QUINO CHECKERSPOT BUTTERFLY

(*Euphydryas editha quino*)

DRAFT RECOVERY PLAN

(January 2001)

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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EXECUTIVE SUMMARY

Current Status: The Quino checkerspot butterfly (*Euphydryas editha quino*, Quino checkerspot) is federally listed as endangered. This taxon occurs in San Diego and Riverside Counties and several localities in Baja California Norte, Mexico. Although some habitat is under public ownership, no known Quino checkerspot habitat complexes are entirely protected, and the species continues to decline throughout its range.

Habitat Requirements and Limiting Factors: The Quino checkerspot is found in association with topographically diverse landscapes that contain low to moderate levels of nonnative vegetation. Vegetation types that support the Quino checkerspot are coastal sage scrub, open chaparral, juniper woodland, forblands, and native grassland. Soil and climatic conditions, as well as ecological and physical factors, affect the suitability of habitat within the species' range. Urban and agricultural development, invasion of nonnative species, habitat fragmentation and degradation, increased fire frequency, and other human-caused disturbances have resulted in substantial losses of habitat throughout the species' historic range. Conservation needs include protection and management of suitable and restorable habitat; habitat restoration and enhancement; and establishment of Quino checkerspot captive breeding program. This plan identifies six Recovery Units. Recovery Units are geographically bounded areas containing extant Quino checkerspot populations that are the focus of recovery actions or tasks. Recovery Units contain both lands that are considered essential to the long-term conservation of the Quino checkerspot (e.g., networks of suitable habitat patches and connecting lands) and lands that are not considered essential (i.e. lands not used by the butterfly such as urban development).

Recovery Priority: 6C, per criteria published in the Federal Register (48 FR 43098; September 21, 1983). The priority is based on its being a subspecies (rather than a full species) with a high degree of threat, a moderate to low potential for recovery, and existing conflict between the species' conservation and development.

Objectives: The overall objective of this recovery plan is to reclassify the Quino checkerspot to threatened and ensure the species' long-term conservation.

Interim goals include (1) protecting habitat supporting known current population distributions (habitat complexes), (2) stabilizing populations within known population distributions (described habitat complexes), and (3) conducting research necessary to refine recovery criteria. Reclassification is appropriate when a taxon is no longer in danger throughout a significant portion of its range. Because data upon which to base decisions about reclassification are incomplete, downlisting criteria in this plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time.

Recovery Criteria:
1) Permanently protect habitat patches supporting known extant population distributions (habitat complexes) and possible landscape connectivity areas among them. Adequate habitat reserve area sizes are estimated to be between 1,200-4,000 hectares (3,000-10,000 acres) total per habitat complex. Recovery Units and habitat complexes described in this recovery plan are: Northwest Riverside Recovery Unit, containing the Gavilan Hills habitat complex; Southwest Riverside Recovery Unit, containing the Warm Springs Creek and Skinner/Johnson habitat complexes; South Riverside Recovery Unit, containing the Oak Mountain/Vail Lake, Sage Road/Billygoat Mountain, and Brown Canyon habitat complexes; South Riverside/North San Diego Recovery Unit, containing the Silverado and Dameron Valley/Oak Grove habitat complexes; Southwest San Diego Recovery Unit, containing the San Diego National Wildlife Refuge, Otay Lakes, Otay Foothills, Otay Mesa, Marron Valley, and Tecate habitat complexes; and Southeast San Diego Recovery Unit, containing the Jacumba Peak habitat complex.

2) Permanently provide for and implement management of described habitat complexes to restore habitat quality, including maintenance of hostplant populations, maintenance of diverse nectar sources and pollinators, control of nonnative plant invasion, and maintenance of internal landscape connectivity. The number of known occupied habitat patches and the density of butterflies within each Recovery Unit should be increased if declines are documented for 2 consecutive years of average to high annual precipitation (based on the past 20 years of local data). Management must be adaptive: i.e., ongoing surveys and monitoring must be conducted to refine management strategies and delimit

temporal and geographic patterns of Quino checkerspot exchange among suitable habitat patches.

3) Establish and maintain a captive propagation program for purposes of re-introduction and augmentation of wild populations, maintenance of refugia populations, and research.

4) Initiate and implement a cooperative educational outreach program targeting areas where Quino checkerspot populations are most threatened.

5) Two additional populations or metapopulations must be documented or introduced in the remaining undeveloped coastal areas of the Quino checkerspot's historic range. Undeveloped coastal areas include the western and northern slopes of the Santa Ana Mountains (northern slope, see proposed North Orange Recovery Unit description in Recovery Strategy section below), the northwest corner of San Diego County (see proposed Northwest San Diego Recovery Unit below), and undeveloped mesas and hills within the cities of San Diego, Poway, and Santee, and adjacent unincorporated land within San Diego County (see proposed South-central San Diego Recovery Unit below). Well-managed coastal preserves in San Diego or Orange County may be able to support stable populations of the Quino checkerspot butterfly. One of the two additional populations must include habitat within 10 kilometers (6 miles) of the ocean to maximize the stable marine climate influence and minimize susceptibility to drought. If new coastal populations are not documented by 2004, experimental populations should be established and maintained until downlisting criteria are refined. Additional inland (east of coastal areas described above) habitat complexes documented outside of Recovery Units will not be counted as one of the two additional populations specified here, but should be considered important to recovery and addressed when delisting criteria are developed.

6) The managed, protected population or metapopulation segments within currently described habitat complexes must demonstrate stability (constancy or resilience) without augmentation. When metapopulation distributions are determined by future research (one or more habitat complexes may belong to a single metapopulation) or defined by reserve boundaries, the unit monitored for

stability becomes the metapopulation. Stable Quino checkerspot populations are defined by this recovery plan as those in which decreases in the number of occupied habitat patches are followed by increases of equal or greater magnitude within the 15 year period. The percent of patches that are occupied should be estimated by surveys for pre-diapause larval clusters (to demonstrate recruitment) in a sample of no less than 50 percent of the total number of patches identified within a population or metapopulation distribution. The surveyed sample of habitat patches must be distributed as equally as possible across the metapopulation distribution to avoid potential error caused by correlation of suitability among nearby patches.

7) Conduct research including: determining the distribution of extant metapopulations; conducting preliminary modeling of metapopulation dynamics; investigating the function of hilltops as a resource for Quino checkerspot populations; investigating the contribution of multiple-year diapause to metapopulation stability; monitoring populations for further evidence of climate-driven range shifts; determining the effects of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot and its hostplant; determining the magnitude of threats from over-collection and non-native natural enemies.

<u>Actions needed</u>:

1) Protect habitat within the distribution of described habitat complexes.
2) Restore habitat patches and enhance landscape connectivity within the distribution of the habitat complexes
3) Erect barriers to prevent dispersal from habitat patches into adjacent high-traffic surface roads.
4) Reduce off-road vehicle activity within the distribution of habitat complexes and identified metapopulations
5) Continue yearly reviews, monitoring and augmentation until stable metapopulations have been maintained for 15 years without augmentation.
6) Establish and maintain a captive propagation program.
7) Initiate and implement an educational outreach program.
8) Conduct biological research needed to refine recovery criteria and guide conservation efforts.

9) Manage activity on trails where habitat occurs in recreational use areas, particularly during the active season for Quino checkerspot larvae and adults.
10) Locate or introduce two populations or metapopulations in the remaining undeveloped coastal areas of the Quino checkerspot's historic range.
11) Survey for habitat and undocumented metapopulations in undeveloped areas outside of Recovery Units.
12) Reduce fire frequency and illegal trash dumping in habitat areas
13) Enter into a dialogue with governmental and nongovernmental organizations in Baja California, Mexico.
14) Enter into dialogue with the Cahuilla Band of Mission Indians.

Total Estimated Cost to Meet Interim Recovery Objectives: $7,678,000+. The estimated costs for many tasks remain to be determined; therefore, total costs listed are lower than the total required to achieve recovery objectives. Some tasks (e.g, habitat protection) will benefit multiple listed species in addition to the Quino checkerspot, so their costs are not wholly attributable to this species.

Date of Recovery: Downlisting could be initiated in 2020, if recovery criteria are met.

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I. INTRODUCTION

A. Brief Overview

The distribution and abundance of the Quino checkerspot butterfly (*Euphydryas editha quino*) have been dramatically reduced during the past century as a result of agricultural and urban development and other land-use changes in southern California. Immediate protection and management of the habitats that support the species, initiation of a captive propagation program, and development of the monitoring scheme and research agenda described in this recovery plan will be necessary to prevent extinction of the Quino checkerspot.

The Quino checkerspot (Figure 1) is now known only from western Riverside County, southern San Diego County, and northern Baja California, Mexico, although the historic range of this taxon included much of coastal California south of Ventura County and inland valleys south of the Tehachapi Mountains (U.S. Fish and Wildlife Service database). More than 75 percent of the Quino checkerspot's historic range has been lost (Brown 1991, U.S. Fish and Wildlife Service database), including more than 90 percent of the coastal mesa and bluff distribution. Quino checkerspot populations have been reduced in number and size by more than 95 percent range-wide primarily due to direct and indirect human impacts including habitat loss and fragmentation, invasion of nonnative plant species, and disrupted fire regimes (D. Bauer, D. Murphy, and M. Singer, pers. comm.).

This recovery plan describes six geographic areas (Recovery Units) containing habitat that supports extant Quino checkerspot populations (Figure 2, Figure 3). Recovery Units contain both lands that are considered essential and lands that are not considered essential to the conservation of the species. Determination of management needs and distribution of habitat required for long-term persistence of the species will require further surveys, monitoring, modeling, and other research described in the recovery task portion of this document. Habitat within the current known distribution of the species ranges from moderately to highly

Figure 1. Quino checkerspot butterfly. Photo used by permission of Guy Bruyea.

Insert Figure 2

Insert Figure 3

disturbed and invaded by nonnative species. No pristine habitat remains for the butterfly north of the international border (D. Murphy, G. Pratt, M. Dodero, and C. Parmesan, pers. comm.).

We listed the Quino checkerspot butterfly as an endangered species on January 16, 1997 (62 FR 2313). Because we concluded that designation of critical habitat was not prudent at that time, critical habitat has not been designated. However, the Ninth Circuit Court has ordered the U.S. Fish and Wildlife Service to reassess the finding of prudency and either publish a notice of determination reaffirming that critical habitat is not prudent by June 1, 2001, or to propose critical habitat by February 1, 2001, with a final determination due by October 1, 2001.

This species has a Recovery Priority of 6C, based on the classification system published in the Federal Register (48 FR 43098; September 21, 1983). This priority number reflects the subspecific status of the butterfly, a high degree of threat, a low potential for recovery, and existing conflict with construction or other land development. This recovery plan attempts to reduce the risk of species extinction by recommending protection and long-term management of habitat necessary to support stable populations or metapopulations. Current habitat conditions are so degraded and population sizes are so low range-wide that long-term adaptive management will also be required. Protection of high-quality habitats with stable Quino checkerspot populations or metapopulations in Baja California, Mexico, is also needed.

B. Description and Taxonomy

The Quino checkerspot butterfly is a member of the family Nymphalidae (brush-footed butterflies) and the subfamily Melitaeinae (checkerspots and fritillaries). The Quino checkerspot is a subspecies of *Euphydryas editha*; it differs from other subspecies in a variety of characteristics including size, wing coloration, and larval and pupal phenotype (Mattoni *et al.* 1997).

The butterfly species now commonly called the Quino checkerspot has undergone several nomenclatural changes. It was originally described as *Melitaea quino* (Behr 1863). Gunder (1929) reduced it to a subspecies of

Euphydryas chalcedona. At the same time, he described *Euphydryas editha wrighti* from a checkerspot specimen collected in San Diego. After reexamining Behr's descriptions and specimens, Emmel *et al.* (1998) concluded that the Quino checkerspot should be associated with *E. editha*, not *E. chalcedona*, and that it was synonymous with *E. editha wrighti.* Because *E. editha wrighti* is a junior synonym for the Quino checkerspot, *E. editha quino* is now the accepted scientific name.

The adult Quino checkerspot butterfly (Figure 1), has a wingspan of approximately 4 centimeters (1.5 inches). The dorsal (top) sides of the wings have a red, black, and cream colored checkered pattern; the ventral (bottom) sides are dominated by red and cream. The abdomen of Quino checkerspots has red stripes across the top. Quino checkerspot larvae are black with a row of nine orange tubercles (fleshy/hairy extensions) on their back. Pupae are mottled black on a pale blue-gray background, and extremely cryptic. Two butterflies that co-occur with the Quino checkerspot and are most morphologically similar are the chalcedon or variable checkerspot (*Euphydryas chalcedona*) and Gabb's checkerspot (*Chlosyne gabbi*). Inexperienced surveyors in the field may also confuse the Quino checkerspot with other butterfly species that have similar coloration and behavior patterns, such as Wright's checkerspot (*Thessalia leanira wrighti*). Chalcedon checkerspot adults are darker and often larger than Quino checkerspots, and have white abdominal stripes and spots instead of red stripes. Male and female Gabb's checkerspot adults have a more orange appearance than Quino checkerspots, but female coloration is higher contrast and may closely resemble Quino checkerspots. Gabb's checkerspots may be differentiated from Quino checkerspots by silver-white spots on their underwings, the lack of red abdominal stripes, and a scalloped (slightly indented) forewing margin. Because adult morphology of *Euphydryas* butterfly species is variable, a combination of morphological characters should be used to distinguish them from similar species in the field.

C. Distribution and Habitat Considerations

The Quino checkerspot was historically distributed throughout the coastal slope of southern California, including Los Angeles, Orange, Riverside, San Diego, and San Bernardino counties, and northern Baja California, Mexico (Mattoni *et al.* 1997, U.S. Fish and Wildlife Service database). That distribution included the westernmost slopes of the Santa Monica Mountains, the Los Angeles plain and Transverse Ranges to the edge of the upper Anza-Borrego desert, and south to El Rosario in Baja California, Mexico (Emmel and Emmel 1973, Mattoni *et al.* 1997, U.S. Fish and Wildlife Service database). Although historical collection records allow for an estimate of a species' range, such records usually underestimate the number of historical sites and extent of local distributions. Collectors tended to frequent well-known sites, and no systematic or comprehensive surveys for the Quino checkerspot have ever been conducted (Mattoni *et al.* 1997).

As recently as the 1950's, collectors described the Quino checkerspot as occurring on every coastal bluff, inland mesa top, and lower mountain slope in San Diego County and coastal northern Baja California (D. Bauer, pers. comm.). These observations indicate that the Quino checkerspot was historically widespread throughout the southern California landscape, and occurred in a variety of vegetation types, including coastal sage scrub, open chaparral, juniper woodland, forblands, and grasslands. By the 1970's, most of the coastal bluff and mesa habitats in southern California had been urbanized or otherwise disturbed. However, the butterfly still occupied known habitat locations inland and at higher elevations including Dictionary Hill, Otay Lakes, and San Miguel Mountain in San Diego County, and the Gavilan Hills in Riverside County. By the middle 1980's the species was thought to have disappeared from the known locations; the petition to list the species in 1988 suggested that it might be extinct. Nonetheless, new populations were discovered in Riverside County, the butterfly was rediscovered in San Diego County, and the species continued to survive in northern Baja California, Mexico (D. Murphy and M. Singer, pers. comm.). Current information suggests that the butterfly has been extirpated from Los Angeles, Orange, and San Bernardino Counties (Figure 2). Most California populations probably occur in marginal habitat on the periphery of historic metapopulation centers (Parmesan 1996; D. Murphy, pers. comm.).

The Quino checkerspot butterfly primarily inhabits grassland, forbland, juniper woodland, and open scrub and chaparral communities that support native species of plantain *(Plantago erecta* and *P. patagonica*, its primary larval hostplants), and a variety of adult nectar resources. It is possible that some populations exclusively use other native plant species such as owl's clover (*Castilleja exserta*) as primary hostplants when *Plantago* is absent; however, this possibility has not been confirmed (G. Pratt, pers. comm.). These areas tend to be distributed as patches in a mosaic of vegetation communities. Habitat patch suitability is determined primarily by larval host plant density, topographic diversity, nectar resource availability, and climatic conditions (Singer 1972, Murphy 1982, Weiss *et al.* 1988, Murphy *et al.* 1990). Combined, these varying habitat features result in local butterfly population density fluctuations and periodic extirpation events within patches of habitat (Ehrlich 1965). Osborne and Redak's (2000) larval microhabitat use study indicated that patches of exposed soil with abundant solar insolation and host plants, combined with interspersed shrub cover and topographic heterogeneity, provides additional long-term stability to Quino checkerspot populations.

Occupancy of a network of habitat patches by *Euphydryas editha* populations over the long term requires a metapopulation dynamic - an exchange of individuals between patches - allowing for recolonization of habitat patches that may be temporarily unoccupied by larvae following local extirpation events (Harrison *et al.* 1988, Harrison 1989, Thomas 1994, Singer and Thomas 1996). Destruction, isolation, or disturbance of habitat patches temporarily not occupied by larvae can disrupt metapopulation structure, reducing the likelihood of recolonization and making extirpation events permanent (Hanski 1999). Metapopulation stability requires a minimum number of habitat patches connected by dispersal corridors (landscape connectivity), below which local persistence is no longer possible. Unfortunately, determining which, if any, habitat patches are not essential is a complex and time-consuming research question. All known Quino checkerspot habitat patch complexes (belonging to as yet undescribed metapopulation distributions) in southern California have been disrupted, resulting in instability and loss of metapopulations (Figure 2) (D. Murphy, pers. comm.).

Disturbances that have compromised Quino checkerspot metapopulation integrity include conversion of habitat by development or vegetation-type changes, grazing, trampling, fragmentation of habitat, and reduction or constraining of the landscape connectivity that facilitates habitat recolonization. Linkage of suitable habitat patches by adult dispersal corridors (landscape connectivity) is crucial to metapopulation stability. Habitat linkage areas should connect as many habitat patches as possible to optimize metapopulation dynamics (Thomas 1994). Habitat patches with fewer and/or longer distance linkages to other patches have lower probability of natural recolonization following local extirpation events. Linkages greater than 1 kilometer (0.6 mile) are not likely to be used by dispersing *Euphydryas editha* adults (Harrison *et al*. 1989). By definition, linkage areas do not support larval host plants in densities sufficient to be considered habitat, but may support nectar sources used by dispersing adult butterflies. Linkage areas must be free of dispersal barriers (artificial structures, dense stands of trees or tall shrubs) and mortality sinks (e.g. high-traffic roads).

Simply preventing agricultural or urban development and grazing in occupied habitat will not be sufficient to protect resident populations. Undeveloped lands infused with or completely surrounded by development experience direct and indirect human disturbance including trampling, off road vehicle use, dumping, pollution, and enhanced nonnative species invasion, all impacts that reduce population stability. Protected areas larger than habitat patch boundaries or highly managed interfaces between development and habitat patches are needed within the distribution of a metapopulation (often referred to as the metapopulation “footprint” [e.g. Launer and Murphy 1994]). The need to protect habitat from indirect effects of nearby or intruding development is evidenced by the apparent extirpation of local populations in the Lake Hodges and Dictionary Hill areas, where butterflies have not been recorded since the 1980's (Figure 2), despite focused efforts to find them (Caltrans 2000; City of San Diego 2000; Faulkner 1998; G. Pratt, pers. comm.) and periodic visits by local lepidopterists (D. Faulkner and K. Williams, pers. comm.). Lake Hodges and Dictionary Hill were large, primarily undeveloped areas with historical records indicating long-term stable occupancy prior to isolation by development (Figure 2). Habitat suitability may be conserved by preservation of undeveloped land between development and habitat areas requiring minimal management, or, if intervening natural lands are absent, by costly perpetual management to restrict human traffic, control nonnative species invasion, and augment butterfly populations.

Spatially clustered Quino checkerspot observations (see Figure 2) are called habitat complexes in this recovery plan. Habitat complexes indicate the approximate distribution of linked habitat patch networks within the distribution of extant metapopulations. Metapopulation distributions (currently undescribed) may include more than one habitat complex and are likely to be greater than the distribution of the habitat complexes described below. Further research is required to determine the maximum distribution of metapopulations required for stability. Habitat considerations listed below are largely drawn from personal observations of our staff and the Recovery Team..

Gavilan Hills habitat complex: Quino checkerspot individuals were observed in Harford Springs County Park in 1998, a site that was once part of a more extensive, well documented distribution (Figure 2). Quino checkerspot butterflies were last observed at the southern margin of Lake Mathews in 1986 (Figure 2). The Quino checkerspot was historically abundant in this area, with consistently high densities reported by collectors from the 1950's to the mid 1980's (Orsak 1978; K. Osborne and G. Pratt, pers. comm.). Therefore the Gavilan Hills habitat complex distribution includes the vicinity of Harford Springs park and also habitat areas south of Lake Mathews that are part of the documented historical distribution (Figure 2).

Habitat Considerations:
The Gavilan Hills area is characterized by high-quality habitat patches with dense, extensive stands of plantain (*Plantago* spp.) in open spaces, juniper woodland, coastal sage scrub, and grassland. Landscape connectivity is compromised primarily by Cajalco road. Landscape connectivity still exists between Harford Springs County Park and Lake Mathews, and apparently suitable habitat containing dense stands of plantain exists south of Lake Mathews in the vicinity of Black Rocks, west of Monument Peak (K. Osborne, pers. comm.). Stands of plantain also occur in the vicinities of Estelle Mountain, Railroad Canyon Reservoir, and the town of Sun City (G. Pratt, pers. comm.). It is possible that the Black Rocks habitat patch was a historical source of butterflies for other habitat patches in the area (K. Osborne, pers. comm.).

The Gavilan Hills area exhibits diverse topography and vegetation that is dominated by chamise chaparral and juniper woodlands. Clay soils are present throughout. Rounded hills provide gentle south- and northwest-facing slopes as well as shallow soils along rock faces where dwarf (or dot-seed) plantain (*Plantago erecta*), the primary hostplant in this area, is locally abundant. Flattened ridge tops may also serve as suitable habitats. Nearby open juniper woodland provides additional habitat.

<u>Warm Springs Creek habitat complex</u>: Recent Quino checkerspot observations are distributed between Interstate 215 and State Route 79 north of Murrieta Hot Springs Road to at least Scott Road concentrated in the vicinity of Warm Springs Creek (Figure 2), although much of the habitat at the southern end of the Hogbacks, where butterflies were recently observed, was disturbed in 1998.

Habitat Considerations:
Western connectivity is constrained by Interstate 215. Landscape connectivity is fragmented by ongoing development in this metapopulation, particularly in the vicinity of Murrieta Hot Springs Road. The extent of landscape connectivity to the north is not known. Quino checkerspot habitat is associated with openings in coastal sage scrub and typified by low rounded hills, clay soil lenses, and cryptogamic soil crusts. Dwarf plantain (*Plantago erecta*) is the primary larval host plant in this area.

<u>Skinner/Johnson habitat complex</u>: Recent Quino checkerspot observations are distributed throughout Southwest Riverside County Multiple Species Reserve, and are concentrated around Lake Skinner and south of Benton and Borel Roads (Johnson Ranch) (Figure 2). Although Quino checkerspots have also recently been observed in eastern Temecula, north and east of Butterfield Stage Road, primarily in the Crowne Hill area (Figure 2), this area is completely isolated by development and authorized for further development (U.S. Fish and Wildlife Service 2000).

Habitat Considerations:
Landscape connectivity within the habitat complex is compromised by surface roads such as Washington Street and Borel Road, which may now or in the future be mortality sinks during periods of high traffic. Any landscape

connectivity that may have existed between other occupied habitat patches and the Crowne Hill habitat area has been constrained by development, leaving the habitat isolated and subject to rapid degradation. Landscape connectivity between the Warm Springs Creek and Skinner/Johnson habitat complexes has been constrained by State Route 79 and associated development. Although State Route 79 separates the Warm Springs Creek habitat complex from the Skinner/Johnson habitat complex, the two complexes might function as one metapopulation if landscape connectivity were restored. Restoration of connectivity between the Skinner/Johnson and Warm Springs Creek habitat complexes could help stabilize populations associated with both habitat complexes. Quino habitat sites are in openings in coastal sage scrub and typified by low rounded hills, clay soil lenses, and soil crusts. Dwarf plantain (*Plantago erecta*) is the primary host plant found in this area.

<u>Oak Mountain/Vail Lake, Sage Road/Billy Goat Mountain, and Brown Canyon habitat complexes</u>: Recent Quino checkerspot butterfly observations are concentrated in the vicinities of Oak Mountain, Vail Lake, Pauba Valley (Figure 2), and in the vicinity of Sage Road from Magee Hills and the town of Sage south and east to Wilson Valley and Billy Goat Mountain (Figure 2). One possibly isolated population occurs just southeast of Hemet in Brown Canyon (Figure 2).

Habitat Considerations:
The site just southeast of Hemet may be isolated from documented metapopulations to the south by intervening areas of contiguous dense chaparral. Landscape connectivity in the habitat complex areas is generally good, and habitat is largely unfragmented. Landscape connectivity most likely exists between the Oak Mountain/Vail Lake and Sage Road/Billy Goat Mountain habitat complexes. Quino checkerspot habitat in these areas is characterized by rounded hills with gabbro clay lenses and soils in the west blending with granitic soils to the east. Habitat patches also occur on stable soil crusts, especially in granitic soil areas, and red clay lenses (U.S. Fish and Wildlife Service 1997b). Dwarf plantain (*Plantago erecta*) and woolly plantain (*P. patagonica*) are the primary host plants found in these areas.

Silverado and Dameron Valley/Oak Grove habitat complexes: Recent Quino checkerspot observations are distributed across Bureau of Land Management holdings and the Silverado Ranch Mitigation Bank south of the Cahuilla Indian Reservation (Figure 2). Increased survey efforts in 2000 expanded the Silverado habitat complex distribution, though much of the area remains to be surveyed. Two recent butterfly observation sites are found distant from the Silverado mitigation bank, one in northern Dameron Valley south of State Route 79, and one just south of that in Oak Grove Valley (Figure 2).

Habitat Considerations:
Habitat patches appear to be well connected in the Silverado Ranch area, and habitat patches are largely unfragmented. The known distribution of this metapopulation is relatively well protected. Habitat areas are primarily owned by the Bureau of Land Management and Silverado Ranch Mitigation Bank (Pratt, 2000). The Oak Grove Valley is highly invaded by nonnative grasses at lower elevations, but much habitat appears to remain on the hills and habitat in areas surrounding Oak Grove remains relatively undeveloped, including the adjacent Chihuahua Valley to the east. Elevation and other habitat elements in the Chihuahua Valley area resemble those found in habitat to the north. Landscape connectivity probably exists between the Dameron Valley/Oak Grove Valley and Silverado Ranch habitat complexes. Apparently suitable habitat has also been observed in the hills along Lost Valley Road just north of State Route 79 near Warner Springs, and may also exist in the Chihuahua Valley. Habitat in these areas is characterized by rounded hills with gabbro clay lenses and soils on the west side blending with granitic soils to the east. Habitat patches also occur on red clay lenses and stable soil crusts (especially in granitic soil areas) (U.S. Fish and Wildlife Service 1997a). Woolly plantain (*Plantago patagonica*) is the only primary host plant found in the Silverado area (Pratt 2000), although dwarf plantain (*P. erecta*) is found to the south and the east.

Marron Valley and Tecate habitat complexes: Recent Quino checkerspot observations are concentrated on the eastern slope of Otay Mountain and ridgelines along the international border in the vicinity of Marron Valley (Figure 2). Occupancy likely extends south across the international border, and it is possible that the majority of the population distribution is in Baja California, Mexico. Another recent record is located east of Marron Valley near the town of Tecate (Figure 2).

Habitat Considerations:
Habitat patches within this complex remain relatively well connected. In addition, some degree of landscape connectivity may exist north and south of Otay Mountain between the Otay Mesa and Marron Valley habitat complexes. Most occupied habitat in this area occur on public owned land. Generally, most occupancy is found along the upper rounded ridgelines, and soils that most often support the Quino checkerspot are red or gray colored clay. Dwarf plantain (*Plantago erecta*) is the primary host plant found in this area.

<u>San Diego National Wildlife Refuge, Otay Lake, Otay Mesa, and Otay Mountain Foothills habitat complexes:</u> Recent Quino checkerspot observations in the area are concentrated northeast and southeast of Otay Lakes (Figure 2), with a smaller cluster concentrated along the southwestern slope of Otay Mountain (Figure 2). Other recent butterfly observations are located on the San Diego National Wildlife Refuge northeast of Sweetwater Reservoir, and along the mesa rim above the Otay River and at the Salt Creek confluence (Figure 2). The Otay Lakes area historically supported a large population that extended south to Otay Mesa and across the international border (Figure 2, Murphy and White 1984). The historic population distribution extended across the entire mesa with high densities being reported from the vicinity of Brown Field. Quino checkerspot habitat restoration activities are currently being undertaken adjacent to a recent Quino checkerspot observation on the mesa rim just west of Johnson Canyon (Figure 2). Restoration of vernal pool habitat that includes essential elements of Quino checkerspot habitat is also ongoing at the site of a collection record on the mesa top between Dennery and Spring canyons (U.S. Fish and Wildlife Service 1997a). Therefore the Otay Mesa habitat complex distribution includes Otay Valley from the Salt Creek confluence to Dennary Canyon, and the adjacent undeveloped mesa tops, canyons and ridges south of Otay Valley (in the vicinity of Brown Field).

Habitat Considerations:
Survival of local Quino checkerspot populations now occupying the Otay Lake habitat patch complex (Figure 2) is due, in part, to the lack of adjacent

development. Protection of undeveloped areas along the eastern Otay Lake margin and within the habitat patches east of the lake are necessary for continued occupancy of nearby habitat patches (see Lake Hodges and Dictionary Hill discussion above). Habitat patches northeast of the lakes are still well connected. Landscape connectivity along the western margin of Otay Lake is constrained by the Olympic Training Center and other development, although some habitat remains along the Salt Creek drainage. Landscape connectivity on the eastern margin of Otay Lake is constrained by stands of woodland vegetation dominated by nonnative species. Historic records indicate that habitat (now in the San Diego National Wildlife Refuge) near Sweetwater River was, and appears to still be, connected to Proctor Valley, San Miguel Mountain, and thus to currently occupied habitat around Otay Lakes (Figure 2). Landscape connectivity on the mesas northeast of Brown Field and southwest of lower Otay Lake is reduced, although no significant dispersal barriers exist. Therefore landscape connectivity could be restored where distance between habitat patches is now too great to provide adequate linkage. Mesa top habitats along the northern margin of Otay Mesa can also possibly be reconnected. Soils in the area that are most often observed to support Quino checkerspots are red or gray colored clay. Dwarf plantain (*Plantago erecta*) is the primary host plant found in this area.

<u>Jacumba Peak habitat complex</u>: Recent Quino checkerspot observations are concentrated northwest of the community of Jacumba (Figure 2). Sites in Jacumba and El Condor in Baja California, Mexico (see below) are about 6 kilometers (4 miles) apart.

Current habitat and landscape connectivity in the Jacumba area are relatively intact. A historic butterfly record occurs north of Interstate 8 in the Table Mountain area (Figure 2). The Table Mountain site and apparently suitable surrounding habitat areas (G. Pratt, pers. comm.) are within the Jacumba National Cooperative Land and Wildlife Management Area, therefore no habitat fragmentation or constraining of landscape connectivity has occurred or is likely to occur in that area. Landscape connectivity between Table Mountain and Jacumba Peak is constrained by Interstate 8. However, connectivity likely exists between the Jacumba Peak habitat complex and El Condor in Baja California, Mexico. Although degraded by grazing in some areas, apparently suitable habitat also exists in the vicinity of McCain Valley. Habitat patches containing dwarf plantain (*Plantago erecta*) can be found on clay lenses scattered throughout open juniper woodland. Woolly plantain (*P. patagonica*) is also found in the area, primarily on granitic soils and along roadsides.

Baja California, Mexico distribution: All populations of Quino checkerspot near the ocean in Baja California appear to have been extirpated by urban development. Many sites farther inland, however, appear to support excellent habitat and dense populations. Unlike most California populations, which probably occur in marginal habitat on the periphery of historic metapopulation centers, most of the extant Baja California populations occur in apparently high-quality habitat.

Quino checkerspot populations currently exist in suitable habitat in northern Baja California, Mexico. There is one population south of El Testerazo along Highway 3. A second population exists at Mesa Redonda (also known as Table Mountain) just east of the city of Rosarita. The third population in Valle de Trinidad was known as "Los Aguajitos" in museum records, but the area is now called "Los Positos." The three Quino checkerspot populations south of the Otay and Marron habitat complexes are distant from each other and probably independent populations. A population also exists south of the Jacumba area, about 6 kilometers (4 miles) south of the town of El Condor.

D. Life History

Few specific studies of Quino checkerspot biology have been conducted. A few older papers reported observations of Quino checkerspot population dynamics (e.g. Murphy and White 1984). More recently, only one quantitative larval habitat use study (Osborne and Redak 2000) and one distribution study (Parmesan 1996) have been published. Therefore, most information in this section is drawn from the abundant literature reporting research on other subspecies of *Euphydryas editha*. Although it is generally true that different subspecies of *Euphydryas editha* have similar life histories, such assumptions must be made with caution, especially with regard to population dynamics (Ehrlich 1992).

1. Life Cycle

The life cycle of Quino checkerspot (Appendix I) typically includes one generation of adults per year, with a 4- to 6- week flight period beginning between late February and May, depending on weather conditions (Emmel and Emmel 1977). If sufficient rain falls in late summer or early fall, a rare second generation of reduced numbers may occur (Mattoni *et al.* 1997). Females are usually mated on the day they emerge from pupae, and lay one or two egg clusters per day for most of their adult life. Adults live from 10-14 days, however, adult emergence from pupae is staggered, resulting in a 1- to 2-month flight season. Peak emergence in most butterfly species (and probably for Quino checkerspots as well) occurs shortly after the beginning of the flight season, usually in the second week (Zonneveld 1991). Eggs deposited by adults on hostplants hatch in 10- 14 days.

The periods between molts (shedding skin) are called instars. Larvae that hatch from eggs are in the first instar, and may undergo as many as 7 instars prior to pupation. During the first two instars, prediapause larvae cannot move more than a few centimeters and are usually restricted to the plant on which the eggs were laid (primary hostplant species). Prediapause larvae spin a web and feed gregariously. Webs are fairly conspicuous and associated with visible feeding damage to the plant. During the third instar (about 10 days after hatching), larvae are able to move among individual hostplants. Third instar larvae usually wander independently in search of food, and may switch from feeding on the plant on which they hatched to another plant of the same species, or another hostplant species (secondary hostplant). During development, the hostplants age, eventually drying out and becoming inedible. At the time of hostplant senescence, if larvae have accumulated sufficient reserves, they are able to enter diapause. Larvae have been observed entering diapause in the lab as early as second instar, and surviving to the next season (K. Osborne and G. Pratt, pers. comm.)

Diapause is a low-metabolic resting state that enables larvae to survive for months during the summer without feeding. While in diapause, larvae are much less sensitive to climatic extremes and can tolerate temperatures from over 49 degrees Celsius (120 degrees Fahrenheit) to below freezing (M. Singer, pers. comm.). The larval exterior, or skin, is distinctive during diapause, becoming much blacker with denser “hairs” (setae) than earlier instars (Appendix I).

Diapausing *Euphydryas editha* larvae have been observed curled up under rocks or sticks, and enclosed in a light webbing (C. Parmesan and M. Singer, pers. comm.). Although the location of diapausing Quino checkerspot larvae in the field is undocumented, the presence of clusters of post diapause larvae found near dense grass and shrub cover indicates they may diapause in these areas (Osborne and Redak 2000).

Like many other related butterflies, *Euphydryas editha* larvae can live for several years. One mechanism that generates longevity is repeated diapause (Singer and Ehrlich 1979). This occurs when larvae emerge from diapause, feed, and then re-enter diapause, postponing development until the next year. It has been suggested that Quino checkerspot larvae may also be able to survive without breaking diapause in extremely dry years (G. Pratt, pers. comm.).

It is not known if Quino checkerspot larvae can store enough energy reserves for prolonged diapause of more than a year. However, the Quino checkerspot's ability to undergo repeated diapause is well-documented. Laboratory studies have repeatedly shown that post-diapause larvae feeding in early spring are able to re-enter diapause and postpone development another season if food resources are exhausted (G. Pratt and M. Singer, pers. comm.). However, repeated diapause in the field has not been studied, and the Recovery Team did not agree on how prevalent it might be under typical environmental conditions. There have been rare field observations of larvae that had re-entered diapause (D. Murphy and M. Singer, pers. comm.). For example, M. Singer (pers. comm.) found more than 50 larvae that had re-entered diapause in the middle of a patch of host plants that had been totally consumed. Re-entering diapause may also occur under conditions when plants are unusually dry or developmentally advanced, because poor host plant conditions indicate high larval mortality. The Recovery Team did agree that under exceptionally poor conditions, most or even all larvae at a site may re-enter diapause, although this occurrence has not been documented in the field. Larvae appear to have a narrow window of time during which diapause may be re-entered. Last instar larvae do not appear to be able to re-enter diapause, and repeated diapause has only rarely been observed in next-to last instar larvae (G. Pratt, pers. comm.). Also, there is probably a significant mortality risk during diapause (Moore 1989), so the likelihood of successful development and reproduction must be lower than the probability of surviving a second season of diapause for repeated diapause to have a fitness benefit. Because Quino checkerspot larvae can re-enter diapause, it is possible that an adult flight period may only include a portion of the original larval population or may not occur at all in some occupied sites under adverse conditions. From the perspective of judging whether a population has been extirpated, it is important to know that a robust population may generate no adults at all under poor environmental conditions.

Sufficient rainfall, usually during November or December, causes larvae to break diapause. Records of late second flight seasons following unusual summer rains indicate that the Quino checkerspot does not require winter chilling to break diapause, and may not diapause at all under some circumstances (Mattoni *et al.* 1997). Rain stimulates germination and growth of the hostplants fed upon by postdiapause larvae, which can crawl up to several meters in search of food. Postdiapause larval dispersal has been well documented in the bay checkerspot butterfly; larvae have been observed to travel up to 3.5 meters (11.5 feet)during a 4-day period (Weiss *et al.* 1987). Greater dispersal distances were rare, but movement up to 10 meters (33 feet) per day has been recorded (Weiss *et al.* 1988). Postdiapause larvae seek microclimates with high solar radiation, which helps speed development (White 1975, Weiss et al. 1987, Osborne and Redak 2000).

Because of variable weather during winter and early spring, the time between diapause termination and pupation can range from 2 weeks if conditions are warm and sunny, to 2 or 3 months if cold, rainy conditions prevail (G. Pratt, pers. comm.). Postdiapause larvae undergo three to as many as seven instars prior to pupating in silken shelters near ground level. Adults emerge from pupae after approximately 10 days, again depending on weather (Mattoni *et al.* 1997).

2. Adult Behavior and Resource Use

Adult Quino checkerspot butterflies spend time searching for mates, basking in the sun to thermoregulate, feeding on nectar, defending territories, and (in the case of females) searching for oviposition sites and depositing eggs. The Quino checkerspot is ectothermic, using air temperatures and sunshine to increase body temperatures to levels required for flight. If air temperature is cool, clear skies and bright sunshine may provide enough thermal power for flight, but flight is not possible below about 16 degrees Celsius (60 degrees Fahrenheit). In warmer air temperatures, flight may still be possible with scattered clouds or light overcast conditions, but has not been observed in very cloudy, overcast, or foggy weather. Adults remain hidden (often roosting in bushes or trees) during fog, drizzle, or rain, and usually avoid flying in windy conditions (sustained winds greater than 24 kilometers (15 miles) per hour). Quino checkerspot butterflies generally fly close to the ground in a relatively slow, meandering flight pattern (M. Singer, pers. comm.).

The Quino checkerspot, like other subspecies of *Euphydryas editha*, show a preference for barren spots in their habitat of low-growing vegetation (Osborne and Redak 2000). Quino checkerspots tend to avoid flying over trees, buildings, or other objects taller than 1.8-2.4 meters (6-8 feet) (G. Pratt, C. Parmesan, and K. Osborne, pers. comm.). Quino checkerspot thermodynamic requirements and natural avoidance of shaded areas deters flight in densely wooded areas and other types of closed-canopy vegetation (M. Singer, pers. comm.).

Male Quino checkerspots, and to a lesser extent females, are frequently observed on hilltops and ridgelines (U.S. Fish and Wildlife Service database), and a number of behaviors characteristics of species known to hilltop have been documented (K. Osborne and G. Pratt, pers. comm.). Largely untested explanations for this behavior include: 1) the active dispersal of male and female butterflies to local hilltops or ridgelines during years of low adult density where the probability of finding mates is increased (facultative hilltopping behavior); 2) the presence of areas of exposed soil resulting in warmer microclimates and superior basking sites than surrounding vegetated slopes and valleys; and 3) the attraction of males to the activities of other butterfly species on hilltops. Hilltops may also represent centers of Quino checkerspot population density in some areas. Because Quino checkerspot adults are frequently observed on hilltops (U.S. Fish and Wildlife Service database), even in the absence of nearby larval hostplants (K. Osborne and G. Pratt, pers. comm.), hilltops and ridgelines should be searched during presence/absence surveys and considered for inclusion in reserve design.

Data from mark-recapture studies indicate that long-distance dispersal (greater than 1 kilometer (0.6 miles)) in *Euphydryas editha* is rare. Nonetheless, Murphy and White (1984) suggested that long-distance dispersal events associated with population outbreaks may contribute significantly to colonization or recolonization of unoccupied areas and hence to long-term survival of the Quino checkerspot.

Most *Euphydryas editha* subspecies exhibit generally sedentary behavior, with adults frequently remaining in the same habitat patch in which they developed as larvae (Ehrlich 1961, 1965; Boughton 1999, 2000). However, female bay checkerspots were found to be more likely to emigrate than males (Ehrlich et al. 1984). Adult dispersal by the bay checkerspot (*Euphydryas editha bayensis*), is typically less than 150 meters (490 feet) between recaptures (Ehrlich 1961, Ehrlich 1965, Gilbert and Singer 1973). Though a study of the Quino checkerspot at Otay Lakes in San Diego County included an estimate of less than 100-meter (330-foot) dispersal distances (White and Levin 1981), this study was not designed to detect long-distance dispersal. Harrison (1989) recaptured bay checkerspots greater than 1 kilometer (0.6 mile) from the point of release in only 5 percent of cases. Long-distance dispersal in bay checkerspot butterflies has been documented as far as 7.6 km (4.7 miles) (D. Murphy pers. comm.), 5.6 km (3.5 miles) (1 male), and 3 km (2 miles) (1 female) (Harrison 1989).

Long-distance habitat patch colonization may be achieved within a single season through long-distance dispersal of individual butterflies, or over several seasons through stepping-stone habitat patch colonization events. In a study of the Morgan Hill bay checkerspot island-mainland type metapopulation, no unoccupied habitat patches farther than 4.5 kilometers (2.8 miles) from the source population were colonized over a 10- year period (Harrison *et al.* 1988). A model, which was conservative with respect to extinction, predicted habitat patches at a distance greater than 7 to 8 kilometers (4 to 5 miles) from the primary source population were not likely to support populations (Harrison *et al.* 1988).

The selection of specific plants by *Euphydryas editha* on which to oviposit (deposit eggs) is genetically determined and strong natural selection can lead to rapid changes in diet (Singer *et al.* 1993). The ability of *Euphydryas editha* larvae to grow and survive on particular hostplant species is variable among individual larvae (Singer *et al.* 1988) and among larval populations (Singer *et al.*

1994, Rausher 1982). Singer *et al.* (1991) found that dwarf plantain (*Plantago erecta*) was preferred over chinese houses (*Collinsia tinctoria*) by Quino checkerspots from the lower Otay lakes area. When female *Euphydryas editha* butterflies fail to encounter preferred hostplants, the likelihood of emigration to other suitable habitat patches increases (Thomas and Singer 1987). Host preference in females can be quantified by measuring the amount of time a butterfly searches before it will deposit eggs on less preferred hostplants (Singer *et al.* 1992).

Most Quino checkerspot oviposition has been documented on dwarf plantain (*Plantago erecta*). However, egg clusters and pre-diapause larvae were recently documented on woolly plantain (*P. patagonica*), which appears to be the sole primary host for the Silverado metapopulation in southern Riverside County (Pratt 2000). Bird's-beak (*Cordylanthus rigidus*) was observed on two occasions in 1999 to have received egg clusters in southern San Diego county (G. Pratt pers. comm.).

Dwarf plantain (*Plantago erecta*) occurs in annual forbland, coastal sage scrub, and open chaparral. It can be found on soils with and without cryptogamic crusts, and is often associated with fine-textured clay soils from gabbro and basalt parent materials. Whether the species has an affinity for these soils or whether the soils reduce competition from invasive nonnative annual forbs and grasses is unknown. Dwarf plantain does not appear to have any special requirements for germination associated with fire. For instance, its seed coat imbibes moisture and forms mucilage (A. Sanders, pers. comm.), which is not a trait of the hard-coated seeds typical of obligate fire-following species. However, it may become more abundant immediately after a fire because of the reduction of canopy cover and other changes that favor the species. Seed bank persistence and dynamics in dwarf plantain are not well understood, but seed set may have major impacts on Quino checkerspot populations and so warrants research. An apparent high degree of annual turnover of *P. insularis* seed was observed at Jasper Ridge (N. Chiariello, pers. comm.). However, there is little annual turnover in dwarf plantain (*P. erecta*) seed in southern San Diego County; at Lower Otay Lakes bouts of total defoliation prior to seed set were followed by dense germination the following year, demonstrating that the seed bank persists at least 2 years in that area (Murphy and White 1984).

The two most important factors affecting the suitability of hostplants for Quino checkerspot oviposition are exposure to solar radiation and phenology, (timing of the plant's development). Quino checkerspots deposit eggs on plants located in full sun, preferably surrounded by bare ground or sparse, low vegetation. Plants shaded through the midday hours (1100 to 1400) or embedded in taller vegetation appear to be less likely targets for oviposition, probably because of high temperature requirements of developing larvae (Weiss *et al.* 1987, 1988; Osborne and Redak 2000). Primary hostplants must remain edible for approximately 4 weeks after eggs are laid (2 weeks for egg maturation and 2 weeks for larval feeding) (Singer 1972, Singer and Ehrlich 1979). Areas with hostplant populations that do not remain edible for sufficient time after oviposition can not provide suitable habitat that season. Adult female butterflies are adept at selecting those plants that receive adequate sunshine and will remain edible the longest (McKay 1985, Parmesan 1991, Singer 1994, Parmesan *et al.* 1995).

Euphydryas editha egg clusters typically contain 20-150 eggs (M. Singer, C. Parmesan, and G. Pratt, pers. comm.). Destruction of eggs by predators and physical disturbance can be substantial. Even so, it would be unusual for an individual *Plantago* plant to support an entire larval cluster to diapause. Normally pre-diapause larvae consume the plant on which they hatch, and then migrate in search for new plants. Their ability to search is quite limited, especially prior to the third instar. First and second instar larvae can find hosts within 30 centimeters (1 foot) of their original host plant. By mid-third instar, larvae can find hosts up to 1 meter (3.3 feet) away (G. Pratt, pers. comm.). Therefore, high local host density is necessary for high larval survival, but hostplants must occur in sufficient open areas with high solar exposure (Osborne and Redak 2000). Where secondary hosts are nearby, the amount of primary host that is needed may be reduced, but must be sufficient for larvae to reach a size at which they can disperse to the secondary host.

Secondary larval hosts may be important both before and after diapause. Some metapopulations of this subspecies may be dependent for persistence on secondary hosts, but thriving Quino checkerspot metapopulations in Baja California have persisted for long periods with no other possible host but *Plantago* spp. (C. Parmesan and M. Singer, pers. comm.). Typically, prediapause secondary hosts are important when the primary hosts undergo senescence before larvae can respond by entering diapause. Such is the case in many populations of the bay checkerspot, where dwarf plantain (*Plantago erecta*) is the primary host, but most larvae survive to diapause by migrating to owl's-clover (*Castilleja exserta*). Prediapause larvae feed on *C. exserta* until diapause, then return to feeding on *P. erecta* when they break diapause in winter (Singer 1972, Ehrlich *et al.* 1975).

Euphydryas editha butterflies use a much wider range of plants for adult nectar feeding than for larval foliage feeding. These butterflies apparently learn to alight on and find nectar in particular flower species, demonstrating some degree of nectar source constancy (McNeely and Singer in press). *Euphydryas editha* has a short tongue, and cannot feed on flowers that have deep corolla tubes or flowers evolved to be opened by bees (M. Singer, pers. comm.). *Euphydryas editha* prefers flowers with a platform-like surface on which they can remain upright while feeding (D. Murphy, G. Pratt, and M. Singer, pers. comm.). The butterflies frequently take nectar from lomatium (*Lomatium* spp.), goldenstar (*Muilla* spp.), milfoil or yarrow (*Achillea millefolium*), fiddleneck (*Amsinckia* spp.), goldfields (*Lasthenia* spp.), popcorn flowers (*Plagiobothrys* and *Cryptantha* spp.), gilia (*Gilia* spp), California buckwheat (*Eriogonum fasciculatum*), onion (*Allium* spp.), and yerba santa (*Eriodictyon* spp.) (D. Murphy and G. Pratt, pers. comm.). Quino checkerspots have been observed flying several hundred meters from the nearest larval habitat patch to nectar sources, however, bay checkerspot studies found butterflies tended to deposit eggs on hosts that are close to, rather than farther from, adult nectar sources (Murphy 1982, Murphy *et al.* 1983).

3. Climatic Effects

Lepidopterists have documented the extirpation of *Euphydryas editha* populations associated with unusual climatic events (Singer and Ehrlich 1979, Ehrlich *et al.* 1980, Singer and Thomas 1996). For example, the severe drought in California from 1975 through 1977 caused the apparent extirpation of 24 percent of surveyed populations of *Euphydryas editha* (Singer and Ehrlich 1979, Ehrlich *et al.* 1980). Observations and experiments suggest that the relationship between weather and survival of *Euphydryas editha* is mediated by the timing of its life cycle relative to that of its host and nectar plants (Singer 1972, Ehrlich *et* *al.* 1975, Boughton 2000). A phenological mismatch was observed in southern California in 1996 when first instar larvae were found on plants that were already dying, making it highly unlikely that they would support the larvae to diapause (Parmesan, in press). In general, weather conditions that speed the plant life cycle relative to that of the insect, such as warm, cloudy weather, causes increased larval mortality (Singer 1983, Boughton 1999). Conversely, conditions that slow the plant life cycle relative to that of the insect increase larval survival. Microtopographic heterogeneity and associated microclimate heterogeneity, on a scale that allows larvae and ovipositing adults to select among sites, should help prolong occupancy of habitat patches (Singer 1972; Singer and Ehrlich 1979; Weiss *et al.* 1987, 1988; Osborne and Redak 2000).

4. Metapopulation Structure

Distribution of the Quino checkerspot butterfly is patchy at many geographic scales. Local resources are not evenly distributed on the scale of meters, clusters of hostplant micro-patches are unevenly distributed to form habitat patches at the scale of kilometers, and these in turn are patchily distributed at even larger scales to form networks of connected habitat patches. Occupancy of habitats at each scale is influenced by habitat patch colonization and extirpation rates at that scale.

Local habitat patch occupancy can be maintained on a set of small patches of hostplant (micro-patches) within a habitat patch separated by open ground or chaparral, provided that the host micro-patches are within the typical flight range of the butterflies (about 50-200 meters (160-660 feet)). At this scale, adult butterflies could be expected to move among micro-patches each season. To estimate the amount of food resources necessary to maintain a local patch, assume that 100 adults, with a balanced sex ratio, might be typical within a habitat patch. Life-history data from the field (Singer 1972, Moore 1989) indicate that in a population that is neither increasing nor decreasing, each mated female would produce, on average, 3 to 4 adults, some of which would emigrate or fail to reproduce. If a mated female lays 3 to 4 clusters, then each egg cluster would generate, on average, a single adult. Based on these assumptions, in a population of 100 adults, 50 females would each need to find 3 to 4 micro-patches, so a local habitat patch would need 50 x (3 to 4), or 150-200 suitable micro-patches of 20 (or more) plants to support the habitat patch's population of prediapause larvae. Larger host patches could accommodate more egg clusters, but no evidence exists to suggest that *Euphydryas edithas* spatially distribute egg masses in a manner that would maximize offspring survival. On the contrary, individual females often apparently independently select the same oviposition sites, leading to high mortality of larvae from competition (Rausher et al. 1981, Boughton 1999).

Each successful post-diapause larva consumes several hundred *Plantago* seedlings, and the impact on a plant population can be severe. Thus post-diapause larval feeding has three consequences for habitat assessments: 1) *Plantago* density estimates made during seedling stages, when post-diapause larvae have not yet finished feeding, must consider future post-diapause feeding needs, 2) the number of plants in a *Plantago* population that currently support Quino checkerspot larvae will be lower than the number in the same population without the butterflies, and 3) measurements of *Plantago* density in unoccupied habitat may overestimate the ability of habitat patches to support a butterfly population. Also, if larvae commonly re-enter diapause during dry years, hostplant density (habitat suitability) may be underestimated due to low germination rates that do not affect the population of larvae. Note that a substantial amount of food, primary or secondary hostplants, must remain after the post-diapause larvae have finished feeding if a habitat patch is to support clusters of pre-diapause larvae clusters. If too few primary hostplants remain, adults must disperse to seek new habitat patches for oviposition.

Local habitats alone are generally not sufficient to ensure the long-term persistence of the butterfly. A local population may be expected to persist on the time scale of years. Persistence for longer terms derives from the interaction of sets of local habitat patch populations at larger geographic scales. These sets of populations are known as metapopulations. For the bay checkerspot butterfly, a metapopulation was described as: "...a set of populations (i.e., independent demographic units; Ehrlich 1965) that are interdependent over ecological time. That is, although member populations may change in size independently, their probabilities of existing at a given time are not independent of one another because they are linked by processes of extirpation and mutual recolonization, processes that occur, say, on the order of every 10 to 100 generations." (Harrison *et al.* 1988). The ability and propensity of larvae to undergo multiple-year diapause in the field, and survival rates during repeated diapause (currently unknown), will also affect the persistence time of local populations.

The timescale of extirpation and recolonization depends on the geographic scale of the metapopulation. Smaller metapopulations, composed of sets of local habitat patches described above, should be stable over the course of decades, with habitat patches recolonized within a few years of extirpation. The distance between habitat patches determines the colonization rate, and for small metapopulations this distance is likely to be under 1 kilometer (0.6 mile). Larval occupancy blinks in and out within the habitat patches, but the metapopulation as a whole remains stable, provided extirpations offset recolonizations. An example of a small bay checkerspot metapopulation is that at Jasper Ridge. At larger geographic scales, sets of small metapopulations can be nested within larger metapopulations. Networks of small metapopulations are separated by greater distances than habitat patches, and these networks experience extirpation and colonization on the scale of centuries rather than decades. However, long-term persistence of species with metapopulation dynamics depends on maintenance of the patches and sets of habitat patches or rare long-distance dispersal events that link larger metapopulations together.

Rare examples exist of *Euphydryas editha* populations that apparently do not require a metapopulation structure for long-term persistence. One example is the small population at Surf, north of Santa Barbara near Point Sal. This local coastal population has persisted in apparent isolation for more than 50 years in a habitat patch no larger than 30 square meters (320 square feet) (Parmesan 1996), perhaps due to the stable marine climate influence. Although the Brown Canyon habitat complex may be small and largely independent (G. Pratt, pers. comm.), most current Quino checkerspot populations probably have a large metapopulation structure (Recovery Team, K. Osborne, pers. comm.).

Two types of metapopulation structure have been described, the island-mainland and Levins types. The bay checkerspot Morgan Hill metapopulation represents an example of a small island-mainland type in which occupancy of a single large source habitat patch persists through time while surrounding small habitat patches regularly are extirpated and must be recolonized by the source population (Harrison *et al.* 1988). However, presence of a "source" habitat patch does not necessarily mean that small surrounding habitat patches are not required to have long-term viability. Non-source habitat patches may well act as temporary refugia during rare geographically specific catastrophic events such as fire, allowing recolonization of an extirpated source patch population. The *Euphydryas editha nubigena* metapopulation along the General's Highway represents a Levins type structure in which each habitat patch (except those disturbed by logging) has a more or less equal probability of extirpation (Thomas *et al.* 1996). Not all larval habitat patches occupancy is extirpated simultaneously, and occupied patches regularly provide migrants for recolonization of empty habitat patches (Singer and Thomas 1996; Thomas *et al.* 1996; Boughton 1999, 2000). When functioning naturally, both metapopulation structures result in a relatively constant number of habitat patches occupied by larvae. Of course it is possible for metapopulation structure to fall somewhere between the two extremes. It is not known which type of metapopulation structure is most common in the Quino checkerspot.

Using metapopulation theory, reserves should be designed to provide sufficient numbers of habitat patches such that: 1) only a small number of habitat patches will likely be extirpated in a single year, and 2) patches are close enough that natural recolonization can occur at a rate sufficient to maintain a relatively constant number of patches occupied by larvae. In general, the more frequent the extirpations, the more patches that are necessary to support a metapopulation for a given length of time (Harrison and Quinn 1989). Environmental diversity among habitat patches should also reduce the probability of simultaneous extirpation of habitat patches (Harrison and Quinn 1989).

Fragmentation of Quino checkerspot habitat has isolated many habitat patches and small networks by more than 5 kilometers (3 miles) from other habitat patches and networks. Extirpation of isolated populations is likely, given that periodic extirpations on a small scale are normal in *Euphydryas editha* (Ehrlich *et al.* 1975). All else being equal, the probability of a small metapopulation being extirpated within a few decades is higher than a larger one because of the increased probability of simultaneous extirpation of each habitat patch. Unless a stable mainland "source" population can be established, Quino checkerspot reserves should be designed to protect presumed Levins-style metapopulation dynamics, in which a relatively constant number of linked habitat patches occupied by larvae persist and natural recolonization of suitable and restored habitat patches occur. Where neither is possible, population augmentation will be necessary after widespread extirpation events.

Table 1. Bay checkerspot metapopulations distribution scales.

	Habitat patch	Small metapopulation	Large metapopulation
Example	Area H	Jasper Ridge	Morgan Hill and environs
Estimate of example area	less than 25 hectares (0.10 square mile)	25-400 hectares (0.10-1.5 square miles)	400-40,000 hectares (1.5-150 square miles)
Estimated number of individuals	50-500	500-2,000	over 2,000
Estimated persistence time	Years	Decades	Centuries

E. Reasons for Decline and Current Threats

The Quino checkerspot is threatened primarily by urban and agriculture development, invasive nonnative species, off-road vehicle use, grazing, and fire management practices (62 FR 2313). Quino checkerspot population decline likely has been, and will continue to be, caused in part by enhanced nitrogen deposition (Allen *et al.* 1997), elevated atmospheric carbon dioxide concentrations (Coviella and Trumble 1998), and climate change (Parmesan 1996, Field *et al.* 1999). Nonetheless, urban development poses the greatest threat and exacerbates other threats. As a result, careful planning that restricts development in the proximity of Quino checkerspot metapopulations will be the key to long-term conservation of the species. Any activity resulting in habitat fragmentation, or host or nectar plant removal reduces habitat quality and increases the probability of Quino checkerspot extinction. Stamp (1984) and White (1986) examined parasitism and predation of the genus *Euphydryas*, although it is not clear whether these mortality factors pose a significant threat to the species. Predation by Argentine ants (*Iridomyrmex humilis*) has been observed in Quino checkerspot laboratory colonies (G. Pratt, pers. comm.), and predation by imported Brazilian fire ants (*Solenopsis invicta*) is likely if they were to co-occur with Quino checkerspot (Porter and Savignano 1990). Brazilian fire ants were discovered in 1998 in the vicinity of historic Quino checkerspot habitat in Orange County, and have subsequently been found in San Diego, Riverside and Los Angeles counties (California Department of Food and Agriculture, see http://www.cdfg.ca.gov). Illegal trash dumping is a problem for some populations (G. Pratt, pers. comm.). Over-collection by butterfly collectors is also a threat (62 FR 2313), although the current prevalence of this threat is unknown.

1. Loss and Fragmentation of Habitat and Landscape Connectivity

More than 90 percent of the Quino checkerspot's historic range has been lost due to habitat degradation or destruction (D. Murphy, pers. comm.) Most of the species' preferred habitat, mesa tops in particular, has been destroyed or is currently threatened by residential, urban, and industrial development and associated indirect impacts on adjacent undeveloped areas.

The probability that suitable habitat patches not occupied by larvae will be recolonized is decreased as metapopulation distributions become smaller (fewer occupied larval habitat patches) and habitat becomes more fragmented. Low population densities also reduce dispersal rates and generally make metapopulations more vulnerable to extirpation. Small, isolated, or poorly interconnected metapopulations are subject to higher rates of genetic drift and inbreeding depression, resulting in reduced genetic variability. Inbreeding depression, or lowered fitness resulting from breeding among closely related individuals, has been documented in the Glanville fritillary (*Melitaea cinxia*), a relative of the Quino checkerspot (Sacchieri *et al*. 1998, Niemen *et al*. in press). Reduced genetic diversity usually decreases the ability of a species to adapt to changing environmental conditions. A large, well-connected metapopulation allows the genetic exchange among habitat patches needed to maintain a genetically diverse pool of individuals.

Research has demonstrated that intact landscape and habitat connectivity promotes persistence of other subspecies of *Euphydryas editha* across a landscape (Murphy and White 1984, Harrison *et al.* 1988, Harrison 1989, Singer and Thomas 1996). Although a year of extremely high rainfall appears to have prompted active long-distance dispersal in Quino checkerspot (Murphy and White 1984), the apparent rarity of this event, generally sedentary nature of the butterfly, current low population numbers, and reduced population distribution (Figure 2), decrease the probability that such natural, long-distance dispersal could reestablish occupancy in most habitat patches.

2. Invasion by Nonnative Plants

Nonnative annual grasses and forbs have invaded Quino checkerspot habitat and dominate many areas throughout the range of the butterfly. Both native shrubs and forbs have been displaced (Freudenberger *et al.* 1987, Minnich and Dezzani 1998, Stylinski and Allen 1999). Nonnative plants invade more rapidly following fire or other disturbance and can displace dwarf plantain (*Plantago erecta*), which appears to be a poor competitor against nonnative grasses. The few existing experimental studies on dwarf plantain have been carried out in northern California on serpentine grassland. After early fall rains dwarf plantain germinated later than a nonnative grass, soft chess (*Bromus mollis* (=*B. hordeaceus*)) (Gulmon 1992). Similarly, dwarf plantain decreased during years of high rainfall, correlated with high productivity of soft chess (Hobbs and Mooney 1991). Soft chess was more competitive than dwarf plantain in greenhouse experiments (Koide *et al.* 1987), and nitrogen fertilization decreased the size and density of dwarf plantain (Koide *et al.* 1988). These studies indicate that weed competition will reduce the occurrence of dwarf plantain in exotic annual grassland. The most abundant nonnatives include species of brome grass (*Bromus*), oat grass (*Avena*), foxtail barley (*Hordeum*), mustard (*Brassica*), and red-stem filaree (*Erodium*). In addition to displacing larval hostplants, nonnative annuals have been replacing nectar plants, including dominant shrubs of coastal sage scrub, throughout the historic range of Quino checkerspot (Freudenberger *et al.* 1984, Minnich and Dezzani 1998, Stylinski and Allen 1999).

Conversion from native vegetation to nonnative annual grassland will be the greatest threat to Quino checkerspot reserves based on observations of the large scale invasions throughout the range (Freudenberger *et al.* 1984, Minnich and

Dezzani 1998, Stylinski and Allen 1999). The increased dominance of nonnative species may reduce the abundance of Quino checkerspot foodplants (Koide *et al.* 1987), and habitat fragmentation exacerbates vegetation type conversion because ground disturbance and edge effects in fragments with large edge-to-area ratios experience higher rates of invasion. Corridors of human activity through unfragmented natural areas such as unpaved roads, trails, and pipelines are also conduits of nonnative seed dispersal (Zink *et al.* 1995). Other causes of vegetation type conversion include fire, grazing, off-road vehicle activity, and increased nitrogen deposition (Allen *et al.* 2000).

Once invasion by nonnatives has occurred, natural succession likely will not allow for the complete recovery of the site to a pre-disturbance state. For example, after surveying 25 coastal sage scrub and chaparral sites disturbed up to 70 years ago in San Diego County, Stylinski and Allen (1999) concluded that all the original plant communities were significantly altered by nonnative plant invasion. These sites were primarily disturbed by mechanical means such as agriculture, landfills, and grading, but sites that have been subject to disturbances that remove vegetation without disrupting the soil, such as frequent fire, also contain persistent stands of nonnative vegetation (Freudenberger *et al.* 1984, Minnich and Dezzani 1998). These kinds of studies indicate that active restoration will be required to control nonnative annuals and reestablish native vegetation. Even disturbance events that do not directly threaten Quino checkerspot populations do so indirectly by exacerbating nonnative invasion, as explained below.

3. Off-road Vehicle Activity

Quino checkerspot populations are threatened in some areas by frequent off-road vehicle use, both for recreational and professional (such as Border Patrol activity) purposes. The level of off-road vehicle damage and its effects on Quino checkerspot populations are increasing as the amount of available undeveloped land decreases. Off-road vehicle use compacts soil, destroys hostplants, increases erosion and fire frequency, creates trails that are conduits of nonnative plant invasion (Frenkel 1970), and greatly increases the probability of egg and larval mortality. Although off-road vehicles can destroy suitable habitat and damage butterfly populations, they can also create habitat if the traffic reduces canopy cover in unoccupied areas (Osborne and Redak 2000; G. Pratt, pers.

comm.). However, continued use of subsequently occupied habitat created by off-road vehicles is likely to create a mortality sink. Destruction of eggs and larvae is of particular concern because the occurrence of Quino checkerspot larval and egg distribution is correlated with bare or sparsely vegetated areas (Osborne and Redak 2000, Pratt 2000) where off-road vehicle and other traffic is most likely to occur.

The primary problem is the combination of off-road vehicle use patterns and Quino checkerspot behavior. Off-road vehicle users like to travel along preexisting dirt paths and/or form new ones, particularly along ridgelines. Adult Quino checkerspots also fly up and down these open trails, especially those along ridges. Females also prefer to deposit eggs on *Plantago* growing in open soil, the same type of soil created by off-road vehicle disturbance (Pratt, 2000). Eggs, which take 2 weeks to develop, and prediapause larvae, which can take an additional 2 weeks, are susceptible to being crushed by off-road vehicle traffic. Prediapause larvae cannot travel great distances and are restricted to a small area near the plant where their mother deposited her eggs. Since postdiapause larvae also tend to bask on open soils and pupate in this type of habitat (Osborne and Redak, 2000), they are also susceptible to being crushed.

Detrimental effects of off-road vehicle use have been observed at the Wilson Valley site in Riverside County where motorcycles destroyed plants with egg and larval clusters. At Oak Mountain, one clay lens habitat where Quino checkerspot females had been observed the previous spring was thoroughly destroyed by off-road vehicles (as evidenced by many tire-tracks), and no *Plantago* could be found there the following spring (G. Pratt, pers. comm.).

4. Grazing

The impacts of grazing on Quino checkerspot habitat vary depending on the species of grazer and the timing, intensity, and duration of grazing. Generally impacts include larval hostplant destruction, soil compaction, cryptogamic crust degradation, and egg and larval trampling (M. Dodero, pers. comm.). Sheep and goat grazing precludes Quino checkerspot survival, although grazing may be of some short-term benefit to *Plantago* populations, presumably through preferential feeding on nonnatives (G. Pratt, pers. comm.).

Consumption of nonnative plants by domestic animals has been used as a tool to prevent further deterioration of already degraded bay checkerspot habitat (restricted to serpentine soils). In the short term, cattle may reduce non-native grass invasion rates in already degraded habitat through preferential grazing and enhanced nitrogen exportation (Weiss 1999). However, in Quino checkerspot habitat cattle have also been observed to cause disturbance to soil crusts that contributes to initial invasion rates (M. Dodero, pers. comm.). Livestock have been found to contribute to non-native plant invasion in the arid western U.S. by: 1) transporting seeds into uninfested sites, 2) preferentially grazing native plant species (although this has not been observed in *Euphydryas editha* habitat), 3) creating bare, disturbed patches of soil and destroying crusts, 4) increasing soil nitrogen concentration (if they are not managed to enhance exportation), 5) reducing soil mycorrhizae, and 6) accelerating soil erosion (Belsky and Gelbard 2000). Observations of coastal sage scrub in the Western Riverside County Multiple Species Reserve found that native forbs were readily consumed if grazing was done at the time of year when they were abundant and flowering (E. Allen, pers. comm.). It is doubtful that even carefully controlled grazing can effectively reduce nonnative plant invasion in the variety of habitats that harbor the Quino checkerspot, and it should be phased out and replaced by other less destructive nonnative plant control methods. Intact cryptogamic crusts appear to exclude nonnative plant invasion better than cattle grazing (M. Dodero, pers. comm.)

5. Fire

Increased fire frequency is a cause of native California plant community decline, and therefore a threat to Quino checkerspot survival. Frequent fire is caused by increased human populations (increased ignition sources), and by increased habitat fragmentation and transportation corridors that allow highly flammable nonnative plants to penetrate undeveloped lands. Studies have shown that short fire intervals of 5 years or less cause conversion of shrubland to grassland, enhancing nonnative grass invasion (Zedler *et al.* 1983, Malanson 1985, Calloway and Davis 1993). The typical fire return interval in coastal sage scrub is approximately 30 years (Keeley and Keeley 1984, Westman and O'Leary 1986). Under shorter fire intervals, shrubs, unlike annuals, cannot grow to maturity and reproduce. Urban parks in western Riverside County (such as Box Springs Mountain and Mount Rubidoux, which were dominated by coastal sage scrub 20 years ago) are now largely annual grasslands because of fires that burned at 2- or 3-year intervals (Minnich 1988). Thus, frequent fire results in the loss of shrubland in urban reserves where ignitions are frequent. Nonnative annual grasses contribute to increased fire frequency by forming continuous fuel more flammable than native shrublands.

The overall impact of fire on Quino checkerspot habitat depends on the intensity, frequency, season of occurrence, and size of the invasive nonnative seed bank (Mattoni *et al*. 1997). Given the restricted and fragmented Quino checkerspot distribution, and low population densities, even historic natural fire frequency could extirpate occupancy of remaining isolated habitat patches that have little chance of natural recolonization. Although fire may have historically played a positive role in metapopulation dynamics by creating openings for new habitat patches, this situation does not apply where weed invasion follows fire. Also, dense populations of dwarf plantain (*Plantago erecta*) have not been observed following fire, indicating the species either lacks a dormant seed bank or requires a light burn for seed survival (J. Keeley, pers. comm.). Fires are particularly common near southern Quino checkerspot populations near the international border.

6. Enhanced Soil Nitrogen

Another factor that influences nonnative plant invasion is soil fertility, as invasive species are often better competitors for soil nutrients than native plant species (Allen *et al*. 1998). Soils in urbanized and agricultural regions are being fertilized by excess nitrogen generated by human activities. Burning of fossil fuels, production of fertilizer, and cultivation of nitrogen-fixing crops now add as much nitrogen to global terrestrial ecosystems as do all natural processes combined (Vitousek *et al*. 1997).

Nitrogen deposition has been found to cause conversions from high-diversity shrub-grasslands to low-diversity grasslands in other regions of the world, notably the Netherlands where as much as 90 kilograms of nitrogen is deposited per hectare per year (80 pounds per acre per year) (Bobbink and Willems 1987). Southern California currently experiences up to 45 kilograms per hectare per year (40 pounds per acre per year) of nitrogen deposition, compared to the background level of about 1 kilogram per hectare per year (0.9 pounds per acre per year) (Bytnerowicz *et al*. 1987, Fenn *et al.* 1996). Most nitrogen arrives during the dry season as nitrate dryfall (particulate and ion deposition to surfaces) produced by internal combustion engines. Soils in the most polluted regions near Riverside have more than 80 parts per million (weight) extractable nitrogen, a value more than 4 times that detected in natural, unpolluted soils (Allen *et al.* 1998, Padgett *et al.* 1999).

Nitrogen fertilization experiments near Lake Skinner (where air pollution is relatively low) demonstrated that after 4 years the cover and biomass of nonnative grasses increased and native shrub canopy decreased (Allen *et al.* 2000). These experiments suggest that the rate of loss and degradation of Quino checkerspot habitat will continue, and may increase, in and near nitrogen polluted lands. Nitrogen deposition in southern California is less severe in coastal than inland areas because prevailing winds move pollution inland (Padgett *et al.* 1999). High emissions from nitrogen sources in Mexico could threaten adjacent Quino checkerspot populations in California.

7. Effects of Increasing Atmospheric Carbon Dioxide Concentration
Increasing carbon dioxide gas has direct effects upon the vegetation and indirect effects on associated insects. Atmospheric concentrations of carbon dioxide have risen from a stable 270 parts per million volume prior to the 1900's, to 364 parts per million volume today, and continue to rise at a rate of 0.4 percent per year (IPCC 1996). Unlike atmospheric nitrate or ammonium that deposit along gradients from the source of emissions, carbon dioxide is globally mixed and thus has global impacts (IPCC 1996). Carbon dioxide has been shown to affect plants primarily through increased growth and photosynthesis rates, an increase in leaf tissue (foliar) carbon to nitrogen ratio (C:N), and increased production of carbon-based defense compounds (IPCC 1996, Coviella and Trumble 1999). Increased plant productivity and biomass in chaparral (Oechel *et al.* 1995) and coastal sage scrub will likely contribute to increased canopy closure and reduction of habitat favored by the Quino checkerspot. Chemical changes in plant tissue have been found to affect food quality for herbivores, and often resulted in reduced performance of leaf-eating insects (reviews by Lindroth 1995, Bezemer and Jones 1998, Coviella and Trumble 1999, and Whittaker 1999).

Responses to carbon dioxide increases by larvae of the buckeye butterfly (*Junonia coenia*, a co-occurring relative of the Quino checkerspot), feeding on English plantain (*Plantago lanceolata,* a co-occurring close relative of *P. erecta*), are particularly relevant. When the current atmospheric carbon dioxide concentration was approximately doubled, recorded effects included a 36 percent increase in larval mortality, increased development time, and decreased biomass (Fajer 1989, 1991; Fajer *et al.* 1989). Growth of early instar (younger) larvae was more reduced than that of later instars (Fajer 1989, Fajer *et al.* 1989). Buckeye butterfly results are generally consistent with those of other studies encompassing taxonomically diverse representatives of the order Lepidoptera, suggesting similarly negative effects on Quino checkerspot populations. An extended development time in early instar prediapause larvae would increase probability of mortality factors prior to reproduction due to early hostplant decline (see Climate Effects section above and Climate Change section directly below).

8. Climate Change

Climate change is likely affecting the Quino checkerspot. A trend toward global warming in the last century has been linked to elevated greenhouse gases (Karl *et al.* 1996, IPCC 1996, Easterling *et al.* 1997). For Mexico and southern California, the first warming appears to have started in the 1930's (Parmesan in press). Despite increased El Niño event frequency and intensity (IPCC 1996), southern California is one of the few regions apparently receiving less overall precipitation (Karl *et al.* 1996). Even if more frequent El Niño events eventually result in increased total precipitation, warmer temperatures and increased evaporation rates could still cause habitats to be drier during the crucial late spring months, and hostplants would decline more quickly than in the past (Field *et al.* 1999).

Using historical records and recent field surveys, Parmesan (1996) compared the distribution of *Euphydryas editha* in the early part of the twentieth century to that in 1994-1996. She found the southernmost populations had the highest apparent extinction rate (80 percent) while northernmost populations had the lowest (less than 20 percent) Populations had apparently been extirpated in areas where habitat patches were otherwise (at least currently) suitable. This skewed extirpation pattern resulted in the apparent contraction of the southern boundary by almost 100 miles, and shifted the average location of a *Euphydryas editha* population northward by 92 km, closely matching the shift in mean yearly temperature. Apparent extirpation rates were also reduced at the highest elevations. These observations suggest that the Quino checkerspot may be at substantial risk to the effects of continuing regional warming and drying. A likely explanation for the apparent extirpation patterns is that climate trends contributed to increased prediapause larval death due to early hostplant aging at the southern range edge, and that this process is contributing to the apparent high Quino checkerspot extirpation rate.

It is difficult to conclusively demonstrate butterfly absence, although Parmesan's (1996) census method was designed to maximize detection and included searching for all life stages. The possibility of multiple-year diapause further complicates interpretation of negative survey results. Nonetheless, Parmesan's conclusions with regard to a range contraction are valid whether data reflect actual extirpations or declining population densities, and whether or not they are attributable to climate change. Even if Quino checkerspot butterflies are more likely to re-enter and survive diapause than other sub-species of *Euphydryas editha*, the population mortality rate would still be higher in years the majority re-enter diapause than it would be in favorable years when they do not. Therefore, undetectable adult densities indicate a decline in local population density even if most larvae remain in or return to diapause. The likelihood of range shifts occurring in North American butterfly species is also supported by the recent documentation of range-shifts by one-third of European butterfly species with a much more extensive monitoring history (Parmesan *et al.* 1999). These European species are similar to the Quino checkerspot in being generally non-migratory, fairly sedentary, and host plant specialists.

In light of the probability of future range shifts, prudent design of reserves should include protected corridors for range shifts northward and upward in elevation. Populations inhabiting large undeveloped areas with a stable (typically marine influenced) climate and a high degree of topographic diversity should be the least affected by climate change. Should the current climate and extirpation trends continue, Quino checkerspot populations along the southernmost boundary (in Mexico) are at the greatest risk. Unfortunately, these are also the habitats that appear to have the greatest hostplant density and the lowest degree of threat from development.

F. Current and Evolving Conservation Measures

Since the 1997 listing of the Quino checkerspot butterfly, several conservation efforts have been undertaken by various Federal, State, and local agencies and private organizations. The following briefly describe statutory protections and a variety of on-the-ground conservation efforts.

Section 9 of the Endangered Species Act of 1973 (the Act), as amended, prohibits any person subject to the jurisdiction of the United States from taking (i.e., harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting) listed wildlife species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the Endangered Species Act (50 CFR 17.3) define "harm" to include significant habitat modification or degradation that results in the killing or injury of wildlife, and intentional or negligent "harassment" as acts that significantly impair essential behavioral patterns (i.e., breeding, feeding).

Section l0(a)(1)(A) of the Endangered Species Act and related regulations provide for permits that may be granted to authorize activities otherwise prohibited under section 9, for scientific purposes or to enhance the propagation or survival of a listed species. Section 10(a)(l)(B) of the Act allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity" if we determine that certain conditions have been met that will minimize the impacts to the listed species. Under this section, an applicant must prepare a habitat conservation plan that specifies the impacts of the proposed project and the steps the applicant will take to minimize and mitigate the impacts. The Quino checkerspot is currently addressed in four approved habitat conservation plans: the Orange County Central-Coastal Natural Community Conservation Plan (described below), the Lake Mathews Habitat Conservation and Impact Mitigation Program, the Assessment District 161 Subregional Habitat Conservation Plan, and the Rancho Bella Vista Habitat

Conservation Plan. Several other plans that include measures to protect the Quino checkerspot are being developed.

Section 7(a)(2) of the Endangered Species Act requires Federal agencies to consult with the U.S. Fish and Wildlife Service prior to authorizing, funding, or carrying out activities that may affect listed species. The section 7(a)(2) consultation process is designed to ensure that Federal actions do not jeopardize the continued existence of the species and provides protection for the Quino checkerspot through reasonable and prudent measures that minimize the adverse effects of take of the species due to project impacts.

Measures generated through formal section 7 consultation for State Route 125 South construction in the Otay area identified several activities to be undertaken, including habitat protection and restoration and a captive breeding program (Service 1999). These activities are currently being implemented. The Riverside County Assessment District 161 Subregional Habitat Conservation Plan mitigation package includes a general program integrating habitat protection, habitat restoration research, educational outreach, and captive propagation (Service 2000). Although it is not currently known from within the reserve boundaries, the Quino checkerspot is conditionally covered by the Lake Mathews Multiple Species Habitat Conservation Plan/Natural Community Conservation Plan.

Recovery Units (see Recovery Strategy section below and Figure 2) serve only to focus recovery actions or tasks; they do not designate essential Quino checkerspot habitat that must be protected or preserved.

1. Regional Planning

In 1991, the State of California enacted the Natural Community Conservation Planning Act to address regional conservation needs throughout the State. The San Diego Multiple Species Conservation Program and Multiple Habitat Conservation Program, initiated by the local jurisdictions including the City of San Diego, County of San Diego, other cities, and private interests are being integrated as a component of the Natural Community Conservation Plan and will extend protection to many natural habitat communities. The Multiple Species Conservation Program encompasses approximately 236,000 hectares (582,000 acres) of southwestern San Diego County, and involves multiple jurisdictions. Approximately 69,600 hectares (172,000 acres) are targeted to be conserved within the preserve. The U.S. Fish and Wildlife Service and California Department of Fish and Game approved the overall Multiple Species Conservation Program and the City of San Diego's Subarea Plan in July 1997. The City of Poway's plan was approved in 1996; the County of San Diego's in 1998; San Diego Gas and Electric in 1995; and the City of La Mesa in 2000. Other jurisdictions, including the City of Chula Vista, are expected to complete their subarea planning processes in the future. The Quino checkerspot is not a covered species for any of the subarea plans within the Multiple Species Conservation Program, although both the County of San Diego and San Diego Gas and Electric are developing amendments to their permits to gain permit coverage for the Quino checkerspot. The Multiple Habitat Conservation Program encompasses roughly 48,118 hectares (118,852 acres) in northwestern San Diego County, and involves seven jurisdictions. This plan is still being developed, although the City of Carlsbad has proceeded ahead of the overall plan and has applied for permits from the Fish and Wildlife Service and California Department of Fish and Game. An estimated 8,100 hectares (20,000 acres) are targeted for conservation within the proposed preserve for the Multiple Habitat Conservation Program. The Quino checkerspot is one of the species being evaluated for permit coverage, however no final determination has been made at this time. The Quino checkerspot is also a target species for the County of San Diego North Multiple Species Conservation Program plan which encompasses unincorporated lands east of the existing Multiple Habitat Conservation Program and north of the Multiple Species Conservation Program planning areas.

The Western Riverside Multiple Species Habitat Conservation Plan was initiated by the County of Riverside on October 8, 1998. The planning area encompasses 530,000 hectares (1.3 million acres) and is proposed to include conservation measures for over 100 species, including the Quino checkerspot. Currently, 12 cities within the western portion of the County have endorsed the planning effort and will participate in the planning efforts. A draft Multiple Species Habitat Conservation Plan is proposed to be released for public review in late 2001.

The U.S. Fish and Wildlife Service and California Department of Fish and Game approved the Orange County Central-Coastal Natural Community Conservation

Plan in July of 1996. No extant Quino checkerspot populations are known in the subregion, and the Quino checkerspot is conditionally covered by the Natural Community Conservation Plan. The Natural Community Conservation Plan authorizes the loss of habitat occupied by small and/or satellite populations, reintroduced populations, or populations that have expanded due to Natural Community Conservation Plan management. Loss of habitat supporting populations that play an essential role in the distribution of the Quino checkerspot in the subregion and adjoining areas is not authorized by the Natural Community Conservation Plan. Should planned activities affect Quino checkerspot habitat, the Natural Community Conservation Plan requires that a mitigation plan be prepared that includes design modifications and other on site measures, compensation for habitat losses, and monitoring and adaptive management of Quino checkerspot and its habitat in a manner that meets the approval of the U.S. Fish and Wildlife Service.

2. San Diego National Wildlife Refuge

Habitat conservation efforts include protection of resident Quino checkerspot populations on the San Diego National Wildlife Refuge. The San Diego National Wildlife Refuge was established in 1996 with the acquisition of 745 hectares (1840 acres) at Rancho San Diego in San Diego County. Acquisitions average about 490 hectares (1,200 acres) per year, with 2941 hectares (7,268 acres) currently owned by the U.S. Fish and Wildlife Service. Funding for acquisition from the Land and Water Conservation Fund has remained steady at about $3 million per year. Our staff have conducted annual Quino checkerspot surveys on the Refuge, with assistance from other certified volunteers, at selected locations. These locations are primarily hilltops and areas with known concentrations of hostplants. Habitat assessments for the Quino checkerspot are generally conducted in conjunction with other surveys, and during some focused surveys for host and nectar sources in the spring. Locations with hostplants are mapped whenever they are found. Surveys to date indicate that the San Diego National Wildlife Refuge has a small Quino checkerspot population on the Rancho San Diego tract, although no adults or larvae were observed in 2000.

In addition to surveying of the Refuge for the Quino checkerspot and its habitat, we are storing host plant and other native plant seeds in a seed bank for future enhancement projects. A small greenhouse is planned to produce more seed from this stock. Refuge Operating Needs System projects for Quino checkerspot habitat restoration funding have been submitted. We anticipate that future Quino checkerspot conservation efforts will increase as staff and volunteer resources grow, and new lands are acquired. Past efforts include a small enhancement project where nonnative grasses were removed, and hostplant and nectar sources were planted. Research needed to identify Quino checkerspot habitat restoration methods for the Refuge have been identified, including a plan written by the U.S. Fish and Wildlife Service and the Recovery Team.

3. Captive Propagation

Captive propagation efforts to date consist of a small population maintained by Dr. Gordon Pratt at University of California Riverside. This population consists of stock from Marron Valley collected in 1996. We are currently working with Dr. Pratt and Dr. Mike Singer to expand and improve current efforts and establish a formal program. Plans include collecting stock (older males and females late in the flight season) and maintaining lines from all possible metapopulations, providing new quality facilities in Riverside County, and establishing a second captive propagation site. Butterfly "ranching" within the distribution of an extant population, possibly Southwest Riverside County Multiple Species Reserve, has also been proposed (U.S. Fish and Wildlife Service 1999). Ranching involves wild adults that lay eggs on host plant in managed habitat. Only the larvae are captive, and are reared in a protected situation, traditional propagation methods use captive adults and are referred to as "farming"(B. Toon, pers. comm.).

4. California Department of Fish and Game

The California Department of Fish and Game funds Quino population and habitat monitoring activities using funds allocated by the U.S. Fish and Wildlife Service under section 6 of the Endangered Species Act. Also, under the California Environmental Quality Act an analysis of direct, indirect, and cumulative project impacts to biological resources, including the Quino checkerspot, occurs. The California Environmental Quality Act sometimes requires development and implementation of mitigation plans for projects that result in loss of habitat.

G. Recovery Strategy

The survival and recovery of the Quino checkerspot depends on protection and restoration of habitat patches within the distribution of metapopulations, augmentation of extant populations, and reintroduction or discovery of metapopulations in areas not known to be currently occupied. Recovery efforts would be greatly facilitated, and ongoing threats reduced, by the advent of a large-scale educational outreach program involving local cooperative partnerships. Because extant metapopulations are unique, and their dynamics and distributions have not been studied, adaptive management practices and monitoring will be key aspects of recovery. Due primarily to the high degree of threat imposed by nonnative plant species invasion, management of all populations will be required into the foreseeable future (Foin *et al.* 1998). Habitat areas that need protection consist of all areas occupied by the butterflies, including patches of larval hostplants and sites used by adults during breeding, oviposition, nectaring, and dispersal. Stable metapopulation structure requires preservation of habitat patches that may be temporarily unoccupied by larvae so they can continue to support local populations in the future. By the time habitat patches are naturally recolonized, larval occupancy of other patches is likely to have been naturally extirpated (see Metapopulation Structure section above).

The best available information indicates the Quino checkerspot is highly endangered: it was at such low densities prior to listing that it was thought to possibly be extinct (62 FR 2315), it currently is only known from approximately 10 percent of its former distribution, it is known to undergo large population fluctuations related to weather (Murphy and White 1984, see Climate Change section above), and most current populations are threatened by ongoing development (see Threats section above). Under current conditions the Quino checkerspot may go extinct in the foreseeable future. Therefore, further losses of suitable or restorable habitat patches that are near or within the distribution of habitat complexes identified in this plan likely will adversely affect the long-term conservation of the Quino checkerspot (see Distribution and Habitat Considerations section above and Figure 2).

Any proposed project that might reduce the area of suitable or restorable habitat should be carefully evaluated, and conservation measures that fully protect and/or restore habitat of greater value should be included in the design. Project proponents are encouraged to begin working with us in the early stages of project design to avoid and minimize project impacts and time delays. A crucial aspect of conserving existing metapopulations is the protection of linkage areas between habitat patches, especially given the high degree of urbanization throughout the current Quino checkerspot range. Protection of landscape connectivity in a configuration that assures metapopulation stability is essential. All habitat areas that support extant Quino checkerspot metapopulations will require management and some degree of restoration. Restoration efforts should be guided in part by modeling efforts to predict metapopulation stability in alternative habitat patch networks. The final management program for a particular habitat complex or metapopulation must be preceded by:

- Creation of detailed maps of habitat patches and linkage areas on a spatial scale that captures the essential landscape connectivity and known distribution of each populations or metapopulation (habitat complex).
- Modeling of metapopulation dynamics for each habitat complex.
- Assessment of varying restoration needs among Recovery Units and habitat patches.
- Identification of significant mortality sinks, such as high-traffic roads.
- Design of management tools and practices to reconstruct essential landscape connectivity and prevent dispersal into mortality sinks.
- Estimation of costs associated with alternative metapopulation management designs.

As management plans are implemented, monitoring will provide the ultimate test of effectiveness. Census surveys should be coordinated to extend over at least a sub-sample of habitat patches throughout the entire metapopulation distribution (see Murphy and Weiss 1988 and Recovery Criteria below), and may be combined with presence-absence surveys to determine habitat patch occupancy patterns. Collection of census data over a period of several years (approximately 15) will be required to reasonably encompass variability of current environmental conditions experienced by the species and associated density fluctuations (Murphy *et al.* 1990).

Along with protecting habitat, equally high priority is assigned to the urgently needed program to augment existing metapopulations and to establish new ones. The likelihood of extinction remains high unless habitat protection, captive breeding, and population augmentation programs are initiated without delay.

1. Modeling

Spatially explicit theoretical models have been successfully used to guide conservation efforts in the Glanville fritillary (*Melitaea cinxia),*a close relative of the Quino checkerspot (Hanski *et al.* 1996, Wahlberg *et al.* 1996). This approach used the incidence function model to predict specific habitat patches crucial to metapopulation stability (Wahlberg *et al.* 1996), and habitat patch structure resulting in the highest probability of metapopulation persistence (Thomas and Hanski 1997). Other types of spatially explicit models that require less detailed biological data may be more appropriate for Quino checkerspot recovery. Models should not assume that extirpation probabilities of habitat patches are independent, and should incorporate environmental correlation whenever possible (Harrison and Quinn 1989). The specific type and complexity of the model used will be dependant on available data and time constraints for recovery implementation.

With habitat quality and local climate varying from the location of one metapopulation to another, acreage needed to sustain stable metapopulations will also vary. Additional analyses of conditions contributing to metapopulation stability (from modeling) and restoration potential of each habitat area must be made before further refinement of metapopulation preserve design and analyses of population viability can be accomplished. Complete data needed to determine specific habitat acreage objectives for each (as yet undescribed) metapopulation are not yet available. It is possible that modeling efforts may require some additional data on site-specific population and life history characteristics of the Quino checkerspot.

2. Restoring Landscape Connectivity

Habitat patches should be connected to as many other patches as possible to enhance dispersal and increase the probability of recolonization following extirpation events. Habitat networks should also be buffered (i.e., imbedded in natural areas as large as possible) to reduce indirect impacts of development and the need for future or ongoing restoration in occupied habitat. Restoration of connectivity in developed areas that still sustain the species will require innovative technology or perpetual management. Obstacles of particular concern are high-traffic roads. The Transportation Equity Act for the 21st Century (TEA-21) offers an opportunity for Federal agencies to facilitate reduction of highway impacts on wildlife, particularly through innovative dispersal corridor technology. Technology that may enhance Quino checkerspot landscape connectivity includes road overpasses coupled with barriers to prevent mortality and channel dispersal. Similar road overpasses and barriers have been used successfully to reduce vertebrate wildlife mortality (e.g. Page *et al.* 1996, Keller and Pfister 1997). A dual recreational use and habitat corridor overpass that would serve as a reasonable model for butterfly overpasses is currently under construction in Florida (Berrios 2000). Possible barriers include tall (3- to 10-meter (10- to 33-foot) fences or tall, dense, woody vegetation (G. Pratt, pers. comm.). Overpass linkages should require little more than nectar resources and relatively bare ground resembling habitat areas including hilltops. It may be possible to manipulate butterfly behavior and direct Quino checkerspot dispersal across overpasses (G. Pratt, C. Parmesan, and M. Singer, pers. comm.). Underpasses are less likely to improve dispersal because Quino checkerspots tend to avoid shaded areas (see Adult Behavior and Resource Use above).

3. Habitat Restoration

The ultimate goal of restoration efforts will be self-sustaining functional native ecosystems similar to those that historically supported Quino checkerspot metapopulations. Restoration efforts must focus on restoring as many habitat components as possible. Effort can range from minimum, such as adding seed of larval food and adult nectar plants to enhance existing resources, to extensive, such as reestablishing native plant communities in fallow agricultural fields. Site-specific ecosystem restoration planning should include data on natural vegetation community composition and physical habitat structure in the vicinity. Other habitat attributes that should be considered include soils and associated plant and animal populations (Osborne and Redak 2000). This information can often be obtained through historical notes and records, maps, photographs, and analyses of nearby relatively unaltered native communities. Data on historic conditions should be used to determine the species composition of each site whenever possible.

In areas targeted for Quino checkerspot habitat restoration, natural physical and biological attributes must be restored. Large-scale monoculture planting of *Plantago* is unlikely to be successful because other vegetation components are essential, including nectar plants and pollinators. Other habitat components, such as appropriate larval diapause and pupation sites (see Osborne and Redak 2000), are also essential. High potential for recolonization exists particularly where native vegetation and historic topography has already been restored. Habitat can be partially or wholly restored using methods that vary in labor intensity, disruption to existing vegetation and soils, and potential for impacts on nontarget plants and animals. Methods should be specifically chosen to meet the needs of each habitat patch (Appendix II). Research may provide additional methods and successful combinations of existing ones. Only locally collected *Plantago* seed should be used for restoration until a better understanding of *Plantago* ecology and genetics is available. Commercial supplies may not be reliable (M. Dodero and B. McMillan, pers. comm.).

4. Surveys and Monitoring

Butterfly conservation biologists have developed a variety of non-destructive monitoring methods for estimating population numbers and long-term density trends (Pollard 1977, Thomas 1983, Murphy and Weiss 1988, Zonneveld 1991, Van Strien *et al.* 1997). These monitoring techniques do not rely on standard mark-recapture methods, but on either adult or on egg cluster/larval web observations. Two different techniques should be adopted, one to measure changes in local densities, and another to determine habitat patch occupancy patterns. The second technique would focus on presence/absence rather than density and maximize area covered in a given time (see Recovery Criteria below).

5. Captive Propagation

The Quino checkerspot butterfly captive propagation program should consist of two separate laboratory facilities (65 FR 56916); and, if possible, include lines from all described habitat complexes. Genetic stock from each habitat complex should be kept separate until further research determines extent of historic or appropriate gene flow between them. Annual augmentation of captive stock with a small number of wild-captured individuals will be necessary to reduce selection for captive conditions and inbreeding depression. Collection of older females and males at the end of the adult flight season is recommended, and should not significantly affect metapopulation persistence (Cushman *et al*. 1994). Captured females that have already deposited most of their eggs can be induced to produce and deposit more eggs than would naturally occur (G. Pratt, pers. comm.). Captive augmentation facilities should also include butterfly ranches within the distribution of extant metapopulations. Butterfly ranches would consist of semi-natural areas designed and managed to produce high density populations that could disperse naturally or be manually distributed to augment extant metapopulations (B. Toon, pers. comm.).

6. Multiple Species Reserves and the Quino Checkerspot

For invertebrates, including the vast number of poorly described or undescribed species that are undoubtedly also endangered but not listed (Redak 2000), the quality of habitat preserved is more crucial than the extent (Ehrlich 1992). Thus mitigation ratios based solely on acreage are not likely to be valid. However, losses of lower quality Quino checkerspot habitat may threaten the preservation of other species, even if butterfly populations are not likely to be jeopardized. *Euphydryas editha* butterflies are good indicators of biodiversity and habitat quality because they are closely tied to the taxonomic diversity of vegetation (Launer and Murphy 1994); more so than, for example, birds (Ehrlich 1992). *Euphydryas editha* is probably sensitive to pesticides and responsive to various other general aspects of habitat quality that are not always apparent (Ehrlich 1992). Launer and Murphy (1994) found that if only sites supporting the largest *Euphydryas editha* populations were preserved, or if portions of a site classified as "marginal" butterfly habitat were lost, the proportion of protected plant species dropped substantially. Also, although it is true that insect populations typically require smaller habitat areas than populations of large vertebrates (Ehrlich 1992), *Euphydryas editha* requires relatively large areas of conserved landscape connectivity. That is, maintenance of dispersal corridors linking a network of habitat patches over a large area will be required to conserve Quino checkerspot metapopulations.

Undeveloped wildlands adjacent to and among Quino checkerspot metapopulation distributions (or habitat complexes if metapopulation distributions are not described) should be maintained because they contain landscape connectivity essential to other species that are part of the Quino checkerspot habitat community. Areas of interface between developed and undeveloped lands require active management to reduce direct and indirect impacts of development on fragmented wildlands.

Restoration of Quino checkerspot habitat patch networks within a multi-species reserve systems can be accomplished, but it will require: 1) ensuring that the reserve system contains a sufficient number of linked suitable or restorable habitat patches; 2) coordinated adaptive management; 3) regulation of activities that affect all habitat patches including those temporarily unoccupied by larvae essential to long-term metapopulation survival (Murphy and Rehm 1990, Murphy and White 1984); and 4) coordination of habitat restoration to reduce and resolve potential biological conflicts. Conflicts may arise when management strategies for different sensitive species, such as coastal California gnatcatchers (*Polioptila californica*), require somewhat denser shrub cover than the Quino checkerspot. Plans should be designed to include a mosaic of shrub-dominated areas interspersed with open habitat patches occupied by native annual and perennial herbs, which together can support multiple sensitive species. Development permits should include provisions allowing or requiring opportunities for salvage of biological material from habitat that will be destroyed. To assure appropriate mitigation, habitat acquisitions should occur within the same Recovery Unit in which take is authorized.

7. Recovery Units

Recovery Units identified in this recovery plan are geographically bounded areas that are the focus of recovery actions or tasks. These Recovery Units contain known occupied habitat and intervening and adjacent lands that may be periodically used by the Quino checkerspot in the future, including linkage areas for dispersal and habitat patches that may be restored or enhanced for the long-term conservation of the species. However, Recovery Units also contain areas that do not support the Quino checkerspot, including large areas of closed canopy chaparral, coniferous forests, agricultural fields, urban development, and other lands not suitable for the species. As a result, Recovery Units include lands both essential and not essential to the long-term conservation of the Quino checkerspot. Recovery Unit boundaries may change if and when additional populations are documented or introduced.

Based on unique components of habitat suitability essential to Quino checkerspot protection and recovery, the six Recovery Units are assigned to four regional environmental groupings. General descriptions of ecological regions and Recovery Units are based on the personal observations of Recovery Team members and our staff who are most familiar with the geographic areas.

Western Riverside County Region

This region includes two Recovery Units divided by Interstate 215, and is located in western Riverside County east of Interstate 15 (Figure 2). Quino checkerspot metapopulations in this region are most commonly, but not exclusively, associated with low rounded, gently sloped, and open exposed southern slopes. Openings in grassland and coastal sage scrub provide habitats for Quino checkerspot throughout most of the region. These habitats typically support scattered shrubs and abundant dwarf plantain (*Plantago erecta*) on exposed soil patches. The Northwest Riverside Recovery Unit exhibits diverse vegetation types including chamise chaparral and juniper woodlands.

Quino checkerspot occupancy is often associated with clay and red soils in this region, particularly dark clay gabbro soils. Cryptogamic crusts have become rare in the region. *Acarospora schleicheri* (a thick yellow lichen) and *Acarospora thelococcoides* (a cream white, donut-shaped lichen) are commonly associated with cryptogamic crusts in Quino checkerspot habitat. *A. thelococcoides* is rare in southern California, but is often found at known Quino checkerspot sites. Bulb species such as blue dicks (*Dichelostemma capitatum*) and chocolate lilies (*Fritillaria biflora*), and the annuals peppergrass (*Lepidium nitidum*), tidy-tips (*Layia platyglossa*), goldfields (*Lasthenia californica*), pygmy weed (*Crassula connata*), and tarplant (*Hemizonia* sp.) are commonly found on occupied habitat in this region. Tarplant may be a good field reference for clay lens habitat because it forms dense stands visible at great distances long after senescence. Another species associated with clay soil is many-stemmed dudleya (*Dudleya multicaulis*).

Yellow composites such as goldfields (*Lasthenia* spp.), goldenbush (*Ericameria* spp.), and golden yarrow (*Eriophyllum* spp.) are probably among the most important genera used as nectar sources. Early blooming individuals of yerba santa (*Eriodictyon* spp.) may also be used. Nectaring on sugar bush (*Rhus* *ovata*), fiddleneck (*Amsinckia* spp.), and phacelia (*Phacelia* spp.) has also been observed. Dwarf plantain (*Plantago erecta*) is the primary hostplant in this region.

Northwest Riverside Recovery Unit:

The Recovery Unit is located south of Lake Mathews, East of Interstate 15, and west of Interstate 215 as mapped (Figure 4). It contains one habitat complex, Gavilan Hills, distributed from the south margin of Lake Mathews into the Gavilan Hills (Figure 2). The closest other Recovery Units are the adjacent Southwest Riverside Recovery Unit to the south, and the proposed North Orange Recovery Unit to the north west. Landscape connectivity may be restorable from the Gavilan Hills to the Southwest Riverside Recovery Unit border, although dispersal is currently constrained by Interstate 215.

Threats: High; primarily habitat destruction and fragmentation due to development, and habitat degradation due to nonnative plant invasion.

Southwest Riverside Recovery Unit:

This Recovery Unit is located in southwestern Riverside County east of Interstate 15 and Interstate 215, north of the east-west oriented section of State Route 79, south of the Santa Fe Railroad line and Scott road (south of State Route 74), and west of Sage Road and Oak Mountain areas as mapped (Figure 5). It contains two habitat complexes, Warm Springs Creek and Skinner/Johnson, divided by State Route 79 (Figure 2). State Route 79 is probably a significant mortality sink, but not currently an impassable barrier between remaining habitat patches on either side. This Recovery Unit is generally contiguous with the South Riverside Recovery Unit to the east. Potential landscape and ecological connections with the Northwest Riverside Recovery Unit are constrained primarily by Interstate 215 and associated development.

Threats: High; primarily habitat destruction, degradation, and fragmentation associated with development outside of Southwest Riverside County Multiple Species Reserve. Within Southwest Riverside County Multiple Species Reserve, nonnative plant species invasion poses the greatest threat.

South Riverside Region

This region contains two Recovery Units, separated by State Route 371 as mapped (Figure 2). In this region Quino checkerspots are generally associated with gently sloped, and open southern exposures. Most Quino checkerspot occupancy is along the upper rounded ridgelines. Habitat occurs in the coastal sage scrub openings in the west, and at higher elevations in the east, habitat opening are in chamise or red shank chaparral. These open habitats principally contain annuals and California buckwheat (*Eriogonum fasciculatum*). Blue dicks (*Dichelostemma capitatum*) is common at most of the sites. California buckwheat, sugar bush (*Rhus ovata*), and jojoba (*Simmondsia chinensis*) are the dominant shrubs in the western portions of the region below 920 meters (3000 feet) in elevation and red shank (*Adenostoma sparsifolium*) and California buckwheat are the dominant shrubs above 920 meters (3000 feet) in elevation. Rainfall in the Silverado habitat complex is higher than at any other known Quino checkerspot sites (G. Pratt unpubl. data), averaging approximately 50 centimeters (20 inches) per year (Oregon Climate Service 1995; see http://www.nws.mbay.net/CA_SOUTH.GIF).

Goldenbush (*Ericameria linearis*), popcorn flowers (*Cryptantha* and *Plagiobothrys* spp.), goldfields (*Lasthenia* sp.), sugar bush (*Rhus ovata*), onion (*Allium* spp.), linanthus (*Linanthus* spp.), layia (*Layia* spp.), goldenbush (*Ericameria* spp.), golden yarrow (*Eriophyllum* spp.), and species of Asteracae are probably most frequently used as nectar sources. Clay soils and gabbro clay lens habitat in the west transition into granitic soils in the east (U.S. Fish and Wildlife Service 1998). Below 920 meters (3000 feet) in elevation, lichens are associated with the cryptogamic crusts, but are rare at higher elevations, where spike-moss (*Selaginella bigelovii*) is more common. The granitic soil crusts in this region are more easily disturbed than those on clay soils. The eastern sites extend to above 1220 meters (4000 feet) in elevation, where known larval habitat is characterized by undisturbed low ridges and broad washes lacking a clay soil component.

Dwarf plantain (*Plantago erecta*) is the primary larval hostplant species at western sites, transitioning to woolly plantain (*P. patagonica*) in the east above 920 meters (3000 feet). Secondary use of owl's clover (*Castilleja exserta*) occurs at certain localities, particularly Oak Mountain. Chinese houses

(*Collinsia concolor*) occurs in small numbers in the Vail Lake area just south of Oak Mountain and may also be used.

South Riverside Recovery Unit:

This Recovery Unit is located south of State Route 74, east of Sage Road and Oak Mountain, west of State Route 371, and west of the desert's edge as mapped (Figure 6). This Recovery Unit contains three habitat complexes, Oak Mountain/Vail Lake, Sage Road/Billygoat Mountain, and Brown Canyon to the north (Figure 2). The closest Recovery Units are the Southwest Riverside Recovery Unit and the South Riverside/North San Diego Recovery Unit. Landscape and ecological connectivity with the Southwest Riverside Recovery Unit to the west is threatened by increasing development. The Recovery Unit is contiguous with the South Riverside/North San Diego Recovery Unit and with relatively undeveloped areas to the south including the north slope of Mount Palomar.

Threats: Medium; this area is threatened by proposed development, off road vehicle activity, and illegal trash dumping (G. Pratt, pers. comm.).

South Riverside/North San Diego Recovery Unit:

This Recovery Unit is located south of State Route 371 in Riverside and San Diego Counties, east of Aguanga and Mount Palomar, north of Warner Springs, and west of the Anza Borrego Desert as mapped (Figure 7). This Recovery Unit contains two habitat complexes: the Silverado habitat complex, distributed on a proposed mitigation bank and Bureau of Land Management property south of the Cahuilla Indian Reservation; and the Dameron Valley/Oak Grove habitat complex (Figure 2). This Recovery Unit is contiguous with the South Riverside Recovery Unit to the west, and also has southern ecological connectivity with surrounding undeveloped areas.

Distribution of historic Quino checkerspot records and habitat characteristics to the south indicate the likelihood of landscape connectivity well into San Diego County. On the southwest side of Mount Palomar between 1220 and 1520 meters (4000 and 5000 feet) in elevation there are two historic Quino checkerspot records, one from 1952 and another 23 years later in 1975 (Figure

2), suggesting the presence of a historically persistent metapopulation in northern San Diego County.

Threats: Low; primarily nonnative plant invasion and fire.

Southwestern San Diego Region

This region contains one Recovery Unit, centered around Otay Mountain, bounded to the south by the international border and to the north by State Route 94 as mapped (Figure 2). Habitat in this region primarily consists of low rounded hills and gently sloped open southern exposures. Quino checkerspot habitats in this region are largely clay soil openings in coastal sage scrub and chamise chaparral. Historically the Quino checkerspot widely used grasslands associated with vernal pools and mima mounds, ridge tops, and mountain slopes supporting stands of dwarf plantain (*P. erecta*). The vegetation of clay lens habitats commonly occupied by the Quino checkerspot includes many bulbs: wavy-leaf soap plant (*Chlorogalum parviflorum*), brodiaea (*Brodiaea* spp.), blue dicks (*Dichelostemma capitatum*), San Diego goldenstar (*Muilla clevelandii*), red-skinned onion (*Allium hematochiton*), and fritillary (*Fritillaria biflora*). Annual herbaceous plants include shooting star (*Dodecatheon clevelandii*) and mesa saxifrage (*Jepsonia parryi*). Other species associated with clay habitat include variegated dudleya (*Dudleya variegata*), a clay lens endemic that ranges from central coastal San Diego County south into northern Baja California. Tarplants (*Deinandra* and *Centromadia* spp.) may prove to be good indicators of habitat in southern San Diego County. Most current Quino checkerspot occupancy is found along the upper rounded ridgelines. Soils in this region most often observed to support the Quino checkerspot are red or gray clay soils.

Onion (*Allium* spp.), goldfields (*Lasthenia* spp.), and linanthus (*Linanthus* spp.) are the most commonly observed nectar sources in the region. Dwarf plantain (*Plantago erecta*) is the primary hostplant in this region. Owl's-clover (*Castilleja exserta*) is also abundant around the remaining Otay Mesa vernal pool areas. Bird's-beak (*Cordylanthus rigidus*) and chinese houses (*Collinsia heterophylla*) may be infrequently used as secondary hosts.

Southwest San Diego Recovery Unit:

This Recovery Unit is located in southern San Diego County south of State Route 94, east of Interstate 805 and associated urban areas, and west of the city of Tecate as mapped (Figure 8). It contains six habitat complexes: San Diego National Wildlife Refuge near Sweetwater Reservoir, Otay Lakes, Otay Foothills (western slope of Otay Mountain), Otay Mesa (northern rim of the mesa including Otay Valley), Marron Valley, and Tecate (Figure 2). The closest Recovery Units are the Proposed South-central San Diego Recovery Unit to the north and the Southeast San Diego Recovery Unit to the east. There may be some degree of landscape connectivity with the Proposed South-central San Diego Recovery Unit through undeveloped lands in central and eastern portions of the county. There may also be landscape connectivity to the Southeast San Diego Recovery Unit through lands in Baja California, Mexico, restricted primarily by development in the Tecate area, and through undeveloped land north of State Route 94. There may be suitable and/or occupied Quino checkerspot habitat in relatively undeveloped lands north of State Route 94. Currently State Route 94 is only a two-lane highway in that area, and would not preclude Quino checkerspot dispersal.

Threats: High; primarily habitat destruction, degradation, and fragmentation associated with development in the western Otay area. Most historical habitats have been developed or heavily disturbed by agriculture, grazing, road grading, off-road vehicle and Border Patrol activity, and pipeline construction. These disturbances have also resulted in serious nonnative plant invasion problems.

<u>Eastern San Diego Region</u>

This region contains one Recovery Unit located in the southeastern corner of San Diego County near the community of Jacumba (Figure 2). The habitats in this region are composed primarily, but not exclusively, of dark brown clay lenses and adjoining sandy, rockier areas on open gentle north-facing slopes. Habitat patches are in open juniper woodlands characterized by scattered shrubs. Barren soils in more exposed areas (i.e. without the woodland vegetation), do not support hostplants. The vegetation in this area is a diverse mixture of desert and coastal slope communities. California buckwheat (*Eriogonum fasciculatum*), catclaw (*Acacia greggii*), California juniper (*Juniperus californica*), holly-leaf cherry (*Prunus fremontii*), sugar bush (*Rhus ovata*), and jojoba (*Simmondsia chinensis*) are the dominant trees and shrubs. Soils associated with Quino checkerspot occupancy in this ecoregion are composed of brown clay lenses and sandy soil. Habitat appears to be characterized by cryptogamic crusts with associated (unidentified) lichen and moss species and open patches of barren soil lacking vegetation.

Goldenbush (*Ericameria linearis*) appears to be the major nectar resource throughout most of this region. Sugar bush and holly-leaf cherry may be important nectar sources in drier years. Dwarf plantain (*Plantago erecta*) is the only documented primary hostplant in this region, but woolly plantain (*P. patagonica*) is also present.

Southeast San Diego Recovery Unit:

The location of this Recovery Unit is centered around the community of Jacumba in southeastern San Diego County east of the Imperial County line and north of the International Border, south of State Route 94 and Interstate 8 and east of Campo as mapped. This Recovery Unit also includes the Table Mountain area north of Interstate 8 (Figure 9). It contains one habitat complex, Jacumba Peak in the vicinity of Jacumba and Table Mountain (Figure 2). The closest other Recovery Unit is the Southwest San Diego Recovery Unit; landscape connectivity between them is restricted primarily by Interstate 8, State Route 94, and development in the Tecate and Campo areas. There may be a landscape connection with the South Riverside/North San Diego Recovery Unit to the north along the western slope of the Laguna Mountains.

Threats: Medium; primarily habitat destruction, degradation, and fragmentation associated with development, off-road vehicles, and Border Patrol activities.

8. Proposed Recovery Units

The three Recovery Units described below are proposed to contain the two additional metapopulations specified by recovery criteria below. The two populations or metapopulations may be located in one or two future Recovery Units. The proposed Recovery Units do not appear to be currently occupied by the Quino checkerspot, but either historically supported populations (Figure 2) or appear to have high potential to support stable metapopulations based on general habitat characteristics. The proposed Recovery Units are within the only remaining large undeveloped coastal areas of Orange and San Diego Counties, but research is needed to determine the extent and location of undocumented populations and suitable or restorable habitat for reintroduction. Although unlikely, it is possible that surveys may identify occupied or restorable habitat patch networks partially or entirely outside the proposed Recovery Unit locations described below, however they must fall within the western coastal areas to meet recovery criteria (see Recovery Criteria below). The purpose of adding the two additional populations is to re-establish a portion of the former coastal Quino checkerspot distribution where the more stable maritime climate should promote population stability.

<u>Proposed South-central San Diego Recovery Unit:</u>
This proposed Recovery Unit in San Diego County includes the vernal pool habitat on Kearny Mesa, Mira Mesa, Del Mar Mesa, and Lopez Ridge; and Sycamore and Little Sycamore Canyons, Iron Mountain and San Vicente Reservoir areas east of State Route 67, and the Fortuna Mountain area. There are historic records of Quino checkerspot scattered throughout this Recovery Unit, however no occupancy has been confirmed in recent years (Figure 2).

This proposed Recovery Unit contains high-quality, historic habitat of the Quino checkerspot similar to the historic condition of Otay Mesa (see Murphy and White 1984). Recent surveys reported cryptogamic crusts and vernal pool complexes supporting extensive dwarf plantain (*Plantago erecta*) stands on mesa tops east of Interstate 805 (Osborne 2000). Maritime climatic influence should help protect larval food plants from heat and drought, thus allowing higher pre-diapause larval survival than in more variable inland regions (see Life History section).

The general ecological description of the Southwestern San Diego region above also describes this proposed Recovery Unit. The mesa areas contain high quality vernal pool and mima mound habitat patches on predominantly reddish and clays soils. Habitat areas in the eastern portions contain cryptogamic crusts and dense patches of dwarf plantain (*Plantago erecta*) mixed with abundant owl's-clover (*Castilleja exserta*). In northeastern areas of this Recovery Unit, apparently suitable Quino checkerspot habitat can be found distributed extensively across open ridge tops of mixed chaparral/coastal sage scrub. Ridge top habitat in the eastern portions of the proposed Recovery Unit may be difficult to detect and access because surrounding slopes are sometimes covered with dense chaparral. However, such relatively narrow zones (several meters) of closed-canopy chaparral are not considered to pose a significant barrier to Quino checkerspot dispersal (K. Osborne, G. Pratt, C. Parmesan, and M. Singer, pers. comm.).

The proposed Recovery Unit is designed to provide landscape connectivity within the least developed central-coastal San Diego mesas and foothills, and is entirely within the San Diego County Multiple Species Habitat Planning Area. Interstates 5, 805, and 15, State Routes 52 and 67; and development in Mira Mesa, Ranch Penasquitos, and Scripps Miramar Ranch constrain the landscape connectivity of a network of otherwise suitable or restorable habitat patches. It may be possible to maintain landscape connectivity between Del Mar Mesa and Marine Corps Air Station Miramar via Los Penasquitos Canyon. Restoration of landscape connectivity (or the equivalent of it) throughout the proposed Recovery Unit would require either technological solutions (see Restoration of Landscape Connectivity section above), or very active management in perpetuity. The possibility of landscape connectivity with Recovery Units to the south and east depends on: protection of open space and enhancement of landscape connectivity east of the proposed Recovery Unit in the vicinity of State Route 67, San Vicente Reservoir, and Black Mountain, and the unknown condition of landscape connectivity to the southeast of the proposed Recovery Unit (may require restoration). Most lowland areas from San Vicente Reservoir north to Iron Mountain and Mount Woodson are currently proposed for land development. To the maximum extent possible, the ecological connectivity of this Recovery Unit to eastern wildlands should also be maintained to protect against indirect effects of nearby human occupancy and decrease the need for active management.

Proposed Northwest San Diego Recovery Unit:
This proposed Recovery Unit is located in northwestern San Diego and southern Orange Counties, including Marine Corps Base Camp Pendleton and adjacent reserve lands and undeveloped areas. No records of the Quino checkerspot are known from this proposed Recovery Unit; however, it has (or formerly had) characteristics of habitats that appear to have historically supported high densities of the Quino checkerspot in Southwestern San Diego County (Murphy and White 1984). The possibility of former occupancy by the Quino checkerspot

within the proposed Recovery Unit is suggested by historical records and accounts (see Distribution and Habitat Considerations section above). Historical collection records near the proposed Recovery Unit (to the northwest in Dana Point, and to the south in Vista) suggest the proposed Recovery Unit lands between them were also formerly occupied (Figure 2).

The lack of historical records is to be expected; Camp Pendleton has been restricted from amateur biological collection since its establishment in 1942. Camp Pendleton management contracted a general base-wide habitat survey in 1996 and 1997, as well as several subsequent site-specific butterfly surveys (Redak 1999). Surveyors stated they found abundant "optimal and adequate Quino checkerspot habitat." However, surveyors did not detect butterflies, and did not conduct comprehensive surveys base-wide.

Huerero soils and clay lenses support vernal pools on coastal terraces in the western portion of this proposed Recovery Unit. Historically, the coastal terrace area also supported mima mounds and vernal pools. Although most vernal pool topography has been degraded or destroyed, it is restorable (M. Dodero, pers. comm.). Other topographic features indicative of Quino checkerspot habitat include mesas, rolling hills, and ridge lines. Vegetation consists of mixed coastal sage scrub and chaparral, with grassland inclusions. Dwarf plantain (*Plantago erecta*) is abundant in patches (Redak 1999, Osborne 2000), but the extent of Quino checkerspot hostplant distribution within the proposed Recovery Unit is unknown. Quino checkerspot nectar plants are also abundant (Redak 1999, Osborne 2000). Similar to the Southwest San Diego Recovery Unit, this proposed Recovery Unit should provide a more stable marine climate influence. Amelioration of hot, dry climatic conditions and its diverse unfragmented topography should make the Proposed Northwest San Diego Recovery Unit a crucial one with regard to climate (see Life History section above).

Efforts to restore habitat or establish experimental populations of the Quino checkerspot could be undertaken on the coastal terrace from the Santa Margarita River north to San Mateo Creek. The interior of the Recovery Unit should be surveyed for Quino checkerspot habitat and occupancy. The coastal sage scrub and mixed chaparral of Camp Pendleton and the area where Orange, Riverside, and San Diego counties intersect have interstitial native grasslands that could currently harbor, or be reintroduction sites for the species.

The closest Recovery Units are the Southwest Riverside Recovery Unit to the east, and the proposed North Orange Recovery Unit to the north. There may be landscape connectivity to the eastern slope of the Santa Ana Mountains, particularly through the lower Santa Margarita River watershed, however no habitat surveys have been done. Murphy and Bomkamp (1999) found small patches of *Plantago* scattered across the southern sub-region of Orange County, including the transportation corridor option. They concluded that resources are currently insufficient to support Quino checkerspot populations, however restoration potential exists. The western slope of the Santa Ana Mountains appears to hold the possibility of landscape connectivity with the proposed North Orange Recovery Unit and would include land in and along the lower elevation portions of the Cleveland National Forest. Habitat buffering and possibly metapopulation augmentation could be achieved by using public open space areas such as the Limestone Canyon Regional Park site, Whiting Ranch Wilderness Park, Oneill Regional Park, and Ronald W. Caspers Wilderness Park. This buffering and connectivity could be further enhanced using private lands associated with the National Audubon Society Starr Ranch Sanctuary, Rancho Mission Viejo Land Conservancy and land in the Foothill Trabuco area.

Proposed North Orange Recovery Unit:

This proposed Recovery Unit is located on the northern slope of the Santa Ana Mountains in Orange County, including the area around Irvine Lake, Black Star Canyon, Gypsum Canyon, Fremont Canyon, Baker Canyon, Weir Canyon, Coal Canyon, Windy Ridge, Upper Blind Canyon and all intervening ridge lines. The Recovery Unit is located west of the Riverside/Orange County line and north of Loma Ridge-Limestone Canyon area. The area around Irvine Lake is the site of a historically stable Quino checkerspot population (Orsak 1978, Figure 2). Occupancy was most recently documented in 1967 in Black Star Canyon (Figure 2), but was apparently extirpated by a fire soon thereafter (Orsak 1978). Informal private re-introduction efforts using Quino checkerspot butterflies from the Gavilan Hills were conducted in there in 1974 (Orsak 1978). It is unknown whether any of the transplanted butterflies released in 1974 established occupancy. Most of the upper canyons have been historically poorly surveyed for wildlife.

The Irvine Lake area no longer supports sustainable resources due to habitat degradation, and restoration is needed before Quino checkerspot metapopulations can be reestablished (D. Murphy, pers. comm.). However, the diverse, unfragmented montane topography in much of this proposed Recovery Unit make the area a good candidate to support a reintroduced population (see Life History section above).

Insert Figure 4

Insert Figure 5

Insert Figure 6

Insert Figure 7

Insert Figure 8

Insert Figure 9

II. RECOVERY

A. Objectives

The overall objective of this recovery plan is to reclassify the Quino checkerspot to threatened and ensure the species' long-term conservation. Interim goals include (1) protect habitat supporting known current population distributions (habitat complexes), and (2) stabilize populations within the described habitat complexes, and (3) conduct research necessary to refine recovery criteria. Reclassification is appropriate when a taxon is no longer in danger throughout a significant portion of its range. Because data upon which to base decisions about reclassification is incomplete, downlisting criteria in this plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time.

B. Recovery Criteria

1) Permanently protect habitat patches supporting known extant population distributions (habitat complexes) and possible landscape connectivity areas among them. Adequate habitat reserve area sizes are estimated to be between 1,200-4,000 hectares (3,000-10,000 acres) total per habitat complex. Recovery Units and habitat complexes described in this recovery plan are: Northwest Riverside Recovery Unit containing the Gavilan Hills habitat complex, Southwest Riverside Recovery Unit containing the Warm Springs Creek and Skinner/Johnson habitat complexes, South Riverside Recovery Unit containing the Oak Mountain/Vail Lake, Sage Road/Billygoat Mountain, and Brown Canyon habitat complexes, South Riverside/North San Diego Recovery Unit containing the Silverado and Dameron Valley/Oak Grove habitat complexes, Southwest San Diego Recovery Unit containing the San Diego National Wildlife Refuge, Otay Lakes, Otay Foothills, Otay Mesa, Marron Valley, and Tecate habitat complexes, and Southeast San Diego Recovery Unit containing the Jacumba Peak habitat complex.

2) Permanently provide for and implement management of described habitat complexes to restore habitat quality, including maintenance of hostplant populations, maintenance of diverse nectar sources and pollinators, control of nonnative plant invasion, and maintenance of internal landscape connectivity.

The number of known occupied habitat patches and the density of butterflies within each Recovery Unit should be increased if declines are documented for 2 consecutive years of average to high annual precipitation (based on the past 20 years of local data). Management must be adaptive: i.e., ongoing surveys and monitoring must be conducted to refine management strategies and delimit temporal and geographic patterns of Quino checkerspot exchange among suitable habitat patches.

3) Establish and maintain a captive propagation program for purposes of re-introduction and augmentation of wild populations, maintenance of refugia populations, and research.

4) Initiate and implement a cooperative educational outreach program targeting areas where Quino checkerspot populations are most threatened.

5) Two additional populations or metapopulations must be documented or introduced in the remaining undeveloped coastal areas of the Quino checkerspot's historic range. Undeveloped coastal areas include the western and northern slopes of the Santa Ana Mountains (northern slope, see proposed North Orange Recovery Unit description in Recovery Strategy section), the northwest corner of San Diego County (see proposed Northwest San Diego Recovery Unit in Recovery Strategy section), and undeveloped mesas and hills within the cities of San Diego, Poway, and Santee, and adjacent unincorporated land within San Diego County (see proposed South-central San Diego Recovery Unit in Recovery Strategy section). It is possible that well-managed coastal preserves in San Diego or Orange County may be able to support stable populations of the Quino checkerspot butterfly. One of the two additional population distributions must include habitat within 10 kilometers (6 miles) of the ocean to maximize the stable marine climate influence and reduce susceptibility to drought. If new coastal populations are not documented by 2004, experimental populations should be established and maintained until downlisting criteria are refined. Additional inland (east of coastal areas described above) habitat complexes documented outside of Recovery Units will not be counted as one of the two additional populations specified here, but should be considered important to recovery and addressed when delisting criteria are developed.

6) The managed, protected population or metapopulation segments within currently described habitat complexes must demonstrate stability (constancy or resilience) without augmentation. When metapopulation distributions are determined by future research (one or more habitat complexes may belong to a single metapopulation) or defined by reserve boundaries, the unit monitored for stability becomes the metapopulation. Stable Quino checkerspot populations are defined by this recovery plan as those in which decreases in the number of occupied habitat patches are followed by increases of equal or greater magnitude within the 15 year period. The percent of patches that are occupied should be estimated by surveys for pre-diapause larval clusters (to demonstrate recruitment) in a sample of no less than 50 percent of the total number of patches identified within a population or metapopulation distribution. The surveyed sample of habitat patches must be distributed as equally as possible across the metapopulation distribution to avoid error from possible correlation of suitability among patches that are near each other.

7) Conduct research including: determining the distribution of extant metapopulations; conducting preliminary modeling of metapopulation dynamics; investigating the function of hilltops as a resource for Quino checkerspot populations; investigating the contribution of multiple-year diapause to metapopulation stability; monitoring populations for further evidence of climate-driven range shifts; determining the effects of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot and its hostplant; determining the magnitude of threats from over-collection and non-native natural enemies.

Downlisting of the Quino checkerspot butterfly is conditioned on the above criteria and the rules set forth under section 4 of the Endangered Species Act. In making any downlisting determinations the Service will consider the following: (1) present or threatened destruction, modification, or fragmentation of its habitat or range; (2) invasion of non-native plant and animal species; (3) overcollection; (4) off-road vehicle use and other recreational activities; (5) detrimental fire management practices; (6) anthropogenic global change factors (i.e. enhanced nitrogen deposition, elevated atmospheric carbon dioxide concentrations, and climate change).

C. Recovery Task Narrative

Priority 1 recommendations:

1. Protect via acquisition, conservation easement, or other means and provide management in perpetuity to enhance habitat and stabilize populations within described habitat complexes.

    1.1. Protect habitat within the distribution of described habitat complexes.

        1.1.1. Northwest Riverside Recovery Unit: protect as much remaining undeveloped suitable and restorable habitat that is part of the known historic Gavilan Hills/Lake Mathews metapopulation distribution (Figure 2) as possible in a configuration designed to support a stable metapopulation (approximately 3,600 additional hectares (9,000 acres) are needed).

        1.1.2. Southwest Riverside Recovery Unit: Develop a comprehensive plan for Southwest Riverside County Multiple Species Reserve and an additional reserve in the vicinity of Warm Springs Creek to preserve dynamics of the existing populations (2 or more). Current needs include continued reserve expansion.

            1.1.2.1. Warm Springs Creek area between the Hogbacks and State Route 79: protect as much remaining undeveloped suitable and restorable linked habitat patches (Figure 2) as possible (approximately 1,600 additional hectares (4,000 acres) excluding Assessment District 161 mitigation acquisitions).

            1.1.2.2. Lake Skinner and Johnson Ranch area: protect as much remaining undeveloped suitable and restorable linked habitat patches (Figure 2) as possible (approximately 800 additional hectares (2,000 acres) excluding Assessment District 161 mitigation acquisitions).

        1.1.3. South Riverside Recovery Unit: protect as much remaining undeveloped suitable and restorable linked habitat patches within and between the three habitat complexes (Figure 2) as possible (Sage/Billygoat Mountain, Oak Mountain/Vail Lake, and Brown Canyon).

        1.1.4. South Riverside/North San Diego Recovery Unit: protect as much remaining undeveloped suitable and restorable linked habitat patches within and between the two habitat complexes (Figure 2) as possible (Silverado and Dameron Valley/Oak Grove).

1.1.5. Southwest San Diego Recovery Unit: protect and manage as much remaining undeveloped suitable and restorable linked habitat patches within and between the six habitat complexes (Figure 2) as possible.

1.1.5.1. San Diego National Wildlife Refuge habitat complex: Protect and manage landscape connectivity through Proctor Valley between the habitats in San Diego National Wildlife Refuge and the Otay Lakes area.

1.1.5.2. Otay Lakes habitat complex: Protect and manage as much remaining undeveloped suitable and restorable habitat that is part of the known historic population distribution (Figure 2), as possible, in a configuration designed to support a stable population. Enhance landscape connectivity along the western and eastern margins of Otay Lake.

1.1.5.3. Otay Mesa habitat complex: Protect and manage mesa areas contiguous with the Otay River Valley. Enhance landscape connectivity between the north rim (above the Otay River) and western mesa top of Otay Mesa.

1.1.5.4. Otay Mountain Foothills habitat complex: protect and manage as much remaining suitable and restorable habitat that is part of the known population distribution.

1.1.5.5. Marron habitat complex: protect and manage, in cooperation with public land owners, as much remaining suitable and restorable habitat that is part of the known population distribution.

1.1.5.6. Tecate: protect and manage as much remaining suitable and restorable habitat that is part of the known population distribution.

1.1.6. Southeast San Diego Recovery Unit: protect and manage as much remaining undeveloped suitable and restorable linked habitat patches in the vicinity of Jacumba Peak and Table Mountain (Figure 2) as possible (Jacumba habitat complex).

1.2. Restore habitat patches and enhance landscape connectivity within and between the distribution of the habitat complexes.

1.2.1. Enhance or restore landscape connectivity between isolated habitat patches in developed areas of habitat complexes (primarily Southwestern Riverside and Southwestern San Diego Recovery Units).

1.2.1.1. Determine where habitat patches and linkage areas would most effectively connect occupied habitat patches.

1.2.1.2. Restore intervening habitat patches and remove any barriers from linkage areas.

1.2.2. Remove cattle and phase in weed control where habitat is currently grazed.

1.2.3. Restore degraded habitat patches occupied by larvae.

1.3. Erect barriers to prevent dispersal from habitat patches into adjacent high-traffic surface roads.

1.4. Reduce off-road vehicle activity within the distribution of described habitat complexes.

2. Continue yearly reviews, monitoring and augmentation until stable habitat complexes, populations, or metapopulations have been maintained for 15 years without augmentation.

2.1. Design and conduct yearly status reviews/monitoring of habitat complexes or identified metapopulations for 15 or more years (see criteria above).

2.2. Augment lowest density populations as needed to help establish stability.

3. Establish and maintain a captive propagation program using genetically diverse butterfly cultures in two separate facilities to provide butterflies for research, population augmentation, and re-introduction (65 FR 56916).

Priority 2 recommendations:

4. Initiate and implement an educational outreach program to inform the public about the biology of the Quino checkerspot and the ecological significance of its decline (that is, as an indicator of ecosystem decline, Ehrlich 1992). Other important educational subjects include the ecosystem services concept (Ehrlich 1992, Field *et al.* 1999), regulatory incentives such as Safe Harbor Agreements and local cooperative partnerships, and habitat restoration techniques. It is important that educational outreach efforts focus on research results over anecdotal accounts in order to remain unbiased and credible. Integration with biological curricula of local high schools emphasizing scientific ecological methodology and hands-on restoration activities is advised.

4.1. Develop and implement the proposed Vista Murrieta High School project (Helix 2000), in the Murrieta area. Restore and maintain occupied habitat adjacent to the high school, augment and monitor populations.

4.2. Initiate a pilot program similar to that proposed for Vista Murrieta High School in the Otay area, associated with the San Diego National Wildlife Refuge complex.

4.3. Initiate further cooperative outreach efforts with local nongovernmental organizations, educational institutions, and local museums.

5. Conduct biological research needed to refine recovery criteria and guide conservation efforts.

5.1. Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit habitat complexes.

5.2. Investigate the function of hilltops as a resource for Quino checkerspot populations.

5.3. Investigate the contribution of multiple-year diapause to metapopulation stability.

5.4. Monitor populations for further evidence of climate-driven range shifts.

5.5. Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot and its hostplant.

5.6. Survey areas between and around habitat complexes to determine where there is intervening and/or additional landscape connectivity (a possible greater metapopulation distribution). Surveys should be conducted in all areas within 7.5 kilometers (4.7 miles) of recent butterfly observations because: 1) The existence of undocumented occupied habitat patches is highly probable, and 2) current population distributions are greatly reduced relative to historic densities and distributions, and occupied habitat patches will be sources of former and future population expansions needed for metapopulation stability (see metapopulation footprint model estimates in Harrison 1989).

5.7. Map habitat complex attributes. Areas that need to be mapped are: habitat patches occupied by larvae, suitable or restorable habitat patches not currently occupied by larvae, habitat linkage areas needed for landscape connectivity, and buffer areas needed to insulate habitat patches from impacts of nearby development. Information gathered concurrently during surveys should include, degree of nonnative species invasion, presence of local threats.

5.8. Northwest Riverside Recovery Unit: Investigate the possibility of remaining occupied or suitable habitat near the (now developed) Quino checkerspot location near Murrieta (Figure 2).

6. Manage activity on trails where habitat occurs in recreational use areas, particularly during the active season for Quino checkerspot larvae and adults (*i.e.* November through May).

7. Locate or introduce two populations or metapopulations in the remaining undeveloped coastal areas of the Quino checkerspot's historic range. Populations may be reintroduced experimental ones or newly documented.

8. Reduce fire frequency and illegal trash dumping in habitat areas.

Priority 3 recommendations:

9. Survey for habitat and undocumented populations in undeveloped areas outside of Recovery Units.

9.1. Between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County, particularly the slopes of the Laguna Mountains and the slopes of Mount Palomar.

9.2. Between State Route 94 and Interstate 8 in southern San Diego County.

9.3. In proposed Recovery Units.

9.4. The eastern slope of the Santa Ana Mountains, south of Lake Elsinore on and around the vicinity of the Santa Rosa Plateau.

10. Survey other areas within Recovery Units (not covered by surveys to determine the extent of metapopulation distributions) to determine whether there is suitable habitat or undocumented populations.

10.1. Northwest and Southwest Riverside Recovery Units: Survey undeveloped areas in the southern portion of the Recovery Unit.

10.2. Southwest and South Riverside Recovery Units: Survey areas between the Brown Canyon site (near Hemet) and the Silverado and Skinner/Johnson habitat complexes.

10.3. South Riverside/North San Diego Recovery Unit: Survey areas south of the Silverado habitat complex and the Oak Grove site.

10.4. Southeast San Diego Recovery Unit: Survey areas west, north, and east of the Jacumba habitat complex.

11. Enter into dialogue with Baja California, Mexico nongovernmental organizations and local governments. Discussion topics include beginning surveys to determine the extent of the Otay foothills, Marron Valley, and Jacumba habitat complex population distributions across the border, and discussing possible protective measures for all Mexican populations.
12**.** Enter into dialogue with the Cahuilla Band of Mission Indians. Discussion topics include investigating the extent of the Silverado habitat complex population distribution within the Cahuilla Indian Reservation and possible protective measures.

D. Preliminary Recommendations for Proposed Recovery Units

Proposed South-central San Diego Recovery Unit:
1. Map distribution and suitability of habitat.
2. Restore vernal pools and other habitat where needed.
3. Survey for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot density in nearby reference metapopulations.
4. Maintain connectivity with undeveloped areas to reduce indirect impacts of development.
5. Determine habitat distribution and landscape connectivity potential in undeveloped areas between the Recovery Unit and the Laguna Mountains.

Proposed Northwest San Diego Recovery Unit:
6. Map distribution and suitability of habitat.
7. Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot density in Riverside County reference populations.
8. Determine what military activities are most likely to affect Quino checkerspot populations and how best to minimize conflict between metapopulation management and essential ongoing military training.
9. Determine extent of imported fire ant (*Solenopsis invicta*) distribution and possible impacts on the native community.
10. Determine extent of landscape habitat connectivity with Proposed North Orange Recovery Unit through the eastern slope of the Santa Ana Mountains.

Proposed North Orange Recovery Unit:

11. Protect the remaining undeveloped suitable habitat areas in higher elevations.
12. Remove cattle grazing from Black Star Canyon and phase in weed control.
13. Restore habitat around Irvine Lake and reintroduce the Quino checkerspot.
14. Determine extent, suitability, and landscape connectivity of habitat along the western slope of the Santa Ana Mountains south of the Recovery Unit as far as the proposed Northwest San Diego Recovery Unit..
15. Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot density in reference populations.
16. Determine extent of imported fire ant distribution and possible impacts on native communities.

III. LITERATURE CITED

A. References

Allen, E. B., P. E. Padgett, A. Bytnerowicz, R. Minnich. 1998. Nitrogen deposition effects on coastal sage vegetation of southern California. Proceedings of the International Symposium on Air Pollution and Climate Change Effects on Forest Ecosystems, Riverside, CA February 5-9, 1996. USDA Forest Service, Pacific Southwest Research Station, PSW-GTR-166, 131-140. [http://www.rfl.psw.fs.fed.us/pubs/psw-gtr-164/fulltext/allen/allen.html#anchor1473574]

Allen, E. B., S. A. Eliason, V. J. Marquez, G. P. Schultz, N. K. Storms, C. D. Stylinski, T. A. Zink, and M. F. Allen. 2000. What are the Limits to Restoration of Coastal Sage Scrub in Southern California? 2nd Interface Between Ecology and Land Development in California. J. E. Keeley, M. B. Keeley and C. J. Fotheringham, eds. USGS Open-File Report 00-62, Sacramento, California.

Behr, H. 1863. Proceedings of the California Academy of Natural Sciences 3:90.

Berrios, M. 2000. Florida Constructs First "Land Bridge" in the United States. Florida Dept. of Transportation, Environmental Management Office, Tallahassee, Fla.

Belsky, A. J. and J. L. Gelbard. 2000. Livestock grazing and weed invasion in the arid west. Oregon Natural Desert Association, Bend, OR.

Bezemer, T. J. and T. H. Jones. 1998. Plant-insect herbivore interactions in elevated atmospheric CO_2: quantitative analyses and guild effects. Oikos 82:212-222.

Bobbink, R., and J. H. Willems. 1987. Increasing dominance of Brachypodium pinnatum (L.) Beauv. in chalk grasslands: a threat to a species-rich ecosystem. Biological Conservation 40:301-314.

Bolton, H. E. 1930. Anza's California expeditions. v.5. Font's complete diary of the Second Anza expedition. Berkeley, Calif., University of California Press.

Boughton, D. A. 1999. Empirical evidence for complex source-sink dynamics with alternative states in a butterfly metapopulation. Ecology 80:2727-2739.

Boughton, D. A. 2000. The Dispersal System of a Butterfly: A test of source-sink theory suggests the intermediate-scale hypothesis. American Naturalist 156:131-144.

Brown, J. 1991. Sensitive and Declining Butterfly Species (Insecta: Lepidoptera) in San Diego County, California. Dudek and Associates, encinitas, California.

Bytnerowicz, A., P. R. Miller, D. M. Olszyk, P. J. Dawson, and C. A. Fox. 1987. Gaseous and particulate air pollution in the San Gabriel mountains of southern California. Atmospheric Environment 21:1805-1814.

Callaway, R. M. and F. W. Davis. 1993. Vegetation dynamics, fire, and the physical environment in coastal central California. Ecology 74:1567-1578.

California Department of Transportation. 2000. Surveys for the Quino checkerspot butterfly, I-15 from SR-163 to SR 78. Submitted to the Carlsbad Fish and Wildlife Office, Carlsbad, California.

City of San Diego. 2000. Survey for the Quino Checkerspot butterfly at Lake Hodges. Submitted to the Carlsbad Fish and Wildlife Office, Carlsbad, California.

Coviella, C. E. and J. T. Trumble. 1998. Effects of elevated atmospheric carbon dioxide on insect-plant interactions. Conservation Biology 13:700-712.

Cushman, J. H., C. L. Boggs, S. B. Weiss, D. D. Murphy, A. W. Harvey, and P. R. Ehrlich. 1994. Estimating female reproductive success of a threatened butterfly: influence of emergence time and hostplant phenology. Oecologia 99:194-200.

Easterling, D. R., B. Horton, P. D. Jones, T. D. Peterson, T. R. Karl, D. E. Parker, M. J. Salinger, V. Razuvayev, N. Plummer, P. Jamason, and C. K. Folland. 1997. Maximum and minimum temperature trends for the globe. Science 277:364-367.

Easterling, D. R., J. L. Evans, J. L., P. Y. Groisman, T. R. Karl, K. E. Kunkel, and P. Ambenje. 2000a. Observed variability and trends in extreme climate events: a brief review. Bulletin of the American Meteorological Society 81:417-425.

Easterling, D. R., G. A. Meehl, C. Parmesan, S. Chagnon, T. Karl, L. Mearns. 2000b. Climate extremes: observations, modeling, and impacts. Science 289: 2068-2074.

Ehrlich, P. R. 1961. Intrinsic barriers to dispersal in a checkerspot butterfly. Science 134:108-109.

Ehrlich, P. R. 1965. The population biology of the butterfly, Euphydryas editha. II. The structure of the Jasper Ridge colony. Evolution 19: 327-336.

Ehrlich, P. R. 1992. Population biology of checkerspot butterflies and the preservation of global biodiversity. Oikos 63:6-12.

Ehrlich, P. R., D. D. Murphy, M. C. Singer, C. B. Sherwood, R. R. White, and I. L. Brown. 1980. Extinction, reduction, stability and increase: the responses of checkerspot butterfly (*Euphydryas*) populations to the California drought. Oecologia 46:101-105.

Ehrlich, P. R., R. R. White, M. C. Singer, S. W. McKechnie, and L. E. Gilbert. 1975. Checkerspot butterflies: a historical perspective. Science 118: 221-228.

Emmel, T. C., and J. F. Emmel. 1973. The butterflies of southern California Natural History Museum of Los Angeles County, Science Series 26:148 pp.

Emmel, J. J., T. C. Emmel, and S. Mattoon. 1998. The types of California butterflies named by Herman Behr: designation of neotypes and fixation of type localities. *In*: Systematics of Western North American Butterflies, T. C. Emmel, (ed.). Mariposa Press, Florida. pp. 95-115.

Fajer, E. D., M. D. Bowers, and F. A. Bazzaz. 1989. The effects of enriched carbon dioxide atmospheres on plant-insect herbivore interactions. Science 243:1198-1200.

Fajer, E. D. 1989. The effects of enriched CO_2 atmospheres on plant-insect herbivore interactions: growth responses of larvae of the specialist butterfly, *Junonia coenia* (Lepidoptera, Nymphalidae). Oecologia 81:514-520.

Fajer, E. D., M. D. Bowers, and F. A. Bazzaz. 1991. The effects of enriched CO_2 atmosphere on the buckeye butterfly, *Junonia coenia*. Ecology 72: 751-754.

Faulkner, D. 1998. Highland ranch, Dictionary Hill Quino Checkerspot Survey. Submitted to the Carlsbad Fish and Wildlife Service Office.

Field, C. B., G. C. Daily, F. W. Davis, S. Gaines, P. A. Matson, J. Melack, and N. L. Miller. 1999. Confronting Climate Change in California:

Ecological Impacts on the Golden State. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, D.C.

Fenn, M. E., M. A. Poth, and D. W. Johnson. 1996. Evidence for nitrogen saturation in the San Bernardino Mountains in southern California. Forest Ecology and Management 82:211-230.

Foin, T. C., S. P. D. Riley, A. L. Pawley, D. R. Ayres, T. M. Carlson, P. J. Hodum, and P. V. Switzer. 1998. Improving recovery planning for threatened and endangered species. Bioscience 48:177-184.

Frenkel, R. E. 1970. Ruderal Vegetation Along Some California Roadsides. University of California Publications in Geography, v. 20. Berkeley, University of California Press.

Freudenberger, D. O., B. E. Fish, and Keeley J. E. 1987. Distribution and stability of grasslands in the Los Angeles basin. Bulletin of Southern California Academy of Sciences 86:13-26.

Gilbert, L. E. and M. C. Singer. 1973. Dispersal and gene flow in a butterfly species. American Naturalist 107:58-72.

Gulmon, S. L. 1992. Patterns of seed germination in Californian serpentine grassland species. Oecologia 89:27-31.

Gunder, J. D. 1929. The genus *Euphydryas* Scud. of Boreal America (Lepidoptera Nymphalidae). Pan-Pacific Entomologist 6:1-8.

Hanski, I. 1999. Metapopulation Ecology. Oxford University Press, Oxford.

Hanski, I., A. Moilanen, T. Pakkala, and M. Kuussaari. 1996. The quantitative incidence function model and persistence of an endangered butterfly metapopulation. Conservation Biology 10:578-590.

Harrison, S. 1989. Long-distance dispersal and colonization in the bay checkerspot butterfly, *Euphydryas editha bayensis*. Ecology 70: 1236-1243.

Harrison, S., D. D. Murphy, and P. R. Ehrlich. 1988. Distribution of the bay checkerspot butterfly, *Euphydryas editha bayensis*: Evidence for a metapopulation model. American Naturalist 132:360-382.

Harrison, S., and J. F. Quinn. 1989. Correlated environments and the persistence of metapopulations. Oikos 56: 293-298.

Helix Environmental Planning Inc. 2000. Assessment District 161 Draft Multiple Species Subarea Habitat Conservation Plan. Submitted to Carlsbad Fish and Wildlife Office.

Hobbs, R. J. and H. A. Mooney. 1991. Effects of rainfall variability and gopher disturbance on serpentine annual grassland dynamics. Ecology 72:59-68.

Intergovernmental Panel on Climate Change. 1996. Climate Change 1995 Report of Working Group I. (J. T. Houghton. *et al.*, eds). Cambridge University Press, Cambridge.

Karl, T. R., Knight, R. W., Easterling, D. R. and Quayle, R. G. 1996. Indices of climate change for the United States. Bulletin of the American Meteorological Society 77:279-292.

Keeley, J. E. and S. C. Keeley. 1984. Postfire recovery of California coastal sage scrub. American Midland Naturalist 111:105-117.

Keller, V., and H. P. Pfister. 1997. Wildlife passages as a means of mitigating effects of habitat fragmentation by roads and railway lines. Pages 70-80, *in*: Canters, K. (Ed.), Proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transportation, Public Works and Water Management, Delft, The Netherlands.

Koide, R. T., L. F. Huenneke, S. P. Hamburg, and H. A. Mooney. 1988. Effects of applications of fungicide, phosphorus and nitrogen on the structure and productivity of an annual serpentine plant community. Functional Ecology 2:335-345.

Koide, R. T., L. F. Huenneke, and H. A. Mooney 1987. Gopher mound soil reduces growth and affects ion uptake of two annual grassland species. Oecologia 72:284-290.

Launer, A. E., and D. D. Murphy. 1994. Umbrella species and the conservation of habitat fragments: A case of a threatened butterfly and a vanishing grassland ecosystem. Biological Conservation 42:145-153.

Lindroth, R. L. 1996. CO_2-mediated Changes in Tree Chemistry and Tree-Lepidoptera Interactions. In: Carbon Dioxide and Terrestrial Ecosystems. Academic Press, Inc. San Diego.

Mackay, D. A. 1985. Prealighting search behavior and host plant selection in ovipositing *Euphydryas editha* butterflies. Ecology 66:142-151.

Malanson, G. P. 1985. Simulation of competition between alternative shrub life history strategies through recurrent fires. Ecological Modelling 27:271-283.

Malo, J. E., and F. Suarez. 1995. Cattle dung and the fate of *Biserrula pelecinus* L. (Leguminosae) in a Mediterranean pasture: seed dispersal, germination and recruitment. Botanical Journal of the Linnean Society 118:139-148.

Mattoni, R., G. F. Pratt, T. R. Longcore, J. F. Emmel and J. N. George. 1997. The endangered Quino checkerspot, *Euphydryas editha Quino* (Lepidoptera: Nymphalidae). Journal of Research on the Lepidoptera 34:99-118.

McNeely, C. and M. C. Singer. Contrasting roles of learning in butterflies foraging for nectar and oviposition sites. Animal Behaviour, in press.

Minnich, R. A. 1988. The biogeography of fire in the San Bernardino Mountains of California. University of California Publications, Geography 28:36-40.

Minnich, R. A. and R. J. Dezzani. 1998. Historical decline of coastal sage scrub in the Riverside-Perris Plain, California. Western Birds 29:366-391.

Minnich, R. A., and E. F. Vizcaíno. 1998. Land of chamise and pines : historical accounts and current status of northern Baja California's vegetation. Berkeley: University of California Press.

Moore, S. D. 1989. Patterns of juvenile mortality within an oligophagous butterfly population. Ecology 70:1726-1731.

Murphy, D. D. 1982. Nectar sources as constraints on the distribution of egg masses by the checkerspot butterfly *Euphydryas chalcedona* (Lepidoptera: Nymphalidae). Environmental Entomology 12:463-466.

Murphy, D. D., A. E. Launer, and P. R. Ehrlich. 1983. The role of adult feeding in egg production and population dynamics of the checkerspot butterfly *Euphydryas editha*. Oecologia 56:257-263.

Murphy, D.D. and T. Bomkamp. 1999. Habitat assessment and focused survey results for Quino checkerspot butterfly, Rancho Mission Viejo 1995-1999. Prepared in support of the Foothill Transportation Corridor-South and Southern Subregion NCCP planning efforts. Submitted to the Carlsbad Fish and Wildlife Office, Carlsbad, California.

Murphy, D. D. and K. M. Rehm. 1990. Unoccupied habitats and endangered species protection. Endangered Species Update, School of Natural Resources, University of Michigan 7:10.

Murphy, D. D., K. E. Freas, and S. B. Weiss. 1990. An environment-metapopulation approach to population viability analysis for a threatened invertebrate. Conservation Biology 4:41-51.

Murphy, D. D. and S. B. Weiss. 1988. A long-term monitoring plan for a threatened butterfly. Conservation Biology 2:367-374.

Murphy, D. D., and R. R. White. 1984. Rainfall, Resources, and Dispersal in Southern populations of *Euphydryas editha* (Lepidoptera: Nymphalidae). Pan-Pacific Entomologist 60:350-355.

Niemen, M., M. C. Singer, W. Fortelius, K. Schops, and I. Hanski. Experimental confirmation that inbreeding depression increases extinction risk in butterfly populations. American Naturalist, in press.

Oechel, W. C., S. J. Hastings, G. L. Vourlitis, M. A. Jenkins, and C. L. Hinkson. 1995. Direct Effects of Elevated CO_2 in Chaparral and Mediterranean-Type Ecosystems. *In*: J. Moreno and W. Oechel (eds.) Global Change and Mediterranean-Type Ecosystems. Ecological Studies, 117:58-75

Orsak, L. J. 1978. The butterflies of Orange County, California. University of California, Irvine.

Osborne, K. 2000. Habitat Assessment and Focused Adult Surveys for Quino checkerspot Checkerspot Butterfly (*Euphydryas editha quino*) for Three Alternative East Miramar Housing Project Sites on MCAS Miramar, San Diego County. Prepared for KEA Environmental. Submitted to U.S. Fish and Wildlife Service, Carlsbad Fish and Wildlife Office.

Osborne, K. H. and R. A. Redak. 2000. Microhabitat conditions associated with the distribution of post-diapause larvae of Euphydryas editha quino (Behr) (Lepidoptera: Nymphalidae). Annals of the Entomological Society of America 93:110-114.

Padgett, P. E., E. B. Allen, A. Bytnerowicz, and R. A. Minnich. 1999. Changes in soil inorganic nitrogen as related to atmospheric nitrogenous pollutants. So. Ca. Atmos. Environ. 33:769-781.

Page, R., S. Bayley, J. D. Cook., J. E. Green, and J. R. Ritchie. 1996. Banff-Bow Valley: at the crossroads. Technical Report to the Minister of Canadian Heritage.

Parmesan, C. 1991. Evidence against plant apparency as a constraint on evolution of insect search behavior. Journal of Insect Behavior 4:417-430.

Parmesan, C. 1996. Climate and species' range. Nature 382:765-766.

Parmesan, C. In press. Butterflies as bio-indicators of climate change impacts. In: C. L. Boggs, W. B. Watt, and P. R. Ehrlich (eds). Evolution and

Ecology Taking Flight: Butterflies as Model Systems. University of Chicago Press, Chicago.

Parmesan, C., M. C. Singer, and I. Harris. 1995. Absence of adaptive learning from the oviposition foraging behavior of a checkerspot butterfly. Animal Behaviour 50:161-175.

Parmesan, C., T. L. Root, and M. R. Willig. 2000. Impacts of extreme weather and climate on terrestrial biota. Bulletin of the American Meteorological Society 81:443-450.

Parmesan, C., N. Ryrholm, C. Stefanescus, J. K. Hill, C. D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru, W. J. Tennent, J. A. Thomas, and M. Warren. 1999. Poleward shifts in geographic ranges of butterfly species associated with regional warming. Nature 399:579-584.

Pollard, E. 1977. A method for assessing change in the abundance of butterflies. Biological Conservation 12:115–132.

Porter, S. D., and D. A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology 71:2095-2106.

Pratt, G. 2000. Silverado Ranch Survey 2000: Survey and Monitoring of the Quino checkerspot. Report submitted to the Carlsbad Fish and Wildlife Office.

Rausher, M. D., D. A. Mackay, and M. C. Singer. 1981. Pre- and post-alighting host discrimination by *Euphydryas editha* butterflies: the behavioral mechanisms causing clumped distributions of egg clusters. Animal Behaviour 29:1220-1228.

Rausher, M. D. 1982. Population differentiation in *Euphydryas editha* butterflies: Larval adaptation to different hosts. Evolution 36:581-590.

Redak, R. 1998. Report of Surveys for the Quino Checkerspot Butterfly at Marine Corps Base Camp Pendleton. Submitted to the Carlsbad Fish and Wildlife Office, Carlsbad, California.

Redak, R. 2000. Arthropods and multispecies habitat conservation plans: are we missing something? Environmental Management 26:97-107.

Saccheri, I. J., M. Kuussaari, M. Kankare, P. Vikman, W. Fortelius, and I. Hanski. 1998. Inbreeding depression and extinction in a butterfly metapopulation. Nature 392:491-494.

Singer, M. C. 1972. Complex components of habitat suitability within a butterfly colony. Science 176:75-77.

Singer, M. C. 1983. Determinants of multiple host use by a phytophagous insect population. Evolution 37:389-403.

Singer, M. C. 1994. Behavioral constraints on the evolutionary expansion of insect diet: a case history from checkerspot butterflies. In: Behavioral Mechanisms in Evolutionary Ecology, L. Real (ed). University of Chicago Press, Chicago.

Singer, M. C., and P. R. Ehrlich. 1979. Population dynamics of the checkerspot butterfly *Euphydryas editha*. Fortschritte der Zoologie 25:53-60.

Singer, M. C., R. A. Moore, and D. Ng. 1991. Genetic variation in oviposition preference between butterfly populations. Journal of Insect Behavior 4:531-535.

Singer, M. C., D. Ng and C. D. Thomas. 1988. Heritability of oviposition preference and its relationship to offspring performance within a single insect population. Evolution 42:977-985.

Singer, M. C., C. D. Thomas, H. L. Billington, C. Parmesan. 1994. Correlates of speed of evolution of host preference in a set of twelve populations of the butterfly *Euphydryas editha*. Ecoscience 1:107-114.

Singer, M. C., and C. D. Thomas. 1996. Evolutionary responses of a butterfly metapopulation to human and climate-caused environmental variation. American Naturalist 148:9-39.

Singer, M. C., D. Vasco, C. Parmesan, C. D. Thomas and D. Ng. 1992. Distinguishing between preference and motivation in food choice: an example from insect oviposition. Animal Behaviour 44:463-471.

Stamp, N. E. 1984. Interactions of parasitoids and checkerspot caterpillars Euphydryas spp. (Nymphalidae). Journal of Research on the Lepidoptera 23:2-18.

Stylinski, C. D. and E. B. Allen. 1999. Lack of native species recovery following severe exotic disturbance in southern California shrublands. Journal of Applied Ecology 36:544-554.

Thomas, J. A. 1983. A quick method for estimating butterfly numbers during surveys. Biological Conservation 27:195–211.

Thomas, C. D. 1994. Extinction, colonization, and metapopulations: Environmental tracking by a rare species. Conservation Biology 8:373-378.

Thomas, C. D. and I. Hanski. 1997. Butterfly metapopulations. *In* Metapopulation Biology. I. A. Hanski and M. E. Gilpin, (eds.) Academic Press, San Diego. Pp. 359-386.

Thomas, C. D. 1994. Extinction, Colonization, and Metapopulations: environmental tracking by rare species. Conservation Biology 8:373-378.

Thomas, C. D. and M. C. Singer. 1987. Variation in host preference affects movement patterns in a butterfly population. Ecology 68:1262-1267.

U.S. Fish and Wildlife Service. 1997a. Biological opinion/Conference Opinion (1-6-95-F-35) for Pardee Construction Company (File No. 95-20130-DZ), Otay Mesa, San Diego County, California. Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service. 1997b. Survey for Listed, Proposed, and Sensitive Species on Selected Federally Owned Lands in Western Riverside County 1997-1998. Prepared for U.S. Bureau of Land Management.

U.S. Fish and Wildlife Service. 1999. Programmatic biological opinion on the effects of State Route 125 South, San Diego County, California (1-6-99-F-14). Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service. 2000. Programmatic biological opinion on for the Assessment District 161 Subregional Habitat Conservation Plan, Western Riverside County (1-6-01-F-725.2). Carlsbad Fish and Wildlife Office, Carlsbad, California.

Van Strien, A. J., R. Van De Pavert, D. Moss, T. J. Yates, C. A. M. Van Swaay, and P. Vos. 1997. The statistical power of two butterfly monitoring schemes to detect trends. Journal of Applied Ecology 34:817–828.

Vitousek, P. M., Aber, J. R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and G. D. Tilman. 1997. Human alteration of the global nitrogen cycle: Causes and consequences. Issues in Ecology No. 1, Ecological Society of America.

Wahlberg, N, A. Moilanen, I. Hanski. 1996. Predicting the occurrence of endangered species in fragmented landscapes. Science, 273:1536-1538.

Weiss, S. B. 1999. Cars, cows, and butterflies: Nitrogen deposition and management of nutrient-poor grasslands for a threatened species. Conservation Biology 13:1476-1486.

Weiss, S. B., R. R. White, D. D. Murphy, and P. R. Ehrlich. 1987. Growth and dispersal of larvae of the checkerspot butterfly *Euphydryas editha*. Oikos 50:161-166.

Weiss, S. B., D. D. Murphy, and R. R. White. 1988. Sun, slope, and butterflies: Topographic determinants of habitat quality for *Euphydryas editha*. Ecology 69:1486-1496.

Westman, W. E., and J. F. O'Leary. 1986. Measures of resilience: the response of coastal sage scrub to fire. Vegetatio 65:179-189.

White, R. R. 1975. Food plant defoliation and larval starvation of *Euphydryas editha*. Oecologia 14:307-315.

White, R. R. and M. P. Levin. 1981. Temporal variation in vagility: Implications for evolutionary studies. American Midland Naturalist 105:348-357.

Whittaker, J. B. 1999. Impacts and responses at population level of herbivorous insects to elevated CO_2. European Journal of Entomology 96:149-156.

Zedler, P.H., C.R. Gautier, and G.S. McMaster. 1983. Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal sage scrub. Ecology 64:809-818.

Zink, T. A., M. F. Allen, B. I. Heindl-Tenhunen, and E. B. Allen. 1995. The effect of a disturbance corridor on an ecological reserve. Restoration Ecology 3:304-311.

Zonneveld, C. 1991. Estimating death rates from transect counts. Ecological Entomology 16:115–121.

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Bauer, D. University of Colorado - Boulder. Boulder, Colorado
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IV. IMPLEMENTATION SCHEDULE

The schedule that follows is a summary of actions and estimated costs for the Quino checkerspot recovery program. It is a guide to meet the objectives of the draft recovery plan as elaborated in Part II, Step-Down Narrative section. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should achieve the recovery objectives. The estimated costs for many tasks remain to be determined; therefore, total costs listed are lower than the total required to achieve recovery objectives. Some tasks (e.g., habitat protection) will benefit multiple listed species in addition to the Quino checkerspot, so their costs are not wholly attributable to this species. Service staff salary is not included in cost estimates. Responsible party listings are based primarily on recent (1997 and later) Quino observation site land ownership data, jurisdictional authority, and responsibility for road and highway construction. Cost is not separated by responsible agency, cost distribution is to be determined. The list of responsible parties is not exhaustive. Any party that is a proponent of or has authority over projects that affect the Quino checkerspot has some responsibility under the Endangered Species Act for listed tasks related to their project.

Definitions and Abbreviations Used in the Implementation Schedule:

Priorities in column one were assigned as follows:

1 = An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2 = An action that must be taken to prevent a significant decline in species' population, habitat quality, or some other significant negative impact short of extinction.

3 = All other actions necessary to meet the recovery objectives.

Key to Acronyms used in the Implementation Schedule:

BLM	Bureau of Land Management
BP	Border Patrol
CalTrans	California Department of Transportation
CCH	City of Chula Vista
CDF	California Department of Forestry
CDPR	California Department of Parks and Recreation
CSD	City of San Diego
LMRMC	Lake Mathews Reserve Management Committee
RC	Riverside County
SDC	San Diego County
SDSU	San Diego State University
TNC	The Nature Conservancy
UCR	University of California at Riverside
USFWS	U.S. Fish and Wildlife Service
USMCCP	U.S. Marine Corps - Camp Pendleton
USMCASM	U.S. Marine Corps - Air Station Miramar
TBD	To be determined.

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
1	1.1.1	Northwest Riverside Recovery Unit: protect as much remaining undeveloped suitable and restorable habitat that is part of the known historic Gavilan Hills/Lake Mathews metapopulation distribution as possible	3	USFWS*, LMRMC, RC	TBD	TBD	TBD	TBD		
1	1.1.2.1	Warm Springs Creek area between the Hogbacks and State Route 79: protect as much remaining undeveloped suitable and restorable linked habitat patches as possible.	3	USFWS*, RC	TBD	TBD	TBD	TBD		

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
1	1.1.2.2.	Lake Skinner and Johnson Ranch area: protect as much remaining undeveloped suitable and restorable linked habitat patches as possible.	3	USFWS*, RC, UCR	TBD	TBD	TBD	TBD		
1	1.1.3.	South Riverside Recovery Unit: protect as much remaining undeveloped suitable and restorable linked habitat patches within and between the two habitat complexes as possible	3	USFWS*, BLM, SDC	TBD	TBD	TBD	TBD		
1	1.1.4.	South Riverside/North San Diego Recovery Unit: protect as much as remaining undeveloped suitable and restorable habitat patches within and between the two habitat complexes as possible.	3	USFWS*, BLM, RC, SDC	TBD	TBD	TBD	TBD		
1	1.1.5.1.	Protect and manage landscape connectivity through Proctor Valley between the habitats in San Diego National Wildlife Refuge and the Otay Lakes area.	2	USFWS*, SDC	TBD	TBD	TBD			

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
1	1.1.5.2.	Otay Lakes habitat complex: Protect and manage as much remaining undeveloped suitable and restorable habitat that is part of the known historic population distribution (Figure 2) as possible, in a configuration designed to support a stable population. Enhance landscape connectivity along the western and eastern margins of Otay Lake.	4	USFWS*, SDC	TBD	TBD	TBD	TBD	TBD	
1	1.1.5.3.	Otay Mesa habitat complex: Protect and manage mesa areas contiguous with the Otay River Valley. Enhance landscape connectivity between the north rim (above the Otay River) and western mesa top of Otay Mesa.	TBD	USFWS*, SDC	TBD					
1	1.1.5.4.	Otay Mountain Foothills habitat complex: protect and manage as much remaining suitable and restorable habitat that is part of the known population distribution.	3	USFWS*, SDC	TBD	TBD	TBD	TBD		

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
1	1.1.5.5.	Marron Habitat Complex: protect and manage, in cooperation with public landowners, as much remaining suitable and restorable habitat that is part of the known population distribution as possible.	3	USFWS*, SDC, USFS, CSD, BLM	TBD	TBD	TBD	TBD		
1	1.1.5.6.	Tecate habitat complex: protect and manage as much remaining suitable and restorable habitat that is part of the known population distribution as possible.	2	USFWS*, SDC	TBD	TBD	TBD			
1	1.1.6.	Southeast San Diego Recovery Unit: protect as much remaining undeveloped suitable and restorable linked habitat patches as possible	3	USFWS*, CDPR, SDC	TBD	TBD	TBD	TBD		
1	1.2.1.1.	All Recovery Units: Determine where habitat patches and linkage areas would most effectively connect occupied habitat patches.	TBD	USFWS*, SDC	TBD					
1	1.2.1.2.	Restore intervening habitat patches and remove any barriers from linkage areas. Start with Vista Murrieta High School and Johnson Ranch areas (in 2-3 years).	TBD	USFWS*, SDC	TBD	TBD	TBD	TBD	TBD	TBD

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
1	1.2.2.	Remove cattle and phase in weed control where habitat is currently grazed.	2	USFWS*, CSD, CDF, BLM	TBD	TBD	TBD			
1	1.2.3.	Restore and manage degraded habitat patches occupied by larvae.	Ongoing	USFWS*, CDF, CDPR, BLM, LMRMC, RC, SDC	TBD	TBD	TBD	TBD	TBD	TBD
1	1.3.	Erect barriers to prevent dispersal from habitat patches into adjacent high-traffic surface roads.	3	CalTrans*, RC, SDC, USFWS	TBD	TBD	TBD	TBD		
1	1.4.	Reduce off-road vehicle activity within the distribution of described habitat complexes.	Ongoing	USFWS*, CDF, CDPR, BLM, LMRMC, RC, SDC	TBD	TBD	TBD	TBD	TBD	TBD
1	2.1.	Design and conduct yearly status reviews/monitoring of habitat complexes or identified metapopulations for 15 or more years.	Ongoing	USFWS*, CDFG	200	10	10	10	10	10
1	2.2.	Augment lowest density populations as needed to help establish stability.	3	USFWS*, UCR	TBD	TBD	TBD	TBD		
1.	3.	Establish and maintain a captive propagation program.	Ongoing	USFWS*, UCR	1,162	6	6	130	60	60
1	4.1.	Develop and implement the proposed Vista Murrieta High School education project.	Ongoing	USFWS*, UCR, Vista Murrieta High School	2,150	130	130	105	105	105

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
1	4.2.	Initiate a pilot program similar to that proposed for Vista Murrieta High School in the Otay area, associated with the San Diego National Wildlife Refuge complex.	Ongoing	USFWS*, UCR, Vista Murrieta High School	2,150	130	130	105	105	105
1	4.3.	Initiate further cooperative outreach efforts with local nongovernmental organizations, educational institutions, and local museums.	Ongoing	USFWS*, UCR	0	0	0	0	0	0
1	5.1	Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit habitat complexes.	3	USFWS*	20	10	5	5		
2	5.2.	Investigate the function of hilltops as a resource for Quino checkerspot populations.	2	USFWS*	8	0	8			
2	5.3.	Investigate the contribution of multiple-year diapause to metapopulation stability.	6	USFWS*	35	10	5	5	5	5
2	5.4.	Monitor populations for further evidence of climate-driven range shifts.	Ongoing	USFWS*	TBD	TBD	TBD	TBD	TBD	TBD

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
2	5.5.	Determine the effect of elevated atmospheric carbon dioxide and nitrogen.	3	USFWS*	120	40	40	40		
2	5.6.	Survey areas between and around habitat complexes to determine where there is intervening and/or additional landscape connectivity.	TBD	USFWS*	TBD					
2	5.7.	Map habitat complex attributes	TBD	USFWS*	TBD					
2	5.8.	Northwest Riverside Recovery Unit: Investigate the possibility of remaining occupied or suitable habitat proximal to the (subsequently developed) Quino checkerspot population near Murrieta	3	USFWS*	36	12	12	12		
2	6	Manage activity on trails where habitat occurs in recreational use areas, particularly during the active season for Quino checkerspot larvae and adults (*i.e.* November through May)	Ongoing	USFWS*, RC, LMRMC, SC, CDPR	TBD	TBD	TBD	TBD	TBD	TBD
2	7.	Locate or introduce two populations or metapopulations in the remaining undeveloped coastal areas of the Quino checkerspot's historic range.	TBD	USFWS*, USMCCP, USMCASM, CSD	TBD					
2	8.	Reduce fire frequency and illegal trash dumping in habitat areas	Ongoing	USFWS*, RC, SDC, BLM	TBD	TBD	TBD	TBD	TBD	TBD

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
3	9.1.	Survey for butterflies and habitat between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County.	TBD	USFWS*, BLM, USFS, SDC, RC, SDSU	TBD					
3	9.2.	Survey for butterflies and habitat between State Route 94 and Interstate 8 in southern San Diego County.	TBD	USFWS* BLM, USFS, CSD, SDC	TBD					
3	9.3.	Survey for butterflies and habitat in proposed Recovery Units	4	USFWS* USFS, USMCCP, USMCASM, CSD, OC, SDC	TBD	TBD	TBD	TBD	TBD	
3	9.4.	Survey for butterflies and habitat along the eastern slope of the Santa Ana Mountains, south of Lake Elsinore	4	USFWS*, USFS, SDSU, TNC	TBD	TBD	TBD	TBD	TBD	
3	10.1.	Northwest Riverside Recovery Unit: Survey undeveloped areas in the southern portion of the Recovery Unit.	3	USFWS*, SDC, BLM, CSD	506	169	169	168		
3	10.2.	Southwest and South Riverside Recovery Units: Survey areas between the Brown Canyon site (near Hemet) and the Silverado and Skinner/Johnson habitat complexes.	3	USFWS*, RC	700	234	233	233		

IMPLEMENTATION SCHEDULE FOR QUINO CHECKERSPOT RECOVERY PLAN											
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
3	10.3.	South Riverside/North San Diego Recovery Unit: Survey areas south of the Silverado habitat complex and the Oak Grove site.	2	USFWS*, RC, BLM	363	182	181			
3	10.4.	Southeast San Diego Recovery Unit: Survey areas west, north, and east of the Jacumba habitat complex.	2	USFWS*, RC, BLM	228	114	114			
3	11.	Enter into dialogue with Baja California, Mexico nongovernmental organizations and local governments.	2	USFWS	TBD	TBD	TBD			
3	12.	Enter into dialogue with the Cahuilla Band of Mission Indians	2	USFWS	TBD	TBD	TBD			

Total Estimated Cost of Recovery Through FY 2020: $7,678,000 +

APPENDIX I

Quino Checkerspot Butterfly Life Cycle Diagram

Prepared by Dr. Gordon Pratt.
Photographs by Greg Ballmer.
Reproduced with permission from the authors.

This diagram represents the typical life cycle. There is overlap in the life stages due to population variability. Seasonal timing is also variable, depending on annual fluctuations in climate (particularly precipitation). Photographs are not to scale.

Insert life cycle picture. (Pdf tif)

APPENDIX II

Habitat Restoration Methods

Prepared by Mark Dodero

The conservation and recovery of the Quino checkerspot butterfly requires not only the preservation of currently suitable, but also the restoration of degraded, habitat for re-establishment of fully functioning metapopulations. Stabilization and re-establishment of the species (within even a small fraction of its historic range) will require long-term restoration and management efforts, possibly in perpetuity. This article discusses a variety of methods involved in, and issues related to, restoration, including: restoring occupied habitat; removing and controlling nonnative (or native) plant species; preparing the site; selecting native plant species; collecting native plant seed; restoring cryptogamic crusts; using salvaged materials; monitoring and maintaining the restored habitat, implementing adaptive management techniques; and the potential costs associated with these activities.

Restoring Occupied Habitat

A primary goal of most habitat restoration programs is to connect and enlarge suitable habitat patches by removing nonnative plants in adjacent areas. Special precautions need to be taken if the site is occupied by the Quino checkerspot or other listed species. Usually, workers should begin removing nonnative plants at the center of occupied habitat patches and work outward, concentrically enlarging and connecting the habitat patches. This work will require on-site monitoring by a biologist familiar with the distribution of Quino checkerspot and other listed or sensitive plant and animal species.

Nonnative plant removal strategies should be site-specific to take advantage of habitat breaks such as those created by large shrub patches, canyon edges, rock outcrops, or roads. These breaks can serve as buffer zones from adjacent areas that are dominated by nonnative plants. Designing the complete restoration of metapopulation habitat patch networks by taking advantage of existing breaks will enable managers to use nonnative plant removal funds most efficiently. Initially concentrating efforts in occupied habitat patches will improve the habitat quality until resources are available to restore larger areas. After nonnative plant removal, populations of native annuals may be enhanced or re-established in and between existing habitat patches by hand seeding.

Restoring Occupied Habitat Dominated by Nonnative Plants when Native Species are Still Present

Native plant communities invaded by nonnative species can be weeded using different methods, depending on the site conditions and the presence of sensitive resources. Some habitat patches will require only spot herbicide spraying, and possibly hand removal of individual nonnative plants. Other methods can also be used, although some nonnative plant control methods, such as the use of pre-emergent or other herbicides, may not be appropriate in Quino checkerspot habitat. Site-specific nonnative plant control strategies will be needed. Timing of nonnative plant control efforts is crucial to success. If nonnative plants are not killed prior to seed set, then removal effort and cost will remain high over time. Another crucial component of the nonnative plant removal method described below is that workers must be trained to distinguish between native and nonnative plants for restoration to be successful.

This method of restoring native plant communities described below, involving removal of dead plant thatch using hand tools and “weed eaters,” and return visits for spraying with glyphosate (a selective herbicide), appears to be successful on sites in central and southern San Diego County. Thick thatch can prevent native species from germinating and/or competing successfully for light and space with nonnatives.

If nonnative plants are present at moderate to high levels in areas that still have significant numbers of native species present, the following de-thatching technique can be used to restore or enhance these sites. De-thatching should be used in areas that have a buildup of organic matter on the soil surface, such as dead mustard or annual grasses.

De-thatch and Repeat Spray Method (in order):

- Cut thatch and dead nonnative plants with "weedeaters." This cutting can be done during the summer or early fall.
- Rake up and collect nonnative plant thatch.
- Remove thatch from site and dispose of it in dumpsters, a landfill, or an area where it can be composted nearby to reduce disposal costs.
- Return to site and spray Roundup (or more selective herbicide) on nonnative plant seedlings after sufficient rains have fallen in winter and spring.
- Repeat spraying as necessary to prevent seed set. Other options include the use of pre-emergent herbicide prior to the first significant rain.
- Repeat spraying as necessary to maintain nonnative plant density to a low level. If nonnative plants are controlled each season prior to flowering and setting seed, the level of effort required should decrease.

The nonnative plant removal process must be carefully monitored because frequently, as the dominant nonnative plant species are removed, other nonnative plant species multiply rapidly and replace the formerly dominant nonnative species. Repeated nonnative plant removal visits are necessary, and adaptive management strategies must quickly address control of newly dominant nonnative species. Frequent site visits are necessary during the growing season to assess nonnative plant removal efforts and to determine whether changes are needed in the strategy being used or the intensity of nonnative plant removal efforts. This type of nonnative plant removal effort requires control efforts prior to flowering and seed development. As nonnative plants are controlled over the first few years, natives will return to dominance. Removal of nonnative plants by hand may be required around small populations of herbaceous natives. Expansion of herbaceous annuals, including goldfields (*Lasthenia*) and plantain (*Plantago*), which may be locally rare because of nonnative plant competition, may require population augmentation and careful hand removal of nonnatives.

Restoring Unoccupied Habitat Completely Dominated by Nonnative Plants

If nonnative plants dominate a heavily disturbed restoration site completely (few or no native plant species occur) and the thatch is well incorporated into the soil, it can be more cost-effective to use heavy equipment over a large area to remove thatch and nonnative plant seed banks. Soil scraping probably works best if there are existing patches of native habitat adjacent to the site to allow immigration of native flora and fauna. This type of nonnative plant control technique can be used for fallow agricultural fields. Bulldozers or other mechanical scraping equipment can be used to remove the top organic thatch-covered layers of soil (a few inches or more if necessary. The goal of scraping is to reach the upper sub-soil, which does not have organic buildup, unnaturally high nutrient levels, or nonnative plant seeds. Soil can be removed from the site and used as fill. If the soil cannot be removed from the site, it should be deeply buried to reduce the likelihood of nonnative plant seed dispersal.

After scraping away the thatch and the top organic layers of soil, salvaged topsoil with a minimal nonnative seedbank can be obtained from other areas and can be spread over the restoration site. This procedure will provide the site with soil microorganisms, fungi, invertebrates, and seeds of native species. After scraping, winter rains will cause nonnative weed seeds to germinate, requiring nonnative plant control efforts. Repeat spraying visits can be used as described above and can be very effective, especially if used in conjunction with high-quality salvaged topsoil.

Heavily disturbed habitats that have not been used for agriculture may contain native plant species such as bunchgrasses and bulbs. To evaluate what methods should be used to remove weed thatch from a site, it is important to visit the site during the spring prior to scraping to determine whether native bulbs or other species are present. These native plants might be missed during a summer visit. This problem should not exist for agricultural fields, only for heavily disturbed areas that were not farmed and may still have natives. If small numbers of native plants are present, they can be avoided or salvaged prior to scraping and then replanted or used for propagation. If no undisturbed areas exist adjacent to the site, or if significant numbers of native species are present, the area should be de-thatched with hand tools as described above to reduce the impacts of weed removal on the soil fauna. It is important that nonnative plant control methods minimize impacts to the native invertebrate fauna.

Native Plants for Habitat Restoration and Enhancement

Seeds of native plant species used in each restoration project should be locally collected whenever possible. If a plant species was historically present in an area but can no longer be found, it should be reintroduced from the locality nearest the restoration site. Local collection of seed is especially important with regard to Quino checkerspot host and nectar plants, but should be done for as many other species as possible. Locally adapted plants are better competitors than plants introduced from a different climate zone. Seed collection should generally occur within 8 kilometers (5 miles) of a proposed restoration or enhancement site. If collecting within this distance is not possible, it is best to collect seeds as close as possible within the same general climate zone. General climate zones outlined in the Sunset Western Garden Book (Sunset Publishing Corporation 1995) can be used as a guide. Reciprocal transplant experiments have shown that plants of genotypes that are not locally adapted are inferior competitors when they are moved to a different climate zone. In addition, introducing plants that are not locally adapted can be detrimental to local herbivorous insects.

Much of the plant material required for restoration of Quino checkerspot habitat will include annuals and bulbs. Many of these species will be difficult to collect from the wild in sufficient quantity to seed the restored areas. Collecting from the wild must be limited so it will not adversely affect source plant populations. To ensure that adequate seed is available, seed bulking (growing seed in cultivation to increase the amount of seeds) of annuals, including *Plantago* and nectar plants, will be necessary. This seed bulking should be done at growing areas that can provide reproductive isolation from related plants from different regions. Plants from different source regions should not be allowed to hybridize at a common growing facility, but locally adapted genotypes for plants should be maintained as much as possible. It can take 3 years to grow bulbs from seed to a size large enough to plant and still have high survivorship when they are planted out. Therefore, restoration of diverse grassland sites, for instance, can require several years of planting.

Enhancement of Pollinator Populations

Providing adequate habitat for pollinator assemblages is crucial to the success of any Quino checkerspot restoration project. Pollinators are required to ensure that Quino checkerspot nectar plants have high seed set and persist over the long term. In arid environments, many potential pollinators, including native bee species, require open ground for nesting (Buchmann and Nabhan 1996). Extensive nonnative plant cover continues to invade and dominate current and historic Quino checkerspot habitat in Southern California, resulting in a loss of open ground suitable for ground nesting pollinators. By reducing available nesting sites, the nonnative plant growth is causing a decline in pollinator numbers and diversity, with negative implications for the entire ecosystem.

As well as reducing the extent of open areas required for ground nesting pollinators, competitive interactions between nonnative and native plant species, including dwarf plantain (*Plantago erecta*), goldfields (*Lasthenia* sp.), bulbs, and rare plants are causing declines in the biological diversity of natural communities. In order to support a diverse assemblage of potential pollinators and native plant species, areas of open ground within associated native plant communities must be restored to support ground nesting bees and other invertebrates. The goal of having open ground for pollinators is compatible with Quino checkerspot restoration efforts because Quino checkerspot larval food and adult nectar plants require open ground for successful reproduction and long-term persistence.

Restoration plantings should include nectar-producing plant species with overlapping flowering periods that extend throughout the typical Southern California growing season. Although there are exceptions, in general many of the nectar producing plants of arid Southwest environments (including coastal sage, grasslands and vernal pools habitats in Southern California) are visited by generalist pollinating insects (Buchmann and Nabhan 1996). Generalist pollinators visit more than one plant species for their nectar and pollen. To support pollinator assemblages throughout the flowering season, re-establishment and enhancement of nectar-producing plant populations may be required as part of restoration efforts. Even though a primary goal of Quino checkerspot habitat restoration is to enhance nectar resources specifically used by Quino checkerspot, generalist pollinators may require additional temporally overlapping nectar resources to support their populations throughout the year. At a minimum, restoration should include several nectar-producing plant species that in combination flower from early spring through late summer, as seen in relatively undisturbed natural ecosystems in Southern California.

For example, species that provide good nectar resources include goldfields (*Lasthenia* sp.) and tidy tips (*Layia* sp.), which flower in early spring; gumplant (*Grindelia* sp.), which flowers later but overlaps with goldfields; and other herbs such as tarplants (*Hemizonia* sp.) and shrubby species such as goldenbush (*Isocoma* sp.), which flower in late spring and during the summer. The re-establishment of these or other appropriate species on a restoration project site will provide a continuous nectar source to keep local pollinator assemblages supplied with resources until the fall, when many pollinating insects become dormant or enter another phase of their life cycle. Each region will has its own set of nectar-producing plants, and restoration projects should be designed on a site-specific basis with the goal of supporting viable populations of potential pollinators.

Restoration of Cryptogamic Crusts

Although the science of restoring cryptogamic crusts is still in its infancy and the regeneration process requires a long time for full development, there are known techniques to promote conditions that are appropriate for the growth of these biotic crusts. Observations of older disturbed habitat in San Diego County and elsewhere indicate that soil crusts can recover following a disturbance. The process takes many years and proceeds more slowly in xeric environments than in more mesic sites. Redevelopment of biotic crust on disturbed sites is likely to produce more species diversity when intact soil crusts exist adjacent to the disturbed area. Moisture and soil conditions are the most important factors to consider when promoting crust growth.

Belnap *et al.* (1999) listed five factors that increase moisture on the soil surface and therefore promote crust development: 1) closely spaced plants; 2) flat areas (depositional surfaces rather than erosional surfaces); 3) limited surface rocks, roots, or light plant litter to slow water and wind; 4) soils with inherently high stability (silt/clay>sandy>shrink-swell clay); and 5) stable microhabitats (under shrubs, away from small washes). As soil stability increases and human-related disturbances decrease, rich communities of cyanobacteria, mosses, and lichens become more widespread, covering all surfaces not occupied by vascular plants and rocks.

Recent attempts have been made to reintroduce soil crust organisms to restoration sites on Otay Mesa, in San Diego County. Crust organisms such as ashy spike-moss (*Selaginella cinerascens*) and other associated crust flora such as liverworts, mosses, fungi, and lichens have been salvaged from recently developed areas and planted into restoration sites. One way to translocate spike-moss is to cut it into squares about the size of a greenhouse flat using hand tools and place the squares into the flats for transport or temporary storage. When soils at the restoration site are moist, the spike-moss can be planted into shallow holes excavated in the shape of the flat. The spike-moss is planted in the hole so that it is flush with or slightly below the surrounding soil surface. This placement reduces the chance that erosion will break apart the crust. New crust organisms have been grown on a small scale by placing salvaged native topsoil in greenhouse flats and then keeping them continually moist in a shaded growing structure.

These small-scale biotic crust restoration trials have produced actively growing liverworts, mosses, and ashy spike-moss. Large-scale production could be used to grow many units of crust, which can be planted at the restoration sites after nonnative plants are removed or under control. Salvaged brush is also being used to promote the growth of crusts by placing branches on open ground after the site is well weeded. The branches alter the soil moisture conditions by reducing evaporation. Mosses and algae have been observed growing under the branches within 1 year after the branches have been put in place. Future efforts to promote crust development will include salvaging crust from development impact sites during the summer dry season and then using the powdered dry soils to sprinkle over stable soil areas that are lightly covered with branches.

Using Salvaged Materials

Topsoil

Salvaged topsoil can also be used from nearby construction sites to enhance the restoration areas, including bringing in native plant propagules and soil fauna. Topsoil should only be salvaged from areas that are not infested with nonnative plants. Salvaged topsoil must be placed at the recipient site as soon as possible to maintain the maximum diversity of seeds and other soil organisms. The greatest chance of success in using salvaged topsoil is to collect soil in the summer or early fall dry period. If soils are wet when moved and spread greater damage to the native seed bank and soil organisms will occur than if the soil is dry and organisms are dormant. Soil should be stockpiled only if absolutely necessary because the longer the soil is stored the greater the loss of seeds and soil fauna. If soil must be stockpiled, it should be kept dry. The depth of piles in storage should not exceed 90 centimeters (3 feet) to avoid composting effects, and a depth of 30 to 60 centimeters (1 to 2 feet) is preferable for maintaining seed banks. The topsoil translocation site should be prepared prior to topsoil delivery.

Brush and Rocks

The following techniques can be used to increase the structural diversity of the restoration area to provide cover sites for invertebrates, including Quino checkerspot. Brush piles, scattered sticks, branches, and rock cobbles can be brought to the restoration site to increase the available cover for many animals, and will provide potential diapause and pupation sites for Quino checkerspot. Brush can be obtained from nearby construction sites, either from brush habitat affected by development or from brush management activities adjacent to structures. Because brush material is considered a waste product and has to be chipped and removed to a landfill, most construction supervisors will truck the material to your restoration site if it is near the construction area. This approach can save the developer costs associated with trucking the material to a landfill. Creative partnerships with developers can result in increased structural diversity of your restoration site.

Placement of decaying wood and brush in the restoration site can provide immediate cover for many animals, including larvae and pupae of Quino checkerspot. By bringing in brush and rocks (if appropriate to the specific site) it is possible to "jump start" restoration by providing cover that would take many years to develop or accumulate otherwise. The use of one or two restoration enhancement techniques, such as placement of brush and rocks, can benefit multiple species when done using an integrated ecosystem approach. For example, brush piles and sticks, which should benefit Quino checkerspot, can also provide food for termites that are the primary food source for orange-throated whiptails, a sensitive species likely to be included in a multiple species conservation program. The use of structural enhancement techniques that benefit multiple species will increase the chance of successful implementation of restoration for multiple species habitat conservation plans.

Native Plants

Many species of native plants can be salvaged from construction impact areas prior to development. Translocation of native shrubs and herbaceous perennials is most successful under cool moist weather conditions after rains have started native plant growth and just prior to anticipated rainfall. Bulbs can be excavated from the soil as they become dormant in late spring after flowering has ceased. Bulbs can be stored until the fall when they can be planted after significant rains.

Restoration Costs

Habitat restoration costs vary per site, depending on site preparation costs, maintenance and monitoring requirements and the number of sensitive species needed to be present reintroduced and managed for to meet specific project standards. For Quino checkerspot restoration, maintenance of the site should last a minimum of 5 years, probably longer for converted agricultural fields, with a monitoring period of 10 years before determination of project success for mitigation purposes. Many of the degraded habitats will require at least 3 years of restoration work before reintroduction of the Quino checkerspot can be initiated. In sites that have been completely reconstructed, such as former agricultural fields, at least 15 years will be required to determine if efforts to re-establish Quino checkerspot have been successful.

De-thatching and Herbicide Spraying

Costs associated with removing thatch and spraying nonnative plants with a selective herbicide vary among restoration sites, but depend primarily on the degree to which the natural habitat has been degraded, including the extent of nonnative plant invasion. The cost of removing nonnatives is generally lowest for areas that require only spot spraying of individual plants. Removing plants by hand is costly, especially for large areas. However, hand "weeding" may be necessary for sites occupied by Quino checkerspot. The de-thatching technique can be used in conjunction with return visits to spray individual nonnative plants; and in some instances a “weed eater” can be used instead of spraying.

The de-thatching technique is typically used only during the first year as part of the site preparation. A crew of approximately ten workers has been used to de-thatch nonnative plants, accomplishing several tasks simultaneously. Activities include weed-whipping the site (4-5 weed-whips can work at one time), raking thatch into piles, collecting thatch and placing it into burlap bundles, and taking the bundles to trucks for removal from the site. Estimated costs per unit area are given below for using the de-thatch and repeat spraying method for sites dominated by nonnative plants, but which still have native plants present.

Using this method, 10 workers can de-thatch approximately 0.4 hectare (1 acre) per day. Costs for the de-thatching range from $4,000 to $5,000 per hectare ($1,600 to $2,000 per acre) (based on a average $20 per hour billing rate for the laborers and supervision time). The work can be physically demanding, especially if the thatch material has to be hauled out of steep canyons. If removing the material is not possible, it can be placed into piles and composted on the site. The nonnative plants that germinate later from the piles will need to be controlled because some nonnative plant seeds will remain. After sufficient rains have fallen in winter, nonnative plant seedlings will require control by return visits to spray Roundup© or other, more selective, herbicides to prevent the plants from maturing and producing seeds. Care must be taken to minimize over-spray onto native species. It is imperative that workers are able to recognize nonnative plants and distinguish them from native plants.

For the first 2 seasons after de-thatching, repeat spraying with an appropriate herbicide up to five times in a season costs approximately $8,400 per hectare ($3,400 per acre)in labor (four workers making five spraying visits) and an additional cost of approximately $500 per hectare ($200 per acre) for herbicide (to spray the entire area once). The amount of spray required will be reduced as the season progresses and fewer nonnative plants are present. After the first 2 years, weeding costs decrease each year if the spraying program is timed to kill the nonnative plants before they set seed. Approximate costs of subsequent years relative to the first year of restoration activities are as follows: year 3, 75 percent; year 4, 50 percent; year 5, 33 percent. These proportions of decreasing costs are approximate and will depend on how weedy the site is initially and how diligently follow-up nonnative plant control efforts are completed. If nonnatives are not killed prior to seeding, costs will not decrease as anticipated. The biologist monitoring the project must ensure that subcontractors or volunteers complete work on schedule and that nonnative plants are controlled prior to seed set for the effort to be effective.

For Quino checkerspot preserve areas, periodic maintenance will likely be required at low levels in perpetuity after the area is turned over to a long-term site manager. The ultimate goal of restoration efforts is to create self-sustaining Quino checkerspot habitat areas. However, management endowments will likely be needed indefinitely to fund periodic nonnative plant control activities and other habitat management tasks.

One restoration planning strategy to reduce long-term management costs is ensuring that native species occupy the newly opened ground as nonnative plants are controlled. Established native plants provide resistance to nonnative plant invasion because the space is already occupied, but careful planning is required to ensure that appropriate plant species are selected for the restoration sites. For example, certain native shrub species can quickly outcompete small herbaceous annuals such as plantain (*Plantago*) and goldenbush (*Lasthenia*), which are important to Quino checkerspots. Shrubs, including California sagebrush (*Artemisia californica*), can quickly dominate a restoration site recently opened up by nonnative plant control efforts if the sagebrush are seeded densely or are present in adjacent areas.

Many restoration projects tend to encourage growth of native species that provide fast-growing shrub cover. Many restoration and revegetation projects require quick cover to minimize erosion. However, the goal of providing dense cover is quite different from the goals of a Quino checkerspot restoration project because areas intended for Quino checkerspot must remain open. Therefore, careful selection of plant material must be incorporated early in the restoration planning process. If not carefully planned, a restoration site can be inadvertently directed toward rapid succession from open ground to dense shrub cover, a habitat unsuitable for Quino checkerspot. Long-term needs of the Quino checkerspot must be considered in the restoration planning process. For example, a site that appears suitable for Quino checkerspot after 2 or 3 years could be completely dominated by shrubs in 10 years if the project is not planned correctly or appropriate maintenance is not conducted. In this situation, the site would no longer provide suitable habitat because shrub density would be excessive. To avoid losing recently restored habitat, long-term monitoring of Quino checkerspot restoration sites and remedial measures implemented to slow or reverse succession will be needed.

Total Costs Of Habitat Restoration Maintenance and Monitoring

In addition to nonnative plant removal and control costs, restoration efforts for heavily disturbed sites may also include costs for additional site preparation. This preparation may include grading or recontouring the soil to reconstruct mima mound topography in former vernal pool areas that have been disturbed by agricultural activities, off-road vehicle traffic, or grazing. Costs for the transport and placement of rock cobbles may be included if appropriate to the site. For complete reconstruction of Quino checkerspot habitat (site preparation and implementation, plant production, planting, weeding, monitoring and annual reporting) the costs can range from $75,000 to $125,000 per hectare ($30,000 to $50,000 per acre) (or possibly more for agricultural fields) for 5 years of maintenance and monitoring. Existing occupied or unoccupied habitat that is relatively intact (with mostly native species) will be less expensive and may range from $12,000 to $50,000 per hectare ($5,000 to $20,000 per acre) depending on the specific site conditions.

Adaptive Management

Adaptive management strategies should be used to deal with unforeseen circumstances. This flexibility is especially important in restoration sites that require complete reconstruction from old agricultural fields. Adaptive management can include management/control of selected native species, such as California sagebrush or other native plant species in Quino checkerspot restoration sites, so that they don't dominate the vegetation. Until the appropriate Quino checkerspot larval food and adult nectar plants are fully established, monitoring and control of aggressive native species may be required in addition to controlling nonnative nonnative plants. Rapid succession from an open-ground habitat to a dense shrub-dominated community can exclude Quino checkerspot food plants through competition.

Restoration techniques such as heavy mulching of newly planted containers or entire sites are promoted by some ecologists but are usually inappropriate for small native annuals. Similarly, a heavy mulching strategy is not appropriate for restoration of most rare annual and perennial herbs, or for Quino checkerspot food plants, such as *Plantago* and *Lasthenia*. The use of light, natural mulch made up of salvaged native sticks and branches is acceptable, but a thick mulch is unnecessary to grow many of the native shrubs and annuals.

Selected Literature

Belnap, J., J. Williams, and J. Kaltenecker. 1999. Structure and function of biological soil crusts. In Proceedings: Pacific Northwest Forest and Rangeland Soil Organism Symposium. R. Meurisse *et al.* (eds.). U.S.D.A. Pacific Northwest Research Station, Portland, Oregon. PNW-GTR-461.

Buchmann, S. L., and G. P. Nabhan. 1996. The Forgotten Pollinators. Island Press/Shearwater Books, Washington D.C. and Covelo, California.

Read, E. A. 1994. The importance of community classification to mitigation and restoration of coastal sage scrub. Restoration Ecology 2:80-86.

Sunset Book and Magazine Editors. 1995. Sunset Western Garden Book. Sunset Publishing Corporation, Menlo Park, California.

APPENDIX III

The Annual Forbland Hypothesis: An extinct vegetation type in remnant Quino habitat?

Prepared by Dr. Edith Allen.

The Quino checkerspot uses exotic annual grasslands that still have a component of native forbs. It is likely that the bottomlands that have mostly been disturbed by agriculture and continuous grazing were once dominated by native forbs rather than exotic grasses. This hypothesis is controversial, as the potential natural vegetation of the Los Angeles Basin and the Riverside-Perris plain was considered by Küchler to be coastal sage scrub (Barbour and Major 1977). However, early Spanish explorers such as de Anza in 1775 (from the diary of Friar Font, translated by Bolton 1930) noted that this region had colorful fields of flowers. Similar observations were made during the late 1700's in northern Baja California; springtime brought a large diversity of colorful flowers to the bottomlands, while shrubs were mentioned for the hillier uplands (Minnich and Franco 1998). It is apparent that if these forblands once existed, they are now a virtually extinct vegetation type. A present day analogue to these forblands exists in the California Poppy Reserve on the west edge of the Antelope Valley, and in the Carrizo Plain of the San Joaquin Valley. These areas are still dominated by native wildflowers in the spring rather than shrubs or grassland, although exotics are a large component of the vegetation. By contrast, in the Perris Plain, Otay Mesa, and Marron Valley the exotic annuals dominate in the lowlands. Dwarf plantain (*Plantago erecta)* is often considered a plant of clay soils (although Jepson states that it ranges from sand to clay, and it occurs locally in decomposed granites). In areas where dwarf plantain is restricted to clay outcrops, it would be interesting to test the hypothesis that it is restricted there by weed competition.

Literature Cited

Barbour, M. G., and J. Major [Editors]. 1977. Terrestrial Vegetation of California. Wiley-Interscience. New York. 1002 pp.

Bolton, H. E. 1930. Anza's California expeditions. v.4. Font's complete diary of the Second Anza expedition Berkeley, Calif., University of California Press.

Minnich, R. A., and E. F. Vizcaíno. 1998. Land of chamise and pines: historical accounts and current status of northern Baja California's vegetation. University of California Press. Berkeley, California.

APPENDIX IV

Glossary of Terms

Diapause: A low-metabolic resting state similar to hibernation that enables larvae to survive for months during the summer without feeding.

Ecological connectivity: The amount of undeveloped wildlands between two areas. May or may not include landscape connectivity between habitat patches. Habitat areas or populations lacking ecological connectivity are termed completely isolated.

Extinction: Global disappearance of a species (or subspecies as used in this recovery plan).

Extirpation: Disappearance of a local population.

Forbland: A vegetation community dominated by forbs (broad-leaved herbaceous plants).

Habitat connectivity: The degree of fragmentation within habitat patches. If roads or other development occurs within a habitat patch to the point that adults cannot move freely between micro-patches of larval hostplants and other required resources, then one habitat patch may effectively become two or more with intervening areas becoming dispersal corridors or linkage areas that support limited exchange between habitat patches. Habitat patches with poor habitat connectivity are termed fragmented, and are generally prone to higher levels of ongoing degradation.

Habitat complex: A spatially clustered set of confirmed Quino checkerspot observation or collection records that delineate at least part of a currently undescribed population or metapopulation distribution.

Instar: The period between hatching from the egg to first molt (shedding skin) in larvae, and between molts after that.

Landscape connectivity: The degree of linkage between habitat patches joined by dispersal corridors or linkage areas. The number of linked habitat patches and their distance from each other determines the landscape connectivity of an area or a metapopulation. Habitat patches completely lacking landscape connectivity are termed isolated.

Larva: A caterpillar.

Larval hostplant: Any plant that caterpillars consume.

Metapopulation distribution: The maximum long-term "footprint" of a metapopulation. This is the area covered by a network of habitat patches (both occupied and temporarily not occupied by larvae), including all the habitat patches that could be occupied by larvae over an approximate time-scale of 50 years. It is assumed that long-term metapopulation stability requires butterfly densities periodically to reach their maximum, and therefore the maximum number of occupied habitat patches. The location of occupied habitat patches will shift from year-to-year, changing the shape of the extant footprint over time, but the metapopulation distribution does not change.

Mortality sink: A location where butterflies experience a high death rate.

Primary hostplant species: Species of hostplant on which adult female butterflies deposit eggs, and which caterpillars consume when they hatch.

Pupa: A chrysalis, sometimes mistakenly called a cocoon (cocoons are pupae with an outer silken layer spun by moth caterpillars).

Secondary hostplant species: Species of hostplants that caterpillars consume, but adult female butterflies do not deposit eggs on.