Journal of Research on the Lepidoptera 29(4):277-304, 1990(92)

The Endangered El Segundo Blue Butterfly

Rudolf H. T. Mattoni

9620 Heather Road, Beverly Hills, CA 90210

Abstract. Conflict concerning land use of the 302 acre sand dunes parcel at the western boundary of the Los Angeles International Airport (LAX) centers on the small butterfly, The El Segundo blue butterfly (ESB). Since the ESB was granted protected status in 1976 under the Endangered Species Act of 1973, the real issues involved in its conservation have been obscured by the polemics of special interests groups that have been arguing without proper data, or worse, with flawed data. This paper reviews all known aspects of the history, biology, and conservation issues, concluding with up-to-date political actions that will affect the survival of the species.

Historical Perspective

SYSTEMATICS

The El Segundo Blue butterfly (*Euphilotes bernardino allyni)* is one of four subspecies of a polytypic species which belongs to the *E. battoides* species complex of many population aggregates not yet clearly defined systematically (Shields and Reveal, 1987; Mattoni, 1989; Pratt, unpub.). Although the *battoides* complex occurs over all of North America west of the Great Plains, from British Columbia to Baja California, *E. bernardino* is distributed in southern California, southern Nevada, Arizona, and northern Mexico, including Cedros Island.

The ESB was formally described by Shields (1975) from specimens collected in El Segundo. These specimens were taken at the Chevron Refinery site. Several experts recognized the ESB as distinct prior to its formal description, including Emmel and Emmel (1973), who illustrated it and called attention to its potential extinction. The ESB is distinguished from all other subspecies by a combination of underside black spot size, amount of orange on the wings, wingspread, foodplant, and other characters (Table 1 in Mattoni, 1989).

NATURAL HISTORY

As with all species in the genus *Euphilotes*, the ESB spends virtually its entire life cycle in intimate association with the flowerheads of some species of buckwheat; in this case the coastal buckwheat, *Eriogonum parvifolium*.. The almost total involvement of all stages with a single plant part is unique among North American butterflies. Adults find one another to mate, usually nectar, lay eggs, perch, and in most cases probably die, on flowerheads. Thus a significant array of population regulating mechanisms operate within the flowerhead environment, for example predation, parasitism, competition, nutrition and disease.

When the time arrives to pupate, however, larvae either drop or crawl to the ground and burrow into the soil. Typically they travel at least two inches below grade, but stay within the root and debris zone where they are protected from desiccation and insulated from temperature extremes. Factors affecting pupae are almost totally unknown even though the species spends 90% of its life span in the pupal stage (see White, 1986).

The ESB has one generation per year, as is obligatory for all members of the *E. battoides* complex under natural conditions. Adults fly from mid-June through the end of August, the exact timing depending on weather. Usually the flight lasts from mid-June to mid-August. The onset of flight is closely synchronized to the beginning of the flowering cycle of the foodplant. Fresh females fly to flowerheads upon emerging from their pupae. There they are found and mated within hours by one of the male population that is constantly moving from flowerhead to flowerhead. The females then immediately begin laying eggs. Laboratory data indicate females produce 15-20 eggs per day, but must continuously nectar to maintain egg production (Mattoni, unpub.). Although field data indicate females at Chevron live an average of four days in nature (Arnold, 1983), in captivity females live two weeks and produce up to 120 eggs (Mattoni, unpub.). Eggs hatch within five to seven days. Larvae undergo four instars to complete growth, a process taking from 18-25 days. The larvae develop honey glands by the third instar, and are thereafter usually tended by the ants *Iridiomyrmex humilis* or *Conomyrmex* sp., which may protect them from parasitoids and small predators. By late August the flowerheads have generally senesced and the larvae have all pupated underground. The natural history data are all reported from the population at LAX.

Mature larvae are highly polymorphic, varying from almost pure white or pure dull yellow to strikingly marked individuals with a dull red-to-maroon background broken by a series of yellow or white dashes or chevrons. They feed in such a manner as to remain concealed by the flowerhead, their patterning adding to this crypsis. The preferred part of the flowerhead is young seeds, which are consumed preferentially to other flowerparts. The latter are loosely webbed together producing the illusion of an intact flowerhead. One larva requires two-to-three flowerheads (which equals 10-15 involucres or 400-500 flowers or their seeds) to complete development. The discrepancy between longevity of adults in the field (2.3 to 7.3 days, Arnold, 1983) and lab (average 16 days, Mattoni, unpub.) adults is most likely due to predation by lynx and crab spiders. These spiders were found at a frequency of about one per 200 flowerheads in 1987 (Mattoni, unpub.). When 15 man hours of direct observation of flowerheads was made, only one capture of a male ESB by lynx spider was seen. The event was rapid, by seizure, with the prey rapidly imbibed and discarded.

The egg population is chiefly regulated by *Trichogramma* sp. nr. *minutum*, which also attacks the eggs of the common hairstreak and at

least two species of microlepidoptera on the flowerheads. Pratt (1987) found 9% of 147 eggs of the common hairstreak collected at the LAX dunes in 1985 parasitized by the wasp. ESB eggs probably have a similar frequency, but appear better placed for concealment in comparison to the hairstreak, so few can be found in nature for testing.

In a sample of 30 mature ESB larvae recovered from flowerheads in 1987, six, or 20%, were parasitized by a braconid wasp, *Apanteles thurberiae*. The same wasp also attacked the common hairstreak, the moth *Lorita scarifica* (=*abornana*)(Cochylidae), and *Aroga sp.* (Gelechiidae), the latter two common microlepidoptera on the flowerheads. The ichneumonid wasp, *Diadegma* sp., was found in the hairstreak and both moth populations in 1987, but not in the ESB (Mattoni, unpub.). Pratt (1987) reported the same pattern in his 1985 survey. The most significant feature of both wasp parasitoids is absence of diapause. Thus they only persist by living on a continuum of alternate larval hosts over an annual cycle. The same is true for the *Trichogramma* egg parasitoid.

Arnold (1983) reported finding pupae parasitized by two unidentified species of tachinid fly at Chevron. No quantitative data were given. The tachinid life cycle coincides with that of its ESB host so alternate hosts are not necessary for its persistence. A set of 28 pupae screened from sand at LAX, just prior to the 1988 flight, produced no parasites.

Pratt (1987) found larvae of *Aroga sp.* and *Lorita scarifica* predominant in *E. parvifolium* flowerheads, up to 50 each, in 1985. He hypothesized that these severely reduced the food available to the ESB larvae, but also had an impact on the ESB by direct predation and indirect harboring of shared parasitoids. Mattoni (1988) found that a sample of flowerheads collected in 1987 produced 30-50% viable seed sets in spite of herbivory from all sources.

HISTORICAL RANGE

Distribution of the ESB is dependent on the occurrance of its foodplant, the coast buckwheat. The butterfly further appears limited to habitats with high sand content. These sites historically consisted of the El Segundo sand dunes, including interrupted extensions to the north into what is present-day Ocean Park, and southerly to Malaga Cove in Palos Verdes (Figure 1). However, after a gap at Santa Monica, the foodplant extends further north along the well-drained, low altitude, steep sandstone slopes of the coastal Santa Monica Mountains and to the south on similar formations along the Palos Verdes peninsula. The plant forms a small colony on the sand dune at Point Dume. Variant ecotypes of *Euphilotes bernardino bernardino* are associated with mixed *Eriogonum parvifolium* and *E. cinereum* plant populations along the sea bluffs of Palos Verdes south to San Pedro. The plant populations become pure stands of *E. cinereum* above the bluff face in Palos Verdes. Both *E. cinereum* and *E. fasciculatum*, are toxic to El Segundo dunes ESB larvae, although ESB females will lay eggs on them in free choice experiments (Mattoni, unpub.).

Figure 1. Distribution of both the El Segundo sand dunes and El Segundo blue butterfly. historically and at present (1991). Extent of the historical dunes and butterfly populations distribution are shown by the stippled areas. Extant butterfly and undisturbed dunes fragments indicated by the black dots or black areas: LAX dunes, Chevron Preserve, and Malaga Cove. Potential restorable habitat is indicated: Hyperion-DWP, and Playa del Rey dunes. The Ballona lagoon fragment is included in the latter site.

The active El Segundo sand dunes historically covered about 4.5 square miles (1295 hectares, 3200 acres), based on data from the 1894 geologic survey (Figure 1) and Cooper (1967). An inaccurate figure of 36 square miles, sometimes miscalculated as 18,000 hectares, has been widely quoted for the dunes area from the summary of California sand dunes by Cooper (1967). The misquoted value included pre-Flandrian sand deposits that formed yet older dunes now having more or less consolidated to form sandstone. Cooper describes the situation clearly in his figure 2 and text, but somehow the detail was overlooked and the original misinterpretation repeated by subsequent authors. This sandstone forms the underlay or base to the present dunes. The edaphic properties of these sandstones do not provide proper adaptive conditions for the indicator sand obligate plants of the dunes community, particularly the coast buckwheat. At El Segundo, coast buckwheat is a key indicator of primary, undisturbed coastal sand dunes sites. A diagrammatic cross section of the El Segundo dune system is given in Figure 2.

The biological community of sand dunes proper is adapted to continuously moving sand and extreme aridity. Once sand is permanently stabilized, community composition changes. Sand obligate plant species decrease in frequency to the benefit of more widespread species and weeds with overall cover increasing. Animal community composition is likely affected as well.

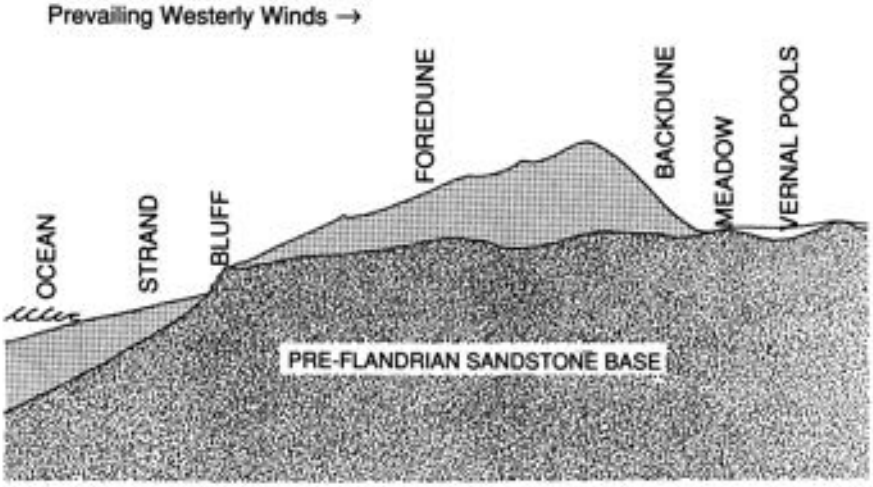

Figure 2. Diagrammatic cross section of typical El Segundo dune in the high dune area. Major physical features denoted.

The dunes and lee deflation plain were undisturbed until rancho development in the 1840's. Farming was then established on the coastal prairie to the east of the dunes proper, but generally started at least a half mile further inland, probably because of agricultural unsuitability of the poorly drained sandstone soil near the backdune.The dunes themselves were undisturbed until the late 1880's when the cities from Redondo Beach to Venice were established, but development was limited. Prior to that time virtually the entire dunes area was pristine, without evidence of disturbance. Redondo Beach separated the main dunes from south Redondo Beach and the Malaga Cove extensions (Figure 1), with development of Venice eliminating the dunes north of the mouth of Ballona Creek. Conversion of the central part of the dunes was slower. Construction of the Chevron refinery in 1911 separated the dunes into two fragments. The southern fragment was gradually converted to residences starting at the turn of the century and rapidly accelerating in the late 1940s. Habitat values were totally destroyed by the 1970s. In the 1950s Henne (pers. comm.) noted a dense ESB population and other rare Lepidoptera in Hermosa Valley, an area soon after destroyed. In 1928 the grid of streets on the LAX dunes were constructed, but development was minimal following the 1929 crash. It was not until after World War II that explosive development occurred, with virtually the entire dunes built upon between 1946 and 1965, where almost all the land was privately owned. Construction of the Hyperion wastewater and Scattergood generating plants in the 1940s, along with dense housing on the present LAX dunes, reduced the northern fragment to about 80 acres of dunes habitat by 1960. The 1.6 acre Chevron butterfly sanctuary site was isolated by residential development in the 1950s.

The most important events affecting the very recent biological history of the LAX dune segment was the purchase and clearing of residences from nearly 200 acres between 1966 and 1972, construction of the VOR, and the excavation and re-contouring of about 70% of the backdune in order to re-align Pershing Drive in 1975. The newly recontoured dunes were stabilized by hydromulch with a presumptive "natural" seed mix and irrigated with a sprinkler system. Unfortunately, the seeds were representative of coastal sage and not dune scrub plant community. The common buckwheat, *Eriogonum fasciculatum*, was introduced by this activity. At the same time the foredune to the south and west of the VOR was graded along with the last coastal prairie fragment between the backdune and Pershing Drive. From 1966 through the late 1970s the natural biota of the LAX dune suffered its major contraction, with about 40 variably undisturbed acres as refugia for subsequent colonization. The 1990 landform classification resulting from these events is mapped in Figure 3.

The most drastic change was the complete destruction of the Los Angeles coastal prairie to the lee of the dunes. This community was a *Stipa* grassland, with a rich occurrence of herbaceous meadow plants and innumerable intermittent vernal pools. The community is now completely extinct.

Extrapolating from an estimated carrying capacity of 1,000 ESB per acre on the backdune and 100 ESB per acre on the foredune (Mattoni, unpub.) the historic El Segundo dunes system, with about 400 acres of backdune and a 2,800 acre foredune, should have had an average total population of about 750,000 adults per year.

PRESENT DISTRIBUTION

The ESB is now (1991) restricted to three locations: the LAX dunes (LAX), the Chevron Refinery dunes (CHEV), and Malaga Cove (MC) (Figure 1, Table 1). In 1988 LAX had the largest population both in terms of area (ca. 4 acres of moderate density and 20 acres of low density populations), number of adult ESB (ca. 2000), and foodplants (1,114 native plants with 206,045 flowerheads) (Figure 4, Table 2). After the initial habitat restoration program, the foodplant population was increased to 3358 in 1991 (Figure 4) with an estimated 5000 ESB flying in 1990 (Table 2). CHEV in 1986 had an area of 1.6 acres, about 400 adult ESB, and about 240 natural plants plus about another 1,000 surviving introduced cultivated seedlings (Arnold 1986). The MC location, discovered in 1983 by J. Morton and T. Leigh, covers about one acre, had a one-day population count of about 60, and less than 50 plants with 30,000 flowerheads in 1984. It is heavily overgrown with ice plant and seriously eroded. Since 1986 the site has been fenced. A 1990 survey (R. Rogers, pers. comm.) indicates the 1984 status remains stable. Fifteen plants (3,000 flowerheads) survived to 1986 on a small dune fragment at Playa del Rey (proposed Ballona Wetlands Reserve). By 1989 half of these

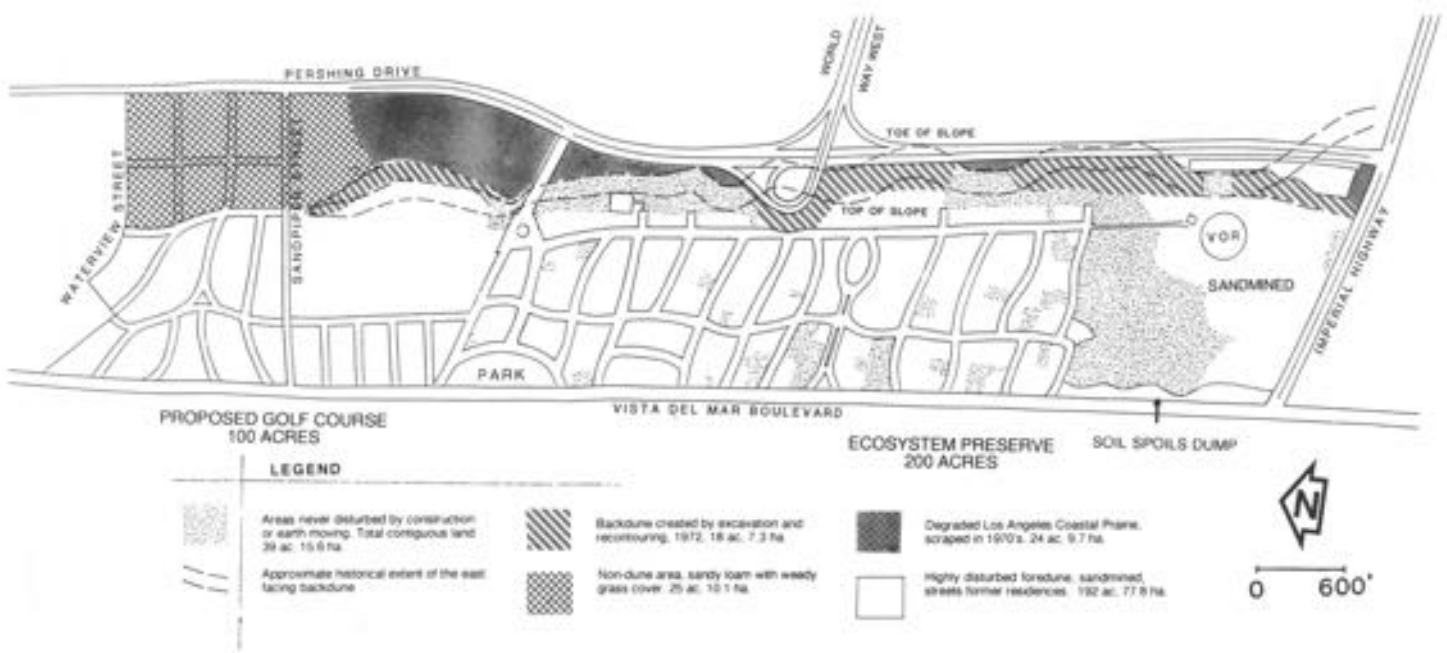

Figure 3. Recent history of land use at LAX El Segundo sand dunes. The land use pattern correlates with the degree of disturbance to the natural biota and hence determines habitat value. The boundary of the preserve area proposed in 1991 is indicated by the heavy line.

Table 1. Land area of all El Segundo sand dune fragments remaining as open space. Both actual habitat with some natural values and parcels that have the potential for being restored are shown. Malaga Cove and Playa del Rey were not connected to the original sand dune mass, but have many shared species. The 25 acre non-sand dune portion of the LAX site is not included. Values are in hectares (acres).

Location	Backdune		Foredune		Meadow		Total	
ACTUAL HABITATS								
LAX								
Pristine	0.8	(2.0)	0.0		0.0		0.8	(2.0)
Relatively Undisturbed	2.6	(7.0)	13.6	(34.0)	0.0		16.2	(41.0)
Total	3.4	(9.0)	13.6	(34.0)	0.0		17.0	(43.0)
Chevron Preserve	0.5	(1.3)	0.1	(0.2)	0.0		0.6	(1.5)
Malaga Cove	0.0		0.5	(1.2)	0.0		0.5	(1.2)
POTENTIAL HABITATS								
LAX								
Disturbed Sites	7.3	(18.0)	78.0	(192.0)	9.7	(24.0)	95.0	(234.0)
DWP	2.0	(5.0)	15.0	(37.5)	5.0	(12.5)	22.0	(55.0)
Hyperion	0.0		16.4	(41.0)	0.0		16.4	(41.0)
Playa del Rey	2.5	(2.5)	0.0		0.0		2.5	(6.2)
Ballona Lagoon	0.0		2.8	(7.0)	0.0		2.8	(7.0)
TOTAL	11.8	(39.5)	126.4	(313.0)	14.7	(40.2)	156.8	(389.0)

buckwheats died. A male ESB was reported at the locality in 1985, but the specimen was not taken and no stages have been collected since, in spite of several attempts. A transient ESB was reported on the DWP right-of-way between CHEV and LAX (R. Rogers, pers. comm.).

The ESB is isolated from its closest relative, a Palos Verdes ecotype of *Euphilotes bernardino bernardino,* by only 2 km at Palos Verdes. To the north *E. bernardino bernardino* occurs throughout the Santa Monica Mountains, where it uses three *Eriogonum* foodplants: *fasciculatum, cinereum*, and *parvifolium*.. *E. bernardino bernardino* ranges along the coast to the south, from the bluffs of the Laguna Hills, feeding on the same

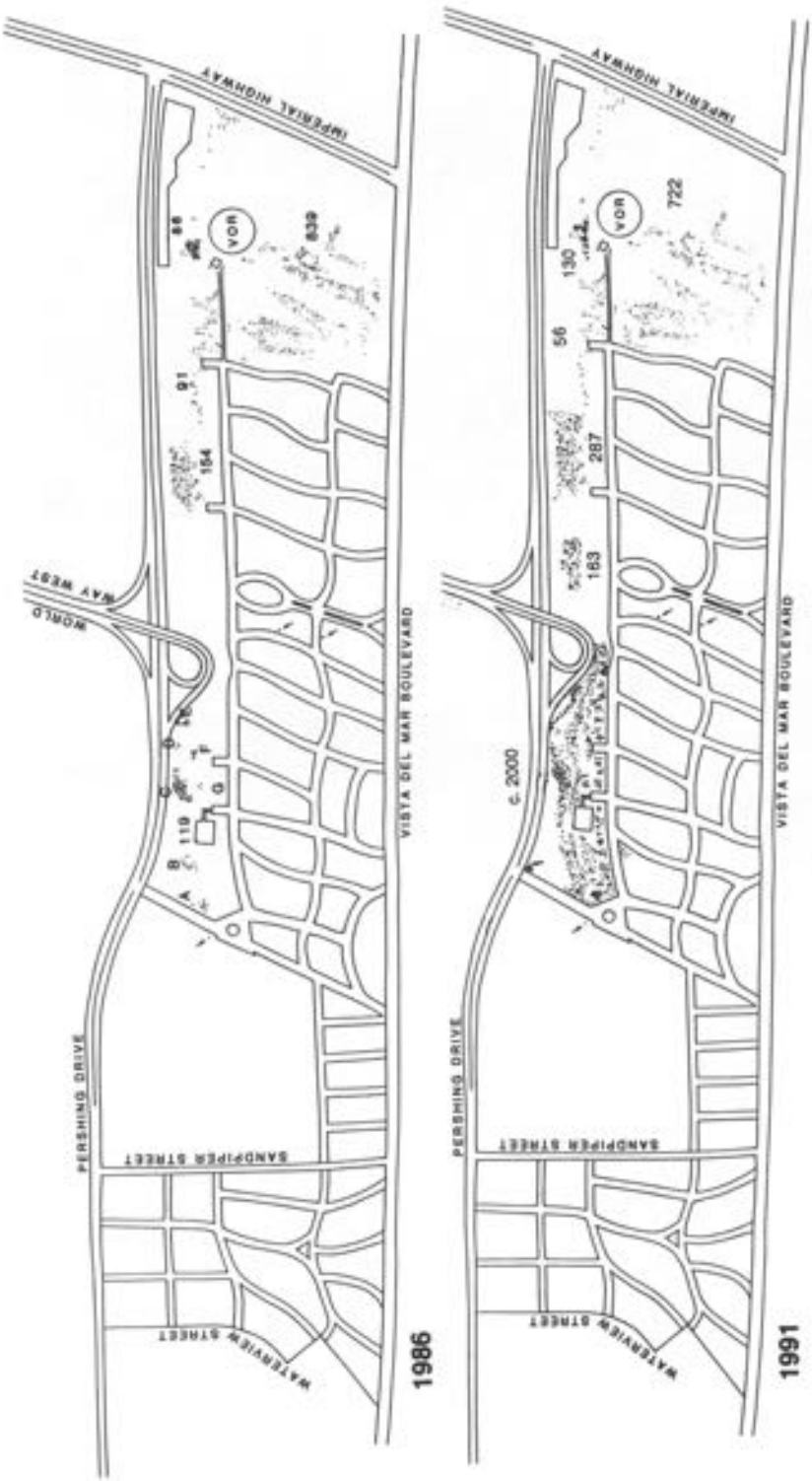

Figure 4 Distribution and abundance of *Eriogonum parvifolium* across the LAX dunes with the number of plants found in each patch in 1986 (above) and 1991 following interim restoration (below).

Figure 5. Photographs taken in the same position facing northwest from the corner of Imperial and Pershing, 1938 (above) and 1988 (below). The early photograph by W. D. Pierce shows Mrs. Pierce in the forground.

three foodplants. Some populations found on the immediate coast, as at Point Loma, strongly resemble the ESB in appearance. This pattern is in all likelihood a convergence and does not represent monophyly with the ESB (Mattoni, 1989). There are no blues at Point Dume, which has a small sand dune and a coastal buckwheat population.

There are no other sites remaining in the historical dunes habitat that can support more than a few random plants. No further ESB populations remain to be found, although two locations, the Ballona dunes and the DWP backdune behind the Hyperion Plant, could be restored to support viable ESB populations.

Table 2. Relative density of adult El Segundo blue butterflies over six years (1984, 1986-1990) along transect counts at five major clusters of *Eriogonum parvifolium* foodplant Number of *Eriogonum parvifolium* from 1986 census: the numerator is the number of plants and flowerheads actually counted for butterflies in each cluster, the denominator the total numbers in the entire cluster (See Figure 3).

Cluster	Number of *E. parvifolium*, 1986		El Segundo Blue Transect Counts					
	plants	flowerheads	1984	1986	1987	1988	1989	1990
Number of days sampled			4	5	9	10	11	10
Span of days sampled			19	35	56	61	54	63
Date of first flight			?	7-9	6-24	6-22	6-23	6-29
Date of last observation			8-8	8-13	8-19	8-22	8-16	8-24
1. Backdune	30	33,600	131	68	207	508	744	648
	119	55,275						
2. Backdune (pristine)	43	15,300	60	109	187	344	466	427
	154	49,700						
3. Crest	35	1,500	2	2	0	3	9	8
	91	3,185						
4. Backdune VOR	20	4750	NC	70	46	159	130	78
	86	8,280						
5. Foredune	65	4940	NC	9	33	35	41	31
	839	89,605						
TOTAL	193	60,090	193	258	473	1049	1390	1192
	1289	206,045						

Preservation Status: Condition of the habitat

The probability of survival of a given species over time is a function of habitat quality and habitat size relative to a minimum critical area (Gilpin and Soule, 1986). The spatial loss of the El Segundo sand dunes habitat to urbanization reached its maximum in the 1970s. The other dune habitats, including restorable sites, cannot be further developed at this time because of legal constraints, safety, or geological hazard. Together these sites are sufficient to maintain El Segundo Blue populations indefinitely, given habitat quality. This viability analysis is based on potential habitat area and topography that could support annual adult populations in the order of 100,000 individuals. However, high quality habitat values do not now exist, nor is there assurance that quality can be maintained over time without some management. The El

Segundo Blue occurs, or could occur, across several governmental jurisdictions and on private land. Each situation presents unique problems.

In addition to the three present sites of the El Segundo Blue at LAX, Chevron, and Malaga Cove; at least three additional sites could be restored to a native dune ecosystem, thereby providing further assurance of long term survival (Table 1). These are l) The Los Angeles Department of Water and Power (DWP) right-of-way for a power line between the Scattergood generating plant and Imperial highway at the south end of the LAX dunes. The site consists of 55 acres of seriously degraded dune and coastal prairie habitat, including over 5 acres of potentially rich backdune. Portions of the dune crest and foredune remnant at the adjacent Hyperion wastewater treatment plant, presently landscaped in exotic vegetation, could be included as restorable contiguous dune habitat with an additional 41 acres. Hyperion-DWP would have high value as a habitat corridor between the LAX and Chevron communities in addition to functioning as an independent habitat unit. 2) The approximate 7 acre Playa del Rey backdune, forming the west end of the proposed Ballona wetlands preserve. 3) Approximately 5 acres of bank lining the Ballona lagoon that are now (1991) being re-vegetated. A proposal to re-introduce the ESB onto the first half acre fragment during 1992 is under consideration. Other potential habitats include Dune park in the city of Manhattan Beach with a 2 acre degenerate backdune fragment about 2 km south of Chevron. Although completely open to public use, parts could be protected and restored. Public school open space of about 1.5 acres each in Hermosa Beach and Manhattan Beach are potential restoration sites.

Without an active restoration and management program, the outlook for the long term persistence of the dunes ecosystems necessary to support the El Segundo Blue is bleak indeed. The centerpiece of any effort must be the LAX site, as LAX alone contains not only the largest fragment, but the closest approximation to prehistoric dune ecosystem composition. Of the 302 acres, about 250 acres are actual sand dunes, of which 39 contiguous acres were at least partially undisturbed, including an almost pristine 2 acres of backdune and 15 acres of foredune. The remainder has either been extensively sandmined, graded, or built upon; has heavy soil spoils; or is concrete or asphalt road (Figure 3). Further trauma included heavy spraying of some sites with oil and introduction of deleterious exotic plants for sand stabilization, and the invasion of non-native animals (Mattoni, 1990 a, b).

Notwithstanding a gradual degradation between the 1938-1939 biological survey by Pierce (1939-1940) and the present, most substantive changes have taken place during the past decade and a half (Mattoni 1990 a, b) as a result of the re-alignment of Pershing Drive, construction of Imperial Highway, moving sand to build the VOR hill, and fragmentation and scraping of the coastal prairie. The manifestation of degradation was extirpation of many native species on the one hand, and the

invasion of the site by exotic plants and animals on the other. The convergence of these forces predict a grim future. Of 20 native terrestrial mammals recorded by von Bloeker (in Pierce notes), most of which were present in 1975 (LAX-EIR, 1975), only three are extant today. In their place are introduced Norwegian rats, red fox and opossum. Of 31 species of butterfly breeding on the site, 7 or 23% have disappeared. Of 18 species of reptiles and amphibians (von Bloeker, 1941), 7 or 39% no longer occur and all 5 scrub dependent birds (Soule et al. 1988) have disappeared. The situation with native plants is fundamentally more serious since plants are the base of food chains and hence ecosystems. A specialized herbivore restricted to one plant species would be lost with extirpation of its food source, as in the case of two extirpated butterflies. Of the 73 native plant species recorded on the sand dunes proper by Pierce *et al.* 22, or 30%, were not found by our 1989 survey, and 19 of the 51 surviving species occurred as less than 100 individuals and faced imminent loss. More seriously, several alien plants, including two Acacia species and *Eriogonum fasciculatum*, had been introduced to the site within the past two decades with serious consequences. Other exotic species present in 1938 have since become serious competitors to the native plant community. Two closely related iceplant species, insignificant in 1938, are now dominant across most parts of the foredune thereby closing options on their occupied territory. Storksbills and alien grasses are also co-opting habitat for native plants. Recently observed Pampas grass and Myoporum present yet new threats. The LAX dunes history is an outstanding example of the effects of uncontrolled, often intentional, introduction of exotic plants which become ecologically devastating. Photographs of identical portions of the backdune show the changes in the landscape between 1938 and 1989 (Figure 5).

The *Eriogonum parvifolium* foodplant of the ESB is only found on undisturbed sand dune habitat. In the fifteen years the LAX dunes have lain fallow since the massive clearing and excavating activities, only three individual plants of 1114 counted in 1986 were found on disturbed sites (Figure 4). Why the plant remains restricted is unknown, whether the limiting factor is poor seed dispersal, seed viability and germination, or establishment. Thousands of seedlings have been observed across several sites following winter rains, yet few establish. It is noteworthy that coastal buckwheat has both highest quality and highest density on the least disturbed backdune sites (Table 2 and Figure 4: clusters of 119, 154, & 86 plants) where invasive exotics are in low frequency. Within these sites, and the relatively undisturbed VOR sections (Figure. 3), native dune scrub plant associations resist significant invasion by exotics. From photographs and notes of Pierce (1938-1940), many of the exotic plant species were present in his time, but were not abundant. The two Acacia species appear exempt from this "exotic exclusion/native cohesion" phenomenon, however, and threaten a breakdown of the remaining native ecosystem by altering soil texture and chemistry.

Acacia populations increased from none detectable in 1976 to 671 individuals in 1987 and was increasing at an annual rate of 46% prior to removal between 1988-1991. The long lived seed bank of Acacia numbers in the millions and will require attention for decades.

Ecosystem disturbance through changes in the mammalian community have been profound as both rabbits and mice influence the differential reproductive efficiency of herbaceous plant species. The absence of mammalian foraging probably relaxed substantial pressure on seed banks, particularly the r-strategist European weeds. Loss of small mammals is linked to the introduction of the European red fox, which themselves now have such limited food resources that they are driven to garbage scavenging, lizards, and even large insects.

Of the other habitats, Malaga Cove was last visited during the flight period of 1990. The site was heavily overgrown with iceplant, which threatens the some fifty buckwheat foodplants, although this site and population have probably persisted in isolation over the past 40 years. The site needs further evaluation particularly because the ESB population has survived in spite of its very small population. According to Pratt (pers. comm.) the Malaga Cove population is genetically identical (allozyme frequency) to that of LAX.

The Chevron site has been isolated at least since the mid 1950s, subsequently carrying an ESB population of about 2000 adults annually from at least 1965 until 1977, when intensive studies on adult population demography began. While determining population sizes for 1977 and 1979, a precipitous drop from an estimated 1328 to 681 between those two years was noted (Arnold 1983). Later Arnold (1986) presented data on densities of both foodplant buckwheat and ESB for each year since 1977, showing a decline between 1977 and 1986 from about 1850 to 350 adult ESB adults and 420 to 300 *Eriogonum parvifolium*. Arnold claimed the primary cause for the declines was stabilization of the dune process of sand movement with correlated exotic plant growth, buckwheat senescence, and reduced buckwheat seedling survival. A more likely cause of crashes of both buckwheat and blue was the impact of the study itself. In small fragile habitats, particularly steep sand dunes, regular walking during the course of observation and data collection is a serious problem (Brown, 1987) that leads to root damage and changing water balances. Another study impact suggested is the citation by Arnold (1983, p. 90) of rearing 839 El Segundo Blue larvae for sex ratio determination. Removal of this many mature larvae from the population could alone explain the drop in population size from 1977 to 1979. Further, as pointed out by Murphy (1984, 1988), the use of mark-release-recapture (MRR) methods on butterflies as delicate as the El Segundo Blue probably profoundly effect behavior, survival and reproductive dynamics. Even with careful netting, legs easily break off these fragile animals and lack of legs has deleterious effects (e.g. Mattoni, 1988). The added trampling necessitated by an intensive MRR program cannot aid recovery.

Sociopolitical aspects of planning

HISTORICAL CONFLICTS — LAX DUNES

A major cause of conflict arose from events attendant to the expansion of the Mines Field into the Los Angeles International Airport (LAX). The major radar installation (VOR) was located on a 60 acre site purchased in 1950. Home construction on the remainder of the dunes continued unchecked until into the 1960s. With increasing air traffic necessitating construction of the north runway, safety considerations and the onset of jet age noise, residential living conditions became increasingly difficult. In a 1965 referendum, over 66% of homeowners elected to be bought out with the remaining property condemned. Between 1965 and 1975, 822 homes were vacated and over 2000 people relocated.

The $60 million cost was 75% reimbursed by the federal government. Almost unnoticed during this hubbub, the ESB was listed as an endangered species in 1976 under the Endangered Species Act passed by the Congress in 1973. All of the LAX dunes south of Sandpiper St. (Figure 3) were proposed as critical habitat in 1977, a finding abandoned by modifications to the Act as amended in 1978. 1976 was also the year the California Coastal Act was enacted in response to a mandate by the voters to guarantee preservation of coastal environmental values. The 1970s was the first time signs appeared of a public awareness that all was not right with the environment. This concern eluded many bureaucrats.

The Los Angeles City Planning Department thereafter began work on a plan to develop the LAX dunes as a recreational facility, emphasizing a 27 hole golf course. With recognition of the ESB, the plan was modified to set aside 80 acres as a conservancy plus 12 acres as a preserve/research/interpretive area. Following requirements set forth by the coastal act, public disclosure and participation processes were initiated and hearings began in early 1981. A public interest group, "Friends of the Dunes", was established and battle lines drawn. The essence of organized opposition to any development on the dunes was the position that the dunes contained a rich biota, exemplified by the listed ESB, and should be left as open space which would restore itself by natural plant succession. After eight public hearings, the city submitted the development plan to the Coastal Commission for action in late 1983.

Two independent studies of the ESB populations at LAX were performed in 1984. Both studies indicated serious and deteriorating habitat conditions. Consequently airport officials developed a memorandum of understanding with both U.S. Fish and Wildlife and the California Department of Fish and Game to support the recreational complex with the key provision that development would generate funds to assure restoration and permanent management of the preserve. A conservancy committee was to oversee long term objectives. Both federal and state agencies recognized the golf course as the least objectionable of the funding solutions because in the long run the sand substratum would remain untouched while the infrastructure of several acres of roads,

foundations, rubble and old utility appurtenances would be removed. With assurance that the unique biota were thereby conserved, future generations would have the option to roll back the golf course with minimum effort. An alternate hypothesis was advanced that the golf course could be viewed as destruction of ESB habitat, thereby permitting development of this area for commercial airport purposes at some indeterminate future.

At its November 12, 1985 public meeting, the Coastal Commissioners followed their staff recommendation and rejected the airport development plan as inconsistent with the Coastal Act by not assuring preservation of a unique sensitive habitat. However, the Commission did not accept a staff recommendation that the airport set aside the entire 302 acre site as "environmentally sensitive habitat," thereby leaving open exploration of other options. In its wisdom, the Commission did recognize that the basic issue of funding was necessary to both maintain and restore the habitat. What remained unresolved was that denial of an institutional funding mechanism would number the days of the "environmentally sensitive habitat."

From studies of population regulation of the ESB discussed above, it was apparent that survival of the ESB was in immediate jeopardy. In the public interest, the Board of Airport Commissioners generously provided a small contract in early 1986 to relieve the situation until a permanent solution could be found. This initial contract was successful in assuring short term survival of the ESB. In 1987 a major biological survey and ecological evaluation of the site was contracted to provide quantitative information to elucidate habitat values and open alternatives to resolving the conflict of providing funding necessary to assure restoration and management. The study recognized that funding must be developed from some form of land use at the site. As appealing as restoration of the whole LAX dune remnant might be, economic realities must be recognized and a consensus established to provide a viable long term solution.

OTHER EL SEGUNDO BLUE BUTTERFLY HABITATS

The federal Endangered Species Act of 1973 states that "The purposes of this act are to provide a means whereby the ecosystems upon which endangered species and threatened species may be conserved (and) to provide a program for the conservation of such endangered species and threatened species,..." The Act goes on to define "critical habitat" as not only the geographic area where such species occur at the time of listing, but "specific areas outside the geographic area occupied by the species at the time it is listed ... upon determination by the secretary that such areas are essential for the conservation of the species."

Recognizing the intent of the law and the role of the ESB as an indicator of the unique El Segundo dunes ecosystem, several other habitats and potential habitats must be dealt with. These have been mentioned above and include: Chevron, Malaga Cove, DWP right-of-way and adjacent

Hyperion property, the Playa del Rey-Ballona backdune, and other miscellaneous parcels.

CHEVRON: In response to concerns of several local lepidopterists, Chevron set aside and fenced the 1.6 acre habitat on their NE corner as butterfly preserve (Oppewall, 1975). A pro bono corporate fund was provided to make a partial restoration, limited to augmenting the ESB, its foodplant, and some weeding. This laudatory, though imperfect approach, produced no conflicts. If judiciously continued, the butterfly should be sustained indefinitely at Chevron, or as long as Chevron is also sustained.

MALAGA COVE: Until now there has been no general awareness of this site, and there are no hard data concerning habitat value at this time. Ownership is undetermined, but geology and landform of the area imply further development is impossible. The site is fenced. There are no obvious conflicts here.

DWP RIGHT-OF-WAY / HYPERION: Since an attempt to permit a nursery was thwarted by public action, no other land use is imminent. Although an effort to restore was suggested in 1981, no action has been taken, with the DWP not yet recognizing the issue. There are no apparent conflicts, however, except that the matter of funding would be an obstacle to any restoration and management program. Major restoration is necessary, but proximity to the LAX dunes suggests shared management expense and greater efficiency, when a program is developed. The adjacent Hyperion wastewater treatment plant includes 30 acres of slope almost completely covered with non-native flora. Plans for an inappropriate exotic landscaping plan were partially implemented, against both the spirit and intent of endangered species legislation and denial of an important heritage value. The issue was rapidly resolved by discussion with a key Public Works Commissioner who understood a restored natural community would be both appropriate and more efficient to manage. The installed landscaping will be removed and the whole area revegetated with native dune vegetation in 1992-1994.

PLAYA DEL REY - BALLONA BACKDUNE: The 6 acre dunes is owned by Playa Vista Properties and was subject to intense public conflict involving many parties. The property is part of the overall 950 acre Ballona Wetlands site. A resolution was tentatively reached (1990) whereby $10 million will be provided by the developer to a conservancy that will restore and otherwise utilize about 260 acres of badly deteriorated habitat that will be deeded as a perpetual preserve. The benefit to the developer will be permission to construct residential and commercial buildings on 748 acres it cannot otherwise now develop. A plan to restore the dunes fragment was approved by the Coastal Commission and other planning agencies, but has not been implemented by the developer (late 1991). The U. S. Fish and Wildlife Service granted permits to reintroduce the ESB. In the meantime habitat values continue to decline while diverse interests fail to agree. The situation parallels the LA-golf

course matter, except LAX involves public property, whereas Playa Vista is private.

BALLONA LAGOON: A 7 acre terrestrial upland exists surrounding a 9 acre tidal lagoon located across the Ballona Creek channel to the north of the above site. A small, 0.2 acre portion was re-vegetated in late 1990 with 41 species of sand dune plants, including 70 coastal buckwheat plants. A second planting is proposed for 1992 and will include sufficient foodplant to attempt an ESB re-introduction. A re-introduction of Behr's metalmark, *Apodemia mormo virgulti*, is scheduled for 1992 as a surrogate for predicting success with the ESB on a small fragment. Revegetation will presently be expanded to the entire site.

Assuring survival of both the ESB and the dunes ecosystem must involve all of the localities cited above. Site multiplicity alone, assuming responsible management, will go far in preserving all the sand obligate plants and animals of the dunes. Although the sites cut across several political boundaries and public interests, their biological commonality must be recognized. The sites are summarized in Table 1.

Biological Aspects of Planning

BACKGROUND INFORMATION

Listing the ESB in 1976 was based largely on intuitive information concerning distribution, abundance, and the nature of threat. Emmel and Emmel (1973) mention that the then undescribed butterfly was in danger of extinction. Their opinion was later backed by supporting historical observations of the mass extirpation of other species on the dunes by urbanization with only remnants left at LAX, Malaga and Chevron. Arnold (1983, 1987) presented quantitative information on the Chevron populations from 1977 to 1986 that showed a steady decline from 1600 to 400 individuals. Transect counts by Mattoni and Murphy (1984 unpub. rept.) provided population estimates at LAX of about 800, or about twice Arnold's (1986) MMR estimates from the same time. For other biological parameters, Shields (1975) first found the butterfly associated with *Eriogonum parvifolium* and Arnold (1983) later gave additional information from Chevron on demographics, dispersal, foodplant numbers, and parasitoids; but these provided only limited useful information for developing a conservation plan and management strategy. Information prior to the Mattoni (1990) report was incomplete through failure to recognize the very significant differences in habitat structure at different sites.

STUDIES CONDUCTED TO DEVELOP A CONSERVATION PLAN: CHEVRON

The conservation plan Arnold (1986) implemented at Chevron essentially followed conventional wisdom without benefit of a planned study or research program. Detailed numerical estimates of ESB population size, a cornerstone of the plan, had little relevance to planning other than

reiterating the obvious. Although the plantations of buckwheat foodplant and removal of iceplant had a salutary effect on the ESB, the efforts did not address the basic biology of either ecosystem structure or its restoration. And as mentioned the damage inflicted by the study itself with extensive and intensive trampling over a small parcel, may have accounted for some reduction of the ESB.

STUDIES CONDUCTED TO DEVELOP A CONSERVATION PLAN: LAX

As the*de facto* major dunes preserve in both land area and habitat diversity, attention will be focussed on LAX. After the initial 1984 studies, Pratt and Mattoni made observations that provided insights explaining the low relative ESB numbers at LAX. Their judgement was based on population density of the foodplant, which implied that several times the observed number of butterflies were to be expected. Operating on a grant from California Department of Fish and Game, they determined that the critical threat to the ESB was high density of two moth species *Lorita scarifica* and *Aroga species*. Abundance of the moths was the result of the presence of introduced common buckwheat that provided them foodplant a month prior to blooming of the coastal buckwheat. Since the moths are multivoltine, and the ESB univoltine, the added generation provided a direct competitive edge as well as high density of the parasitoids they share with the ESB. The Airport Commission consequently provided emergency funding to remove the buckwheat and otherwise augment the habitat.

A comprehensive restoration and management plan needs information not only on the biology of the ESB, but of other components of the ecosystem which impact not only the ESB, but other sensitive species found at the site. In order to test ESB population responses, a standard transect was established for annual monitoring of adult ESB. The transect path was designed to minimize damage to the substrate. The biological survey of distribution and abundance of all dunes plants and animals provide data for a model of the ecosystem to document restoration. The study included information collected by Pierce and his colleagues in 1938-1939, collections by others, and old aerial and ground photographs. The study was funded by the Airport Commission a report now available (Mattoni 1990). A comprehensive restoration and management plan is in final preparation and funding sources are being pursued.

EL SEGUNDO BLUE POPULATION MONITORING

A general estimate of butterfly population size is needed to evaluate both the impact of management techniques and status. Although mark-release-recapture (MRR) techniques can be useful, deleterious effects of such handling on so delicate an insect cannot be justified. In addition to mortality (reported as 10% in the mission blue butterfly by Reid and

Murphy, 1986) and behavior modification (Morton, 1984), any perceived precision MRR might provide is unsupportable for studies involving fragile endangered species. The alternative of visually scoring along a regular transect is adequate for providing needed data, but even here the trampling problem must be minimized. Since MRR had been used simultaneously with a transect in 1984, crude numbers for calibration are available (Thomas 1983). Because of the unique behavior of adult *Euphilotes* butterflies, the transect count method may be more accurate than MRR. Since adult ESB spend over 90% of their time on flowerheads of the foodplant, moving less than 10% of the time and then usually only when travelling to a nearby flowerhead, a direct estimate of the total instantaneous population size is possible by making a rapid count of adults on flowerheads from a sample of each colony aggregate, given a count of total number and distribution of flowerheads.

An accurate estimate of total population size over the entire flight period, however, depends upon estimates of birth and death rates and immigration and emigration. Because these parameters rely on estimates only obtainable from MRR, with its faulty assumptions, total population size estimates from transect counts will have a large error component (Mattoni, in prep.).

Monitoring is also possible by sampling flowerheads to determine numbers and species of larvae. The procedure would be useful to estimate population densities of the two moths which interact with ESB larvae as well. Lastly, ESB can also be estimated from pupae counted in sifted soil from the base of foodplants.

DISTRIBUTION

The ESB is limited to the occurrence of its foodplant, but the relationship is not random. Table 2 lists ESB population counts from five major clusters of buckwheat foodplant in 1984 and 1986-1990 with numbers of plants and their flowerhead number (Figure 4). The lack of correlation between butterfly and foodplant is clearest when comparing clusters 1 and 2 (backdune) with 5 (foredune/VOR). The former each yielded 1.6 butterflies per thousand flowerheads, the latter only 0.14. This distribution pattern emphasizes the heterogeneity in habitat values, with the importance of any given plant being its location. The general distribution of high quality plants largely on the backdune near the toe of the slope is a key to conservation. The few high quality plants on the foredune only grow in small depressions with leeward protection.

DISPERSAL

Adult ESB are sedentary animals that spend the bulk of their time perching and searching for mating opportunities (males) and ovipositing and feeding (females). From MRR work, a few individuals moved distances equivalent to the farthest reaches of the habitat (Arnold 1986). Using a different approach, Mattoni and Pratt (unpub.) set out mature

potted foodplants at sites up to 0.5 km. outside their normal distribution area with the objective of finding offspring of dispersing females. The results were negative. All the flowerheads of two isolated plants in the disturbed foredune area (see map, Figure 4) were sampled with no ESB early stages found on 184 flowerheads in 1987. These data indicate dispersal, and/or distant foodplant locating ability across distances as small as 200 meters, is not common. Although movement between the main buckwheat clusters is probably more limited than within clusters, from a practical viewpoint further investigation is not now warranted. For purposes of population genetics, even with low inter-cluster movement, the population of LAX is a single unit (Forney and Gilpin, 1989).

The small colonies at Chevron and Malaga Cove are isolated with probably no effective gene flow possible with the LAX "metapopulation". Recent data of Pratt (unpub.) found allozyme frequencies of Malaga indistinguishable from LAX indicating these populations have not been separated for enough time to permit deviation in frequency of the tested loci.

Habitat Values

An ecosystem is physically described by the distribution and abundance of all plant and animal species in a circumscribed area, or habitat, to which they are co-adapted. High natural value habitat can thus be characterized by the community of species found prior to human interference. Only 1 ha backdune and 5 ha foredune at LAX can thus be considered relatively pristine habitat, with another dozen hectares moderately undisturbed. These pristine sites provide species area curve models for restoration and foci from which to carry out restoration based on species area curves. Alien species require identification with a plan for their regulation. Particular care must be devoted to assessing whether apparent natives are historic natives. The common buckwheat was heretofore believed a native plant of the dunes, for example, yet proved to be a serious threat to the ESB because it was not.

All extirpated plants must be re-introduced into their proper microhabitats. Where precise information is lacking, this can only be done by over planting and allowing selection to later segregate density and distribution. Animal re-introduction will require care to avoid excess herbivory while maintaining assurance of population regulation within the food web. Re-establishment of the historic mammalian community is impossible because of isolation and area limitation for megapredator support. The absence of models for the sequence of introduction of smaller mammals is another problem.

Biological Program

The biological program outlines the concerns which affect the viability of the entire plant and animal communities of the dunes ecosystem. Although focus remains on the ESB, over 30 identifiable species of

Table 3. Species of special interest on the El Segundo sand dunes. Included are extirpated species that may be reintroduced, extinct species, species with restricted sand dune distributions, and species recognized by institutional listing. Site: location on prairie (P) or dunes (D). Listing categories: Federal, Endangered, Fed. 1 is awaiting listing, Fed 2 is candidate for listing, Fed 3 is probably not listable; California Department of Fish and Game, Cal E is endangered, Cal T is threatened, SSC is a species of special concern; CNPS is the California Native Plant Society listing. Status indicates population condition at the dunes.

Common name	Scientific name	Site	Listing	Status
Species restricted to the El Segundo sand dune system				
Plants				
El Segundo spineflower	*Chorizanthe californica var.Suksdorfii*	DP	CNPS 1B	increasing
Animals, Invertebrates				
El Segundo blue butterfly	*Euphilotes battoides allyni*	D	Endangered	increasing
El Segundo goat moth	*Comadia intrusa*	D	none	holding
Ford's sand dune moth	*Psammobotys fordi*	D	Fed. 2	extinct?
El Segundo scythrid moth	*Scythris n. sp. 1*	D	none	abundant
Lesser dunes scythrid moth	*Scythris n. sp. 2*	D	none	rare
El Segundo jerusalem cricket	*Stenopelmatus n. sp*	DP	none	decreasing ?
Dorothy's El Segundo Dune weevil	*Trigonoscuta dorothea dorothea*	D	Fed. 2	very common
Lange's El Segundo Dune weevil	*Onychobaris langei*	DP	Fed. 2	very rare
no common name weevil	*Cylindrocopturus n. sp.*	D	none	rare
El Segundo crab spider	*Ebo n. sp.*	D	none	abundant
Sand obligate species restricted to southern California coastal dunes				
Plants				
Seaside red maids	*Calandrinia maritima*	D	CNPS 4	extirpated
Beach spectacle-pod	*Dithyrea maritima*	D	Fed. 2 Cal T	extirpated
California Orcutt grass	*Orcuttia californica*	P	Endangered	extirpated
Coastal dunes milk-vetch	*Astragalus tener var. titi*	P	Fed. 1, Cal E	extirpated
Ventura marsh milk-vetch	*Astragalus pycnostachus var. lanosissimus*	P	Fed. 1	extinct

Animals, invertebrates

Santa Monica dunes moth	*Copeblepharon sanctaemonicae*	D	none	abundant
River's dune moth	*Euxoa riversii*	D	none	rare
Lora Aborn's moth	*Lorita scarifica (=abornana)*	DP	Fed. 3B	misident/widespread
Busck's gall moth	*Carolella busckana*	DP	Fed. 2	extirpated
Henne's eucosman moth	*Eucosma hennei*	DP	Fed. 2	stable, low pops.
Globose dune beetle	*Coelus globosus*	DP	Fed. 2	rare
South coast scarab beetle	*Psammodius macclayi*	D	none	rare
Dunes convex scarab beetle	*Aegilia convexa*	D	none	rare
Belkin's dunes tabanid fly	*Brennania belkini*	D	Fed. 3C	stable, uncommon
Dunes robberfly	*Proctocantha coquilleti*	D	none	uncommon
El Segundo giant flower loving fly	*Raphiomidas terminatus terminatus*	DP	none	extinct
California dunes sand roach	*Arenivaga n. sp.*	D	none	common
Coastal dunes tarantula	*Apostichus simus*	D	none	rare, local
Coastal dunes whip scorpion	*Eremobates n. sp.*	DP	none	uncommon
Augustson's red mite	*Erythraeus tuberculatus*	D	none	common

Species of special concern, listed, proposed for listing, or under study-review that were found on the dunes, but have or had wider distributions.

Animals, Vertebrates

Ornate shrew	*Sorex ornatus salicornicus*	P?	Fed.2	extirpated
Pacific little pocket mouse	*Perognathus longimembris pacificus*	P	Fed.2	extirpated
Long eared kit fox	*Vulpes macrotis macrotis*	PD		extinct
Burrowing owl	*Athene cunicularia*	PD	SSC	extirpated?
Least tern	*Sterna antillarum browni*	D	Endangered	rare (nesting)
San Diego horned lizard	*Phrynosoma coronatum blainvillei*	PD	Fed.2, SSC	increasing
California legless lizard	*Aniella pulchra*	PD	in review	decreasing
Western Spadefoot toad	*Scaphiopus hammondi*	P	in review	extirpated

concern and those limited in distribution to southern California coastal dunes ecosystems will all be aided by re-establishing an optimal environment for the ESB. Unfortunately emphasis on the butterfly has been and will remain important since most non-biologists, including politicians, attorneys, and planners, can more easily deal with a single organism rather than a complex system that is both conceptually and in reality vague (Jensen et al. 1990).

The LAX dunes are a leading "hotspot" of biodiversity nationally when judged by the number of unique species for area size. To date 11 species have been identified that are endemic to the El Segundo dunes system, with many more variously listed as species of concern or significance (Table 3). These include the extinct El Segundo giant flower-loving fly, *Raphiomidas terminatus terminatus*; the San Diego horned lizard, *Phrynosoma coronatus blainvillei*; the seaside calandrinia, *Calandrinia maritima*; and the beach spectaclepod, *Dithyrea maritima*.

Principles that will be utilized to develop a plan include:

1. Restoration. The major emphasis for dunes conservation will be restoration. With only two acres of backdune in pristine condition, re-establishment the entire backdune area must have highest priority, since this is the site of highest ESB population density. Effort will also be directed to maintain and restore habitat diversity on foredune areas and the prairie area based upon species present for the 1938 survey. The coastal prairie, though not ESB habitat, is significant by providing interface to the backdune. This "edge" produces the highest diversity of any part of the dunes. It is also a buffer area into which ESB extensively wanders.

2. Free sand. Sufficient area is necessary, including the prairie deflation plain, to accommodate free movement of sand, by wind and water. Sand movement is necessary to maintain this physical process to which the unique sand obligate biota are adapted. The amount of net movement may be on the order of one centimeter of depth annually.

3. Human activity negatively impacts the ESB and its foodplant. The sand dune substrate must be protected from trampling or other degrading contact.

4. Alien plants are a major threat to both the ESB and its foodplant either directly (shading, choking seedlings) or indirectly (by chemically and physically modifying the soil or by serving as alternate hosts to predators or competitors). Most other native dunes species are also threatened by alien plants. Evidence indicates the majority of the native flora is not spreading, but is rapidly being replaced. Active management is required to reverse this trend.

5. Alien animals have had serious effects that are only partially understood. The European red fox, responsible for the loss of nearly a dozen small mammals and scrub obligate bird species, must be extirpated. Two of the five most abundant ground dwelling insects, the Argentine ant and the European earwig (Mattoni, 1990a), have displaced

native species and are having other effects. Regulation must be attempted.

6. Reintroductions. All extirpated native plant and most animal species must be reintroduced. These include species known to have occurred on the dunes and for which similar genetic stock can be obtained. Globally extinct species such as the El Segundo giant flower-loving fly, *Raphiomidas terminatus terminatus* cannot be resurrected. Extirpated species are all theoretically available, although some may be rare.

7. Management. All techniques used must minimize damage to native species while eliminating alien plants and animals.

8. Monitoring. is essential to assess progress of the program and to provide advance warning of shifting conditions which might otherwise be unnoticed.

There are a number of uncertainties for carrying out the plan which suggest continuing research, including pollution effects from JP-4 jet fuel hydrocarbons and borates, high noise levels, and possibly extra low frequency electromagnetic radiation. There is clearly potential to perform meaningful experiments for community ecology and to provide contributions to basic scientific knowledge. The plan must include provision for local universities and colleges that will enable students to participate through new research programs.

Institutional Program

An institutional program will be developed to establish a committee to represent all parties with vested interests in land use, biology, and environmental concerns. The committee will set policy to implement the biological program.and be charged with administering the habitat conservation plan.

A funding mechanism is crucial to the plan for both the restoration program and continuing management. The recreational facility plan put forth for the Department of Airports by the Los Angeles city planning department in l983 was designed to finance a habitat conservation plan through fees generated by the facility developer. The privately managed facility was to include a 27 hole golf course plus an active recreation area. Nature was to be served through the establishment of a permanent 80 acre conservancy and 12 acre preserve. All undisturbed areas were included in the 80 acre conservancy.

The matter is unresolved (1991), yet the clear message from data gathered to date is that without an active program, the dunes ecosystem will continue to collapse (Mattoni 1990b). At what point the ESB will disappear cannot be predicted, but the event could be within decades without further augmentation efforts. Species recently extirpated from the dunes cannot be restored without manipulated reintroduction because there are no nearby natural areas. Exotic plants and animals continue spreading and can only be controlled or eliminated by directed

intervention. The restoration and management program will require funding. The 1983 plan was one approach to solving the problem, although with an unfavorable land area.

Prognosis

Long term survival of the ESB is dependent on a habitat restoration and management. To best serve the needs of the butterfly, the entire useable remnant 277 acre El Segundo dunes ecosystem should be conserved. To conserve the biota, a habitat conservation plan has been prepared which addresses the following issues:

1. The ESB and its coastal buckwheat foodplant are essentially restricted to land which has not been disturbed by human activity. Both species are indicators of habitat quality and conditions which promote them will serve to restore other components of the dunes ecosystem.
2. Human activity negatively impacts the ESB and its foodplant. The sand dune substrate must be protected from trampling or other degrading contact.
3. Alien plants are a major threat to both the ESB and its foodplant. Other native components of the dunes ecosystem are also threatened by alien plants. Active management is required to reverse this trend.
4. Patterns of herbivory have been modified by the extirpation of most mammal species. Alien carnivores must be removed and native herbivores replaced by programmed reintroduction. These actions require reestablishment of a food web similar to that originally responsible for regulating the entire community.
5. Any plan should coordinate programs which encompass all former habitat which can be restored to a condition approaching the historical state. This includes the habitat fragments at Malaga Cove, Chevron, DWP right-of-way, and Playa del Rey dune.

Coda

The re-election of Ruth Galanter for the local city council in summer 1991, in part for her strong stand on protecting the LAX dunes, provided the climate to establish a new Specific Plan with 200 acres devoted to a preserve while retaining a 100 acre golf course to satisfy constituency (Figure 3). The rough areas of the golf course will be vegetated as native habitat. The Specific Plan was adopted by the Airport Board of Commissioners, the City Planning Department, and the City Council. Final approval of the California Coastal Commission is the last step before implementation. A detailed habitat restoration and conservation plan has been completed. The major remaining obstacle is funding.

There are no funds now available and no provision in the LAX charter for the use of airport funds for either restoration or habitat maintenance. Although the Department of Airports paid over $300,000 for both the biological study and initial enhancement programs, their use of general funds were justified in promoting the 1983 golf course plan.

Over 43 acres have been revegetated to a degree that over 90% of the plant cover is native (1991). Part of the work was performed by a team of 60 - 140 volunteers. Expansion of the volunteer program is projected to provide over 30% of the effort to complete the revegetation phase of the program. The value of volunteers has proved greater than their donated time alone both in quality and sensitivity of their work and their influence in the political base.

Among the other parcels: the Hyperion foredune is scheduled for native revegetation by the Department of Public Works, contact has just been made for the DWP backdune, the Chevron butterfly garden program continues, Malaga Cove remains ignored, the Playa del Rey dune restoration project has been delayed by its project developer, but the Ballona Lagoon restoration and ESB re-introduction plans are proceeding.

Acknowledgments. Gordon Pratt contributed substantial information concerning many aspects of *Euphilotes* systematics and biology which are invaluable to our understanding of these animals. The format of this report follows that of T. Reid and D. D. Murphy (1987) in their report "The Endangered Mission Blue Butterfly." For comparative purposes it seemed valueable to use a standard format to present background information for planning purposes where diverse interests and institutions are involved. Selected staff of the Los Angeles Department of Airports were extremely helpful for many favors and support. In particular Paul Principe not only made fieldwork a pleasure, but provided graphics support. The airport commissioners, in particular Ms. Maria Hummer, generously provided early funding and demonstrated concern for the broader issues of my biological study of the dunes. Councilwoman Ruth Galanter, her staff including especially Rubelle Helgesson and Betty Fisher, Mayor Tom Bradley, and many individuals across several city departments cannot be commended enough for their efforts and sensitivity to permanently preserve the ESB, its habitat at three sites, and the entire dunes biotic community. The California Coastal Conservancy has provided short term funding until other sources are developed.

Last, but hardly least, I thank Jeremy Thomas, Paul Opler, and Otakar Kudrna for their comments that helped both enrich and clarify an earlier version of this paper.

Literature Cited

ARNOLD, R.A. 1983. Ecological studies of six endangered butterflies (Lepidoptera, Lycaenidae): Island biogeography, patch dynamics, and the design of habitat preserves. Univ. Calif. Berkeley Pub. Entomology. 99. 161 pp.

———1986. Private and government funded conservation programs for endangered insects in California. Natural Areas Journal 5:28-39.

BROWN, D. R. 1986. The effect of human trampling on the dune-mat vegetation of the Landphere-Christensen Dune Preserve. Rept. to The Natural Conservancy, San Francisco. 12 pp.

COOPER, W.S. 1967. Coastal dunes of California. Geol. Soc. Amer. Mem. 104:1-131.

FORNEY, K. A. and M. E. GILPIN, 1989. Spatial structure and population extinction: A study with Drosophila flies. Conservation Biology 3: 45-51.

GILPIN, M. E. and M. SOULE 1986. Minimum viable populations: processes of species extinction. pp. 19-34 in M. E. Soule ed/ Conservation Biology: the science of scarcity and diversity. Sinauer. Sunderland, MA.

JENSEN, D., M. Torn, and J. HARTE. 1990. In our hands: A strategy for conserving biological diversity in California. California Policy Seminar, Univ. Calif.

LAX-EIR 1975. Physical environmental studies, Los Angeles International Airport. Unpublished report by Olson Laboratories.

MATTONI, R.H.T. 1988. Captive propagation of California endangered butterflies. Report to Calif. Dept. Fish and Game. Contract C-1456.

——— 1989. The Euphilotes battoides complex: Recognition of a species and description of a new subspecies. Jr. Res. Lepid. 27: 173-185.

——— 1990. Habitat evaluation and species diversity on the LAX El Segundo sand dunes. Rept. to the LAX board of airport commissioners.

——— 1990a. Unnatural acts: succession on the El Segundo sand dunes in California. Proc. Soc. Ecol. Restoration and Management: 581-593.

MURPHY, D. D. 1984. Book Review: Ecological studies of six endangered butterflies (Lepidoptera. Lycaenidae): Island biogeography, patch dynamics and the design of biological Reserves. by R. A. Arnold. Jr. Res. Lepid. 22: 267-269.

——— 1988. Are we studying our endangered butterflies to death. Jr. Res. Lepid. 26: 236-239.

MORTON, A. C. 1984. in R. I. Vane-Wright and P. A. Ackery eds. The biology of butterflies. (Symposium of the Royal Entom. Soc. Lond. No. 11). Academic, London.

OPPENWALL, J. C. 1975. The saving of the El Segundo Blue. Atala 3: 25-28.

PIERCE, D. W. 1938-1940. Unpublished notes on the El Segundo sand dune study. 5 vols. Natural History Museum of Los Angeles County.

PRATT, G. 1987. Competition as a controlling factor of Euphilotes battoides allyni larval abundance. Atala 15: 1-9.

REID, T. and D. MURPHY. 1986. The endangered mission blue butterfly. U. S. Forestry Service "Syllabus on managing viable populations".

SHIELDS, O. 1975. Studies on North American Philotes IV. Taxonomic and biological notes and new subspecies. Bull. Allyn Museum No. 28. 36 pp.

SHIELDS, O and J. Reveal. 1988. Sequential evolution of Euphilotes (Lycaenidae, Scolitantidini) on their plant host Eriogonum (Polygonaceae, Eriogonoideae). J. Linn. Soc. 33:51-91.

VIVRET, N. J. and C. H. MULLER. 1977. Mechanism of invasion and dominance of coastal grassland by Mesembryanthemum crystallinum L. Ecol. Monogr. 47: 302-318.

VON BLOEKER, J. 1941. Amphibians and Reptiles of the Dunes. Bull. So. Calif. Acad. Sci. 40:29-38.

WHITE, R.R. 1986. Pupal mortality in the bay checkerspot butterfly (Lepidoptera:Nymphalidae). Jr. Res. Lepid. 25:52-62.