbirds, especially waterfowl (Heitmeyer et al. 1989). Significant portions of the Grasslands are now in state or federal ownership or easements (Fig. 3). Efforts to increase public ownership and easements will continue.

Status of San Joaquin Valley Wetlands

The importance of the Grassland Study Area is imminently clear because of the size, diversity of wetland types, and juxtaposition of remnant habitats (Table 7). Nevertheless, the Grasslands are a tiny remnant of wetlands that historically served as an important wetland corridor between the Delta and the Tulare Basin. Nevertheless, remnant wetlands in the entire San Joaquin Valley account for about half of the remnant wetlands in the Central Valley. Loss of wetlands has been so severe in the Sacramento and San Joaquin valleys that the Grasslands account for about one-third of all remaining wetland habitats in the Central Valley; even though the original area of the adjacent wetland habitat in the Delta and the Tulare Lake Basin were of greater size and provided habitat for much larger numbers of wildlife. In contrast to the wetland area remaining in the Grasslands, the Delta, which originally encompassed about 450,000 wetland acres, has only about 18,000 acres of wetlands remaining. Unfortunately these habitats occur primarily as sump areas that were created by levee blowouts during floods or as narrow strips of robust emergent vegetation adjacent to rivers and sloughs

Table 7. Status of existing wetlands in the California Central Valley, the Suisun Marsh, and the Delta, 1989.

Basin	Protected[1] Federal fee title	State fee title	Federal easement	Private	Total	Unprotected[2] (%)	Total
Sacramento	23,040	8,600	7,935	0	39,575	27,950 (41)	67,525
Delta	0	3,500	0	1,550[3]	5,050	4,300 (45)	9,350
Suisun	1,100	10,900	0	46,000	58,000[4]	0 (0)	58,000
San Joaquin	16,580	8,590	28,130	0	53,300	67,000 (55)	120,300
Tulare	2,300	12,105	0	2,325[5]	16,730	19,650 (54)	36,380
Totals	43,020	43,695	36,065	49,875	172,655	118,900 (41)	291,555

[1] Protected wetlands are those held in fee title by federal, state, or county agency or privately owned wetlands with perpetual conservation easement.

[2] Any privately owned wetland not covered by a perpetual easement.

[3] Consumnes Preserve owned by The Nature Conservancy modified from Central Valley Habitat Joint Venture Implementation Plant 1990.

[4] The entire 58,000 acre Suisun Marsh was protected by the Suisun Marsh Protection Act of 1977.

[5] Includes 1,425 acres owned by Kern County.

(Fredrickson et al. 1989, Fredrickson and Laubhan 1991). This nearly complete destruction and high fragmentation of habitats has reduced wetland values of Delta habitats to minuscule amounts compared to historic values. Similar losses have occurred in the Tulare Lake Basin. Historically, Tulare Lake sometimes reached a total area of over 500,000 acres but today about 36,000 wetland acres are present in the Basin (San Joaquin Valley Drainage Program 1990).

Status of Grasslands Wetlands

Wetland habitats within the study area largely fall within three general groups: vernal pools dominated by annual vegetation and temporary flooding regimes, seasonal marshes with annual and perennial vegetation, and tule marshes dominated by robust perennial vegetation with seasonal or semipermanent flooding. The distribution of these three types is distinct with the abundance of vernal pools concentrated at higher elevations and greater distances from the primary floodplain.

Vernal Pools----Vernal pools are small basins that occur at higher elevations throughout the study area. The East Grasslands has an abundance of this wetland type. The undulating topography and porous soils of this region, in conjunction with the depth to ground water, determine the number of basins and the total area that is flooded. The hydrology of the vernal pools is driven by winter rainfall within the study area, whereas the hydrology of the tule marshes is strongly influenced by precipitation events outside the boundaries of the study area.

Many vernal pools were not subject to consistent riverine flooding, thus land use impacts that affect their hydrology are different than for tule marshes. The shallow nature and infrequent flooding of vernal pools make them especially vulnerable to activities such as land leveling, filling by sedimentation, and activities that influence groundwater level. Activities that lower the groundwater table either eliminate vernal flooding or change the length of the flooding regime.

Seasonal Marshes----Seasonal marshes are the most abundant type of wetlands in the study area. They are dominated by alkali bulrush, saltgrass, alkali heath, baltic rush and brassbuttons. Flooding of seasonal marshes is strongly influenced by flows from lateral streams including Los Banos Creek, Creek, Silver Creek, Mud Slough, Garzes Creek, San Luis Creek, and Orestimba Creek. Seasonal wetlands are normally dry by May. Many seasonal basins were not flooded naturally until winter rains began. Where seasonal basins are under intensive management, flooding of some basins may occur as early as September.

Tule Marshes---Tule marsh habitats were distributed within the floodplain of stream systems; the San Joaquin River being the most important and extensive floodplain habitat in the study area. Overflow from the river annually replenished tule marsh habitats. The area of inundation, and thus the number of basins and area flooded within the floodplain, was related to rainfall and snow melt in areas upstream from the Grasslands (Ogden 1988). In extreme cases the flooding also was influenced by overflow into the San Joaquin drainage from the Tulare Basin. Soils with high clay content are common within the San Joaquin River floodplain and have an important influence on the hydroperiod of seasonal and semipermanent marshes. Flooding in areas of soils having a high clay content are less influenced by ground water.

The historic hydrology of the river floodplain was changed forever with the conversion to agriculture, construction of dams, and development of the irrigation infrastructure. The capture of water upstream and its distribution via irrigation and agricultural drainage systems removed the natural flooding regimes that annually overflowed onto the floodplain and replenished the tule marsh system. Today these marsh systems would be even more limited in size and function without state, federal, and private efforts. Although the original values and functions cannot be completely duplicated, intensive management provides opportunities to assure that viable wetland habitats continue to be an important feature of the San Joaquin Valley. A new infrastructure of water supply from wells and irrigation canals, along with water control developments such as levees and water control structures, are used to maintain and restore wetlands in the area. Federal, state, and private entities have different priorities that provide different water regimes. Federal lands largely were purchased to meet the requirements of the Migratory Bird Treaty. State lands also are important in meeting state and federal mandates but hunting is an important component. Private wetlands are primarily duck clubs and hunting is critical to the maintenance of habitat. Each of these entities flood wetlands via intensive water movements and manipulations. Thus, some of the values and functions of the original system have been maintained as is evidenced by the extensive use by a large number of waterbirds. Emulating the natural hydrology, including within-season and among-season fluctuations, has the highest potential to optimize benefits for a diversity of wetland wildlife. However, incorrect application of water regimes and application of intensive management at the wrong time can compromise the health of the ecosystem.

Grasslands wetland habitats are unique and of critical importance in California and North America because these remnant habitats are clustered and include a mix of ephemeral, seasonal, and semipermanent basins. The unique size and distribution of these wetlands within the Grasslands Study Area have benefits that extend far beyond the boundaries of Merced County and the State of California. Migratory populations that move across the North American continent, as well as those that move into Central and South America, rely upon the resources provided in the Grasslands.

HISTORY OF WATERBIRD POPULATION CHANGES IN THE PACIFIC FLYWAY

PACIFIC FLYWAY

The Pacific Flyway is one of four flyways where cooperating federal, state, and provincial entities provide management direction to benefit waterfowl populations. The political boundary of the Pacific Flyway includes lands west of the continental divide extending from Alaska, southward through the western provinces of Canada and the Rocky mountain states, including western portions of Mexico. Because waterfowl do not follow political boundaries, populations using the Pacific Flyway also breed in areas such as the prairie provinces of Canada or locations in northern Asia that lie outside the area described as the Pacific Flyway. Historically, the Pacific Flyway held the highest concentrations of wintering waterfowl, but this Flyway had the smallest area of native wetland habitats even before man severely disrupted wetland ecosystems (Bellrose 1976). California and Mexico are of critical importance for wintering waterfowl because they provide habitats required by a majority of waterfowl species using this Flyway. Thus, any changes in the area or quality of habitat in California have the potential to influence the outcome of annual cycle events and subsequently the fecundity and mortality of waterfowl populations extending from the prairies of North America to northern Asia (Raveling and Heitmeyer 1989).

IMPORTANCE OF THE CENTRAL VALLEY

Historically, the Central Valley held some of the largest and most impressive concentrations of migratory waterfowl in the Pacific Flyway and North America as well. Early accounts are anecdotal but the descriptions of massive numbers of birds in the Sacramento Valley, the Delta, and the Tulare Basin were consistent even though numbers are vague and the species described might be unclear (Day 1949). As Central Valley wetland habitats were destroyed (Day 1949), there was concern for migratory bird populations extending back to the early 1900's.

California was more fortunate in maintaining large populations of wintering waterfowl into the 1970's than other areas of the United States. Undoubtedly, this was related to the distribution of breeding waterfowl that wintered in California. These populations largely are associated with the more western prairie provinces of Canada and the U.S. that were less affected by land use changes influencing the area and quality of breeding habitats before 1970. Thus, considerable assemblages of waterfowl continued to congregate in the Central Valley before the 1980's.

Wintering waterfowl populations in the Central Valley have ranged from 8 to 12 million ducks and geese. Although total numbers have declined, the area continues to support 60 percent of the Flyway wintering waterfowl population. Thus, this area is extremely important as the southern terminus or intermediate stopover for Pacific Flyway waterfowl that are produced in the prairies and parklands of western Canada and the river valleys and deltas of Alaska (Kozlik 1975). For example, of nine basins that consistently winter waterfowl in the Central Valley, the San Joaquin Valley holds 25% of the wintering waterfowl population (Heitmeyer 1989) and has 156,680 acres of the 291,555 acres of habitats available in the Central Valley (Table 7).

The significance of the Central Valley wintering habitats is apparent from the peak population objectives for the North American Waterfowl Management Plan (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986, Central Valley Joint Venture 1990). The goal for ducks in the Central Valley Habitat Joint Venture is a peak population of 4.7 million birds (Table 8). Further, the Central Valley provides habitat for 100% of the Aleutian Canada goose (*Branta canadensis leucopareia*) and the Tule white-fronted goose (Table 8), 80% of the cackling Canada goose (*B. canadensis minima*) and Ross' goose (*Anser rossii*), and 66.7% of the Pacific white-fronted goose (*Anser albifrons*) and Tundra swan (*Cygnus columbianus*) populations.

Table 8. Peak population objectives for wintering waterfowl established by the Central Valley Habitat Joint Venture relative to those of the North American Waterfowl Management Plan.

	Central Valley	North America	Central Valley as % of total
Total ducks[1]	4,700,000		
Mallard	531,000		
Northern pintail	2,800,000		
Total geese and swans[2]	875,000	5,701,000	15.3
Cackling Canada goose	200,000	250,000	80.0
Aleutian Canada goose	5,000	5,000	100.0
Lesser snow goose	320,000	1,760,000	18.2
Ross' goose	100,000	125,000	80.2
Tule white-fronted goose	5,000	5,000	100.0
Pacific white-fronted goose	200,000	300,000	66.7
Tundra swan	40,000	60,000	66.7

[1] No winter goals for ducks have been established in the North American Waterfowl Management Plan.
[2] Reflects recent winter distribution patterns and adjusted for 25% annual recruitment.

GENERAL DECLINE OF WILDLIFE IN FLYWAY

Early reports of wildlife populations in the Valley are poorly documented, but suggest that wild species generally were abundant. Survival and reproduction apparently were high for many species based on the descriptions in these early but poorly documented reports. Clearly, the abundance and distribution of wildlife have changed dramatically since the first settlers reached the Valley over 200 years ago.

Change in size and diversity of wildlife populations is directly related to the changing landscape and the type and intensity of human activities in the study area. The pattern of land use over the past 200 years has moved through a series of stages that influenced plant communities and wildlife populations. Land use changes were characterized by pulses of activities that impacted large areas or changed the intensity or type of use. The first major modification in native habitats resulted from intensive grazing by domestic stock. This land use changed the plant composition and structural features of the habitat. Nevertheless, areas that were grazed by domestic stock continued to provide open space as well as the required food and habitat for some species. More dramatic changes in the study area occurred where native habitats were converted to agricultural uses other than grazing. Conversion to row crops and orchards was far more devastating to the integrity of native habitats than grazing. Despite intensive agricultural practices that require annual cultivation, open space for some wildlife is provided in these agricultural environments. However, overall species richness and the density of many species are reduced greatly. The most severe loss of open space in the study area occurs when agricultural or remnant habitats are replaced by more intense uses where hard surfaces, and buildings reduce open space and high levels of human activity create continuous disturbance to natural systems (Murphy 1988).

The biological diversity of the Grasslands likely was little impacted by the first human activity. Asian immigrants largely were hunters and lacked the technology to dramatically influence natural systems with domestic stock or the development of population centers. However, there is some evidence that their hunting activities, and some environmentally related changes, impacted large herbivore populations (Burney 1993). Early settlers had little impact on open space because populations were small and the culture was oriented around hunting. Likewise, the natural hydrology was not impacted because these early cultures lacked the technology to dam rivers or dig channels and did not practice agriculture or graze domestic stock.

Large mammals which require extensive areas of undisturbed habitat to survive and reproduce have been influenced the most by human impacts on natural habitats (Murphy 1988). Grizzly bears (*Ursus arctos*), free-ranging tule elk (*Cervus elaphus nannodes*) and pronghorn antelope (*Antilocarpa americana*) have been extirpated from the San Joaquin Valley for

Table 9. Mean number of selected waterfowl counted in the Central Valley, Suisun Marsh, and Delta, winter 1978–87.

Species	Sacramento Valley	San Joaquin Valley (%)	Suisun Marsh	Delta
Mallard	314,712	30,438 (8)	15,221	4,667
Gadwall	11,698	23,137 (65)	602	25
American wigeon	403,038	10,913 (3)	9,318	847
Green-winged teal	16,336	90,479 (79)	6,913	961
Cinnamon teal	137	2,541 (94)	42	2
Northern shoveler	122,557	209,142 (58)	28,456	3,022
Northern pintail	1,429,698	238,191 (13)	60,347	141,190
Canvasback	11,735	2,036 (8)	3,446	7,056
Ring-necked duck	3,896	917 (14)	404	85
Ruddy duck	16,361	15,985 (43)	2,558	2,184
White-fronted geese	20,092	4,884 (9)	6,491	20,768
Snow/Ross geese	304,310	35,397 (10)	82	19,278
Cackling Canada goose	10,792	4,128 (23)	2,520	830
Aleutian Canada goose	360	1,035 (67)	72	59
Tundra swan	21,283	357 (1)	4	19,999

a considerable period. Clearly the reduced size and increasing fragmentation of native habitats in the study area have been foremost in the demise of these native animal populations. Today the smaller habitat remnants are only suitable for providing the necessary space for smaller species. These changes in habitat area and quality have been so extensive that smaller carnivores such as the San Joaquin kit fox (*Vulpes macrotis mitica*) are now being severely impacted by land use changes and have reached a status of endangered.

Today, California remains one of the principal wintering and migratory stopover points for waterfowl using the Pacific Flyway in spite of great habitat loss. Historically, as many as 81% of waterfowl band recoveries in California were from waterfowl banded in Alaska (1948). The Central Valley is of foremost importance for migratory and wintering waterfowl, shorebirds, and other waterbirds. Although the Central Valley composes only 11% of the land area of the state, the area consistently supports 60% of the total wintering waterfowl population of the Pacific Flyway.

IMPORTANCE OF GRASSLANDS HABITATS FOR BIRDS

Although the most comprehensive information on bird numbers, distribution, and habitat use within the Grasslands relates to waterfowl and shorebirds, many other migratory birds also are dependent on habitats within the study area. Counts of waterfowl numbers date back to at least the 1940's but information on shorebird numbers, distribution, and chronology of use primarily is from the past 10 years, with the most complete census work between 1988 and 1993. Counts of birds including waterbirds and nonwaterbirds are inconsistent. Numbers and chronology of movements by neotropical migrants is lacking. In contrast, numbers and distribution of raptors are undoubtedly more complete than for groups other than waterfowl and shorebirds.

Waterfowl

Fifteen species of waterfowl commonly use San Joaquin Valley habitats in winter. Concentrations of five species of waterfowl account for more than 50% of the wintering waterfowl in California during the period 1978-87 (Table 9). Species using Grasslands habitats extensively in winter include gadwall (65%), green-winged teal (79%), cinnamon teal (*Anas cyanoptera* 94%), northern shoveler (58%), and Aleutian Canada goose (67%). More recently (1985-1989) wintering waterfowl in the San Joaquin Valley have declined (Table 10). For example, gadwall (*Anas strepera*) accounted for 65% of the species in the Central Valley (1978-87) but only 34% in 1985-89. Northern pintail showed a similar decline from 13% to 6.7%.

Table 10. Midwinter (January indices of waterfowl in the San Joaquin Valley, the Central Valley, and the Pacific Flyway, 1985–89 average [percentages]). From Bartonek, J. C., USFWS Office Migratory Bird Management 9/13/89.

	San Joaquin Valley	Central Valley	Pacific Flyway
Mallard	23,090 (4.9)[1]	295,559 (76.3)[1]	1,402,119 (21.1)[2]
Gadwall	15,722 (34.1)	40,781 (88.5)	55,687 (73.2)
American wigeon	6,480 (1.9)	264,390 (75.8)	489,026 (54.1)
Green-winged teal	50,868 (21.5)	215,076 (90.9)	279,668 (76.9)
Blue-winged teal	1,126 (34.4)	2,332 (71.1)	3,316 (70.3)
Cinnamon teal			
Northern shoveler	51,557 (20.9)	163,547 (66.2)	256,144 (63.8)
Northern pintail	55,800 (6.7)	715,377 (86.0)	945,085 (75.7)
SUBTOTAL DABBLERS	200,578 (9.5)	1,697,153 (80.0)	3,431,701 (49.5)
Redhead	176 (24.0)	189 (25.8)	20,285 (0.9)
Canvasback	2,184 (7.3)	3,297 (11.0)	42,411 (7.8)
Scaup	274 (0.3)	285 (0.3)	146,945 (0.2)
Ring-necked duck	1,810 (13.5)	12,273 (91.7)	21,793 (56.3)
Ruddy duck	13,751 (18.2)	25,186 (33.4)	86,991 (29.0)
SUBTOTAL DIVERS	18,674 (6.6)	42,121 (14.9)	503,205 (8.4)
TOTAL DUCKS	221,273 (9.2)	1,743,626 (72.7)	3,996,245 (43.7)
Snow and Ross geese	27,604 (7.5)	308,584 (83.7)	403,756 (76.4)
White-fronted geese	2,814 (3.9)	45,844 (63.9)	71,861 (63.8)
Canada geese	9,822 (15.3)	26,551 (41.4)	323,878 (8.2)
TOTAL GEESE	40,240 (8.0)	380,979 (75.4)	816,624 (46.7)
Tundra swan	486 (1.0)	34,869 (71.4)	61,121 (57.0)
American coot	18,840 (18.0)	54,359 (51.9)	185,456 (29.3)
TOTAL WATERFOWL	280,839 (9.2)	2,213,833 (72.4)	5,051,006 (43.8)
Cranes	2,282 (31.2)	3,020 (41.3)	17,416 (17.3)

[1] % of 1985–89 average index for California.
[2] % Pacific Flyway in Central Valley.

Waterfowl that use the Grasslands during the nonbreeding period either use the Grasslands habitats (1) as a southern terminus for their annual movements or (2) as a stopover site as they move to or from (e.g., northward staging white-fronted geese) habitats at more southern locations. Species such as the cackling Canada goose, Aleutian Canada goose, lesser snow goose (*Anser caerulescens*) and Ross goose use the grasslands as a southern terminus during their annual movements (Fig. 10). In contrast species such as the northern pintail (*Anas acuta*), white-fronted goose, and cinnamon teal use Grasslands habitats as a southern terminus but also as a stopover during movements to wintering habitats in Mexico (Fig. 11). Waterfowl also breed in the Grasslands, the most common nesting species are mallard (*Anas platyrhynchos*), gadwall, and cinnamon teal.

Shorebirds

During the past decade there has been an increasing interest in waterbirds other than waterfowl. Shorebirds represent a group with high interest to bird watchers. These generally small waterbirds largely exploit shallowly flooded wetland habitats with little vegetation and excellent horizontal visibility. Recent surveys have identified at least 20 species that regularly use Grasslands habitats with numbers ranging from a single bird of a rare species to over 100,000 birds of more common species (Kjelmyr et al. 1991, Shuford et al. 1993; Table

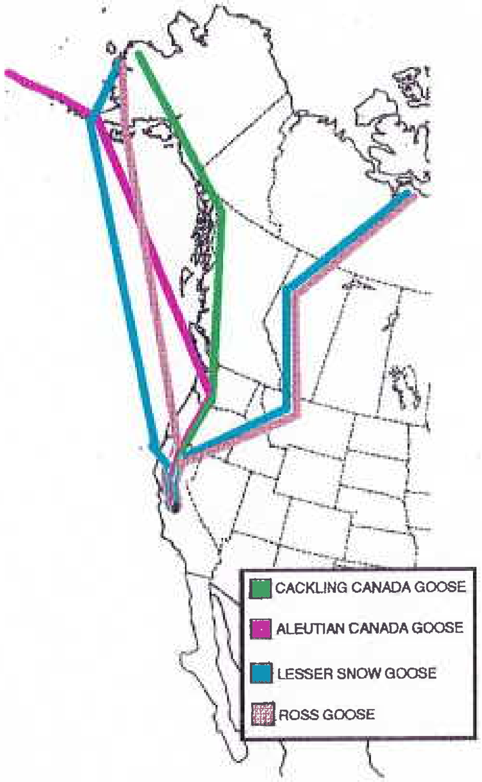

Fig. 10. Migratory movements of geese that use the Grasslands as a southern terminous during winter.

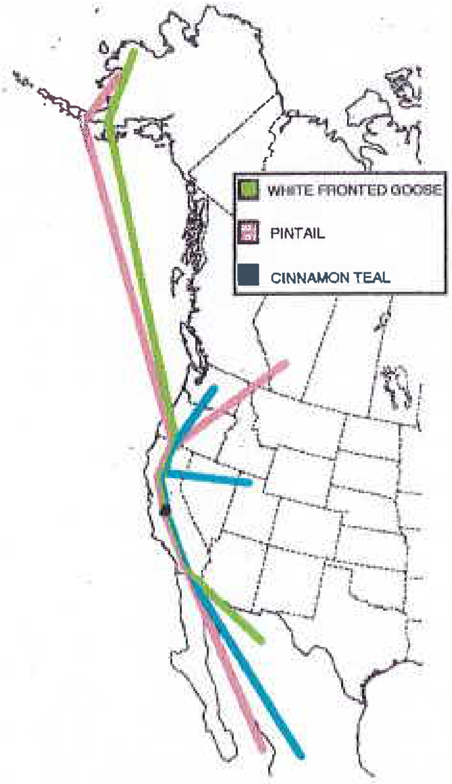

Fig. 11. Migratory pathways of three migratory waterfowl that use the Grasslands as a stopover area during migration or as a southern terminous during winter.

Table 11. Summary of shorebird populations surveys (1988-90 and 1992-93), Grasslands Wildlife Management Area.

Species	1988-90			1992-93
	January	April	September	Winter
Black-bellied plover	582	3,190	653	2,795
Snowy plover	5	21	0	174
Semi-palmated plover	0	286	3	0
Killdeer	366	211	334	2,517
Black-necked stilt	4,038	3,024	2,634	6,179
American avocet	994	3,068	352	2,050
Greater yellowlegs	351	223	323	1,270[1]
Lesser yellowlegs	9	57	139	1
Solitary sandpiper	0	1	0	0
Willet	0	6	0	40
Spotted sandpiper	0		1	0
Whimbrel	0	187	0	0
Long-billed curlew	115	31	1,687	1,012
Sanderling	125	0	0	0
Marbled godwit	0	87	4	121
Western/least sandpiper	11,051	118,778	2,277	19,425
Dunlin	20,007	48,437	25	26,824
Dowitcher spp.	24,733	38,971	3,357	29,922
Common snipe	90	41	10	175
Red-necked phalarope	0	2	13	0
Ruff	0	1	0	0
TOTAL	62,466	216,624	11,812	92,517

11). Spring migration appears to be one of the most important times of the year for shorebird use in the Grasslands. In part this is related to the timing of seasonal flooding of Grasslands habitats. Most wetlands are not flooded until late fall and habitat is unavailable to fall migratory shorebirds, which typically begin southward movements as early as July (Fig. 12). However, Grasslands habitats provide winter habitats to some shorebirds, including dowitchers, dunlins, and western and least sandpipers (Table 11). Peak numbers of shorebirds move northward in April and May on their way to Arctic nesting habitats. The abundance of suitable shorebird habitat in the Grasslands is high in April. Shallowly flooded habitats provide ideal foraging areas where presumably shorebirds acquire the necessary reserves for migration and successful breeding.

Three shorebirds, American avocet (*Recurvirostra americana*), black-necked stilt (*Himantopus mexicanus*), and killdeer (*Charadrius vociferus*), remain on Grasslands habitats to breed. Annual production of young for these species has been estimated at 1,660 avocets, 2,000 black-necked stilts, and 4,000 killdeers.

Fig. 12. Migratory pathways of shorebirds that use the Grasslands as a stopover area during migration or as a southern terminous during winter.

Other Waterbirds

Grasslands habitats also provide important requirements for breeding, migrating, and

Table 12. Waterbird use of West Grasslands (West Grasslands 1978).

Species	Type of use[1]	Average. production	Estimated number		Average duration of use(weeks)
			Average	Peak	
Pied-billed grebe	b,w,f,s	60	250	1,000	52
Western grebe	w,f		25	100	26
Am. bittern	b,w,f,s	200	500	1,000	52
Gr. blue heron	b,w,f,s	700	1,000	2,000	52
Snowy egret	b,w,f,s	100	1,000	2,000	52
Great egret	b,w,f,s	100	300	500	52
Black-crowned night-heron	b,w,f,s	600	2,000	3,000	52
Lesser sandhill	w,f		5,000	12,000	26
California gull	w,f		1,000	1,500	26
Ring-billed gull	w,f		1,000	1,500	26
Common moorhen	b,w,f,s	600	2,000	8,000	52
Sora	b,w,f,s	400	400	2,000	52
Black tern	w,f		200	300	26
Whitefaced ibis	w,f		65	160	26
Subtotals			14,740	35,063	

[1] b = breeding, w = winter, f = fall, s = spring.

Table 13. Estimates of bird use other than waterfowl reported in the Grasslands (West Grasslands 1978)

Group/Species	Type of use[1]	Average production	Estimated number		Average duration of use (weeks)
			Average	Peak	
OTHER MIGRATORY BIRDS					
Brewers blackbird	b,w,f,s	4,000			52
Yellow-headed blackbird	b,w,f,s	600			52
Redwing blackbird	b,w,f,s	6,000	1,000,000	5,000,000	52
Tricolored blackbird	b,w,f,s	1,000			52
Starling	b,w,f,s	10,000	500,000	2,000,000	52
Western burrowing owl	b,w,f,s	150	500	800	52
Great-horned owl	b,w,f,s		75	150	52
Short-eared owl	w,f			20	26
Marsh hawk	b,w,f,s		300	600	52
Red-tailed hawk	b,w,f,s	100	300	600	52
American kestrel	b,w,f,s	400	1,000	2,500	52
Red-shouldered hawk	b,w,f,s	20		10	52
Rough-legged hawk	w,f		2	12	26
Ferruginous hawk	w,f			1	26
Swainson's hawk	b,w,f,s	60	10	50	52
White-tailed kite	b,w,f,s	70	75	300	52
Prairie falcon	w,f		2	6	26
Sharp-shinned hawk	w,f		20	40	26
Golden eagle	w,f,s		6	15	39
Turkey vulture	w,f,s		35	100	39
Mourning dove	b,w,f,s	3,500		10,000	52
Total			25,900	1,507,325	7,025,204
RESIDENT WILDLIFE					
California quail	b,w,f,s	250	200	400	
Ring-necked pheasant	b,w,f,s	300	250	500	
Total		550	450	900	

[1] b = breeding, nesting, brood; w = wintering; f = feeding; s = summer. Degree of accuracy of these estimates is unknown and some important species are missing including bald eagle, peregrine falcon, barn owl, marsh wren, and Cooper's hawk.

wintering birds that are neither shorebirds nor waterfowl. At least 15 waterbird species other than shorebirds and waterfowl use Grasslands habitats, eight of which breed in the area (Table 12). The most abundant are great blue heron, black-crowned night-heron (*Nycticorax nycticorax*), common moorhen (*Gallinula chloropus*) and sora (*Porzana carolina*).

Other Birds

Although populations estimates are lacking for most other birds, some information is available for certain groups because of their potential to cause agricultural depredations or because they are threatened or endangered (Table 13). Raptor abundance and distribution probably are most complete because a large body size allows easier identification and census and there is concern for their status. In contrast, smaller birds often have secretive habits and are difficult to census. The most abundant group is blackbirds which total over 1 million birds on average with peaks exceeding 7 million.

Threatened and Endangered Species

Intensive land use has resulted in widespread changes in numbers and distribution, as well as extirpation and/or extinction, of plants and animals native to California. Some species have disappeared from the state. In 1990 72 animals and 140 plants were classed as threatened or endangered. There is concern that 60 additional animals and 600 additional plants may face serious reduction or extinction (California Department of Fish and Game 1991). Thus, remaining habitats, especially those of larger size, are of critical importance in maintaining the viability of species with decreasing populations.

The Grasslands Study Area includes habitats that are identified as having potential value to threatened and endangered species (U.S. Fish and Wildlife Service 1990, W. White pers. comm). Ten species are listed as endangered by federal assessmant and include one reptile, the blunt-nosed leopard lizard (*Gambelia silus*); two birds, the American peregrine falcon (*Falco peregrinus anatum*) and least bell's vireo (*Vireo bellii pusillus*); and three mammals, the San Joaquin kit fox, Fresno kangaroo rat (*Dipodomys nitratoides exilis*), and giant kangaroo rat (*D. ingens*); three invertebrates, Conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*B. longiantenna*), and vernal pool tadpole shrimp (*Lepidorus packardi*); and one plant, palmate-bracted bird's beak (*Cordylanthus palmatus*). Threatened species according to federal standards in the study area include one reptile, the giant garter snake (*Thamnophis gigas*); two birds, the Aleutian Canada goose and bald eagle (*Haliaeetus leucocephalus*); two invertebrates, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) and vernal pool fairy shrimp (*Branchinecta lynchi*); and one plant, palmate-bracted bird's beak. The U.S. Fish and Wildlife Service and the state of California also have generated lists of proposed and candidate species that include amphibians, reptiles, birds, mammals, invertebrates, and plants (Table 14).

The fauna and flora of the Grasslands have specific requirements that control reproductive success and survival. Collectively, the degree of individual success determines population size and fluctuations, as well as extirpations and extinctions. Over geologic time, extinctions and extirpations are common. However, human populations and their activities have created conditions that have accelerated changes in native animal and plant populations and distribution patterns. In fact, some scientists have stated that the rate of extinction is higher today than during the period when dinosaur extinctions occurred. Foremost among these perturbations are those that modify or destroy plant communities and the amount and distribution of open space. Thus, agriculture and urbanization are two of the most common threats associated with human activities that impact ecosystems and subsequently the size and distribution of wildlife populations (Murphy 1988, Warner and Brady 1994).

An understanding of these effects requires information on habitat requirements and chronology of use relative to life history events of individual species. In this report we focus on waterfowl life history requirements because of the high interest in this species group by individuals and agencies associated with the Grasslands. General requirements for a few select species other than waterfowl also are included. However, it must be remembered that successful completion of life history events for any species is dependent on ecosystem conditions. Thus, it is not possible to separate habitat perturbations from populations dynamics, nor is it possible to look solely at waterfowl species without considering other animal and plant assemblages.

Table 14. Proposed, threatened, and endangered species in the Grasslands Study Area of concern to state and federal agencies.

Taxonomic Group	Species	Status	
		Federal	State
Amphibians			
	California tiger salamander, *Ambystoma californiense*	2	CSC
	California red-legged frog, *Rana aurora draytonii*	1	CSC
	Western spadefoot, *Scaphiopus hammondii*		CSC
Reptiles			
	Blunt-nosed leopard lizard, *Gambelia silus*	E	E
	Giant garter snake, *Thamnophis gigas*	T	T
	Western pond turtle, *Clemmys marmorata*	2	CSC
	California horned lizard, *Phrynosoma coronatum frontale*		CSC
	Silvery legless lizard, *Anniella pulchra pulchra*		CSC
	San Joaquin whipsnake, *Masticophis flagellum ruddocki*		CSC
Birds			
	Bald eagle, *Haliaeetus leucocephalus*	T	E
	American peregrine falcon, *Falco peregrinus anatum*	E	E
	Aleutian Canada goose, *Branta canadensis leucopareia*	T	
	Least bell's vireo, *Vireo bellii pusillus*	E	E
	Ferruginous hawk, *Buteo regalis*	2	CSC
	White-faced ibis, *Plegadis chihi*	2	CSC
	Western snowy plover, *Charadrius alexandrinus nivosus*	PT	CSC
	Mountain plover, *Charadrius montanus*	2	CSC
	Black tern, *Chlidonias niger*	2	CSC
	Long-billed curlew, *Numenius americanus*	3C	CSC
	Fulvous whistling duck, *Dendrocygna bicolor*	2	CSC
	Tricolored blackbird, *Agelaius tricolor*	2	CSC
	California horned lark, *Eremophila alpestric actia*	2	CSC
	Loggerhead shrike, *Lanis ludovicianus*	2	CSC
	Western least bittern, *Ixobrychus exilis hesperis*	2	CSC
	Swainson's hawk, *Buteo swainsoni*		T
	Cooper's hawk, *Accipiter cooperii*		CSC
	Sharp-shinned hawk, *Accipiter striatus*		CSC
	Golden eagle, *Aquila chrysaetos*		CSC
	Northern harrier, *Circus cyaneus*		CSC
	Osprey, *Pandion haliaetus*		CSC
	Prairie falcon, *Falco mexicanus*		CSC
	Merlin, *Falco columbarius*		CSC
	Short-eared owl, *Asio flammeus*		CSC
	Long-eared owl, *Asio otus*		CSC
	Western burrowing owl, *Athene cunicularia*		CSC
	Greater sandhill crane, *Grus cancdensis tabida*		T
	White pelican, *Pelecanus erythrorhynchos*		CSC
	Double-crested cormorant, *Phalacrocorax auritus*		CSC
	Western yellow-billed cuckoo, *Coccyzus americanus*		E
	Willow flycatcher, *Empidonax flasiventris (traillii)*		E
	Yellow warbler, *Dendroica petechia brewsteri*		CSC

Table 14. (cont.) Proposed, threatened, and endangered species in the Grasslands Study Area of concern to state and federal agencies.

Taxonomic Group	Species	Status	
		Federal	State
Mammals			
	San Joaquin kit fox, *Vulpes macrotis mutica*	E	T
	Giant kangaroo rat, *Dipodomys ingens*	E	E
	Fresno kangaroo rat, *Dipodomys nitratoides exilis*	E	E
	Southwestern otter, *Lutra canadensis sonorae*	2	CSC
	San Joaquin antelope squirrel *Ammospermophilus nelsoni*	1	T
	San Joaquin Valley woodrat, *Neotoma fuscipes riparia*	1	CSC
	San Joaquin pocket mouse, *Perognathus inornatus inornatus*	3B	
	Spotted bat, *Euderma maculatum*	2	CSC
	California mastiff bat, *Eumops perotis californicus*	2	CSC
	Arizona myotis, *Myotis lucifugus occultus*	2	CSC
	Townsend's western big-eared bat, *Plecotus townsendii townsendii*	2	CSC
	Badger, *Taxidea taxus*		CSC
Invertebrates			
	Valley elderberry longhorn beetle, *Desmocerus californicus dimorphus*	T	
	Conservancy fairy shrimp, *Branchinecta conservatio*	E	
	Longhorn fairy shrimp, *Branchinecta longiantenna*	E	
	Vernal pool fairy shrimp, *Branchinecta lynchi*	T	
	California linderiella, *Linderiella occidentalis*	PE	
	Vernal pool tadpole shrimp, *Lepidurus packardi*	E	
Plants			
	Palmate-bracted bird's beak, *Cordylanthus palmatus*	E	E
	San Joaquin Valley Orcutt grass, *Orcuttia inaequalis*	PE	E
	Hispid bird's-beak, *Cordylanthus mollis* ssp. *hispidus*	2	
	Delta button celery, *Eryngium racemosum*	2	E
	Colusa grass, *Neostapfia colusana*	PT	E
	Merced phacelia, *Phacelia ciliata* var. *opaca*	2	
	Bearded allocarya, *Plagiobothrys hystriculus*	3A	
	Heartscale, *Atriplex cordulata*	2	
	Valley spearscale, *Atriplex joaquiniana*	2	
	Slough thistle, *Circium crassicaule*	2	

E = Endangered
T = Threatened
PE = Proposed for listing as endangered
PT = Proposed for listing as threatened
1 = Candidate 1, FWS has information on taxa to support a listing proposal
2 = Candidate 2, listing may be appropriate, but FWS needs additional information to support any listing
3A = Species considered extinct
3B = Taxa no longer regarded as separate subspecies
3C = Taxa found to be more abundant than previously believed
CSC = California species of concern.

FUNCTIONAL ASPECTS OF THE GRASSLAND ECOSYSTEM

To understand the impacts of land use on wetland communities, a conceptual framework of wetland values and functions is essential. This section describes the intricacies of wetland habitats and the complexities animals face in meeting life history requirements.

WETLANDS: A CONCEPTUAL PERSPECTIVE

Wetlands are best described as transitional habitats between aquatic and terrestrial systems where the water table usually is at or near the surface or the land is covered by shallow water (Mitsch and Gosselink 1993:25). Wetlands are characterized by having one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes (plants adapted to flooded conditions); (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Wetlands classed as palustrine are the most common type in the Grasslands (Cowardin et al. 1979). Dynamic changes among seasons and years are characteristic of all wetlands where organic material, nutrients, and energy flow into and from the system. Within the study area, the California Prairie surrounds the floodplain and is interspersed among depressions that are characterized as vernal pools, sloughs, and other wetland habitats. Uplands surrounding wetlands are integrally linked to the wetland basin or system. A conceptual model of wetlands (Fig. 13) depicts biotic and abiotic components related to habitat values and functions of importance to wildlife. These components are surrounded by a dotted line to indi-

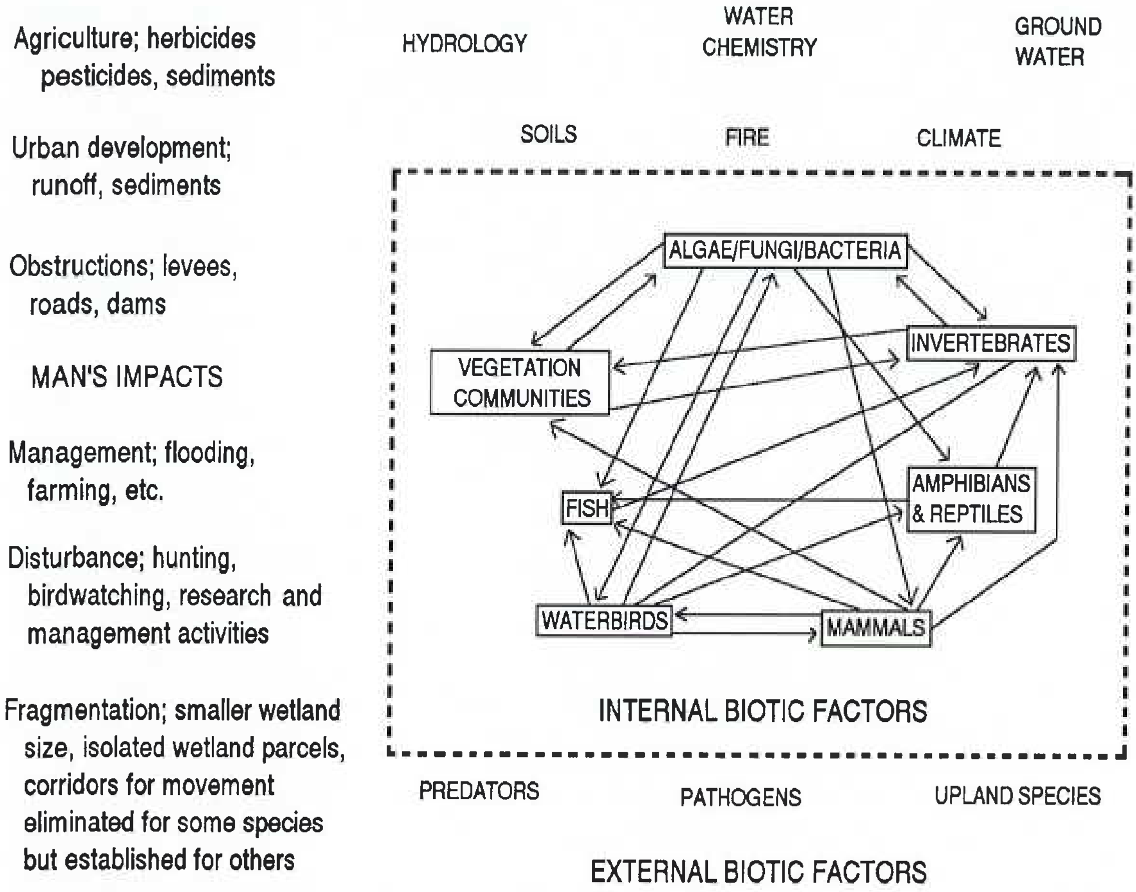

Fig. 13. A conceptual wetland model. The dotted line indicates the indistinct boundary of a wetland and suggests that energy and nutrients flow into and from the wetland.

cate the transitional nature of wetlands and to suggest nutrient transport into and from the system. In this model the wetlands in Merced County are used as an example of the important wetland ecosystem components between the Coast Range and the Sierra Nevada before development. Factors that influence these components fall into two distinct groups; Abiotic (non-living) and Biotic (living).

Abiotic Factors

Abiotic factors (e.g., physical and chemical) include hydrology, groundwater, soils, climate, fire, and water chemistry. Foremost among these factors is hydrology because the time, duration, and depth of flooding not only control productivity of plant communities but also determine the value of habitats for myriad wildlife (Fredrickson and Laubhan 1994a). Historically the hydrology in Merced County was influenced by flooding events that fall into two general categories: within Valley rainfall that occurs primarily in winter, and melt water from Sierra Nevada snowpack that primarily occurs in spring (Ogden 1988, San Joaquin Valley Drainage Program 1990). The combination of these events created dynamic flooding conditions within Grasslands wetlands. Wetlands at low elevations within the floodplain of the San Joaquin River had a high flood frequency, whereas wetlands at higher elevations flooded less frequently.

The complex interactions among hydrology and climatic factors determine soil and water chemistry (e.g., salinity), which in turn influence plant community establishment and productivity, decomposition, and nutrient cycling in Grasslands wetlands. These factors directly influence the amount and type of food and cover available during the annual cycle of waterfowl and other wildlife.

Other factors strongly influencing wetland dynamics are related to man's activities and include: agricultural practices; developments for irrigation and urban water; construction of roads, levees, and canals; wetland and wildlife management practices such as flooding, drawdowns, and farming; and urbanization and industrial developments (Fredrickson and Reid 1990). Agricultural practices have many impacts resulting in sedimentation; soil subsidence; accumulations of herbicides, pesticides, and fertilizers; and pollution of agricultural drainwater with soil concentrations of elements such as selenium and boron. In California, human impacts that compromise wetland values and functions are as diverse, extensive, and intensive, if not more so, than those that occur in other states.

Biotic Factors

Biological factors, such as disease, predation, and competition, exert important influences on wetland community dynamics and productivity, which directly or indirectly influence waterfowl and other wildlife.

Components of wetland communities closely associated with wildlife use are: plants (algae, perennials, annuals), wetland macroinvertebrates, and decomposing vegetation. The dynamic interactions among biotic and abiotic components provide a basis for understanding land use impacts on California's wetlands, thereby identifying opportunities to protect, restore, and manage these important habitats. These different components have varying roles in providing food and cover for wetland wildlife. Each plant has its specific role or value in a wetland that is highly variable depending on the time of year and stage in the life cycle of the plant or animal. Some plants only provide food, others provide both food and cover, and some play a major role only as cover. Additionally, plants are of critical importance in the nutrient dynamics within wetlands.

ALGAE AND DUCKWEED

Although poorly studied, algae and duckweeds respond quickly to readily available nutrients in the water column and can account for a large proportion of annual productivity. There is good evidence that algae plays an important role in tying up readily available nutrients, thereby preventing export from wetland basins. Furthermore, algae are an important component in the decomposition process. Immediately after plant litter accumulates, algae colonize living and dead material and play a key role in conditioning the litter for macroinvertebrates. Algae serve as a source of food for many invertebrates and for some vertebrates as well (Euliss and Grodhaus 1987). For example, species such as American coot (*Fulica americana*) and gadwall readily consume algae.

ANNUAL MARSH VEGETATION

Annual vegetation characteristically is associated with portions of wetland basins that exhibit seasonal water fluctuations. Ephemeral, temporary, and seasonal wetlands, as well as higher elevations in semipermanent wetlands that are exposed during the hottest and driest portions of the year, typically have a predominance of annual vegetation.

Some of these annual plant species always are associated with wetlands, whereas during drier seasons or at the highest elevations within a basin annual vegetation classed as terrestrial is most likely to develop.

Common annual wetland plants in the Grasslands include watergrass (*Echinochloa* spp.), smartweeds (*Polygonum* spp.), swamp timothy (*Heleochloa schoenoides*), and sprangletop (*Leptochloa* spp.). Annual plants are particularly important as seed producers, and species that have a complex plant structure such as smartweed also provide important substrates for aquatic invertebrates once they are flooded (Severson 1987).

PERENNIAL MARSH VEGETATION

Cattails (*Typha* spp.), hardstem bulrush (*Scirpus acuta*), and alkali bulrush (*S. robustus*) are typical examples of perennial marsh vegetation with a ubiquitous distribution in Grasslands wetlands. Such robust plants serve a particularly valuable role in providing breeding habitat and cover for waterfowl as well as other waterbirds. The robust structure of these plants provides materials for nest construction, sites for nest attachment, cover from predators, and largely determine the cover/water interspersion that provides seclusion for pairs. This robust vegetation also provides important cover for broods. During other times of the year when weather conditions are harsh, tule marshes provide protective cover that appears to give birds a "thermal advantage." However, too much robust vegetation is undesirable. When dense monocultures of robust vegetation develop throughout a marsh system the wetland loses value, and use of the basin by waterbirds declines.

Some perennial marsh plants, such as hardstem and alkali bulrush, produce foods of value to wildlife. In contrast, some species produce abundant seed that is of little or no value as a food source for vertebrates because the seeds are too small or have a hard seed coat. Hard seeds are difficult to digest and often pass through the digestive tract intact (Buckley 1989). However, the underground parts and some fleshy plant material of these species may be used by some avian grazers (e.g., geese), muskrats, and beaver.

Perennial marsh plants produce a tremendous amount of biomass annually. In prairie marsh systems cattails may produce 12 tons/acre/year. In most areas of California, these marsh plants senesce because of seasonal environmental conditions related to droughts or climate. Following senescence, this robust litter serves as an important nutrient source for certain invertebrate communities (e.g., substrate, food).

INVERTEBRATES

California's wetlands provide many habitat niches for invertebrates, which are important foods for many wetland wildlife. Furthermore, invertebrates play an important role in decomposition and nutrient cycling processes (Merritt et al. 1984, Reid 1985, Magee 1993, Fig. 14). Invertebrates have myriad life history strategies that allow them to exploit such diverse habitats as bottom substrates; submergent, floating, and emergent vegetation; leaf litter from herbaceous and woody vegetation; accumulated organic matter; and the water surface (Moore 1980, Minshall 1984, Fredrickson and Reid 1988a). Each habitat type has a distinctive invertebrate community that is adapted to the characteristic hydrology, vegetative structure, and water quality of the wetland basin. Because invertebrates are so abundant and serve as an important source of protein, they provide a critical nutrient link between detrital resources, plant community structure, and wildlife (Batema et al. 1985). In the Grasslands, swamp timothy and watergrass provide habitats for invertebrate groups of importance to wildlife (Severson 1987).

Short- and long-term hydrologic regimes have shaped the life history strategies of wetland macroinvertebrates. These strategies are based on adaptations of macroinvertebrates to tolerate or avoid drought. Adaptations that have evolved as a result of long-term hydrologic cycles require one or more of the following characteristics: (1) the ability to withstand drought in the egg, pupal or larval state; (2) rapid growth; (3) the ability to produce numerous offspring; (4) the ability to complete the life cycle within 1 year; and (5) high mobility.

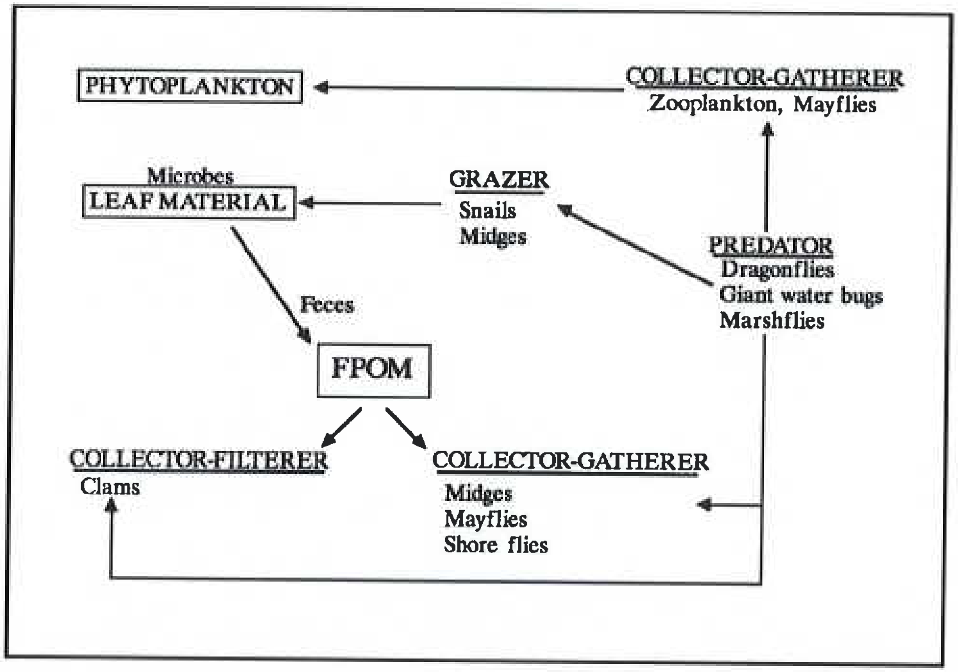

Fig. 14. Invertebrate functional groups associated with herbaceous seasonal and perennial marshes in the Grasslands.

The ability to withstand drought is an important characteristic shared by many macroinvertebrates that are common in Grassland wetlands (Reid 1985, Fredrickson and Reid 1988a). Understanding life history strategies is important to predict how perturbations might impact invertebrate populations and their functional role in wetland systems. Several invertebrate groups including flatworms; fairy, clam, and seed shrimp; water fleas; mayflies; mosquitoes; phantom midges; and marsh flies all represent species with drought resistant egg stages. In contrast, oligochaete worms may use mucosal secretions to survive drought, whereas chironomid larvae often resist drought by aestivating in cocoons. Fingernail clams rely on their shells to resist dessication, but also burrow into the wet litter layer to avoid predation, disease, and drought. Isopods and amphipods have no morphological adaptations to resist drought, but will aestivate as adults and appear to find adequate moisture during the dry season within the deeper litter layers or in refugia that remain flooded.

Because of the dynamic nature of the flooding regimes in Grasslands wetlands, macroinvertebrates that grow rapidly while water and nutrients are available have an advantage. Furthermore, producing large numbers of offspring and completing the life cycle within a year allow for greater success for each species. When water levels decline, species that cannot tolerate drought must be able to avoid dry conditions. Thus, species that avoid drought successfully often are highly mobile; either moving to deeper water or emigrating from the basin. Beetles and hemipterans, in particular, respond well to drawdowns by having an aerial dispersal to more permanent waters (Fredrickson and Reid 1988a).

Although long-term hydrologic cycles influence adaptive strategies of invertebrates, their occurrence, growth, and reproduction at any given time is determined by short-term water regimes and abiotic and biotic factors. The presence of wetland macroinvertebrates in newly flooded wetlands is apparent soon after inundation by floodwaters. Peaks in abundance are often dramatic and short-lived, as invertebrates respond to fluctuating water levels and nutrient inputs. This general response of "pulsing" by invertebrate populations, although variable among years and habitat types, is typical of invertebrates that exploit fluctuating waters and nutrient rich detrital resources. Nutrients and organic matter are rapidly leached from leaf litter and detritus upon initial contact with flood waters. This leaching results in rapid increases in nutrient concentrations in standing water. Waterfowl that exploit macroinvertebrates as food resources are influenced by these dramatic invertebrate pulses. Thus waterfowl numbers and distribution during certain portions of the annual cycle partially reflect the abundance, availability, and distribution of macroinvertebrates.

VERTEBRATES

Vertebrates in General

Vertebrates are the most obvious and best understood members of wetland communities. They tend to have large body sizes compared to invertebrates and represent consumer groups at the upper end of the food chain (Fig. 15). Waterbirds represent the most visible vertebrate component because, in addition to a large body size, many species exhibit bright colors, high mobility, interesting behavior including songs and calls, and diurnal activity. In addition many birds often form large concentrations during winter or migration that regularly attract public attention. The most adaptable waterbird group is waterfowl because they fill many niches in wetlands; some primarily are herbivores, some are omnivores, while others are carnivores.

Frogs, toads, and snakes tend to be smaller than many waterbirds and are less mobile. Apparently amphibians are less adaptable to changing conditions or modification in wetland environments because their numbers have dropped precipitously at many locations across the continent. This group usually is less visible

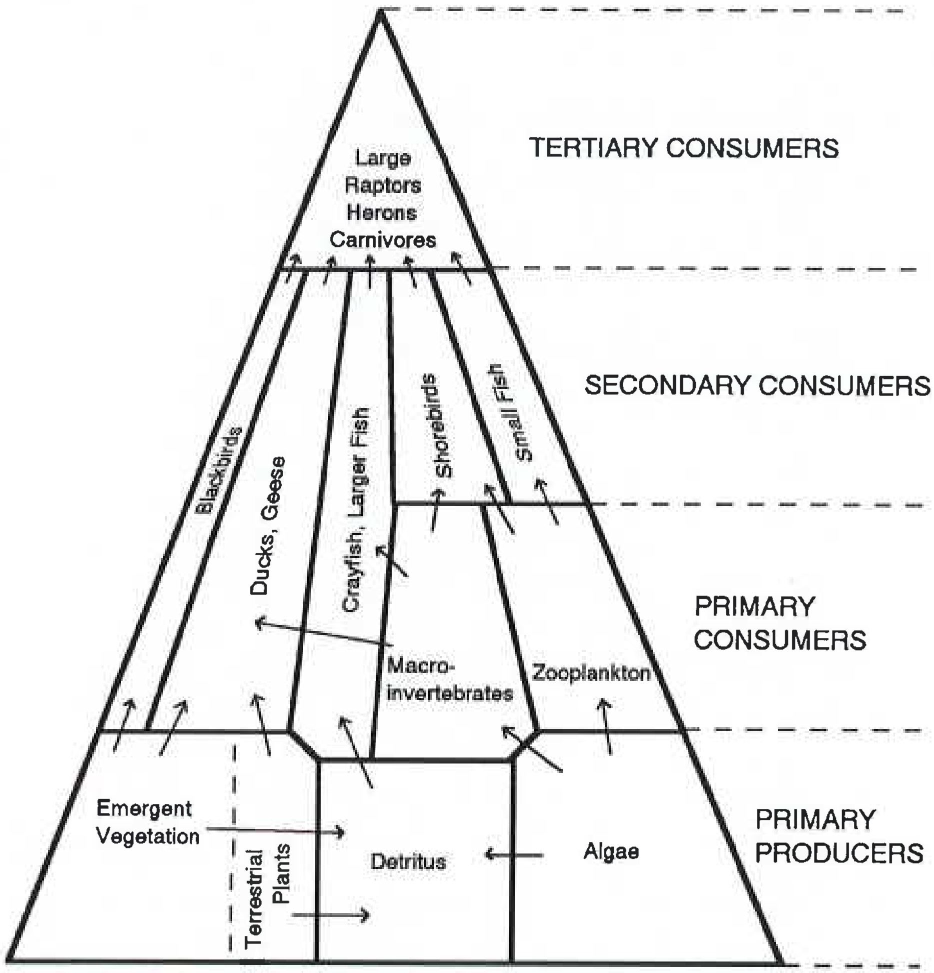

Fig. 15. Trophic pyramid of Grasslands wetlands.

than birds because they tend to be nocturnal; only vocalize during the breeding season; and remain buried in mud, under water, or in dense cover for most of their life cycle. Some reptiles (snakes and turtles) have been severely impacted by wetland loss and modification. The giant garter snake is an example of a federally listed threatened species present in the Grasslands. Fish are the other cold blooded vertebrates found in wetlands; but their abundance is limited in the seasonal wetlands, of the San Joaquin Valley.

Although mammals require water as a basic life requisite, few have completely adapted to aquatic environments (Weller 1987). The most abundant forms are herbivores such as muskrats and beaver. By comparison, carnivores are not abundant, but their predatory habits may have an important influence on other animal populations by influencing breeding success or mortality rates of young animals.

Vertebrates serve as the "canaries" in wetland systems. Their numbers, distribution, and reproductive success are indicators of wetland conditions. For example, listing of the giant garter snake suggests that some important habitats required for life history success have been compromised in the Grasslands. The distribution, size, and fecundity of the less mobile vertebrate populations are the most sensitive indicators to changing wetland conditions, but many of these species are so poorly understood that detecting changes in populations or distribution is difficult. Birds serve as more obvious indicators of changing conditions because their numbers and distribution are much easier to document.

Birds are important consumers in the Grasslands Study Area. The abundance of herons and raptors is low compared to other bird groups because they are at the top of the trophic pyramid (Fig. 15). Ducks and geese are classed as primary and secondary consumers; whereas shorebirds are secondary consumers because they are predominantly carnivores. Because waterfowl have been so well studied, they will serve as a model to describe their role in the wetland system.

Waterfowl Life History Strategies

Waterfowl are well adapted to exploit the dynamic wetland and upland habitats associated with the Grasslands. Compared to other birds, waterfowl have large body sizes. Geese and swans are largest, and ducks are smallest (Bellrose 1976). Ducks vary considerably in size from the largest, such as mallards, to the smallest in North America, the teal. The large body size enables waterfowl to store a considerable amount of energy and/or protein that can be readily used for future needs. Thus, body size alone has an important influence on flight distances, fasting time, and thermal regulation. Furthermore, waterfowl are highly mobile and can move long distances in short time periods. This high mobility allows waterfowl to effectively exploit wetland habitats across the continent. For example, geese that breed in the far north migrate to the Grasslands for the winter where they use open habitats with good forage.

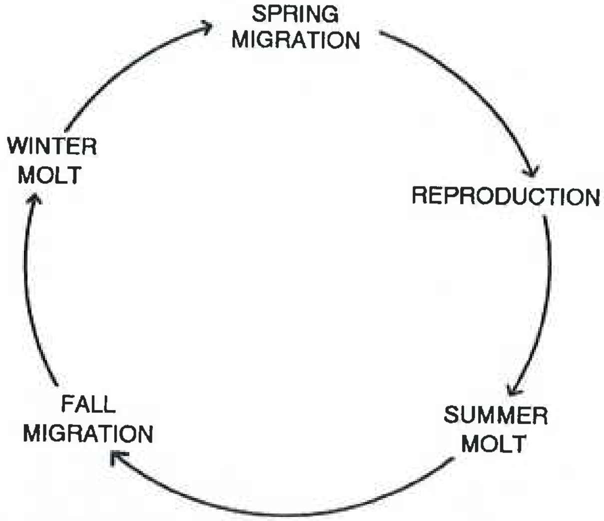

Fig. 16. The five major life cycle events of a typical dabbling duck such as a pintail.

Waterfowl life history requirements occur as a continuum of events that overlap and are interdependent, and require diverse foods and cover (Fredrickson and Reid 1988b). A typical dabbling duck, faces five major energetic events during the annual cycle (Fig. 16) including reproduction, two molts, and two migratory periods. To successfully complete each of these events there are specific behavioral, physiological, habitat, and/or nutritional needs that must be met (Fig. 17). For example, the dietary needs for molt and migration are quite different (Fredrickson and Reid 1988b). Because feathers are high in protein, replacement requires large amounts of protein. In contrast, migration is an energetically expensive event that requires large lipid accumulation. Thus, the foods necessary to complete both events tend to be somewhat different. A complicating factor in this scenario is that molt and migration may overlap

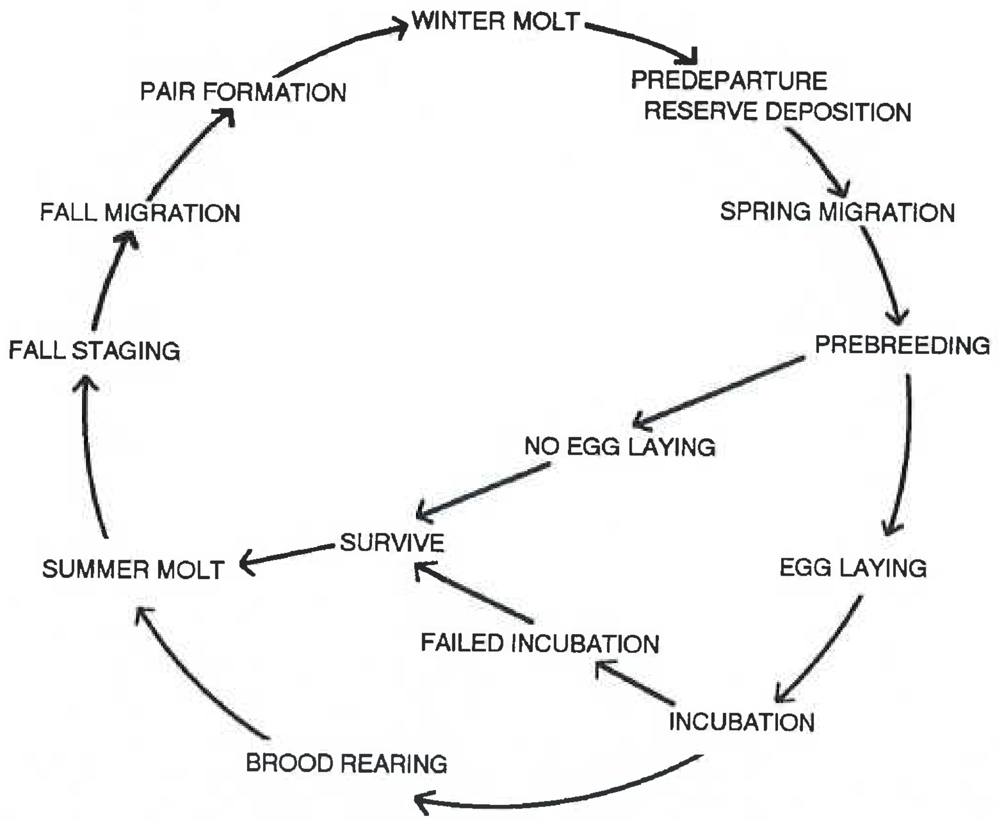

Fig. 17. The continuous sequence of events in the life cycle of a typical female dabbling or diving duck.

(Alisaukas and Ankney 1992). Thus, food and other components (e.g., habitat structure) necessary for both events must be available concurrrently.

Each waterfowl species that uses Grasslands habitats has a somewhat different life history strategy (Fig. 18). These strategies range from arctic nesting geese that acquire necessary reserves on migrating and wintering habitats to the ruddy duck which primarily acquires necessary reserves on the breeding grounds (Owen and Reinecke 1979, Alisaukas and Ankney 1994). The locations where arctic nesting geese acquire the different components for breeding varies by species and population (Krapu and Reinecke 1992), but habitats outside the breeding area are important. Environmental conditions in different seasons and on widely separated habitats may have an important influence on the success of sequential activities in the annual cycle of waterfowl.

Mallard strategies differ from strategies of arctic nesting geese. Most of the lipid reserves and as much as half of the protein required for reproduction in mallards are transported to the breeding ground as body reserves (Krapu and Reinecke 1992). Wood ducks (*Aix sponsa*) and ruddy ducks (*Oxyura jamaicensis*) differ from

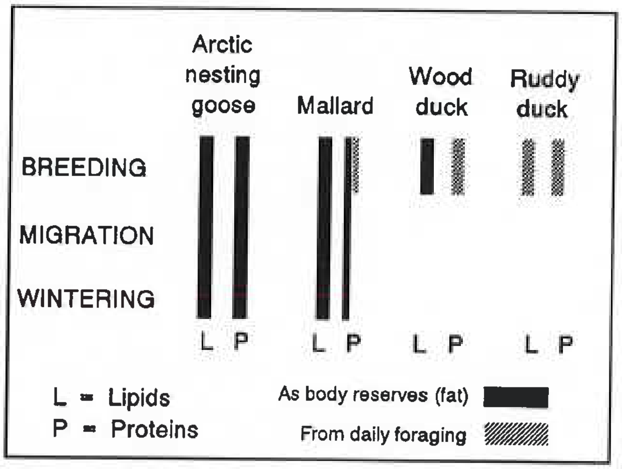

Fig. 18. Life history strategies of selected waterfowl showing when lipids and proteins are acquired from Grasslands habitats.

mallards and geese because they acquire lipid and protein for reproduction primarily from breeding habitats. However, wood ducks acquire lipids prior to laying but rely on daily foraging for acquisition of all protein requirements (Drobney 1980).

Understanding these different strategies and the timing of these needs is important because land use activities that compromise the size and quality of habitats can differentially affect the reproductive success of individual species (Raveling and Heitmeyer 1989, Nudds 1992).

Northern pintails are one of the most abundant species using Grasslands habitats. Pintails either use the Grasslands as a southern terminous or continue into Mexico for winter. During their stay in the Grasslands, more than one event may occur concurrently (Fig. 19). Pintails, as well as other dabbling and diving ducks, have constantly changing nutritional requirements depending upon the stage in the annual cycle (Table 15; Connelly and Chesemore 1980, Euliss and Harris 1987, Miller 1987, Krapu and Reinecke 1992, Alisaukas and Ankney 1992, Fredrickson and Heitmeyer 1991). These diverse and constantly changing nutritional requirements must be met by exploiting diverse wetland habitats where the mix of plant and animal foods are readily available.

In the Grasslands, meeting this challenge requires attention to size and distribution of wetland habitats. Because no single wetland can provide all the energetic and environmental requirements for a single species during the annual cycle nor can a single wetland type provide requirements for a group of species, each acre of habitat in this disrupted landscape is important (Fredrickson and Heitmeyer 1989). These interrelationships among habitats to provide critical resources emphasize the importance of all habitats in western Merced County that surround the Grassland Water District. Wetland habitats are critical, but agricultural lands such as pastures and cereal grain fields are important in California because they add open space and foods required to successfully complete the annual cycle successfully.

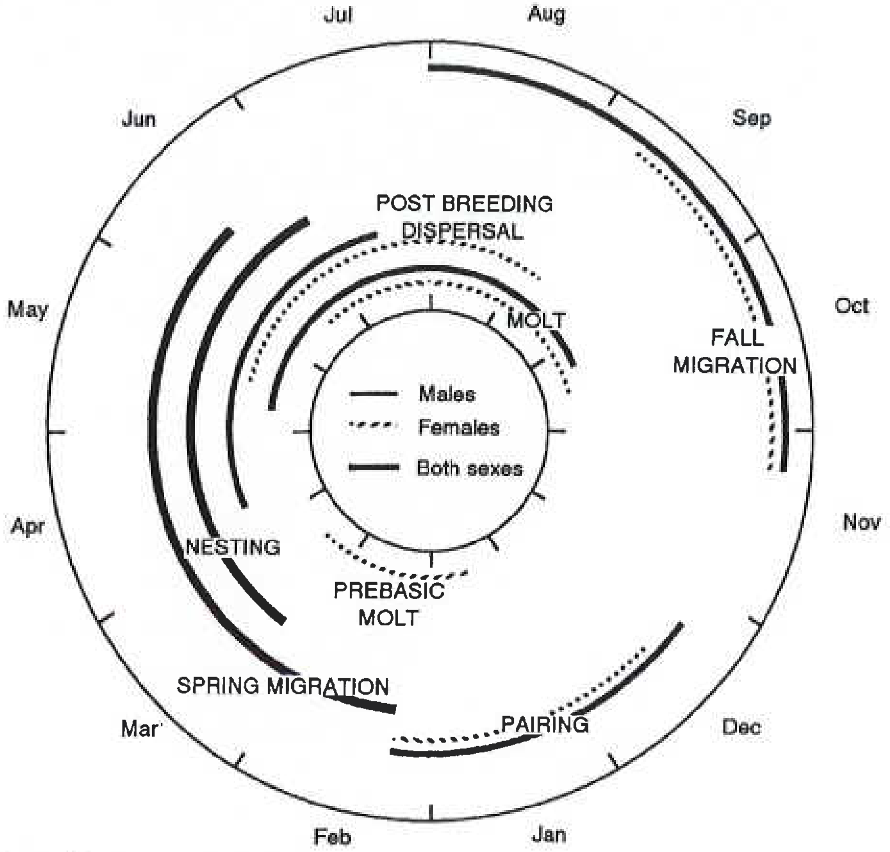

Fig. 19. Annual cycle of the northern pintail.

Table 15. General changes in nutritional requirements during the annual cycle of waterfowl.

Life stage	General needs	Specific needs		
		Geese/Swans	Dabbling ducks	Diving ducks
Premigration	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Spring Migration	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Prebreeding	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Egg laying	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Brood rearing Early	High Protein	Plants-Browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Brood rearing Late	High Energy	Plants-Browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers
Summer molt	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Fall staging migration	High Energy	Plants-Browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Pairing	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Winter molt	High Protein	N/A	Macroinvertebrates	Macroinvertebrates

CURRENT KNOWLEDGE CONCERNING HABITAT FRAGMENTATION APPLIED TO THE GRASSLANDS STUDY AREA IN MERCED COUNTY

RATIONALE FOR CONCERN OF CONTINUED FRAGMENTATION/LOSS OF OPEN SPACE AND HABITAT IN WESTERN MERCED COUNTY

Historically, disturbed areas were surrounded by large areas of natural habitats and animals simply had to move around these small areas of disturbance (Csuti 1991). Today, the situation is reversed. Human impacts occur across the landscape and often represent the major land use in many geographic areas of the country, including the Central Valley of California. Such impacts are diverse and include agriculture, grazing, and mining, as well as transportation and utility networks, cities, and industrial areas. Many of these land uses have long-term, if not permanent, impacts that tend to isolate native habitats. As large blocks of contiguous habitats become segmented into smaller isolated parcels, any given parcel eventually reaches a size that cannot support viable populations of certain plants or animals, and the final result can be local extirpation or eventually extinction (Wilcove 1987). Thus, many areas that once supported a diverse flora and fauna now only contain remnant populations of native species. As a result, an increasing number of scientists are reaching the conclusion that "habitat fragmentation is the most serious threat to biological diversity and is the primary cause of the present extinction crisis" (Wilcox and Murphy 1985:884). As natural areas continue to be disrupted by human activities, animal and plant populations become isolated in "island habitats" where genetic inbreeding, depredation of large species, and proliferation and domination of human-adapted species all interact to increase rates of extinction (Cutler 1991). An example sometimes used to illustrate the potential impacts of fragmentation, loss, and isolation of habitats are the declining populations of animal species on lands administered by the National Park Service. Forty-two species of native mammals have become extirpated on lands forming 14 parks even though these species were present when the parklands were established, and they were protected thereafter from direct harm from humans and development (Chadwick 1991). Extirpated species include badger (*Taxidea taxus*), black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), northern flying squirrel (*Glaucomys sibrinus*), beaver (*Castor canadensis*), gray fox (*Urocyon cinereaoargeteus*), spotted skunk (*Spilogale putorius*), ermine (*Mustela erminea*), mink (*Mustela vision*), and river otter (*Lutra canadensis*). The degree of negative impacts relating to continuing habitat fragmentation and loss is difficult to determine, but a recent study suggests that California alone may have 220 animal and 600 plant species threatened with serious reduction or extinction (Chadwick 1991). Although the exact cause of such declines in species diversity is not scientifically known, habitat fragmentation and isolation surely must be considered as important factors.

The importance of maintaining the integrity of the lands composing the Grasslands Study Area has not been fully quantified. Scientific evaluation and study of the short- and long-term impacts of habitat fragmentation on ecosystem functions is in its infancy. However, several pertinent statements can be made concerning past efforts at protecting species. First, we have learned that trying to maximize species diversity on every acre is not the solution (Samson and Knopf 1982). Second, it is inefficient to save selected species while allowing the natural communities and ecosystems that support them to deteriorate (Scott et al. 1991). Recent estimates (Erwin 1988, Wilson 1988) indicate there are more than 30 million species on earth, but a quarter of them may not survive to the year 2010 (Norton 1988). Most are insects that play critical roles in the function of natural ecosystems (Wilson 1987). Thus, the species approach to conserving biological diversity in the absence of habitat conservation is likely to fail (Hutto et al. 1987). For example, even though the federally endangered Aleutian Canada goose uses habitats within the Grasslands Study Area, our efforts should not be directed solely at providing what is perceived to represent suitable habitat for this species to the exclusion of all other species. We simply do not understand the synergistic interactions among abiotic and biotic factors that ultimately determine habitat characteristics. Thus, our efforts may fail if the system is not considered in its entirety. Finally, many human-related losses of biological diversity have been the result of simplistic notions of ecosystems and ecosystem processes (Cooperrider 1991). Often we assume that human ingenuity can diminish any impacts that change the landscape. Appreciation of the complexity of ecosystems will hopefully discourage the use of quick-fix, high-technology solutions without knowledge of their long-term impacts.

THE ROLE OF ISLAND BIOGEOGRAPHY THEORY IN MAINTAINING THE ECOLOGICAL VALUE OF THE GRASSLANDS STUDY AREA

Although much site-specific information concerning the dynamic processes that govern habitat dynamics within the Grasslands is lacking, some general principles concerning habitat fragmentation undoubtedly apply. These principles must be incorporated into any decisions that may fragment or otherwise affect (e.g., habitat loss or degradation) the Grasslands. Foremost is the theory of island biogeography (MacArthur and Wilson 1967). Although originally applied to islands in the ocean, this theory has been applied successfully in cases where habitat "islands" are represented by isolated natural areas amid disturbed landscapes in the interior United States. Thus, the theory of island biogeography is applicable when considering potential fragmentation and habitat loss in the Grasslands. The primary tenet of island biogeography is the species/area rule: large geographic areas support a greater diversity and density of species than small geographic areas. Further, smaller islands exhibit a marked decrease in species diversity over time. A second tenet of island biogeography is the relationship between degree of isolation and diversity: the greater the isolation, the less the flora and fauna on an island have in common with the nearest similar communities. In general, if two "islands" are similar with the exception that one island is only one-tenth as large as the other, the smaller island may be expected to hold only about half as many species and often far fewer (Waller 1991).

Although the statement that "the larger the area the greater the diversity and density of species" appears simplistic, there are underlying principles that tend to support the aforementioned tenets of island biogeography. First, the larger the geographic area, the greater the probability of encompassing a diversity of habitat types and microclimates that can support a diverse flora and fauna. This is particularly applicable in the Grasslands, which if viewed in a cursory manner, appears to be relatively homogenous in relation to topography and habitats. However, if examined meticulously, variations in plant communities and basin topography are evident within and among the lands east and west of the San Joaquin River and north and south of Highway 152. These variations largely may account for the differential use of waterfowl and other wildlife among the different regions composing the Grasslands. Second, the smaller and more isolated the geographic area, the greater the chance for extinction because: (1) isolated populations of species lack the genetic flexibility to cope with changes in the environment and their vulnerablity worsens as undesirable traits accumulate through inbreeding, (2) the greater the isolation the lower the probability that new individuals from other populations will immigrate into an area, and (3) natural catastrophic events (e.g., floods) can destroy a small island as well as entire populations of associated species.

The main principle of island biogeography with regard to the optimum size of a contiguous land base has been summarized by Waller (1991):

> "We cannot tuck species away in little preserves, as if we were storing pieces in a museum. The essence of life is change. Organisms are constantly growing, interacting, adapting, evolving. Their numbers and distribution across the landscape fluctuate in cycles linked to climatic patterns and to other less understood rhythms. They are defined as much by their place in food webs and nutrient flows as by their own physical traits or any current geographic location. Many alter their range and behavior under different conditions. Some assume entirely new behavior through learning. In short, an ecosystem is not a collection of plants and animals. It is a seamless swirl of communities and processes. If the processes are not saved, the parts cannot be saved. Thus, if a preserve is to be created, it had better be a large one."

Although the "bigger is better" theory of island biogeography has been proven in several cases, the answer to "how big an area is needed" still remains ambiguous because of our lack of understanding concerning ecosystem processes and functions. However, many areas designated primarily for the purpose of protecting habitat/species are now known to be too small. For example, the oldest and largest national park in the West, Yellowstone, is not large enough to contain viable populations of many species, thus necessitating the need for management based on the "Greater Yellowstone Ecosystem" (Clark and Zaunbrecher 1987). Further, a number of national wildlife refuges with well-managed wetland habitat have become poor producers of waterfowl and other aquatic birds because so many eggs, nesting females, and young are taken by predators (Waller 1991). The general public views these areas administered by Federal and State agencies as sufficient to maintain biological diversity. However, none of the areas is large enough to protect all the migratory species that use it. Regardless, such areas often are managed as if they existed in isolation. Surrounding seminatural lands are exploited for resource production at the expense of the substantial natural diversity they support (Cooperrider 1991). Such is the case in the Central Valley. The complex of national wildlife refuges (Kesterson, Merced, San Luis) cannot preserve or maintain a functioning ecosystem that supports a diverse biota on only 23,000 acres. In general, current preserve systems in the U.S. are of limited effectiveness by themselves because: (1) most were not established to preserve biological diversity (Blockstein 1989); (2) many preserves are not large enough to maintain viable populations of target species, much less self-sustaining ecosystems; and (3) no preserve is truly pristine or totally protected. Air pollution, exotic plants and animals, polluted water, and other "nonnatural" elements cross preserve boundaries as readily as they cross county lines (Cooperrider 1991). Rather, the integrity of the ecosystem and its associated value to wildlife is largely dependent on privately owned lands that constitute the majority of the Grasslands Study Area. In fact, it is widely recognized among resource agencies that private and multiple-use lands will be critical to conserving biodiversity. Some scientists have even stated that such lands are more important than parks and preserves (Norse et al. 1986, Wilcove 1988). How much destruction or degradation, if any, can occur before the "health" of the Grasslands is significantly impacted is unknown. However, past experience has shown that once the damage is done it is difficult, if not impossible, to reverse and repair. Therefore, any proposed alteration to the existing land base composing the Grasslands must be evaluated prior to implementation. Of particular concern is the planned urban encroachment that would further separate the North and South Grasslands into separate entities. Not only would new housing construction potentially impact the functioning of the current ecosystem, but the associated sewage treatment facilities, roads, powerlines, and domestic animals also represent important impacts. For example, boat and automobile traffic is the number one habitat-fragmenting force and the primary cause of human-related mortality for all of Florida's large threatened and endangered species (Harris and Frederick 1990); powerline strikes are a major source of mortality of sandhill cranes in the San Luis Valley of Colorado and of mute swans in Britain (Ogilvie 1966); domestic pets are known to seriously impact nesting success of many bird species; and the use of sewage effluent in wetland management can have differential effects on natural plant and animal communities depending on trophic level, type of nutrient enrichment, and stage of ecosystem development (Carson and Barrett 1988, Levine et al. 1989).

THE ROLE OF CORRIDORS IN MINIMIZING THE IMPACTS OF HABITAT FRAGMENTATION

Many of the most significant human effects on biodiversity involve changes in the connectivity of biological processes (Noss 1991). Human activities may either reduce or increase connectivity. The consequence of some landscape modifications induced by humans has resulted in the creation of artificial barriers that hamper species dispersal (both plants and animals). The ultimate impact of creating such a barrier is the potential isolation of populations which become more vulnerable to extinction because of reduced access to resources, genetic deterioration, and increased susceptibility to environmental catastrophes and demographic accidents, among other problems (Harris 1984, Soule 1987). However, in other cases, human modification of the landscape has effectively eliminated natural barriers (Noss 1991). Although this may be viewed as beneficial, often degradation of natural barriers is detrimental. Floras and faunas that once were distinct and endemic can become dominated by unwanted exotics and cosmopolitan weeds (Noss 1991). The two most prevalent causes of such invasions are human transporation systems that facilitate the spread of certain species far beyond their natural dispersal capacities, and habitat modifications that favor weedy invaders (Elton 1958; Mooney and Drake 1986). The end result of this process is a homogenization of floras and faunas (Noss 1991). What is of critical importance is the fact that organisms differ in their dispersal abilities (Noss 1991). Thus, whether a given barrier alters species dispersal from one habitat island to another is dependent upon the life history of individual species (MacArthur and Wilson 1967). The same road that restricts movement of certain animal species may encourage movement of others. Likewise, certain types of corridors, whether created or maintained, could become avenues for the spread of exotic or pest species or lead to mingling of communities that normally would remain separate and intact. As a consequence, it is critical that the dimensions of the corridor linking the North and South Grasslands be considered carefully, lest significant ecological impacts occur that are irreparable.

FACTORS IMPORTANT IN DETERMINING APPROPRIATE CORRIDOR DIMENSIONS

The role of corridors in preserving ecosystem functions is difficult to assess because little quantitative information exists. This is evidenced by the variety of definitions that have been applied to the term "corridor," including: (1) a linear landscape feature that facilitates the biologically effective transport of animals between larger patches of habitat dedicated to conservation functions, including frequent foraging movements, seasonal migrations, or the once-in-a-lifetime dispersal of juvenile animals (Soule 1991); (2) any area of habitat through which an animal or plant propagule has a high probability of moving (Noss 1991); and (3) any naturally occurring or restored linear landscape feature that connects two or more larger tracts of essentially similar habitat and functions as either a movement route for individuals or an avenue for the spread of genes or other natural ecological processes across the landscape (Harris and Atkins 1991). Based on these definitions, the primary difference between a corridor and habitat is that corridors provide only life requisites necessary for travel, whereas habitats provide all life requisites. Regardless of definition, it is known that natural landscapes are basically interconnected and that connectivity declines with human modification of the landscape (Godron and Forman 1983, Noss 1987a). Further, it has been proven that fragmentation does impact natural processes, and these impacts can sometimes be devastastating (Wilcove et. al 1986). Although no irrefutable proof exists that corridors are essential to preserving the value of remnant habitats, it is known that fragmentation and isolation of habitats are not beneficial. From our perspective, definition (3) is the best approach to viewing the corridor linking the North and South Grasslands and East and West Grasslands because it embodies connectivity of large tracts of land for the purpose of providing transitional continuity among habitats. Too often humans view habitats as separate entities, whereas in reality they are interacting, functional components of the landscape ecosystem (Noss 1987b). If processes integral to the functioning of the system are disrupted, the entire system may collapse even though they appear physically connected. Thus, connectivity of process is just as important as connectivity of habitat (Noss 1991). A prime illustration is the role of fire in the pinelands of the Gulf coastal plain (Noss and Harris 1986): "Fires periodically burn down gradual slopes and prune back wetland shrubs that otherwise would encroach from adjacent swamps. As a result, fire functions to maintain an open herb-bog community with an extremely diverse flora adjacent to swamps. If fires are suppressed, or fire lanes are constructed that disrupt the hydrology of the slope-moisture gradient, its unique flora is destroyed." Based on such general information, destruction or modification of existing corridors should be avoided from an ecological perspective. Consequently, the most prudent decision is to prevent disruption of the existing corridor connecting the North and South Grasslands until sufficient evidence has been collected to determine the relative value of this area and the potential impacts caused by modification. Although current plans for urban expansion do not indicate that the corridor will be completely destroyed, leaving only a remant strip of habitat may not be sufficient if it is too narrow. In fact, evidence indicates that linear strips that are too narrow may function more as a liability because they often promote predation or increase the probability that alien species (i.e., species which do not naturally occur) will invade the site (Harris and Atkins 1991).

Unfortunately, current information regarding optimum corridor dimensions is scant. However, corridor width has been identified as a primary determinant of corridor function. Width determines the extent of the edge effect, which influences predation rates and the potential for invasion of alien species (Janzen 1986). In many cases, limiting the dispersal of opportunistic, invasive organisms (especially exotics) may be as important as enhancing the dispersal of native taxa (Noss 1991). Edge effects vary depending on habitat type, but can range from 200 to 600 yards in forested communities (Temple and Cary 1988, Wilcove et al. 1986). Width also determines the potential for a single natural disturbance (e.g., flood, fire) to sever the corridor linkage. Finally, width influences the movement of flora and fauna. The wider the corridor and the greater the contrast between corridor and the adjacent habitat, the more effective a barrier it becomes and the more likely the corridor interior will have a characteristic assemblage of animal species (Johnson et al. 1979, Chasko and Gates 1982).

Although this information does not quantify the desired width of corridors, it illustrates that the "optimum" width varies depending on objectives, habitats, and species being considered. Thus, it is important to explicitly state the objectives of the corridor. A corridor can be tailored to the needs of specific species, but at the same time it must not compromise the viability of other species (Soule 1991). A thorough understanding of life history strategies of species using the area also is essential. Important factors to consider include movement (type, rate, and magnitude), demographics (birth/death rates), age, and sex of individual species; interactions among and within species (displacement, predator/prey relationships, territoriality, competition); and habitat requirements (composition/structure of plant communities, barriers to movement, effects of edges on mortality; Soule 1991).

Although the current concern regarding the future of the Grasslands may be perceived as a struggle between waterfowl and human needs, the scope of concern actually is much larger. Waterfowl are only one component of a much larger ecosystem. A more appropriate question that must be addressed is "What are the long-term impacts to the species assemblages (plants and animals) that may result following modification of the landscape?" Because species diversity/richness of an area largely are dependent on various aspects of habitat (e.g., type, interspersion, juxtaposition, quantity, quality), maintaining existing habitat characteristics is a primary concern. If this is accomplished, the long-term health of the system (including waterfowl) will be better ensured. Thus, the entire Grasslands entity, including the corridor, must be viewed at a scale that considers dispersal capabilities of plant propagules, for example, as well as waterfowl movements among habitats. Otherwise, a strategy that appears to maintain biodiversity in the short term may fail to preserve viable populations and ecological integrity over a longer time span (Noss 1991). Based on this perspective, and our views regarding the value of the Grasslands on a local, regional, and continental scale, the optimum corridor width would enable the full spectrum of native species to move between not only the North and South Grasslands, but also help ensure that migratory species that winter in the Grasslands arrive on the breeding grounds in the best physiological state possible.

IMPACTS OF AGRICULTURAL LAND USE ON NATIVE HABITATS IN WESTERN MERCED COUNTY

Agricultural activities largely were responsible for the initial changes that converted western Merced County from a natural ecosystem to a fragmented landscape. Early settlers in the Valley recognized its potential for agriculture and set in motion changes that converted natural wetland and grassland habitats to the intensive agricultural industry of the 20th century (Association of Bay Area Governments 1991). The intensity is apparent based on the agricultural income from Merced and the surrounding counties (Table 16). Fresno County has an annual agricultural income of over $2 billion, whereas Merced and Stanislaus counties each approach annual incomes of $1 billion. The greater amount of prime farmland in Fresno County is reflected in the higher annual farm income and clearly indicates why there was a conversion from natural systems to agricultural uses (Table 16).

The first changes in land use were related to grazing by domestic stock. Although the pristine plant communities had already been modified before sizable numbers of European settlers moved into the Valley in the mid-1800's, more intense grazing by domestic stock in the late 1800's further changed the plant communities. Environmental variation among wet and dry periods, in combination with the onset of intense continuous grazing, further changed the plant communities. Dry-land farming was practiced widely. The intensive manipulation of soils as compared to grazing changed plant communities further. Conversion of native habitats and pasture to cereal grain production associated with dry-land farming provided cover for wildlife during a portion of the year, and waste grains served as an important food source for some wildlife.

IRRIGATION INFRASTRUCTURES

The value of irrigation was recognized in the 19th century, but development of the system was not completed until the middle of the 20th century. Improvements to the system continue today. The irrigation infrastructure impacted land use in western Merced County in three important ways: (1) the amount of area used for intensive agriculture, (2) the extent to which the hydrology of natural streams was modified, and (3) developments serve as barriers or conduits for animal movements. The conversion of natural systems to intensive agriculture has already been discussed extensively in this report and needs no further explanation.

The effects of land use changes in relation to flowage patterns of natural streams was mentioned earlier in this report but not discussed in detail. These changes in hydrology fall into two distinct situations: (1) modifications in drainage patterns at a distant location and (2) modification in flow of natural stream systems. Because

Table 16. Agricultural production, farmland area, and human populations in Fresno, Merced, and Stanislaus counties, California.

	Fresno	Merced	Stanislaus
Agriculture production($)	2,270,170,000	942,482,000	881,336,710
Agriculture production (Rank in state)	1	6	7
Human population			
1988	600,000	180,000	330,000
2000	730,000	260,000	460,000
Urban land	65,064	17,257	38,165
Land use			
Prime farmland	31,749	4,738	19,699
Total farmland	55,045	18,678	25,133
% irrigated crops w/saline soil	43	68	6

most of the water available in the San Joaquin Valley results from winter snowfall in the mountains or as winter rainfall in the Valley, water storage projects were required to capture this water for use during the growing season. Reservoirs were built on all of the major streams flowing into the Central Valley, and water primarily was transferred by canals (Figs. 4, 5, and 6). In some cases sections of natural stream channels were used, or these natural stream channels were modified to enhance the transfer of water. The capture of water at distant points upstream from the wetlands in western Merced County changed the amount of water available to recharge wetlands. Modifications to the natural stream channels within Merced County were related to flood control projects and to the transfer of water for irrigation. The natural drainage patterns were modified further because agricultural drain water (tail water or subsurface water) must be transferred from the site of application to prevent soils from becoming water logged and to prevent accumulation of salts, toxicants, fertilizers, or trace elements. The canals supplying and draining irrigation waters extend over hundreds of miles in Merced County. They cover a considerable area and create a network of barriers for movement of land animals but may also provide conduits for movement of some species (Figs. 4, 5, and 6; Table 17).

WATER QUALITY

Agricultural activities have impacted water quality in many different ways in western Merced County. Soil disturbance during agricultural operations increases erosion and results in a heavy sediment load (Table 17). A portion of the herbicides, pesticides, and fertilizers applied to agricultural fields move into waterways or into the groundwater where they have toxic effects on food chains, cause eutrophication, or have direct toxic effects on humans or wildlife.

Irrigation practices have the potential to exacerbate salinity, drainage, and/or toxicity problems (NRC-Committee on Irrigation-Induced Water Quality Problems 1989). Some salts and trace elements are present in all soils and water, whether the water supply is from surface flows (local or imported) or pumped groundwater. As irrigation water is applied, dissolved solids are added to the soil, and various mineral salts and trace elements present in the soil are dissolved. In the San Joaquin Valley, irrigation water adds 1.62–1.77 million tons of total dissolved solids to the region annually (San Joaquin Valley Drainage Program 1990). Water and dissolved solids are taken up by plants, but some water passes below the crop root zone and carries dissolved solids into deeper soils and groundwater. Depending on soil properties, the groundwater table may rise to the level of the root zone. Crop production is threatened when roots are flooded with saline water. Where the groundwater is very near the surface, evaporation and capillary action also can draw dissolved salts to the surface resulting in salinization of soils. Thus, depending on the elements involved, akalinity or salinity of soils and water increase. Increased salt levels in wetland systems compromise plant and invertebrate communities which in turn influence the numbers and types of vertebrates in the system.

One of the most insidious aspects of subsurface irrigation drain water is the mobilization of trace elements such as arsenic, boron, chromium, molybdenum, and/or selenium that potentially have toxic effects when they are present in elevated concentrations. This group of elements associated with marine sediments is present in the western portions of the San Joaquin Valley (U.S. Department of the Interior and California Resources Agency 1990). Irrigation water moving through fields in this region is particularly prone to incorporating these elements as part of the dissolved solids. Agriculture has taken two approaches to solve the problem of increased salinity in groundwater near the root zone. Either lands are abandoned when they have high salt concentrations or the drain water must be removed via drainage ditches or through a subsurface drainage system. This drain water usually is discharged into surface waters. Thus, these potentially toxic elements are common components of drain water in the western portion of the San Joaquin Valley. Such trace elements are then transferred in drain water through the irrigation infrastructure and can spread well beyond their point of origin. Because these elements influence plant and animal growth and mortality, their presence in the study area is a challenge that requires constant monitoring and regulation to prevent areas of trace element concentration that will severely impact native food chains.

Table 17. Summary of the effects of different land use impacts in the Grasslands Study Area

Land use impact	Effect on size of functional area	Functional corridors	Ecosystem function	Wildlife distribution	Hydrology	Wildlife life history events	Water quality
Agriculture	Major reduction in functional area	Disrupts riparian corridors	Destroys natural system; Fragments habitats	Reduces native populations; Discontinuous distribution	Increased runoff	Disrupts required habitats	Increased sedimentation, herbicides, pesticides, and fertilizers
Highways	Moderate/ small reduction in functional area	Establishes barrier in corridor for terrestrial and aquatic animals; Increases noxious plant dispersal	Fragments habitats	Promotes discontinuous distribution	Disrupts natural hydrology	Causes wildlife mortality	Oils, gas, rubber, garbage
Irrigation system	Moderate reduction in functional area	Disrupts corridor	Fragments native habitats	Separates populations	Changes flow patterns	Restricts movement and dispersion; May cause mortality	Drain water has salts, chemicals, and toxicants
Urban expansion	Moderate reduction in functional area	Disrupts corridors	Fragments habitats	Reduces populations	Increased runoff	Displaces populations	Increased sediments and toxicants
Rural housing expansion	Major reduction in functional area	Disrupts corridors	Fragments habitats	Disrupts distribution	Increased runoff	Displaces populations	Increased sediments and toxicants
Wastewater treatment facilities	Small reduction in functional area	N/A	Disease potential to wild animal populations	Often concentrates certain species	N/A	Concentrates birds, causes mortality	Increased nutrient loading
Domestic pets	N/A	N/A	Increased predation	Mortality of wildlife populations	N/A	Causes mortality; Disrupts activities	Pet waste increases nutrient load
Stormwater	Small reduction in functional area	N/A	Potential fragmentation	N/A	Increased runoff	N/A	Increased sediments and pollutants
Golf courses	Small reduction in functional area	Disrupts corridor	Destroys natural systems; Introduces exotics	Reduces native wildlife populations	Increased runoff	Compromises life history strategies	Increased fertilizer, herbicides, and pesticides

TRANSPORTATION

Roads are critically important for transportation of people, supplies, equipment, and commodities. The effects of transportation systems on open space and ecosystem function are similar regardless of whether the primary purpose of the road is for agricultural or urban uses. Agricultural development in western Merced County required a transportation system to interconnect farms and ranches with supply centers and markets. Furthermore, major highways also interconnect larger communities with other population and commercial centers in California. Open land within the study area has been converted from agricultural and natural systems to alternative uses for transportation including railroads, airports, and highways. The most extensive use of land for transportation has been for roads and highways. Because the construction of roadways is expensive and because roads often follow the most direct route, highways often pass directly through valuable agricultural lands or native habitats rather than circumventing such areas. This is the case in western Merced County because road systems cut directly through wetlands, riparian zones, native lands, and agricultural areas. Thus, some areas of habitat were lost from the construction of roads and road right-of-ways.

In addition to the loss of open areas, the development of road systems fragment landscapes. Roads often disrupt the natural hydrology by transferring water along road ditches, by intersecting drainages, and by forming obstructions to or changing the flow pattern of water where movement is a sheet flow (Table 17). In addition, roads often function as barriers to wildlife movement and can result in significant mortality of some species. The highest mortality often occurs during annual periods of dispersal from wintering habitats or during reproduction. However, frogs, toads, and turtles can be very susceptible to mortality during the breeding season. Likewise, some mammals are more active during periods when young disperse or during breeding. Sizable numbers become roadkills during such dispersal. Disturbance from roads also affects the distribution of species (van der Zande et al. 1980). Some birds move a mile or more from heavily traveled highways (Madsen 1985). Plant communities also are influenced by roadways, primarily because transportation corridors also serve as corridors for plant dispersal.

In western Merced County, there are primary roads within and surrounding the study area that influence the movements, mortality, and distribution of plants and animals. Divided highways require the largest land area and create the widest barrier to movements and disruption of hydrology. One of the primary impacts of road systems on natural environments is the division of large parcels into smaller ones. Primary roads such as I-5 and California highways 152, 165, and 99 have the most severe impacts because of the width of the right away, volume of traffic, and amount of noise and air pollution. California highways 152 and 165 effectively divide the study area into north and south and east and west sections, respectively. Thus, severe fragmentation of the study area is related to these transportation corridors that pass directly through the Grassland Study Area.

SUMMARY

A combination of factors related to agricultural activities and a gradual urbanization of western Merced County changed the pristine character of the landscape. Native plant and animal communities largely have been replaced by planted pasture and crops and only remnant plant and animal communities remain. No single factor led to these changes, rather many factors in combination have resulted in the present condition of the remaining natural communities. Agricultural development was not possible without a combination of economic incentives or opportunities, technological developments for irrigation by agricultural interests in a semiarid environment, government programs and subsidies, and a social perspective that promotes conversion of wildlands to other uses.

IMPACTS OF URBAN LAND USE ON NATIVE HABITATS IN WESTERN MERCED COUNTY

LOSS OF OPEN SPACE ASSOCIATED WITH HOUSING

The increasing human population within western Merced County can be classed into two general categories: urban and rural. As human populations expand, more space is required for housing. New housing associated with this population growth can be classed as either high or low density developments (Council on Environmental Quality 1974). Low density housing developments occur within some incorporated communities, but they are most common on small rural acreages and are becoming increasingly common within the rural setting of the study area.

Urban expansion associated with incorporated communities and/or housing developments also is common in western Merced County. New developments where large numbers of individuals are packed together are appearing on every side of the study area. Urban population growth in this report focuses on the communities of Los Banos, Volta, Santa Nella, Gustine, and Dos Palos (Table 18). In contrast, rural population growth is the diffuse expansion of new housing on larger land parcels among the agricultural lands in the county. Both types of population growth have important implications in reduction of open space and continuing fragmentation of existing habitats. Further encroachment can be expected with the growth in population in western Merced County. Communities in the Grasslands Study Area will grow and require more open space for this expansion

Rural Population Expansion

The effects of uncontrolled development of rural housing has severe impacts on natural systems because large areas of native plant and animal communities can be disrupted (Table 19). Likewise, rural housing can disrupt the agricultural environment and reduce open space and the value of agricultural habitats for wildlife. The expansion of rural housing is associated with individuals that enjoy country living either because they are in agribusiness and prefer to live on their properties, or have purchased parcels of a few acres. Individuals build houses and/or stables for horses, or some other type of stock, or they just enjoy having more property. As more rural housing develops, the infrastructure for transportation and utilities constantly expands or improves with a concurrent fragmentation and decrease of open space (Table 19). Considerable expansion of rural housing is occurring in the western portion of the study area between I-5 and lands within the Grasslands Study Area. Most development is immediately adjacent to developed roads where there is access to electric power. In some cases the developments are improvements to housing on agricultural lands. Such improvements are not changing the character of the fragmented landscape further (i.e., there is little or no additional conversion of agricultural lands for housing). The most troublesome expansion of rural housing in relation to reduction of open space and further landscape fragmentation in western Merced County is associated with the develop-

Table 18. Projected population increases for selected cities in Merced County, California (1990-2010).

City	1990	1995	2000	2005	2010
Dos Palos[1]	5,845	7,909	10,738	14,543	19,667
Gustine[2]	3,931	5,173	6,874	9,134	12,137
Los Banos[3]	14,060	17,110	20,810	25,320	30,810
Santa Nella[4]				1,150	
Atwater[4]				31,000	
Merced[4]				79,260	

[1] Merced County Association of Governments 1990. City of Dos Palos Draft General Plan. 146pp.

[2] Merced County Association of Governments 1992. City of Gustine, General Plan. 170pp.

[3] Grunwald and Associates. 1988. The comprehensive general plan for the city of Los Banos, California [4.0% rate of increase] Sacramento.

[4] Merced County Planning Department. 1990. Merced County year 2000 general plan, Merced County.

Table 19. Impacts associated with expansion of rural housing.

Impacts	Effects
Development of small parcels	Decrease in open space-habitat fragmentation
Construction site	Erosion and siltation from runoff
Access road construction	Erosion and siltation from runoff
Increase in imperious surfaces (roads)	Hydrologic changes - greater runoff
Increased traffic	Air pollution
Wastewater/septic systems	Ground and surface water pollution
Solid wastes and litter	Greater need for landfills
Domestic pets	Destruction of wildlife or disruption of life history events
Illegal hunting	Reduction in wildlife populations

From: Council of Environmental Quality, 1974.

ment of small parcels that were formerly in agricultural uses such as pasture, row crop, or orchard. In some cases these developments are on sites that had natural values because they were not in agricultural production or the lands had never been extensively developed.

Such developments disrupt remnant plant communities and wildlife populations either by direct loss or by modification of the local hydrology, increased sedimentation, or perturbations that increase the import of exotic species. The construction of rural housing and other buildings is associated with some road development, improved drainage systems, hydrological modifications to wetlands, development of facilities for treatment of human wastes (septic systems), construction of additional obstructions to wildlife movements (i.e., fences), and development of lawns with the associated application of herbicides and pesticides (Table 19). These unplanned sprawling developments also generate more sediments than well planned high density developments (Fig. 20). With the addition of each house there is increased vehicular traffic on roads and an increase in general disturbance related to human activities.

Urban Population Expansion

In comparison to rural housing, the effects of urban housing on the study area are more severe at site specific locations, but the size of the impact area is smaller. Urban development has many of the same problems as rural development, but the problems are intensified. Within the study area, current and planned urban developments generally change open space from an agricultural setting to one that more completely restricts use or access by wildlife. Thus, the location of the housing developments in and near the study area is critical because of site-specific and associated effects of development in relation to the functions and values of the natural system. Sedimentation can be extensive (Ferguson 1978; Fig. 20) when vegetation is disrupted and is of concern near wetlands because water systems can be clogged, wetlands filled, and wetland functions compromised. There will be negative effects to natural systems regardless of where the development occurs but the effects will be less severe as distance between developments and the study area increases. Continuing development of urban areas within and surrounding the Grasslands Study Area will have increasing implications for the viability of the Grasslands ecosystem (Table 20). Los Banos is the most critical site because of its size, location

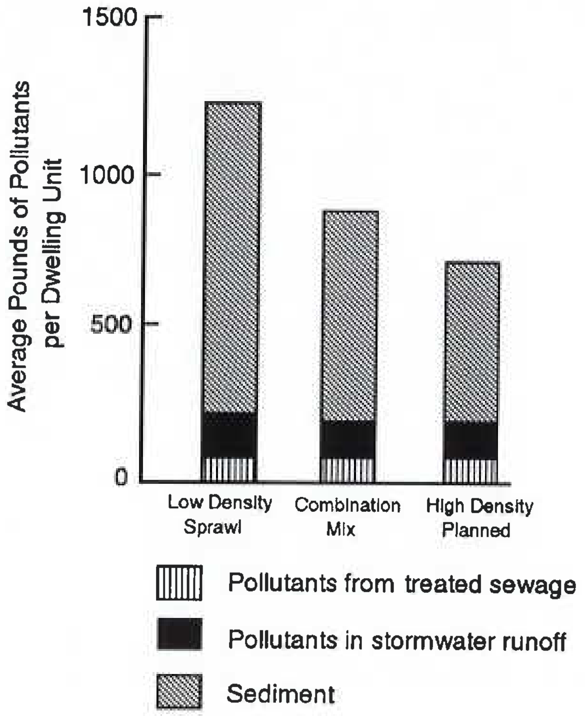

Fig. 20. Pollutants generated from dwellings of different densities.

Table 20. Projected effects of urban expansion in the Grasslands Study Area of western Merced County.

City	Proximity to wetland habitat	Size of development	Corridor expansion	Projected population growth	Collective encroachment
Los Banos	+++	+++	+++	+++	+++
Dos Palos	+++	++	+	++	++
Volta	+++	+	+	+	+
Santa Nella	++	++	+	++	+
Gustine	+++	++	+	+	++
Atwater	+	+++	+	+++	+++
Merced	+	+++	+	+++	+++

immediately adjacent to Grasslands habitats, and the size and location of existing corridors.

TRANSPORTATION

Highways have been discussed under agricultural developments but transportation corridors are critically important for urban areas. Thus, the locations of urban developments that require road access have important implications in relation to functions and values of natural habitats.

WASTEWATER

Municipalities in western Merced County use effluent lagoons to treat wastewater. Several facilities are located adjacent to or within the Grasslands Study Area, but the communities of Los Banos, Gustine, and Dos Palos have the most significant treatment facilities (Fig. 21). Impacts are related to changes in habitat conditions or to conditions related to operations of the treatment facility. In some cases wetland habitats or important open space for wildlife are converted to treat-

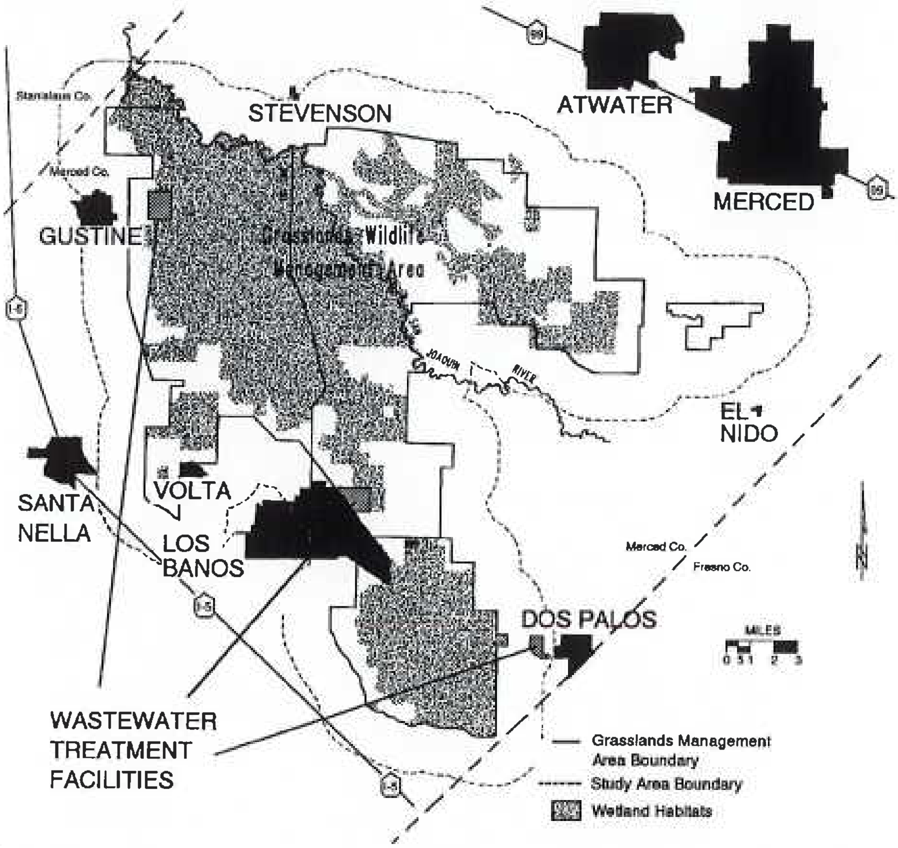

Fig. 21. Location of wastewater treatment facilities within and near the Grasslands Study Area.

ment facilities. Depending on the size, location, operation, juxtaposition to other habitats, local rainfall, and rates of evapotranspiration, operation of wastewater treatment facilities may have beneficial and/or negative impacts on wetland wildlife (Brennan 1985, Wilhelm et al. 1989).

Within the study area, much of the effluent that enters the treatment facility remains within the lagoons because evaporation rates are high in the San Joaquin Valley. Discharge into surface waters is restricted, and excess water is typically applied to pastureland during the irrigation season (Brown and Caldwell Consulting Engineers 1989). The discharge of excess water laden with toxic materials, heavy metals, chlorine, or materials with high organic matter or Biological Oxygen Demands (BOD) often associated with urban effluent normally is limited to lands owned by municipalities in Merced County. Thus, wastewater treatment on the study area has limited negative impacts for wildlife compared to other areas of the country where the combination of higher rainfall and lower evaporation requires that considerable water be discharged (with the undesirable components) into surface waters to prevent damage to lagoons by uncontrolled overflows.

The potential value of wastewater facilities and use of wastewater for wetland wildlife has been identified for many years (Uhler 1956). Uhler discovered that waterfowl use of wastewater lagoons was widespread throughout many parts of the U.S. A great abundance of some invertebrates has been identified as an important attractant for some waterbirds (Swanson 1977), and some treatment facilities have high densities of important invertebrate foods. Wastewater habitats are used by many waterbirds throughout the annual cycle (Uhler 1956, 1964, Swanson 1977).

Heavy use of wastewater facilities by waterbirds occurs in the study area in winter. Large aggregations of waterfowl occur regularly on the Los Banos and Dos Palos treatment facilities. Use of these treatment facilities probably is related to a combination of factors including extensive disturbance on wetland habitats during the hunting season, the security provided by the sanctuary effect of the treatment facility (little disturbance), and the abundance of certain food resources. Species that filter feed (northern shoveler) or feed on algae (gadwall, coot) tend to be the most abundant.

The concentration of waterfowl on treatment lagoons has negative impacts including the redistribution of waterfowl, and the potential for disease transmission. The most obvious and important impact of wastewater treatment in the study area is the concentration and redistribution of highly mobile vertebrates such as birds and the potential for avian diseases to be spread from these concentration areas. The treatment facilities in the study areas are of sufficient size to attract and hold sizable numbers of waterfowl (over 200,000 waterbirds, including 160,000 shovelers have been counted on the Los Banos treatment facility; California Fish and Game files, 1994).

Dense aggregations of waterbirds on wastewater lagoons have the potential for disease transmission (Friend 1985). Potential disease problems tend to be more severe from agricultural wastewater (especially poultry) than from urban wastes. Nevertheless, the lower water quality in wastewater systems in combination with the potential presence of pathogens has resulted in avian mortality in the San Joaquin Valley at the Modesto treatment facility (Zahm pers. comm.). Avian cholera is of primary concern because of the history of the disease in the Central Valley (Titche 1979, Friend 1989).

STORMWATER

Stormwater runoff from urban areas includes many pollutants that have accumulated from industrial, commercial, and residential developments (Environmental Protection Agency 1977). The amount of stormwater runoff is related to the area of impermeable surfaces such as roofs, driveways, roads, and parking lots (Huff 1977). The most common polluting materials from hard surfaces that occur in stormwater or from street washing are rubbish, oil, gasoline, rubber, salts, and animal feces (Council on Environmental Quality 1974, Shaheen 1975). Sediments are another important component of stormwater and are particularly abundant from construction sites or from exposed soils that are subject to erosion (Ferguson 1978, Fig. 23). Herbicides, pesticides, and fertilizers are used heavily on residential lawns and gardens to protect or control household pests such as termites and other noxious plants, insects, or vertebrates (Environmental Protection Agency 1972). Rainfall removes air pollutants such as nitrates and sulfates from combustion which produces acidic water conditions. These contributions to stormwater can contribute as much pollutant load as the sanitary sewage effluent (U.S. Department of the Interior 1970).

AIR POLLUTION

Air pollution is governed by two major factors: the presence of pollution generating sources and the inherent or modified meteorological conditions of the region. The region's meteorology determines the extent to which pollutants are imported from other regions and the extent to which locally produced pollutants are dispersed (Council on Environmental Quality 1974). Pollution sources generally are defined as point sources (e.g., a smoke stack from an industrial plant), ribbon sources (from highways), or dispersed sources (dispersed traffic, home furnaces and fireplaces). The major types of air pollutants are carbon monoxide, nitric oxides and oxidants, and sulfur particles and oxides. Vehicles emit carbon monoxide and the nitric oxides that chemically react in the atmosphere to form smog, whereas sulfur compounds are emitted primarily from fossil fuel plants, home and industrial furnaces, and certain industrial processes and incinerators.

The extent of air pollution from vehicle traffic is related to the amount of travel, amount of congestion, and average length of a trip. Air pollution from vehicles varies during the day and generally is more severe in the morning when engines are cold, air is more static, and congestion is more severe as workers travel to their place of employment (Maya 1967). Thus, the development pattern in western Merced County can have an important influence on the frequency of travel and distances traveled. Because congestion is such an important aspect of air pollution from vehicles, providing even traffic flow on major roads by eliminating interruptions----frequent access to the road from stores and homes, stop signs, and poorly timed stop lights----is of great importance. Providing clustered and convient commercial areas and public facilities also eliminates the amount of travel (Voorhees and Associates 1971).

DOMESTIC PETS

Domestic pets are an integral part of the environmental dynamics associated with human populations (Beck 1973). Regardless of whether pets are controlled or are free roaming, they can have an important influence on wildlife populations and their wastes have important implications in stormwater runoff. Thus, as human populations change in size and distribution, populations of domestic pets must be one of the aspects considered in land use impacts.

Domestic pets also cause direct mortality of wildlife or disrupt life cycle events that reduce natality of wild populations (McMurray and Sperry 1941, Eberhard 1954, Parmalee 1953, Toner 1956). Free roaming pets are of the greatest concern and cause the most interference with wildlife populations. Even in places where dogs are required to be on a leash a certain proportion run free. On a wetland in Britain, as many as 60% of the dogs were not on leashes and, of this total, 8% were running wild (Yalden and Yalden 1988). Dogs out of control, compared to those "at heel," caused seven times more red grouse to be disturbed (Hudson 1938). Thus, wildlife populations within the free roaming distances of urban pets are subject to high disturbance and mortality.

MOSQUITO ABATEMENT

Human populations have a long history of conflict with annoying insects that are associated with natural ecosystems. Mosquitoes are often abundant in wetland systems and are of concern to humans because they are vectors for transmission of human (e.g., malaria) and livestock (e.g., encephalitis) diseases. In addition, an abundance of mosquitoes is annoying to most individuals whether or not disease is a consideration. Thus, control of mosquito populations in the vicinity of urban areas has been practiced in the U.S. for many years. Control is achieved by habitat modification (drainage or level ditching of wetlands), by changes in water management (e.g., open water management), with chemicals, with biological control, or with a combination of these techniques. As human populations grow and as population distribution changes, there is an increasing demand to control mosquito populations.

Techniques used to control mosquitoes often are in direct conflict with the presence of wetlands and their natural functions. Drainage and/or hydrological modifications to wetland habitats change plant and invertebrate communities that in turn influence other components in the system. Water management for mosquito control may compromise the life cycle of invertebrates that play a role in decomposition or are important food for wetland wildlife (Balling et al. 1980). Availability of foods or habitats may also be compromised by water management designed for mosquito control. Nonselective chemicals can kill important invertebrate food sources and thus reduce the reproductive or survival potential of vertebrates.

The projected population increase for Merced County suggests that increasing pressure to control mosquitoes can be expected. The area of control and the type of control will have an important influence on the natural functions and values of Grasslands wetlands.

Mosquito control is a factor in the management of Grasslands habitats and will become increasingly important as the human population grows. From 1992 to 1994 there were nearly 1,000 requests for mosquito abatement in the North and South Grasslands (Table 21). About the same number of requests came from north and south of California Highway 152. Requests for control begin in April and gradually increase over the course of the growing season, with the greatest number of requests occurring in October (Table 21). The Merced County Mosquito Abatement District applies Altosid Liquid Larvicide (ALL) and Duplex (ALL + *Bacillus thuringienses* var. *israelensis*) in aerial applications to Grasslands habitats from August to October. The first application of ALL occurs during flood-up, whereas the final treatment of Duplex is applied just before the hunting season in October. The final treatment on flooded wetlands controls *Culex tarsalis* and late *Aedes* hatches.

The use of chemicals in wetlands, regardless of the purpose, is always of concern because of the potential to compromise the values and functions of these important habitats. This is especially true where habitats are limited and are subjected to other perturbations in addition to the effects of chemicals. Historically, the use of nontarget chemicals in wetlands was disastrous because many desired species were impacted along with the noxious organisms. When biomagnification occurred in the food chain, organisms near the top of the food web often were affected adversely. As environmental concerns became more prominent, manufacturers have made an effort to develop chemical or biological controls that are effective on problem organisms but have little or no effect on desirable organisms. Not only have chemicals become much more target specific, but their biomagnification in food chains has been reduced or eliminated. Although these newer control methods are far superior there is still concern for the effects on vertebrates because of disruptions in the food chain. For example, in experiments mallard ducklings had slower growth and higher mobility (i.e., apparently they had to search for more food) immediately after treatment (Cooper et al. 1989).

Table 21. Abatement requests made from 1992-94. North and South Grasslands are separated by Highway 152.

Month	North Grasslands	South Grasslands	Total
April	5	10	15
May	29	20	49
June	59	32	91
July	27	29	56
August	60	36	86
September	66	115	181
October	200	257	457
Total	446	499	945

One commonly used biological approach for mosquito control in Merced County is use of *Bacillus thuringiensis* (Bti), a potent bacterial larvicide. Toxicity is limited to nematocerous dipteran families, including mosquitoes (Culicidae) and blackflies (Simuliidae) (Kreig and Langenbruch 1981). The activity of Bti is dependent on the action of proteolytic enzymes within the gut. Because digestibility declines with age, older instars may be less susceptible (Maddox 1975). Abbott Laboratories provides a list of nontarget aquatic organisms found in association with mosquito larvae but are not affected by Bti (serotype H-14). The list includes amphibians, fish, crustaceans, insects, flatworms, earthworms, and mollusks (Abbott Laboratories 1992). A study in the Midwest compared field and laboratory results using Vectobac-G or Bti, (serotype H-14, Charbonneau et al. 1994). In the laboratory, field treatment levels affected *Chironomus riparius*, but there were not discernible effects on this chironomid in field tests. These results as well as other literature indicate that toxicity of Vectobac-G can vary. In this Minnesota study temperature, water depth, macrophyte surface area coverage, and instar differences affected the efficacy of

Vectobac-G to benthic organisms (Charbonneau et al. 1994). Factors such as algal mats (Garcia et al. 1983), foraging by snails and other organisms (Aly 1983), and adhesion to leaves all influence the effectiveness of Vectobac-G. The effects of temperature are related to feeding rates (i.e., more feeding and thus greater ingestion of control agents when temperatures are high, Wraight et al. 1981, Farghal 1982).

Information on Altosid or methoprene (Zoecon 1990) provides results from different tests (e.g., acute and subacute oral, acute dermal, reproductive, teratology) conducted to determine the effects of Altosid on different organisms, including rat, dog, rabbit, guinea pig, mallard, bobwhite, and chicken. No environmental persistence (half-life of 10 days or less) has been identified and no toxic effects have been observed in the field. Such testing is costly, cannot cover all species, and certainly cannot address the complex conditions that exist in wetlands. Thus, the testing provides guidance in understanding the actions of the chemicals or biological control in nature, but actual results from field use can be highly variable. For example, water depth, temperature, pH, turbidity, amount and type of aquatic vegetation, and substrate type are just a few factors that may change the effects predicted from laboratory experiments. These variables may cause the control agent to work more effectively or less effectively in relation to laboratory tests with similar variability in the response by nontarget organisms to control agents. Furthermore the method of application is an important variable determining the effectiveness of control or the effects on nontarget organisms. In addition to the effects of chemicals, the method of application can have important implications. For example, aerial application on flooded wetlands causes disturbances that have unknown effects on wetland wildlife. In contrast granulated material with slow release can be applied before flooding.

In summary, mosquito abatement strategies that reduce conflicts with wetland functions and values in the Grasslands will be an increasing challenge as human populations increase and encroach on wetland habitat. Unfortunately some of the effective control strategies for mosquitoes that do not include chemical or biological control agents, conflict with management designed to emulate natural hydrological regimes in seasonally flooded wetlands that are critical to the success and survival of wetland wildlife. Shallow water interspersed with vegetation provides the ideal habitat for invertebrate production as well as the desired foraging habitat for the majority of wetland birds. Because shallow water in association with vegetation creates ideal conditions for some mosquitoes, conflicts are inevitable. Thus, close communication, cooperation, and coordination of efforts between mosquito abatement and wetland management interests are essential to reduce conflicts while meeting conflicting goals.

IMPORTANCE OF UNDERSTANDING HABITAT FRAGMENTATION AND ITS EFFECTS

The combination of factors related to human activities and land use in western Merced County now and in the future will impact the size, fragmentation, function, and value of Grasslands wetlands.

SIZE

As the population of Merced County grows, the projected population of 260,000 by the year 2000 will create an increasing demand for space that will be met by conversion of agricultural or native habitats to urban uses (Spalding and Heady 1977). Pressures that result in decreasing size of functional habitats are greatest immediately surrounding the cities and towns in the Grasslands. As the size of a natural area diminishes, there is an important impact on the number of individuals and number of species that can survive within the smaller area of habitat (Geiss 1974, Adams and Dove 1989; Fig. 22). The largest animals remaining in remnant habitats are those with the highest potential to be extirpated or to have reductions in populations.

FRAGMENTATION

Developments associated with urbanization have high potential to further fragment the remaining habitats. Increase in traffic will require upgrading highways and development of more transportation arteries. The current highway system, in conjunction with the irrigation infrastructure, already has an important impact on the functions and values of the natural system. The interconnection of habitats of the pristine valley has been disrupted by the transportation and irrigation corridors and other land use developments. Currently wetland functions largely are restricted to smaller parcels compared to the pristine condition. Fragmentation has important impacts for animals that require a large habitat area or those that have restricted mobility. The large carnivores and herbivores were eliminated from the Grasslands ecosystem many years ago, but a continuing decrease in the size of habitat parcels because of fragmentation influences small carnivores and other moderate sized animals (Fig.

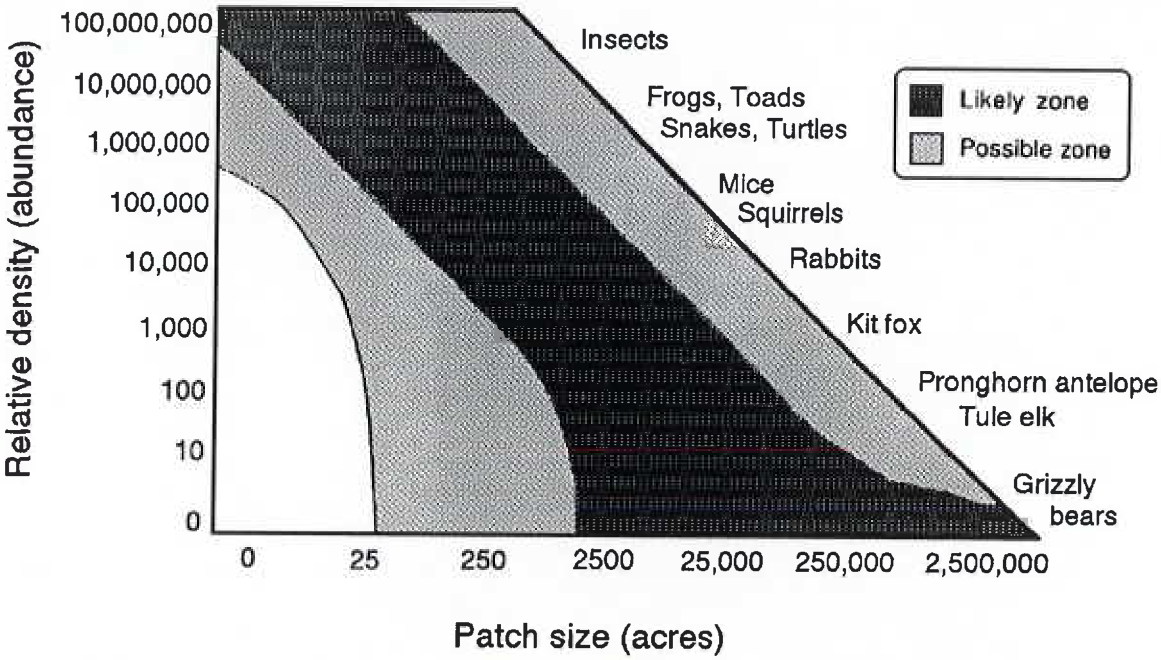

Fig. 22. Area of habitat required for the successful survival of different animal groups. From Soule 1991.

22). Birds have high mobility and can more easily move among isolated parcels. These movements increase energetic costs. Other factors associated with human population growth such as disturbance of wildlife, degradation of habitats, and mortality of wildlife tend to decrease population size or compromise reproductive potential of wild populations.

Although the 180,000 acres in the study area appears to be huge, the actual functional area for many species is greatly reduced because of existing roads and towns. Clearly species with large home ranges have very few areas of suitable size for survival. Thus, a few additional activities resulting in fragmentation will impact many more species.

The impacts of size and fragmentation have important implications on the survival and reproductive potential of any species. The effects of fragmentation and decreasing habitat area are projected for waterfowl in western Merced County because waterfowl are of great interest in the study area and so much is known about waterfowl compared to other waterbirds (Table 22). Some effects are obvious, but many others are indirect or subtle and tend to gradually decrease habitat values for waterfowl. Thus the potential exists to further reduce waterfowl populations.

Table 22. Potential effects of fragmentation and reduced habitat size on the timing and/or completion of annual cycle events of a typical female dabbling or diving duck.

Life cycle event	Fragmented habitat	Degraded habitat	Reduced area of habitat
Pair formation	Less seclusion; Pairing delayed; Disturbance forces flight to alternate habitat	Required cover for pairing inadequate; Inadequate foods to gain necessary body mass for pairing	Some pairing delayed; Body condition inadequate for pairing
Winter molt	Inadequate area for seclusion; Disturbance disrupts foraging; Molt delayed	Deficient food supply; Molt delayed	Smaller food supply; Molt delayed
Predeparture reserve deposition	Food supply distributed over large area; Flight time reduces amount of energy for reserves; Inadequate body reserves for migration	Deficient food supply; Inadequate body reserves for migration	Smaller food supply; Inadequate body reserves for migration
Prebreeding	Small patches of nesting cover, more predation likely	Lack of nesting cover; Poor food resources	Reduced area for breeding; More predation likely; Poor food resources
Egg laying	Food resources widely scattered; More predation likely	Poor food resources; More predation likely	More nest interference; More predation likely
Incubation	High predation; Female mortality	High predation; Female mortality	High predation; Female mortality
Brood rearing	High mortality from movements between habitat patches	Reduced food supply; High mortality	Smaller food supply; Predation higher than on larger areas
Summer molt	Inadequate area for seclusion; Disturbace disrupts foraging	Reduced food supply; Poor cover; Molt delayed	Smaller food supply; More predation
Fall staging	Smaller area for food production	Reduced food supply	Smaller food supply; Molt delayed

NUTRIENT ENRICHMENT AND TOXIC SUBSTANCES

Chemicals from agricultural activities that enter surface or groundwater influence the functions of wetland systems (Table 23). Agricultural chemicals have differing effects depending on the amount and type. Fertilizers that enter surface waters can cause eutrophication. The increase in algae production related to an abundance of available nutrients from agricultural fertilizers or runoff from livestock operations can change wetland plant and invertebrate communities. Depletion of oxygen from wetlands can change invertebrate communities, influence plant community composition and structure, and kill aquatic organisms such as fish.

The most common toxic materials in the Grasslands are herbicides, pesticides, and trace elements. Herbicides may have direct effects on plant communities, but indirect effects may influence animal communities as well. Herbicides can control the structure of wetland communities, reduce diversity, and disrupt the food chain for invertebrates as well as some vertebrates. Algae are an important component in wetlands because they quickly tie up available nutrients, are important in the decomposition process, and serve as food for invertebrates. Herbicides can compromise this important component of the food chain and result in a greatly modified trophic pyramid.

Pesticides from agriculture, urban household uses, and mosquito abatement programs have the potential to be toxic to aquatic organisms. Aquatic organisms have varying degrees of sensitivity to different chemicals. In some cases a certain chemical may have no direct impact on aquatic organisms. In other cases numbers of aquatic organisms may be reduced and in the most severe situations certain organisms may be completely removed from the system. Changes in the food chain are not readily visible because the physical structure of the wetland appears unchanged.

Trace elements have the potential to be toxic to consumers higher in the food chain. Elements such as selenium and arsenic can cause mortality or disrupt reproduction by increasing mortality or causing deformities.

DOMESTIC PETS

Domestic pets are one of the external biotic factors that influence wetland functions. Their most important influence on wetland communities is the potential to increase predation on adults and young and to disrupt life cycle events such as pair formation, egg laying, brood rearing, or dispersal (Table 23). The proximity of urban developments to native habitats is critical in relation to the severity of the effects on wild populations. The number of cats and dogs will increase along with the human population as Merced County becomes more urban. Thus, as the interface between urban sites and the Grasslands expands, domestic pets likely will increase. With more domestic pets, disturbance to wildlife will increase. This disturbance will increase energetic costs or compromise life history events for wildlife. In the worst cases, actual mortality of wildlife will occur.

GENERAL DISTURBANCE ASSOCIATED WITH HUMAN ACTIVITIES

Human activities intrude into wildlife habitats or disrupt life cycle events (Fig. 23, Table 23). The greater the human population the greater the potential for activities that will affect wildlife directly or indirectly. Some of the most obvious effects are related to activities such as hunting where some animals are harvested but a much larger number are forced to change their local distribution or move to more distant habitats. Other direct effects occur from disturbance (Korschgen and Dahlgren 1992). Depending on the time of year or stage in the annual cycle, disturbance may have a significant impact on wildlife populations. Disturbance might cause a redistribution of the population, emigration from the disturbed area, reduced time to acquire critical energy or nutrients, disrupted courtship, or reproductive failures (Owens 1977; Table 23). In areas of the highest use even trampling of vegetation can be a problem requiring years for recovery (Liddle 1975).

Table 23. Potential effects of land use practices on wetland functions and values in western Merced County.

			Biotic				
	Abiotic		Plants				
Land use activity	Hydrology	Water quality	Algae	Macrophytes	Invertebrates	Herps	Birds
Agriculture							
Irrigation water storage	Changes timing and volume of flow	—	Area and volume of flooding reduced	Volume and area of flooding reduced	Less habitat flooded	Less habitat flooded	Less habitat flooded
Irrigation canals	Change flow patterns	Transport salts and trace elements	—	—	—	—	—
Irrigation drain water	—	Concentrates salt and trace elements	Reduced biomass	Modified composition	Mortality	Mortality; Deformities	Mortality; Deformities
Herbicides	—	Add nonpoint pollution	Reduced biomass	Reduced biomass and structure	—	—	—
Pesticides	—	Add nonpoint pollution	—	—	Mortality	Mortality	Mortality
Fertilizers	—	Lead to eutrophication	Increased biomass; Reduced species richness	Increased biomass; Reduced species richness	Reduced species richness	—	—
Cultivation	Changes flow patterns	Increases sediments and pollutants	Reduced species richness	Reduced species richness	Smaller populations; Reduced species richness	Smaller populations; Reduced species richness	Smaller populations; Reduced species richness
Transportation	Disrupts flow patterns	Increases pollutants and sediments	Reduced species richness	Reduced species richness	Reduced species richness	Mortality; Disrupts movements	Mortality
Urban							
Stormwater	Changes flow patterns	Increases pollutants	—	—	—	—	—
Wastewater	—	Increases pollutants in discharged water	Increased biomass; Reduced species richness	—	—	—	Concentrates birds; Exposure to pathogens
Domestic pets	—	Wastes increase pollution	—	—	—	Mortality	Mortality; Disrupt life cycle events
Expansion	Changes flow pattern	Increased pollution: streets, lawns, household, and industry	Reduced species richness and biomass	Reduced species richness and biomass	—	—	—
General disturbance	—	—	—	Trampling	—	Disrupts life cycle events	Disrupts life cycle events

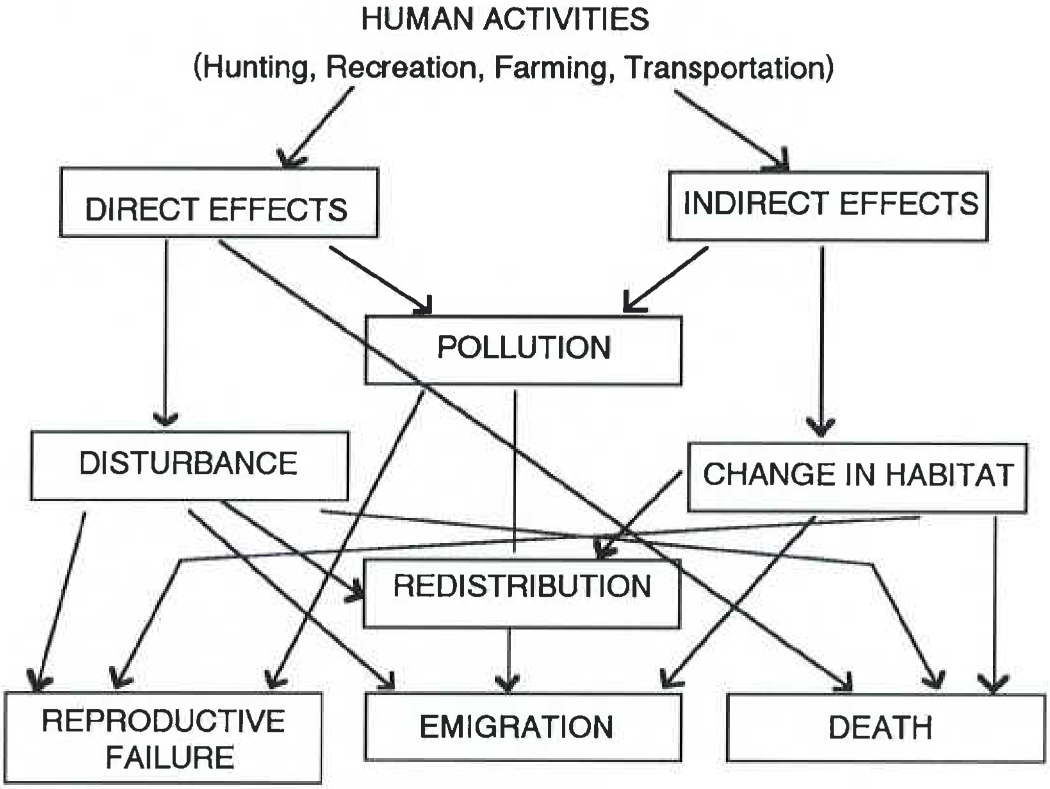

Fig. 23. Potential effects of human activities on wildlife populations.

GENERAL STRATEGY

The area and quality of Grasslands habitats have declined significantly over the past 200 years. This decline, as well as major changes in plant and wildlife communities that have occurred, did **NOT** result from a single factor but from a complex combination of factors driven by economics, legislative and political decisions, technology, and cultural or social implications (Fig. 24). Consequently, protection of remnant habitats requires more than a single faceted approach if future generations are to enjoy this remnant wetland ecosystem (Caldwell 1993, Froke 1986). Creative methods must be developed that incorporate economic potentials, current and future technologies, and social factors inherent to the area. This process has started and is clear from the shift in legislation from exploitative to protective mandates (Tables 3, 4, and 5). Additional efforts should include the identification and implementation of economic incentives, development of additional legislation, continued purchase and/or easements of important habitats, promoting changes in farm products, and educating the public regarding the importance of Grasslands habitats.

FUNCTIONAL SIZE

The size of the Grasslands ecosystem must be protected. Size is one of the critical factors that determines whether a species has the space necessary to meet life history requirements. In addition, the type and diversity of habitats, whether natural or agricultural, are critical components when determining the required size of an area. The relationship between habitat size and survival for each organism inhabiting the Grassland Study Area has not been established, but a clear relationship exists between the size of an organism and size of the home range essential for survival of a viable population (Fig. 22). Even though the Grassland Study Area encompasses nearly 180,000 acres, this is a minor fraction (4.5%) of the 4 million acres of

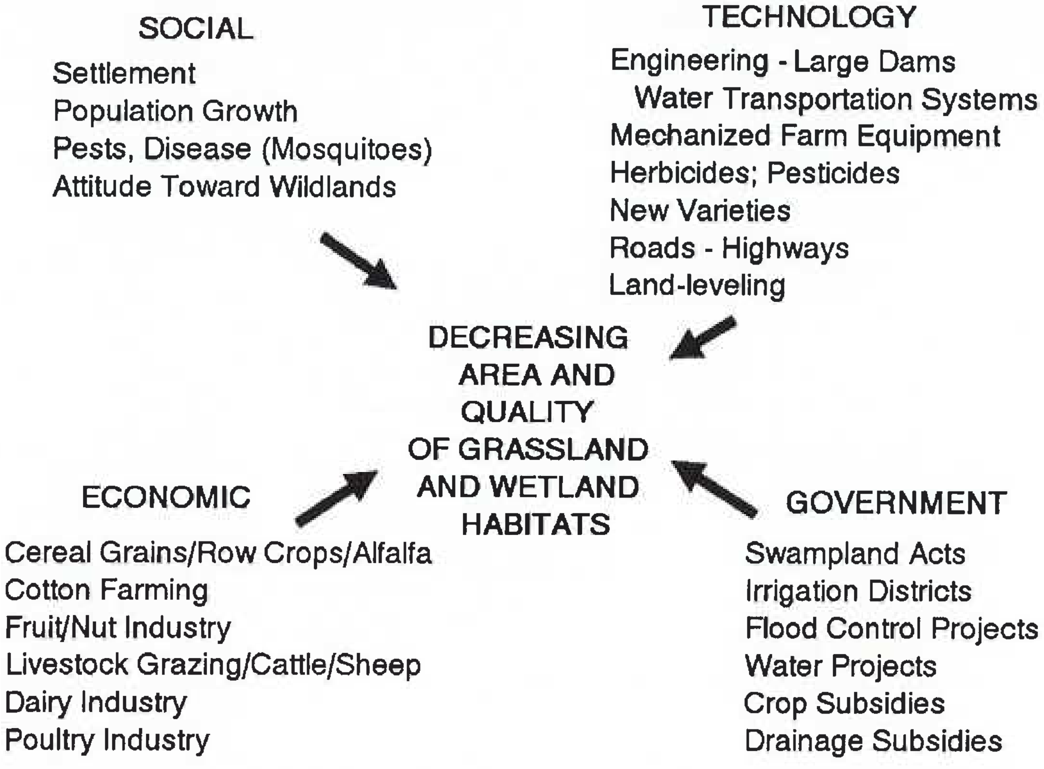

Fig. 24. Factors influencing the land use and the amount and quality of native habitats in western Merced County.

wetland habitat that once was present in the Central Valley.

The challenge of providing habitat area requirements in the Grasslands is similar to the conditions surrounding urban areas across the U.S. Historically, disturbed sites were surrounded by large areas of native habitats. In contrast, current landscapes are characterized by small areas of remnant habitats in the midst of disrupted environments. Consequently, non-preserve lands or those not in public ownership are as important as parks and preserves for maintaining biodiversity and ecosystem functions (Norse et al. 1986, Wilcove 1988). In many cases, however, the combined land base remains small relative to the area requirements of all species composing an ecosystem. Thus, consideration must be given to the types of benefits that can be effectively and reliably provided for certain species, while realizing that efforts to assure the viability of certain populations will likely create conditions that will compromise the survival of others (Samson and Knopf 1982, Scott et al. 1991).

One of the greatest values of the Grasslands Study Area is that it is the single largest block of wetland habitat remaining in the state of California and accounts for about one-third of all wetlands remaining in the entire Central Valley. Furthermore, the Grasslands represent the most important habitats in the San Joaquin Valley, accounting for about 75% of the remaining wetland habitat. If this habitat were to diminish in size or be further degraded, the impacts would influence not only the local area but also have a profound impact on all the migratory species that use the Grasslands as a southern terminus during their annual cycle, exploit Grasslands resources during their annual movements between their wintering and breeding grounds, or depend on these habitats for breeding.

CONTROL FRAGMENTATION

Even though the study area represents the largest remaining contiguous block of wetland habitat in the Central Valley, the existing habitat is highly fragmented. Every effort should be made to control any additional developments within the Grassland Study Area that will result in further fragmentation. Expansion of transportation corridors; development of new roads; construction of new electric transmission lines; and expansion of wastewater treatment facilities, golf courses, and urban areas are only a few examples of developments that contribute to a continuation of fragmentation. Foremost among the factors that determine the effects of fragmentation is the connectivity of biological processes (Noss 1991). Preserving the size of all remaining habitats is critical because as habitats are fragmented and isolated, biological processes are disrupted and interacting functional components of the larger system are degraded. Thus, the location and area of habitat impacted by such developments should be considered carefully in the planning process.

EXPANSION OF PUBLIC LANDS AND EASEMENTS

The importance of Grasslands habitats to California, the Pacific Flyway, and the Nation should be used to justify the necessity of acquisition strategies to assure protection of all wetland types, develop reserves of adequate size to protect target populations, and promote the development of habitat corridors to link properties administered by state, private, and federal organizations. Expansion of state or federal ownership of key habitats and/or corridors important to maintaining wetland functions and values in the Grassland Study Area should continue.

Easements have been and will continue to be a valuable tool for protecting the Grasslands. The focus of current and historic easement efforts has been to secure a core area of wetland habitats. This strategy can be embellished in two ways. The first requires advanced planning to secure areas that connect existing habitats and ensure the integrity of biological processes. The second strategy requires integrating programs and goals with the private sector to create a buffer zone of open lands surrounding the Grasslands Wildlife Management Area. Developing such cooperative ventures with the private sector is the essence of the theme suggested by and Wilcove (1988). Careful planning allows private individuals to continue meeting economic objectives but within a framework that maximizes wetland and wildlife benefits.

RECOGNITION OF GRASSLANDS HABITATS AS IMPORTANT RESERVES

The unique nature of the Grasslands habitats are of sufficient significance that recognition of this area as a special reserve is worthy of investigation. The Ramsar Convention identifies wetlands of international importance. Efforts should be made to determine the feasibility for adding the Grasslands as a Ramsar Wetland. Identification of other programs that may contribute to increased recognition or protection of the Grasslands region also should be explored.

AREA OF CRITICAL IMPORTANCE

The area of critical importance must be one that allows natural processes to continue with minimal interference and to prevent conflicting management from disrupting farm, commercial, urban, or wetland management. Protection of natural corridors and land surrounding the Grassland Study Area, prevention of additional hydrologic changes, and reducing management conflicts between different sectors within this core area are critical to maintaining system integrity. Clearly, protection of the core area of wetland habitats should continue as the focus of local easement and land protection programs. Promoting connectivity of habitats will increase the value of this program.

WETLAND MANAGEMENT

The development of agriculture was the primary reason for the loss and conversion of wetland habitats in the Grasslands Study Area. Nationwide, intensive management on federal, state, and private wetlands has been recognized as providing important habitats for wetland wildlife (Kadlec and Smith 1992, Kaminski and Weller 1992). Although current wetland distribution differs from historic conditions, modern landscapes are dominated by a different proportion of wetland types, and current functions and values are different from pristine conditions. Existing wetlands are critical for wetland wildlife within Merced County and in the Pacific Flyway. Although management activities can be disruptive to hydrological regimes or provide benefits for some species while compromising conditions for other species, the strategies used in intensive management are necessary to maintaining values and functions that relate to biodiversity (Fredrickson and Reid 1986, 1990, Laubhan and Fredrickson 1993, Fredrickson and Laubhan 1994b). As new opportunities with additional lands and programs are implemented, as new information is generated, and as the status of plant and animal species change, changes must be made in the strategies used in wetland management (Fig. 25). Management of every site in North America likely can be improved and the Grasslands are no exception. The judicious development and modification of wetlands, the use of substrate manipulations, and the effective use of water in intensive wetland management are all part of the bigger picture to maintain the functions and values of remnant wetlands. These actions must be well planned and implemented to maximize the potential of this important remnant wetland complex in the San Joaquin Valley.

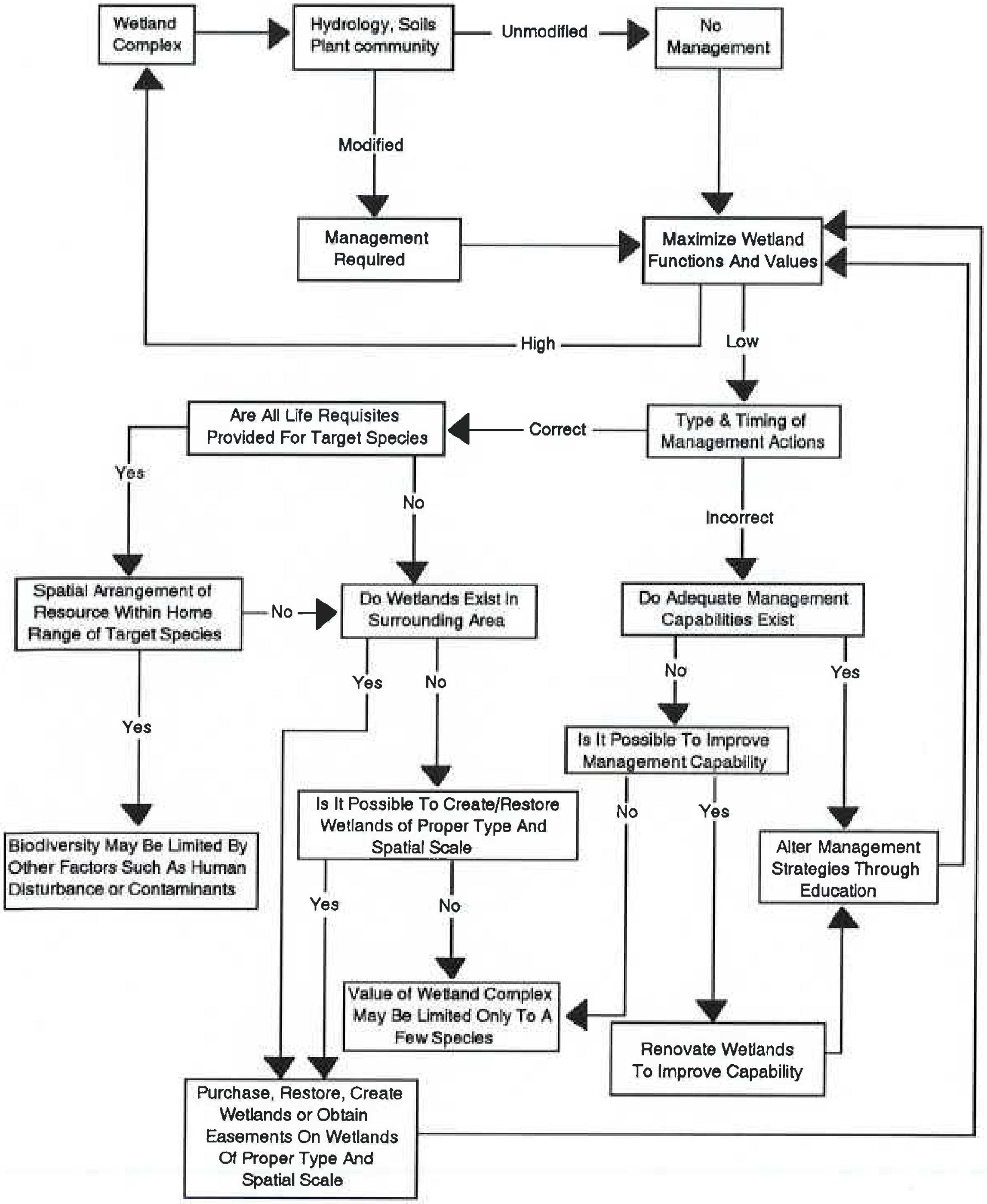

Fig. 25. Considerations required to make wise management decisions in man-modified landscapes.

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APPENDIX 1. SCIENTIFIC NAMES OF BIRDS NOT APPEARING IN THE TEXT (*Listing in taxanomic order*)

Pied-billed grebe, *Pdilymbus podiceps*
Western grebe, *Aechmophorus occidentalis*
American bittern, *Botaurus lentiginosa*
Great egret, *Casmerodius albus*
Snowy egret, *Egretta thula*
Green-winged teal, *Anas crecca*
Blue-winged teal, *Anas discors*
Northern shoveler, *Anas clypeata*
American wigeon, *Anas americana*
Canvasback, *Aythya valisneria*
Ring-necked duck, *Aythya collaris*
Turkey vulture, *Cathartes aura*
White-tailed kite, *Elanus caeruleus*
Red-shouldered hawk, *Buteo lineatus*
Red-tailed hawk, *Buteo jamaicensis*
Rough-legged hawk, *Buteo lagopus*
American kestrel, *Falco aparvirius*
Ring-necked pheasant, *Phasinus colchicus*
California quail, *Callipepla californica*
Lesser sandhill crane, *Grus canadensis*
Black-bellied plover, *Pluvialis squatarola*
Semi-palmated plover, *Charadrius semipalmatus*
Greater yellowlegs, *Tringa melanoleuca*
Lesser yellowlegs, *Tringa flavipes*
Solitary sandpiper, *Tringa solitaria*
Willet, *Cataptrophorus semipalmatus*
Spotted sandpiper, *Actitis macularia*
Whimbrel, *Numenius phaepus*
Marbled godwit, *Limosa fedoa*
Sanderling, *Calidris alba*
Western sandpiper, *Calidris mauri*
Least sandpiper, *Calidris minutilla*
Dunlin, *Calidris alpina*
Ruff, *Philomachus pugnax*
Dowitcher, *Limnodromus spp.*
Common snipe, *Gallinago gallinago*
Red-necked phalarope, *Phalaropus lobatus*
Ring-billed gull, *Larus delawarensis*
California gull, *Larus californicus*
Mourning dove, *Zenaida macroura*
Great-horned owl, *Bubo virginianus*
European starling, *Sturnus vulgaris*
Red-winged blackbird, *Agelaius phoeniceus*
Yellow-headed blackbird, *Xanthocephalus xanthocephalus*
Brewer's blackbird, *Euphagus cyanocephalus*