CURRENT KNOWLEDGE CONCERNING HABITAT FRAGMENTATION AS 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 GRASSLAND 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 degredation) 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 geographical 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 biogeogrphy 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 these areas are 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 United States 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 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 AND ROLE OF CORRIDORS

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 have 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 have 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 modification 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 2 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 is 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 1989): "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 supressed, 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 chacteristic 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 complete 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 snow fall 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 was 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 ground water 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 ground water. 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 to 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 ground water. Depending on soil properties, the ground water table may rise to the level of the root zone. Crop production is threatened when roots are flooded with saline water. Where the ground water 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, molybedum 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 ground water 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 Grassland 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 Introduce 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 is 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 often are 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 amongst 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 Grassland 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 for their use. 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 Grassland 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.

ditions related to operations of the treatment facility. In some cases wetland habitats or important open space for wildlife are converted to treatment 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 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 as compared to other areas of the country where the combination of higher rainfall and lower evaporation require 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 United States. 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 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).

STORM WATER

Storm water runoff from urban areas includes many pollutants that have accumulated from industrial, commercial, and residential developments (Environmental Protection Agency 1977). The amount of storm water 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 storm water 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 storm water 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 storm water 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 stake from an industrial plant), ribbon sources (from highways), or dispersed sources (dispersed traffic and 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.

Pollution from Vehicles

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 (Maga 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 such as frequent access to the road from stores and homes, stop signs, and poorly timed stop lights are of great importance. Providing clustered and convient commercial areas and public facilities also eliminates the amount of travel.

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 storm water 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, and 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, as compared to those "at heel", caused 7 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 are 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 United States 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 important 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. Non-selective 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 Grassland wetlands.

Mosquito control is a factor in the management of Grassland 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 Grassland 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 non-target 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, experiments with 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) (Krieg 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 non-target aquatic organisms found in association with mosquito larvae but are not affected by *Bacillus thuringiensis* (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 lab, field treatment levels effected *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, macrophytes 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 and 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 and 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 variable may cause the control agent to work more effectively or less effectively in relation to laboratory tests with similar variability in the response by non-target organisms to control agents. Furthermore the method of application is an important variable determining the effectiveness of control or the effects on non-target organisms. In addition to the effects of chemicals, the method of application can have important implications. For example, aerial application on flooded wetlands cause disturbance 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.

NUTRIENT ENRICHMENT AND TOXIC SUBSTANCES

Chemicals from agricultural activities that enter surface or ground water 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, disrupt courtship, or cause 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.

	ABIOTIC		BIOTIC				
			Plants				
Land use activity	Hydrology	Water quality	Algae	Macro-phytes	Inverte-brates	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	Changes flow patterns	Transports salts and trace elements	—	—	—	—	—
Irrigation drain water	—	Concentrates salt and trace elements	Reduced biomass	Modify composition	Mortality	Mortality Deformities	Mortality Deformities
Herbicides	—	Adds non-point pollution	Reduced biomass	Reduced biomass and structure	—	—	—
Pesticides	—	Adds non-point pollution	—	—	Mortality	Mortality	Mortality
Fertilizers	—	Leads to eutrophication	Increased biomass Reduced species richness	Increased biomass Reduced species richness	Reduced species richness	—	—
Cultivation	Changes flow patterns	Increased 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	Disrupt 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	—	Increased 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	—	Disrupt life cycle events	Disrupt life cycle events

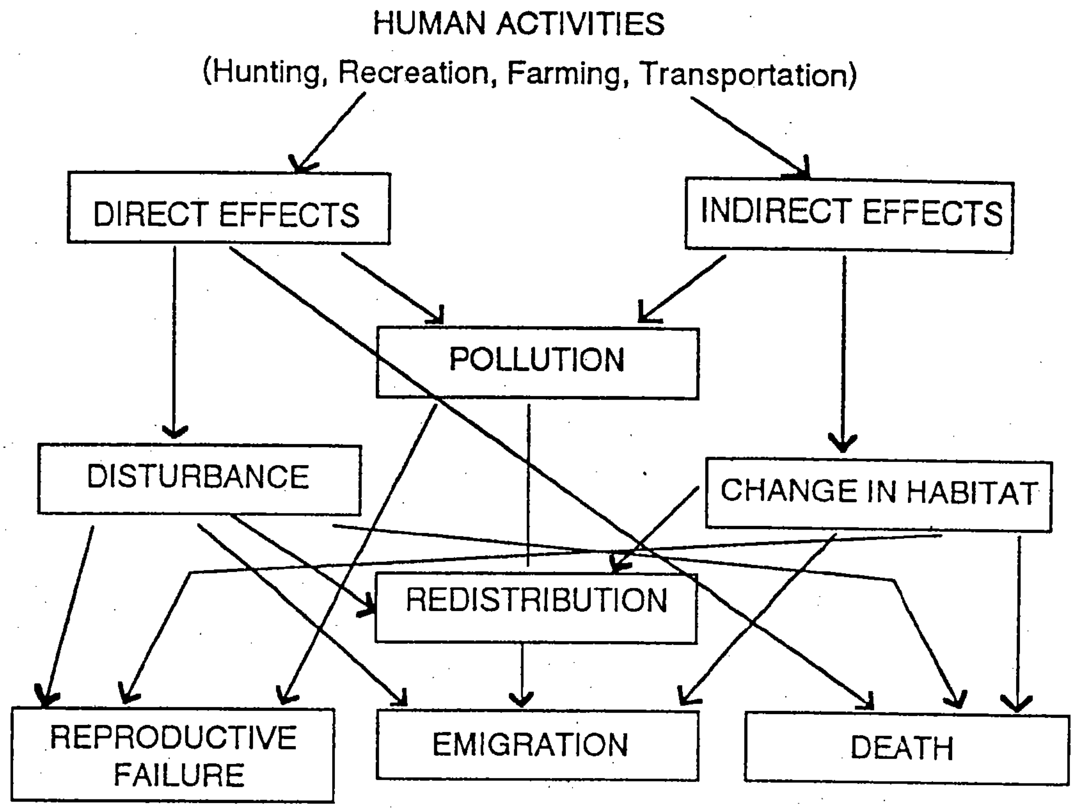

Fig. 23. Potential effects of human activities on wildlife populations.

STRATEGIES FOR PROTECTION

GENERAL STRATEGY

The area and quality of Grassland habitats has 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, Clark 1979, 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 exploitive 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 Grassland habitats.

FUNCTIONAL SIZE

The size of the Grassland 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, is a critical component 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

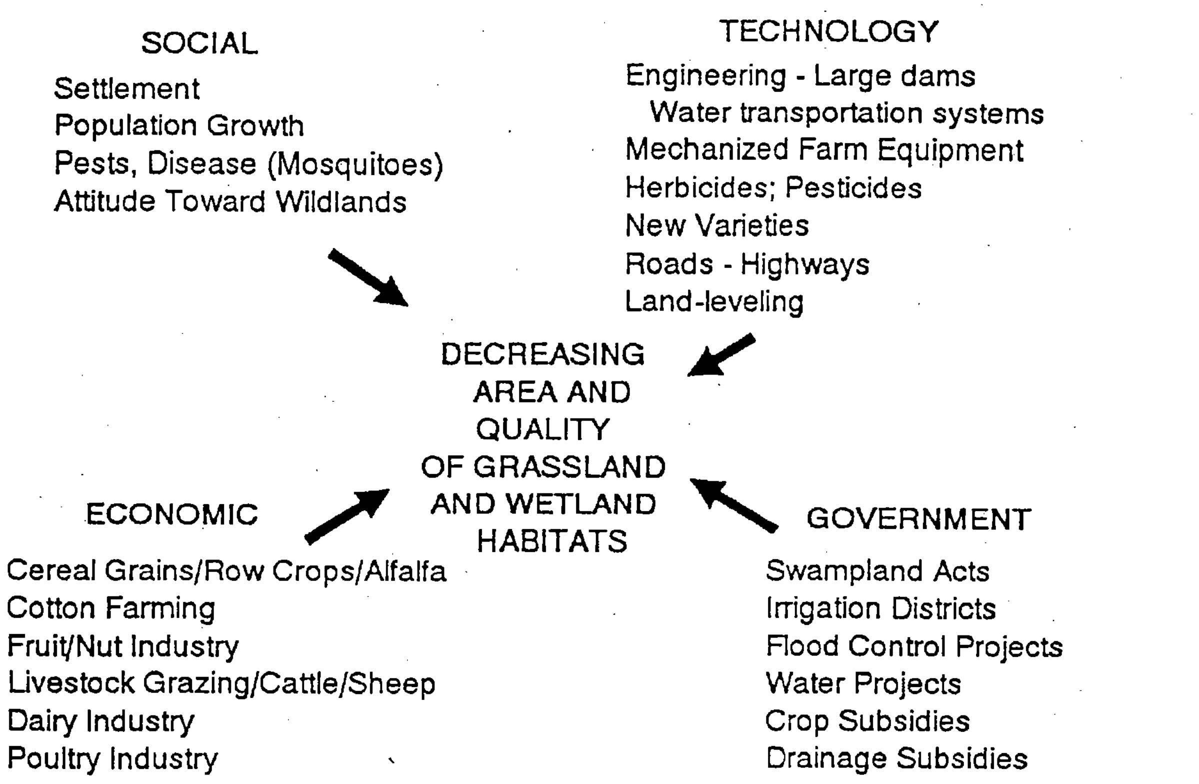

Fig. 24. Factors influencing the land-use and the amount and quality of native habitats in western Merced County.

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, the importance of non-preserve lands or those not in public ownership is 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 1983, Scott et al. 1991).

One of the greatest values of the Grassland 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 also represent the most important habitats remaining 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 Grassland 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 Grassland 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 have 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 insure 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 Grassland Wildlife Management Area. Developing such cooperative ventures with the private sector is the essence of the theme suggested by Morse et al. (1986) 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 GRASSLAND HABITATS AS IMPORTANT RESERVES

The unique nature of the Grassland 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 Grassland 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 Grassland 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.

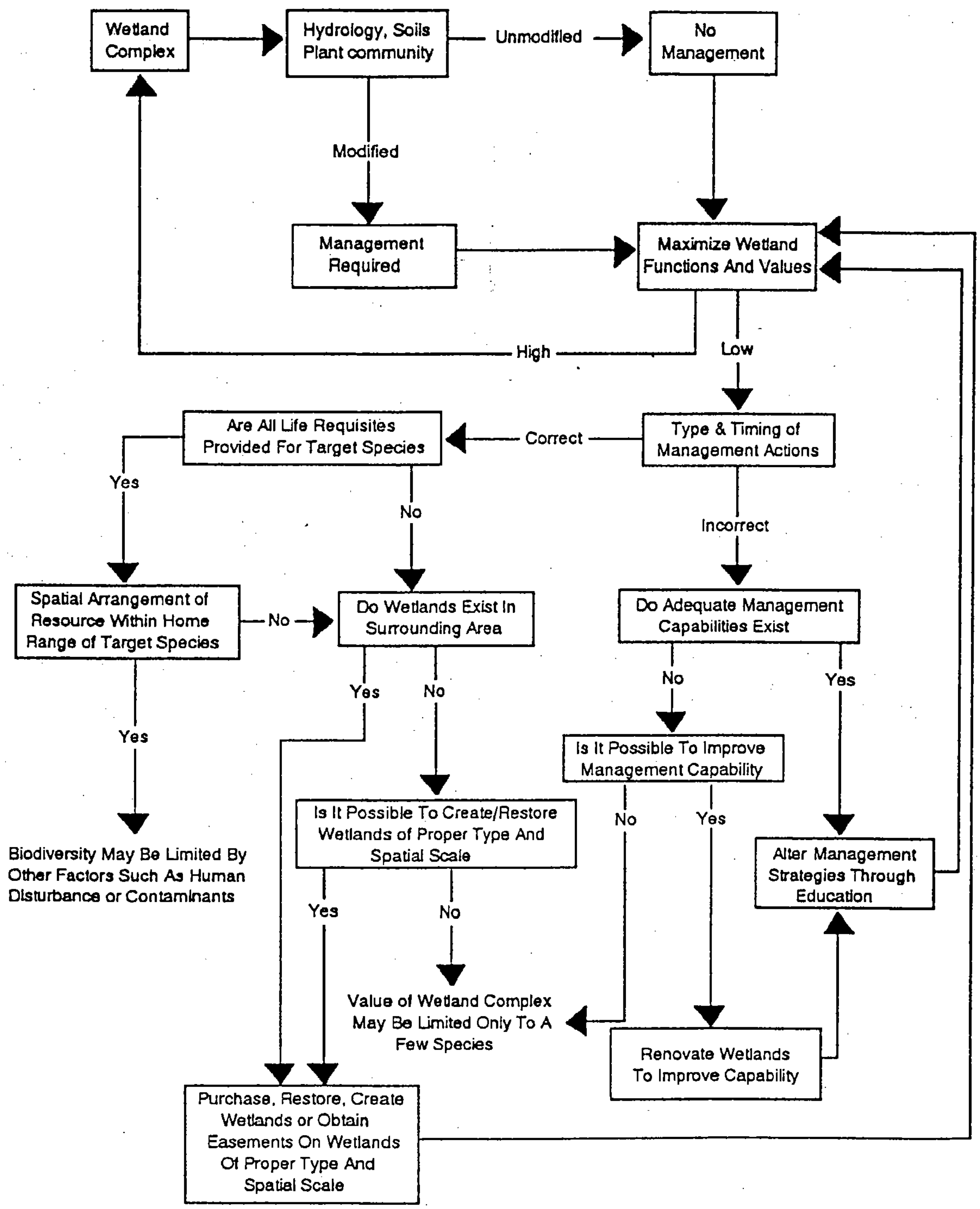

Fig. 25. Considerations required to make wise management decisions in man-modified landscapes.