U.S. Fish & Wildlife Service

Recovery Plan for the Quino Checkerspot Butterfly

(Euphydryas editha quino)

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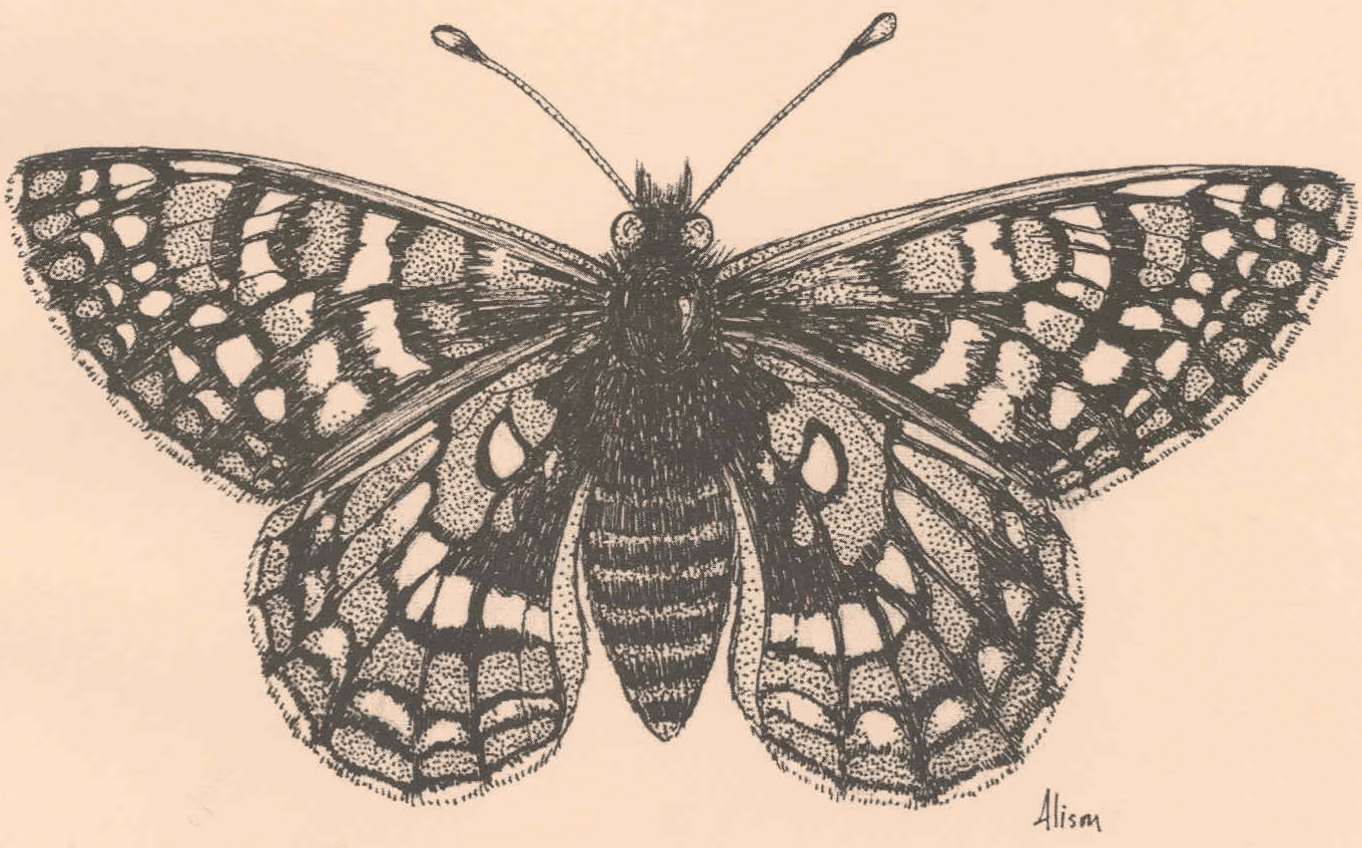

RECOVERY PLAN

FOR THE

QUINO CHECKERSPOT BUTTERFLY

(*Euphydryas editha quino*)

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

Approved: Steve Thompson
Manager, California/Nevada Operations Office
Region 1, U.S. Fish and Wildlife Service

Date: AUG 11 2003

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Recovery plans delineate actions required to recover and protect federally listed plant and animal species. We (the U.S. Fish and Wildlife Service) publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Recovery teams serve as independent advisors to the Fish and Wildlife Service. Draft recovery plans are published for public review and submitted to scientific peer review before we adopt them. Objectives of the recovery plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific recovery actions and do not necessarily represent the view, official position, or approval of any individuals or agencies involved in the plan formation other than our own. They represent our official position only after they have been signed by the Director, Regional Director, or California/Nevada Operations Manager as approved. Approved recovery plans are subject to modification as directed by new findings, changes in species status, and the completion of recovery actions.

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http://pacific.fws.gov/ecoservices/endangered/recovery/default.htm and at
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EXECUTIVE SUMMARY

Current Status: The Quino checkerspot butterfly (*Euphydryas editha quino*), is federally listed as endangered. This taxon occurs in San Diego and Riverside Counties and several localities in Baja California Norte, Mexico. Although no long-term empirical monitoring of populations has been conducted, some conclusions may be drawn regarding the species' overall status. The Quino checkerspot butterfly has apparently undergone a limited increase in abundance and distribution following its disappearance during the prolonged 1980's drought. However, current species abundance and distribution remain far below the pre-drought 1970's levels, and there is no evidence that the long-term decline due to human impacts has slowed (see section I.C.5 below, Metapopulation Resilience). Although large portions of occupied habitat are under public ownership, few, if any, known population distributions (preliminarily delineated in this document as occurrence complexes, further defined below) are entirely protected. There are no populations currently known to be resilient. Destruction and degradation of occupied habitat continues throughout the range of the Quino checkerspot butterfly, and some level of ongoing degradation exists in all occupied habitat.

Habitat Requirements and Limiting Factors: The Quino checkerspot butterfly is found in association with topographically diverse open woody canopy landscapes containing low to moderate levels of nonnative vegetation compared to disturbed habitat. Vegetation types that support the Quino checkerspot butterfly include coastal sage scrub, open chaparral, juniper woodland, and native grassland. Soil and climatic conditions, as well as other 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, and other human-caused disturbances have resulted in substantial losses of habitat and declines in habitat suitability throughout the species' historic range. Conservation needs include protection and management of landscape connectivity (habitat patches and intervening dispersal areas); habitat restoration and enhancement; and establishment of a formal Quino checkerspot butterfly captive breeding program.

The recovery strategy focuses on landscape-level protection of metapopulations that experience marked fluctuations in density and geographic distribution on a scale of 5 to 10 years. This recovery plan identifies six recovery units (Northwest Riverside, Southwest Riverside, South Riverside, South Riverside/North San Diego, Southwest San Diego, and Southeast San Diego). Recovery units are the major units for managing recovery efforts. Most recovery units contain one or more existing core (relatively large) occurrence complexes. A number of factors were considered in identifying recovery units, primarily biological and genetic factors, political boundaries, and ongoing conservation efforts. In some instances, recovery unit boundaries were modified to maximize efficiency of reserves, encompass areas of common threats, or accommodate logistic concerns. Recovery units may include areas of apparently suitable networks of habitat patches and dispersal areas that are not known to be occupied, when biological evidence warrants. Biologically, Quino checkerspot butterfly recovery units include areas within which gene flow is currently possible.

Recovery Priority: 6C, per criteria published in the Federal Register (U.S. Fish and Wildlife Service 1983a, 1983b). The priority is based on designation as a subspecies 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 butterfly from endangered to threatened status and ensure the species' long-term conservation. Interim goals include: (1) protect and manage habitat supporting known current population distributions (occurrence complexes) and landscape connectivity between them; (2) maintain or create resilient populations; and (3) conduct research necessary to refine recovery criteria. Reclassification to threatened status is appropriate when a taxon is no longer in danger of extinction throughout a significant portion of its range. Because data upon which to base reclassification decisions are incomplete, downlisting criteria in this recovery plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time.

Recovery Criteria:

The Quino checkerspot butterfly could be downlisted to threatened when the following criteria are met:

1) Permanently protect the habitat within occurrence complexes (estimated occupied areas based on habitat within 1 kilometer (0.6 mile) of recent butterfly occurrences; see section I.D below, Distribution and Habitat Considerations), in a configuration designed to support resilient populations. One or more occurrence complexes may belong to a single greater population distribution, or an occurrence complex may contain more than one whole or partial population distributions. When population distributions are determined, they will replace the occurrence complex as the protected unit. There are currently 46 described occurrence complexes.

2) Conduct research including: determine the current short-term and potential long-term distributions of populations and associated habitat; conduct preliminary modeling of metapopulation dynamics for core occurrence complexes identified in section I.D below (Distribution and Habitat Considerations).

3) Permanently provide for and implement management of occurrence complexes (or population distributions when delineated) to restore or enhance habitat quality and population resilience. Management should be implemented as described in Recovery Action 1 (section II.C below, Recovery Action Narrative).

4) The protected, managed (conserved) population segments within core occurrence complexes (or population distributions when delineated) must demonstrate evidence of resilience. Evidence of resilience is demonstrated if a decrease in the number of occupied habitat patches over a 10- to 20-year period within an occurrence complex (or population distribution when delineated) is followed by increases of equal or greater magnitude. Monitoring must be initiated in the third of three years of favorable climate (total annual January and February precipitation within one standard error of the average total for those months over the past 30 years, based on local or proxy climate data).

Populations that do not demonstrate resilience after 20 years should be augmented and monitoring reinitiated.

5) One additional population should be documented or introduced within the Lake Matthews population site (formerly occupied, not known to be currently occupied) in the Northwest Riverside Recovery Unit. At least one of the extant populations outside of current recovery units (*e.g.* the San Vicente Reservoir occurrence complex) must meet resilience specifications above unless an additional population is established or documented within 10 kilometers (6 miles) of the ocean (a more stable marine climate influence should minimize susceptibility to drought and reduce probability of extirpation).

6) Establish and maintain a captive propagation program for purposes of maintenance of representative refugia populations, research, and reintroduction and augmentation of wild populations as appropriate.

7) Initiate and implement a cooperative outreach program targeting areas where Quino checkerspot butterfly populations are concentrated in western Riverside and southern San Diego Counties.

At present there is insufficient information about the biology of the species to establish criteria and timeframes for delisting. Research needs for development of delisting criteria are described under Recovery Action 6 below.

<u>Actions Needed</u>:

1) Protect and manage as much remaining habitat as possible that is part of the known population distributions in a configuration designed to support resilient metapopulations in all recovery units. Conduct intensive restoration of agricultural and grazed areas and degraded habitat in the Southwest San Diego and Southwest Riverside Recovery Unit core occurrence complexes.
2) Continue yearly reviews and monitoring as needed as part of adaptive management until resilient occurrence complexes or populations are achieved.
3) Assess and augment lowest density populations.
4) Establish and maintain a captive propagation program.
5) Develop and implement community outreach projects.
6) Conduct research needed to refine recovery criteria and guide conservation

efforts (survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity; map habitat patch distributions; monitor habitat loss; conduct preliminary modeling of metapopulation dynamics; investigate key natural history questions and threats).
7) Locate or reintroduce at least one population within the Lake Matthews population site.
8) Reduce firearm use and unauthorized trash dumping in habitat areas.
9) Continue dialogue with the Cahuilla Band of Indians.
10) Survey for habitat and/or undocumented populations within recovery units.
11) Survey other areas that could possibly support Quino checkerspot butterfly populations.
12) Enter into dialogue with Baja California, Mexico, nongovernmental organizations and local governments.

Total Estimated Cost to Meet Interim Recovery Objectives: $ 140,990,000 + additional costs that cannot be determined at this time.

Date of Recovery: Downlisting could be initiated in 2018 or sooner, 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 butterfly.

The Quino checkerspot butterfly (Figure 1) is currently 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 (Figure 2). More than 75 percent of the Quino checkerspot butterfly's historic range has been lost (Brown 1991, Figure 2), including more than 90 percent of its coastal mesa and bluff distribution. Quino checkerspot butterfly populations appear to 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.). In this recovery plan, populations associated with Quino checkerspot butterfly occurrences recorded in the 1990's or more recently are considered to be extant; any older records are deemed historic occurrences.

This recovery plan describes six geographic areas called recovery units (Figure 3), which are based primarily on habitat regions that support extant Quino checkerspot butterfly populations. Habitat regions are described below in section I.D (Distribution and Habitat Considerations), and the recovery units associated with these habitat regions are specifically delineated in section I.G.1. (Recovery Units). 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 habitat configurations required for long-term persistence of the species will require further surveys,

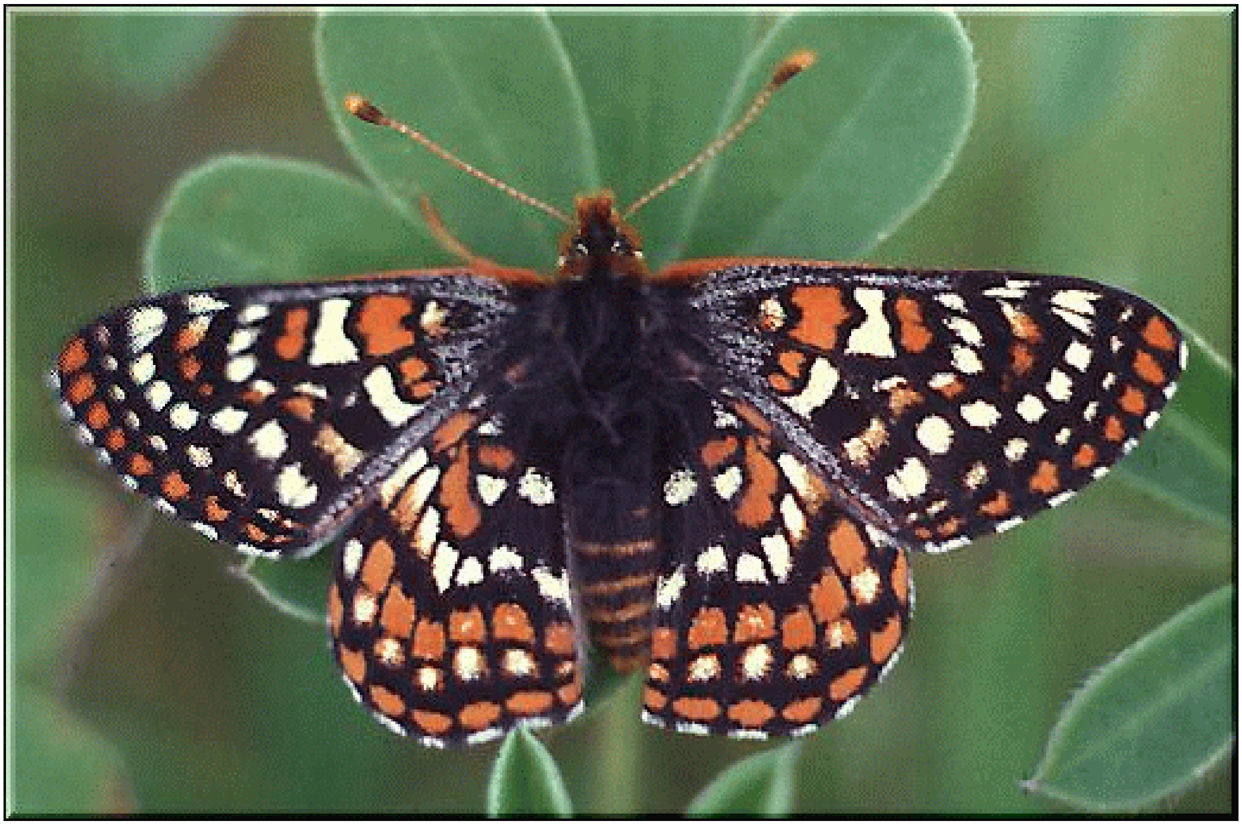


Figure 1. Quino checkerspot butterfly. Photo used by permission of Guy Bruyea.

UNITED STATES
Department of the Interior
U.S. Fish and Wildlife Service
Carlsbad, California

DATA SOURCES:

BASE DATA - Teale Data Center, Sandag, USFWS

QUINO DATA - Year 2002 Quino Recovery Areas USFWS based on biological staff input, data compiled from the above Base Data Sources.

Map prepared by Edwin Turner
July 1, 2003

Quino Checkerspot Butterfly Historic U.S. Distribution

30 0 30 60 Miles

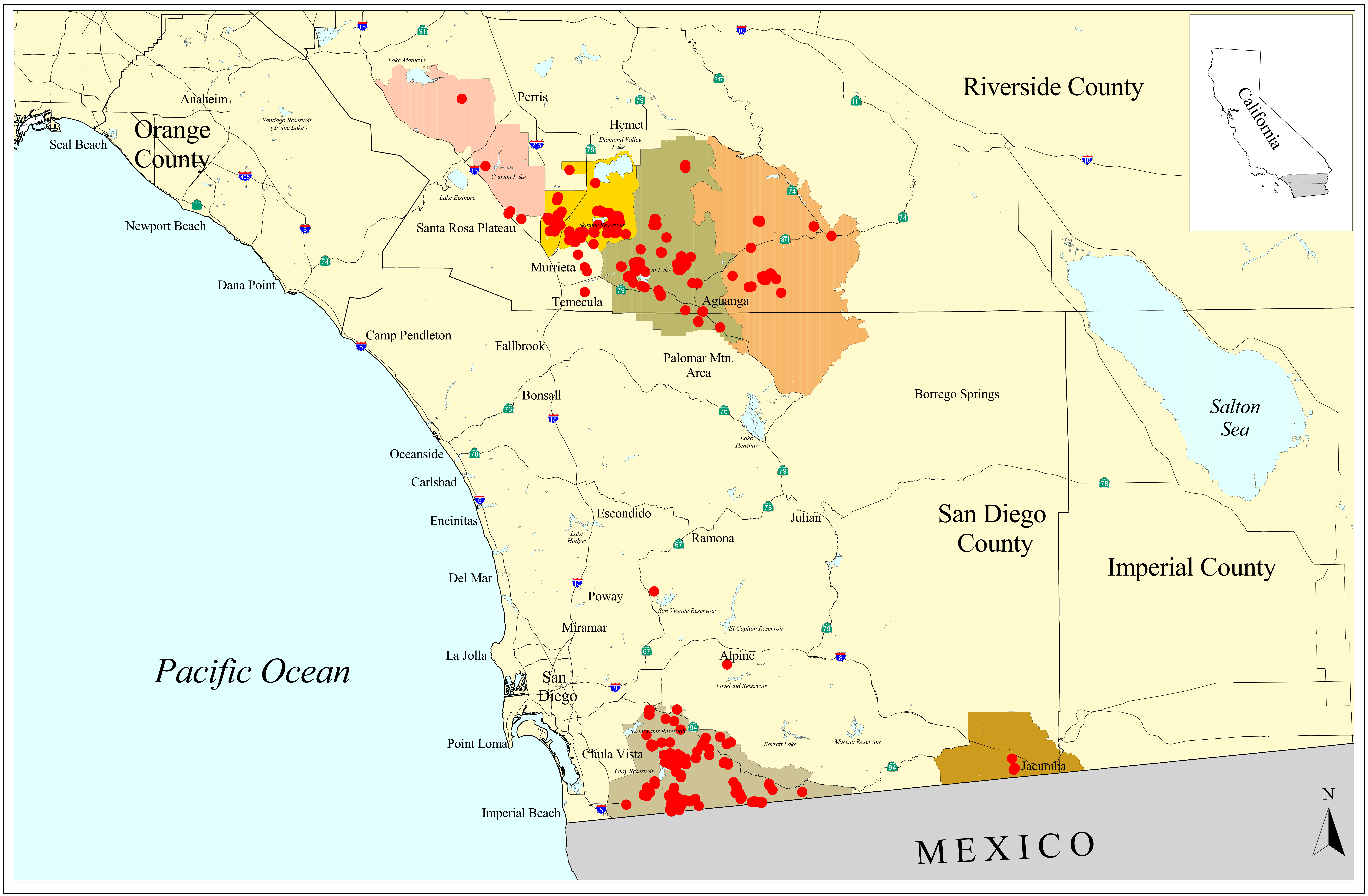
30 0 30 60 90 Kilometers

70000 0 70000 140000 210000 Feet

Occurrence symbols cover a geographic area of 2 kilometers (diameter)

Quino Data Locations
1890 - 1986
1986 - 2003

Figure 2



UNITED STATES
Department of the Interior
U.S. Fish and Wildlife Service
Carlsbad, California

Quino Checkerspot Butterfly Recovery Units and Recent U.S. Occurrences

20 0 20 40 Miles

20 0 20 40 60 Kilometers

50000 0 50000 100000 150000 Feet

Quino Data and Recovery Units

- Northwest Riverside
- Southwest Riverside
- South Riverside
- South Riverside / North San Diego
- Southwest San Diego
- Southeast San Diego
- 1986 - 2003

BASE DATA - Teale Data Center, USFWS

QUINO DATA - Year 2002 Quino Recovery Areas USFWS
based on biological staff input, data compiled from the above Base Data Sources.

/stem/edstemp/quino/aprs/qfru_0703.apr
July 17, 2003

Some occurrences are within areas recently authorized for development.
Occurrence symbols cover a geographic area of 2 kilometers (diameter).

Figure 3

monitoring, modeling, and other research described below in section II.C (Recovery Action Narrative). Habitat within the current known distribution of the species ranges from moderately to highly 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 (the U.S. Fish and Wildlife Service) listed the Quino checkerspot butterfly as an endangered species on January 16, 1997 (U.S. Fish and Wildlife Service 1997a). On February 7, 2001, we proposed critical habitat for the Quino checkerspot butterfly (U.S. Fish and Wildlife Service 2001a), and on April 15, 2002, final critical habitat was designated (U.S. Fish and Wildlife Service 2002a). This species has a Recovery Priority of 6C, based on the classification system published in the Federal Register (U.S. Fish and Wildlife Service 1983a, 1983b). This priority number reflects the subspecific status of the butterfly, a high degree of threat, a moderate to low potential for recovery, and existing conflicts with construction or other land development. This recovery plan attempts to reduce the risk of the species' extinction by recommending protection and long-term management of habitat necessary to support resilient populations. Due to highly degraded habitat conditions and very low population sizes range-wide, long-term adaptive management will also be required. Protection of high-quality habitats with resilient Quino checkerspot butterfly populations 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 butterfly is a subspecies of the Edith's checkerspot butterfly (*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 taxon now commonly called the Quino checkerspot butterfly 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 butterfly specimen collected in San Diego. After reexamining

Behr's descriptions and specimens, Emmel *et al.* (1998) concluded that the Quino checkerspot butterfly 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 butterfly, *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 a checkered red and cream pattern. The abdomen of the Quino checkerspot butterfly has red stripes across the top. After their second molt, Quino checkerspot butterfly larvae can be recognized by the characteristic dark-black coloration and row of 8 to 9 orange tubercles (fleshy/hairy extensions) on their back. Before their first molt, larvae have a predominantly yellow coloration, and before their second molt they are grey with black markings (G. Pratt, pers. comm. 1999). Pupae are mottled black on a pale blue-gray background, and extremely cryptic. Inexperienced surveyors in the field may confuse the Quino checkerspot butterfly with three other co-occurring butterfly species: the chalcedon or variable checkerspot (*Euphydryas chalcedona*), Gabb's checkerspot (*Chlosyne gabbi*), and Wright's checkerspot (*Thessalia leonira wrighti*). Chalcedon checkerspot butterfly adults are darker and often larger than Quino checkerspot butterflies, and have white abdominal stripes and spots instead of red stripes. Male and female Gabb's checkerspot butterfly adults have a more orange appearance than Quino checkerspot butterflies, but female coloration is of higher contrast and may closely resemble Quino checkerspot butterflies. Gabb's checkerspot butterflies can be differentiated from Quino checkerspot butterflies by silver-white spots on their underwings, the lack of red abdominal stripes, and a scalloped 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. Life History

Few specific studies of Quino checkerspot butterfly biology have been conducted. One paper reported observations of Quino checkerspot butterfly population dynamics (Murphy and White 1984) and another addresses local movement behavior (White and Levin 1981). More recently, one quantitative larval habitat use study (Osborne and Redak 2000) and two distribution studies (Parmesan 1996 and Pratt *et al*. 2001) have been published. Therefore, most information in this section is drawn from the abundant literature reporting research on other subspecies of *Euphydryas editha*, in particular the bay checkerspot butterfly (*E. editha bayensis*). Although it is generally true that different subspecies of *E. editha* have similar life histories, such assumptions must be made with caution, especially with regard to characteristics affected by unique local environmental conditions.

1. Life Cycle

The life cycle of the Quino checkerspot butterfly (Appendix I) typically includes one generation of adults per year, with a 4 to 6 week flight period beginning from late January to early March and continuing as late as early May, depending on weather conditions (Emmel and Emmel 1973, U.S. Fish and Wildlife Service 2003). 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 to 14 days; however, adult emergence from pupae is staggered, resulting in a 1 to 2 month flight season. Peak emergence in most brush-footed (nymphalid) butterfly species, and probably for the Quino checkerspot butterfly as well, occurs shortly after the beginning of the flight season, usually in the second week (Zonneveld 1991). Eggs deposited by adults hatch in 10 to 14 days.

The periods between molts (shedding skin) are called instars. Larvae that hatch from eggs are in the first instar, and may subsequently 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 eggs were laid (the primary host plant species). Prediapause larvae spin a web and feed in groups. 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 to new individual host plants. 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 (primary host plant), or another host plant species (secondary host plant).

During larval development, the host plants age, eventually drying out and becoming inedible (senescence). At the time of host plant senescence, if larvae are old enough and have accumulated sufficient reserves, they are able to enter diapause. Larvae have been observed entering diapause in the lab as early as the second instar, and surviving to the next season (K. Osborne and G. Pratt, pers. comm.).

Diapause is a resting state that enables larvae to maintain a low metabolic rate and may occur during periods when host plants are not available. 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 sites of Quino checkerspot butterfly larvae in the field has not been researched, 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), which 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 butterfly larvae may also be able to survive without "breaking" diapause to feed in extremely dry years (G. Pratt, pers. comm.).

It is not known if Quino checkerspot butterfly larvae can store enough energy reserves to prolong diapause without feeding at all for more than a year. However, the Quino checkerspot butterfly's ability to undergo repeated diapause is thoroughly documented. Laboratory studies have repeatedly shown that post-diapause *Euphydryas editha* 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 experts do 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 bay checkerspot butterfly larvae that had re-entered diapause in the middle of a patch of host plants that had been totally consumed. Return to diapause may also occur under conditions when plants are unusually dry or developmentally advanced, because poor host plant conditions can result in 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 butterfly 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 normally robust population may generate no adults at all in a given year if poor environmental conditions preclude an adult flight period.

Sufficient rainfall, usually during November or December, apparently causes larvae to break diapause. Records of rare late second flight seasons following unusual summer rains indicate that the Quino checkerspot butterfly 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 host plants fed upon by postdiapause larvae. Postdiapause bay checkerspot butterfly larval dispersal has been documented; larvae have been observed to travel up to 3.5 meters (11.5 feet) during a 4-day period (Weiss *et al.* 1987). Greater larval dispersal distances were rare, but movement up to 10 meters (33 feet) per day has been recorded (Weiss *et al.* 1988). During one study of Quino checkerspot butterfly larvae at Lake Skinner, Riverside County, post-diapause larvae were observed to typically move 0.5 to 1 meter (20 to 40 inches) per hour while grazing, many moving up to 30 to 40 meters (100 to 130 feet) during the course of development (K Osborne, pers. comm.) Postdiapause larvae seek microclimates with high solar exposure, 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 six molts prior to pupating in silken shelters near ground level. Adults emerge from pupae after approximately 10 days, 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 butterfly 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). *Euphydryas editha* butterflies generally fly close to the ground in a relatively slow, meandering flight pattern (M. Singer, pers. comm.).

Adult (K. Osborne, pers. comm. 2002) and larval (Osborne and Redak 2000) Quino checkerspot butterflies, like some other subspecies of *Euphydryas editha*, show a tendency to occur in barren spots amidst low-growing vegetation. Quino checkerspot butterflies tend to avoid flying over trees, buildings, or other objects taller than about 2 meters (7 feet), but natural vegetation does not constitute an impermeable barrier to dispersal (D. Murphy, G. Pratt, C. Parmesan, and K. Osborne, pers. comm.). Other subspecies of *E. editha*, whose host plants are more diffusely distributed than the bay checkerspot butterfly, have been observed to fly over tall vegetation (Gilbert and Singer 1973). It is thought that the typically sedentary nature of bay checkerspot butterflies is associated with the well-defined boundaries of their serpentine grassland habitat patches, termed "intrinsic barriers," rather than restriction by true vegetation "barriers" (Gilbert and Singer 1973). Quino checkerspot butterfly thermodynamic requirements and natural avoidance of shaded areas deter flight in densely wooded areas and other types of closed-canopy vegetation (M. Singer, pers. comm.).

Male Quino checkerspot butterflies, and to a lesser extent females, are frequently observed on hilltops and ridgelines (Carlsbad Fish and Wildlife Office GIS Quino checkerspot butterfly database and metafile, Osborne 2001). A number of behaviors characteristic of species commonly found on hilltops have been documented. For example, male Quino checkerspot butterflies have been observed perching consistently in prominent locations on hilltops devoid of host plants and have been seen "attacking" other male Quino checkerspot butterflies as well as other species of butterfly that approach (Osborne 2001, Pratt 2001). Further evidence that *Euphydryas editha* may display hilltopping behavior was found in Colorado, where the males of an *E. editha* population were observed aggregating on hilltops during a time when population densities were low and the females of the species traveled to seek mates (Ehrlich and Wheye 1986, as discussed in Ehrlich and Murphy 1987). Hilltops may also represent centers of Quino checkerspot butterfly population density in some areas. Hilltops appear to be a resource contributing to Quino checkerspot butterfly survival. Because adult Quino checkerspot butterflies are frequently observed on hilltops (U.S. Fish and Wildlife Service database), even in the absence of nearby larval host plants (Osborne 2001), hilltops and ridgelines may be crucial for population survival and therefore should be searched during presence/absence surveys and included in reserve designs.

Bay checkerspot butterflies appear to exhibit sedentary behavior during the majority of their adult life in most seasons. Most bay checkerspot recaptures have occurred within 100 to 200 meters (330 to 660 feet) of release (Ehrlich 1961, 1965, Gilbert and Singer 1973, White and Levin 1981, Harrison 1989, Boughton 1999, 2000). Harrison *et al.* (1988) documented no between-habitat patch transfers of marked bay checkerspot individuals greater than 1 kilometer (0.6 miles). In a second study, only 5 percent of marked adult bay checkerspots were recaptured in a target habitat patch greater than 1 kilometer (0.6 miles) from the point of release (Harrison 1989). Average recapture distances for

Finnish checkerspot butterfly species closely related to the Quino checkerspot butterfly ranged from 151 to 646 meters (495 to 2,119 feet; Wahlberg *et al.* 2002). However, dispersal tendency appears to be relatively plastic in *Euphydryas editha* (White and Levin 1981) and may have evolved to fit local or regional situations (Gilbert and Singer 1973). White and Levin (1981) noted that "It seems likely from the lower return rate in 1972 [a dry year] and from the observed pattern of out-dispersal, that many marked [male Quino checkerspot butterfly] individuals dispersed beyond the area covered by our efforts that year." White and Levin (1981) also noted that when released in Quino checkerspot butterfly habitat in San Diego County, bay checkerspot butterflies behaved more like Quino checkerspot butterflies (moved significantly greater distances) than did bay checkerspot butterflies in their native San Francisco Bay area habitat. Female checkerspot butterflies have been found to be more likely to emigrate than males (Wahlberg *et al.* 2002), and older adults appear to have a greater tendency to disperse as host plant suitability and female egg loads decline (White and Levin 1981, Harrison 1989).

When quality host plants are in short supply, adult Quino checkerspot butterflies apparently respond by dispersing (White and Levin 1981, Murphy and White 1984). Quino checkerspot butterfly dispersal tendency greatly increased in 1977 when population density was extremely high and many habitat patches were defoliated (Murphy and White 1984). Dispersal tendency also increased when densities were low and dry conditions reduced the number and suitability of host plants for depositing eggs (oviposition) (White and Levin 1981). Long-distance dispersal in bay checkerspot butterflies has been documented as far as 6.4 kilometers (4 miles; 1 male) (Murphy and Ehrlich 1980; D. Murphy, pers. comm. 2001), 5.6 kilometers (3.5 miles; 1 male), and 3 kilometers (2 miles; 1 female) (Harrison 1989). Individual long-distance dispersal may be prevalent under certain conditions, but the likelihood of long-distance colonization by a given individual is usually low because environmental conditions promoting dispersal are not likely to also allow successful colonization. In 2002, an unusually dry season throughout the range of the Quino checkerspot butterfly, females did not appear to be dispersing from their natal habitat patches early in the season, despite the lack of suitable host plants on which to oviposit (A. Anderson, pers. observ. 2002, K. Osborne, G. Pratt, pers. comm. 2002).

Dispersal direction in the bay checkerspot butterfly was generally found to be random (Harrison 1989), but dispersing butterflies were likely to move into habitat patches when they passed within 50 meters (160 feet), and were most likely to stay where existing density was lowest (Harrison 1989). Bay checkerspot butterfly research data also suggested that patches separated from a source population by hilly terrain were less likely to be colonized than patches separated by flat ground (Harrison 1989). Harrison (1989) concluded that because establishment rates were low (during her study) and initial dispersal direction was random, relatively large numbers of butterflies must have emigrated from the source population at some point to explain the apparent long-term habitat patch recolonization pattern. High emigration and habitat patch colonization rates probably only occur during rare outbreak years, when high local densities combine with favorable establishment conditions in "unoccupied" patches (not supporting larval development; Harrison 1989). Rare outbreak events are thought to play a crucial role in Quino checkerspot butterfly metapopulation resilience (Murphy and White 1984).

Establishment of local populations in distant habitat patches may be achieved within a single season through dispersal of individual butterflies, or over several seasons through "stepping-stone" habitat patch establishment events. Research conducted during the late 1970's and late 1980's on the Morgan Hill metapopulation of bay checkerspot butterflies recorded island habitat patch reestablishment distances from the mainland habitat patch averaging 3.4 kilometers (2.8 miles), with a minimum individual butterfly movement distance of 1.4 kilometers (0.9 mile) up to a maximum of 4.4 kilometers (2.8 miles) in individual dispersal or stepping-stone movements (Harrison *et al.* 1988). Dispersal studies in sum suggest that long distance movements by individuals are not common, but may be sufficient to allow for infrequent between-patch exchanges of up to 6 kilometers (3.7 miles). Bay checkerspot butterfly habitat patch reestablishment patterns and models suggest that habitat patches as distant as 7 kilometers (4.3 miles) may provide sources of reestablishment for each other via stepping-stone dispersal over a 40- to 50-year period (Harrison 1988).

The selection of specific plant species by *Euphydryas editha* on which to deposit eggs is genetically determined, and strong natural selection can lead to rapid changes in diet (Singer *et al.* 1991). Host plant preference in females can be quantified by measuring the amount of time a butterfly searches before it will deposit eggs on less preferred host plants (Singer *et al.* 1992). The ability of *E. editha* larvae to grow and survive on particular host plant species is variable among individual larvae (Singer *et al.* 1988) and among larval populations (Singer *et al.* 1994, Rausher 1982). When female *E. editha* butterflies fail to encounter preferred host plants, the likelihood of emigration to other suitable habitat patches increases (Thomas and Singer 1987). Host plant preference, host plant availability, and host plant resistance to herbivores all affect butterfly diet, which in turn affects habitat colonization rates and local population persistence (Hanski and Singer 2001). Because aspects of metapopulation dynamics are apparently emergent properties affected by a number of host plant and butterfly characteristics, further research should be conducted on these interactions.

Most Quino checkerspot butterfly ovipositing has been documented on *Plantago erecta* (dwarf plantain). Rahn (1979) described the habitat of *P. erecta* as "dry sandy soil in dunes, grassy hills and flats, and clearings in woods." *Plantago erecta* occurs in southern California within annual forbland, scrub, grassland, and open chaparral plant communities. It can be found on soils with or without cryptogamic crusts (a thin organic crust composed of cyanobacteria, lichens, mosses, and fungi), and is often associated with fine-textured clay soils (Pratt 2001, K. Osborne, pers. comm. 2002). It is not known whether the plant species has an affinity for clay soils in southern California, or the soils reduce competition from invasive nonnative annual forbs and grasses. *Plantago erecta* 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 obligate fire-following species. 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 *P. erecta* are not well understood, but they may have major impacts on Quino checkerspot butterfly populations, and warrant further research. An apparent high degree of annual turnover of *P. ovata* (desert indianwheat plantain) seed was observed at Jasper Ridge (N. Chiariello, pers. comm.). However, at Lower Otay Lakes, San Diego County, bouts of total defoliation of host plant patches prior to seed set were followed by dense germination the following year, indicating that the seed bank persists at least 2 years in that area (Murphy and White 1984). Female Quino checkerspot butterflies appear to prefer ovipositing on individual *P. erecta* plants that exhibit a more spreading growth - specifically, on leaves closest to the ground (Pratt 2001). *Plantago erecta* flowers in April and May (Rahn 1979).

Another apparently important, but only recently documented, primary host plant is *Antirrhinum coulterianum* (white snapdragon; Pratt 2001). All Quino checkerspot butterfly egg and larval clusters found during the 2001 season in the Silverado Occurrence Complex, Riverside County (see section I.D, Distribution and Habitat Considerations), were on this plant species. *Antirrhinum coulterianum* appears to be a facultative fire-follower in nondesert areas; Thompson (1988) described the plant's habitat as follows:

> This species can be found dependently, year after year, in desert plant communities, often growing between shrubs. In parts of its range that are dominated by chaparral or coastal sage plant communities, fire or other disturbance seems to be required for the appearance of this species; it is on burns in these plant communities that the plants reach their largest size; a few comparatively small plants can be found in these areas at other times, usually on exposed or disturbed sites.

Antirrhinum coulterianum is generally found between 2 and 520+ meters (5 and 1,700+ feet) in elevation and flowers from April through July (Thompson 1988); thus its availability for larval consumption early in the season may be similar to the availability of *Plantago* host species, although it probably remains edible longer because of its larger, more robust morphology.

Antirrhinum coulterianum displays a number of morphological characteristics that make it unique in the genus *Antirrhinum* (Thompson 1988), and one of them may explain why it is the only species of this genus reported to be a primary host plant of *Euphydryas editha*. Large individuals often produce a substantial cluster of spreading leaves close to the ground (Thompson 1988), similar to the growth form of *Plantago erecta* apparently preferred by female Quino checkerspot butterflies for oviposition.

The hypothesis that *Antirrhinum coulterianum* played an important role in the evolution and ecology of the Quino checkerspot butterfly is also corroborated by the plant species' distribution relative to that of the butterfly. *Antirrhinum coulterianum* has the most restricted range of any of the Quino checkerspot butterfly's primary host plant species. The plant species' range also corresponds very closely with the historic range of the Quino checkerspot butterfly (Figure 2), and the Southwest California Floristic Province (Hickman 1996). If fire-following populations of *A. coulterianum* were an essential component of Quino checkerspot butterfly habitat prior to the advent of fire suppression practices, that would partly explain the absence of recent Quino checkerspot butterfly observations in parts of its historic range, such as central San Diego County and the Santa Ana Mountains in Orange County. Further research into the current and historic relationships between the Quino checkerspot butterfly and *A. coulterianum* should be conducted.

Another species of *Plantago* that was recently documented as a primary host plant for the Quino checkerspot butterfly is *Plantago patagonica* (woolly plantain; Pratt 2000, 2001). *Plantago patagonica* is the only species of *Plantago* found in the Silverado Occurrence Complex (see section I.D, Distribution and Habitat Considerations), and numerous egg and larval clusters were documented on this plant species during the 2000 season. *Plantago patagonica* occurs in dry and sandy soil, generally between 200 and 2,000 meters (656 and 6,562 feet) in elevation (Rahn 1979). This species overlaps in distribution with *P. erecta* at lower elevations, but *P. erecta* is probably more edible (less "hairy," and softer), for small pre-diapause larvae. It may be used for oviposition only when other host plant species are less available or less suitable. *Plantago patagonica* has only been documented thus far in occupied Quino checkerspot butterfly habitat where either *P. erecta* or *Antirrhinum coulterianum* also occur.

Cordylanthus rigidus (thread-leaved bird's beak), a partially parasitic plant often found at high densities in disturbed areas (Chuang and Heckard 1986), is perhaps the most widely distributed of all the primary host plants. Habitat of the plant is described as "open slopes and flats of foothill woodlands, chaparral margins, and coniferous forests" (Chuang and Heckard 1986). As noted for *A. coulterianum*, the range of the subspecies *C. rigidus setigerus* that has been documented as a primary Quino checkerspot butterfly host plant corresponds very closely with the historic range of the butterfly (Figure 2), and the Southwest California Floristic Province (Hickman 1996). However, unlike other primary host plant species, it is doubtful that *C. rigidus* could support a Quino checkerspot butterfly population in isolation from other host plants. Because it is a late-blooming hemi-parasite, it is believed by some to be too small in stature and too low in abundance early in the season to support post-diapause larval populations. *Cordylanthus rigidus* flowers in July and August (Chuang and Heckard 1986).

Plant species may be used as primary, or secondary (species of host plants consumed by larvae but not used by adults for ovipositing) hosts depending on site conditions. Other possible primary host plants include *Castilleja exserta* (owl's-clover) and other native *Plantago* species. *Castilleja exserta* is probably most important, however, as a secondary host plant (see secondary host plant discussion below). In some situations, specific combinations of host plant species should enhance habitat suitability. Various combinations of *P. erecta*, *P. patagonica, Antirrhinum coulterianum, C. exserta,* and *Cordylanthus rigidus* can be found at sites occupied by Quino checkerspot butterflies. All primary host plants for the Quino checkerspot butterfly overlap in range with others in some areas, and the presence of multiple host plant species may be an indication of habitat quality. The species of plant used for oviposition at a given site may change depending on the prevailing environmental conditions. At occupied high-elevation sites (1,219 to 1,524 meters [4,000 to 5,000 feet]) (*e.g.* the Silverado Occurrence Complex; see section I.D, Distribution and Habitat Considerations), *A. coulterianum* and *P. patagonica* co-occur. All observed eggs at the Silverado Occurrence Complex were laid on *P. patagonica* in 2000, and on *A. coulterianum* in 2001 (Pratt 2001). *Antirrhinum coulterianum* was not recorded at the Silverado Occurrence Complex in 2000 (Pratt 2001), and may be too sparse in some years to support reproduction.

Secondary host plants may be important before and after larval diapause. Secondary host plants are important for pre-diapause larvae when the primary hosts become inedible before larvae can enter diapause. Such was the case with populations of the bay checkerspot butterfly where *Plantago erecta* was the primary host plant, but most larvae survived to reach diapause by migrating to *Castilleja exserta*. Pre-diapause larvae fed on *C. exserta* until diapause, then returned to feeding on *P. erecta* when they broke diapause in winter (Singer 1972, Ehrlich *et al.* 1975). Some populations of Quino checkerspot butterfly may also be dependent for survival on multiple overlapping primary and secondary host plant distributions. In 2001, host plant micro-patches near Barrett Junction, San Diego County, had abundant populations of *Cordylanthus rigidus* and *C. exserta* intermingled with *P. erecta*, but all the larval clusters (where oviposition occurred) were found on *C. rigidus* (Pratt 2001, A. Anderson pers. observ.). It is possible that *P. erecta* is an important post-diapause secondary host plant species at this site, because *C. rigidus* is immature and less abundant than *P. erecta* when larvae come out of diapause (Pratt 2001). At occupied sites where *P. erecta* and *P. patagonica* co-occur, *P. erecta* often dries out earlier than *P. patagonica*; therefore, *P. patagonica* may serve as a pre-diapause secondary host plant at some sites (Pratt 2001).

The two most important factors affecting the suitability of host plants for Quino checkerspot butterfly oviposition are exposure to solar radiation and phenology, (timing of the plant's development). Female Quino checkerspot butterflies deposit eggs on plants located in full sun, preferably surrounded by bare ground or sparse, low vegetation. Adult female butterflies are adept at selecting those plants that receive adequate sunshine and will remain edible the longest (Mackay 1985, Parmesan 1991, Singer 1994, Parmesan *et al.* 1995). 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 the high temperature requirements of developing larvae (Weiss *et al.* 1987, 1988; Osborne and Redak 2000). However, females have been observed depositing eggs on host plants shaded by shrubs late in the season when host plants in open areas were declining in suitability (K. Osborne, pers. comm. 2002). Primary host plants 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).

Euphydryas editha egg clusters typically contain 20 to 150 eggs (M. Singer, C. Parmesan, and G. Pratt, pers. comm.), only a small fraction of which are likely to survive to maturity. 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, then disperse in search of new plants. The ability of pre-diapause larvae to search is limited, especially prior to the third instar. First and second instar larvae can find hosts within 30 centimeters (1 foot) of their natal host plant. By mid-third instar, larvae can travel up to 1 meter (3.3 feet) to find host plants (G. Pratt, pers. comm.). Therefore, high local host density is necessary for high larval survival rates, but most host plants should occur in sufficiently open areas with high solar exposure. When secondary hosts are nearby, the density of primary host plants that is needed may be reduced.

Euphydryas editha butterflies use a much wider range of plant species 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* spp. (lomatium), *Muilla* spp. (goldenstar), *Achillea millefolium* (milfoil or yarrow), *Amsinckia* spp. (fiddleneck), *Lasthenia* spp. (goldfields), *Plagiobothrys* and *Cryptantha* spp.(popcornflower), *Gilia* spp. (gilia), *Eriogonum fasciculatum* (California buckwheat), *Allium* spp. (onion), and *Eriodictyon* spp. (yerba santa) (D. Murphy and G. Pratt, pers. comm.). *Salvia columbare* (chia) (Orsak 1978; K. Osborne, pers. comm. 2001; G. Pratt, D. Murphy, pers. comm. 2001), and *Dichelostemma capitatum* (blue dicks) (K. Osborne, pers. comm. 2002) may also be used for nectar feeding. Quino checkerspot butterflies have been observed flying several hundred meters from the nearest larval host plant micro-patch to nectar sources (White and Levin 1981). However, studies of bay checkerspot butterflies found that they tended to deposit eggs on hosts that are close to, rather than farther from, adult nectar sources (Murphy 1982, Murphy *et al.* 1983).

Although habitat patch delineation may theoretically be estimated based on host plant micro-patch and nectar source distribution, and host and nectar plant density, delineation of long-term habitat patch footprints (and areas of extant larval occupancy) is difficult to estimate at any given time in the field. Plant population quality, density, and distribution change over time for a variety of reasons, and Quino checkerspot butterfly populations have evolved to respond to shifting habitat patch suitability in space and time (White and Levin 1981, Murphy and White 1984, Osborne and Redak 2000). For example, environmental conditions may not favor plant germination one season, or favor germination of other plant species, but low-density germination of host plant individuals and/or a seed bank may still result in abundant germination at a later date. Lower primary host plant density may be sufficient if secondary host plant species are present; however, feeding by herbivores, including Quino checkerspot butterfly larvae, will reduce the density of host plants, even under the best environmental conditions.

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 northern California from 1975 through 1977 caused the apparent extirpation of 24 percent of surveyed populations of *E. editha* (Singer and Ehrlich 1979, Ehrlich *et al.* 1980). Observations and experiments suggest that the relationship between weather and survival of *E. 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). Phenological mismatches have been observed in southern California on several occasions 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, K. Osborne, pers. comm. 2002, A. Anderson pers. observ. 2002). In general, weather conditions that hasten completion of a plant's life cycle relative to that of the butterfly, such as warm, cloudy weather, cause increased larval mortality (Singer 1983, Boughton 1999). Conversely, conditions that slow the completion of a plant's life cycle relative to that of the butterfly can 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).

Severe local climatic events can profoundly affect *Euphydryas editha* populations. The prolonged drought in California in the 1980's is credited as being largely responsible for near-extirpation of the Quino checkerspot butterfly (Mattoni *et al.* 1997). Similar effects were observed in the Jasper Ridge bay checkerspot butterfly metapopulation during the drought from 1976 to 1978 (Murphy and Ehrlich 1980). In a 1983 study, unusually cold temperatures combined with wet conditions were a major mortality factor for bay checkerspot butterfly pupae placed in the field (White 1986). Mortality during the pupal stage was high and variable enough to affect adult numbers and population dynamics (53 to 89 percent; White 1986). Historical accounts and precipitation records also suggest that a severe flood was at least partially responsible for extirpation of lower elevation Quino checkerspot butterfly populations in Orange County (see section I.C.5, Metapopulation Resilience). Weather may directly destroy individuals, or indirectly destroy them by increasing vulnerability to disease and predation (White 1986).

It has been hypothesized that the Quino checkerspot butterfly is probably better adapted to survive dry conditions, and has been selected to undergo multiple-year diapause more frequently than more northern subspecies of *Euphydryas editha* because the climate is generally warmer and drier and rains are less predictable (K. Osborne, pers. comm.). Nevertheless, two of the most severe droughts in recorded history appear to have primarily occurred in northern areas. The 1929 to 1934 drought in California, characterized as the "longest, most severe in the State's history" (Paulson *et al.* 1989) does not appear to have affected Quino checkerspot butterfly populations, and is not reflected in the Los Angeles rainfall record (A. Anderson *in litt.* 2003). The 1975 to 1977 drought that apparently contributed to extirpation of local bay checkerspot butterfly populations was characterized as "Statewide, except southwestern deserts," and "The driest 2 years in State's history, most severe in northern 2/3 of state," (Paulson *et al.* 1989). The 1975 to 1977 drought was not reflected in San Diego County rainfall records; furthermore, it immediately preceded the Quino checkerspot butterfly population explosions in southwestern San Diego County documented in the late 1970's (Murphy and White 1984). Therefore, any conclusions regarding enhanced ability of the Quino checkerspot butterfly to survive drought compared to other subspecies of *E. editha* (*e.g.* as an explanation for Parmesan's 1996 results) must be considered speculative.

4. Population Structure

Distribution of the Quino checkerspot butterfly, and many other subspecies of *Euphydryas editha*, is patchy at several geographic scales (Hanski 1999). Local resources are unevenly distributed on the scale of meters, clusters of host plant 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 called metapopulations. Butterfly metapopulations may belong to larger interdependent networks forming greater metapopulations (Murphy and Ehrlich 1980, termed “megapopulations” by Hanski 1999).

Interaction of individuals among local habitat patch populations in a metapopulation is reduced compared to interaction within local populations. Individuals interact among local populations enough to reduce the extinction probability of the metapopulation compared to the extirpation probability of any local population (extirpation probabilities are not independent). In this case, interaction specifically refers to emigrants re-colonizing neighboring habitat patches where the local population has been extirpated, not just occasional exchanges of genetic material. Metapopulations differ from pan-mictic (well-mixed) populations with patchily-distributed habitat in that exchange of adult individuals between larval habitat patches is relatively restricted on a seasonal basis, but frequent enough that vacant habitat patches are likely to be recolonized in ecological time (Hanski 1999). All individuals in pan-mictic populations are assumed to interact equally. The pan-mictic and metapopulation models form two extremes of a continuum (Hanski 1999), with most butterfly populations probably lying somewhere in between.

Local habitat patches in *Euphydryas editha* populations are generally composed of a set of larval host plant "micro-patches" within the typical flight range of the adult butterflies (about 50 to 200 meters [160 to 660 feet]), thus comprising a greater adult "habitat patch." To estimate the amount of food resources necessary to maintain a local population, we assumed that a population of 100 adults, with a balanced sex ratio, is 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, three to four adults, some of which would emigrate or fail to reproduce. If a mated female lays three to four egg 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 of host plants, so a local habitat patch would need 50 x (3 to 4), or 150 to 200 suitable micro-patches of 20 (or more) *Plantago erecta* plants to support a local population of prediapause larvae. Lower density of *Plantago* spp. host plants may be sufficient if other host plant species are present.

Larger host plant "micro-patches" could accommodate more egg clusters, but no evidence exists to suggest that *Euphydryas editha* butterflies 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. Therefore, 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 observable/detectable plants in a *Plantago* population that currently supports Quino checkerspot butterfly larvae will be lower than the number in the same population without the butterflies; and 3) measurements of *Plantago* density in habitat patches not supporting larval development may overestimate the ability of habitat patches to support a butterfly population. Also, if many larvae re-enter diapause during dry years, habitat suitability with respect to required host plant density may be underestimated due to low germination rates that do not affect the population of larvae. Note, a substantial amount of primary or secondary host plants must remain after the post-diapause larvae have finished feeding if a habitat patch is to support clusters of pre-diapause larvae. If too few primary host plants remain, females must disperse to seek new habitat patches for oviposition.

Local habitats alone are generally not sufficient to ensure the long-term persistence of butterfly metapopulations (Hanski 1999). A local population may be expected to persist on the time scale of years. Persistence for longer terms (decades) derives from the interaction between 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 population's geographic/temporal scale (hierarchical level) in question (Table 1). Smaller metapopulations, composed of sets of local habitat patches described above, should persist over the course of many decades, with habitat patches recolonized within a few years to more than a decade of extirpation (Harrison *et al.* 1988). Larval occupancy blinks in and out within the habitat patches, but the metapopulation as a whole remains resilient, provided extirpations offset recolonizations. An example of a small bay checkerspot butterfly metapopulation occurs at Jasper Ridge, San Mateo County. As stated above, at larger geographic scales, sets of small metapopulations can be nested within larger "megapopulations" (Hanski 1999). Small metapopulations experience extirpation and recolonization at the megapopulation scale over the course of

Table 1. Distribution Scales of Bay Checkerspot Metapopulations.

	Habitat patch	Metapopulation	Megapopulation
Example	Area H	Jasper Ridge	Morgan Hill and associated metapopulations
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

centuries rather than decades. However, long-term persistence of species with metapopulation dynamics may depend on maintenance of geographically intermediate habitat patches or rare long-distance dispersal events that link larger metapopulations.

Rare examples exist of *Euphydryas editha* populations that apparently do not require a metapopulation structure for long-term persistence. One example is the small *E. editha* population at Surf, north of the City 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. In contrast, the size of the mainland habitat patch supporting the most stable local population of the Morgan Hill metapopulation of bay checkerspot butterfly is approximately 17 by 3 kilometers (11 by 2 miles), a large geographic area (Harrison et al. 1988). In Colorado, diffuse, well-mixed populations of *E. editha* have been documented that inhabit many square kilometers of more or less continuous habitat (Ehrlich and Murphy 1987). Several metapopulations of butterfly species in Finland closely related to the Quino checkerspot butterfly (*Euphydryas aurinia, E. maturna, Melitaea cinxia, M. diamina,* and *M. athelia*) were documented to have Levin's-style population structures (see below), and all occupied distributions were close to 1,500 by 1,500 kilometers (930 by 930 miles) in size, and composed of 12 to 20 local populations (Wahlberg *et al.* 2002). At a population scale, habitat may support similar densities of *E. editha* in pan-mictic populations compared to metapopulations, but at a habitat-patch/local population scale densities may be greater for metapopulations.

Three theoretical types of metapopulation structure have been described: the mainland-island, source-sink, and Levin’s types (Hanski 1999). The bay checkerspot butterfly metapopulation at Morgan Hill represents an example of a mainland-island type in which occupancy of a single, large mainland habitat patch persists through time while outlying small island habitat patches must be regularly recolonized (Harrison *et al.* 1988). This population structure is similar to the one Murphy and White (1984) hypothesized exists for the Quino checkerspot butterfly in the Otay Lakes area, San Diego County. A mainland-island metapopulation contains one or more very large habitat patch/population (the mainland) with a lower risk of extirpation, and other, smaller (island) habitat patches/populations with higher risks of extirpation than the mainland population due to their limited size. This type is slightly different from the "source-sink" population model (below), in that island populations can have the same growth rates as the mainland patch. Island populations may be collectively just as important to metapopulation persistence as is the mainland population, and they are likely to serve as sources of immigration for each other, or even the mainland patch in case of catastrophic events such as wildfire.

A source-sink metapopulation contains one or more local populations that are commonly sources of colonization for associated sink populations. In source populations, emigration exceeds immigration, while in sink populations, immigration exceeds emigration. Sink populations are dependent, at least temporarily, on source populations to maintain nonnegative growth rates. It would be a mistake to assume source populations are more resilient over time, as the status of local populations can change and may even be reversed when changing environmental or density-dependent factors alter the growth rates of local populations (Boughten 1999, 2000). Even if immigration exceeded emigration in a sink, as long as sinks produce some emigrants, they may occasionally recolonize neighboring habitat patches (they are just less likely to do so than a source population).

A Levin's-type metapopulation, as exemplified by the *Euphydryas editha nubigena* (Sierra Nevada Edith's checkerspot butterfly) metapopulation along the General's Highway in Tulare County, has a 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 local populations are extirpated simultaneously, and patches supporting larval development regularly provide immigrants for habitat patches temporarily not supporting larvae (Singer and Thomas 1996; Thomas *et al.* 1996; Boughton 1999, 2000). It is possible for a metapopulation structure to exhibit aspects of all three types. It is not known which type of metapopulation structure is most common in the Quino checkerspot butterfly, but most populations of this species almost certainly have an element of metapopulation structure at some geographic and spatial scale.

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 supporting larval development. 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 member habitat patches should also reduce the probability of simultaneous extirpation of habitat patches (Harrison and Quinn 1989). Landscape connectivity between and within metapopulations should be maintained whenever possible.

Fragmentation of Quino checkerspot butterfly habitat has isolated many habitat patches and small networks from other habitat patches and networks, therefore the need for active future management is anticipated. Extirpation of isolated local populations is likely, given that periodic extirpations on that scale is common 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 resilient mainland population is documented, Quino checkerspot butterfly 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 extirpation and recolonization of all local populations occurs with equal frequency.

The scientific literature commonly refers to habitat patches within a metapopulation as “occupied” or “unoccupied,” depending on whether they support larval development, and adult use is detectable. However, to avoid confusion between the metapopulation scale use of the term occupancy, and the habitat patch/local population scale use of this term, in this document we avoid referring to habitat patches within the current distribution of a metapopulation as unoccupied. Although local populations, may be “extirpated,” and habitat patches may be recolonized, all habitat patches within a metapopulation distribution are considered to be occupied by adults. If a population is well-mixed, then the “habitat patch” defines its distribution, and the term “occupancy" is used.

5. Metapopulation Resilience

The term resilience is used here to describe persistent Quino checkerspot butterfly populations. Although no quantitative analysis of a model to fit Quino checkerspot butterfly population dynamics is possible at this time, populations do appear to fit the qualitative description of a resilient system. Resilient natural systems tend to maintain their integrity when subject to disturbance; examples include periodic insect population outbreaks resulting from a hard loss of stability (resistance to restabilization) and hysteresis (presence of a lag-time prior to effect observation) (Ludwig *et al.* 1997). Although resilient populations may naturally show great fluctuations in size, they are capable of maintaining the their integrity over time if suitable habitat remains available.

Local Quino checkerspot butterfly populations that survive such negative environmental events as prolonged drought appear to have the potential to rapidly increase in density and recolonize habitat patches under favorable conditions. This ability is characterized by rapid increases in density and then dispersal to habitat patches not currently supporting larval development when natal patches become too densely occupied (Harrison 1989, Murphy and White 1984). Dispersal events primarily serve to recolonize habitat patches where local populations were extirpated by catastrophic events such as fire, by prolonged unfavorable environmental conditions, by stochastic population events, or by density-dependent intra-specific competition. Single and multiple-year diapause allows local populations to persist short-term (1 or more years) in habitat patches when environmental conditions remain unfavorable for less prolonged periods (maximum number of years unknown). This combination of population-regulation mechanisms has been termed “density-vague,” where both density-dependent and environmental factors contribute to long-term population dynamics (Strong 1986).

There appears to be a delicate balance between the ability of Quino checkerspot butterfly populations to survive detrimental environmental conditions and rapidly increase in number under favorable conditions, and their vulnerability to habitat destruction and adverse environmental conditions (Murphy and White 1984). In the past the Quino checkerspot butterfly has exhibited population outbreaks (Orsak 1974, Murphy and White 1984) and these outbreaks have, in some cases, been followed by population extirpation (Orsak 1974). Environmental conditions that would naturally result in a temporary population crash followed by recovery, may result in extirpation of the population when their effects are exacerbated by human impacts to habitat.

Accounts of large population density fluctuations at historic Quino checkerspot butterfly population sites (Orsak 1973, Murphy and White 1984), and collection record data (A. Anderson *in litt.* 2003), indicate that the Quino checkerspot butterfly is a climate-sensitive, “eruptive” species that semi-regularly increases its adult densities by orders of magnitude over a period of 5 to 10 years, then drops back to much lower densities over a similar period of time (Orsak 1974, A. Anderson *in litt*. 2003). Droughts, fires, and floods appear to severely reduce population densities, but intermediate amounts of precipitation, combined with high temperatures, appear to restore high population densities (Murphy and White 1984, A. Anderson *in litt.* 2003). These major weather pattern-driven fluctuations in Quino checkerspot butterfly population densities are similar to the long-term population fluctuations in the bay checkerspot butterfly recorded by Paul Ehrlich’s research group at Jasper Ridge (Ehrlich *et al.* 1975). The balance between resilience and vulnerability appears to have been disrupted in this case, because the Jasper Ridge bay checkerspot butterfly population is believed to have been extirpated in 1997 (Mattoni *et al.* 1997). The last range-wide Quino checkerspot butterfly population density and/or distribution low was in the late 1980's. Other documented historic range-wide density and/or distribution lows for this species occurred in the mid 1960's, early 1950's, the late 1930's-early 1940's, and the mid-1920's (A. Anderson *in litt.* 2003). The Quino checkerspot butterfly appears to exhibit population lows about every 10 to 20 years corresponding with either drought or flood conditions (A. Anderson *in litt.* 2003). Increased late 1990's/early 2000's population levels (relative to the 1980's) were certainly reduced relative to past levels (pre-1980's) due to extensive, cumulative habitat and population loss caused by humans. If past patterns and the severe "100-year" 2002 drought (National Climatic Data Center 2002) are any indication, we may experience another decline over the next 5 years. It is not clear that the remaining populations are resilient enough to survive another decline such as the one that occurred in the 1980's.

The apparent extirpation of the Quino checkerspot butterfly from Orange County is probably an example of a large-scale loss of populations and regional resiliency (megapopulation extirpation). Examination of the history of Orange County Quino checkerspot butterfly populations (A. Anderson *in litt*. 2003) indicates that a combination of naturally occurring events (*e.g.* drought, cold-snaps, flood, and fire), exacerbated by ongoing human-caused habitat destruction and degradation (development, agriculture, and grazing), resulted in the apparent extirpation of formerly resilient Quino checkerspot butterfly populations from Orange County. In 1938, a 100-year flood (Paulson *et al.* 1989) apparently eliminated what was left of the low-elevation Quino checkerspot butterfly populations in Orange County (A. Anderson *in litt.* 2003) and marked the last year of any recorded lower-elevation Quino checkerspot butterfly collection in Orange County (A. Anderson, *in litt.* 2003). The severity of this flood was described as:

> ...some of the heaviest rain ever recorded occurred in 1938. A storm hit February 27 and did not subside until five days later. Ten inches fell on the fourth day alone, at times measuring two inches an hour. Roads and bridges were washed out and 19 people drowned (Orange County Water District 2001).

If the lower elevation population of the butterfly that existed at Irvine Park, Orange County, had not been permanently extirpated, apparently by a combination of human-related impacts and catastrophic natural events, it probably would have served as a source of recolonization for the higher-elevation Black Star Canyon/Hidden Valley population (approximately 5 kilometers [3 miles] away) after the 1967 fire that apparently extirpated that population. Conversely, if most of the habitat at Irvine Park had not been degraded, higher elevation populations might have recolonized that habitat following the 1938 flood event.

On the scale of the species-wide distribution of the Quino checkerspot butterfly (and in most cases on the population scale as well), each consecutive population density high and low during the 20th century must have been reduced from the previous one, due to ongoing human-caused destruction of habitat and source populations. This undeniable long-term downward population trend, superimposed on apparent 10- to 20-year population density peaks, must be considered when assessing current species' status and planning for recovery. For some recovery units, we may be approaching an extirpation threshold in the long-term population density and distribution decline, the threshold where the cycle is disrupted and resilience is lost, but that may not be apparent for 5 or more years.

It has been over 10 years since the drought of the 1980's ended, and rainfall has been relatively abundant in the 1990's (A. Anderson *in litt.* 2003), indicating we may have reached the latest 10- to 20-year population density and distribution peak in southern San Diego County. However, Quino checkerspot butterfly densities remain far below what they were in the late 1970's (D. Murphy, M. Singer, pers. comm.). Dispersal and recolonization events were probably high during the 1999 season because it was a relatively dry year preceded by a wet year (Murphy and White 1984, Anderson 2000, A. Anderson *in litt*. 2003). It is likely that there will be yet another drought-induced Quino checkerspot butterfly crash during the next 5 to 10 years, such as the ones that occurred in the 1980's and during the 1960's (A. Anderson *in litt*. 2003). Without intervention such a crash would be likely to result in extirpation of populations as apparently happened in Orange County and the Rancho Santa Fe/Lake Hodges area, San Diego County (A. Anderson *in litt.*). Recent evidence supports Murphy and White's (1984) hypothesis:

> The extirpation of a single, large reservoir population of [Quino checkerspots] may effectively deny other habitats necessary migrants, creating a ripple effect of irreversible long-term extinctions. We suspect that just such a circumstance has eliminated *Euphydryas editha* [*quino*] from Orange County and much of coastal San Diego County, and now threatens populations in Riverside and inland San Diego Counties in California.

Unfortunately we do not yet know how much local Quino checkerspot butterfly density, distribution, and habitat availability can be reduced without critically compromising the species' resiliency, but we are likely approaching that threshold in some areas. Even in cases where a species has been historically resilient and has had a high reproductive capacity under favorable conditions, it is still possible for human alteration of crucial habitat elements in the right places at the right time to cause its extinction (Lockwood and Debray 1990). Therefore, despite the discovery of new occupied sites from 2001 through 2003, it remains crucial that as many habitat patches as possible (regardless of known occupancy) be conserved, restored, and managed, and that we attempt to maintain all populations that can feasibly be managed for resilience.

D. Distribution and Habitat Considerations

The Quino checkerspot butterfly was historically distributed throughout the coastal slope of southern California, including Los Angeles, Orange, western Riverside, San Diego, and southwestern San Bernardino Counties (Figure 2), and northern Baja California, Mexico (Mattoni *et al.* 1997). The Quino checkerspot butterfly's 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). Although historical collection records permit estimation of a species' range, such records usually underestimate the number of historical sites and extent of regional distributions. Butterfly collectors tended to frequent well-known sites, and no systematic or comprehensive surveys for the Quino checkerspot butterfly have ever been conducted (Mattoni *et al.* 1997). Multiple observations of Quino checkerspot butterflies have been reported across a wide elevation range, from approximately 153 meters (500 feet) in elevation to over 1,533 meters (5,000 feet).

As recently as the 1950's, collectors described the Quino checkerspot butterfly 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 butterfly was historically widespread throughout the southern California landscape and occurred in a variety of vegetation types, including coastal sage scrub, open chaparral, juniper woodland, forbland, and grassland communities. 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 (U.S. Fish and Wildlife Service 1997a). By the mid-1980's, the species was thought to have disappeared from all remaining locations; the petition to list the species in 1988 suggested that it might be extinct (U.S. Fish and Wildlife Service 1997a). Nonetheless, new populations were discovered in Riverside County, the butterfly was rediscovered in San Diego County, and it continued to survive in northern Baja California, Mexico (Parmesan 1996). Current information suggests that the butterfly has been extirpated from Los Angeles, Orange, and San Bernardino Counties (Figure 2). Most California populations of the butterfly probably occur in degraded, marginal habitat on the periphery of historic metapopulation centers (Parmesan 1996; D. Murphy, pers. comm.).

Extant Quino checkerspot butterfly populations primarily inhabit grassland, remnant forbland, juniper woodland, and open scrub and chaparral communities that support the primary larval host plants and a variety of adult nectar resources. These areas tend to be distributed as patches in a mosaic of vegetation communities. A recent larval microhabitat use study indicated that patches of exposed soil with abundant solar exposure and host plants, combined with interspersed shrub cover and topographic heterogeneity, provides additional long-term resilience to Quino checkerspot butterfly populations (Osborne and Redak 2000). 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). In combination, these varying habitat features result in extremely localized butterfly population density fluctuations and periodic local population extirpation and recolonization events within patches of habitat (Ehrlich 1965).

Although environmental variation among occupied habitats has made it difficult to identify habitat indicator plant species, several species that frequently co-occur with the butterfly's host plants and Quino checkerspot butterfly populations are worth mentioning (Pratt 2001). The annuals *Lepidium nitidum* (peppergrass), *Layia platyglossa* (tidy-tips), *Lasthenia californica* (goldfields), *Crassula connata* (pygmy weed), and *Hemizonia* sp. (tarplant) are commonly found on occupied habitat. Bulb species such as *Dichelostemma capitatum* (blue dicks), *Fritillaria biflora* (chocolate lilies), and *Zigadenus fremontii* (star lilies) are also known from occupied habitat. *Hemizonia* may be a good field reference for clay lens habitat because it forms dense stands visible at great distances long after senescence. *Dudleya multicaulis* (many-stemmed dudleya) and *Dudleya variegata* (variegated dudleya) are also clay soil indicators. *Eriogonum fasciculatum* (California buckwheat) has been found in all occupied Quino checkerspot butterfly habitat documented to date (Pratt 2001). *Acarospora schleicheri* (a thick yellow lichen) and *A. thelococcoides* (a cream white, donut-shaped lichen) are commonly associated with cryptogamic crusts in occupied Quino checkerspot butterfly habitat. *Acarospora thelococcoides* is rare in southern California. Above 920 meters (3,000 feet) in elevation *Selaginella* *bigelovii* (spike-moss) is more commonly associated with soil crusts than lichens. Although *E. fasciculatum* is very common throughout southern California, its absence could be an important indicator of Quino checkerspot butterfly absence (Pratt 2001).

Disturbances that have compromised Quino checkerspot butterfly metapopulation integrity include conversion of habitat by development or vegetation-type changes, grazing, trampling, fragmentation of habitat, and reduction or severing of the landscape connectivity that facilitates habitat patch recolonization. Linkage of suitable habitat patches by adult dispersal areas (landscape connectivity) is crucial to metapopulation resilience. Dispersal areas should connect as many habitat patches as possible to facilitate metapopulation dynamics (Thomas 1994). Habitat patches that have fewer and/or longer dispersal area connections to other patches, all else being equal, have lower probabilities of natural recolonization events following local extirpation. Based on the results of Harrison *et al.* (1988) and Harrison (1989), dispersal areas greater than 2 kilometers (1.2 miles) distant do not appear likely to be used by adult bay checkerspot butterflies belonging to the same metapopulation. By definition, dispersal areas do not support larval host plants in densities sufficient to be considered habitat, but may support nectar sources used by dispersing adult butterflies. Dispersal areas should be free of presumed dispersal deterrents (*e.g.*, large artificial structures) and mortality sinks (*e.g.* high-traffic roads).

Simply protecting occupied habitat from direct destruction by agricultural or urban development and grazing will not be sufficient to protect resident populations (see section I.C.4, Population Structure). Rural lands that are infused with or surrounded by development experience direct and indirect human-caused disturbance including trampling, off road vehicle use, dumping, pollution, and enhanced nonnative species invasion, all of which reduce population resilience. Protected areas larger than habitat patch boundaries are needed within the long-term distribution of a metapopulation (often referred to as the metapopulation “footprint” [*e.g.* Launer and Murphy 1994]) to conserve landscape-level habitat integrity. 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 Quino checkerspot 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. 2001; D. Faulkner and K. Williams, pers. comm.). The Lake Hodges and Dictionary Hill butterfly population sites were within 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 areas of development and habitat or by costly perpetual management to control human traffic, prevent repeated nonnative species invasions, and other measures such as augmentation of butterfly populations.

Spatially clustered Quino checkerspot butterfly observations are called occurrence complexes in this recovery plan; the largest ones (in area or number of reported individuals) are termed "core occurrence complexes". Occurrence complexes represent current short-term documented local occupancy, probably within the greater distribution of extant metapopulations. Occurrence complexes are mapped using 1-kilometer (0.6-mile) movement radii. This distance delineates the area within which we would expect to find the habitat associated with the observed butterfly (Gilbert and Singer 1973, Harrison *et al.* 1988, Harrison 1989). Occurrences within 2 kilometers (1.2 miles) of each other are considered to be part of the same occurrence complex because such observations are proximal enough that the observed butterflies are likely to have come from the same population (Ehrlich and Murphy 1987, Harrison *et al.* 1988, Harrison 1989). Population distributions (not yet fully described) may include more than one occurrence complex and metapopulation distributions are likely to be greater than the distribution of most occurrence complexes. Core occurrence complexes may represent current population density centers. Further research is required to determine the specific population distributions required for resilience. The distribution of the Quino checkerspot butterfly across its range is described in more detail below, organized geographically by habitat regions based on unique components of habitat suitability essential to Quino checkerspot butterfly protection and recovery. Habitat considerations described in this section are largely drawn from the personal observations of the authors, and examination of GIS data and aerial photography.

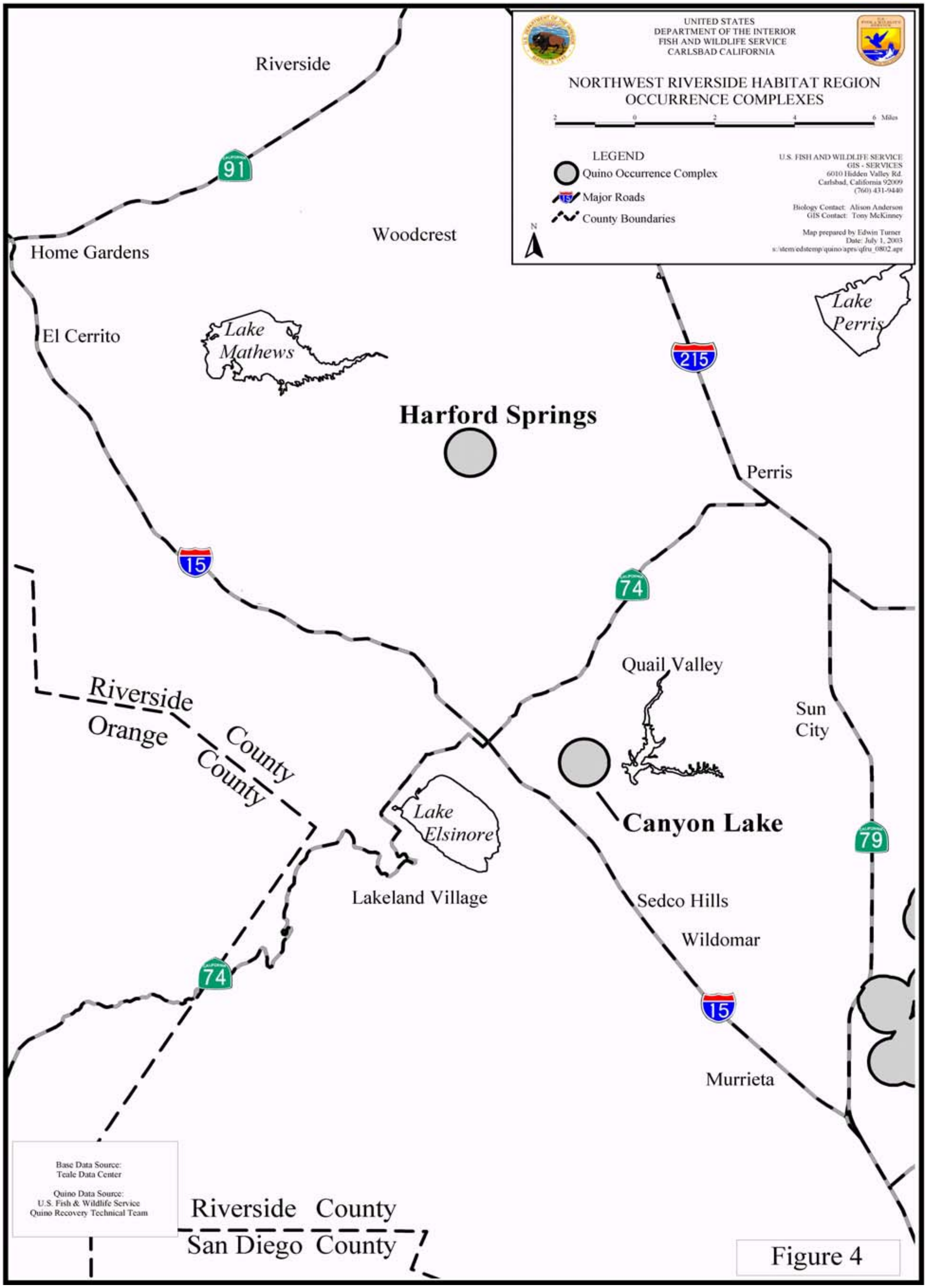
1. <u>Northwest Riverside County Habitat Region</u>

Harford Springs and Canyon Lake Occurrence Complexes, and Lake Mathews population site (Figure 4):

One Quino checkerspot butterfly larva was observed in Harford Springs County Park, Riverside County, in 1998. This site was once part of a more extensive, well documented distribution south and east of Lake Matthews, Riverside County (Figure 2). Adult Quino checkerspot butterflies were last observed south of Lake Mathews in 1985 (Figure 2). The Quino checkerspot butterfly was historically abundant in this “Gavilan Hills” area, with consistently high densities reported from the Harford Springs area (called “Lilly Hill”) by collectors from the 1950's to the mid-1980's (Orsak 1978; K. Osborne and G. Pratt, pers. comm. 2000). Other recent Quino checkerspot butterfly observations were reported at two sites near the intersection of Clinton Keith Road and Interstate 15 (Figure 2), however, these habitat areas were highly degraded and considered to be isolated, and were subsequently authorized for development. In 2002, a Quino checkerspot butterfly was observed just north of the intersection of Interstate 15 and Railroad Canyon Road (Canyon Lake Occurrence Complex, Figure 4). This observation confirms continued occupancy of habitats in the vicinity of Lake Elsinore and Canyon Lake, as suggested by 1980's observations north of Lake Elsinore (Figure 2).

Habitat Considerations:

This habitat region is generally located in northwestern Riverside County, west of Interstate 215, and south of Lake Mathews. These habitats typically support abundant *Plantago erecta* on exposed soil patches. Currently and formerly occupied sites exhibit diverse vegetation types, remnant forbland, grassland, coastal sage scrub, and open juniper woodlands. Quino checkerspot butterfly occupancy is often associated with clay soils in this region, but cryptogamic crusts have become rare. *Plantago erecta* is the primary host plant found in this region, but there are some *Antirrhinum coulterianum* records as well (Thompson 1988).



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FISH AND WILDLIFE SERVICE
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U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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Quail Valley
Sun City
Riverside County
Orange County
Lake Elsinore
Canyon Lake
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Lakeland Village
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Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Riverside County
San Diego County

Figure 4

The Gavilan Hills area south and east of Lake Mathews is characterized by high-quality habitat patches with dense, extensive stands of *Plantago erecta* in juniper woodland, coastal sage scrub, and grassland. Landscape connectivity still exists between Harford Springs County Park and Lake Mathews, and apparently suitable habitat containing dense stands of *P. erecta* 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 (A. Anderson, pers. observ. 2001). 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. 2000). Possibly suitable habitat and abundant host plants are found in coastal sage scrub and remnant forblands in the vicinity of Canyon Lake, particularly on Bureau of Land Management-administered lands to the north (Kabien Park and environs) (G. Pratt, pers. comm. 2000, A. Anderson, pers. observ. 2001).

Although much habitat remains in the region that appears to still be suitable, degradation of the most well-document historic sites was evident. Observations in 2001 of formerly suitable habitat revealed pervasive habitat degradation problems at the historic collection site known as Lily Hill adjacent to Harford Springs Park. This area is privately owned. Observations of Lilly Hill from Gavilan Road and from Harford Springs Park (where larvae were observed in 1997) in 2001 revealed high levels of disturbance, indicative of recent off-road-vehicle use and possibly discing. There was also a considerable amount of refuse dumping that had occurred in the surrounding juniper woodlands. Scattered *Zigadenus fremontii* plants could still be observed from a distance, but based on current habitat conditions, it is unlikely that Quino checkerspot butterfly populations remain in the vicinity of Lily Hill, outside of Harford Springs Park (A. Anderson, K. Cleary-Rose, pers. observ. 2001). Type conversion of native habitat to exotic grassland at historic collection sites was observed within the Lake Mathews Population Site, just south of the western end of Lake Matthews. Type conversion appeared to be primarily a result of past grading activity (A. Anderson, pers. observ. 2001, K. Osborne, pers comm. 2001). Despite the degraded habitat conditions described above, these sites may still be restored.

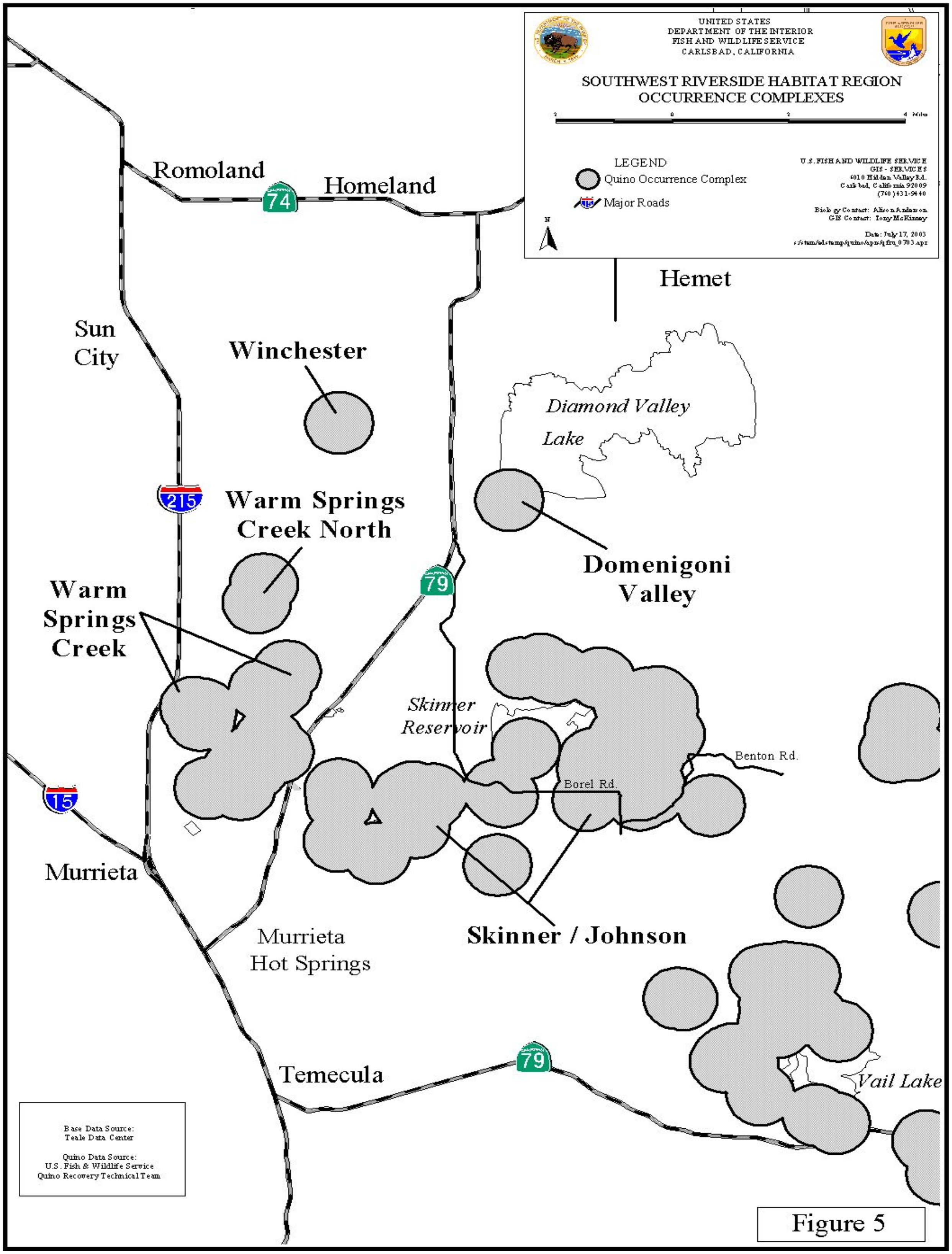
2. <u>Southwest Riverside County Habitat Region</u>

Warm Springs Creek (core), Warm Springs Creek North, Winchester, Domenigoni Valley, and Skinner/Johnson (core) Occurrence Complexes (Figure 5):

Recent Quino checkerspot butterfly observations west of State Route 79 are distributed between Interstate 215 and State Route 79 north of Murrieta Hot Springs Road to Diamond Valley, concentrated in the vicinity of Warm Springs Creek (Figure 2). Habitat in the Murrieta area, at the southeastern end of the Hogbacks, where butterflies were recently observed, was disced in 1998, but was still occupied in 1999 (M. Couffer pers. comm 1999). Recent Quino checkerspot butterfly observations east of State Route 79 are distributed throughout the Southwest Riverside County Multiple Species Reserve, and are concentrated around Lake Skinner and south of Benton and Borel Roads (Figure 5). Quino checkerspot butterflies have also recently been observed in the eastern portion of the City of Temecula, north and south of State Route 79, and in the hills southwest of the town of Winchester (Figure 2). In 2001, a new observation was reported southeast of Lake Skinner, extending the Skinner/Johnson Occurrence Complex east toward the Black Hills (Figure 5). A second observation in 2001 also resulted in identification of the Domenigoni Valley Occurrence Complex north of Bachelor Mountain, near the southwestern margin of Diamond Valley Reservoir (Figure 5). Most Quino checkerspot butterfly records in this region occur below 610 meters (2,000 feet) in elevation.

Habitat Considerations:

This habitat region is generally located in western Riverside County east of Interstate 215 to about 760 meters (2,500 feet) in elevation, between the town of Winchester and the City of Temecula. Quino checkerspot butterfly populations in this region are most commonly, but not exclusively, associated with low rounded hills and gentle south-facing slopes. Openings in grassland, remnant forblands, and coastal sage scrub provide habitat for the butterfly throughout most of the region. These habitats typically support scattered shrubs and abundant *Plantago erecta* on exposed clay soil patches. *P. erecta* is the primary host plant found in this region, but there are some *Antirrhinum coulterianum*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Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Date: July 17, 2003
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Diamond Valley Lake
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Warm Springs Creek North
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Skinner Reservoir
Benton Rd.
Borel Rd.
15
Murrieta
Murrieta Hot Springs
Skinner / Johnson
79
Temecula
Vail Lake
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

Figure 5

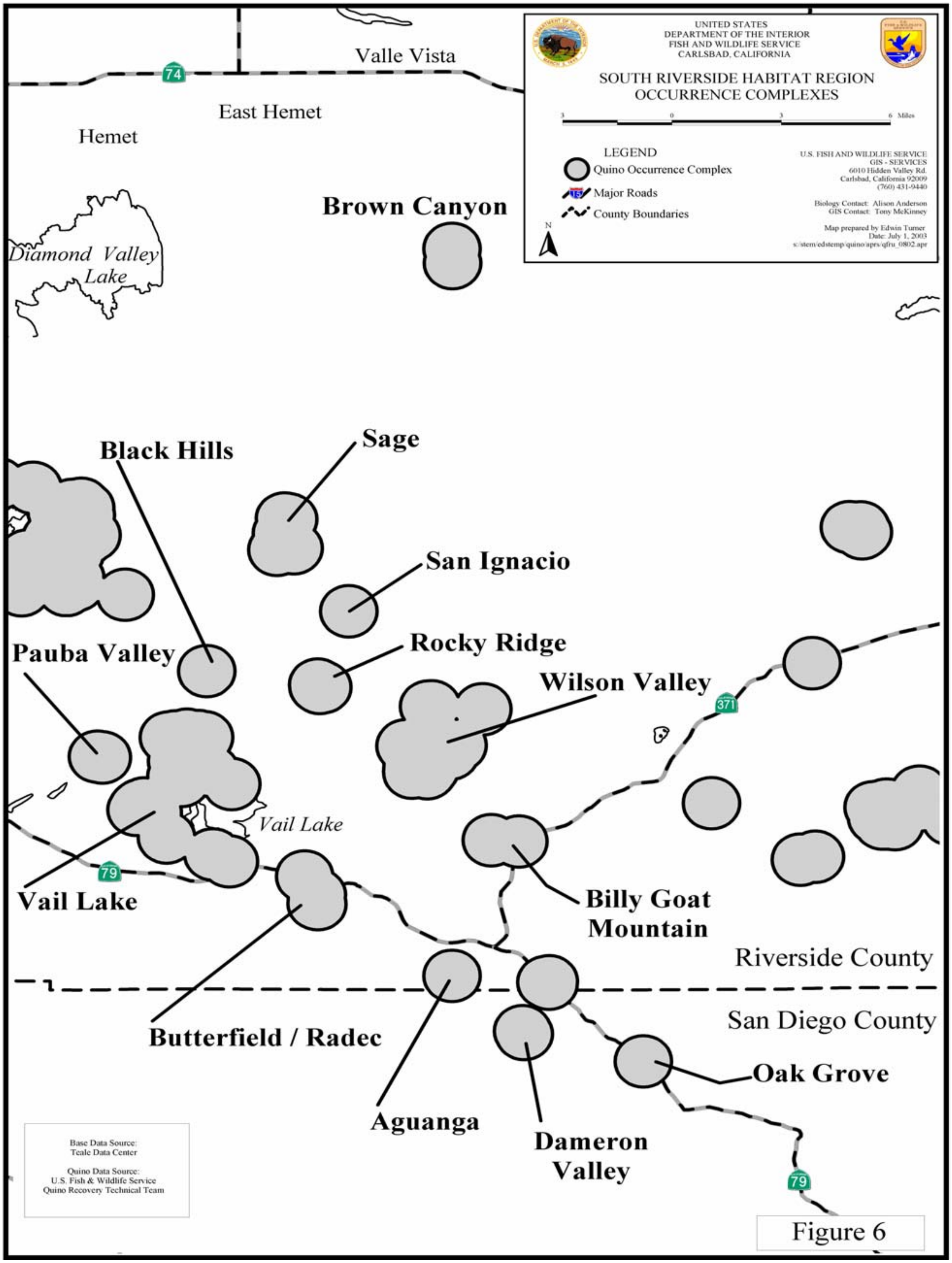
records in the region as well (Thompson 1988). In habitat surrounding Lake Skinner (Osborne 1999), dense stands of *P. erecta* and scattered *Eriogonum fasciculatum* occur on red clay lenses, surrounded by dense stands of nonnative brome and oat grasses. Habitat supporting larval development also occurs in natural inclusions in areas of encroaching development and recently or currently active agricultural land (*e.g.* Johnson Ranch).

Landscape and habitat connectivity is fragmented by agriculture and ongoing development throughout this region, with the exception of the Southwest Riverside County Multiple Species (Shipley) Reserve area. Any landscape connectivity that may have existed in the vicinity of the City of Temecula, south of the described habitat complexes (*e.g.* Crowne Hill; Figure 2) and north of Scott Road in the French Valley area has been highly compromised. Habitat in those areas is not considered important for recovery. Landscape connectivity between the Warm Springs Creek and Skinner/Johnson Occurrence Complexes has been compromised by State Route 79 and associated development. Landscape connectivity between the Skinner/Johnson and Warm Springs Creek Occurrence Complexes may need to be enhanced or artificially accomplished by ongoing butterfly augmentation efforts in order to maintain a resilient western Riverside County population of the butterfly.

<u>3. South Riverside County Habitat Region</u>

Pauba Valley, Black Hills, Vail Lake (core), Sage (core), Brown Canyon, San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Billy Goat Mountain, Aguanga, Dameron Valley, and Oak Grove Occurrence Complexes (Figure 6):

Recent Quino checkerspot butterfly observations are scattered throughout the lower elevation areas between the northeastern slope of Palomar Mountain, and the town of Hemet (Figure 6). Observations are concentrated in the Oak Mountain (a historic collection site), Vail Lake, and Wilson Valley areas. New observations were reported in 2001 and 2003 south of State Route 78 on the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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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Valle Vista
74
East Hemet
Hemet
Brown Canyon
Diamond Valley Lake
Black Hills
Sage
San Ignacio
Pauba Valley
Rocky Ridge
Wilson Valley
371
Vail Lake
79
Vail Lake
Billy Goat Mountain
Riverside County
San Diego County
Butterfield / Radec
Oak Grove
Aguanga
Dameron Valley
79
Base Data Source:
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Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Figure 6

northern slope of Palomar Mountain, resulting in identification of the Butterfield/Radec and Aguanga Occurrence Complexes (Figure 6). Two occurrence complexes are found in San Diego County, one in northern Dameron Valley south of State Route 79, and one farther south in Oak Grove Valley (Figure 6). In 2001, two Quino checkerspot butterfly observations were made on the Highpoint Fuelbreak above Dameron Valley, confirming continued occupancy on the northern slope of Palomar Mountain and expanding the Dameron Valley Occurrence Complex. One possibly isolated occurrence complex (Brown Canyon) is found southeast of the town of Hemet (Figure 6).

Habitat Considerations:

This habitat region is generally located between the northeastern slope of Palomar Mountain (south of State Route 79) and the town of Hemet (south of State Route 74). In this region, Quino checkerspot butterflies are generally associated with gentle south-facing slopes. Habitat primarily occurs in coastal sage scrub openings. Clay soils in the west transition into granitic soils in the east (U.S. Fish and Wildlife Service 1997). *Plantago erecta* and *P. patagonica* are the primary host plants found in this region, but there are some *Antirrhinum coulterianum* (Thompson 1988) and *Cordylanthus rigidus* (Chuang and Heckard 1986) records from this region as well. Landscape connectivity between occurrence complexes is generally good, but destruction of occupied habitat in the Vail Lake and Wilson Valley Occurrence Complexes by off-road vehicles and refuse dumping has reached a critical level (G. Pratt, pers. comm. 2001). Oak Grove Valley is highly invaded by nonnative grasses and is actively grazed at lower elevations, but much habitat appears to remain on the hills. Lands surrounding Oak Grove Valley remain relatively undeveloped, including Chihuahua Valley to the east.

Although it may be somewhat isolated from other occupied habitat, the Brown Canyon Occurrence Complex is nevertheless considered to be important for the species' recovery. The Brown Canyon Occurrence Complex is the northeastern-most complex within the current range of the butterfly, and is contiguous with the last remaining possible landscape connectivity to the northern portion of its former range. Further, the Brown Canyon Occurrence Complex has apparently been insulated from habitat impacts associated with development and recreational activities due to adjacent forested, mountainous terrain and publicly owned lands.

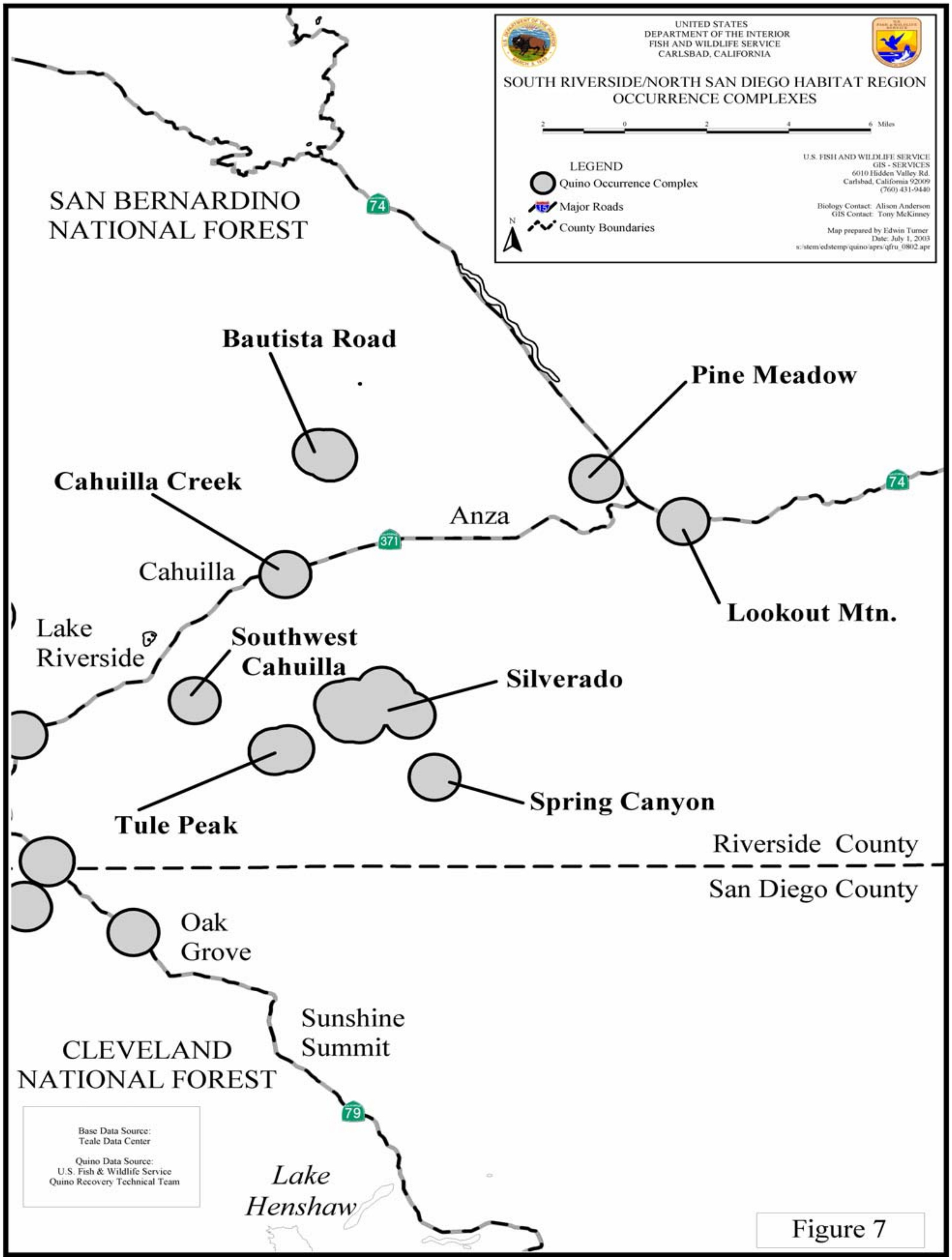
4. South Riverside/North San Diego County Habitat Region:

Southwest Cahuilla, Tule Peak (core), Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain Occurrence Complexes (Figure 7):

Recent Quino checkerspot butterfly observations are concentrated along the southern border of the Cahuilla Indian Reservation in the Tule Peak and Silverado Occurrence Complexes (Figure 7). Survey efforts in 2001 resulted in addition of the Tule Peak and the Bautista Road Occurrence Complexes (Figure 7). The Spring Canyon Occurrence Complex is located at the north end of Iron Springs Canyon (Figure 7). In 2002 and 2003, Quino checkerspot butterflies were observed just above 1,520 meters (5,000 feet) in elevation south of Garner Valley near the intersection of State Route 371 and State Route 74 (Pine Meadow and Lookout Mountain Occurrence Complexes; Figure 7). In 2003 a Quino checkerspot butterfly was observed in the parking lot of the Cahuilla Creek Casino that must have come from habitat in the surrounding area, resulting in identification of the Cahuilla Creek occurrence complex. Most Quino checkerspot butterfly records in this region occur between 1,220 and 1,520 meters (4,000 to 5,000 feet) in elevation.

Habitat Considerations:

This habitat region is generally located from 1,070 to 1,520 meters (3,500 to 5,000 feet) elevation between the southeast slope of Palomar Mountain and the desert's edge. Habitat primarily occurs on granitic soils in scrub and open areas within red shank chaparral. The eastern sites extend to above 1,220 meters (4,000 feet) in elevation, where known larval habitat is characterized by low ridges and broad washes lacking a clay soil component. Rainfall in the Silverado Occurrence Complex is higher than at any of the other known Quino checkerspot butterfly sites (G. Pratt unpubl. data), averaging approximately 50 centimeters (20 inches) per year (Oregon Climate Service 1995). *Antirrhinum coulterianum* and *Plantago patagonica* are the primary host plants found at the higher elevations in this region in Riverside County (G. Pratt 2001), but there are also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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
SAN BERNARDINO
NATIONAL FOREST
74
Bautista Road
Pine Meadow
Cahuilla Creek
Anza
371
Cahuilla
Lookout Mtn.
Lake
Riverside
Southwest
Cahuilla
Silverado
Spring Canyon
Tule Peak
Riverside County
San Diego County
Oak
Grove
Sunshine
Summit
CLEVELAND
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79
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U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Lake
Henshaw
Figure 7

Cordylanthus rigidus records (Chuang and Heckard 1986). *Plantago patagonica*, *A. coulterianum* (Thompson 1988), and *C. rigidus*, are found in San Diego County habitats (A. Anderson pers. observ.).

Habitat patches appear to be well connected, except where lands have been developed north and west of the Cahuilla Tribal trust lands. Much of the Silverado Occurrence Complex is relatively well protected, but ongoing habitat destruction in the Southwest Cahuilla Occurrence Complex (and designated critical habitat) of least three sites estimated to be between 10-50 acres each in size was documented in 2003 (A. Anderson, pers. observ.). Most known occupied habitat areas are owned by the Bureau of Land Management, the San Bernardino National Forest, and Gregg Reeden (owner of the Silverado Ranch Pre-approved Mitigation Area), with portions of the occurrence complexes overlapping the Cahuilla Tribal trust lands. Surveyors expressed concern regarding habitat destruction by off-road vehicles in 2001 within the Tule Peak Habitat Complex (S. Reed, pers. comm. 2001). Landscape connectivity probably exists between the occurrence complexes in both San Diego and Riverside Counties, and between complexes in Riverside County through undeveloped lands east of the Cahuilla Tribal trust lands. Apparently suitable habitat has been observed in the southern portion of the region along Lost Valley Road, just north of State Route 79 near Warner Springs (Pratt 1999). The Lost Valley Road habitat appeared to be coastal sage scrub vegetation created by human clearing of chaparral along the roadside (A. Anderson, pers. observ.). The valley east of Lake Henshaw (San Jose Del Valle; currently leased rangeland), contains a large expanse of nonnative grassland with inclusions of scattered, diminutive *Eriogonum fasciculatum* shrubs and abundant *Plantago patagonica* host plants (A. Anderson pers. observ. 2001, K. Winter, pers. comm. 2001).

Experts who have done extensive work with the Quino checkerspot butterfly in San Diego County (G. Pratt and K. Osborne, pers. comm 2002) believe that the unique habitat in this habitat region may support the most stable (not just resilient) populations in the county. Apparent population stability may be attributable to a combination of high rainfall that mitigates drought conditions, the predominant use of a host plant (*Antirrhinum coulterianum*) that always persists long enough to support larvae to diapause when present, and other unique habitat characteristics. The habitat in this region is not typical for *A. coulterianum* either; throughout much of its range *A. coulterianum* grows in more closed-canopy vegetation (Thompson 1988), a situation that is not as conducive to larval development as the relatively open woody canopy found in occupied Quino checkerspot butterfly habitat near Anza.

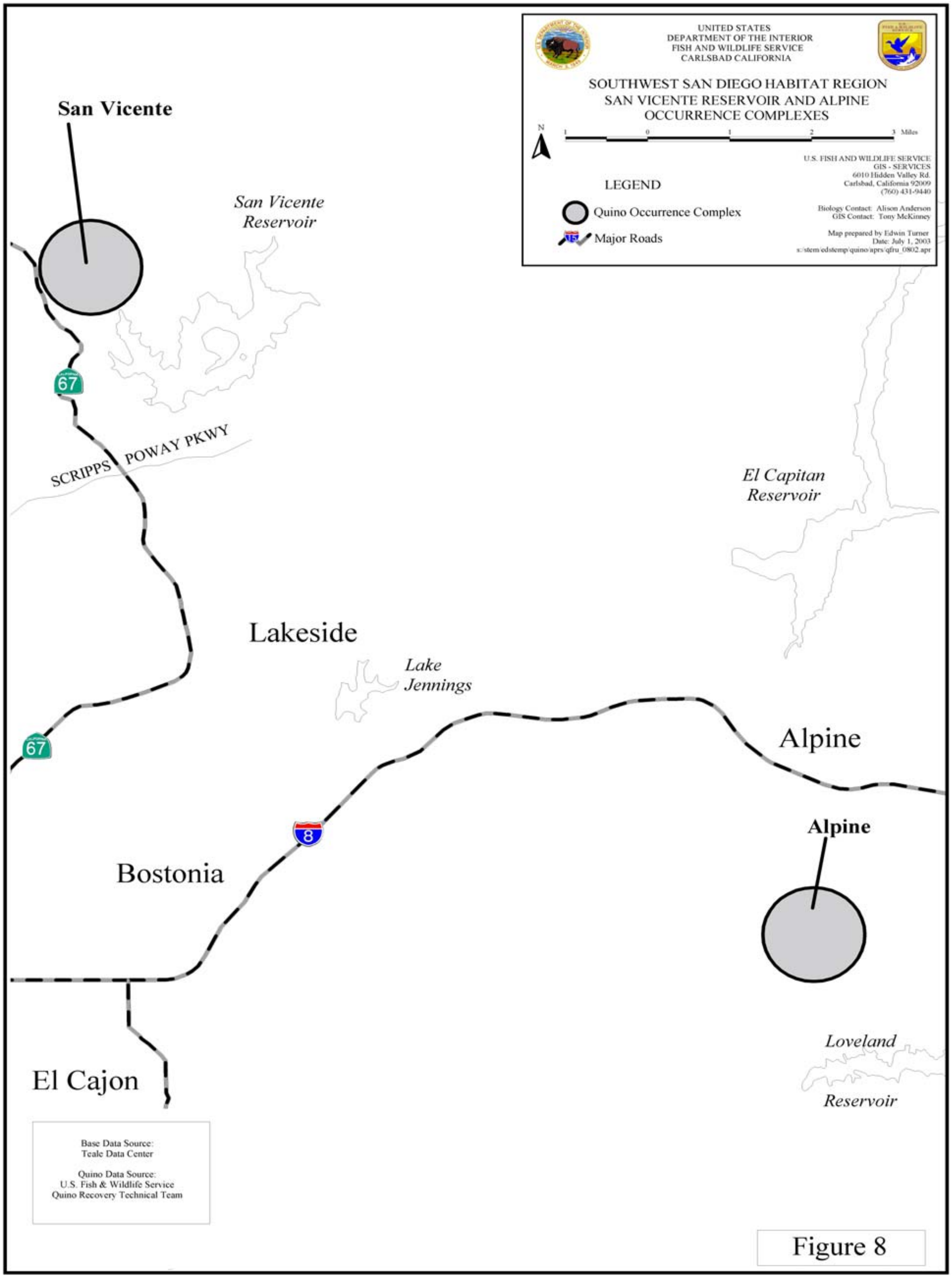
Because of the apparent stability, populations in this region may be important as a source of immigrants to the South Riverside habitat region. As demonstrated by the apparent timing of the 2003 Quino checkerspot butterfly flight seasons in Riverside County, in some years the higher elevation flight seasons can be relatively synchronized with those of lower elevations (U.S. Fish and Wildlife Service 2003; http://carlsbad.fws.gov/Rules/QuinoDocuments/Quino_htms /Flight_Info_2003.htm), making it possible for immigrants from higher elevations to colonize lower elevation sites. In fact, the drought season of 2002 appears to have almost extirpated the Lake Skinner population (only four butterflies were observed where they are normally abundant), indicating that following prolonged drought, recolonization of lower elevation sites by individuals from higher elevation populations may be necessary.

5. Southwest San Diego Habitat Region

Northern Occurrences; San Vicente Reservoir and Alpine Occurrence Complexes (Figure 8):

During the 2001 flight season, two Quino checkerspot butterflies were reported from the hills north of San Vicente Reservoir (Sproul and Faulkner 2001). Documentation included several distinct photographs. There is also evidence of prior occupancy in the hills north of San Vicente Reservoir in 1992, and more evidence of recent occupancy in Sycamore Canyon Open Space Preserve west of State Route 67 (Appendix V). During the 2003 flight season two Quino checkerspot butterflies were also reported just south of currently developed land in the vicinity of the community of Alpine (Lee 2003).

Southern Occurrences; West Otay Mesa, Otay Valley (core), West Otay Mountain (core), Otay Lakes/Rancho Jamul (core), Proctor Valley, Jamul, Hidden Valley, Rancho San Diego, Los Montañas, Honey Springs, Dulzura, Marron Valley (core), Barrett Junction, and Tecate Occurrence Complexes (Figure 9):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Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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San Vicente
San Vicente Reservoir
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El Capitan Reservoir
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Lake Jennings
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Loveland Reservoir
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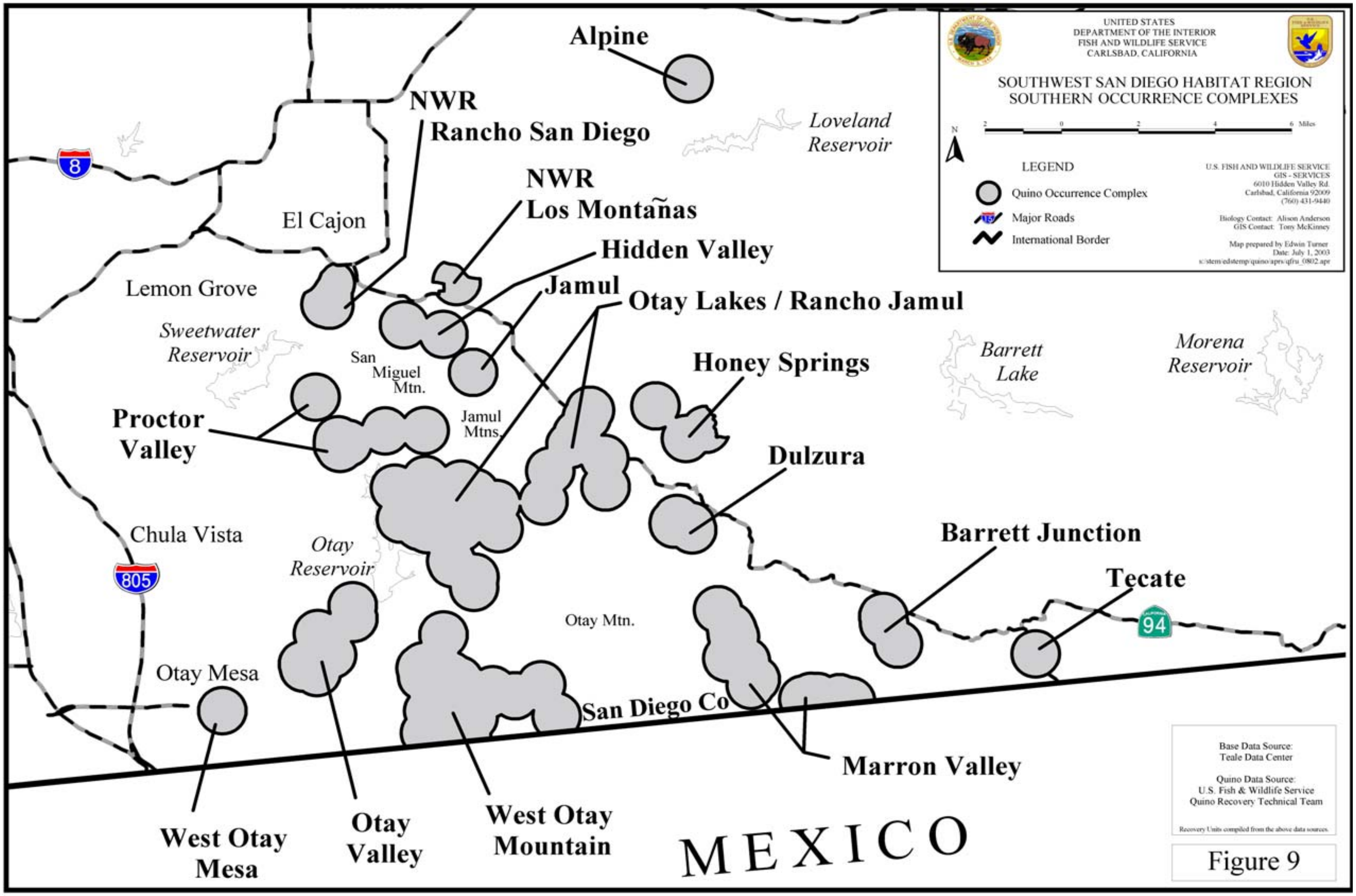
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

Figure 8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Date: July 1, 2003
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Alpine
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Rancho San Diego
Loveland
Reservoir
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NWR
Los Montañas
El Cajon
Hidden Valley
Jamul
Otay Lakes / Rancho Jamul
Lemon Grove
Sweetwater
Reservoir
San
Miguel
Mtn.
Honey Springs
Barrett
Lake
Morena
Reservoir
Proctor
Valley
Jamul
Mtns.
Dulzura
Chula Vista
Otay
Reservoir
805
Barrett Junction
Tecate
94
Otay Mtn.
Otay Mesa
San Diego Co
Marron Valley
West Otay
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Valley
West Otay
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Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 9

Recent Quino checkerspot butterfly observations in southwestern San Diego County are concentrated in lower elevation areas surrounding east Otay Valley, Otay Mountain, the Jamul Mountains, and San Miguel Mountain. The Otay Lakes area historically supported large, high density local populations (White and Levin 1980, Murphy and White 1984). Historic population distributions extended across Otay Mesa, with high densities reported from the vicinity of Brown Field (Murphy and White 1984). A Quino checkerspot butterfly was observed in 2001 in a vernal pool habitat restoration project on the mesa top between Dennery and Spring Canyons, resulting in identification of the West Otay Mesa Occurrence Complex. Other 2001 observations resulted in delineating a western extension of the Otay Lakes/Rancho Jamul Occurrence Complex, and identification of the Los Montañas, Hidden Valley, Jamul, and Dulzura Occurrence Complexes. The Rancho San Diego and Los Montañas Occurrence Complexes are on the Otay/Sweetwater Unit of the San Diego National Wildlife Refuge. Recent Quino checkerspot butterfly observations east of Otay Mountain are concentrated on the eastern slope of Otay Mountain and ridgelines along the international border in the vicinity of Marron Valley (Figure 9). Two other recent records of the butterfly are located east of Otay Mountain, one near Barrett Junction, and another near the town of Tecate (Figure 9). Observations reported in 2003 resulted in identification of the Honey Springs Occurrence Complex (Figure 9). Occupancy extends across the international border south of Otay Mountain (D. Murphy and M. Dodero, pers. comm. 2001). It is possible that the West Otay Mountain and Marron Valley Occurrence Complexes belong to a metapopulation dependent on local mainland or "source" populations in Mexico (C. Parmesan, pers. comm. 2001).

Habitat Considerations:

This habitat region is generally located in southwestern San Diego County, and includes recently discovered occurrences in the vicinity of Alpine and San Vicente Reservoir (Figure 8), as well as several southern occurrence complexes in the vicinity of Otay Mountain (Figure 9). This region contains the only vernal pool/mima mound mesa habitat characteristic of historic Quino checkerspot butterfly population centers that remains within the current distribution of the butterfly. The Otay Mesa habitat containing the vernal pools also is the only known occupied habitat with a marine climate influence. Marine climate influence was prevalent throughout most of the species' historic range and is thought to be beneficial to population resilience because it provides climatic stability and higher average humidity, minimizing host plant susceptibility to drought. Soils contain both granitic and clay components. *Plantago erecta* is the most abundant host plant found in this area, but *Castilleja exserta* is also present within most of the occurrence complexes (A. Anderson, pers. observ.), and *Antirrhinum coulterianum* has been collected just north of State Route 94 (Thompson 1988).

Landscape connectivity remains relatively intact in the vicinity of the San Vicente Reservoir Occurrence Complex, except where it is compromised by ongoing development associated with the City of Poway and the town of Ramona. Landscape connectivity with potentially occupied habitat to the west is slightly compromised by increasing traffic load on State Route 67. Large areas of habitat in the vicinity have been conserved, including the San Vicente Occurrence Complex, the City of Poway's Iron Mountain Open Space Preserve to the north, and the County of San Diego's Sycamore Canyon Open Space Preserve to the west. Ecological connectivity (lands in a natural state), and possibly landscape connectivity (intervening habitat patches) extend west and south into Marine Corps Air Station Miramar and the City of San Diego's Mission Trails Regional Park. It is also probable that landscape connectivity extends east of the occurrence complex (G. Pratt, pers. comm. 2001), providing the only possibility for connectivity with the Alpine occurrence complex and southern occurrence complexes.

Landscape connectivity between the southern occurrence complexes appears to be mostly intact. In addition, some degree of landscape connectivity apparently exists south of Otay Mountain in Baja California, Mexico, between the west Otay Mountain and Marron Valley Occurrence Complexes. A combination of the regional distribution of occurrence complexes (Figure 9), historic records and accounts (Figure 2; Murphy and White 1984), and geographic features suggests that habitat in the Otay Lakes area is a regional keystone with regards to Quino checkerspot butterfly landscape connectivity. If hilly or mountainous terrain reduce the ability of *Euphydryas editha* to locate and colonize habitat patches (Harrison 1989) and support less suitable habitat than lower elevation areas; and if development (including agriculture) also compromises landscape connectivity, then the Otay Lakes/Rancho Jamul Occurrence Complex is not only a documented historic population center (Murphy and White 1984), but a confluence of landscape connectivity for all populations in the Southwest Habitat Region (Figure 9). Landscape connectivity is severed by development at the western periphery of these occurrence complexes (no habitat to connect to, ongoing development), and is compromised by ongoing development and agriculture in the vicinity of the town of Jamul. Landscape connectivity appears to be constrained between some occurrence complexes by intervening hills and mountains, primarily Otay Mountain, San Miguel Mountain, and the Jamul Mountains. Landscape connectivity to the Alpine Occurrence Complex appears to be least constrained by vegetation and other less suitable habitat characteristics in the area northeast of Honey Springs and Rancho Jamul, but may be intact directly north of Rancho Jamul.

6. Southeast San Diego Habitat Region

Jacumba Occurrence Complex (Figure 10):

Recent Quino checkerspot butterfly observations are concentrated northwest of the town of Jacumba (Figure 10), in the vicinity of Jacumba Peak, and within the Anza Borrego Desert State Park boundary south of Interstate 8. The Jacumba Occurrence Complex and occupied habitat in El Condor in Baja California, Mexico, are about 6 kilometers (4 miles) apart. One historic Quino checkerspot butterfly record from 1947 occurs north of Interstate 8 within the Bureau of Land Management Table Mountain National Cooperative Land and Wildlife Management Area.

Habitat Considerations:

This habitat region is located in the high-desert transition area between the Anza Borrego Desert and the international border. The habitats in this region are composed primarily, but not exclusively, of dark brown clay lenses and adjoining sandy, rockier areas on gentle north-facing slopes. Occupied habitat is found in open juniper woodlands. Barren soils in more exposed areas (*i.e.,* without woodland vegetation) do not support host plants. The vegetation in this area is a diverse mixture of desert and coastal slope communities. *Plantago erecta* and *P. patagonica* are the primary host plants found in the area, and both occur together in the occupied habitat below Jacumba Peak (A. Anderson pers.

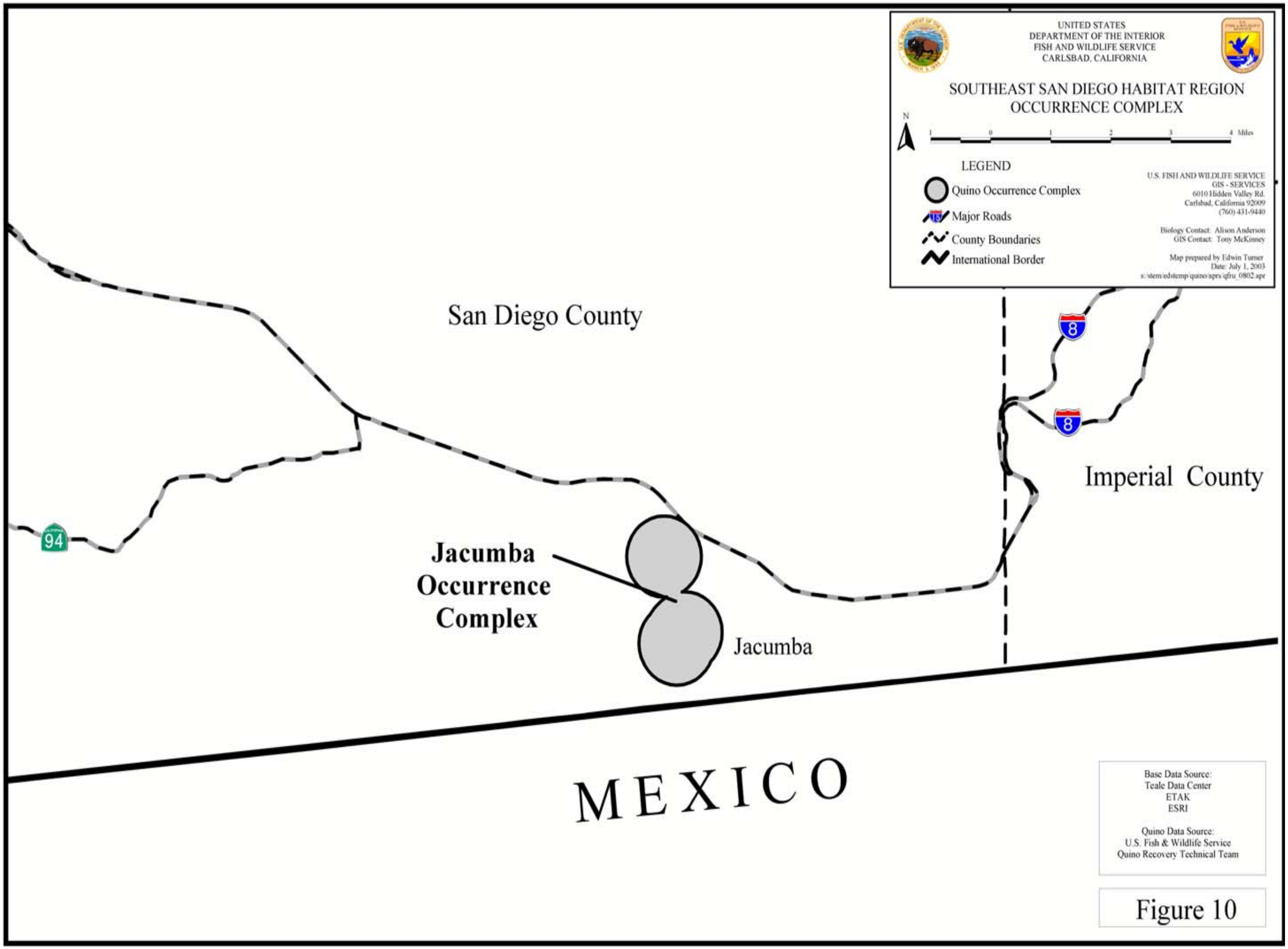

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Figure 10

observ.). Habitat in the Jacumba area has not been heavily invaded by nonnative plants, and these resident Quino checkerspot butterfly populations may be the only ones that will not require extensive management to reduce or prevent degradation due to nonnative plant invasion (G. Pratt, pers. comm. 1999). Habitat and landscape connectivity in the Jacumba area are relatively intact, with limited fragmentation occurring near Jacumba Peak (A. Anderson, pers. observ. 2001). Landscape connectivity between apparently suitable habitat in the Table Mountain area and the Jacumba Occurrence Complex has been compromised by Interstate 8, and appears to be constrained by intervening hills and ridges composed primarily of boulders and large rock outcrops (A. Anderson, pers. observ. 2001).

Although degraded by grazing in some areas, apparently suitable habitat also exists northwest of Jacumba in the vicinity of McCain Valley (M. Dodero, pers. comm. 2000). Connectivity likely exists between the Jacumba Occurrence Complex, the Table Mountain area, and occupied habitat in El Condor in Baja California, Mexico.

7. Baja California, Mexico:

All populations of the Quino checkerspot butterfly near the ocean in Baja California, Mexico, appear to have been extirpated by urban development. Many sites farther inland, however, appear to support excellent habitat and dense populations, including a semi-pristine site discovered in 2001, south of Otay Mountain (M. Dodero, D. Murphy, pers. comm. 2001). Unlike most California populations, which probably occur in marginal habitat on the periphery of historic metapopulation centers, most of the extant Baja California, Mexico, populations occur in apparently high-quality habitat.

The newly discovered population area south of Otay Mountain appears to be connected to both the Marron Valley and West Otay Mountain Occurrence Complexes, although more research is required to determine the extent of connectivity. There is one population south of El Testerazo along Highway 3. A population also exists at Mesa Redonda (also known as Table Mountain) just east of the city of Rosarita. Another population in Valle de Trinidad was known as "Los Aguajitos" in museum records, but the area is now called "Los Positos." The three southernmost Quino checkerspot butterfly population sites south of the

West Otay Mountain and Marron Occurrence Complexes are distant from each other and are probably independent populations. A population also exists south of the Jacumba area, about 6 kilometers (4 miles) south of the town of El Condor, and may be connected to the Jacumba Occurrence Complex.

E. Reasons for Decline and Current Threats

The Quino checkerspot butterfly is threatened primarily by urban and agricultural development, invasion by nonnative species, off-road vehicle use, grazing, and fire management practices (U.S. Fish and Wildlife Service 1997a). Other factors contributing to the species' population decline likely have been, and will continue to be, enhanced nitrogen deposition (Allen *et al.* 1998), elevated atmospheric carbon dioxide concentrations (Coviella and Trumble 1998), and climate change (Parmesan 1996, Field *et al.* 1999, Parmesan in press). Nonetheless, urban development poses the greatest threat and exacerbates other threats. As a result, careful planning that ensures maintenance of existing Quino checkerspot butterfly metapopulations will be the key to long-term conservation of the species. Any activity resulting in habitat fragmentation or removal of host or nectar plants from habitat reduces habitat quality and increases the probability of extinction of the Quino checkerspot butterfly.

When the Quino checkerspot butterfly was listed under the Endangered Species Act, predation and collecting were identified as possible threats (U.S. Fish and Wildlife Service 1997a). 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 butterfly laboratory colonies (G. Pratt, pers. comm.), and predation by imported Brazilian fire ants (*Solenopsis invicta*) is likely if they were to co-occur with the butterfly (Porter and Savignano 1990). Brazilian fire ants were discovered in 1998 in the vicinity of historic Quino checkerspot butterfly habitat in Orange County, and have subsequently been found in San Diego, Riverside, and Los Angeles Counties (California Department of Food and Agriculture 1999). Over-collection by hobbyists and dealers is also considered a threat (U.S. Fish and Wildlife Service 1997a, E. Hein *in litt.* 2003), although the current impact of this threat is unknown.

Unfortunately, our assessment in the draft recovery plan that "the species continues to decline throughout its range" (U.S. Fish and Wildlife Service 2001b) was not negated by the discovery of new occupied sites in Riverside and San Diego Counties during the 2001 flight season. Reports of habitat destruction and degradation at newly discovered Quino checkerspot butterfly sites frequently accompanied reports, and the same was true for many monitored reference sites. Threats most commonly reported were off-road vehicle damage, exotic plant invasions, and trash dumping (K. Osborne, G. Pratt, and S. Reed, E. Stanton, pers. comm.; A. Anderson, pers. observ.). These factors combine to result in type-conversion from native forbland and scrub habitat to chronically disturbed "dumps" dominated by nonnative plants such as *Bromus diandrus* (ripgut grass) and *B. tectorum* (cheat grass) (A. Anderson pers. observ.).

1. Loss and Fragmentation of Habitat and Landscape Connectivity

More than 90 percent of the Quino checkerspot butterfly'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 temporarily not supporting larval development will be recolonized is decreased as metapopulation distributions are reduced and habitat becomes more fragmented. Low population densities reduce dispersal rates and generally make metapopulations more vulnerable to extirpation. Small, isolated, or poorly connected 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 butterfly (Saccheri *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 of Quino checkerspot butterflies in the 1970's (Murphy and White 1984), the apparent rarity of this event, current low population numbers, and reduced population distributions decrease the probability that such natural, long-distance dispersal could reestablish occupancy in isolated habitat patches. Efforts need to be made to reestablish and maintain habitat and landscape connectivity within and between the recovery units.

2. Invasion by Nonnative Plants

Nonnative annual grasses and forbs have invaded Quino checkerspot butterfly habitat and dominate many areas throughout the range of the species, displacing native shrubs and forbs (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 *Plantago erecta*, which appears to be a poor competitor against nonnative grasses. In addition to displacing larval host plants, nonnative annuals have been replacing nectar plants, including dominant shrubs of coastal sage scrub, throughout the historic range of the butterfly (Freudenberger *et al.* 1984, Minnich and Dezzani 1998, Stylinski and Allen 1999).

The few existing experimental studies on *Plantago erecta* have been carried out in northern California on serpentine grassland. After early fall rains, *P. erecta* germinated later than a nonnative grass, *Bromus mollis* [=*B. hordeaceus*] (soft chess) (Gulmon 1992). Similarly, *P. erecta* decreased during years of high rainfall, correlated with high productivity of *B. mollis* (Hobbs and Mooney 1991). *Bromus mollis* was more competitive than *P. erecta* in greenhouse experiments (Koide *et al.* 1987), and nitrogen fertilization decreased the size and density of *P. erecta* (Koide *et al.* 1988). These studies indicate that weed competition will reduce the occurrence of *P. erecta* in exotic annual grassland. The most abundant nonnative plants include species of *Bromus* (brome grass), *Avena* (oat grass), *Hordeum* (foxtail barley), *Brassica* (mustard), and *Erodium* (red-stem filaree).

Conversion from native vegetation to nonnative annual grassland will be the greatest threat to Quino checkerspot butterfly reserves, based on observations of 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 butterfly food sources (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 butterfly populations do so indirectly by exacerbating nonnative invasion, as explained below. Methods for restoration and controlling invasive species are described in Appendix II.

3. Off-road Vehicle Activity

Quino checkerspot butterfly populations are threatened in many areas by frequent off-road vehicle use. The level of off-road vehicle damage and its effects on Quino checkerspot butterfly populations are increasing as the amount of available undeveloped land decreases. Off-road vehicle use compacts soil, destroys host plants, increases erosion and fire frequency, creates trails that are conduits of nonnative plant invasion (Frenkel 1970), and causes egg and larval mortality. Although off-road vehicles can destroy suitable habitat and damage butterfly populations, they can also temporarily create habitat if the traffic reduces canopy cover in unoccupied areas (Osborne and Redak 2000; G. Pratt, pers. comm.). However, continued disturbance of subsequently occupied habitat created by off-road vehicles is likely to create a mortality sink because the occurrence of Quino checkerspot butterfly larvae 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. 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 female Quino checkerspot butterflies were observed one spring was 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.). Off-road vehicle activity must be managed within the recovery units.

4. Grazing

The impacts of grazing on Quino checkerspot butterfly habitat vary depending on the species grazing and the timing, intensity, and duration of grazing. Generally, impacts include larval host plant destruction, soil compaction, cryptogamic crust degradation, and egg and larval trampling (M. Dodero, pers. comm.). Grazing by sheep and goats is more intensive than grazing by cattle, and apparently precludes Quino checkerspot butterfly survival.

Consumption of nonnative plants by domestic animals has been used as a tool to prevent further deterioration of already degraded bay checkerspot butterfly habitat restricted to serpentine soils. In the short term, cattle may reduce nonnative grass invasion rates in already degraded habitat through preferential grazing and enhanced nitrogen exportation (Weiss 1999). However, cryptogamic crusts, which inhibit invasion by nonnative plants, are also extremely vulnerable to trampling. Cattle have been observed to cause disturbance to cryptogamic crusts in Quino checkerspot butterfly habitat and increase initial rates of invasion by nonnative plants (M. Dodero, pers. comm.). Livestock have been found to contribute to nonnative plant invasion in the arid western United States by: a) transporting seeds into uninfested sites; b) preferentially grazing native plant species; c) creating bare, disturbed patches of soil and destroying crusts; d) increasing soil nitrogen concentration (if they are not managed to enhance exportation); e) reducing soil mycorrhizae; and f) accelerating soil erosion (Belsky and Gelbard 2000). Observations of coastal sage scrub in the Western Riverside County Multiple Species Reserve indicate native forbs were readily consumed if grazing occurred at the time of year when they were abundant and flowering (E. Allen, pers. comm.). Although studies are underway, it is doubtful that even carefully controlled grazing can effectively reduce nonnative plant invasion in the variety of habitats that harbor the Quino checkerspot butterfly as it has for bay checkerspot butterfly populations (Weiss 1999). Commercial grazing 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.). Experiments that control timing and intensity of grazing to control weeds in disturbed habitat outside of habitat patches are still warranted.

5. Fire

Increased fire frequency is a cause of native California plant community decline, and therefore a threat to Quino checkerspot butterfly 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 butterfly habitat depends on the intensity, frequency, and season of occurrence of fire and the size of the invasive nonnative seed bank (Mattoni *et al.* 1997). Given the restricted and fragmented Quino checkerspot butterfly distributions, and low population densities, even historic natural fire frequency could permanently extirpate local populations in 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, such is not the case where weed invasion follows fire. Also, dense populations of *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 the international border and southern Quino checkerspot butterfly populations. Frequent wildfires can be reduced by controlling exotic grasses, which are the major ignition fuel source. In addition, controlled burns over small areas should be implemented to avoid landscape-scale wildfires. Some controlled burn experiments should be conducted in Quino checkerspot butterfly habitat, to test the effects of such burns.

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 are 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, California, have more than 80 parts per million (weight) extractable nitrogen, a value more than four 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 butterfly habitat will continue, and may increase, in and near nitrogen polluted lands. Nitrogen deposition in coastal areas of southern California is less severe 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 butterfly populations in California. Restoration of N-eutrophied soils will depend upon future local reductions of nitrogen emissions. In the meantime, exotic grass productivity will continue to be high, and more extensive weed control will be necessary in most Quino checkerspot butterfly habitat.

7. Increasing Atmospheric Carbon Dioxide Concentration

Increasing atmospheric carbon dioxide gas concentration 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 increase plant growth and photosynthesis rates, increase leaf tissue (foliar) carbon to nitrogen ratio (C:N), and increase production of carbon-based defense compounds (IPCC 1996, Coviella and

Trumble 1999). Increased plant photosynthesis and biomass in chaparral (Oechel *et al.* 1995) and scrub communities will likely contribute to increased canopy closure and reduction of habitat favored by the Quino checkerspot butterfly. These 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 butterfly), feeding on *Plantago lanceolata* (English plantain, a co-occurring close relative of *P. erecta*), are particularly relevant. When the atmospheric carbon dioxide concentration was approximately doubled, effects included a 36 percent increase in larval mortality, increased development time, and decreased biomass (Fajer 1989; Fajer *et al.* 1989, 1991). Buckeye butterfly research results are generally consistent with those of other studies encompassing taxonomically diverse representatives of the order Lepidoptera, suggesting similarly negative effects may be experienced by Quino checkerspot butterflies. An extended development time in early instar prediapause larvae would increase the probability of mortality due to early host plant decline and predation (see section I.C.3, Climate Effects, and section I.E.8, Climate Change). Research into the effects of elevated carbon dioxide on the Quino checkerspot butterfly, in both the field and the laboratory, should be conducted. When the direct effects of elevated carbon dioxide on the Quino checkerspot butterfly are better understood, it will be possible to recommend appropriate adaptive management tools.

8. Climate Change

Evidence of local climate change and a corresponding change in the Quino checkerspot butterfly's range-wide distribution supports the conclusion that climate change is a substantial threat to the species' survival in the foreseeable future. A trend toward warming in the last century has been linked to elevated greenhouse gases globally (Karl *et al.* 1996, IPCC 1996, Easterling *et al.* 1997), and locally in southern California (Field *et al.* 1999, Environmental Protection Agency 2001). The National Academy of Sciences (2001) recently assessed the status of research on climate change within the scientific community, affirming the validity of climate change findings and warning of severe impacts to natural ecosystems if ignored. Regional warming is suspected to be contributing to the extirpation of populations of *Euphydryas editha*, with disproportional losses among Quino checkerspot butterfly populations (Parmesan 1996, Parmesan, in press). The suspicion is that drier winter-spring cycles have reduced host plant density and altered the critical timing of host plant availability.

Although concerns about a drier climate damaging butterfly populations may seem to contradict predictions of increased El Niño frequency, this is not the case. The El Niño phenomenon is a marine current change, often, but not always, accompanied by increased precipitation. 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 annual precipitation, warmer temperatures and increased evaporation rates could still cause habitats to be drier during the crucial late spring months, and host plants 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 20th century to their distribution from 1994 to 1996. She found the southernmost populations, including the Quino checkerspot butterflies, had the greatest number of disappearances (80 percent of previously known populations) while northernmost populations had the lowest (fewer than 20 percent). This skewed detection pattern indicates contraction of the southern boundary of the species' distribution by almost 160 kilometers (100 miles), and a shifting of the mean location of *Euphydryas editha* populations northward by 92 kilometers (57 miles); closely matching recent shifts in mean yearly temperature (Parmesan 1996). An explanation for the apparent pattern is that climate trends contributed to increased prediapause larval death due to early host plant aging at the southern range edge. Parmesan’s (1996) observations suggest that the Quino checkerspot butterfly may be at risk from the effects of ongoing regional warming and drying. 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 butterfly in that they are generally nonmigratory, fairly sedentary, host plant specialists.

In light of the recent warming and drying trends, prudent design of reserves and other managed habitats should include landscape connectivity to other habitat areas and ecological connectivity with undeveloped lands in order to accommodate range shifts northward and upward in elevation.

F. Current and Evolving Conservation Measures

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

Section 9 of the Endangered Species Act 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)(1)(B) of the Endangered Species Act allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity". Section 10(a)(2)(B) states that permitted take must “not appreciably reduce the likelihood of the survival and recovery of the species in the wild”. Under these sections, 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 of the project. The Quino checkerspot butterfly is currently addressed in three approved habitat conservation plans: the Orange County Central-Coastal Natural Community Conservation Plan (Central-Coastal NCCP) (described below), the Lake Mathews Habitat Conservation and Impact Mitigation Program, and the Assessment District 161 Subregional Habitat Conservation Plan, Western Riverside County. The Riverside County Assessment District 161 Subregional Habitat Conservation Plan includes a general program integrating Quino checkerspot butterfly habitat protection, habitat restoration research, educational outreach, and captive propagation (U.S. Fish and Wildlife Service 2000). Although it is not currently known from within the reserve boundaries, the Quino checkerspot butterfly is conditionally covered by the Lake Mathews Multiple Species Habitat Conservation Plan/Natural Community Conservation Plan. Several other plans that include measures to protect the Quino checkerspot butterfly are currently in development.

Section 7(a)(2) of the Endangered Species Act requires Federal agencies to consult with us 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 butterfly through reasonable and prudent measures that minimize the adverse effects of take of the species due to project impacts. For example, measures generated through formal section 7 consultation for State Route 125 South construction in the Otay Mesa area identified several activities to be undertaken, including habitat protection and restoration and a captive breeding program (U.S. Fish and Wildlife Service 1999). These activities are currently being implemented.

On April 15, 2002, we published the final designation of critical habitat for the Quino checkerspot butterfly (U.S. Fish and Wildlife Service 2002a), and it became effective May 15, 2002. Critical habitat is defined as specific areas that have been found to be essential to the conservation of the species and which may require special management considerations or protection. The primary constituent elements for Quino checkerspot butterfly occur in undeveloped areas that support various types of open-canopy woody and herbaceous plant communities. They include, but are not limited to, plant communities that provide populations of host plant and nectar sources for the Quino checkerspot butterfly. Specifically, primary constituent elements consist of:

(1) Grassland and open-canopy woody plant communities, such as coastal sage scrub, open red shank chaparral, and open juniper woodland, with host plants or nectar plants;

(2) Undeveloped areas containing grassland or open-canopy woody plant communities within and between habitat patches, utilized for Quino checkerspot butterfly mating, basking, and movement; or

(3) Prominent topographic features, such as hills and/or ridges, with an open woody or herbaceous canopy at the top. Prominence should be determined relative to other local topographic features.

With regards to designated critical habitat, section 7(a)(2) of the Endangered Species Act requires Federal agencies, including us, to ensure that actions they fund, authorize, or carry out do not destroy or adversely modify critical habitat to the extent that the action appreciably diminishes the value of the critical habitat for the survival and recovery of the species. Individuals, organizations, states, local governments, and other non-Federal entities are affected by the designation of critical habitat only if their actions occur on Federal lands, require a Federal permit, license or other authorization, or involve Federal funding.

1. Regional Planning

The San Diego Multiple Species Conservation Program (MSCP) and Multiple Habitat Conservation Program (MHCP) was initiated by local jurisdictions including the City of San Diego, County of San Diego, other cities, and private interests, and is being integrated as a component of California's Natural Community Conservation Plan Act. Implementation of the MSCP and MHCP will extend protection to many natural habitat communities in San Diego County. The Quino checkerspot butterfly is also a target species for the County of San Diego North Multiple Species Conservation Program, currently under development, which encompasses unincorporated lands east of the existing MHCP and north of the MSCP planning areas.

The MSCP 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. Goals of the MSCP include: conserving listed and sensitive species, conserving biodiversity in the MSCP Plan Area, and achieving certainty in the land development process. Each take authorization holder will prepare a framework management plan to provide general direction for all preserve management issues. We and the California Department of Fish and Game approved the overall MSCP and the City of San Diego's Subarea Plan in July 1997. The City of Poway's sub-area 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 butterfly is not a covered species for any of the sub-area plans within the MSCP, although both the County of San Diego and San Diego Gas and Electric are developing amendments to their permits to gain coverage for the Quino checkerspot butterfly. We recently awarded the State of California $10,000,000 to purchase 333 additional hectares (824 acres) of Quino checkerspot butterfly habitat in the Proctor Valley area of southwest San Diego County (Southwest San Diego Recovery Unit; see section I.G.1, Recovery Units) (U.S. Fish and Wildlife Service 2002b).

The MHCP 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 us and the California Department of Fish and Game. An estimated 8,100 hectares (20,000 acres) of land are targeted for conservation within the proposed preserve for the MHCP. The Quino checkerspot butterfly is one of the species being evaluated for incidental take coverage, however no final determination has been made at this time.

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 164 species, including the Quino checkerspot butterfly. Currently, 12 cities within the western portion of the County have endorsed the planning effort and will participate in the planning efforts. A draft was released for public review on November 15, 2002, and the public comment period closed on March 14, 2003. We are currently processing the permit application.

We and the California Department of Fish and Game approved the Central-Coastal NCCP in July 1996. No extant Quino checkerspot butterfly populations are known to occur within this planning area, and the species is only conditionally covered by the plan. Specifically, loss of habitat supporting populations that play an essential role in the distribution of the Quino checkerspot butterfly in the subregion and adjoining areas is not authorized by the Central-Coastal NCCP. The Central-Coastal NCCP authorizes the loss of habitat occupied by small and/or satellite populations, reintroduced populations, or populations that have expanded as a result of management actions. Should planned activities affect Quino checkerspot butterfly habitat, the Central-Coastal NCCP requires a mitigation plan be prepared that includes design modifications and other on site measures, compensation for habitat losses, and monitoring and adaptive management of the Quino checkerspot butterfly and its habitat in a manner that meets our approval.

2. San Diego National Wildlife Refuge

Habitat conservation efforts include protection of resident Quino checkerspot butterfly populations on the San Diego National Wildlife Refuge (Refuge). The Refuge was established in 1996, with the acquisition of 745 hectares (1,840 acres) at Rancho San Diego in San Diego County. The Refuge Planning Area for the Otay-Sweetwater Refuge Unit encompasses 18,605 hectares (45,974 acres) within the Southwest San Diego and Possible Future Central San Diego Recovery Units, with 31,126 hectares (7,691 acres) currently managed by the Refuge, and 21,295 hectares (5262 acres) managed by the California Department of Fish and Game. Funding for acquisition from the Land and Water Conservation Fund has remained steady at about $3 million per year. Our staff conducted Quino checkerspot butterfly surveys on the Refuge in 2001, with assistance from other certified volunteers. Surveyed locations were primarily hilltops and areas with known concentrations of host plants in the vicinity of San Miguel Mountain. Refuge surveys in 2001 resulted in expansion of the Rancho San Diego Occurrence Complex, and discovery of the Proctor Valley and Los Montañas Occurrence Complexes. Independent project-based surveys (not conducted by Service staff) in 2003 resulted in expansion of the Proctor Valley Occurrence Complex.

In addition to surveying the Refuge for the Quino checkerspot butterfly 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 butterfly habitat restoration funding have been submitted. We anticipate that future Quino checkerspot butterfly 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 host plant and nectar sources were planted. Research needed to identify Quino checkerspot butterfly habitat suitability and restoration methods for the Refuge is being developed.

3. Captive Propagation

Captive propagation efforts to date consist of a small population maintained by Dr. Gordon Pratt at University of California, Riverside. We are currently working with Dr. Pratt and Dr. Mike Singer to expand the program. We collected additional stock during the drought season in 2002, and are maintaining lines from five core occurrence complexes. Under the auspices of the Assessment District 161 Habitat Conservation Plan in Riverside County, the Murrieta Unified School District is building a new captive propagation facility, and we are working to establish a second captive propagation site. Butterfly "ranching" within the distribution of an extant population has been proposed in the Southwest San Diego habitat region (U.S. Fish and Wildlife Service 1999). Ranching involves wild adults that lay eggs on host plants in managed habitat; captive-hatched larvae are reared in a protected situation (B. Toon, pers. comm.).

4. California Department of Fish and Game

The California Department of Fish and Game has funded Quino checkerspot butterfly population and habitat monitoring activities using funds allocated by us 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. The California Department of Fish and Game manages over 24,700 hectares (10,000 acres) of occupied Quino checkerspot butterfly habitat within the current MSCP preserve.

5. Government-to-Government Coordination

The Carlsbad Fish and Wildlife Office has initiated two Government-to-Government cooperation dialogues, one with the Mexican Government via a proposal submitted to the United States/Canada/Mexico Trilateral Shared Species Committee, and one with the Cahuilla Band of Indians in Riverside County. The Trilateral Committee proposal submitted in 2002, outlines research to be done on distribution of and threats to the Quino checkerspot butterfly in Baja California Norte, Mexico, focusing on areas near the international border that likely contain cross-border populations. The Cahuilla Tribal dialogue was initiated in 2002, and focused on voluntary Quino checkerspot butterfly conservation measures for the Cahuilla Indian Reservation. We have offered to assist with preparation of an environmental management plan for the Tribe, and continue to explore conservation partnership opportunities with them.

G. Recovery Strategy

The survival and recovery of the Quino checkerspot butterfly depends on protection, restoration and management of habitat within the distribution of metapopulations, augmentation of extant populations, and reintroduction or discovery of populations in areas not known to be currently occupied. Recovery efforts would also be greatly facilitated, and ongoing threats reduced, by the advent of a large-scale educational outreach program involving local cooperative partnerships. Because each extant population is 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, ongoing 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 host plants and sites used by adults during breeding, oviposition, nectaring, and dispersal. Resilient metapopulation structure requires preservation of habitat patches that may temporarily not support larval development.

The best available information indicates the Quino checkerspot butterfly is highly endangered: it was at such low densities prior to listing that it was thought to possibly be extinct (U.S. Fish and Wildlife Service 1997a). The species is currently known from less than 25 percent of its former distribution; it is known to undergo large population fluctuations related to weather (Murphy and White 1984) (see sections I.C, Life History, and I.E.8, Climate Change), and most current populations are threatened by ongoing habitat degradation and development (see section I.E, Threats). Under current conditions, the Quino checkerspot butterfly may go extinct in the foreseeable future. Therefore, further losses of landscape connectivity within recovery units will increase the extirpation probability of extant populations and adversely affect recovery of the Quino checkerspot butterfly.

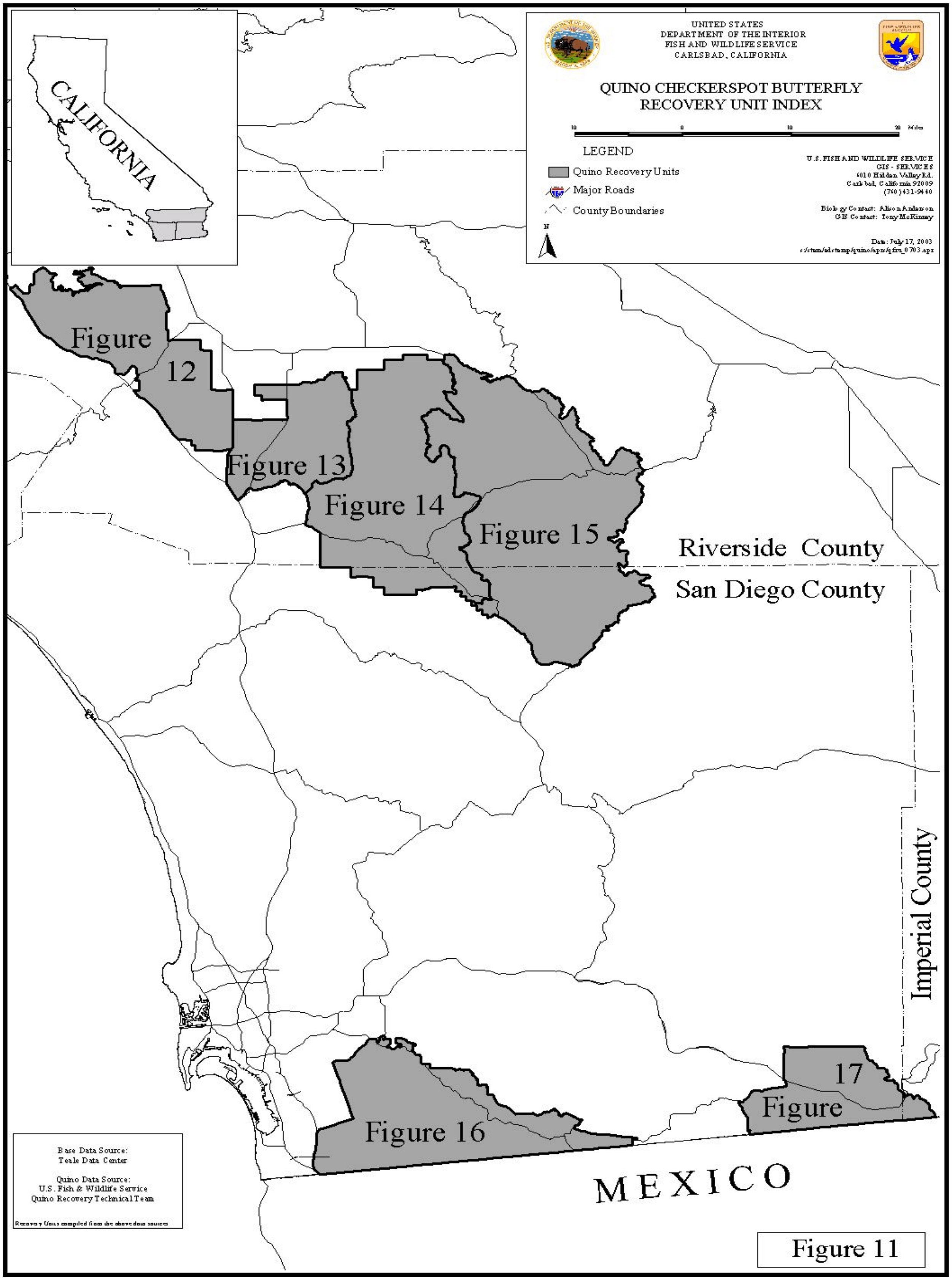
Any proposed project that might reduce the area of suitable or restorable habitat should be carefully evaluated, and conservation measures that fully protect and/or restore habitat of greater value should be outlined. Project proponents are encouraged to begin working with us in the early stages of project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

- Creation of detailed maps of habitat patches and dispersal areas on a spatial scale that captures the essential landscape connectivity and known distribution of each populations or occurrence complex.
- Modeling of metapopulation dynamics for each occurrence complex.
- Assessment of varying restoration needs within 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 population management designs.

As management plans are implemented, monitoring will provide the ultimate test of effectiveness. Census surveys should be coordinated to extend over a representative sub-sample of habitat patches throughout a 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 establishment or discovery of at least one new, coastal population and determining the need to augment declining populations (*e.g.* the Harford Springs Occurrence Complex). The likelihood of extinction remains high unless habitat conservation (protection and management) and captive breeding programs are developed and advanced without delay.

1. Recovery Units

Recovery units identified in this recovery plan (Figures 3 and 11) are the major units for managing recovery efforts. Most recovery units contain one or more existing core (large) occurrence complexes within each habitat region. Boundaries of the Southwest San Diego, Southwest Riverside, South Riverside, and South Riverside/North San Diego Recovery Units have been modified from the draft plan (U.S. Fish and Wildlife Service 2001) to include newly discovered populations and their habitat, and/or to better reflect habitat regions described in section I D (Distribution and Habitat Considerations) above. A number of factors were considered in identifying recovery units, primarily ecological and genetic factors, political boundaries, and ongoing conservation efforts. In some instances, recovery unit boundaries were designed to maximize efficiency of reserves, encompass areas of common threats, or accommodate logistic concerns. Wherever a recovery unit shares a boundary with another recovery unit, it is crucial to maintain landscape connectivity to one or more populations in the other recovery unit in order to maintain natural metapopulation dynamics and avoid the need for costly, perpetual management. If natural landscape connectivity is not maintained, it may be necessary to undertake costly population augmentation in perpetuity in order to maintain population resilience. Recovery units may include areas of apparently suitable habitat patch networks and dispersal areas (landscape connectivity) that are not known to be occupied,



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD, CALIFORNIA
QUINO CHECKERSPOT BUTTERFLY
RECOVERY UNIT INDEX
10 0 10 20 Miles
LEGEND
Quino Recovery Units
Major Roads
County Boundaries
N
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Date: July 17, 2003
CALIFORNIA
Figure 12
Figure 13
Figure 14
Figure 15
Riverside County
San Diego County
Imperial County
Figure 16
Figure 17
MEXICO
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Figure 11

when biological evidence warrants inclusion (*e.g.* the southern portion of the South Riverside/North San Diego Recovery Unit). Where sufficient evidence supporting inclusion of lands in recovery units is lacking, surveys and habitat assessments of possible habitat should be conducted (e.g. the eastern slope of the Santa Ana Mountains).

Biologically, Quino checkerspot butterfly recovery units include areas within which gene flow was historically, or is currently, possible. Recovery units include lands both essential and not essential to the long-term conservation of the butterfly, and comprise a variety of habitat types. Recovery unit boundaries may change if and when additional populations are documented or introduced.

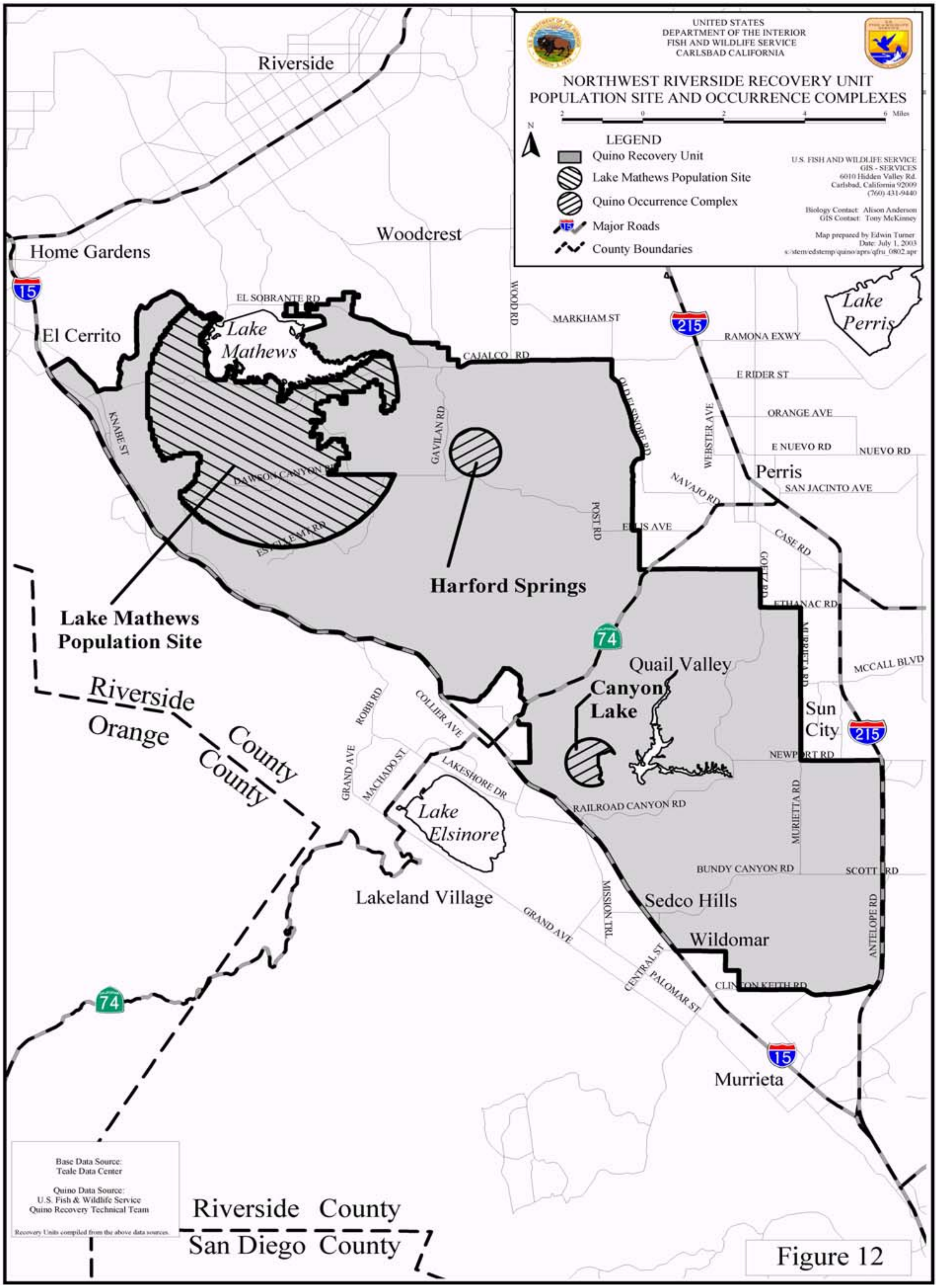
Recovery units were designed to facilitate recovery by placing the scope on a smaller spatial scale than the entire species' range, on a scale that is likely to support a megapopulation or large resilient metapopulation. Recovery units are believed to be minimum viable units, within which landscape connectivity must be maintained. Focusing recovery on smaller areas is advantageous because the three general occupied regions - western Riverside County, southwestern San Diego County, and southeastern San Diego County - are apparently isolated from one another. Thus, a narrower scope allows recovery actions to be focused on specific threats to particular habitats and encourages implementation of recovery actions by local interests. Although biological and nonbiological issues (*i.e.,* jurisdictional and logistical concerns) were considered in identifying recovery units, recovery units have a biological basis in that they are groupings of Quino checkerspot butterfly populations among which gene flow is believed to currently occur.

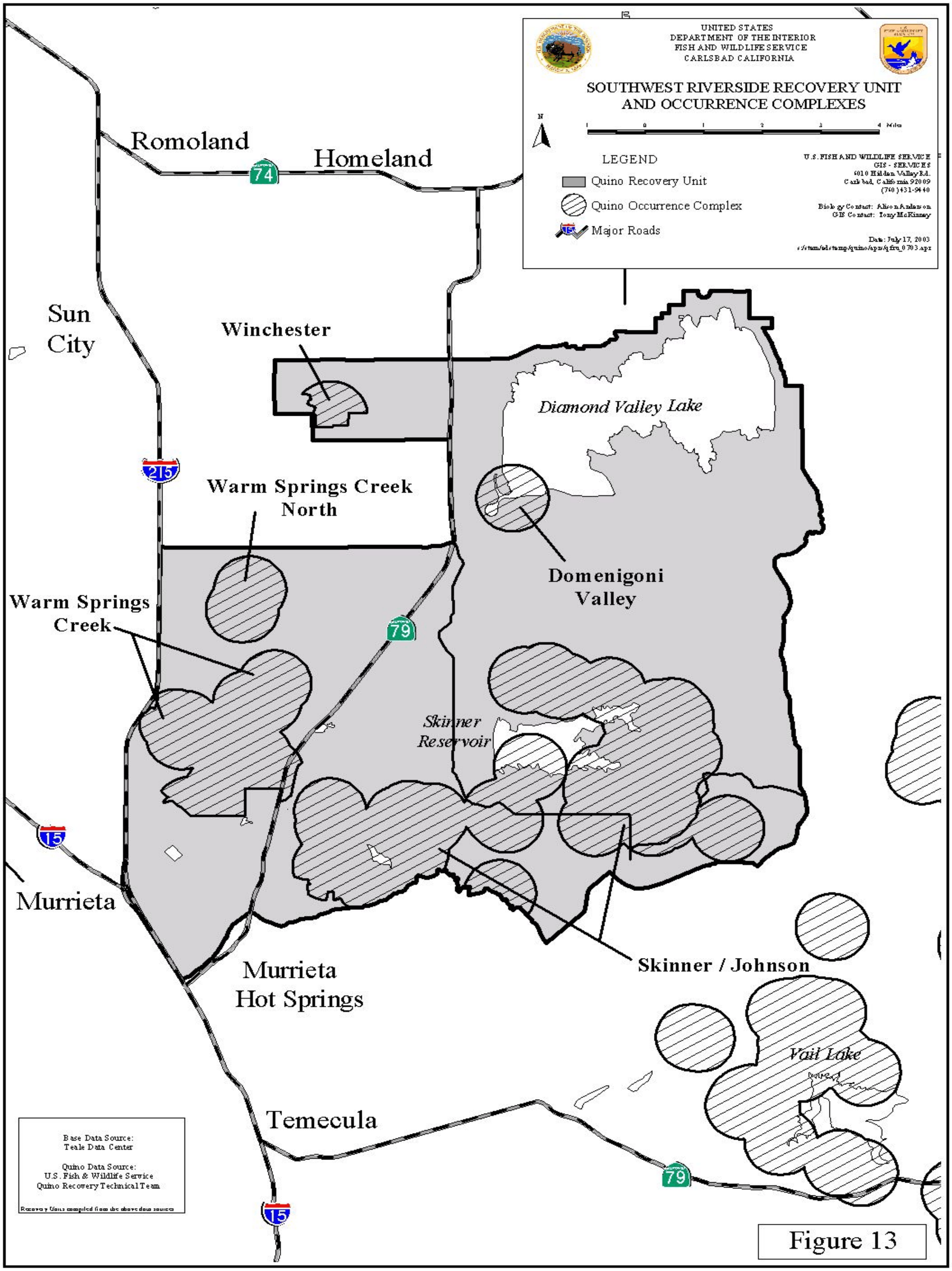
Each recovery unit is important and each is at the appropriate scale by which to gauge progress toward recovery for large-scale metapopulations (megapopulations) and the species as a whole within southern California. Recovering the Quino checkerspot butterfly within each recovery unit will maintain the overall distribution of the species throughout the remainder of their native range in the United States. Conserving populations and their habitats within recovery units should preserve genotypic diversity and allow Quino checkerspot butterflies access to diverse habitats. This maintenance of diversity is needed because a Quino checkerspot butterfly population may contain individuals adapted to the prevailing regional environmental conditions (Gilbert and Singer 1973). Individuals or local populations with an atypical genetic makeup may persist in a metapopulation in much lower abundance than those with locally adapted genes. As environmental conditions change due to natural and human-influenced processes, the survival of individuals adapted to previous conditions may no longer be enhanced. If changing environmental conditions could lead to extirpation of a population, it is possible that the area could be repopulated by individuals from another population whose survival is enhanced under the new conditions if diverse local populations are conserved. When the overall genetic diversity distributed across Quino checkerspot butterfly populations is reduced, the ability of the species to respond to changing conditions is likewise reduced, leading to a higher extinction probability. Consequently individual recovery units are necessary to the broader survival and recovery of the species. Continued survival and recovery of local populations is critical to the persistence of any metapopulations within recovery units and their role in recovery of the species.

<u>Northwest Riverside Recovery Unit</u>:
This recovery unit is located south of Lake Mathews, east of Interstate 15, and west of Interstate 215 as mapped (Figures 3, 11 and 12). It contains two occurrence complexes (Harford Springs and Canyon Lake) and one historically occupied population site (Lake Mathews) (Figure 12). These sites encompass what was apparently the distribution of an historically resilient metapopulation (Figure 2). The nearest recovery units are the adjacent Southwest Riverside Recovery Unit to the south, and the possible future North Orange Recovery Unit to the northwest. A degree of ecological connectivity persists throughout most of the Southwest Riverside Recovery Unit, and it is possible that some degree of landscape connectivity persists as well, at least in the northern portion.

Threats: High; primarily from habitat destruction and fragmentation due to development, and habitat degradation due to off-road vehicle activity, nonnative plant invasion, and grazing.

<u>Southwest Riverside Recovery Unit</u>:
This recovery unit is located in southwestern Riverside County (Figures 3, 11, and 13), east of Interstate 15 and Interstate 215, south of the town of Winchester and Scott Road, and north of urban areas in the city of Temecula as mapped. It


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
NORTHWEST RIVERSIDE RECOVERY UNIT
POPULATION SITE AND OCCURRENCE COMPLEXES
LEGEND
Quino Recovery Unit
Lake Mathews Population Site
Quino Occurrence Complex
Major Roads
County Boundaries
Riverside
Woodcrest
Home Gardens
El Cerrito
Lake Mathews
Lake Perris
Perris
Harford Springs
Lake Mathews Population Site
Quail Valley
Canyon Lake
Sun City
Riverside County
Orange County
Lake Elsinore
Lakeland Village
Sedco Hills
Wildomar
Murrieta
Riverside County
San Diego County
Base Data Source: Teale Data Center
Quino Data Source: U.S. Fish & Wildlife Service Quino Recovery Technical Team
Figure 12


UNITED STATES
DEPARTMENT OF THE INTERIOR
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SOUTHWEST RIVERSIDE RECOVERY UNIT
AND OCCURRENCE COMPLEXES
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Quino Occurrence Complex
Major Roads
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GIS - SERVICES
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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Date: July 17, 2003
Romoland
74
Homeland
Sun
City
Winchester
Diamond Valley Lake
215
Warm Springs Creek
North
Domenigoni
Valley
Warm Springs
Creek
79
Skinner
Reservoir
15
Murrieta
Skinner / Johnson
Murrieta
Hot Springs
Vail Lake
Temecula
79
15
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

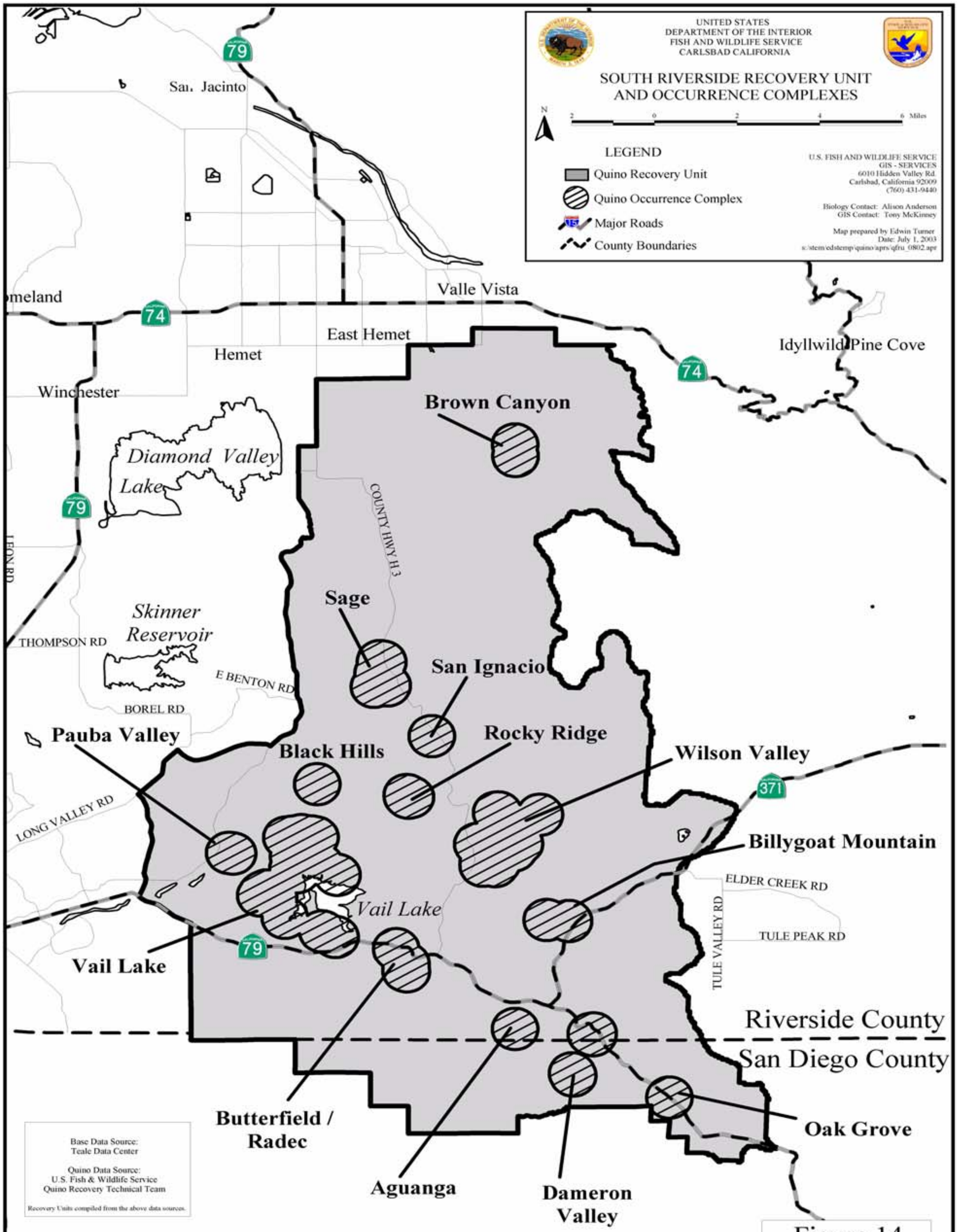
Figure 13

contains five occurrence complexes, Warm Springs Creek (core), Warm Springs Creek North, Skinner/Johnson (core), Winchester, and Domenigoni Valley (Figure 13). State Route 79 and associated development are probably a dispersal deterrent and source of mortality, but are not currently an impassable barrier between habitat patches on either side. This recovery unit is generally contiguous with the South Riverside Recovery Unit to the east. Potential ecological and landscape connectivity with the Northwest Riverside Recovery Unit are compromisedprimarily by Interstate 215 and associated development.

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

<u>South Riverside Recovery Unit</u>:
This recovery unit is located south of State Route 74, including the Sage Road and Oak Mountain areas, on lands below 1,070 meters (3,500 feet) in elevation and north of Palomar Mountain as mapped (Figures 3, 11 and 14). This recovery unit contains 13 occurrence complexes - Pauba Valley, Black Hills, Vail Lake (core), Sage (core), San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Aguanga, Billy Goat Mountain, Dameron Valley, Oak Grove and Brown Canyon (Figure 14). 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. This recovery unit is contiguous with the South Riverside/North San Diego Recovery Unit and includes relatively undeveloped areas to the south including the north slope of Palomar Mountain.

Threats: High. This area is threatened by proposed development, nonnative plant invasion, off-road vehicle activity, and illegal trash dumping (G. Pratt, pers. comm.). Habitat destruction by off-road vehicle activity and dumping was particularly severe on BLM parcels where reference populations were being monitored in 2001 through 2003.


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTH RIVERSIDE RECOVERY UNIT
AND OCCURRENCE COMPLEXES
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LEGEND
Quino Recovery Unit
Quino Occurrence Complex
Major Roads
County Boundaries
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
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Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
s:/stem/edstemp/quino/aprs/qfru_0802.apr
79
San Jacinto
Valle Vista
74
East Hemet
Hemet
Winchester
Idyllwild Pine Cove
Brown Canyon
Diamond Valley Lake
COUNTY HWY H3
Sage
Skinner Reservoir
THOMPSON RD
E BENTON RD
BOREL RD
San Ignacio
Rocky Ridge
Pauba Valley
Black Hills
Wilson Valley
371
LONG VALLEY RD
Billygoat Mountain
ELDER CREEK RD
TULE VALLEY RD
TULE PEAK RD
Vail Lake
Vail Lake
Riverside County
San Diego County
Butterfield / Radec
Aguanga
Dameron Valley
Oak Grove
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.
Figure 14

South Riverside/North San Diego Recovery Unit:
This recovery unit is located between 1,070 and 1,520 meters (3,500 and 5,000 feet) in elevation in Riverside and San Diego Counties, surrounding the community of Anza and the Cahuilla Indian Reservation, east of Mount Palomar, north of Warner Springs, and west of the Anza Borrego Desert as mapped (Figures 3, 11, and 15). This recovery unit contains eight occurrence complexes: Southwest Cahuilla, Tule Peak (core) , Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain (Figure 15). This recovery unit is contiguous with the South Riverside Recovery Unit to the west, and also has ecological connectivity with surrounding undeveloped areas.

Distribution of historic Quino checkerspot butterfly records and habitat characteristics to the south indicate the likelihood of landscape connectivity well into San Diego County. The distribution of all four primary host plants is generally continuous all the way south to the other San Diego County Recovery Units.

Threats: High; primarily off-road vehicle use, increasing development pressure (Coronado 2003), grazing, nonnative plant invasion, and fire.

Southwest San Diego Recovery Unit:
This recovery unit is located in southern San Diego County roughly south of State Route 94, east of Interstate 805 and associated urban areas, and west of the city of Tecate as mapped (Figures 3, 11 and 16). It contains 15 occurrence complexes: West Otay Mesa, Otay Valley, West Otay Mountain (core), Otay Lakes/Rancho Jamul (core), Proctor Valley, Jamul, Hidden Valley, Rancho San Diego, Los Montañas, Honey Springs, Dulzura, Marron Valley (core), Barrett Junction, and Tecate (Figure 16). The closest recovery units are the possible future 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 to the possible future Central San Diego Recovery Unit through undeveloped lands in central portions of the county. Eastern landscape connectivity has been compromised by development associated with the towns of Tecate and Campo. There may also be connectivity to the Southeast San Diego Recovery Unit through lands in Baja California, Mexico, and through undeveloped land north of State Route 94. Currently, State Route 94 is limited

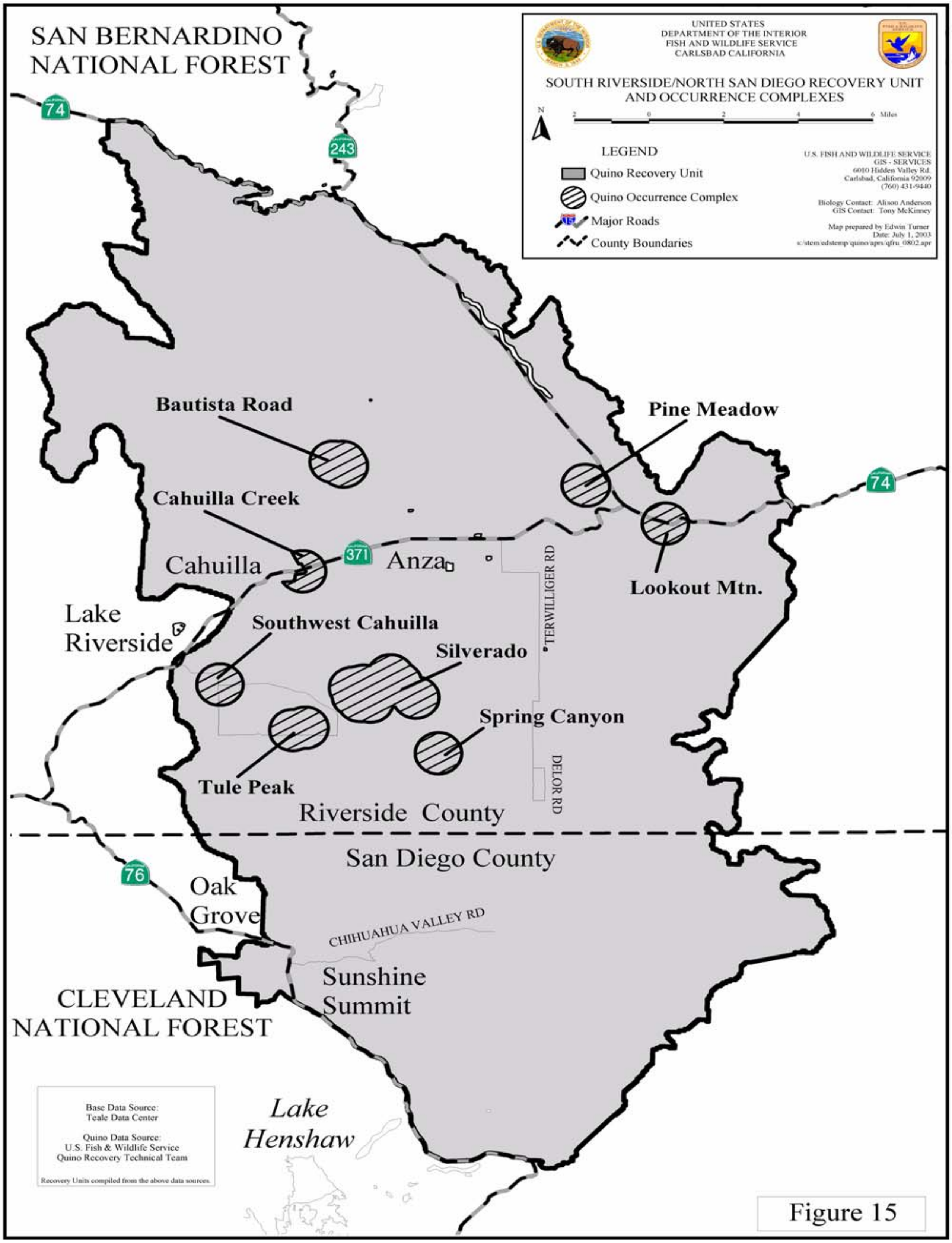
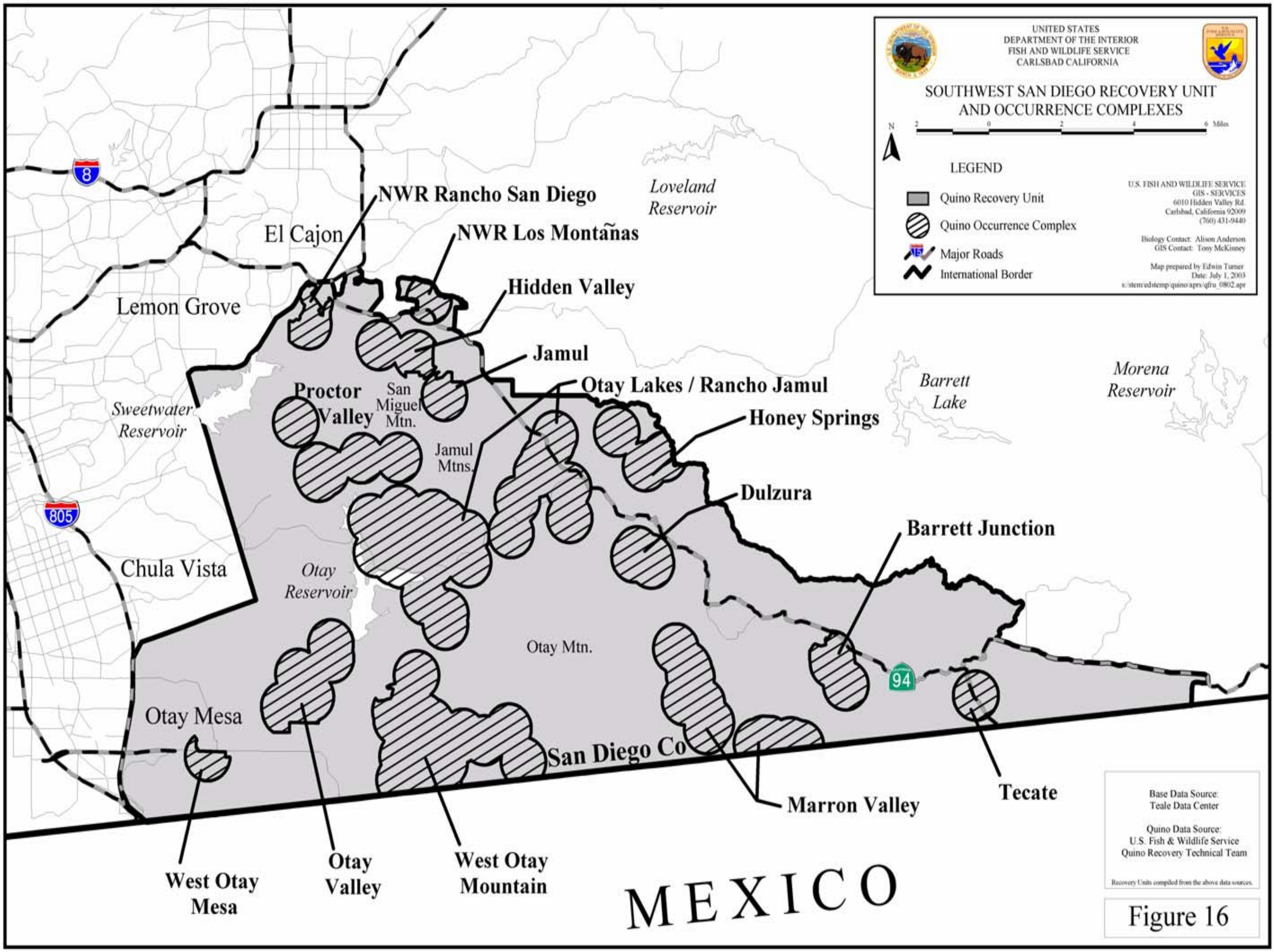

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTH RIVERSIDE/NORTH SAN DIEGO RECOVERY UNIT
AND OCCURRENCE COMPLEXES
LEGEND
Quino Recovery Unit
Quino Occurrence Complex
Major Roads
County Boundaries
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
SAN BERNARDINO
NATIONAL FOREST
74
243
Bautista Road
Pine Meadow
Cahuilla Creek
Cahuilla
371
Anza
TERWILLIGER RD
Lookout Mtn.
Lake
Riverside
Southwest Cahuilla
Silverado
Spring Canyon
DELOR RD
Tule Peak
Riverside County
San Diego County
76
Oak
Grove
CHIHUAHUA VALLEY RD
Sunshine
Summit
CLEVELAND
NATIONAL FOREST
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.
Lake
Henshaw

Figure 15


UNITED STATES
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FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTHWEST SAN DIEGO RECOVERY UNIT
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Major Roads
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6010 Hidden Valley Rd.
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Biology Contact: Alison Anderson
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s:/stem/edstemp/quino/aprs/qfru_0802.apr
8
805
94
El Cajon
Lemon Grove
Sweetwater Reservoir
Chula Vista
Otay Mesa
Loveland Reservoir
Barrett Lake
Morena Reservoir
NWR Rancho San Diego
NWR Los Montañas
Hidden Valley
Jamul
Otay Lakes / Rancho Jamul
Honey Springs
Dulzura
Barrett Junction
Proctor Valley
San Miguel Mtn.
Jamul Mtns.
Otay Reservoir
Otay Mtn.
San Diego Co
West Otay Mesa
Otay Valley
West Otay Mountain
Marron Valley
Tecate
MEXICO
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 16

to two lanes in that area, and does little to compromise Quino checkerspot butterfly dispersal ability.

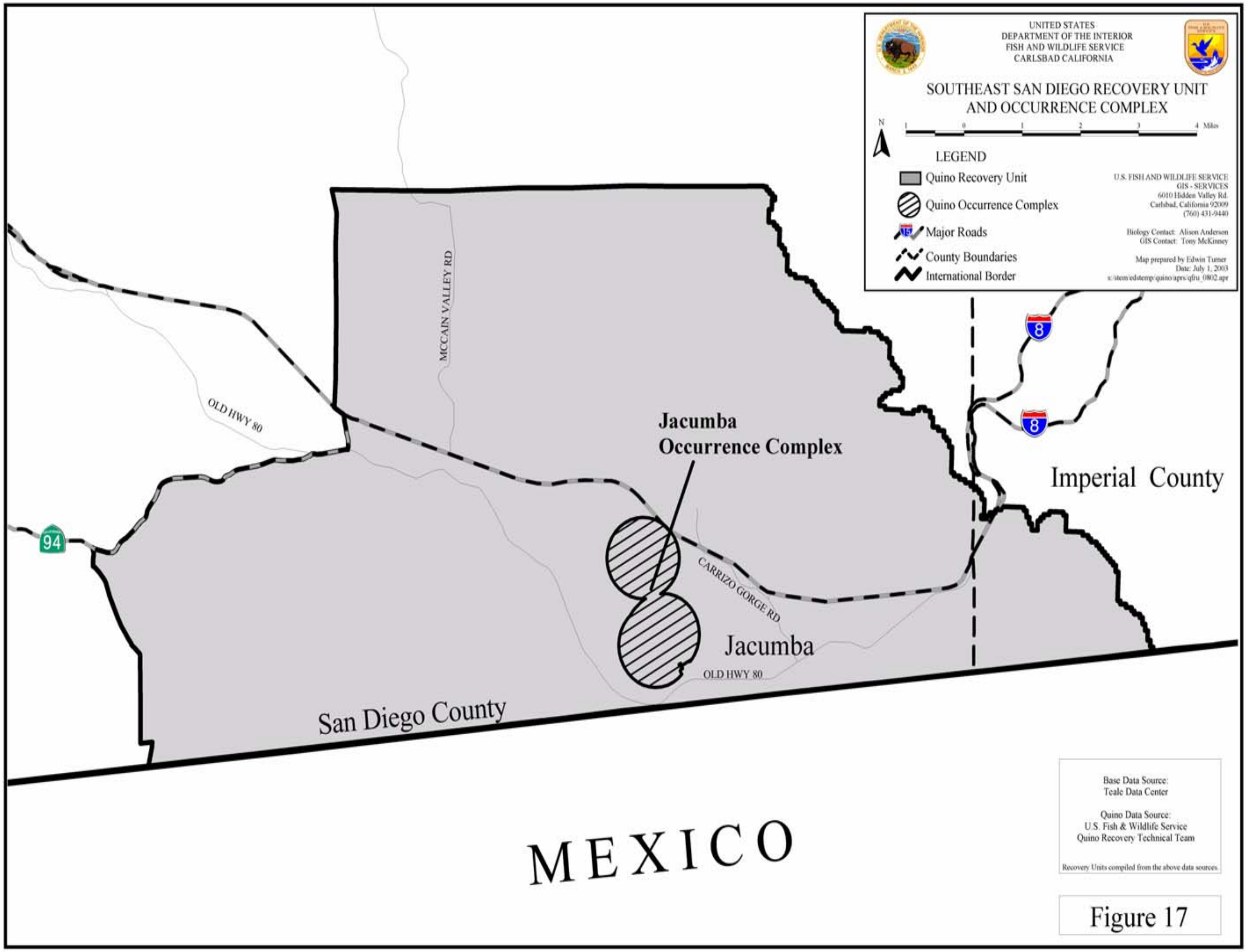
Threats: High; primarily habitat destruction, degradation, and fragmentation associated with development in the western areas. Most historic coastal habitats have been destroyed and/or isolated by development (*e.g.* Dictionary Hill). Remaining occupied habitat areas continue to be threatened by encroaching development and ongoing agriculture, grazing, road grading, and off-road vehicle and Border Patrol activities. These disturbances have also resulted in, and continue to exacerbate, nonnative plant invasion problems.

<u>Southeast San Diego Recovery Unit</u>:
The location of this recovery unit is centered around the town 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 east of Campo as mapped. This recovery unit also includes the Table Mountain area north of Interstate 8, McCain Valley, and a small area in Imperial County (Figures 3, 11, and 17). It contains the Jacumba Occurrence Complex (Figure 17). The closest other recovery unit is the Southwest San Diego Recovery Unit; landscape connectivity between them is compromised primarily by development in the Tecate and Campo areas. There is ecological, and possibly landscape, connectivity with the South Riverside/North San Diego Recovery Unit to the north along the western slope of the Laguna Mountains.

Threats: Low; primarily habitat destruction, degradation, and fragmentation associated with development, and off-road vehicle use.

2. Possible Future Recovery Units

The three possible future recovery units described below include areas that are considered suitable to sustain the populations outside of current recovery units specified by Recovery Criterion 5 (see section II.B below). The Possible Future Central San Diego Recovery Unit contains two occurrence complexes necessary to meet Recovery Criteria 1 to 3, and provides at least one of the two additional populations specified by Recovery Criterion 5 in the Draft Quino Checkerspot Butterfly Recovery Plan (U.S. Fish and Wildlife Service 2001). Although two of the possible future recovery units do not appear to be currently occupied by the


UNITED STATES
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FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTHEAST SAN DIEGO RECOVERY UNIT
AND OCCURRENCE COMPLEX
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Quino Recovery Unit
Quino Occurrence Complex
Major Roads
County Boundaries
International Border
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(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
MCCAIN VALLEY RD
OLD HWY 80
94
8
8
Jacumba
Occurrence Complex
Imperial County
CARRIZO GORGE RD
Jacumba
OLD HWY 80
San Diego County
MEXICO
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 17

Quino checkerspot butterfly, they either historically supported populations (Figure 2), or are within the greater historic range and appear to have a high potential to support managed metapopulations based on general habitat characteristics. The possible future 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, or suitable or restorable habitat for reintroduction. Although unlikely, it is possible that occupied or restorable habitat patch networks with a marine climate influence may be identified partially or entirely outside the areas described below. Well-managed coastal preserves in San Diego or Orange County may be able to support resilient populations of the Quino checkerspot butterfly.

<u>Possible Future Central San Diego Recovery Unit</u>:

This possible future recovery unit in San Diego County includes vernal pool habitat on Kearny Mesa, Mira Mesa, Del Mar Mesa, and Lopez Ridge. The unit also includes inland habitat in the vicinity of Sycamore and Little Sycamore Canyons, Iron Mountain, San Vicente Reservoir, the Fortuna Mountain area, El Capitan Reservoir, the community of Alpine, and south to the Southwest San Diego Recovery Unit border near the community of Jamul. As an alternative, this unit as described could be split into two units based on coastal climate influence, or part of this unit as described could be included in an expansion of the Southwest San Diego Recovery Unit. There are historic records of Quino checkerspot butterflies scattered throughout this recovery unit. Occupancy was documented in 2001 after the draft recovery plan (U.S. Fish and Wildlife Service 2000) was published, in the northeastern section near San Vicente Reservoir (San Vicente Occurrence Complex; Sproul and Faulkner 2001), and south of the community of Alpine in 2003 (Alpine Occurrence Complex; Lee 2003, Figure 8). Pending further analysis of areas for inclusion in this recovery unit (based on further habitat and butterfly surveys) and opportunity for public review, we intend to propose this possible future recovery unit as one or more recovery units in an addendum to this recovery plan.

This possible future recovery unit contains high-quality, historic habitat of the Quino checkerspot butterfly similar to the historic condition of Otay Mesa (see Murphy and White 1984). Recent surveys reported cryptogamic crusts and vernal pool complexes supporting extensive *Plantago erecta* stands on mesa tops east of Interstate 805 (Osborne 2000). Marine climate influence should help protect larval food plants from heat and drought, thus increasing host plant abundance and suitability, and allowing higher rates of pre-diapause larval survival than in more climatically variable inland regions (see section I.C, Life History).

The general ecological description of the southwestern San Diego County region above also describes this possible future recovery unit. The mesa areas contain relatively high quality vernal pool and mima mound habitat patches on predominantly red clay soils. Habitat areas in the eastern portions of this unit contain cryptogamic crusts and dense patches of *Plantago erecta* mixed with abundant *Castilleja exserta*. In northeastern areas of this recovery unit, apparently suitable Quino checkerspot butterfly habitat can be found distributed extensively across open ridge tops of mixed chaparral/coastal sage scrub. In 2001, occupied habitat north of San Vicente Reservoir contained *P. erecta*, *Cordylanthus rigidus*, *C. exserta*, and abundant nectar sources (A. Anderson, pers. observ.). Ridge top habitat in the eastern portions of the possible future recovery unit can 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 barrier to Quino checkerspot butterfly dispersal (K. Osborne, G. Pratt, C. Parmesan, and M. Singer, pers. comm.). Satellite imagery indicates that habitat from the town of Alpine south to State Route 94 still has landscape connectivity. Large potential habitat patches have been reported in the vicinity of Sycuan Peak (R. Riggin 2003), and it is possible that extant Quino checkerspot butterfly populations may exist in that area south of the Alpine Occurrence Complex (Figure 8). Collection records of *Antirrhinum coulterianum* indicate populations of that host plant exist throughout the unit (Thompson 1988).

The possible future Central San Diego Recovery Unit is designed to provide landscape connectivity within the least developed coastal and inland mesas and foothills of San Diego County, and is entirely within the San Diego County Multiple Species Habitat Planning Area. Landscape connectivity within a network of otherwise suitable or restorable habitat patches has been compromised by Interstates 5, 805, 8, and 15; State Routes 52 and 67; and development in Mira Mesa, Rancho Penasquitos, Scripps Miramar Ranch, and Alpine. Restoration of landscape connectivity (or the equivalent) in westernmost portions of the possible future recovery unit would require either technological solutions, or active management in perpetuity. The possibility of landscape connectivity with recovery units to the north and east depends on protection of open space and enhancement of landscape connectivity in the vicinity of State Route 67, San Vicente Reservoir, Iron Mountain, and south and east of the town of Alpine. To the maximum extent possible, the ecological connectivity of this recovery unit to northern and eastern natural areas should also be maintained to prevent isolation, retain possible landscape connectivity with the northern range of the species, and decrease the need for active management.

<u>Possible Future Northwest San Diego Recovery Unit</u>:

This possible future recovery unit encompasses portions of 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 butterflies are known from this possible future recovery unit; however, it has characteristics of other habitats that historically supported high densities of the species in southwestern San Diego County, as described by Murphy and White (1984). Historic Quino checkerspot butterfly collection records near the possible future recovery unit, northwest in Dana Point, and south in Vista, suggest this possible future recovery unit was formerly occupied (Figure 2) (see section I.D, Distribution and Habitat Considerations). Records exist for *P. erecta* (Rahn 1979), *A. coulterianum* (Thompson 1988) and *C. rigidus* (Chuang and Heckard 1986) collections within this possible future recovery unit.

The lack of historical Quino checkerspot butterfly records on Camp Pendleton is to be expected; access has always been limited, and Camp Pendleton has been restricted to amateur biological collectors since its establishment in 1942. Camp Pendleton management contracted for a general base-wide habitat survey in 1996 and 1997, as well as several subsequent site-specific butterfly surveys (Redak 1998). Surveyors stated they found abundant “optimal and adequate Quino checkerspot butterfly habitat;” however, surveyors did not detect butterflies, and did not conduct comprehensive surveys base-wide (Redak 1998).

Huerero soils and clay lenses support vernal pools on coastal terraces in the western portion of this possible future 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 butterfly habitat include mesas, rolling hills, and ridge lines. Vegetation consists of mixed coastal sage scrub and chaparral, with grassland inclusions. Although *Plantago erecta* is abundant in patches (Redak 1998, Osborne 2000), the full extent of Quino checkerspot butterfly host plant distribution within the possible future recovery unit is unknown. Quino checkerspot butterfly nectar plants are also abundant (Redak 1998, Osborne 2000). Similar to the Southwest San Diego Recovery Unit, this possible future recovery unit should provide a more stable marine climate influence. Amelioration of hot, dry climatic conditions and its diverse, largely undeveloped topography should make the possible future Northwest San Diego Recovery Unit a crucial one with regard to climate change (see section I.C, Life History).

Efforts to restore habitat or establish experimental populations of the Quino checkerspot butterfly 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 butterfly 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 the species, or be suitable as reintroduction sites.

The closest recovery units are the Southwest Riverside Recovery Unit to the east, and the possible future 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. Murphy and Bomkamp (1999) concluded that resources are currently insufficient to support Quino checkerspot butterfly populations, but that restoration potential exists. However, subsequent to Murphy and Bonkamp's study, new species of primary host plants have been documented, and these species are found in the Santa Ana Mountain foothills (*e.g. Antirrhinum coulterianum*, see Thompson 1988). The western slope of the Santa Ana Mountains appears to hold the possibility of landscape connectivity with the possible future North Orange Recovery Unit and would include land in and along the lower elevation portions of the U.S. Forest Service's Cleveland National Forest. Ecological and landscape connectivity 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 landscape 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.

Possible Future North Orange Recovery Unit:

This possible future recovery unit is located on the northern slope of the Santa Ana Mountains in Orange County, including the areas 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. This possible future recovery unit is located west of the Riverside/Orange County line and north of the Loma Ridge-Limestone Canyon area. The area around Irvine Park is the site of a historically dense Quino checkerspot butterfly population (Orsak 1978, Figure 2). Quino checkerspot butterfly occupancy was last documented in Orange County in 1967, at a site in the northern Santa Ana Mountains called Black Star Canyon (Figure 2), but was apparently extirpated by a fire the same year (Orsak 1978). Informal private reintroduction efforts using Quino checkerspot butterflies from the Gavilan Hills, Riverside County, were conducted there in 1974 (Orsak 1978), however, it is not known if any of the transplanted butterflies released in 1974 established occupancy. Most of the canyons have been historically poorly surveyed for wildlife. Recently, the Irvine Company transferred title of the "Fremont Conservation Area" (a large portion of this possible future recovery unit) to The Nature Conservancy.

The Irvine Park area does not appear to support sustainable resources due to habitat degradation, and restoration is needed before Quino checkerspot butterfly metapopulations can be reestablished (D. Murphy, pers. comm.).

However, the diverse, unfragmented montane topography in much of this possible future recovery unit makes the area a good candidate to support a reintroduced population (see section I.C, Life History).

II. RECOVERY

A. Objectives

The overall objective of this recovery plan is to reclassify the Quino checkerspot butterfly from endangered to threatened status and ensure the species' long-term conservation. Interim goals include: (1) protecting habitat supporting known current population distributions (occurrence complexes) and landscape connectivity between them; (2) maintaining or creating resilient populations; and (3) conducting research necessary to refine recovery criteria. Reclassification to threatened status is appropriate when a taxon is no longer in danger of extinction throughout a significant portion of its range. Because data upon which to base reclassification decisions are incomplete, downlisting criteria in this plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time; research tasks necessary to develop appropriate delisting
criteria are identified in the Recovery Action Narrative below (section II.C).

B. Recovery Criteria

1) Permanently protect the habitat within occurrence complexes (estimated occupied areas based on butterfly occurrences; see section I.D, Distribution and Habitat Considerations), including larval host plants, adult nectar resources, hilltops, and dispersal areas and landscape connectivity between occurrence complexes in a configuration designed to support resilient populations. One or more occurrence complexes may belong to a single greater population distribution, or an occurrence complex may contain more than one whole or partial population distribution. When population distributions are determined by future research or delineated by development and reserve boundaries, the population distribution will replace the occurrence complex as the protected unit.

Recovery units and included occurrence complexes described in this recovery plan are:

- Northwest Riverside Recovery Unit, containing the Harford Springs and Canyon Lake Occurrence Complexes;
- Southwest Riverside Recovery Unit, containing the Warm Springs Creek (core), North Warm Springs Creek, Winchester (but see Action 1.2 below), Domenigoni Valley, and Skinner/Johnson (core) Occurrence Complexes;

- South Riverside Recovery Unit, containing the Pauba Valley, Black Hills, Vail Lake (core), Sage (core), San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Aguanga, Billy Goat Mountain, Dameron Valley, Oak Grove and Brown Canyon Occurrence Complexes;
- South Riverside/North San Diego Recovery Unit, containing the Southwest Cahuilla, Tule Peak (core), Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain Occurrence Complexes;
- Southwest San Diego Recovery Unit, containing the Rancho San Diego, Los Montañas, Hidden Valley, Jamul, Proctor Valley, Otay Lakes/Rancho Jamul (core) , Honey Springs, Dulzura, Barrett Junction, Marron Valley (core), Tecate, West Otay Mountain (core), Otay Valley, and West Otay Mesa Occurrence Complexes;
- Southeast San Diego Recovery Unit, containing the Jacumba Occurrence Complex; and
- San Vicente and Alpine Occurrence Complexes (Possible Future Central San Diego Recovery Unit).

2) Conduct research including: determine the current short-term and potential long-term distributions of populations and associated habitat; conduct preliminary modeling of metapopulation dynamics for core occurrence complexes identified in section I.D, Distribution and Habitat Considerations; investigate the dispersal and colonization potential of the Quino checkerspot butterfly (including genetic relationships among populations), investigate the function of hilltops as a resource for Quino checkerspot butterfly populations; investigate the contribution of multiple-year diapause to population resilience; monitor populations for further evidence of local decline; determine the effects of elevated atmospheric carbon dioxide, nitrogen fertilization, and invasive plants on the Quino checkerspot butterfly and its host plant; conduct studies to determine the magnitude of threats from over-collection and natural enemies.

3) Permanently provide for and implement management of occurrence complexes (or population distributions when delineated) to restore or enhance habitat quality and population resilience, including enhancement of host plant populations, enhancement of diverse nectar sources and pollinators, control of nonnative plant invasion, and enhancement of landscape connectivity. Management should be

implemented as described in Recovery Action 1 (section II.C below, Recovery Action Narrative).

4) The protected, managed population segments within core occurrence complexes (or population distributions when delineated) must demonstrate evidence of resilience. Evidence of resilience is demonstrated if over a period of at least 10 and not more than 20 years, a decrease in the number of occupied habitat patches within an occurrence complex (or population distribution when delineated) is followed by increases of equal or greater magnitude. This monitoring period must begin in the third of three years with favorable climate (total annual January and February precipitation within one standard error of the average total for those months over the past 30 years [1974 to 2003], based on local or proxy climate data). Sample size should be determined using appropriate science, including information on metapopulation dynamics, patch size, relative patch distribution, and modeling. The surveyed sample of habitat patches should be spatially distributed as evenly as possible to avoid error due to correlation of suitability among nearby patches. Population viability models or equivalent modeling that provides evidence of resilience may be substituted for the above described monitoring if such a model undergoes independent peer review by at least three modeling experts and is deemed valid both by us and reviewers (including Quino checkerspot butterfly experts). The 10 to 20-year time period is based on the apparent 10- to 20-year natural population density/distribution cycles of the Quino checkerspot butterfly. If populations do not demonstrate resilience over a 10 to 20-year period, then augmentation should be implemented as in Recovery Action 1 and the 10 to 20 year monitoring period should be reinitiated. However resilience should still be evaluated with reference to the original starting point to ensure that long-term declining trends are not disregarded.

5) One additional population should be documented or introduced within the Lake Matthews population site (formerly occupied, not known to be currently occupied) in the Northwest Riverside Recovery Unit. At least one of the extant populations outside of current recovery units (*e.g.* the San Vicente Reservoir Occurrence Complex) must meet resilience specifications above unless an additional population is established or documented within 10 kilometers (6 miles) of the ocean (a more stable marine climate influence should minimize susceptibility to drought and reduce probability of extirpation).

6) Establish and maintain a captive propagation program for maintenance of representative refugia populations, research, and reintroduction and augmentation of wild populations as appropriate. Genetic stock from populations throughout the current range of the species should be maintained at two separate, independent facilities. Captive propagation may include on-site butterfly ranching in habitat if augmentation or reintroduction is deemed necessary. Any population augmentation must be followed by monitoring.

7) Initiate and implement a cooperative outreach program targeting areas where Quino checkerspot butterfly populations are concentrated in western Riverside and southern San Diego Counties.

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 determination we 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) over-collection by hobbyists and dealers; (4) off-road vehicle use and other recreational activities; (5) detrimental fire management practices; and (6) anthropogenic global change factors (*i.e.,* enhanced nitrogen deposition, elevated atmospheric carbon dioxide concentrations, and climate change).

C. Recovery Action Narrative

Priorities rankings 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.

Priority 1 Recommendations:

1. <u>Protect (via acquisition, conservation easement, or other means) habitat patches and dispersal areas within and between mapped occurrence complexes, and provide ongoing management to enhance habitat and maintain or create resilient populations</u>. Protection will primarily be accomplished through regional multiple species plans and Habitat Conservation Plans. *Euphydryas editha* requires relatively large areas of conserved landscape connectivity to maintain populations, whether they are diffusely distributed well-mixed populations, or metapopulations. Maintenance of dispersal areas linking a network of habitat patches across the greater landscape will be required to conserve resilient Quino checkerspot butterfly metapopulations. Ecological connectivity of land supporting Quino checkerspot butterfly populations with adjacent undeveloped lands, even if they do not contain potential habitat, should remain intact whenever possible. Such lands are likely to contain landscape connectivity essential to other species that are part of the ecological community supporting Quino checkerspot butterfly populations, such as pollinators, higher predators (that control butterfly predators), and woody plant species. Areas of interface between developed and undeveloped lands will require ongoing active management to reduce direct and indirect impacts of development on fragmented wild lands, such as nonnative plant invasion and off-road vehicle activity. Management should also include measures to reduce movement of butterflies into developed areas, especially those known to be sources of mortality, such as roads.

An increase in efforts to enhance the suitability of habitat patches within an occurrence complex (or population distribution, when delineated) should be implemented if a decline in the number of butterflies observed in monitored, occupied habitat patches is documented during 2 consecutive years of total annual January and February precipitation within one standard error of the average total for those months over the past 30 years (based on local or proxy climate data). Management should be adaptive: i.e., ongoing surveys, monitoring, and research (to determine habitat suitability, appropriate butterfly population status indices, and delimit temporal and geographic patterns of Quino checkerspot butterfly movement) should be conducted and management strategies refined accordingly.

If the population is determined not to be resilient based on the number of occupied habitat patches (as specified in Recovery Criterion 4 above) after 20 years of monitoring, then population augmentation should be implemented. If no occupancy is documented within an entire occurrence complex or population distribution (not a local population within a metapopulation) for 3 consecutive years, reintroduction from captive stock and evaluation of reasons for decline including but not limited to standard measures of habitat quality (e.g. pesticide contamination) should be initiated, and an intensified level of management and monitoring maintained until resilience is achieved.

1.1. Northwest Riverside Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat that is part of the known historic Gavilan Hills/Lake Mathews population distribution (including the Lake Matthews population site and the Harford Springs Occurrence Complex), in a configuration designed to support a resilient metapopulation. Develop an integrated, comprehensive Quino checkerspot butterfly management plan for the Lake Mathews/Estelle Mountain Preserve. Include as much habitat associated with the Canyon Lake Occurrence Complex as possible in the reserve.

1.2. Southwest Riverside Recovery Unit: Protect as much as possible of the remaining undeveloped suitable and restorable habitat that is part of the known population distributions in a configuration designed to support resilient metapopulations. Develop an integrated, comprehensive Quino checkerspot butterfly management plan for Southwest Riverside County Multiple Species Reserve and an additional reserve in the vicinity of Warm Springs Creek between Interstate 215 and State Route 79 to preserve dynamics of the existing populations. Current needs include continued reserve expansion, especially in the Warm Springs Creek area. Off-road vehicle and other recreational activity disturbance on public land and in dedicated preserve/mitigation areas should be reduced. Dispersal areas are in particular need of protection in this recovery unit, because of the high degree of fragmentation due to development. Population augmentation (e.g. ranching) will probably be needed in the Warm Springs Creek area, although habitat mapping and monitoring must first be conducted. The Winchester occurrence complex may already be extirpated; if it is determined that this occurrence complex is not extant and/or viable it should be excluded from Recovery Criterion 1.

1.3. South Riverside Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within and between the occurrence complexes. A particular management need is reduction of off-road vehicle and other recreational activity disturbance on public land and in pre-approved mitigation areas in the vicinity of the Oak Mountain and Wilson Valley Occurrence Complexes. Protection needs include maintenance of landscape connectivity between the core Skinner/Johnson and Sage Occurrence Complexes, and within the landscape connectivity bottleneck in the vicinity of the Billygoat Mountain Occurrence Complex. This "landscape connectivity bottleneck" between the towns of Aguanga and Anza is caused by development associated with the towns and State Routes 79 and 371, and ecologically by the vegetation and topography of Palomar Mountain to the south and Cahuilla Mountain to the north.

1.4. South Riverside/North San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable linked habitat patches and dispersal areas within and between the occurrence complexes. Of particular concern is protection of land within and between the Tule Peak and Southwest Cahuilla Occurrence Complexes and reduction of off-road vehicle activity in that area.

1.5. Southwest San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within and between the occurrence complexes. Protection and management should focus on maintaining landscape connectivity between occurrence complexes in lower elevation areas surrounding Otay Mountain, San Miguel Mountain, and the Jamul Mountains. North-south landscape connectivity, as well as east-west connectivity between populations of the species in this portion of the United States is apparently achieved through the core Otay Lakes/Rancho Jamul Occurrence Complex, thus, it is critical that this connectivity be maintained. East-west landscape connectivity south of Otay Mountain and through Mexico may be maintained by the core West Otay Mountain and Marron Valley Occurrence Complexes. Protection and management of mesa areas contiguous with the Otay River Valley is also needed. Because it is possible that the core West Otay Mountain and Marron

Valley Occurrence Complexes are dependent on local populations in Mexico for persistence, the first priority should be to protect the Otay Lakes/Rancho Jamul Occurrence Complex.

1.6. Southeast San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within the recovery unit, especially south of Interstate 8.

1.7. Restore or enhance habitat patches and landscape connectivity within and between occurrence complexes. Restoration and habitat enhancement are proposed as an important component of this plan because of the pervasive alteration to Quino checkerspot butterfly habitat throughout the species' known range, as summarized above (section I.E, Current Threats). Because the Quino checkerspot butterfly was only recently listed, and there is a high level of development and outdoor recreation activity occurring throughout the species' range, much land that may be conserved is already fragmented and degraded. Even most currently conserved lands will require restoration and management to ensure Quino checkerspot butterfly recovery.

The ultimate goal of restoration efforts will be self-sustaining, functional native ecosystems similar to those that historically supported Quino checkerspot butterfly 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 more extensive programs, 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 butterfly 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. Habitat can be partially or wholly restored using methods that vary in labor intensity, disruption to existing vegetation and soils, and potential for impacts to 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.).

1.7.1. <u>Enhance or restore landscape connectivity between isolated habitat patches in developed areas</u>. Because of the pervasive, ongoing habitat degradation caused by nonnative plant invasion, off-road vehicle activities, and other development-related impacts it is probable that habitat within all population distributions will require some level of enhancement. Restoration of habitat that has been completely destroyed by agriculture or grazing, and enhancement of dispersal areas will be necessary primarily in the Southwest Riverside and Southwest San Diego Recovery Units. Habitat patches should be connected by dispersal areas to as many other patches as possible to increase the probability of recolonization following extirpation events. Habitat networks should also be embedded 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 landscape 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 area technology. Technology that may enhance Quino checkerspot butterfly landscape connectivity includes road overpasses coupled with deterrents to reduce mortality and channel dispersal. Similar road overpasses and deterrents 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 multiple species/butterfly overpasses is currently under construction in Florida (Berrios 2000). Possible deterrents 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 sparsely vegetated habitat areas including hilltops. It may be possible to manipulate butterfly behavior and direct dispersal across overpasses (G. Pratt, C. Parmesan, and M. Singer, pers. comm.). Underpasses are less likely to improve dispersal because Quino checkerspot butterflies tend to avoid shaded areas (see section I.C.2, Adult Behavior and Resource Use).

1.7.1.1. Intensive restoration of agricultural areas and degraded habitat in the Southwest San Diego Recovery Unit will be needed within the Otay Lakes/Rancho Jamul Occurrence Complex, in Proctor Valley, and on Otay Mesa. Landscape connectivity should be enhanced across Otay Mesa through continued expansion of vernal pool restoration and other habitat restoration activities.

1.7.1.2. Intensive restoration of agricultural areas and degraded habitat in the Southwest Riverside Recovery Unit will be needed primarily in the core Skinner/Johnson Occurrence Complex, south of Lake Skinner (Johnson Ranch), and in the Warm Springs Creek/Hogbacks area.

1.7.2. <u>Remove cattle or sheep and phase in weed control where habitat is currently grazed</u>. Although grazing may suppress nonnative plant invasion, it also destroys cryptogamic crusts that naturally slow weed invasion. Cows and, in particular, sheep can trample larvae and they also eat larval host plants. Sheep grazing on Bureau of Land Management lands, as observed in Kabian Park near the Canyon Lake Occurrence complex (A. Anderson, pers. obs. 2001) should be discontinued/prohibited.

2. <u>Continue yearly reviews and monitoring as needed as part of adaptive management until there is evidence that populations associated with core occurrences are resilient</u>. Evidence of resilience is demonstrated if long-term monitoring shows that populations meet the standards summarized in Recovery Criterion 4 above. Monitoring should also be initiated subsequent to undertaking any population augmentation. One possible metapopulation viability model that could be used to determine a habitat patch occupancy threshold as described in Criterion 4 is Hanski's (1999) incidence function model, although an acceptable extirpation probability must first be identified.

Monitoring programs will be necessary to determine population trends and inform site-specific management. Butterfly conservation biologists have developed a variety of non-destructive monitoring methods for estimating population numbers and long-term density trends (Pollard 1977, Thomas and Simcox 1982, Murphy and Weiss 1988, Zonneveld 1991, Van Strien *et al.* 1997, Mattoni *et al.* 2001). These monitoring techniques do not rely on standard mark-recapture methods, but on either adult or larval web observations. Two different techniques should be adopted, one to determine habitat patch occupancy patterns within metapopulation distributions (*e.g.*, Zonneveld *et al.* in press, U.S. Fish and Wildlife Service 2002c), and another to measure changes in densities (Pollard 1977, Thomas and Simcox 1982, Murphy and Weiss 1988, Zonneveld 1991, Van Strien *et al.* 1997, Mattoni *et al.* 2001). The second technique would focus on presence/absence rather than density monitoring and maximize the area covered in a given time. Whenever possible, monitoring and research methods should be designed to simultaneously determine density and occupancy patterns (see Recovery Criteria), answer key ecological questions such as habitat suitability factors, and determine population phenology. Methods should also avoid and minimize larval mortality and habitat destruction (trampling).

3. Assess and augment lowest density populations as needed to help establish resilience. It is probable that populations associated with occurrence complexes in the Northwest Riverside Recovery Unit are no longer resilient, or may even have been extirpated. Focused surveys and monitoring should be conducted throughout the Gavilan Hills area, especially in the vicinity of the Lake Mathews population site and the Harford Springs Occurrence Complex to determine the status of Quino checkerspot butterfly occupancy in these habitat areas. These surveys should be conducted in addition to the surveys to determine resiliency described in recovery action 2 and the recovery criteria above. If no Quino checkerspot butterfly population is found after 3 consecutive years of focused surveys, augmentation should be undertaken using ranching of captive reared stock collected from the nearest known occupied habitat.

4. Establish and maintain a captive propagation program. The Quino checkerspot butterfly captive propagation program should consist of two separate, formal laboratory facilities and, if possible, include lines from representative sites throughout the species' range. Stock from each site should be kept separate until further research determines extent of historic or appropriate gene flow between them. Captive propagation is needed to ensure maintenance of locally adapted populations, to maintain local adaptations and genetic diversity, and to provide individuals from local populations for adaptive reserve management research. Stock will probably also be needed for population augmentation and reintroduction, especially in the Northwest Riverside Recovery Unit. Captive propagation should be established in a manner consistent with our policy on controlled propagation of endangered species (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2000).

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 (Cushman *et al.* 1994) or when environmental conditions are not conducive to larval survival (*e.g.* drought) is recommended, and should not significantly affect metapopulation persistence. Captured females that have already deposited most of their eggs can be induced to produce more eggs than would naturally occur (G. Pratt, pers. comm.). Captive rearing facilities should also include butterfly ranches within the distribution of extant metapopulations where augmentation is deemed necessary. 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.). Continued support should be provided for the captive propagation facilities currently under development at Vista Murrieta High School in Riverside County. Captive rearing should also be implemented in San Diego County as generally described by Dudek and Associates (2001).

Priority 2 Recommendations:

5. Initiate and implement an outreach program to inform the public about the biology of the Quino checkerspot butterfly and the ecological significance of its decline (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 outreach efforts rely on facts derived from research in order to remain unbiased and credible. Integration with biological curricula in local high schools emphasizing scientific ecological methodology and hands-on restoration activities is advised.

> 5.1. Develop and implement the proposed Vista Murrieta High School Project, in the Warm Springs Creek/Murrieta area. Current plans include developing a curriculum focused on the Quino checkerspot butterfly and its native ecology (Helix Environmental Planning 2000). Activities at the on-site captive propagation facility run by University of California, Riverside (see action 4 above) will be integrated into the educational outreach program. Other research activities that may be integrated with the high school curriculum are maintenance and enhancement of occupied habitat adjacent to the high school, and monitoring and possibly augmentation of populations.
>
> 5.2. Initiate a pilot program similar to that proposed for Vista Murrieta High School in the Southwest San Diego Recovery Unit, associated with the San Diego National Wildlife Refuge. An educational outreach program with Steele Canyon High School (adjacent to Refuge parcels

occupied by Quino checkerspot butterflies) has been initiated, but there is no captive propagation component.

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

5.4. Initiate an outreach program with local off-road vehicle clubs and organizations to promote mutual understanding and cooperation in the community for conservation of the Quino checkerspot butterfly and access to managed recreation areas. Emphasize common concerns, such as reduction of open space due to ongoing development and population growth. Work to encourage responsible use and create appropriate designated off-road vehicle activity areas.

6. Conduct biological research needed to refine recovery criteria and guide conservation efforts. Research will not only help to better understand the species, it is also necessary for adaptive management and forms the backbone of the recovery strategy. Some needs are simple, such as habitat mapping, but this type of fundamental information is needed before more complex adaptive management research may proceed. Research is also necessary to develop appropriate delisting criteria.

6.1. Survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity (a possible greater metapopulation distribution). Surveys should be conducted within 7 kilometers (4.4 miles) of recent butterfly observations and within all areas encompassed by recovery units because: 1) The existence of undocumented occupied habitat patches is probable; and 2) current population distributions are greatly reduced relative to historic densities and distributions, and habitat patches that support larval development will be sources of former and future population expansions needed for metapopulation resilience (see metapopulation model estimates in Harrison 1989).

6.2. Map habitat patch distributions associated with occurrence complexes. Areas that need to be mapped include: habitat patches that currently support larval development, suitable or restorable habitat patches not currently occupied by larvae, habitat areas needed for landscape connectivity, and areas where management is needed protect habitat patches from impacts of nearby development. Information gathered concurrently during surveys should include degree of nonnative species invasion and presence of local threats. Habitat mapping should be integrated with more advanced research, such as habitat suitability investigations and population modeling, as soon as possible.

6.3. Monitor ongoing habitat loss and exotic species invasion within mapped critical habitat and occurrence complexes. Because habitat loss due to development, land use changes, and off-road vehicle use is the primary threat to Quino checkerspot butterfly populations, it should be monitored. Although monitoring of butterfly populations is essential and needed to determine the status of the species, it is not enough. Butterfly population monitoring is dependent on the weather and may not be valid some years, is difficult and expensive to do, and is not easy to interpret. Butterfly population decline may also lag behind the threats that cause it. If all the recovery actions and implementation undertaken on behalf of the species do not significantly curtail habitat destruction, then there can be no recovery for the species. Landscape-scale land use changes and off-road vehicle damage can be monitored relatively easily and cheaply through aerial imagery available to us. Historic images should be examined and rate of habitat loss determined and tracked.

Exotic plant invasion is not as simple to monitor as habitat destruction, but species presence, density, and distribution sampling should at least be carried out at monitored, occupied Quino checkerspot butterfly habitat sites. Eventually invasive plant eradication and monitoring should be included in the adaptive management of occupied wildlife reserves for the Quino checkerspot butterfly and other species.

6.4. Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit occurrence complexes. These two recovery units are specified for metapopulation modeling because they contain the greatest amount of current or planned urban and suburban development, are the focus of regional Habitat

Conservation Plans that should soon provide specific Quino checkerspot butterfly management, have established and managed preserves already in place, and contain the core occurrence complexes for which we have the most historic and recent population information.

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 butterfly (Hanski *et al.* 1996, Wahlberg *et al.* 1996). This approach used the incidence function model to predict specific habitat patches crucial to metapopulation resilience (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 butterfly 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 dependent on available data and time constraints for recovery implementation at the time of initiation.

Because habitat quality and local climate vary from the location of one population to another, acreage needed to sustain resilient populations will also vary. Additional assessment and modeling of conditions contributing to population resilience and the 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 (not yet described) metapopulation are not currently available. It is possible that modeling efforts may require extensive additional data on site-specific population and life history characteristics of the Quino checkerspot butterfly. Innovative modeling methods that could help overcome current knowledge gaps and anticipate population outbreaks include multi-valent (fuzzy) logic models based on expert knowledge (*e.g.* Salski 1992, Cao 1995), and self-organized criticality models (*e.g.* Lockwood and Lockwood 1997).

6.5. Investigate the function of hilltops as a resource for Quino checkerspot butterfly populations. It is imperative to demonstrate the nature of hilltop use by the Quino checkerspot butterfly. Answers to this question will help inform reserve design and possibly help us to understand the nature of the species' dispersal tendencies and general population dynamics.

6.6. Investigate the contribution of multiple-year diapause to metapopulation resilience. This crucial question must be answered, because it may be the key to the species' survival. The answer to this question will determine management activities such as how we conduct future monitoring, how we assess population resilience, how we manage fire regimes, and the need for population augmentation.

6.7. Investigate host plant preference and host-related larval development success on a population-by-population basis. Host plant preferences and suitability can affect metapopulation dynamics (Hanski and Singer 2001). Therefore it is important to know what effects the host plant species composition of habitat patches may have on immigration and emigration for population modeling and other management tools.

6.8. Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot butterfly and its host plant. It is scientifically well established that carbon dioxide levels in the atmosphere are increasing, and this increase will have profound ecological effects above and beyond associated global climate change. Although information is accumulating about the effects of elevated carbon dioxide on host plants and insect species, we know little about specific ecosystem-level effects, or possible effects on *Euphydryas editha*. Indirect effects of elevated carbon dioxide, like climate-driven range shifts, are likely to affect not only all aspects of the Quino checkerspot butterfly recovery strategy in the foreseeable future, but also the future of every other native species in southern California.

7. Document or reintroduce a population within the Lake Matthews Population Site in the Northwest Riverside Recovery Unit. The Lake Matthews population site is based on historic observations south of Lake Matthews and remaining

natural areas, primarily within the Lake-Matthews/Estelle Mountain Reserve (Figure 12). Locations likely to be suitable include the Black Rocks area, or near the new landfill to the west. Existence of a population is considered to be crucial for survival of the species, as this area was a historically stable stronghold for the species, and appears to still contain large areas of suitable habitat. If the species cannot be maintained in this area under management, we do not believe it should be downlisted.

8. Reduce firearm use and unauthorized trash dumping in habitat areas. In the South Riverside Recovery Unit, dumping and target shooting are not as destructive, but are just as pervasive in occupied butterfly habitat, as off-road vehicle activity. Dumping is also a problem in the Northwest Riverside Recovery Unit. Such activities that impact Quino checkerspot butterfly populations also reduce the visual attractiveness of natural areas and may encourage further habitat degrading activities.

9. Continue coordination with the Cahuilla Band of Indians. Discussion topics include investigating the extent of Quino checkerspot butterfly population distributions within the Cahuilla Indian Reservation and possible voluntary conservation measures. Assist in development of an environmental management plan for the Cahuilla Indian Reservation.

Priority 3 Recommendations:

10. Survey for habitat and undocumented populations in undeveloped areas outside of recovery units. There may be undocumented Quino checkerspot butterfly populations outside of recovery units that would help to meet recovery criteria, or reestablish landscape connectivity between the northern and southern recovery units.

> 10.1. Between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County, particularly the west slope of the Laguna Mountains, inland hills and valleys, and the slopes of Mount Palomar. The Recovery Team believes it is possible that these areas support one or more undocumented populations of the Quino checkerspot butterfly. These areas may provide landscape connectivity between the northern and southern recovery units.

10.2. Between State Route 94 and Interstate 8 in southern San Diego County. There are several historic collections of Quino checkerspot butterflies in this area, and it may contain undocumented populations. Occupied habitat was documented at two locations just north of State Route 94 in 2001, resulting in the expansion of the final Southwest San Diego Recovery Unit compared to the draft recovery unit (U.S. Fish and Wildlife Service 2001b).

10.3. In possible future recovery units. It is possible that these areas support one or more undocumented Quino checkerspot butterfly populations (see recovery unit descriptions above). Such a population was discovered by chance in 2001, in the easternmost portion of the possible future Central San Diego Recovery Unit (Sproul and Faulkner 2001). Any viable populations discovered in these areas would be considered important to recovery of the species. It is essential that occupancy status is thoroughly investigated in these areas prior to attempts to establish any experimental populations.

10.4. Possible habitat areas in conserved areas of the Santa Ana Mountains and foothills. The large number of historic and current Quino checkerspot butterfly records in this area and surrounding areas indicate it is possible that undocumented extant populations may be found there. The possibility of extant populations in the Santa Ana Mountains is further supported by the presence of scattered areas of open-canopy vegetation and clay soils, a maximum elevation below the maximum elevation documented for Quino checkerspot butterfly populations, and newly documented species of larval host plants that have also been collected in this area.

11. Survey areas not otherwise recommended for surveys that fall within the latest recommended survey area map. There are a number of areas where Quino checkerspot butterfly population distributions, or isolated local populations, may fall outside of areas specifically named above. These areas fall within the recommended survey areas on the latest Quino checkerspot butterfly survey protocol map (U.S. Fish and Wildlife Service 2002c). These areas, although not currently considered to be important for recovery, could still contain occupied habitat. Surveys are important to avoid possible unauthorized take of the

butterfly under section 9 of the Endangered Species Act. Occupied habitat discovered by surveys could also be determined to be important to recovery at a later date, and would be considered if downlisting criteria are revised or delisting criteria are developed.

12. Enter into dialogue with Baja California, Mexico nongovernmental organizations and local governments. Discussion topics include beginning surveys to determine the extent of the West Otay Mountain, Marron Valley, and Jacumba population distributions across the border, and protection and management of landscape connectivity south of Otay Mountain.

D. Preliminary Recommendations for Possible Future Recovery Units

Possible Future Central San Diego Recovery Unit:

- Assess current information on population status in this area (including data from further habitat and butterfly surveys) and determine appropriate recovery unit boundaries, including if it should be two Recovery Units or one, and if it should be two, which unit should contain the San Vicente Reservoir Occurrence Complex.
- Based on analysis of habitat and determination of recovery unit boundaries, develop a draft addendum to the final recovery plan describing one or two new recovery units and an edited step-down narrative and implementation schedule. Submit draft addendum for Recovery Team review and publish for public review and comment.
- Determine the extent of the population distributions associated with the two recently documented occurrence complexes.
- Maintain and restore landscape connectivity between the eastern occupied habitat areas and the western mesa habitat areas.
- Map distribution and assess suitability of habitat.
- Restore vernal pools and other habitat where needed.
- Survey for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density at monitored reference sites. Follow monitoring recommendations in San Vicente Reservoir and Alpine Occurrence Complexes.
- Maintain connectivity with eastern undeveloped areas to reduce indirect impacts of development.

- Determine habitat distribution and landscape connectivity potential in undeveloped areas between the recovery unit and the Laguna Mountains.
- Reintroduce an experimental population somewhere in th western coastal mesa habitat areas.
- Determine what military activities are most likely to affect Quino checkerspot butterfly populations and how best to minimize conflict between population management and essential ongoing military training.

Possible Future Northwest San Diego Recovery Unit:

- Map distribution and suitability of habitat.
- Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density in Riverside County reference populations.
- Determine extent of imported fire ant (*Solenopsis invicta*) invasion and possible conflicts with Quino checkerspot butterfly occupancy.
- Determine extent of landscape connectivity with possible future North Orange Recovery Unit and the eastern slope of the Santa Ana Mountains.
- Determine what military activities are most likely to affect Quino checkerspot butterfly populations and how best to minimize conflict between population management and essential ongoing military training.

Possible Future North Orange Recovery Unit:

- Develop integrated comprehensive Quino checkerspot butterfly management plan for the Fremont Conservation area and adjacent Cleveland National Forest lands within the survey area (U.S. Fish and Wildlife Service 2002c).
- Remove cattle grazing from Black Star Canyon and phase in weed control.
- Restore habitat around Irvine Lake and reintroduce the Quino checkerspot butterflies.
- Determine extent, suitability, and landscape connectivity of habitat along the western slope of the Santa Ana Mountains to the possible future Northwest San Diego Recovery Unit.
- Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density in monitored reference sites.

- Determine extent of imported fire ant (*Solenopsis invicta*) invasion and possible conflicts with Quino checkerspot butterfly occupancy.

III. IMPLEMENTATION SCHEDULE

The schedule that follows is a summary of actions and estimated costs for the Quino checkerspot butterfly recovery program. It is a guide to meet the objectives of the recovery plan as elaborated in Part II, Step-Down Narrative section. This schedule indicates recovery action priorities, action numbers, action descriptions, duration of actions, responsible agencies, and estimated costs. These actions, when accomplished, should achieve the recovery objectives. The estimated costs for some actions remain to be determined, and funding for some actions will come from sources not wholly attributable to the Quino checkerspot butterfly. Our staff salary is not included in cost estimates. Responsible party listings are based primarily on recent (1986 and later) Quino checkerspot butterfly observation site land ownership data, jurisdictional authority, and responsibility for road and highway construction. Cost is not separated by responsible agency; distribution of costs among agencies is to be determined. Listing a party as responsible does not necessarily mean that responsibilities are increased above and beyond prior responsibilities or costs, nor are responsibilities necessarily obligate. The list of responsible parties is not exhaustive.

Please note that costs in the implementation schedule are *estimates* based on the best information available to us, and do not constitute a comprehensive economic analysis of the resources needed to accomplish recovery tasks for the Quino checkerspot butterfly. Actual task costs may be greater or lesser than the estimates provided below.

<u>Definitions and Abbreviations Used in the Implementation Schedule</u>:

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:

ABDSP	Anza Borrego Desert State Park
BCNG	Baja California Norte Government
BLM	Bureau of Land Management
BP	Border Patrol
Caltrans	California Department of Transportation
CBI	Cahuilla Band of Indians
CCL	City of Canyon Lake
CCV	City of Chula Vista
CDF	California Department of Forestry
CDPR	California Department of Parks and Recreation
CLE	City of Lake Elsinore
CM	City of Murrietta
CNF	Cleveland National Forest
CP	City of Perris
CPW	City of Poway
CSD	City of San Diego
CT	City of Temecula
IC	Imperial County
LMEMRMC	Lake Mathews/Estelle Mountain Reserve Management Committee
MCASM	Marine Corps Air Station, Miramar
MCBCP	Marine Corps Base, Camp Pendleton
MNG	Mexican National Government
MVSD	Murrieta Valley Unified School District
NGO	Nongovernmental Organizations
OC	Orange County
PP	Project proponents (unspecified)
PU	Pepperdine University
RC	Riverside County
SBNF	San Bernardino National Forest
SDC	San Diego County
SDNHM	San Diego Natural History Museum
SDSU	San Diego State University
SDZ	San Diego Zoo
TBD	To be determined
TNC	The Nature Conservancy
UCI	University of California, Irvine

UCR	University of California, Riverside (in some cases authorized staff)
UCSD	University of California, San Diego
USD	University of San Diego
USAW Inc.	USA Waste Incorporated
USFWS	U.S. Fish and Wildlife Service
UTA	University of Texas, Austin (authorized staff)
WRMSRMC	Western Riverside County Multiple Species Reserve Management Committee

*	Lead responsible agency
†	Costs of land acquisition and management for the six recovery units are a major component of the cost of recovery, but cannot be reasonably estimated. Total estimated acreage requiring acquisition is approximately 55,000 hectares (135,000 acres), of which approximately 40,000 hectares (100,000 acres) are privately owned. Land acquisition costs vary substantially among and within recovery units, ranging roughly from \$4,000 to \$35,000 per acre, and may change over time in response to zoning changes or the real estate market. Costs of land protection may be reduced through participation in land swaps, habitat conservation plans, conservation easements, management agreements, or other conservation tools. Much of the Quino checkerspot butterfly habitat to be protected under the San Diego County MSCP and Western Riverside County MSHCP will also serve to conserve other cooccurring endangered species and will be funded independently of Quino checkerspot conservation, so the cost of habitat protection is only partially attributable to the Quino checkerspot butterfly.

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.1.	Northwest Riverside Recovery Unit: Protect and manage as much as possible of the habitat that is part of the known historic Gavilan Hills/Lake Mathews population distribution and associated with the Canyon Lake Occurrence Complex, in a configuration designed to support a resilient metapopulation. Develop a Quino checkerspot butterfly management plan for the Lake Mathews/Estelle Mountain Preserve.	Ongoing	USFWS*, LMRMC, RC, BLM, USAW Inc., CLE, CCL, CP, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.2.	Southwest Riverside Recovery Unit: Protect and manage as much of the remaining habitat as possible that is part of the known population distributions, in a configuration designed to support resilient metapopulations. Develop a Quino checkerspot butterfly management plan for Southwest Riverside County Multiple Species Reserve (Lake Skinner) and an additional reserve in the vicinity of Warm Springs Creek. Preserve as much natural area as possible in the French Valley between occurrence complexes.	Ongoing	USFWS*, CDFG, RC, CT, CM, UCR, WRMSRMC, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†
1	1.3.	South Riverside Recovery Unit: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations.	Ongoing	USFWS*, RC, BLM, CNF, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN

Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.4.	<u>South Riverside/North San Diego Recovery Unit</u>: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations.	Ongoing	USFWS*, BLM, RC, SDC, PU, CBI, CNF, SBNF, NGOs	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]
1	1.5.	<u>Southwest San Diego Recovery Unit</u>: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations. Specifically, surrounding Otay Mountain, east through Tecate Peak, and north through Proctor Valley.	Ongoing	USFWS*, BLM, SDC, CCV, CDFG, CDF, CSD, NGOs, BP	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]
1	1.6.	<u>Southeast San Diego Recovery Unit</u>: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within the recovery unit, especially south of Interstate 8.	Ongoing	USFWS*, SDC, ABSP, BLM, NGOs, BP	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.7.1.1.	Intensive restoration of agricultural and grazed areas or otherwise degraded habitat in the Southwest San Diego Recovery Unit.	13	USFWS*, SDC, CSD, CCV, CDFG	67,600	20	30	25,000	21,000	8,000
1	1.7.1.2.	Intensive restoration of agricultural areas and degraded habitat in the Southwest Riverside Recovery Unit	15	USFWS*, RC, CT, CM	71,000	0	20	40	29,000	23,000
1	1.7.2.	Remove cattle or sheep and phase in weed control where habitat is currently grazed.	5	USFWS*, BLM, SBNF, CSD	28	8	8	6	4	2
1	2.	Continue yearly reviews, monitoring as needed as part of adaptive management until there is evidence that populations associated with core occurrence complexes are resilient.	16	USFWS*, CDFG, SDC, RC	192	12	12	12	12	12
1	3.	Assess and augment lowest density populations as needed to help establish resilience.	TBD	USFWS*, CDFG, SDC, RC	15+	5	5	5	TBD	TBD
1	4.	Establish and maintain a captive propagation program.	Ongoing	USFWS*, MVSD UCR, Caltrans, UTA	490	40	30	30	30	30

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN

Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's) FY 03	FY 04	FY 05	FY 06	FY 07
2	5.1.	Develop and implement the proposed Vista Murrieta High School educational outreach project (Helix 2000), in the Warm Springs Creek/Murrieta area.	Ongoing	USFWS*, UCR, MVSD	2	1	1			
1052	5.2.	Initiate an educational outreach similar to that proposed for Vista Murrieta High School in the Southwest San Diego Recovery Unit, associated with the San Diego National Wildlife Refuge Complex.	Ongoing	USFWS*, NGOs	48	3	3	3	3	3
2	5.3.	Initiate further cooperative outreach efforts with local nongovernmental organizations, educational institutions, and local museums.	Ongoing	USFWS*, NGOs, SDNHM, SDSU, USD, SDSU, UCR, UCSD, UCI, SDZ	32	2	2	2	2	2
2	5.4.	Initiate a outreach program with local off-road vehicle clubs and organizations to promote mutual understanding and cooperation in furthering conservation of the butterfly.	6	USFWS*, RC, BLM, NGOs	9	1	2	3	1	1
2	6.1.	Survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity.	6	USFWS*, RC, SDC, BLM, SBNF, CNF, PP	140	25	35	35	25	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	6.2.	Map habitat patch distributions associated with occurrence complexes.	10	USFWS*, SDC, RC, CDFG	94	6	8	10	10	10
2	6.3.	Monitor ongoing habitat loss and exotic species invasion within mapped critical habitat and occurrence complexes.	Ongoing	USFWS*, SDC, RC, CDFG	168	12	12	12	12	10
2	6.4.	Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit occurrence complexes.	2	USFWS*, SDC, RC	22	0	10	12	0	0
2	6.5	Investigate the function of hilltops as a resource for Quino checkerspot butterfly populations.	4	USFWS*, SDC, RC	32	0	8	8	8	8
2	6.6.	Investigate the contribution of multiple-year diapause to metapopulation resilience.	8	USFWS*, SDC, RC	48	0	6	6	6	6
2	6.7.	Investigate host plant preference and host related larval development success on a population-by-population basis.	4	USFWS*	32	0	8	8	8	8
2	6.8.	Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot butterfly and its host plant.	10	USFWS*	150	15	15	15	15	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	7.	Document or reintroduce a population within the Lake Matthews Population Site in the Northwest Riverside Recovery Unit.	TBD	USFWS*, RC, LMEMRMC	12+	4	4	4	TBD	TBD
2	8.	Reduce firearm use and unauthorized trash dumping in habitat areas.	6	USFWS*, BLM, RC, SDC, NGOs	200	50	50	40	30	20
2	9.	Continue dialogue with the Cahuilla Band of Indians.	Ongoing	USFWS*, CBI	19	2	2	2	1	1
3	10.1.	Survey for habitat and undocumented populations between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County.	6	USFWS*, SDC, CNF, SDSU, PP	120	20	30	30	20	10
3	10.2.	Survey for habitat and undocumented populations between State Route 94 and Interstate 8 in southern San Diego County.	6	USFWS*, SDC, CNF, CDFG, BLM?, PP	120	20	30	30	20	10
3	10.3.	Survey for habitat and undocumented populations in possible future recovery units.	6	USFWS*, SDC, OC, USMCCP, USMCASM, CSD, PP	140	25	35	35	25	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
3	10.4.	Survey for habitat and undocumented populations in the Santa Ana Mountains and foothills.	6	USFWS*, OC, RC, CLE, TNC, SDSU	120	20	30	30	20	10
3	11.	Survey areas not otherwise recommended for surveys that fall within the latest recommended survey area map.	Ongoing	USFWS*, SDC, RC, OC, USMCCP, USMCASM, IC, CSD, CCV, CPW, CT, CM, CLE, CCL, SBNF, CNF, ABDSP, BLM, CDFG, PP	165	20	30	30	20	10
3	12.	Enter into dialogue with Baja California, Mexico, nongovernmental organizations and local governments.	Ongoing	USFWS*, MG, BCNG, NGOs	19	2	2	2	1	1

Total Estimated Cost of Recovery Through Fiscal Year 2018: $140,990,000 + additional costs that cannot be determined at this time.

IV. 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.

Anderson, A. 2000. Year 2000 Quino checkerspot butterfly (*Euphydryas editha quino*) population densities and likelihood of detection by adult focused protocol surveys. Internal report to Carlsbad Fish and Wildlife Office, Carlsbad, CA.

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, Florida.

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

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.4. 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 Food and Agriculture. 1999. California Action Plan: Red Imported Fire Ant. California Department of Food and Agriculture, Sacramento, California.

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

Cao, G. 1995. The definition of the niche by fuzzy set theory. Ecological Modeling 77:65-71.

Chuang, T.I. and L.R. Heckard. 1986. Systematics and evolution of *Cordylanthus* (Scrophulariaceae-Pedicularieae): *Cordylanthus rigidus*. Systematic Botany Monographs 10:34-48.

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

Coronado, M. 2003. Economist sees movement east. In: The Press-Enterprise. Riverside, California. July 17, 2003.

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 host plant phenology. Oecologia 99:194-200.

Dudek and Associates. 2001. Modified Captive Propagation Program Related to the Restoration of Quino Checkerspot Butterfly on Otay Mesa. Prepared for California Transportation Ventures, Inc. Submitted to Carlsbad Fish and Wildlife Office, Carlsbad, California.

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.

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., and D. D. Murphy. 1987. Conservation lessons from long-term studies of checkerspot butterflies. Conservation Biology 1:122-131.

Ehrlich, P.R. and D. Wheye 1986. Non-adaptive "hilltopping" behavior in male checkerspot butterflies (*Euphydryas editha*). American Naturalist 124:527-539.

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.

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.

Emmel, T.C., and J.F. Emmel. 1973. The butterflies of southern California. Natural History Museum of Los Angeles County, Science Series No. 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.

Environmental Protection Agency. 2001. Global Warming Impacts; State Impacts-California. http://yosemite.epa.gov/oar/globalwarming.nsf/content /ImpactsStateImpactsCA.html.

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. 1989. The effects of enriched carbon dioxide atmospheres on plant-insect herbivore interactions. Science 243:1198-1200.

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, England. 313 pp.

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.

Hanski, I. and M.C. Singer. 2001. Colonization and oviposition preference in butterfly metapopulations. American Naturalist 158:341-353.

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.

Hickman, J. (editor). 1996. The Jepson Manual: Higher Plants of California.. University of California Press, Berkeley, California.

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., R.W. Knight, D.R. Easterling, and R.G. Quayle, 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, and H.A. Mooney 1987. Gopher mound soil reduces growth and affects ion uptake of two annual grassland species. Oecologia 72:284-290.

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.

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, California.

Lockwood, J.A. and L.D. DeBrey. 1990. A solution for the sudden and unexplained extinction of the Rocky Mountain grasshopper, *Melanoplus spretus* (Walsh). Environmental Entomology 19:1194-1205.

Lockwood, D.R. and J.A. Lockwood. 1997. Evidence of self-organized criticality in insect populations. Complexity 2:49-57.

Ludwig, D., B. Walker, and C.S. Hollig. 1997. Sustainability, Stability, and Resilience. Conservation Ecology [Online] 1:7. (Available at: http://www.consecol.org/vol1/iss1/art7).

Mackay, D. A. 1985. Pre-alighting 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 Modeling 27:271-283.

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.

Mattoni, R., T. Longcore, C. Zonneveld, and V. Novotny. 2001. Analysis of transect counts to monitor population size in endangered insects: the case of the El Segundo blue butterfly, *Euphilotes bernardino allynii*. Journal of Insect Conservation 5:197-206.

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

Minnich, R. A. 1988. The biogeography of fire in the San Bernardino Mountains of California. University of California Publications in 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. University of California Press, Berkeley, California.

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 P.R. Ehrlich. 1980. Two California checkerspot butterfly subspecies: One new and one on the verge of extinction. Journal of the Lepidopterists Society 34:317-320.

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.

Naheed, F.S. Chapin III, R. Costanza, P.R. Ehrlich, F.B. Golley, D.U. Hooper, J.H. Lawton, R.V. O'Neill, H.A. Mooney, O.E. Sala, A.J. Symstad, and D. Tilman. 1999. Biodiversity and ecosystem functioning: maintaining natural life support processes. Ecological Society of America Issues in Ecology No. 4.

National Academy of Sciences. 2001. Climate change science: An analysis of some key questions. Report to the White House (available at www.nas.edu).

National Climatic Data Center. 2002. Climate of 2002 - June: U.S. Drought. NOAA/NCDC monthly report (available at http://lwf.ncdc.noaa.gov/oa/climate/research/2002/jun/us-drought.html).

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

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. Pp. 58-75 *in*: J. Moreno and W. Oechel (eds.) Global Change and Mediterranean-Type Ecosystems. Ecological Studies 117.

Orange County Water District. 2001. Orange County Water District History Available online at: (www.ocwd.com/_html/history.htm).

Orsak, L.J. 1978. The butterflies of Orange County, California. Museum of Systematic Biology: Research Series No. 4. University of California, Irvine, California.

Osborne, K. 2001. Observations of *Euphydryas editha quino* made on April 16, 2001 in the vicinity of Lake Skinner. Submitted to U.S. Fish and Wildlife Service, Carlsbad Fish and Wildlife Office. 24 Hour Survey Report # 8.

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 in southern California. Atmospheric Environment 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., 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.

Paulson, R.W., Chase, E.B., Roberts, R.S., and Moody, D.W. 1989. National Water Summary 1988-89-- Hydrologic Events and Floods and Droughts: U.S. Geological Survey Water-Supply Paper 2375.

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. 1999. The Quino checkerspot 1998-99 report. Biology, behavior, and present known geographic range of the checkerspot butterfly, *Euphydryas editha quino*. Submitted to the Carlsbad Fish and Wildlife Office, Carlsbad, California.

Pratt, G. 2000. Silverado Ranch Survey 2000: Survey and Monitoring of the Quino checkerspot. Report submitted to the Carlsbad Fish and Wildlife Office. California Dept. of Fish and Game Account title CDFG Fg7182ES LUCK 6/98. Submitted to the California Dept. of Fish and Game.

Pratt, G. 2001. The Quino checkerspot: Its biology and life history. Final Section 6 grant research report submitted to the California Dept. of Fish and Game, account title CDFG Fg7182ES LUCK 6/98.

Pratt, G. F., E. W. Hein, and D. M. Krofta. 2001. Newly discovered populations and food plants extend the range of the endangered Quino checkerspot butterfly, *Euphydryas editha quino* (Nymphalidae) in southern California. J. Lep. Soc. 55:169-171.

Rahn, K. 1979. *Plantago* ser. *gnaphaloides* Rahn, A taxonomic review. Botanisk Tidsskrift 73:137-154.

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.

Real, L.A., and J.H. Brown. 1991. Foundations of Ecology: Classic Papers with Commentaries. The University of Chicago Press, Chicago, Illinois. 905 pp.

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.

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.

Salski, A. 1992. Fuzzy knowledge-based models in ecological research. Ecological Modeling 63:103-112.

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. Pp. 276-296 in: Behavioral Mechanisms in Evolutionary Ecology, L. Real (ed). University of Chicago Press, Chicago, Illinois.

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., 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., 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 Behavior 44:463-471.

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.

Sproul, F.T, and D. Faulkner. 2001. Foster Canyon Quino Checkerspot Butterfly Report. Submitted to U.S. Fish and Wildlife Service, Carlsbad Fish and Wildlife Office. Survey Report # 1113.

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

Strong, D.R. 1986. Density-vague population change. Trends in Ecology and Evolution 1:29-31.

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

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

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

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

Thomas, J.N., M.C. Singer, and D.A. Boughton. 1996. Catastrophic extinction of population sources in a butterfly metapopulation. Am. Nat. 148:957-975.

Thompson, D.M. 1988. Systematics of *Antirrhinum* (Scrophulariaceae) in the New World. Systematic Botany Monographs 22:1-142.

U.S. Fish and Wildlife Service. 1983a. Endangered and threatened species: Listing and recovery priority guidelines. Federal Register 48:43098-43105. September 21, 1983.

U.S. Fish and Wildlife Service. 1983b. Endangered and threatened species: Listing and recovery priority guidelines correction. Federal Register 48:51982. November 15, 1983.

U.S. Fish and Wildlife Service. 1997a. Endangered and threatened wildlife and plants: Determination of endangered status for the Laguna Mountains skipper and Quino checkerspot butterfly. Federal Register 62:2313-2322. January 6, 1997.

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 the Assessment District 161 Subregional Habitat Conservation Plan, Western Riverside County (1-6-01-F-725.2). Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service. 2001a. Endangered and threatened wildlife and plants: Proposed designation of critical habitat for the Quino checkerspot butterfly (*Euphydryas editha quino*). Federal Register 66:9475-9507. February 7, 2001.

U.S. Fish and Wildlife Service. 2001b. Draft recovery plan for the Quino checkerspot butterfly (*Euphydryas editha quino*). Portland, Oregon. x + 123 pp.

U.S. Fish and Wildlife Service. 2001c. Notice of availability of a draft recovery plan for the Quino checkerspot butterfly for review and comment. Federal Register 66:9592-9593. February 8, 2001.

U.S. Fish and Wildlife Service. 2002a. Endangered and threatened wildlife and plants: Designation of critical habitat for the Quino checkerspot butterfly (*Euphydryas editha quino*). Federal Register 67:18355-18395. April 15, 2002.

U.S. Fish and Wildlife Service. 2002b. News Release: U.S. Fish and Wildlife Service Awards $68 million in grants to 16 States for Endangered Species Habitat Conservation Planning and Habitat Acquisition Projects. Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service. 2002b. Quino Checkerspot Butterfly *(Euphydryas editha quino*): Survey Protocol Information. Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service. 2002c. Quino Checkerspot Butterfly *(Euphydryas editha quino*): Survey Protocol Information. Carlsbad Fish and Wildlife Office, Carlsbad, California.

U.S. Fish and Wildlife Service 2003. Quino checkerspot butterfly monitored reference site information. Carlsbad Fish and Wildlife Office, Carlsbad, California. http://carlsbad.fws.gov/Rules/QuinoDocuments/Quino_htms/Flight_Info_2003.htm. Updated May 13, 2003.

U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration. 2000. Policy regarding controlled propagation of species listed under the Endangered Species Act. Federal Register 65:56916-56922. September 20, 2000.

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.

Wahlberg, N, T. Klemetti, V. Selonen, I. Hanski. 2002. Metapopulation structure and movements in five species of checkerspot butterflies. Oecologia 130:33-43.

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. 1986. Pupal mortality in the bay checkerspot butterfly (Lepidoptera: Nymphalidae). Journal of Research on the Lepidoptera 25:52-62.

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.

Zonneveld, C., T. Longcore, and C. Mulder. In press. Optimal schemes to detect presence of insect species. Conservation Biology.

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Winter, K. Cleveland National Forest, U.S. Forest Service. Rancho Bernardo, California.

C. *In Litt*. References

Anderson, A. 2003. Evidence for Metapopulation Dynamics of the Quino Checkerspot Butterfly and Possible Extinction Thresholds. White Paper, Carlsbad Fish and Wildlife Office, U.S. Fish and Wildlife Service. Carlsbad, California.

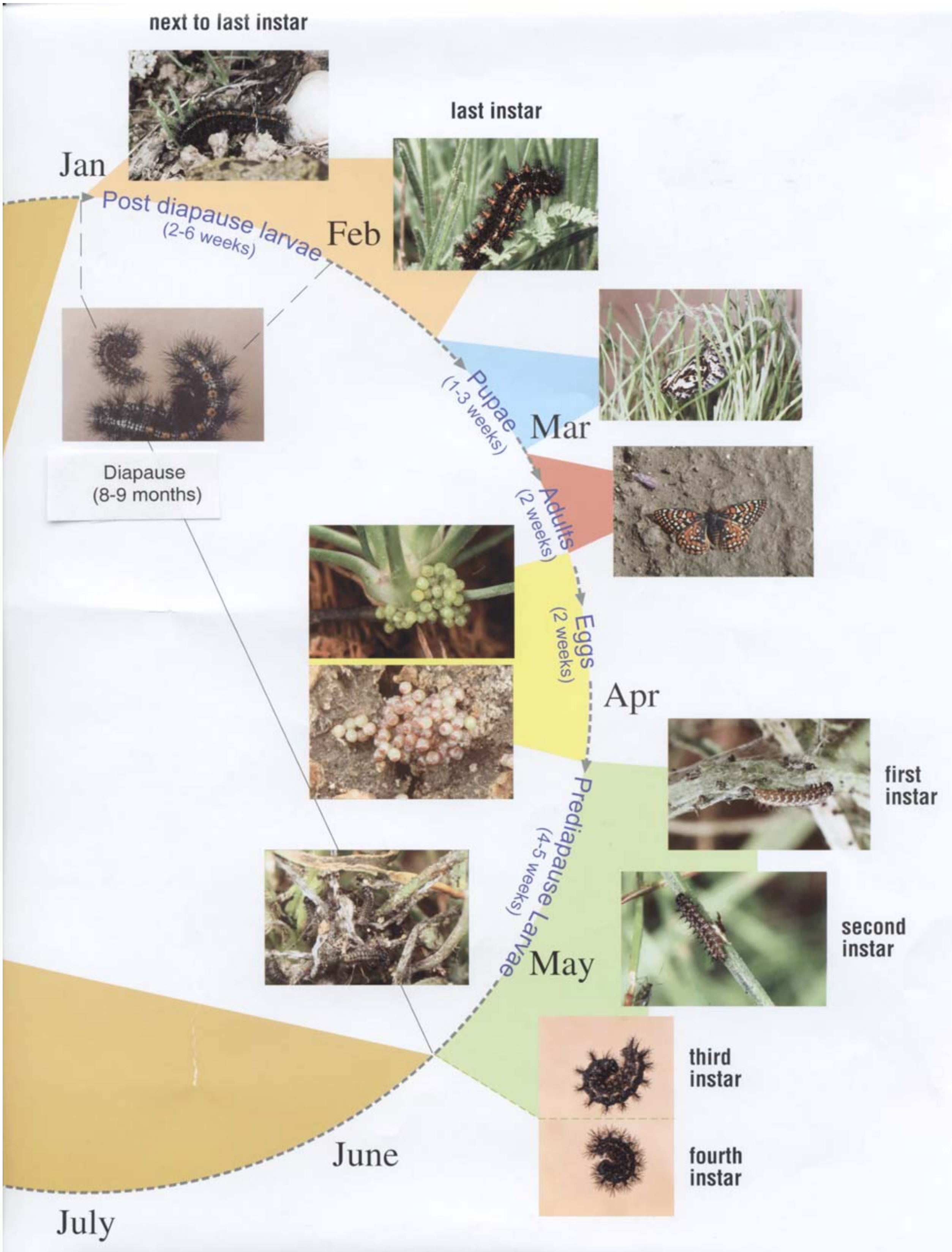
Hein, E. 2003. E-mail message to Alison Anderson regarding trade in Quino checkerspot specimens. U.S. Fish and Wildlife Service. April 7, 2003.

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 depicts a typical Quino checkerspot butterfly 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.



next to last instar
last instar
Jan
Post diapause larvae
(2-6 weeks)
Feb
Diapause
(8-9 months)
Pupae
(1-3 weeks)
Mar
Adults
(2 weeks)
Eggs
(2 weeks)
Apr
first instar
Prediapause Larvae
(4-5 weeks)
second instar
May
third instar
fourth instar
June
July

APPENDIX II

Habitat Restoration Methods

Prepared by Mark Dodero, RECON, Inc.

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 habitat occupied by larvae; 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 Habitat Occupied by Larvae

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 butterfly 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 butterfly 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 butterfly 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 *Lasthenia* (goldfields) and *Plantago* (plantain), which may be locally rare because of nonnative plant competition, may require population augmentation and careful hand removal of nonnatives.

Restoring Habitat not Occupied by Larvae, 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 butterfly 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 butterfly 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 butterfly restoration project. Pollinators are required to ensure that Quino checkerspot butterfly 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 butterfly 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 *Plantago erecta* (dwarf plantain), *Lasthenia* sp.(goldfields), 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 butterfly restoration efforts because Quino checkerspot butterfly 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 butterfly habitat restoration is to enhance nectar resources specifically used by Quino checkerspot butterflies, 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 *Lasthenia* sp. (goldfields) and *Layia* sp. (tidy tips), which flower in early spring; *Grindelia* sp. (gumplant), which flowers later but overlaps with goldfields; and other herbs such as *Hemizonia* sp. (tarplants) and shrubby species such as *Isocoma* sp. (goldenbush), 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 *Selaginella cinerascens* (ashy spike-moss) 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 butterflies. 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 butterflies. 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 butterflies. 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 the Quino checkerspot butterfly, can also provide food for termites that are the primary food source for orange-throated whiptail lizards (*Cnemidophorus hyperythrus*), 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 butterfly 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 butterfly 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 the Quino checkerspot butterfly have been successful.

<u>De-thatching and Herbicide Spraying</u>

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 butterflies. 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 butterfly 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 butterfly 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 *Plantago* (plantain) and *Lasthenia* (goldfields), which are important to Quino checkerspot butterflies. Shrubs, including *Artemisia californica* (California sagebrush), 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 butterfly restoration project because areas intended for the species 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 butterflies. Long-term needs of the butterfly must be considered in the restoration planning process. For example, a site that appears suitable for Quino checkerspot butterflies 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 butterfly 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 butterfly 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 butterfly restoration sites, so that they don't dominate the vegetation. Until the appropriate Quino checkerspot butterfly larval food and adult nectar plants are fully established, monitoring and control of aggressive native species may be required in addition to controlling nonnative plants. Rapid succession from an open-ground habitat to a dense shrub-dominated community can exclude the species' 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 butterfly 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.

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?

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The Quino checkerspot butterfly 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 Vizcaino 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 nonnative plants 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. Although pockets of remnant forblands with lower levels of nonnative invasion can be found in bottomland areas of western Riverside County (*e.g.* an approximately 0.4-ha [1-acre] poppy field in Kabian park, north of Railroad Canyon Reservoir), these areas are rapidly disappearing (A. Anderson pers. observ. 2000). Unfortunately it is possible that in some areas where nonnative plant invasion is slowest and remnant forbland components persist (*i.e.* where semiarid soils dry quickly), host plants may not remain edible long enough to support larvae to maturity. *Plantago erecta* (dwarf plantain) 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 *P. erecta* is restricted to clay soils, 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. University of California Press. Berkeley, California.

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

Cryptogamic crust: A tightly bound mesh of various cyanobacteria, lichens, mosses, and fungi holding the soil down. These crusts prevent soil erosion and provide a hospitable environment for germinating plants. They were probably the first land-based communities of life.

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

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

Extinction: Global disappearance of a species or subspecies.

Extirpation: Disappearance of a 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 host plants and other required resources, then one habitat patch may effectively become two or more with intervening areas becoming dispersal 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.

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 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: An immature butterfly, a caterpillar.

Larval host plant: Any plant that caterpillars consume.

Levins-style metapopulation: A theoretical metapopulation in which each local population has an equal probability of extinction. Each habitat patch is equally likely to provide immigrants for recolonization of neighbor patches temporarily not supporting larval development, and therefore is equally important. The likelihood of metapopulation extirpation is equally increased for each habitat patch rendered permanently unsuitable. The model assumes that habitat patches are equally connected to each other, and departure from this model occurs whenever patches are fundamentally different in quality (*e.g.* size, host plant density), or distribution of patches is clumped in space.

Mainland-island metapopulation: A metapopulation containing one or more very large habitat patches/populations (the mainland) with a lower risk of extirpation, and other, smaller (island) habitat patches/populations with higher individual risks of extirpation than the mainland population due to their size. This type is slightly different from the "source-sink" model, in that island populations can have the same growth rates and rates of immigration and emigration per unit habitat patch area as the mainland patch. Island populations may be collectively just as important to metapopulation persistence as the mainland population is, and they are likely to serve as sources.

Metapopulation: A population that is composed of a number of local populations. Interaction of individuals among local populations is reduced compared to interaction within local populations. Individuals interact among local populations just enough to reduce the extinction probability of the metapopulation compared to the extinction probability of any local population. In this case interaction specifically refers to emigrants re-colonizing neighboring habitat patches where the local population has been extirpated, and not simply occasional exchange of genetic material.

Metapopulation distribution: The maximum long-term "footprint" of a metapopulation, comprising the area covered by a network of habitat patches (both supporting and temporarily not supporting larval development), and including all the habitat patches that could support larval development over an approximate time-scale of 50 years. It is assumed that long-term mainland-island metapopulation resilience requires butterfly densities to periodically reach their maximum distribution, and therefore the maximum number of habitat patches supporting larval development. Short-term mainland-island metapopulation distributions will tend to fluctuate as much in size as in shape. Levin's-style metapopulations will generally maintain a constant number of habitat patches supporting larval development, therefore the approximate size of the extant distribution will remain constant, but not the shape. The location of habitat patches occupied by larvae will shift from year to year, changing the shape of the short-term distribution over time, but the long-term metapopulation distribution does not change. Both metapopulation models (Levin's and mainland-island) are opposite extremes of the theoretical continuum, and the dynamics/distribution of most metapopulations fall somewhere in-between the two. Local populations within a metapopulation distribution may exhibit dynamics of all three models, Levin's, mainland-island, and source-sink. For example, a distribution may contain one large habitat patch with a local population that has a low probability of extirpation and emigration exceeds immigration, a cluster of habitat patches with equal, intermediate rates of local population extirpation (immigration is equal to emigration), and several habitat patches with high rates of extirpation where immigration exceeds emigration.

Mortality sink: Any location where butterflies experience a high death rate, often, but not necessarily attractive to adults. Examples of mortality sinks include roads that fragment habitat patches, or patches of host plant that are regularly grazed. Different from habitat patches that support local sink populations within source-sink metapopulations. Sink populations are defined by emigration and immigration rates.

Occurrence complex: A spatially clustered set of confirmed Quino checkerspot butterfly observation or collection records that delineate putative short-term pan-mictic population or metapopulation distributions. We used 1-kilometer (0.6-mile) radii around confirmed observations to map occurrence complexes. This distance delineates the area within which we would expect to find the habitat patch associated with the observed butterfly (Gilbert and Singer 1973, Harrison *et al.* 1988, Harrison

1989). Occurrences within 2 km (1.2 mi) of each other are considered to be part of the same occurrence complex because such observations are proximal enough that the observed butterflies would have come from the same population (Ehrlich and Murphy 1987, Harrison *et al.* 1988, Harrison 1989).

<u>Pan-mictic population:</u> A population inhabiting a single isolated (possibly very large) habitat patch, where all individuals have an equal probability of interaction. Although habitat elements (*e.g.* larval host plants) and larval residents may be patchily distributed, adults are able to move freely and frequently between them within a season (definition of a habitat patch based on butterfly use and genetic exchange).

<u>Population distribution</u>. See also Metapopulation Distribution. The maximum long-term "footprint" (geographic area occupied at any time over approximately 50 years) of a pan-mictic population or metapopulation, as delineated and verified by research and monitoring. Occurrence complexes serve as preliminary estimates of population or metapopulation distribution boundaries.

<u>Population site</u>: An area (e.g., vicinity of Lake Mathews) where we have at least strong qualitative information indicating that good habitat remains, and there was a well-documented historic population as recently as the 1980's, but where we have no recent occurrences to use to map an occurrence complex. By comparison, in occurrence complexes recent occupancy (1990's or later) is certain. Re-introduction is necessary to recover the species.

<u>Primary host plant species</u>: Species of host plant on which adult female butterflies deposit eggs, and that caterpillars consume when they hatch.

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

<u>Resilience:</u>

- In general, the ability of a Quino checkerspot butterfly metapopulation or population to survive periodic extreme and unpredictable environmental circumstances and persist long-term (50+ years) in an ecosystem not compromised by human impacts.

- Resilient Quino checkerspot butterfly populations are characterized by the potential to rapidly increase in density under favorable conditions after being seriously reduced, and the ability to continue diapause and/or disperse to more favorable habitat patches when their natal one becomes too densely occupied or otherwise unfavorable. Dispersal events primarily serve to recolonize habitat patches where local populations were extirpated by catastrophic events such as fire, or prolonged unfavorable environmental conditions. Diapause allows local populations to persist in habitat patches that are not favorable for less prolonged periods (maximum number of years unknown). For a general explanation of ecological concepts from which this characterization was derived see Strong (1986).
- For recovery monitoring purposes resilience is demonstrated if a decrease in the number of habitat patches supporting larval development (as demonstrated by adult delectability) within a occurrence complex or population (metapopulation or pan-mictic population) is followed by increases of approximatly equal, or greater, magnitude over a 15-year period without augmentation, or over a 10-year period with augmentation. The percent of patches that are occupied should be estimated by surveys in a sample of no less than 50 percent of the total number of habitat patches identified within a population distribution. Occupancy for the purpose of population resilience monitoring must include adults (reproductive individuals) and pre-diapause larval clusters (their offspring). The surveyed sample of habitat patches must be distributed as equally as possible across a metapopulation distribution to avoid error from possible correlation of suitability between proximal patches.

<u>Secondary host plant species</u>: Species of host plants that caterpillars consume, but on which adult female butterflies do not deposit eggs.

<u>Source-sink metapopulation:</u> A metapopulation composed of local populations, one or more of which are sources of colonization for other, usually dependent, sink populations. In source populations, emigration exceeds immigration, in sink populations, immigration exceeds emigration, and the sink populations are dependent, at least intermittently, on source populations to maintain a nonnegative growth rate. It would be a mistake to assume source populations are more stable, as the status of local populations can change and may even be reversed over time, as changing environmental or density-dependent factors alter the growth rates of

local populations. Even if immigration exceeded emigration in a sink, as long as they produce some emigrants, they may recolonize neighboring habitat patches (they are just less likely to do so than source populations). Only complete mortality sinks, habitats that always attract dispersing individuals that would otherwise colonize more suitable habitat, and do not produce emigrants capable of colonizing neighboring habitat patches, are likely to reduce rather than enhance metapopulation resilience.

APPENDIX V
Unconfirmed Quino Checkerspot Butterfly Observations

Some Quino checkerspot butterfly observations have been reported that, although they were convincing, were not accompanied by enough evidence to be considered conclusive. To be considered conclusive, reports must be made by a biologist permitted to survey for Quino checkerspot butterflies, and be in the general proximity of previously confirmed recent (1990's) Quino checkerspot populations (*e.g.* within recovery units). If observations do not meet the above criteria, evidence such as concurrent or subsequent observations by another permitted biologist or a photograph and field notes must have been provided (*e.g.* the San Vicente Reservoir Occurrence Complex discovered in 2001). Three unconfirmed reports are worth mentioning in particular. In 1992 (pre-listing) a now-permitted biologist reported observing what he believes was a Quino checkerspot butterfly on a hilltop north of San Vicente Reservoir (Pacific Southwest Biological Services 1993, D. Mayer, pers comm. 2003). The reported San Vicente Reservoir observation was located on the southern border of the San Vicente Reservoir Occurrence Complex (Figure 8). In 1999 a permitted U.S. Fish and Wildlife Service staff biologist reported having observed a Quino checkerspot butterfly in the northern region of Sycamore Canyon Open Space Preserve, south of the city of Poway (M. Van Hoffman, pers. comm. 1999). The reported Sycamore Canyon observation was approximately 1 kilometer (0.6 mile) east of the San Vicente Reservoir Occurrence Complex (Figure 8). Also in 1999 a non-permitted biologist who had correctly identified photographs of larvae reported larvae in the Harmony Grove area west of Escondido (C. Hertzog pers comm. 1999). In all cases no photographic documentation was provided, and subsequent searches by permitted biologists in the vicinities did not result in further observations.

<u>Literature Cited</u>

Pacific Southwest Biological Services. 1993. San Diego County Water Authority Emergency Water Storage Project Biological Resource Assessment. Prepared for The San Diego County Water Authority, San Diego, California.

Personal Communications

Hertzog, C. 1999. Biologist.

Mayer, D. 2003. California Department of Fish and Game. San Diego, California.

VanHoffman, M. 1999. U.S. Fish and Wildlife Service. Carlsbad, California.

APPENDIX VI
Summary of Comments

On February 8, 2001, we released the Draft Quino Checkerspot Butterfly Recovery Plan for a 45 day public comment period that ended March 26, 2001, for Federal agencies, State and local governments, and members of the public (U.S. Fish and Wildlife Service 2001c). Comments were received from three expert biologists, two Federal agencies, four local agencies, four businesses, and one private party. These comments, where appropriate, have been incorporated into the final recovery plan. Many of the comments requested that information from the 2001 Quino checkerspot butterfly flight season be considered and incorporated into the final plan. Much relevant biological information was gathered during the 2001 flight season, and additional biological information not related to the 2001 flight season was also gathered and analyzed. All new information gathered since draft recovery plan publication has been fully considered and incorporated into the final plan; most changes were related to new information. We feel that some comments require a fuller response and explanation, to this end we offer the following responses to comments.

Issue 1: Two commenters thought the plan gave the impression that rare long-distance dispersal and colonization events were not important to the biology of the butterfly, and that closed-canopy woody vegetation presented an impermeable barrier to dispersal. One commenter stated that the importance and possible frequency of long-distance (5-10 km) dispersal events needed to be clearly stated in the plan. He thought there was evidence that Quino checkerspot butterflies semi-regularly, both in the course of aging and under certain environmental conditions, undergo behavioral shifts and enter long-distance dispersal modes.

Service Response: We concur that long-distance dispersal and colonization events probably play important roles in long-term butterfly metapopulation dynamics and persistence, and the degree of rarity of such events has not been quantified. We also concur that closed canopy woody vegetation and similar structures present only dispersal deterrents and not impermeable barriers. As a result the text has been changed to correct any false implications.

Issue 2: One commenter suggested that hilltopping behavior plays a critical role in reproductive success of the Quino checkerspot butterfly, and therefore in its population ecology and conservation planning. He felt the role of this behavior should be stated in the recovery plan, with reduced emphasis on other hypotheses for frequency of butterfly observations on hilltops.

Service Response: We believe that disagreement within the scientific community on the subject of hilltopping stems primarily from the technical definition of the words "hilltopping behavior," and not the use of hilltops as a means of locating mates. Edits were made to better emphasize the nature and importance of hilltops as a resource for the Quino checkerspot butterfly.

Issue 3: The same commenter felt that the threat of global warming was accurately presented, but was given too much weight compared to urban growth and development.

Service Response: We believe sufficient emphasis is given in the plan to threats presented by urban growth and development, and global warming is a future, if not current, threat to the Quino checkerspot butterfly potentially equal to and exacerbated by habitat destruction. We edited the text to better explain current knowledge of the threat of global warming, and added suggestions for how to begin addressing local recovery actions and planning. In most cases recovery actions addressing global warming effects are the same as or reinforce those addressing habitat destruction and development.

Issue 4: Three commenters appeared to have confused the definitions and regulatory implications of recovery units and critical habitat. They thought lands that did not contain habitat should be excluded from areas mapped as recovery units. They were concerned that inclusion of land within a recovery unit meant that land was considered butterfly habitat, and established regulatory protection of the mapped land. One commenter thought that we mapped recovery unit boundaries with the intent of imposing greater regulatory burdens and heightened land use scrutiny within those areas.

Service Response: Recovery plans and recovery units are not regulatory in nature, and are separate from critical habitat designation, which is regulatory. As part of the unique criteria for defining proposed critical habitat for the Quino checkerspot butterfly, mapped areas of possible critical habitat were limited to within mapped draft recovery unit boundaries (U.S. Fish and Wildlife Service 2002a). Therefore, draft recovery unit boundaries limited the total area proposed as critical habitat to those areas that were the focus of draft recovery actions. All other proposed critical habitat criteria were not related to mapped recovery unit boundaries, other than coincidentally. Recovery units do not have hard outer geographic boundaries, unlike critical habitat, and are only partially habitat based. Recovery units in this plan define areas that are the focus of any recovery action, including urban-wildland interface areas that are the focus of educational outreach and cross-boundary management actions. All mapped potential critical habitat should be within recovery units, but not all mapped recovery unit areas are potential critical habitat. Heightened regulatory scrutiny was intended only where regulatory scrutiny is currently inadequate. It was not our intent to create unjustified or redundant regulatory or economic burdens on landowners.

Issue 5: One commenter felt the plan emphasized habitat restoration over preservation, and that this emphasis should be reversed. They said that the plan assumed that a highly manipulated environment will be as suitable for re-colonization by the Quino checkerspot butterfly as intact undisturbed habitat.

Service Response: We do not believe emphasis on either subject was misplaced, and think it is clear that funds should not be spent on restoration of habitat that is not first preserved. We believe that this commenter's objection was partially based on different connotations of the term "restoration." We agree that the first recovery priority must be habitat preservation, but under current conditions all habitat areas will continue to decline in suitability without some restoration-based management activities (including activities such as enhancement and weed control, not just reconstruction of former habitat). It is important that policy makers understand that land acquisition alone is not sufficient for recovery, and that there is no intact, undisturbed habitat left.

Issue 6: The same commenter thought that there should be a recovery task recommending research be done on the effects of herbicides that might be used in restoration activities.

Service Response: We concur that herbicides are an important restoration tool, and research should be done on the effects of herbicides on the Quino checkerspot butterfly. As a result the narrative has been changed to recognize this need for research.

Issue 7: Two commenters thought the draft recovery plan was too vague and lacked specific information needed to determine land preservation priorities. One commenter claimed that the plan failed to provide the clear principles supported by sound science needed to guide landowners and regulators. They expressed discontent with frequent use of the term “may,” and speculative language in the recovery strategy.

Service Response: Although we strive to provide detail, when possible and appropriate, our limited knowledge of the species often precludes specific recommendations. We have added some level of detail to the text based on new information and further analysis. We added the conclusion that extinction of the species in the foreseeable future appears to remain a distinct possibility; and any occupied habitat should be preserved unless there is sound scientific evidence indicating it does not contribute to the persistence of a greater population. Although we did describe general principles supported by sound science, detailed explanations of the scientific principles are beyond the scope of this text, and can be found in cited ecological literature. In general, the issue of uncertainty is pervasive in science, and especially in the study of complex ecological systems:

> “There will always be major uncertainties in how ecological systems will respond to management actions and society must make important decisions in the face of such uncertainty. The reason ecology is more difficult is plain: experiments take longer, replication, control, and randomization are harder to achieve, and ecological systems have the nasty habit of changing over time... Rocket scientists have it easy!” (Hillborn and Ludwig, Ecological Applications 3:550; see also Weiner, Journal of Ecology 83:153; Ehrlich, Oikos 63:6)

Predicting how ecological systems will react to management actions is complicated by the extreme difficulty of predicting emergent properties; even if one understands how all the parts will react in isolation under controlled conditions, the system may behave entirely differently because of interactions among components. In cases involving rare endangered species, ecological research is even more difficult to do than usual, and the best scientific information available is often limited. Therefore, with regard to endangered insect species, natural history information, such as current and historic site occupancy information, and probable population trends, must be sufficient sound science upon which to base preliminary recommendations (Ehrlich 1992).

Issue 8: One commenter cited the statement "Undeveloped wildlands adjacent to and between Quino checkerspot metapopulation distributions should be maintained because they contain landscape connectivity essential to other species that are part of the Quino checkerspot habitat community." from the draft recovery plan (p. 51). The commenter pointed out that this statement contained no scientific documentation and claimed that "many such undeveloped wildlands have no habitat components that are supportive of Quino." The commenter claimed the draft recovery plan basically said all undeveloped land should remain so.

Service Response: We agree that the quoted statement should be qualified with regards to feasibility, the text has been edited accordingly. However, we believe it was clear in other sections of the text that we were not advocating a moratorium on development of wildlands, only that wildlands adjacent to and between populations should be spared from development whenever possible. We also respectfully disagree with their statement that "many such undeveloped wildlands have no habitat components that are supportive of Quino. Ecological communities, especially in highly diverse Mediterranean-type climate areas, are complex and composed of thousands of interdependent species evolved to survive in unique and variable environmental conditions; we know very little about many such arthropod species. Species in ecological communities have overlapping, but not identical, distributions within an ecosystem. Species that provide crucial ecological services such as pollination, nutrient cycling, predation, water and soil detoxification, and seed dispersal cannot survive in isolation from each other below the ecosystem level (that is, in part, the definition of a natural ecosystem). Not all species supporting a given Quino checkerspot population could possibly persist entirely within the distribution of the butterfly population. Please refer to the following references for support of our statement: Real and Brown (1991) and Naheed *et al.* (1999). The ultimate purpose of the Endangered Species Act is to prevent the collapse of ecosystems upon which endangered species depend (Section 2(b) of the Endangered Species Act). Preservation of wildlands adjacent to endangered species habitat also supports endangered species by providing insulation from the degrading effects of development on habitat and reduces the need for intensive, expensive management. Effects of adjacent development include habitat destruction and population depletion due to recreational activity, illegal dumping, enhanced invasion of exotic species, external mortality sinks, increased fire frequency, and pollution.

Issue 9: One commenter claimed that all known populations and the best habitat in the South Riverside/North San Diego recovery unit is north of Chihuahua Creek and that the recovery unit boundaries were drawn inconsistently with the way others were drawn, and recommended the boundary be retracted to the creek.

Service Response: We respectfully disagree, and do not believe the recovery unit boundary should be retracted. We have learned much recently about the biology of the Quino checkerspot butterfly and its habitat. We know that some apparent Quino checkerspot butterfly habitat does exist at the southern end, and that the distribution of its newly discovered primary host plant (*A. coulterianum*) also extends to the southern end of the recovery unit. Much of the southern end of the recovery unit is open chaparral habitat similar to known occupied areas to the north. Although it was not explicitly stated in the text, another reason this unit extends so far south of known populations is that the southern area represents bottlenecks between the two mountains (Palomar, Combs Peak area) and the mountains and the desert (Combs Peak area and the Anza Borrego Desert) that are the best possibility for current or future north-south range-wide landscape connectivity.

Issue 10: The same commenter claimed that the proposed North Orange recovery unit is not viable because it is isolated from other recovery units and has a history of extirpation, despite large areas of habitat. They recommended that the proposed recovery unit be dropped from the plan.

Service Response: We respectfully disagree. We are not certain that the Quino checkerspot butterfly has been extirpated from the proposed recovery unit, as no comprehensive surveys have been conducted. The recovery unit was proposed because we believe it may be viable. Historic extirpation that occurred at Black Star Canyon appears to have been caused primarily by manageable circumstances (fire, habitat degradation, and destruction of lower-elevation source populations, see discussion in section I.C.5, Metapopulation Resilience). The probability of this recovery unit being viable was recently increased by the Irvine Company's gift of the Fremont Conservation Area to The Nature Conservancy. Most Quino checkerspot butterfly populations will require management to persist in the future, and viability for recovery purposes does not depend on complete self-sufficiency of populations. We believe the proposed recovery unit is a large and protected enough area to support an experimental or managed Quino checkerspot butterfly metapopulation in isolation from other recovery units.

Issue 11 Two commenters requested that the implementation schedule provide more comprehensive and rigorous cost estimates.

Service Response: We provided the best cost estimates possible within the time, resource, and knowledge constraints under which the draft recovery plan was developed. It is not possible to provide realistic estimates of the cost of implementing many actions because costs depend on the outcome of other actions that are of unknown magnitude. We have revised cost estimates wherever it was possible and appropriate.

Issue 12: One commenter appeared to be concerned that the task specifying the Service "enter into dialogue" with the Cahuilla Band of Mission Indians was given too low a priority ranking and was listed last in the implementation schedule. They also stated that coordination with the tribe should have occurred prior to release of the draft plan, and any efforts to conserve endangered species on the reservation will have to occur through voluntary actions of the tribe.

Service Response: The recovery action priorities are based entirely on biological necessity and current threats. Although we did believe occupied habitat on the Cahuilla Indian Reservation was crucial to survival and recovery of the species, we did not believe current threats to the butterfly were great enough on the reservation to warrant a high priority. Priorities are assigned as follows (pg. 92):

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.

Also, the order in which primary recovery actions are listed in the implementation schedule within the prioritization categories is not chronological or priority based. Because the Tribal representatives informed us at a meeting in 2002 that occupied habitat on the reservation is planned for economic activities and fire-break clearing (threats we did not know of before), and we believe maintenance of this occupied habitat is probably necessary to prevent a significant decline of the species' habitat quality and population, we have changed the recovery action to a priority 2.

We regret the lack of coordination with the Tribe prior to release of the draft recovery plan; unfortunately our attempts to do so were not successful. One of our staff members did establish initial contact with the tribal grants administrator (when attempting to contact the tribal spokesperson) during development of the draft recovery plan, and informed him that we were working on the plan, and that there might be Quino checkerspot butterflies on the reservation. However, subsequent attempts by other Carlsbad Fish and Wildlife Office staff members to establish contact with tribal representatives prior to draft recovery plan publication were unsuccessful. We have subsequently contacted and initiated discussion with the Cahuilla Band of Indians, and offered to assist with preparation of an environmental management plan for the reservation. We also refined our recommendations to specify solicitation of voluntary conservation efforts.

APPENDIX VII. Summary of Threats and Recommended Recovery Actions

LISTING FACTOR	THREAT	RECOVERY CRITERIA	TASK NUMBERS
A	Urban and agricultural development*	1, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 6.3
A	Grazing*	3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3
A	Displacement of larval food plants by exotic plants*	2, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3, 6.7
A	Trash dumping*	3, 7	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 5.1, 5.2, 5.3, 9
A	Off-road vehicle use*	3, 7	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 5.1, 5.2, 5.3, 5.4
A, E	Habitat fragmentation*	1, 2, 3, 4, 5	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 6.1, 6.2, 6.3, 6.4, 6.5, 7, 8, 11, 12
A, E	Increased fire frequency/severity*	3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6
B	Over-collection by butterfly collectors*	2, 7	5.1, 5.2, 5.3
B	Vandalism by landowners*	1, 3, 7	5.1, 5.2, 5.3
C	Predation by introduced insects associated with exotic plants*	2, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3, 6.7
D	Lack of adequate protection by CESA, CEQA, and NEPA*	N/A	Beyond scope of recovery plan.

Listing Factor	Threat	Recovery Criteria	Task Numbers
D	Lack of regional conservation planning programs*	1, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 10, 13
E	Drought*	2, 3, 5	6.6, 7
E	Genetic drift and inbreeding associated with low population size*	1, 2, 3, 4, 5, 6	3, 4, 7, 8, 11
E	Elevated carbon dioxide levels	2	6.8
E	Nitrogen fertilization	2	6.8

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment Of Its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes (not a factor)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence
* Identified as threat in listing rule.