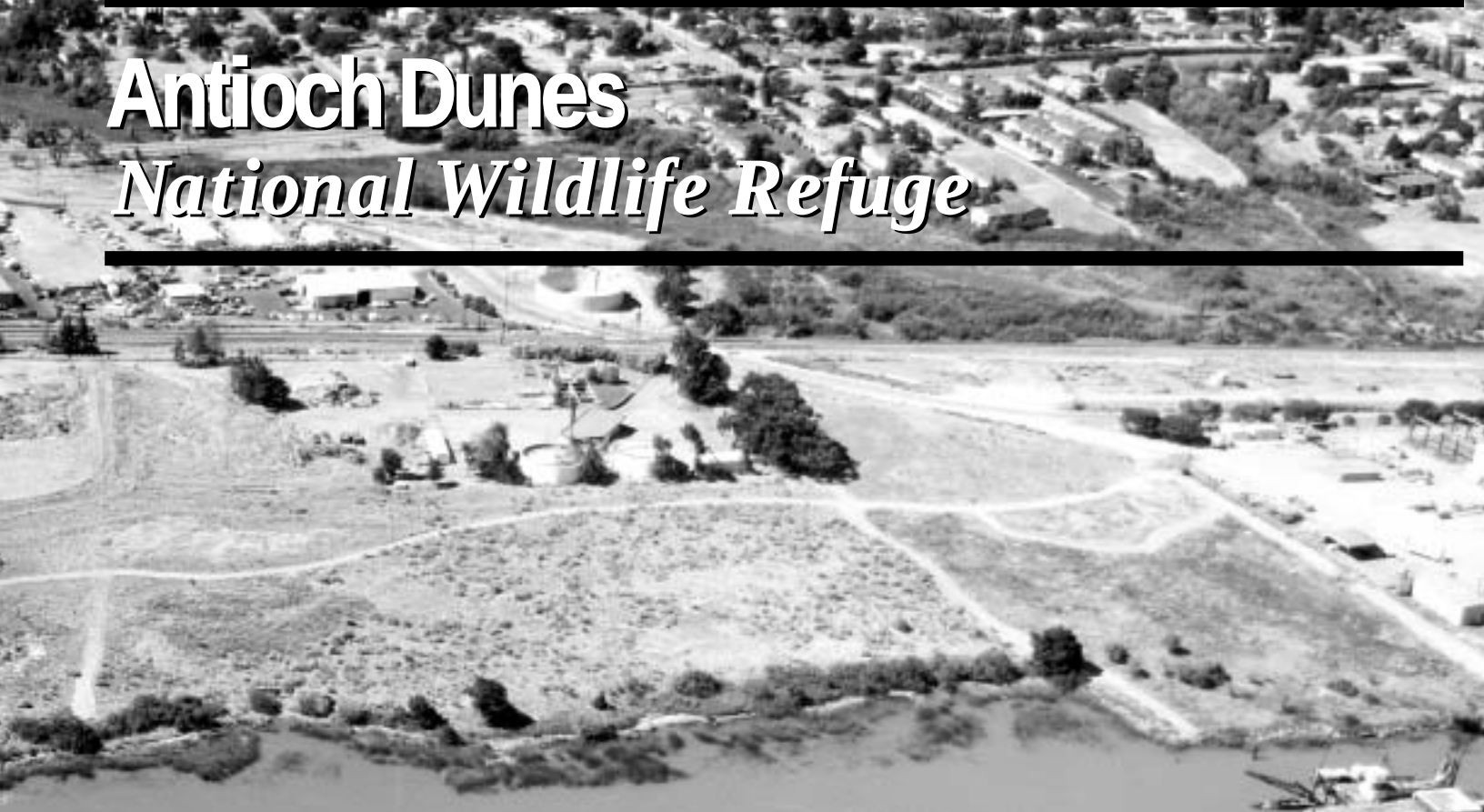
U.S. Fish & Wildlife Service

Antioch Dunes
National Wildlife Refuge



Draft Comprehensive Conservation Plan
Plan and Environmental Assessment

Antioch Dunes National Wildlife Refuge

Draft Comprehensive Conservation Plan

September 2001

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Acronyms

U.S. Fish and Wildlife Service	Service
Antioch Dunes National Wildlife Refuge	Refuge
National Wildlife Refuge	refuge
Sacramento-San Joaquin River Delta	Delta
Antioch Dunes evening primrose	primrose
Contra Costa wallflower	wallflower
Lange's metalmark butterfly	Lange's
California Department of Transportation	Caltrans
California Department of Parks and Recreation	DPR
California Native Plant Society	CNPS
Pacific Gas and Electric Company	PG&E
University of California	UC
Environmental Assessment	EA
National Wildlife Refuge System	Refuge System
Comprehensive Conservation Plan	CCP
Naked stem buckwheat	buckwheat
National Environmental Policy Act	NEPA
Global positioning system	GPS

Scientific Names

Oenothera deltoides howellii (e)	Antioch Dunes evening primrose
Erysimum capitatum angustatum (e)	Contra Costa wallflower
Apodemia mormo langei (e)	Lange's metalmark butterfly
Eriogonum nudum auriculatum	naked stem buckwheat
Centaurea solstitialis	yellow starthistle
Bromus diandrus	ripgut brome
Vicia villosa varia and *Vicia sativa nigra*	vetch
Lepidium latifolium	pepperweed
Cortaderia selliana	pampas grass
Arundo donax	giant reed
Robinia psuedoacacia	black locust
Nerium oleander	oleander
Ailanthus altissima	tree of heaven
Croton californicus	Croton

Chapter 1 - Introduction

Introduction

The Antioch Dunes National Wildlife Refuge (Refuge) is the first and only wildlife refuge in the country established to protect endangered plants and insects. Created in 1980 by the U.S. Fish and Wildlife Service (Service), this riverside Refuge provides protection and critical habitat for three endangered species: Lange's metalmark butterfly (*Apodemia mormo langei*)(Lange's), Contra Costa wallflower (*Erysimum capitatum angustatum*)(wallflower), and Antioch Dunes evening primrose (*Oenothera deltoides howellii*)(primrose). The Refuge, 55-acres of former dunes, in addition to the adjacent 12 acres of Pacific Gas and Electric Company (PG&E) land, is an isolated patch of what was once a larger dune system that hosted a unique assemblage of plants, insects, and reptiles. A major effort is currently underway to restore and improve dune habitat on the Refuge. The Refuge is managed by Refuge staff based in the San Francisco Bay National Wildlife Refuge Complex office in Fremont, California.

Antioch Dunes Evening Primrose and Contra Costa Wallflower

Purpose and Need for the Plan

The Service prepared this Comprehensive Conservation Plan (CCP) to guide wildlife and other natural resource management, as well as public use, on the Refuge for the next 15 years. The CCP is flexible; it will be revised periodically to ensure that its goals, objectives, implementation strategies, and timetables are still valid and appropriate. Major revisions will require public involvement and NEPA review, if needed. The CCP will:

- Provide a clear statement of direction for the management of the Antioch Dunes National Wildlife Refuge over the next 15 years.
- Provide a clear vision of the desired future conditions of the Refuge.
- Provide the public with an understanding of the reasons for management actions on the Refuge.
- Ensure that management of the Refuge reflects the mission, policies, and goals of the National Wildlife Refuge System (Refuge System).
- Ensure the compatibility of current and future uses of the Refuge.
- Provide long-term continuity of Refuge management.
- Provide a basis for operation, maintenance, and development budget requests.

The U.S. Fish and Wildlife Service and the National Wildlife Refuge System

U.S. Fish and Wildlife Service Responsibilities

The Service is the primary Federal agency responsible for conserving and enhancing the Nation's fish and wildlife populations and their habitats. Although the Service shares this responsibility with other Federal, State, Tribal, local, and private entities, the Service has specific responsibilities for migratory birds, threatened and endangered species, anadromous fish, and certain marine mammals. The Service has similar responsibilities for the lands and waters it administers to support the conservation and enhancement of fish and wildlife.

The National Wildlife Refuge System

The National Wildlife Refuge System is the world's largest collection of lands specifically managed for fish and wildlife conservation. Unlike other Federal lands that are managed under a multiple-use mandate (e.g., National Forests and lands administered by the U.S. Bureau of Land Management), the Refuge System is managed for the benefit of fish, wildlife, and plant resources and their habitats.

Operated and managed by the Service, it comprises more that 500 national wildlife refuges with a combined area of more than 92 million acres. The majority of refuge lands (approximately 77 million acres) are located in Alaska. The remaining 15 million acres are spread across the other 49 states and several island territories.

The mission of the National Wildlife Refuge System is "to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Amercians" (16 USC668dd et seq.). The goals of the National Wildlife Refuge System are to:

- preserve, restore, and enhance in their natural ecosystems (when practicable) all species of animals and plants that are endangered or threatened with becoming endangered;

- perpetuate the migratory bird resource;

- preserve a natural diversity and abundance of fauna and flora on refuge lands; and

- provide an understanding and appreciation of fish and wildlife ecology and the human role in the environment and to provide refuge visitors with high-quality, safe, wholesome, and enjoyable recreational experiences oriented toward wildlife to the extent these activities are compatible with the purposes for which the refuge was established.

Legal and Policy Guidance

National Wildlife Refuges are guided by the mission and goals of the Refuge System, purposes of the Refuge, Service policy, laws, and international treaties. Relevant guidance includes the National Wildlife Refuge System Administration Act of 1966,

as amended by the National Wildlife Refuge System Improvement Act of 1997, Refuge Recreation Act of 1962, and selected portions of the Code of Federal Regulations and Fish and Wildlife Service Manual.

The Refuge Recreation Act of 1962, as amended, authorized the Secretary of the Interior to administer refuges, hatcheries, and other conservation areas for recreational use when such uses did not interfere with the area's primary purpose. The National Wildlife Refuge System Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997, identified a new mission statement for the Refuge System; established six priority public uses (hunting, fishing, wildlife observation and photography, environmental education and interpretation); emphasized conservation and enhancement of the quality and diversity of fish and wildlife habitat; stressed the importance of partnerships with Federal and State agencies, Tribes, organizations, industry, and the general public; mandated public involvement in decisions on the acquisition and management of refuges; and required, prior to acquisition of new refuge lands, identification of existing compatible wildlife-dependent uses that would be permitted to continue on an interim basis pending completion of comprehensive conservation planning.

The National Wildlife Refuge System Improvement Act of 1997 establishes the responsibilities of the Secretary of the Interior for managing and protecting the Refuge System; requires a CCP for each refuge by the year 2012; provides guidelines and directives for the administration and management of all areas in the Refuge System, including wildlife refuges, areas for the protection and conservation of fish and wildlife threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas.

The Improvement Act of 1997 also establishes a formal process for determining compatibility of uses. Before any uses, including priority public uses, are allowed on refuges, Federal law requires that they be formally determined "compatible." A compatible use is defined as a use that, in the sound professional judgement of the refuge manager, will not materially interfere with or detract from the fulfillment of the purposes of the refuge. Sound professional judgement is defined as a finding, determination, or decision that is consistent with the principles of sound fish and wildlife management and administration, available science and resources (funding, personnel, facilities, and other infrastructure), and applicable laws. The Service strives to provide priority public uses when compatible. If financial resources are not available to design, operate, and maintain a priority use, the Refuge manager will take reasonable steps to obtain outside assistance from the State and other conservation interests.

The Refuge has completed draft compatibility determinations for environmental education, interpretation, wildlife observation and photography, and research (Appendix A - Compatibility Determination). These will be finalized with the CCP.

The Antioch Dunes National Wildlife Refuge

Location

The Refuge is adjacent to the City of Antioch along the south shore of the San Joaquin River in an area that was part of an expanse of riverine sand dunes (Figure 1). The site is in Contra Costa County. The Refuge consists of two disjunct parcels

Figure 1. Location Map

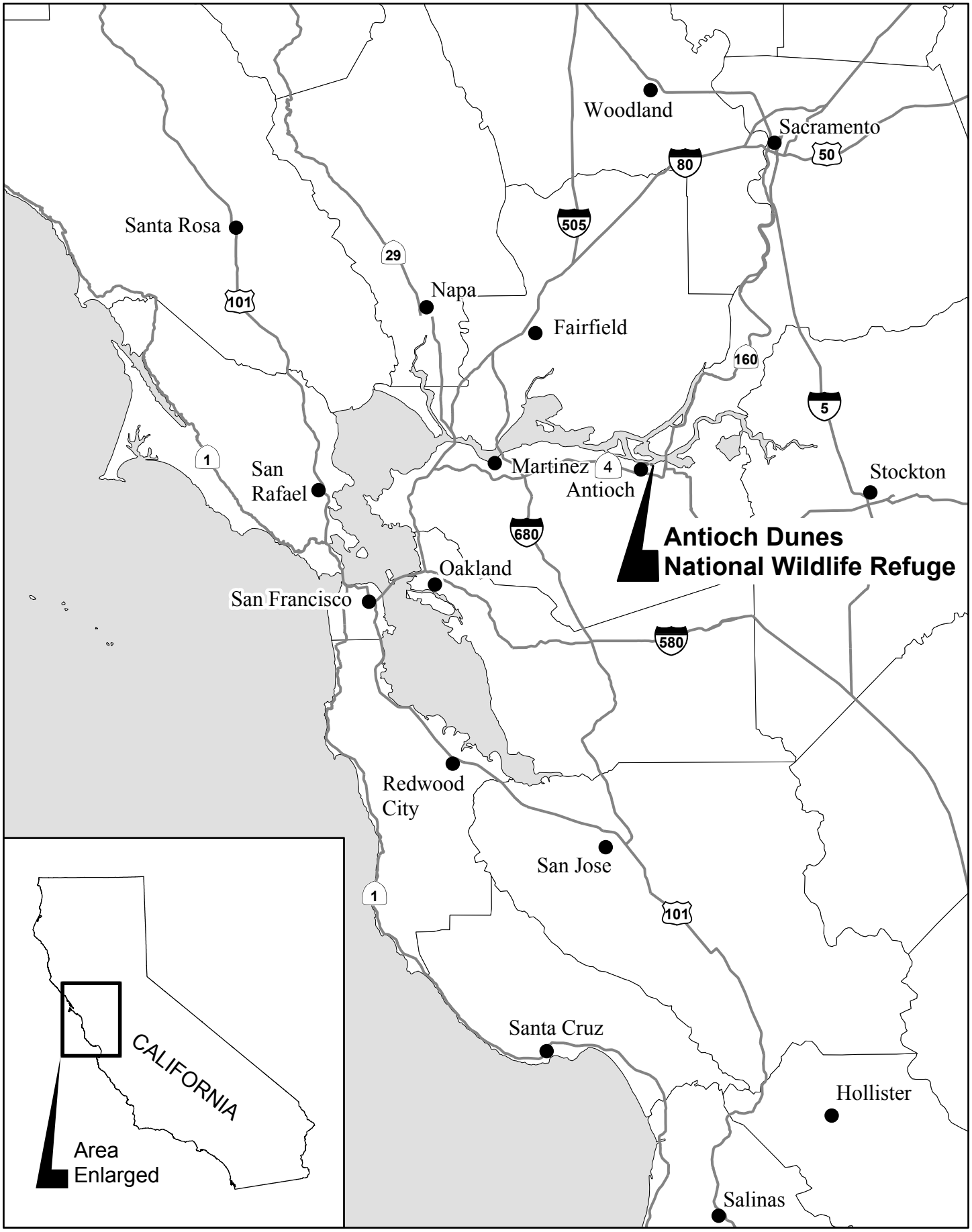
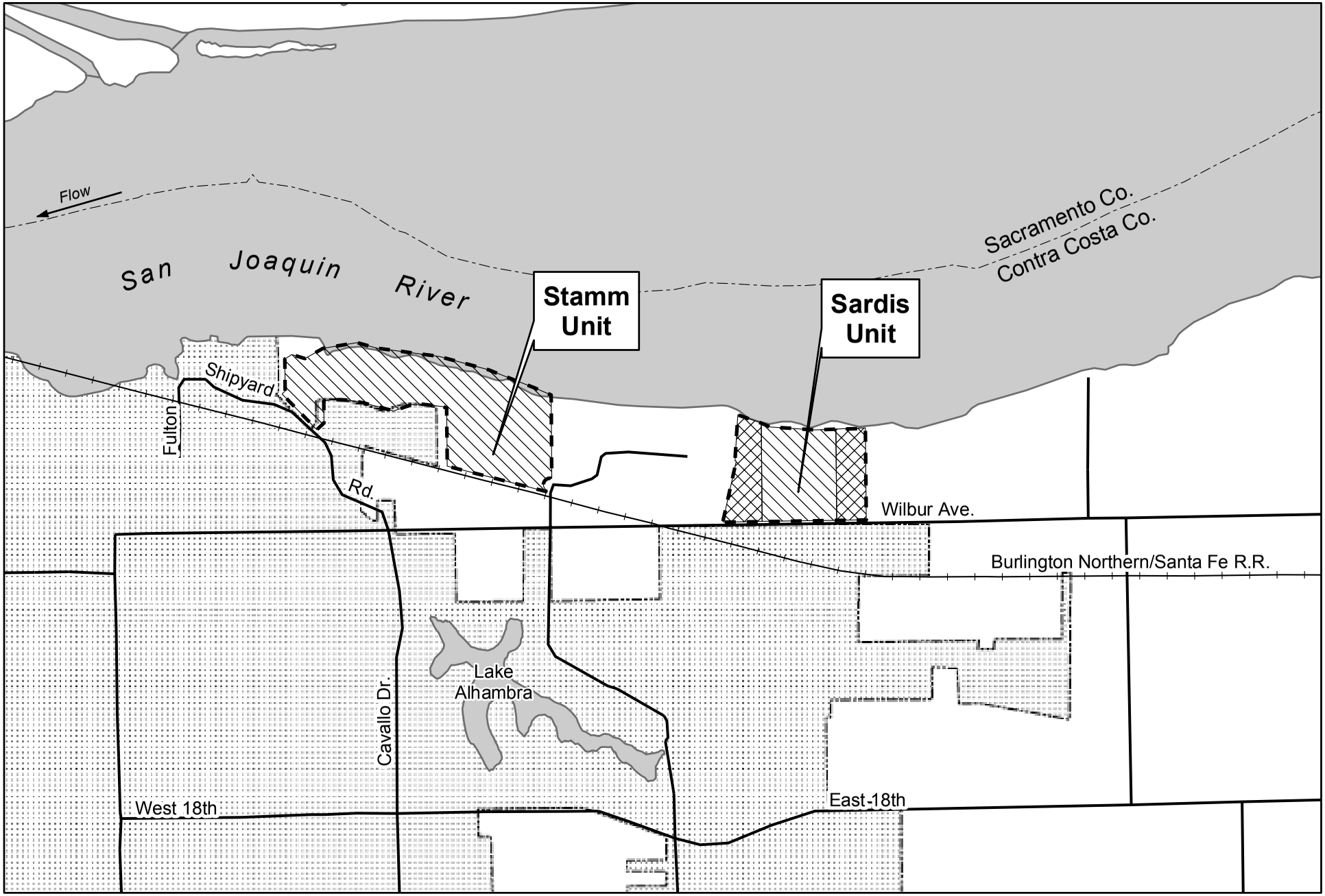


Figure 2. Antioch Dunes National Wildlife Refuge



CA/NV Refuge Planning Office, July 2001

Approved Refuge Boundary | City of Antioch | Unincorporated Contra Costa County

U.S. Fish and Wildlife Service Lands | Pacific Gas and Electric Lands

(Figure 2). The westernmost unit, called the Stamm Unit, is bordered to the west by Fulton Shipyard; to the east by the Georgia-Pacific gypsum plant; to the south by Fulton Shipyard Road, Burlington Northern/Sante Fe Railroad, and a city wastewater treatment plant and transfer facility; and to the north by the San Joaquin River. The easternmost unit is referred to as the Sardis Unit. It is bordered to the west by the Georgia-Pacific gypsum plant; to the east by Kemwater North American Company (Kemwater); to the north by the San Joaquin River; and to the south by Wilbur Avenue.

Land Ownership

The approved Refuge boundary encompasses 67 acres, 55 acres of which are owned by the Service. The additional 12 acres owned by PG&E, are part of the same remnant dune ecosystem, and have been managed in the past (1985 to 1995) by the Service under a cooperative agreement with PG&E. The area includes remnant dunes, and riparian cover types. The Service and PG&E are currently in the process of renegotiating the cooperative agreement. Under the new agreement, it is anticipated that the Service will conduct some management activities, such as biological monitoring and weed control, on the PG&E parcel. In the interim, PG&E has continued to allow biological surveys to be conducted on their lands. This CCP will only address management of lands owned by the Service.

Sardis Unit

Partnerships

The Refuge has benefitted from partnerships with several entities and individuals. In addition to the PG&E partnership, described above, the Refuge has benefitted from the work of many scientists who have conducted research at the dunes. Refuge partners include the California Department of Fish and Game, Solano and Napa County Mosquito Abatement Districts, Mills College, University of California (UC) Berkeley, UC Santa Cruz, UC Davis, the California Department of Transportation, Center for Natural Lands Management, and many dedicated volunteers and individuals.

Refuge Setting

The Refuge is in an area that was once part of a more expansive sand dune system. The Antioch Dunes were once a large, ancient, aeolian (wind blown) dune system extending along the southern bank of the San Joaquin River just east of the town of Antioch (Powell 1983). A 1908 U.S. Geological Survey topographic map showed the bulk of the dunes to be along a two mile stretch of the river, averaging approximately one-sixth of a mile in width and totaling roughly 190 acres (Howard and Arnold 1980). Isolation of this sand dune habitat resulted in the development of species and subspecies of plants and insects that are found nowhere else in the world.

Around the early 1900s, this biological “island” began to experience a dramatic change. Human development and sand mining destroyed most of the dunes that historically reached heights of 120 feet. The easily-accessible sand was mined to make bricks, many of which were used to rebuild San Francisco after the 1906

earthquake. Large-scale sand mining and industrial development continued to fragment the sand dune habitat until only a small portion of the original ecosystem remained. A small portion of the dunes were protected from further development and mining when the Refuge was established in 1980. However, invasive nonnative grasses and vegetation encroached on the sand dunes to crowd the few remaining endangered plants. When the Refuge was established, only a few acres of remnant dune habitat supported the last natural populations of primrose, wallflower, and Lange's. The Refuge was open for public use until 1986 when it was closed to protect the endangered plants from trampling and wildfires.

Refuge History

140,000 years ago	Sand dunes are formed by winds blowing loose sand off the coastal strand habitat.
10,000 years ago	Horses, bison, camels, mastodons, and ground sloths live in the area. Their bones are found in the dunes in 1940.
1772	The Fages expedition finds a Native American village at the dunes. The habitat is oak woodland. Deer, antelope, tule elk, and beaver abound in the area.
1776	The de Anza expedition travels through present-day Antioch and the dunes.
1836	The Los Meganos Land Grant is awarded to Jose Noriega.
1849	Settlers are encouraged to take up residence on the land grant. Smith's landing, on land grant land, will later be called Antioch.
1852	A brick factory is built in town.
1853	A dairy, piggery, sheep fold, and store are established in the dunes and later a shipyard is built. Wild oats (*Avena barbata, A. fatua*) and red-stemmed filaree (*Erodium cicutarium*) introduced from Europe are growing in the dunes. Cattle roam freely in the area including the dunes.
1860s	A vineyard is planted in Antioch Dunes.
1869	The first known botanical visit to the dunes is conducted by Albert Kellogg, a founder of the California Academy of Sciences.
1889	Two brickyards are located in the Antioch Dunes.
1896	Wallflower is described by E. L. Greene.
1900	Tracks for the Atcheson, Topeka, and Santa Fe Railroad are laid along the southern margin of the dunes. Spur lines into the sand dunes facilitate the removal of sand and bricks.
	Oak cord wood is being removed for sale.

	Russian thistle (*Salsola tragus*) is found in the Antioch Dunes.
1903	Wilbur Avenue is built, providing road access to the dunes.
1906	The San Francisco Earthquake occurs; in later years, the city will be rebuilt with bricks made of sand from the Antioch Dunes.
1909	The Great Western Power Company builds a transmission line across the dunes. This company will be acquired by PG&E.
1915	Three brick-making companies operate in the dunes.
1930s	The Stamm family acquires the western portion of sand dunes, including the vineyard. The Stamms will mine sand from the property for almost half a century.
	The dunes are discovered by entomologists from the University of California and California Academy of Sciences. Ultimately, 29 new taxa will be discovered in the dunes.
1933	Various beaches, dance pavilions, wharfs, and recreational cottages attract visitors to the shore of the San Joaquin River. Antioch Beach is very popular.
	Lange's are discovered. They will be described by John Adams Comstock in 1938.
1936	John Thomas Howell and Alice Eastwood collect the first specimens of Antioch Dunes evening primrose which will be described by P.A. Munz in 1949.
1940	Jack Little buys an eastern parcel of the dunes from the owners of a brickyard. He builds the Little Corral Bar from the company's mess hall. Little will mine sand there for 33 years.
	Insect collectors from all over the west continue investigating the unique insect fauna and refresh themselves afterward in the Little Corral Bar.
1947	The Fibreboard Company purchases a parcel in the Antioch Dunes, clears the oaks, levels the sand, and builds a paper mill.
early 1950s	Crown-Zellerbach builds another mill in the dunes. The City of Antioch buys land from the Stamms and builds a sewage treatment plant in the dunes.
1955	Life Magazine features the flora and fauna of the Antioch Dunes.
1976	Lange's is placed on the Federal Endangered Species List. The Antioch Dunes are designated as "critical habitat."

1977	Mildred Mathias and Lincoln Constance describe a state listed rare plant, Mason's lilaeopsis (*Lilaeopsis masonii*) collected from the dunes. Arnold starts a capture-and-release population study to estimate the number of Lange's at the Refuge.
1978	The wallflower and the primrose are listed as endangered species. The dunes are designated as "critical habitat."
1979	The wallflower and primrose appear on U.S. postage stamps.
	Congressman George Miller begins receiving mail from plant and butterfly fanciers from all over the country.
	The Service conducts negotiations with the property owners to establish a purchase price. The owners are prepared to sell the property to a developer for the construction of a marina and condominium complex.
1980	The Refuge is established, the first acquisition ever by the Service specifically for the protection of plants and insects. Cost of the 55 acres is $2,135,000.
	PG&E plants 445 seedlings of the naked stem buckwheat (buckwheat), host plant for the Lange's, to protect the few remaining Lange's on its property.
1983	Most of the vineyard planted in the 1860s is restored to natural habitat.
	Arnold (1983a) concludes a capture-and-release population study of Lange's started in 1977.
1986	Service personnel and volunteers count 186 Lange's during the population peak count for that year.
	The Refuge is officially closed to all public use as a result of trampling of endangered species and wildfires.
1991	3,000 cubic yards of riverine sand donated by PG&E are trucked into the Refuge to re-create habitat for the endangered species.
1992	PG&E donates an additional 4,000 cubic yards of sand to create new dunes.
1992-1995	Plants of many species native to the area, including the primrose, wallflower, and buckwheat, are planted on the new dunes.
1997	Prescribed burning is initiated to combat nonnative weeds.
1999	Service personnel and volunteers count 2,342 Lange's during the population peak count for that year. This is the highest count on record.

(Arnold et al. 1983, Arnold pers. comm. 1999; Howard and Arnold 1980; Loredo pers. comm. 2000)

Refuge Purpose

The Refuge was established under the authority of the Federal Endangered Species Act of 1973 which provides for the protection of endangered and threatened species of fish, wildlife, and plants. In addition to providing a basis for making compatibility determinations, a refuge's purpose also serves as a guide for refuge management and public use. The Refuge purpose is:

> "To conserve fish or wildlife which are listed as endangered species or threatened species or plants . . . " 16 USC § 1534 (Endangered Species Act of 1973).

The Refuge was established in 1980 to protect a unique riverine dune ecosystem, including designated "critical habitat" and three endangered species. The 67 acres within the approved Refuge boundary, along with some lands on the Georgia-Pacific gypsum plant and Kemwater properties, support the last known natural populations of the endangered primrose, wallflower, and Lange's.

Land and Water Conservation Fund money was used to acquire lands. The acquisition was in accordance with the recovery plan for the three species (Fish and Wildlife Service 1984).

Related Projects and Studies in the Area

U.S. Fish and Wildlife Service

The Recovery Plan for the Primrose, Wallflower, and Lange's

In 1984, the Service prepared the Recovery Plan for Three Endangered Species Endemic to Antioch Dunes, California: the primrose, wallflower, and Lange's. The recovery plan describes the species and sets forth recommendations for their management. The plan identified fuelbreak maintenance (a barrier of cleared land intended to stop the spread of fire), public recreation, and nonnative vegetation as the greatest threats to the endangered species. Recommendations included:

- acquiring the Stamm and Sardis properties;
- developing cooperative agreements for habitat management with landowners adjacent to these parcels;
- conducting additional research on the three endangered species to determine habitat requirements;
- monitoring the three endangered species to determine their population sizes;
- possible captive breeding of the Lange's;

- propagating and planting buckwheat (host plant for the Lange's), primrose, and wallflower;
- rebuilding natural dune substrate and topography by adding sand;
- removing nonnative vegetation, including the vineyard;
- restricting public access to both the Stamm and Sardis Units; and
- developing interpretive and environmental education programs.

Most of these recommendations were implemented or are in progress. The only recommendation not fully implemented was developing an interpretive and environmental education program. Although the Refuge has developed some interpretive and environmental education partnerships and programs, funding and staff to fully accomplish this recommendation has not been available.

Other Agencies

Brannan Island State Recreation Area

Brannan Island State Recreation Area was established in 1962 by the California Department of Parks and Recreation (DPR) and supports a self-sustaining population of primrose (Riblet pers. comm 2000). The Recreation Area is about 16 miles north of the Refuge, along the Sacramento River, Jackson Slough, and Three Mile Slough. The southern portion of Brannan Island consists of a dredge spoil area. Sands washed down the Sacramento River (probably from historic hydraulic mining activities in the Sierra Nevada Mountains) were dredged to deepen the Sacramento River Deep Water Ship Channel and deposited on the southern portion of Brannan Island. The dredged sand on the island is very fine and has been used to manufacture glass.

Primrose were planted on "low dunes" of Brannan Island in 1969, by Knight, former staff member of the Regional Parks Botanic Garden, as a possible solution to the "grave threat sand mining posed" to populations at Antioch Dunes. Roof, director emeritus of the botanic garden, was the inspiration behind Knight's action to initiate dispersal to remote dune areas suitable for primrose (Fish and Wildlife Service 1984). Since then, there have been no management actions to enhance the primrose population. Although an area surrounding the planted primrose has been fenced, the primrose that has spread into other locations in the Recreation Area have not received any special protection. Interestingly, the new locations are not aligned with the existing population and prevailing winds on the island, and therefore the seeds were probably not wind-dispersed. DPR believes that rabbits have spread primrose seeds on the island through their digestive tract (Riblet pers. comm 2000). The original planting location is in a protected area, along with several elderberry *(Sambucus mexicana)*, host plant for the federally endangered valley elderberry longhorn beetle *(Desmocerus californicus dimorphus)*. Other primrose growing outside the fenced area have been seen at the edges of pathways and along the beach. Park personnel have noted that the primrose seem to do better in these areas of disturbance.

The Regional Parks Botanic Garden at Tilden Regional Park

The East Bay Regional Park District owns and operates the Regional Parks Botanic Garden in Berkeley. The garden grows both the primrose and wallflower in small plots of no more than 200 square feet each. The primrose and wallflower have required diligent maintenance, including weed removal and outplanting, to maintain their numbers.

Montezuma Wetlands

Montezuma Wetlands, near Collinsville, across the river from the Refuge, is a wetland restoration project that demonstrates the beneficial reuse of dredge material. The project will use dredge disposal material from the Federal channels of the Oakland Harbor and the berths that are maintained by the Port of Oakland. About 1,800 acres of the site will be restored as wetland. An additional 50 acres will be used to dewater and desalinate dredge material for sale to other entities. Dredge material that is resold will be processed at a rehandling facility where materials will be washed and cleaned prior to sale and placement. Montezuma Wetlands offers a potential source for clean sand (to restore dunes) in close proximity to the Refuge. The project is being undertaken by private entities.

CALFED

CALFED, a consortium of stakeholders and State and Federal agencies, is in the process of developing a plan to address the agricultural, municipal and wildlife demands on the water supply of the Sacramento-San Joaquin River Delta (Delta). The Refuge is in the study area for the CALFED plan and has been specifically identified as a potential area for habitat restoration under the Ecological Restoration Program of CALFED. The CALFED Ecological Restoration Program Plan's (1999) goals include protection and enhancement of the Refuge and surrounding dunes, the recovery of state listed rare species including, Mason's lilaeopsis *(Lilaeopsis masonii)*, Suisun marsh aster *(Aster lentus)*, delta tule pea *(Lathyrus jepsonii* var*. jepsonii)*, and Federally endangered species including Lange's, primrose, and wallflower, all of which can be found on the Refuge.

Arnold conducted a captive breeding program for the Lange's in the early 1980's, following the low counts. The program was discontinued after on e season because habitat improvement was considered to be a more effective means of increasing the Lange's population (Arnold, pers. comm. 2001, Arnold 1985, Arnold 1981).

Chapter 2 - The Planning Process

The Planning Process

The process followed for the development of this CCP was guided by the Refuge Planning Chapter of the Fish and Wildlife Service Manual (Part 602 FW 2.1, November 1996) and evolving policy related to the Refuge System Improvement Act of 1997. Key steps include:

- preplanning;
- identifying issues and developing vision;
- gathering information;
- analyzing resource relationships;
- developing alternatives and assessing environmental effects;
- identifying a preferred alternative;
- publishing the draft plan;
- documenting public comments on the draft plan;
- preparing the final plan;
- securing approval of the California/ Nevada Operations; and finally,
- implementing the plan.

The CCP may be amended as necessary at any time under an adaptive management strategy. Major revisions will require public involvement and NEPA review if needed.

In a Federal Register Notice, dated December 30, 1998, the Service announced that it was preparing a plan for the Refuge. The first planning update for the Refuge was released in December 1998. This update informed the public about the Refuge and the planning process. When the update was written, Refuge and planning staff did not anticipate much general interest or controversy over Refuge management and decided not to schedule a public scoping meeting, unless requested by the public. Instead, the planning update encouraged the public to provide comments and concerns about Refuge management via e-mail, phone, or mail, with the understanding that the Service would hold a meeting if public interest in, or controversy over, Refuge management was high. The planning update generated no requests for a meeting and little controversy, so a public meeting was not held.

A technical panel was convened in February of 1999, to assemble the nearly 20 scientists who have conducted research at the Refuge and other experts. The panel spent a day discussing the implications of their research on Refuge management. The panel included university faculty and staff, consultants, graduate students, other agency personnel, and Service personnel (see Appendix B - Technical Panel).

The second planning update, released in May 1999, described the issues, concerns, and opportunities identified at the technical panel. A second technical panel was convened in November 1999 to solicit comments and provide answers to questions on the draft documents. The third planning update, released in July 2000, discussed the goals and objectives. The fourth planning update was released in July 2001. This planning update announced the upcoming draft and informed the public about how to comment on the draft.

This draft CCP and Environmental Assessment (EA; Appendix C) released in August 2001, has been distributed to Refuge partners, adjacent landowners, government agencies, local jurisdictions, community groups, and private citizens. The public has 30 days from its release to provide comments. Please refer to the cover letter for details on how to submit comments. The final CCP, and planning update are scheduled for release in October 2001. The CCP will be implemented following the signing of the documents.

The CCP will be reviewed by Refuge staff while preparing annual work plans and updating the Refuge Operational Needs System database. This database describes the unfunded budget needs for each refuge and is the basis upon which the Refuge receives funding increases for operational needs. The plan may also be reviewed during routine inspections or programmatic evaluations. Results of the reviews may indicate a need to modify the plan. The periodic review of the objectives and strategies is an integral part of plan implementation, and management activities may be modified if the desired results are not achieved. If minor changes are required, the level of public involvement and National Environmental Policy Act (NEPA) documentation will be determined by the refuge manager. The CCP will be formally revised about every 15 years.

Issues

Issues, concerns, and opportunities were identified through discussions with planning team members, members of the technical panel, other key contacts, and through the public scoping process. Comments were received in writing, via e-mail and regular mail. The following issues, concerns, and opportunities are a compilation of information developed by the Service throughout the planning process. The most significant issues identified are nonnative vegetation, public use, trespassing, and wildfires.

Issues Identified by the Public

- Open the Refuge to the public for fishing and swimming.
- Provide guided tours of the Refuge.
- Provide opportunities for volunteers.
- Maintain the Refuge as a sanctuary.
- Extensive invasive nonnative vegetation should be controlled by burning (where appropriate), herbicide application, and mechanical removal methods.
- Restrict native plantings until nonnative weeds are under control.
- Provide a part-time caretaker to repair fences and practice weed control. An off duty fireman could possibly oversee the refuge and provide a presence on the Refuge.

Issues Identified by Refuge Staff, Panel of Experts, and Other Agencies

- Develop and complete an agreement with PG&E for long-term management of the 12 acres they own within the approved Refuge boundary.
- Control invasive nonnative plant species.
- Identify and develop techniques for successful restoration.
- Consult with experts in dune ecology, restoration, and invasive nonnative vegetation.
- Explore methods of creating sand disturbances in dunes.
- Investigate effects of prescribed burning on air quality.
- Lack of adequate funding and staff.
- Determine scope and compatibility of public use.
- Increase efforts to stop trespassing and vandalism.
- Conduct more research on the effect of fire on native insects.
- Public use - most are not compatible.
- Explore possible land acquisition, by fee title or easement.
- Effects of wildfires

Resource issues and opportunities were also identified during the scoping process. The results of this effort are described in Chapter 4, Problems and Opportunities.

Contra Costa Wallflower on sloping terrain.

Chapter 3 - Refuge and Resource Description

Management Area Designations

In an effort to divide the Refuge into areas with similar topographic features and/or species abundance, the Stamm and Sardis Units have been divided into different management areas (Figures 3 and 4).

Ecoregion Setting

The Refuge is in the Delta which sits in the San Francisco Bay-Delta Watershed, a 61,000 square mile area of California (CALFED 2001). The Delta is composed of about 750,000 acres of tidal marshland, shallow back swamps, farmland, and municipalities (California Department of Fish and Game and the Service 1980). The Refuge occupies a unique place within the ecoregion in that inland dunes are very limited within the Delta, occurring only in the vicinity of the Refuge (CALFED 1999).

Geographic and Physical Setting

The Refuge is near the southwestern boundary of the Delta, about five miles upstream of the confluence of the Sacramento and San Joaquin Rivers. The Delta covers 738,000 acres with hundreds of miles of interlaced waterways. The Delta is the major collection point for water that serves two-thirds of California's population (California Department of Water Resources 1995).

Before the regulation of flows and the channelization of rivers, the Delta was characterized by sluggish river channels, oxbow and floodplain lakes, swamps, and sloughs. Native fish thrived in weedy backwaters and large stretches of open water. The region's dense tules, willows, and cottonwoods supported more than 250 species of birds and mammals.

The 55-acre refuge, along with the 12 adjacent acres owned by PG&E, is virtually all that remains of a unique system of riverside sand dunes that once reached heights of 120 feet and stretched up to 5.6 miles along the southern bank of the San Joaquin River east of Antioch (Roof 1969).

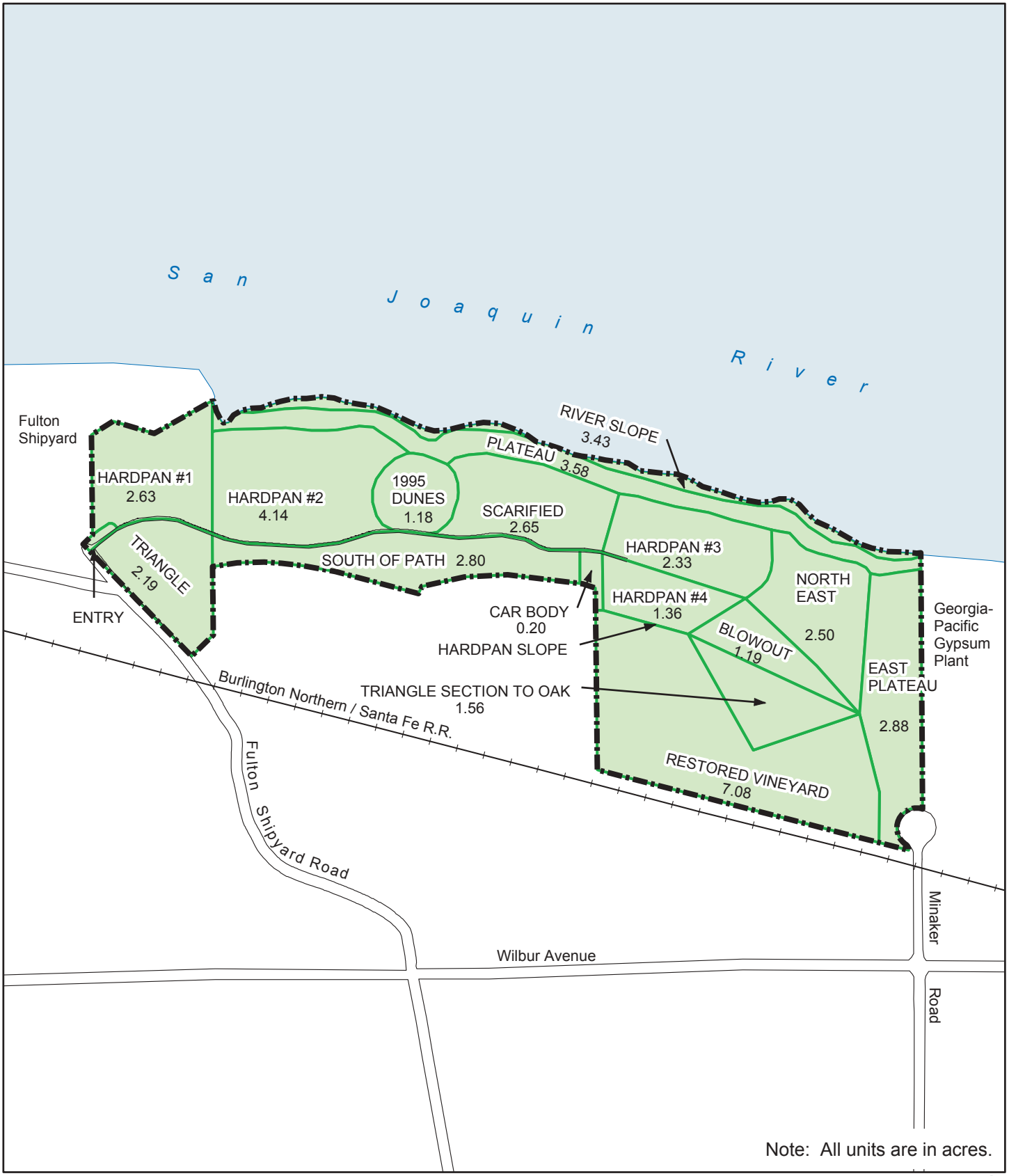
Beginning in the 1880s, Antioch Dunes pure sands were systematically mined for use in brick making and construction. Much of the brick used to rebuild San Francisco after the 1906 earthquake came from Antioch Dunes. Today, the last remnants of the dunes are surrounded by a shipyard, a gypsum plant, and a sewage treatment plant and vary from zero to 50 feet high.

The Refuge currently exists as an isolated habitat surrounded by industrial development (Service 1997b). The existing habitat has been highly disturbed by sand mining and agriculture, which is reflected in extensive weediness and inability to support healthy populations of native species.

Topography

The Stamm Unit terrain is characterized by rolling dunes that range from zero to 50 feet, as measured from the river water surface elevation. The Sardis Unit, which

Figure 3. Management Areas with Acreages - Stamm Unit

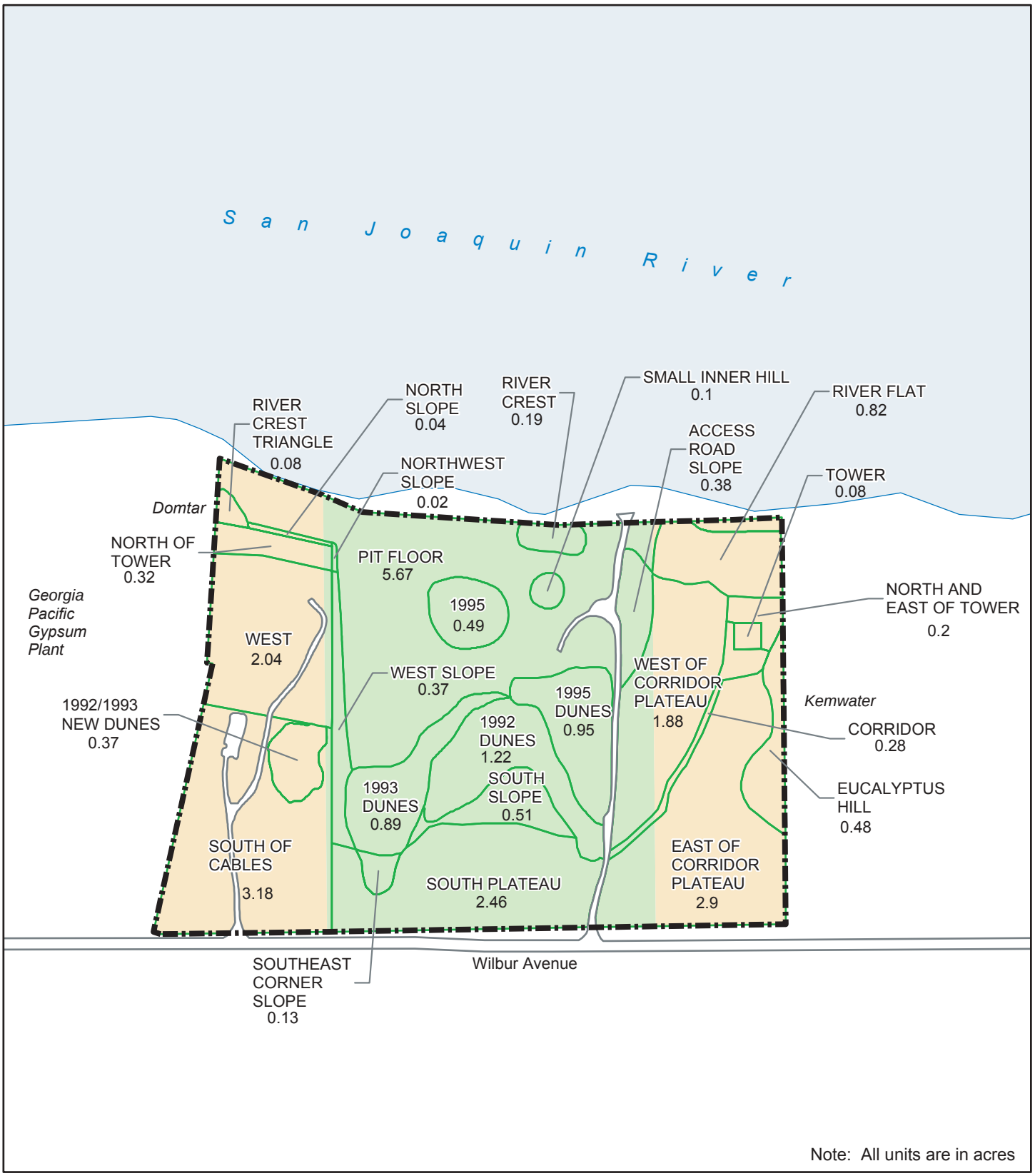


CA/NV Refuge Planning Office - August 2001

100 0 100 200 300 400 500 Feet

Approved Refuge Boundary Management Areas

Figure 4. Management Areas with Acreages



CA/NV Refuge Planning Office - Aug 2001

100 0 100 200 300 400 Feet

Approved Refuge Boundary | Management Areas on PG&E Property | Management Areas on USFWS Property

ranges from 1 to 50 feet is located between two higher parcels owned by PG&E, that are about 80 feet above the water surface elevation. It is likely that the PG&E parcels more closely resemble the native topography than the

Refuge units because the PG&E parcels were never mined for sand (Ivette Loredo pers. comm 1999). In 1927, the northern portion of the eastern PG&E parcel was leveled to construct a tower. The central and southern portions of this parcel, amounting to two or three acres, were never developed and are the only sections in the Refuge area that retain original height and contours (Arnold, et al. 1983). It is presumed that the western PG&E parcel is naturally fairly level.

Geology

The aeolian (wind-blown) sand at the Refuge is contiguous with the sheer aeolian sand underlying much of the flat lands between the Mount Diablo foothills and the western margin of the Delta. Most of the exposed aeolian sand near Antioch accumulated between 10,000 and 40,000 years ago, during the late Pleistocene period. Atwater (1982) theorized that most of the exposed sand at the Refuge accumulated during the most recent major glaciation of the Sierra Nevada. The retreating glaciers deposited glacially eroded sand and silt onto the floodplains of the Central Valley's rivers and drainages. Summer winds sweeping the floodplains would have picked up the sand and deposited it as dunes, generating the dune field of eastern Contra Costa County.

Evidence of at least two discrete episodes of aeolian deposits is exposed in a river bluff adjacent to the Refuge. About 50 feet of young sand dunes overlies 5 to 6.5 feet of older sand dune. Though dunes could have formed near Antioch at least five times during the last 500,000 years, the last deposits probably occurred 140,000 years ago (Atwater 1982). The dunes were formed by ancient deposits of glacial sands carried downriver from the Sierra Nevada, left isolated along the river after the Mojave Desert receded in prehistoric times. Over thousands of years, ocean winds and bay tides slowly shaped these sands into high dunes. Isolation of this sand dune habitat resulted in the development of species and subspecies of plants and insects that are found nowhere else in the world.

Soils

Carpenter and Cosby (1939) mapped the Refuge area as Oakley sands. Soil types at the Refuge have been classified as ranging from sand to sandy-loam; pH averages 6.4 (range 5.6 to 7.0). The Service hired a contractor to collect and analyze soil samples from several sites at the Refuge. The soils report (Jones and Stokes 2000) indicated that the Refuge lacks a true soils association. The native soils have been severely mined, from a height of about 120 feet to a current height at about 10 to 50 feet.

Climate

The Antioch area has a modified Mediterranean climate with hot dry summers and moist, mild winters. Rainfall averages 12.5 inches annually, falling mainly from November through April. Typically, the months of May through September are dry. The average annual temperature is 61.8° F with an average annual maximum temperature of 74° F. Average high temperatures in the area range from above 90° F in

July, August and September to the mid 30° F in December and January. The hottest recorded temperature is 114° F, and the lowest recorded temperature is 14° F. Summer winds flow from the river from the west or northwest at an average of 10 to 20 mph.

Air Quality

The Antioch area has good air flow. The area is exposed to winds both from the west and east, and the terrain provides little protection from the wind. Average wind speeds in the Antioch area are relatively high and calm conditions are infrequent. The air quality near Antioch is generally good. However, there are point sources of air pollution near the Refuge that potentially affect air quality on the Refuge. The Sardis Unit is adjacent to and generally downwind of the Georgia-Pacific gypsum plant which emits gypsum dust that covers vegetation in surrounding areas. The Southern Company power plant, owned by PG&E until 1999, is about one mile from the eastern boundary of the Refuge. The Southern Company plant emits benzene (35 lbs/yr) and formaldehyde (1,700 lbs/yr) (BAAQMD 1999a). Air pollution generated by the Refuge is caused by temporary, short term disturbances, such as annual prescribed burning and earthmoving activities. There is currently limited public use allowed on the Refuge and there are minimal maintenance activities; on-site vehicular emissions are infrequent.

The State Air Resources Board has statewide responsibility for air quality in the area, and the Bay Area Air Quality Management District has permitting authority for stationary air pollutant sources in the region. The District regulates federally regulated air pollutants, particulate matter, organic compounds, nitrogen oxides, sulfur dioxide and oxides, carbon monoxide, hydrogen sulfide, ground level ozone, and acid deposition.

Air quality in Contra Costa County is generally good. Because the air quality monitoring station closest to the Refuge (in Pittsburg, CA) has exceeded air pollution standards for ozone twice for the maximum one-hour emission and once for the maximum eight-hour emission, the county is a non attainment area (BAAQMD 1999b). Contra Costa County contains a multitude of air pollutant sources. Controls placed on automobiles and stationary sources of air pollutants, such as factories and refineries, as well as on nonpoint sources such as paints, solvents, and gas stations, have not resulted in all air quality standards being attained in the Bay Area. Inventories of these sources have been prepared by the Bay Area Air Quality Management District (BAAQMD 1999a and 1999b). Mobile air sources, including automobiles, busses, and trucks contribute about 50 percent of the air pollutants and air toxins (Richardson pers. comm. 2001) except for sulfur dioxide, which is primarily generated by petroleum refining and power plants (DeBecker pers. comm. 2001).

The Antioch area contains a large portion of the industrial sources of pollutants within the County, and is downwind of both the greater Bay Area and the Diablo Valley. As a result, ozone levels exceed both the Federal and State standards. Carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, and hydrogen sulfide levels are within the Federal and State standards.

There is concern that gypsum dust from the adjacent gypsum plant may affect plant health, particularly that of the endangered species, by affecting soil chemistry and/or photosynthesis (gypsum is a common fertilizer and soil additive). Many plants on the

PG&E parcels and Sardis Unit are covered with a fine layer of gypsum. The gypsum suspended in the air is also a concern for the health of Refuge staff and visitors.

Contaminants

The Service's Denver Engineering Division contracted a contaminants survey of the Refuge in 1999 (Clark and Witham 1999). Phase I of the survey included site reconnaissance, reviewing historical use of the site, and reviewing records and reports of environmental incidents at or near the Refuge. Phase II included the collection and analysis of soil and ground water samples from the Refuge. Past land uses had indicated that the survey should pay special attention to potential contamination by creosote, pesticides, and asbestos.

The survey found that no environmental incidents involving the release of chemicals to the soil or ground water are recorded to have occurred on the Refuge nor on the properties owned by Fulton Shipyard, Georgia Pacific gypsum, the railroad, or the City of Antioch Sewage Treatment Plant. Soluble metals and other contaminants are recorded as present in the soil and ground water at the Kemwater plant.

Pesticides, creosote, and asbestos testing of soil samples gave results below detection limits set by the analytical laboratories, except for a soil sample from Sardis Unit which indicated the presence of Chlordane. The chlordane encountered on the Sardis Unit, based on past land use and the half life of this chemical species, is most likely a remnant of past agricultural land use. Chlordane was applied directly to soil or foliage to control a variety of insect pests on corn, citrus, deciduous fruits and nuts; for home, garden, and ornamentals; lawns, turf, ditch banks, and roadsides. Groundwater samples for pesticide and creosote were below the detection limits set by analytical laboratories. Chrysotile, however, was found at about 20 feet below the surface at Hardpan #1 and #2 (Stamm Unit, Figure 3). Chrysotile is a naturally occurring asbestos found throughout California. It is common to find chrysotile in soil and groundwater in the San Francisco Bay Area, and given the depth and location of the chrysotile, the chrysotile observed in the groundwater at these two sites appears to be naturally occurring. Although the survey found no contaminant issues that currently affect the Refuge, the report recommends that further contaminants monitoring should concentrate on ground water monitoring along the eastern boundary of the Sardis Unit (adjacent to the Kemwater Plant) and along the southern boundary of the Stamm Unit (adjacent to the former sewer treatment plant).

Hydrology

The San Joaquin River forms the northern boundary of the Refuge. The Refuge's river frontage is about two-thirds of a mile long and is tidally influenced. The riparian corridor generally, is less than 10 feet wide due to the tall and steep embankments along the river's edge. Like most of the Refuge, the riparian corridor has been altered and includes nonnative vegetation.

The San Joaquin River adjacent to the Refuge is affected by the saline conditions of the ocean and flows at around 340,000 cubic feet per second. Tides in the area cause water level fluctuations from about 3 feet above sea level at high tides to about 2.2 feet below sea level at low tides during a typical 25-hour tidal cycle. Groundwater beneath the Refuge is predominately influenced by the level of the adjacent San Joaquin River. As the ocean tides raise and lower the surface eleva-

tion of the river, the groundwater level fluctuates in response. Groundwater level is approximately 15 feet below the surface at the Hardpan #1 site, 27 feet at the Restored Vineyard site, and 17 feet at the Car Body Area at the Stamm Unit (Clark and Witham 1999).

Water Supply

Refuge management requires very little water. No water is currently being used for irrigation. Water, used for fire suppression, is supplied from a hydrant by the southern boundary of the Stamm Unit. The Refuge is in the Contra Costa Water District.

Vegetation

Historic accounts of the Refuge indicate that oak-woodland was the primary vegetative community at the Antioch Dunes. The presence of oak woodland suggests that there was a stabilized substrate, however, it is also known that native flora, such as wallflower, primrose, butterweed (*Senecio* sp.), and California matchweed *(Gutierrezia californica)* would have required dynamic substrate as well. It is possible that slumping caused by weather, gravity, trees falling, wind erosion, and natural plant senescence would have provided occasional open areas of sand that would have been colonized by the sand-loving primrose. It is not known what role, historically, fire played in the Antioch Dunes ecosystem.

Littoral zone where Mason's lilaeopsis is found.

Three main habitat types are found within the 67-acre approved Refuge boundary (Figure 5): littoral (owned by State Lands Commission), riparian, and unique stands at Antioch Dunes (Sawyer and Keeler-Wolf 1995). The littoral zone, along the river's high and low watermarks, contains a state listed rare plant, Mason's lilaeopsis as well as other rare species including Suisun marsh aster (*Aster lentus*), Delta mudwort (*Limosella subulata*), and Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*). Other littoral zone species include cattail (*Typha angustifolia)*, tufted hairgrass (*Deschampsia cespitosa),* alkali marsh butterweed (*Senecio hydrophilus)*, and low club rush (*Scirpus cernuus)*.

The riparian area is characterized by native species such as coast live oak *(Quercus agrifolia)*, narrow-leaved willow *(Salix exigua)*, arroyo willow *(Salix lasiolepis)*, toyon *(Heteromeles arbutifolia)*, and elderberry *(Sambucus mexicana)*. A steep embankment at the river's edge provides a narrow space for riparian vegetation. The riparian corridor has been altered and includes nonnative vegetation such as oleander and pampas grass. Irregularly shaped pieces of broken concrete slabs have been placed on the river bank at the west end of the Stamm Unit, perhaps serving as revetment.

The "unique stands at Antioch Dunes" (a separately described cover type) are described by Sawyer and Keeler-Wolf (1995) as consisting of scattered forbs and grasses which form a ground canopy and uplands consisting of stabilized or partially stabilized dunes. In addition to the primrose, wallflower, and buckwheat, other common native plants in the dunes include elegant clarkia (*Clarkia unguicalata*), California poppy (*Eschscholzia calfornica*), California croton (*Croton californicus*), Grindelia *(Grindelia sp.*), deerweed (*Lotus scoparius*), telegraph weed (*Heterotheca*

grandiflora), California matchweed (*Gutierrezia californica*), and silver bush lupine (*Lupinus albifrons*).

These native plants, which composed these “unique stands,” still exist on the Refuge, mostly in areas that have had the least amount of sand mining or human degradation or in areas that have been intensively managed. Fringe areas along the river in the Stamm and Sardis Units are examples of unmined remnants that have concentrated native species (Service 1997b). The highest proportion of native species on the Refuge, including the primrose, wallflower, buckwheat, croton (*Croton californicus*), deerweed *(Lotus scoparius)*, and many others (Appendix D - List of Vascular Plant Species) have traditionally been found on the open dune area of the Blowout (Stamm Unit, Figure 3). The Blowout Unit most represents the historical ecology of the original riverine dunes including the original topography, sandy nutrient-poor soils, and wind currents. The native plants in this area also seem to be shorter and less robust, indicative of plants in this ecological region.

The viability of native plants on the Refuge is one of the Refuge’s primary concerns. Once a diverse habitat for many types of insects and wildlife, the dunes now support thriving nonnative plant populations that do not support the same invertebrate diversity (see invertebrates section).

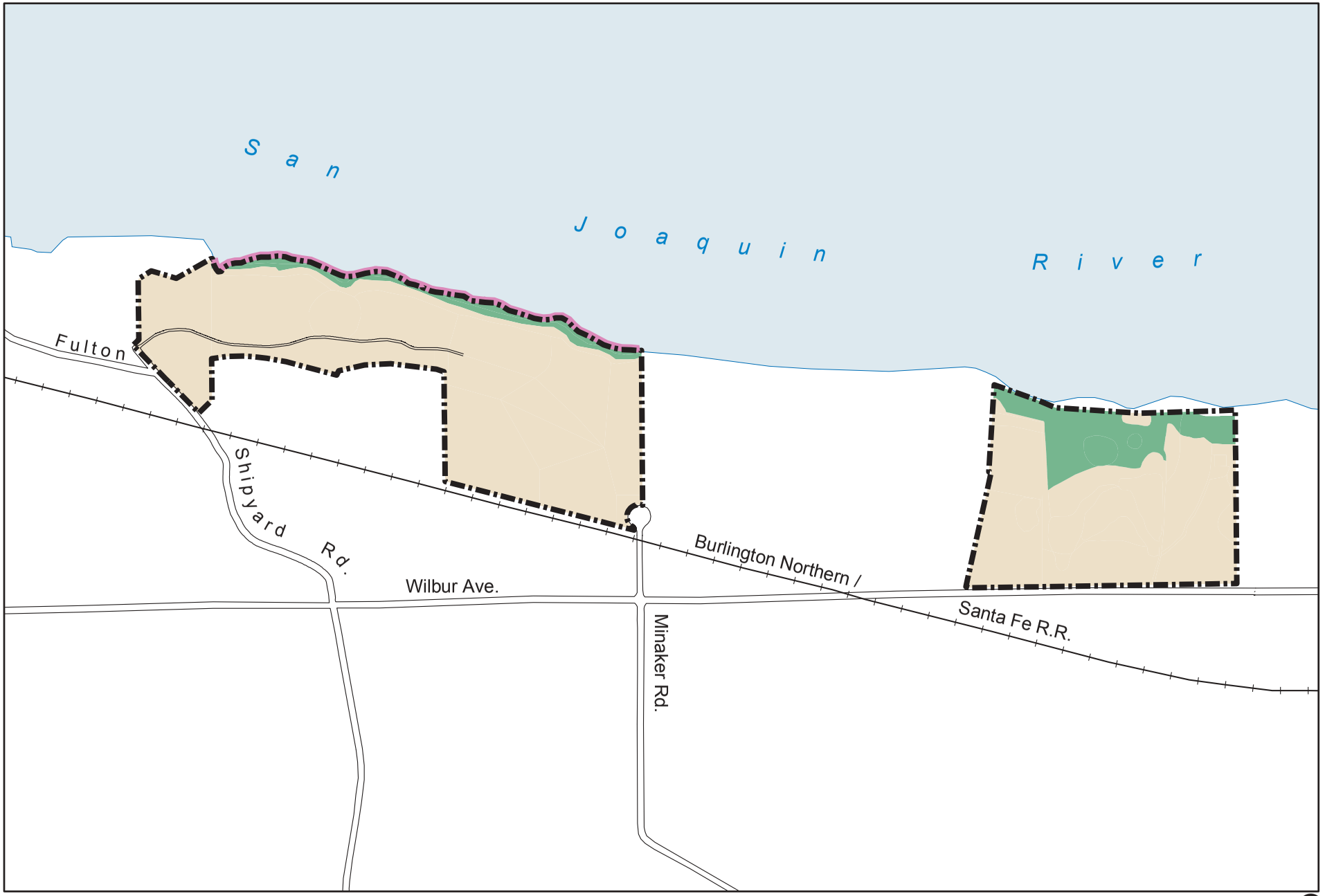
Prior to Refuge establishment, the areas with the highest concentration of nonnative weeds were disced (turning large discs through the soil using heavy equipment) annually (Powell 1983). This included the unmined southern portion of the Sardis Unit, along with its mined-out pit. Some of these areas became almost entirely nonnative, invasive vegetation. Because of this, the Refuge no longer uses discing as a weed control measure. Nonnative species dominate some areas of the Refuge. Primarily of concern are ripgut brome (*Bromus diandrus*), yellow starthistle (*Centaurea solstitialis*), vetch (*Vicia* spp.), and Russian thistle (*Salsola tragus*).

Wildlife

The Refuge provides important habitat for many types of wildlife, including mammals, reptiles, and resident and migratory birds. Historical accounts indicate that mink *(Mustela vison)*, desert cottontail rabbit *(Sylvilagus auduboni)*, beaver *(Castor canadensis)*, muskrat *(Ondatra zibethica)*, opossum *(Didelphis marsupialis)*, weasel *(Mustela frenata)*, and skunk *(Spilogale gracilis)* were found at the Refuge. Recent observations of mammals have been limited. Gopher *(Thomomys bottae)*, gray fox *(Urocyon cinereoargenteus)*, Beechy ground squirrel *(Spermophilus beecheyi)*, coyote *(Canis latrans)*, blacktail jack rabbit *(Sylvilagus bachmani)*, muskrat, raccoon *(Procyon lotor)*, Townsend’s mole *(Scapanus townsendi)*, weasel, and red fox *(Vulpes fulva)* are mammals recently seen at the Refuge. Gopher mounds and rabbit droppings abound and burrows and dens of squirrels and fox are commonly observed. Beaver have also been seen along the river’s edge.

In 1977, Papenfuss, then a graduate student at UC Berkeley, completed an inventory of Refuge reptiles, including the California legless lizard (*Anniella nigra*), side-blotched lizard (*Uta stansburiana*), coast horned lizard (*Phrynosoma coronatum*), San Joaquin whipsnake (*Masticophis flagellum ruddocki*), glossy snake (*Arizona elegans*), western whiptail lizard (*Cnemidophorus tigris*) and the fence lizard (*Sceloporus occidentalis*). In 1982, Papenfuss followed up this inventory with an

Figure 5. Three main habitat types on the Refuge.



CA/NV Refuge Planning Office - July 2001

100 0 100 200 300 Meters

Approved Refuge Boundary | Riparian | Antioch Dunes Unique Stands (Sawyer, Keeler-Wolf 1995) | Littoral Zone

effort to trap herpetofauna on the Refuge and identify which species were still present. Only two species of reptiles were found at that time, side-blotched lizards and fence lizards. Since then, few reptiles have been reported or collected. No amphibians were found, however, historical collections for the Refuge include the western toad.

Two California silvery legless lizard sightings occurred in 2000. Fence lizards have also been seen on the Refuge recently as well as a gopher snake *(Pituophis melanoleucus)* and racers *(Coluber constrictor)* (Loredo pers. comm. 2000b). Numerous bird species have been observed on the Refuge, including migratory and resident birds. Appendix E lists birds found at the Refuge. Gadwalls *(Anas strepera)* and mallards *(A. platryhynchos)* have also been observed nesting on the Refuge (Buffa pers. comm. 2001).

Fish

The Service's Sacramento/San Joaquin Estuary Fishery Resource Office has monitored fish populations in the San Joaquin River from a beach seining station on the Refuge since 1979. The fish are sampled at the station monthly. Listed species caught offshore of the Refuge include winter-run chinook salmon *(Oncorhynchus tshawytscha)* (state and federally listed endangered), delta smelt *(Hypomesus transpacificus)* (state and federally listed threatened), steelhead trout *(O. mykiss)* (federally threatened), and Sacramento splittail *(Pogonichthys macrolepidotus)* (federally threatened). The complete list of fish species found at the Refuge sampling station is included as Appendix F - Fish Species Found Offshore of the Refuge.

Invertebrates

Antioch Dunes has been known as an entomological hotspot since the 1930s when entomologists began collecting in what is now the Sardis Unit. The area attracted remarkable attention for its large and colorful species with desert affinities. In the 1930s, many species of wasps and flies, particularly the giant flower-loving fly (*Thaphiomydas trochilus*) were completely new to the region's collectors. A total of 27 taxa were described from Antioch Dunes during this decade. Today we know that eight of these taxa are endemic to Antioch, four are now extinct, three are of uncertain status, and the eighth is Lange's, discussed in the Endangered Species section.

J.A. Powell and associates conducted a survey of insects at the Refuge from 1976 to 1982, following a seasonal visitation schedule similar to that of past collectors but with a higher frequency during late summer and fall, compiling 94 visits representing all months (Powell 1983). Because no complete historical list of insects for the Antioch area exists, Powell chose 14 families to form a basis of comparison with historical collections, based on their sand-dune affinity characteristics. Three eras of insect collections were examined in detail: 1933 to 1939 (extensive sand-mining), 1948 to 1954 (extensive industrial buildup), and 1976 to 1984 (final sand-mining and extensive weediness).

Powell found no significant difference between the diversity (number of species) recorded in the three selected eras. He noted, however, that collectors of early eras did not sample thoroughly; data indicate that 1930's workers overlooked small and nocturnal species, while those of the postwar era overlooked small species to a lesser degree and tended to ignore some families. Therefore, he suggests that

decline in diversity is best documented by species disappearance. Only 69 percent of the 279 species recorded more than once in previous surveys were observed during Powell's 1976-1982 survey. Loss of insect species at the Refuge happened surprisingly early–35 species have not been sighted since the 1930s–and showed no marked correlation with an exploitation event. The extinction rate was gradual until the period of his study, when it appeared the extinction rate rapidly increased.
In January 1995, Wes Maffei of the Alameda County Mosquito Abatement District began investigations to assess the presence or absence, approximate abundance, and the distribution of special status insects at the Refuge (Maffei 1997). Though a total of 249 insect taxa were identified, only three special status taxa were found: the robber fly (*Efferia antiochi*), the scarab beetle (*Polyphylla stellata*), and Lange's. Maffei found only 35 percent of species that Powell recorded in his 1976-1982 surveys in the major families that were investigated. In particular, Maffei found a decline in native bee species, the pollinators of most of the native plants. Powell believes the declines are the result of nonnative, invasive vegetation and lack of soil disturbance (Powell pers. comm. 1999). Maffei noted this as well; in the 1995 Dune area (Stamm Unit, Figure 3), an increasing loss of insect species occurred as the nonnative vegetative cover increased with each successive season, resulting in minimal sand movement (Maffei 1997, Maffei pers. comm. 2000).

According to Maffei's study, a number of insects have colonized the Refuge since the industrial buildup and sand mining of the early 1950s. This would be expected of species that occupy weedy habitats, but even among the flies and wasps, several newcomers have been recorded. This is best documented in spider wasps (Family Pompilidae) where the diversity clearly increased from entomologist collections 30 years ago. Maffei's insect list is included as Appendix G - Insect Species Found at the Refuge.

Endangered Species

The three federally listed endangered species–wallflower, primrose, and Lange's–are found within and near the approved Refuge boundary. The California Natural Diversity Database also lists eight species that are Federal "species of concern" at the Refuge, which have no protection under the Endangered Species Act: the San Joaquin dune beetle (last seen in 1974 and probably since extirpated - species of concern), the Antioch cophuran robberfly (last seen in 1939), Antioch efferian robberfly, Antioch adrenid bee, Antioch mutilid wasp, Middlekauf's shieldback katydid, the Suisun marsh aster, Mason's lilaeopsis, and the delta tule pea. The California Natural Diversity Database also lists three state listed species that have been found within or near the approved Refuge boundary. These species include Mason's lilaeopsis (rare), primrose (endangered), and the wallflower (endangered).

Lange's Metalmark Butterfly - Apodemia mormo langei

Background

The Lange's was first discovered in 1933 and was described five years later. In June 1976, this local subspecies was one of the first eight insects to be listed as endangered under the Federal Endangered Species Act. Following the listing, the Lange's remnant habitat was purchased by the Service and designated a Refuge (Powell and Parker 1993). Lange's continue to inhabit the Refuge, with their populations concentrated in the 1992 and 1993 Dunes at the Sardis Unit, and the Blowout

and 1995 Dunes at the Stamm Unit (Figures 3 and 4). The Refuge, in addition to the PG&E property and a portion of the Kemwater property, about 67 acres of suitable habitat, constitutes the entire present range for the Lange's.

Lange's, like most other butterflies, has a close relationship with its larval food plant, the buckwheat, and produces one brood per season. Adults typically begin to emerge in late July or early August and can be observed until mid September. Numbers typically peak two or three weeks following the earliest emergence of a butterfly from a pupal case. The peak in male emergence is generally earlier than that of females (Powell and Parker 1993). They live for approximately one week during which they feed, mate, and locate the host buckwheat on which to deposit the eggs.

Lange's Metalmark Butterfly

Female Lange's lay eggs throughout the adult flight period. The gray eggs are laid on the stem axils of the lower half of the buckwheat, where the foliage is withered. They are often deposited in clusters of two or four. The eggs remain attached and dormant until the rainy season, at which time new growth of buckwheat appears, the eggs hatch and the larvae crawl to the base of the plant where they overwinter and feed on new foliage (Arnold 1983b). The larvae are nocturnal feeders and feed on new plant growth through the winter and spring. Pupation occurs in mid-summer in the litter at the base of the buckwheat (U.S. Fish and Wildlife Service 1984).

Powell found that adults of both sexes are perchers and are capable of long flights between perches (US Fish and Wildlife Service 1984). The majority of males move locally (less than 100 feet) while females may travel up to 1,300 feet. Both sexes prefer buckwheat flowers as perches and as a nectar source. Females tend to be more mobile, visiting a greater variety of secondary nectar sources and searching for egg-laying sites. Males, on the other hand, tend to perch and aggregate more than the females.

The primary limiting factors for the Lange's are availability of nectar sources for adults, adequate host plant for egg-laying, and sufficient food for larvae (U.S. Fish and Wildlife Service 1984). The highest density of buckwheat on the Refuge occurs in open areas, where both nonnative ripgut brome and yellow starthistle, also occur. Invasion by nonnative vegetation is detrimental to the Lange's because it reduces the amount of suitable buckwheat stands available for habitat. Modification of the microclimate at the base of the buckwheat plants, which is also affected by nonnative weed encroachment, also seems to reduce the viability of the larvae (Arnold and Powell 1983). Moreover, additional losses of buckwheat were caused by past discing for fuelbreaks and by wildfires. At the Sardis Unit in 1976, a wildfire consumed some Lange's habitat, but the Lange's has managed to regain their former numbers. In 1999 a wildfire in the Blowout subunit of the Stamm Unit destroyed some of the best Lange's habitat. The buckwheat in this unit quickly resprouted, and

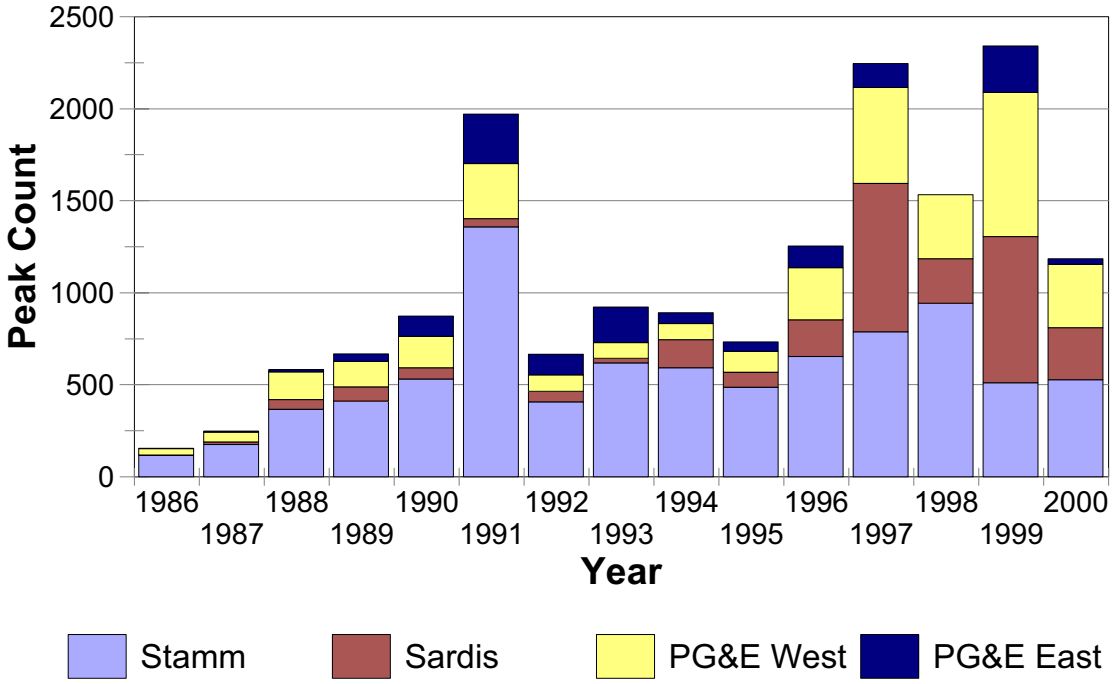
Lange's are beginning to move back into the area, presumably from adjacent units that were not affected by the wildfire.

Population Size and Status

Prior to 1985, population estimates for the Lange's were obtained from mark and recapture methods used by R.A. Arnold (1983a). From 1977 to 1983, Arnold documented a decline from more than 2,000 individuals to fewer than 400 reproducing individuals (effective adult population number) (Arnold 1983a). He concluded that the Lange's population decline was linearly correlated with the loss and alteration of habitat. Also, a trend analysis suggested that if then current habitat conditions continued, the extinction of the Lange's at the Sardis and the Stamm Units, the PG&E parcels, the Georgia-Pacific gypsum plant, and Kemwater property, could have occurred within one to five years (Arnold 1983a). Then, in 1985, Arnold documented a Lange's population increase at both the Sardis and the Stamm Units, 1.6 times greater and 2.2 times greater, respectively, than in 1984. Since the population rebounded from its low in 1982, Arnold theorized that at least 400 is a viable, self-sustaining population size for the Lange's (Second Technical Panel pers. comm).

It should be noted that Arnold's population count methodology is different from the Refuge staff's current low impact peak count methodology that began in 1986 (Figure 6). Arnold captured, counted, and marked the Langes' daily. He could distinguish which Lange's had been counted already and which had not. Population estimates were calculated using these counts. The Refuge's current methodology counts Lange's once a week during their flight period (Aug-Sept) and uses the highest count during those surveys as the year's peak count, without distinguishing

Figure 6. Lange's Metalmark Butterfly Survey Results



Antioch Dunes Evening Prim-rose

between individuals that have already been counted (Arnold pers. comm. 2001). The peak counts of the adult butterflies are used as an annual index of the relative size of the population. The highest peak count was in 1999 with more than 2,342 Lange's counted. Arnold's population count could be as much as five to ten times the Refuge's weekly peak count. They are different sampling methods that cannot be directly compared (Parker pers. comm. 2000). Table 1 provides a summary of general trends for the three endangered species.

Antioch Dunes Evening Primrose, Oenothera deltoides spp. *howellii*

Background

The primrose is a member of the Onagraceae family, subgenus Anogra. In 1949 it was recognized as a separate variety by Munz, and in 1962, Klein distinguished it as a subspecies. The primrose was federally listed as endangered in 1978. The primrose is endemic to Antioch Dunes; its naturally occurring population is confined to the two disjunct units of the Refuge, the PG&E parcels and a portion of the Kemwater property. The subspecies has also been grown at the East Bay Regional Parks Botanic Garden at Tilden Regional Park in Berkeley since 1970, and introduced to Brannan Island State Recreation Area, Point Reyes National Seashore, and Brown's Island in the Delta. Of these sites, the primrose persists only at Tilden Regional Park and Brannan Island.

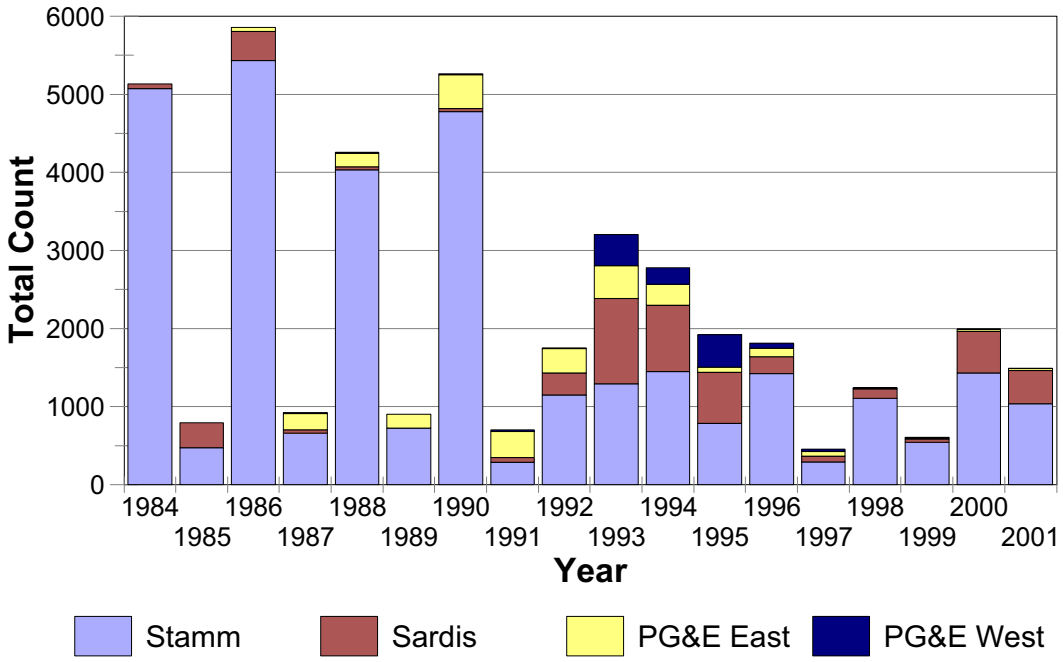
The primrose is a short-lived perennial, with some individuals persisting for several years. Arnold (pers. comm. 1999) believes that bees are the primary pollinating agent at the Refuge. Although hawkmoths were not known on the dunes until 1983, they have been reported as pollinators of other *Oenothera* species. However, their role as pollinators of the primrose has not been documented. Studies are needed to determine the phenology and pollinators of this subspecies.

Because the primrose prefers disturbed sites with nearly pure sand, it is vulnerable to encroachment from nonnative weedy species. Greene (1995) found no primrose seedlings around mature primrose that were surrounded by weed species, yet seedlings were found near about 40 percent of mature primrose that were not

surrounded by weed species. Greene determined that nonnatives compete with the primrose seedlings for water and light, resulting in reduced seedling germination and survival. She also determined that removing nonnative weeds around adult primrose enhanced germination rates. Weeds also have a negative impact on seedling germination success because they stabilize the dunes. Slowik (pers. comm. 1999) confirmed the primrose's need for regular disturbance by treatments on seedlings grown under cultivation. She found that primrose seedlings germinated more readily in sand when the sand was disturbed and turned over.

Factors that may limit primrose reproduction were investigated in 1993 by Pavlik and Manning. Although they identified low genetic variation and limited pollinators as potential factors that limit seed production, seed production was not considered a limiting factor for primrose reproduction. Pavlik et al. (1988a), Pavlik et al. (1993), and Pavlik and Manning (1993) also studied the seed bank dynamics, seed production, and seedling demography to assess the limitations on primrose growth. They found that more than half the ovules that were initiated failed to become seeds because effective pollinators were not available. Their work also indicated that substrate makeup and exposure were not critical to primrose seed germination, though competition with ripgut brome for light and moisture was. Although substrate makeup was not critical for seedlings to germinate, they found that primrose only reached reproductive maturity on sandy soils. Primrose produced many viable seeds, but seed output production over two years ranged from 26 percent to 37 percent of the maximum. Other factors, such as weather and pre-dispersal seed predation, also contributed to lowered seed production, but lack of pollinators was believed to play a role.

Figure 7. Antioch Dunes Evening Primrose Survey Results



The Service has been conducting an annual census of the primrose to track changes in the population since 1985 (Figure 7). In an effort to reverse the decline in primrose populations, the Service began outplanting the primrose by collecting seed from the Refuge, growing them in the Service nursery and contract nurseries, and then planting seedlings at the Refuge.

Population Size and Status

From 1984 to 1991, the total primrose population was estimated to range from 4,300-5,800 individuals. During this time, total primrose counts on the Refuge's Stamm Unit were only conducted every other year. During odd-numbered years, primrose numbers in Stamm were roughly estimated from transect counts. Figure 7 shows actual numbers of primrose counted during these years, therefore odd numbered years are under-represented on the graph. In 1992, the Service observed a dramatic decline to 1,200 individuals and began outplanting primrose seedlings. Since then, a complete count of primrose has been conducted every year. In 1997, the primrose population reached a low of 455 individuals. This marked the 11th year of general decline in the number of primrose at the Refuge since 1986. In 1998, the downward trend in the primrose population ended and increased to 785 individuals. Primrose plantings in December 1997 were probably a bigger factor in this increase than natural reproduction. The steady decline of noncultivated primrose and primrose outplanting continues today. Encroachment of nonnative vegetation continues to be the largest problem affecting the primrose (Table 1).

Contra Costa Wallflower

Contra Costa Wallflower, Erysimum capitatum spp. *angustatum*

Background

The wallflower is an herbaceous plant in the Brassicaceae family and is a biennial or short-lived perennial; individuals die after setting seed in their second year. The wallflower was originally described in 1896 by E.L. Greene and modified in 1958 by George Rossbach. Like the primrose, the wallflower is endemic to the Antioch Dunes. The wallflower was listed as endangered in 1978. The entire known wild population of wallflower exists at the Refuge and adjacent PG&E and Kemwater lands.

Little is known about the reproductive phenology of the wallflower. Germination may occur in October, and leafing from October through December. Budding occurs in February, while flowering begins in March, peaking in April or May. A number of different insect species have been observed visiting the plant and carrying pollen away with them. Fruiting begins in April and peaks in July. Seeds are wind-dispersed beginning in mid-May and peaking in September (Endangered Species Information System 1996).

The wallflower grows in soil types classified as sand, to sandy loam, with a pH averaging 6.4 (range 5.6 to 7.0). Precise information about the species' particular requirements are not known at this time. Service personnel have observed the wallflower growing in steep areas of unstable sand, especially on north-facing slopes immediately adjacent to the river (Service 1984). These slopes are generally not as densely vegetated and therefore may enable the wallflower to compete more

effectively for resources. Rossbach (1958) believed that the wallflower was restricted to stable dunes of fine sand containing some clay. The habitat was characterized as “sparse herbs and shrubs,” or less often pasture grasses, herbs, and scattered live oaks. Johnson (1978) suggested that reproducing individuals occurred primarily on uneven sites (i.e., river front bluff faces and edges).

Although current populations of wallflower at the Refuge seem to be concentrated on steep, north-facing slopes by the river, wallflower at one time grew on flat terrain in an excavated area within the dunes on the Kemwater property (Figure 4). Today there are individual plants growing 160 to 660 feet away from the river bank in a flat hard pan area of the Refuge. In these areas the hard pan has been broken and the loose, sandy soil below has been exposed. A large stand of wallflower is found on the East PG&E parcels adjacent to the Refuge. This stand is atop and over a ledge leading down to the San Joaquin River. Currently the wallflower is found where vegetative cover ranges from 50 percent to 100 percent. Although their population is now self-sustaining, overall, the wallflower appears to be more physically restricted within the dunes than the primrose.

Not much is known about wallflower pollinators except that they are bees that nest in open banks. Unlike other Brassicaceae, which are typically pollinated by specialized insects, the wallflower does not require a specific pollinator.

The wallflower is grown at the Botanic Garden at Tilden Regional Park. It was found to be the most adaptable of the wallflowers cultivated. Unlike the primrose, the wallflower apparently may not require sandy soil, at least not in cultivation. Although the wallflower is endangered, it has been doing fairly well on the Refuge, propagating on its own. After the wallflower was planted in 1995, on dunes created in 1992 and 1993, it was self-propagating until nonnative invasive vegetation began to invade. Other than limited available habitat (wallflower seem to prefer north-facing slopes at the Refuge), nonnative invasive vegetation pose the only apparent significant threat to the wallflower.

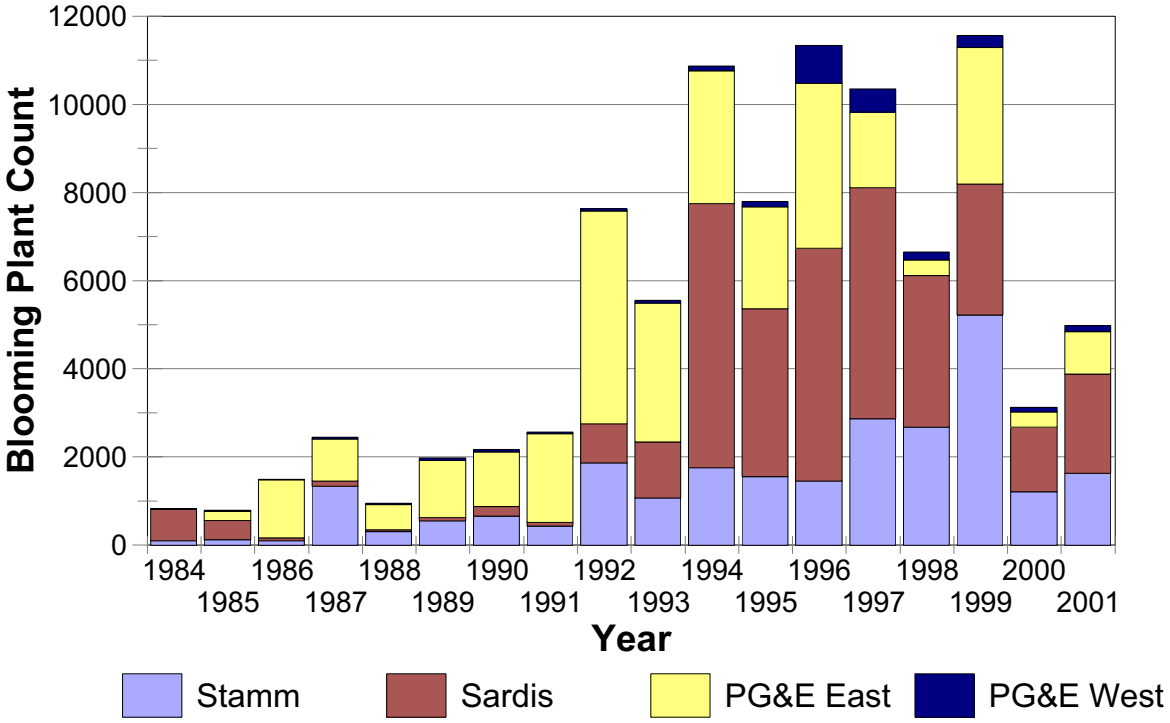
Population Size and Status

In 1999, the population peaked at 11,567 individuals, the greatest number of wallflowers ever counted (Figure 8). It is possible that the increase in the number of mature plants was due to the influence of El Nino during the winter of 1997/1998.

Table 1. General Trends for Refuge Endangered Species

Species	Population Status	Current Threats
Lange’s	Has generally been stable, peak counts in 1999 were the highest since surveys began in 1987. Despite this high, 1999 Stamm Unit counts were low as a result of a 1999 wildfire that swept through the unit.	Wildfire and nonnative invasive vegetation.
primrose	Natural populations of self-reproducing individuals have generally been declining since 1992.	Nonnative invasive vegetation and lack of substrate disturbance.
wallflower	Cyclical, but generally stable.	Nonnative invasive vegetation.

Figure 8. Contra Costa Wallflower Survey Results



Seeds that germinated that winter would have reached reproductive maturity in 1999. Seedling germination or survival may have been higher than normal as a result of increased rainfall, although this has not been studied. Population survey results indicate that the total number of mature plants is highly variable year to year. Wallflower is a biennial species, typically living only two years, thus, it would be expected to track yearly variation in weather and other environmental parameters much more closely than a longer-lived species. See Table 1 for a summary of trends for the three endangered species.

Public Use

The management goals and objectives for each individual refuge of the Refuge System vary. The National Wildlife Refuge System considers wildlife first when deciding whether to allow a public use. Public use at an individual Refuge unit must be determined to be compatible with the specific Refuge's purpose. At the Antioch Dunes Refuge, public access to the Refuge is restricted based on the sensitivity and limited distribution of the three endangered species. Refer to the Compatibility Determinations in Appendix A. Historically, the Antioch Dunes area and San Joaquin River were used for recreation such as biking, walking, sunbathing, fishing, picnicking, and swimming, while the upland areas were used for biking and walking.

The Refuge is fenced and was closed to the public in 1986 to protect the endangered species and their habitat, a concern that arose as a result of several incidents. Visitors using the Refuge prior to this time commonly built illegal fires

along the waterfront. On several occasions, the fires escaped and threatened the survival of the three species by indiscriminately burning surrounding habitat. In 1986, endangered plants were trampled by hundreds of people as they flocked to the Refuge to see a whale (nicknamed Humphrey) swim up the San Joaquin River.

Although the Refuge is now closed to the public, volunteers help Refuge staff by participating in endangered species counts, wallflower and primrose plantings, picking up trash, and weeding. Occasional interpretive tours are also given to various groups, such as the local Sierra Club chapter or community college groups.

Despite boundary signs and perimeter fences around both the Sardis and Stamm Units, unauthorized use of the Refuge continues. Unauthorized visitors have been seen fishing at the Refuge and numerous encampments have been found.

Easements

Several parties have easements on the Refuge including:

- Contra Costa County has an easement for roadway slope and drainage affecting the southern ten feet of the Refuge, which adjoin Wilbur Avenue.

- The City of Antioch has an easement and right-of-way for two underground outfall sewer pipelines.

- Georgia-Pacific Gypsum Company has easements for roadway, water, gas, oil, and sewer pipelines, and associated facilities.

Cultural Resources

Early Spanish explorers mentioned encountering Native American villages in the Antioch area. According to Davidson (1907), the diary of the 1772 expedition led by Lt. Fages and Padre Crespi refers to camping at a Native American village thought to be near the site of present-day Antioch. According to Padre Font, who accompanied Captain de Anza's 1776 expedition, the Anza expedition visited a Native American village on the site of Antioch. The village was "situated in the plain a little before the sierra (translated from Spanish in Font's diary to "oak ridge") toward which we were going, and so close to the water that from it to the huts it could not have been a dozen steps" (Bolton 1933). Abella, Fages, Font, and other explorers in the late 1700s and early 1800s mentioned large numbers of deer, antelope, tule elk, and beaver. The abundance of game, oak, and other foodstuffs, and proximity to water were undoubtably key features attracting human settlers to the Refuge site. As in many other Native American settlements, European contact in the early 1800s caused a swift decline in the local Native American community, primarily through introduced diseases.

Settlement of the Antioch area by persons of European descent began in 1836 and continued in various forms of residence, agriculture, industry, grazing, and recreation until the Refuge was established in 1980. Although extensive human activity is known from the area, little evidence of this activity remains because of sand mining that began in the 1890s and continued through the next century. Some more recent

cultural artifacts can still be found among what remains of the leveled dunes. Old bottles and ceramic fragments were found in the Stamm Unit in 1999. It is presumed that the Refuge was used as a de facto garbage dump during the period that the Refuge was mined for sand (Valentine pers. comm. 2000).

Land Use

The Refuge and surrounding lands have been used for industrial and recreational purposes. Throughout the years, agricultural and industrial use has been intense. Since the mid-1800s, the area has been used as a dairy farm, vineyard, brick factory, sand mine, docking facility, and a tavern site. Today, the Georgia-Pacific Gypsum Plant separates the Stamm and Sardis Units. Because the area had been one of the few sites for river access in the Antioch vicinity, it was historically a popular location for fishing, swimming, and sunbathing.

Current Management Practices

The Service actively manages for the three endangered species using a variety of measures that are outlined in this section. Habitat management for the primrose, wallflower, and buckwheat, the host plant for the Lange's, is labor intensive and includes annual surveys, nonnative weed control, prescribed burning, importing sand, and revegetation. Emphasis is on adaptive management; monitoring the effects of management actions on endangered species populations and habitat health, and adjusting as necessary.

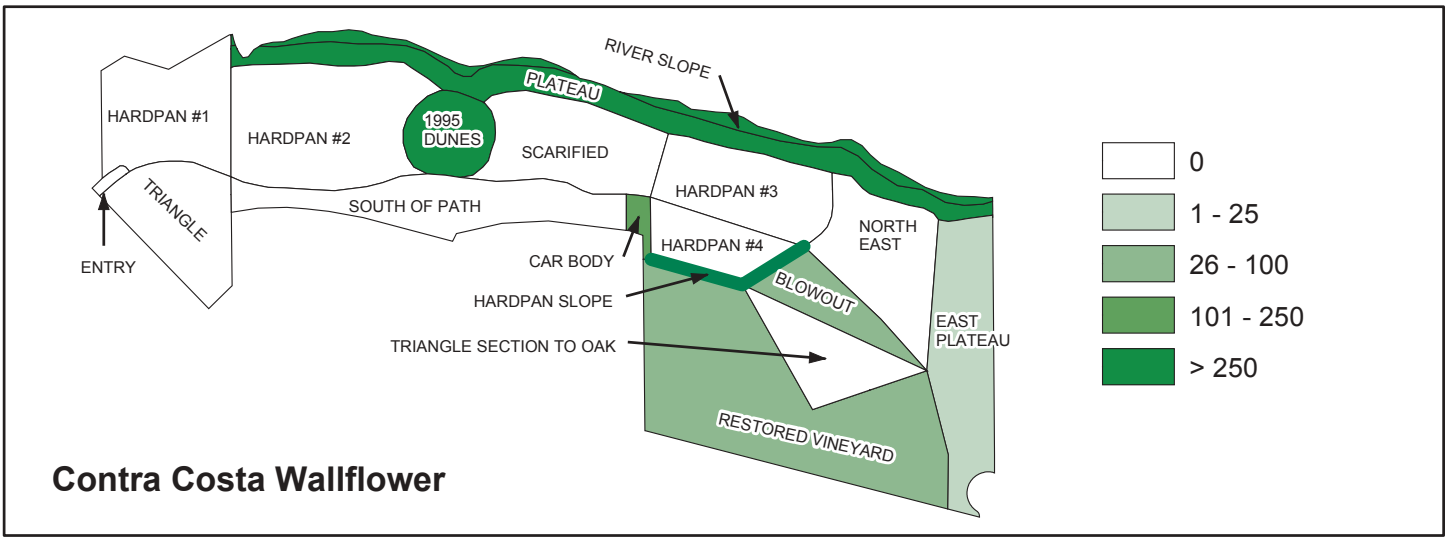
Annual Surveys

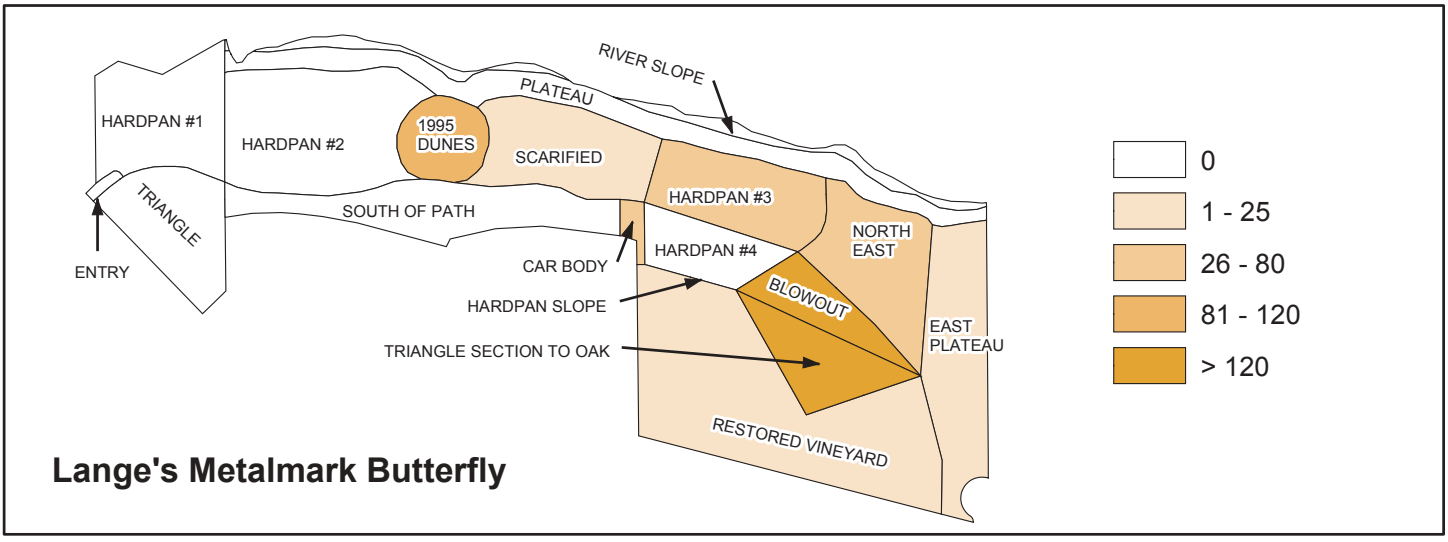
Populations of the three endangered species are surveyed annually to determine their status, prioritize management efforts, and analyze the effects of various management prescriptions by specific Refuge subunit (Figures 3 and 4). Recent surveys have documented fairly healthy wallflower and Lange's populations, but have shown low rates of primrose natural regeneration (See Figures 6, 7, and 8). Thus, propagation efforts over the past few years have focused on the primrose. The 1998 survey densities for the primrose, wallflower, and Lange's are shown in Figures 9 and 10.

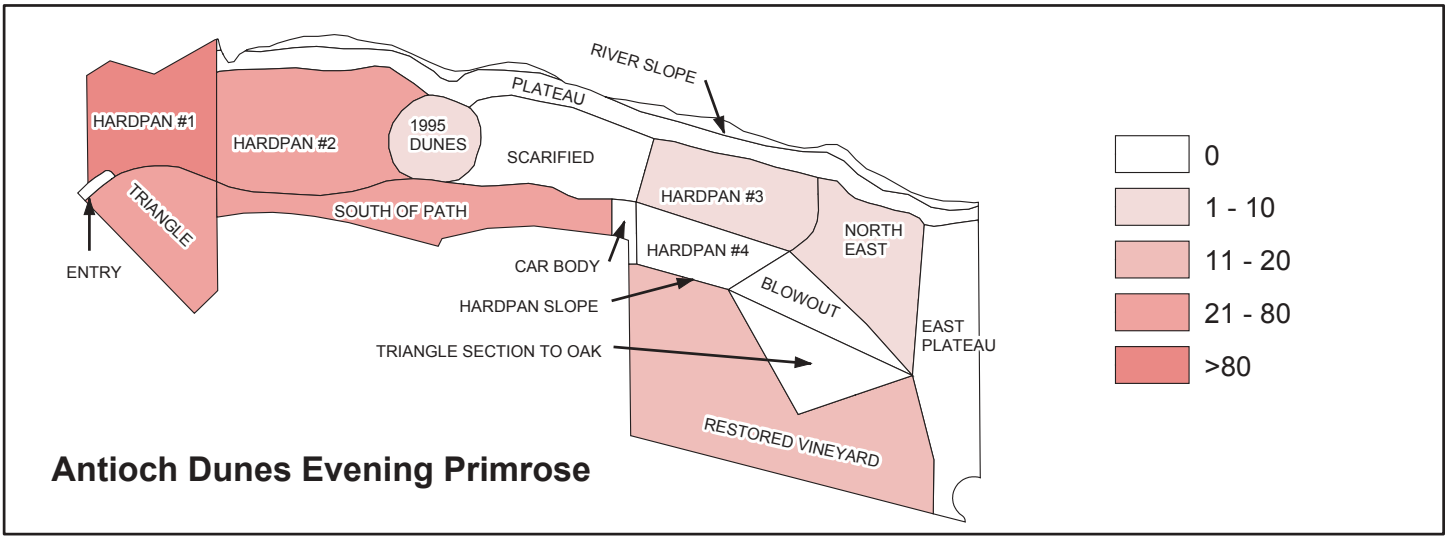
Nonnative Weed Control

Although a number of weedy species occur at the Refuge, the recent arrival of yellow thistle has caused the most destruction. Various weed control methods have been employed at the Refuge including hand weeding, treating with herbicide, and prescribed burning. A series of experimental plots were developed to test the response of nonnative weeds to burning, flaming, broad-spectrum herbicide (Roundup®), grass-specific herbicide (Poast®), pre-emergent herbicide, a more specific herbicide (Transline®), and mowing. Early results indicate that invasive species do respond to these techniques to varying degrees. Poast®, a grass-specific herbicide, has been effective in controlling *Bromus*. Other treatments (including Transline®) have also been effective at controlling *Bromus*, except flaming. Treating starthistle with Transline® provided excellent control. Starthistle also responded to flaming before seed set and responded to burning and somewhat to mowing. However, Transline® also killed buckwheat (Rusmore 1999) and therefore cannot be used in areas with buckwheat stands.

Figure 9. Stamm Unit Densities (no./acre) Based on 1998 Counts





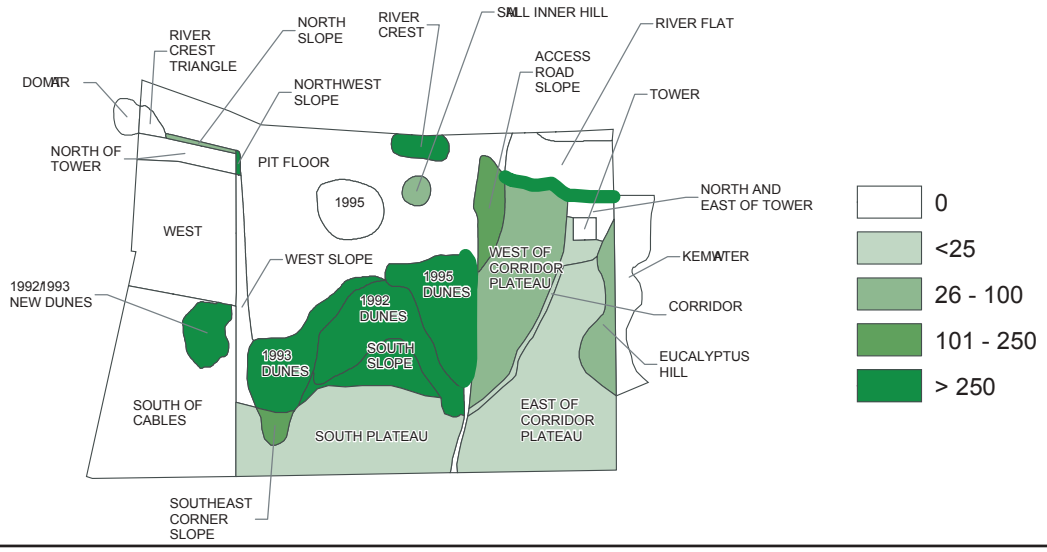


CA/NV Refuge Planning Office - July 2001

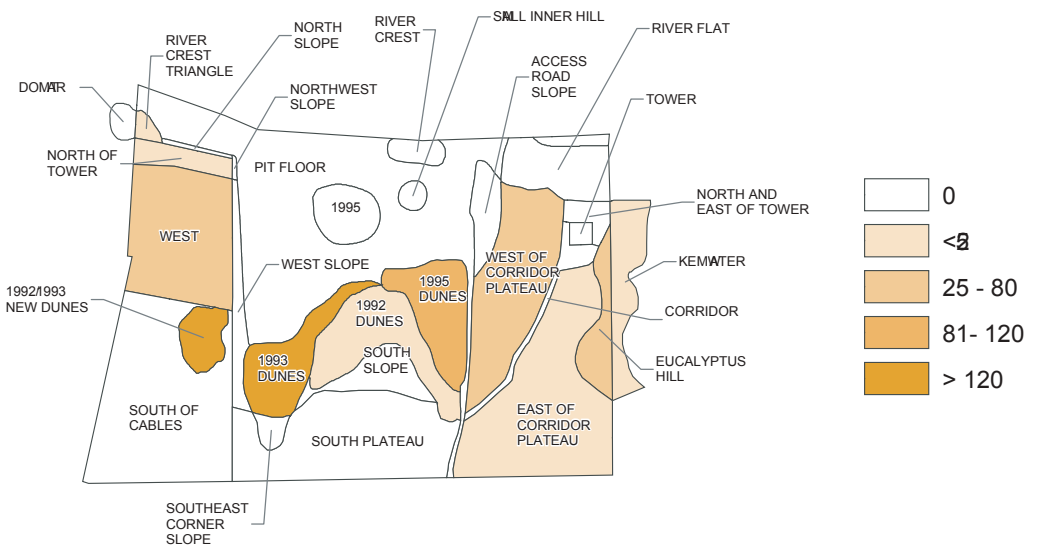
500 0 500 1,000 Feet

Figure 10. Sardis Unit Densities (no./acre) Based on 1998 Counts

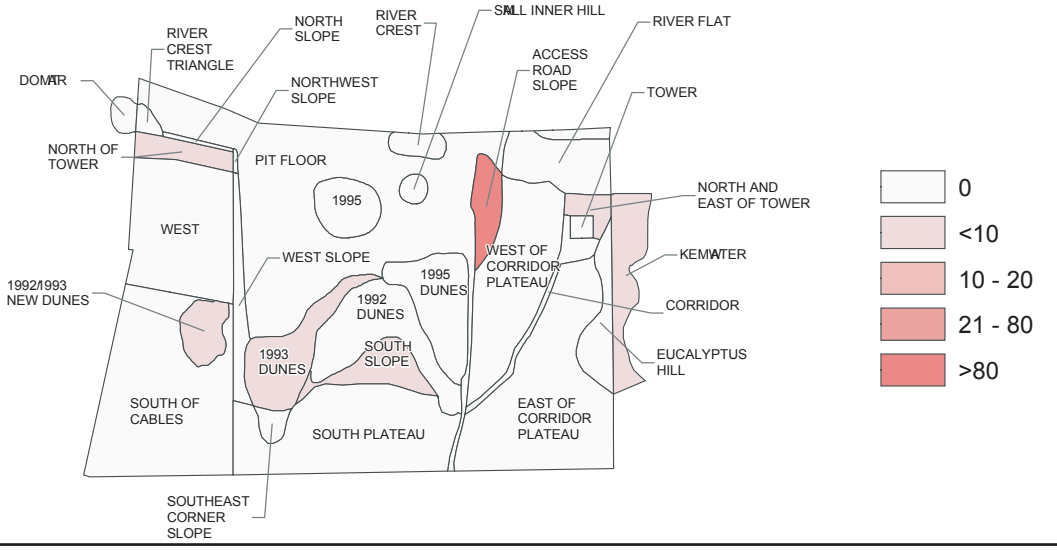
Contra Costa Wallflower



Lange 's Metalmark Butterfly



Antioch Dunes Evening Primrose



CA/NV Refuge Planning Office - Aug 2001

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In 1997, the Service prepared an EA for the Prescribed Burn Program for the Refuge (US Fish and Wildlife Service 1997b). The Refuge then conducted its first prescribed burn in 1997 and burned about 12 acres total, divided among the Triangle Unit and a portion of the Restored Vineyard Unit of Stamm and the South Plateau Unit of Sardis, areas dominated by nonnative invasive vegetation (Figures 3 and 4). The goal was to burn these areas for three constructive years to kill the nonnative weeds and reduce their seed bank. Persistent starthistle was spot treated with Round-up®. As of 1999, these areas had been burned for three consecutive years and were recently replanted with native vegetation. Two other Refuge units, Hardpan #1 and the remainder of the Vineyard, were added to the burn program in 1999 and were also burned for three consecutive years.

The burned areas showed promising though mixed results. Primrose and other native plants within the Triangle Area of the Stamm Unit responded positively. Unfortunately, other nonnative weeds like filaree and vetch moved into the burned areas quickly (Rusmore 1999). Vetch is currently being controlled with herbicide. Starthistle has been effectively controlled through three years of prescribed burning.

Continuing research efforts in invasive plant control will enable the Refuge to determine the most effective method to control invasive nonnative vegetation. Methods that prove effective will continue to be implemented (Fernandez 1997, Rusmore 1999, Loredo pers. comm. 2000). The Refuge will continue to burn areas that are dominated by invasive nonnative vegetation (Fernandez 1997), unless other methods are determined effective. Only areas that do not support many Lange's will be considered for the program. In addition, small firebreaks will be constructed around any individual primrose or wallflower in the proposed burn areas. This will minimize effects to endangered species (See Appendix I - Fire Management Plan).

Constructing dunes using existing sand.

Hand weeding and mowing also continue to be important tools in controlling weeds to promote native plant growth, particularly the primrose. Each of the endangered species on the Refuge are dependent on an open sand dune environment. To stabilize and increase their populations, management actions must continue to re-create this environment to the extent possible.

Importing Sand

New dunes were created by the Service with the help of PG&E by using imported sand. The first major dune restoration effort began in 1991. The Service imported native riverine sand to create new dunes from a stockpile at a PG&E power plant about one mile from the eastern boundary of the Refuge. The dunes were contoured to mimic the historic dunes and were then planted with nursery-grown endangered and native plants endemic to the Refuge. Nonnative vegetation was

hand-pulled and sprayed with herbicide to prevent encroachment on the newly restored site. The dune restoration was continued for an additional year. A total of three dunes were created in the Sardis Unit and one in the Stamm Unit.

Overall, about 7,000 cubic yards of sand (Morton pers. comm. 2000) were imported and thousands of buckwheat, primrose, and wallflower were established on the new dunes in an attempt to create an open sand dune environment similar to conditions prior to sand mining. Buckwheat and Lange's have persisted on these created dunes, however, primrose and wallflower are found only in small numbers on these dunes, if at all. As has happened on most of the Refuge, nonnative vegetation has heavily colonized the restored dunes, and are probably out-competing the endangered species (Fernandez 1997). Dunes created during this project can be identified in Figures 3 and 4 as 1992 Dunes, 1993 Dunes, and 1995 Dunes. Though these dunes were all created in 1991 and 1992, they are named for the year they were planted. In addition, there have been several recent dune construction projects on Stamm that have utilized existing substrate material. Using heavy equipment, existing sand was pushed up to form steep sided dune formations. In the fall of 1999, three dunes were recontoured in the Vineyard area using a grant from Chevron Corporation. In February of 2000 an additional dune was constructed in Northeast as part of a City of Antioch mitigation project. CalTrans provided labor for this project and, additionally, constructed a fourth dune in the Vineyard.

Revegetation

The Service has propagated primrose, wallflower, and buckwheat in the past, and will add other sensitive native species to its propagation efforts in the future. During seed collection, no more than 5 percent of the seeds are collected from Refuge plants for propagation. These seeds are grown in a nursery during the fall for planting on the Refuge in the winter. Plants are grown either in the Refuge greenhouse, which had limited space, or contracted out to commercial nurseries. In 2000, the Service completed construction of an additional greenhouse to accommodate an increased quantity of endangered plant propagation. In the 1999-2000 season, the Service propagated and planted 835 primrose to augment the wild population (Loredo pers. comm. 2000).

Firebreaks

The City of Antioch requires the Service to maintain a firebreak between the Refuge and the adjacent railroad tracks. The Refuge has tried both scraping and discing to remove potentially flammable materials. Discing resulted in more nonnative vegetation than had previously existed. Scraping (removing the top 1 to 2 inches of soil by scraping the soil surface with heavy equipment, such as a bulldozer with a blade), however, seemed to open up more habitat and allowed endangered species to resprout in greater numbers than prior to scraping (First Technical Panel pers. comm. 1999). The Service also established firebreaks internally to the Refuge to contain prescribed burns on the Refuge. Again, scraping proved to be more beneficial to endangered plants than discing (First Technical Panel pers. comm. 1999).

Chapter 4 - Problems and Opportunities

Problems

The Refuge was established to protect three endangered species. Maintaining a sustainable population of the three endangered species in a small area, while providing habitat for other plants and animals known to inhabit the dune ecosystem, presents a demanding challenge. A web of many interrelated and cumulative factors contribute to the problems of maintaining self-sustaining populations of three endangered species.

Many factors, including urban development, habitat fragmentation, and sand mining, have contributed to the decline of the species the Refuge was created to protect. Although numbers of the Lange's and wallflower have fluctuated over the past 10 years (Tables 2, 3, and 4), their populations overall have increased. However, primrose numbers have declined in the last 10 years. There were 5,800 mature primrose in 1984, and only 963 mature primrose in 1996, a decrease of 83 percent. The main problem affecting the primrose and wallflower is nonnative weeds. Other potential problems include lack of suitable substrate, lack of insect pollinators, inadequate land base, and predation.

Planning staff, the technical panel, and other key contacts identified problems plaguing the Refuge's endangered species and other resources. The problems are described below and are grouped into general categories. Although the divisions can seem arbitrary, categorizing the problems make them easier to understand and grasp.

Dune Habitat

Loss of habitat, primarily through sand mining and industrial development, was a key factor in the decline of the endangered plants present at the Refuge. Early industrialization and agricultural conversion (vineyards and grazing) have contributed to the destruction of habitat. The dune habitat has been almost completely altered by sand mining by effectively leveling the mined areas. Historical records corroborate that the dunes probably consisted of upland vegetation with a few patches of sandy habitat that formed in eroded portions on the river side of the dunes. Since the former 2-mile dune system has been reduced to the narrow extent of the Refuge, there is no longer enough riverfront property to sustain endangered species habitat at historic levels (Arnold et al. 1983). Problems related to dune habitat include:

- Lack of ecosystem function,
- Lack of native plant diversity,
- Loss of habitat,
- Fragmentation and associated problems (i.e. decreased genetic diversity), and
- Decreasing populations and species diversity of native insects, reptiles, mammals, and birds.

Nonnative Weeds

Although considerable evidence indicates that the dunes were stabilized in historic times with the “blowout areas” supporting the primrose, the major threat to the primrose, wallflower, and other native species, is the invasion of nonnative vegetation such as yellow starthistle and ripgut brome. Nonnative vegetation leads to lower germination and seedling survival rates and have been identified as the leading problem for endangered species and the dune ecosystem habitat at Antioch Dunes.

The problems caused by, and associated with, invasive nonnative plants are complex and interrelated. Nonnative vegetation not only out-competes natives for sunlight, moisture, space, and nutrients, but it also stabilizes what little remains of the dunes. Primrose has evolved on shifting, wind-blown riverine sand dunes and appears to thrive with a certain amount of disturbance. Unfortunately, the soil stabilization provided by nonnative plants prevents the dunes from shifting, increasing competition for resources and posing a significant problem to those species requiring open sandy substrate for survival.

In general, invasive nonnative vegetation affects the primrose and wallflower in a similar manner. Nonnative vegetation affect Lange’s indirectly by affecting the buckwheat. Invasive vegetation on the Refuge form dense stands, areas Lange’s tend not to frequent. Lange’s uses native plants for egg laying and nectar sources. Without a sufficient number of buckwheat plants at the appropriate density, the butterfly population will not be supported.

The first technical panel (1999) hypothesized that excessive nitrogen in the soils might limit the reproductive success of the primrose, wallflower, and buckwheat. Increased nitrogen can promote nonnative weeds, while too little nitrogen can inhibit reproduction of the primrose, wallflower, and buckwheat. Factors that contribute to increased nitrogen include accumulated biomass, herbicide application (herbicides can increase the nitrogen load in the soil), and prescribed burning. In 1999, a soil survey was conducted at the Refuge to investigate differences in soil conditions between areas that supported healthy populations of primrose, wallflower, and buckwheat (population sites) versus areas that did not support these species but instead were dominated by non-native weeds (control sites) (Jones and Stokes, 2000). The survey found no significant difference in soil nitrogen levels between the two types of sites. Instead, soil from population sites was found to be significantly lower in percent organic matter and phosphorus compared to soil from control sites. Thus, the three species are adapted to less fertile, rapidly permeable soils, presumably where they can outcompete nonnatives.

Invasion by nonnative vegetation also leads to lower native plant diversity. Decreased plant diversity leads to lower insect diversity. Maffei (1997) correlated weeds stabilizing sand with a decline in insect diversity. He observed 30 species of velvet ants in 1995 and only six in 1997. Similar declines were seen for other insects. Lower insect diversity can ultimately lead to a decrease in pollinators, which can lead to a decrease in the endangered species populations (Second Technical Panel pers. comm. 1999).

Disturbance

Primrose, wallflower, and buckwheat, host for Lange's, all have different tolerances to disturbance. Primrose requires some level of disturbance and responds well to prescribed burns, firebreak scraping, and weed pulling in close vicinity to a plant. Wallflower prefers steep north-facing slopes which receive natural disturbance through erosion. Lange's and buckwheat do not particularly respond favorably to disturbance. Lange's can be immediately negatively impacted by disturbances such as burns and scraping, and healthy buckwheat populations can be found in areas with little disturbance. However, Lange's prefers buckwheat in various successional stages and some disturbance may be necessary to provide a this range. This must be balanced by direct negative effects to Lange's. The varying tolerances and needs for disturbance of the three species poses management problems.

Predation

Several predation problems were identified for the three endangered species within the approved Refuge boundaries.

Mammals

Mammals have been known to eat primrose (Technical Panel 1999). Although the specific predator has not yet been identified, it is presumed to be a subterranean animal, probably a rodent. The predator eats roots, leaving primrose severed at the tap root, effectively killing the plant. There has also been evidence of mammals eating the above ground portions of the plant (Loredo, pers. comm. 2000a).

Insect Predators

Powell (1999) has identified three insect predators for the primrose. One is *Mompha murtfeldtella*, a moth that feeds on growing tips but does not seem to limit the primrose's ability to be self-sustaining. Another moth, *Mompha eloisella*, grazes in the interior of primrose stems, but also does not have a major effect (Powell 1992). However, *Altica sp.*, a leaf eating beetle, reduces plants to skeletons in early summer, and does present a potential threat to the sustainability of the primrose population.

The wallflower (Powell, pers. comm. 1999) is also a host plant for three herbivorous insects, *Chalceopla simpliciella*, a moth that feeds on immature wallflower seeds and later is believed to feed on new wallflower leaves, *Calcus* sp*.,* a moth that lays eggs on the wallflower, and *Plutella xylostella*, an external feeder whose larvae have been found on the wallflower.

Problems Relating to Viable Seed Production

The lack of pollinators for the primrose has been discussed in at least two papers, Pavlik et al. (1993), and Pavlik and Manning (1993), and at a technical panel (1999). Although seed production in the primrose is high, indicating that the primrose is being adequately pollinated, a lack of pollinators may contribute somewhat to its decline in the future. Primrose are primarily pollinated by bees. Other species of primrose have been known to be pollinated by a hawkmoth, although there are no documented cases of the Antioch Dunes evening primrose being pollinated this way.

Factors related to lack of viable seed production are complex. Low insect diversity is a contributing factor to the decrease in pollination. Low native plant diversity is a likely cause of low insect diversity and a decrease in pollinators. Greene (1995) and Thompson (1997) have also conducted research into the effect of low plant genetic diversity on seed viability and have found that the lack of genetic variability in the primrose likely leads to a decrease in seed viability.

Wildlife

Historically, the Refuge was home to the western toad, western rattlesnake, coast horned lizard, western fence lizard, side-blotched lizard, California legless lizard, glossy snake, fence lizard, racer, and gopher snake. However, few of the reptiles have been seen in recent years. For example, the last horned lizard was seen in 1933. The lack of reptile diversity on the Refuge could possibly be attributed to the lack of native vegetation and loose sand, and destruction of habitat throughout the area. Furthermore, the range of the dunes has become limited and fragmented after a long history of extreme disturbance.

Human Disturbance

At the first technical panel meeting (1999), human disturbance, such as wildfire, habitat management, and foot, bike, and motorcycle trespassers, was identified as a problem on the Refuge. Disturbance destroys plants growing in the immediate area of the disturbance. However, the primrose repopulates the area quickly if the disturbance is not too frequent or repeated. It is possible that some walking-related disturbance may be beneficial, even necessary, to the primrose and other plant species native to dune systems that are adapted to natural disturbances such as strong winds, shifting dunes, or river erosion.

However, uncontrolled human presence can cause undesirable impacts to the Refuge, such as litter, trampling of threatened and endangered species, wildfires, and vandalism. A lack of staff presence at the Refuge and insufficient law enforcement patrols result in higher incidences of trespassing and vandalism.

Wildfires

All fires not classified as prescribed fires are wildfires. Unlike prescribed burns, wildfires are uncontrolled. Therefore, wildfires can be extremely destructive to endangered species. Lange's, in particular, takes many years to recover from wildfires since fires tend to kill all larvae or destroy eggs (depending on the timing). Also, areas supporting healthy populations of endangered plants could be damaged by wildfires. When planning prescribed burns, on the other hand, units are chosen and care is taken to minimize effects to endangered species.

Wildfires set by trespassers or escaping from adjacent properties have negatively affected the endangered species and other native habitat on the Refuge. For example, Refuge Officer Barry Tarbet and Service fire crew leader Chuck Berner conducted a site visit to investigate the cause and origin of the May 1999 wildfire. They surveyed the entire riverfront and fire boundary and found evidence that the wildfire was started at the river by a trespasser's campfire. The 10-acre wildfire spread through the northeastern portion of the Stamm Unit, burning the entire Blowout section of the Refuge (Figure 3). The Blowout had previously provided

excellent Lange's habitat. Because the Lange's spend their larval phase in the lower leaves of the buckwheat, it is likely that the entire population of Lange's throughout the burn area perished. Many native plant species, including croton and buckwheat, have recovered well. However, fire-tolerant weeds, such as vetch and filaree, have increased, competing with native plants.

External Factors

A number of external factors may also contribute to Refuge problems. The first technical panel (1999) voiced concerns about the effect of surrounding land uses on the Refuge, specifically, the effect of chemical uses on surrounding lands. Pesticides, for example, have the potential to drift onto the Refuge, and also affect potential pollinators on adjacent lands. Nonnative vegetation can expand from adjacent properties onto the Refuge.

The Sardis Unit of the Refuge is located downwind of a gypsum plant. The leaves of the plants at Sardis, especially those adjacent to the plant, are covered with a layer of gypsum dust. It is unknown at this time what effect gypsum may have on soil chemistry, photosynthesis, and other factors that affect plant growth, reproduction, viability, and seedling survival.

Lack of Information

Lack of information is problematic for managing any refuge. Although an abundance of data has been gathered at Antioch, some factors remain unknown. The list of identified unknowns include:

- The effects of scraping, burning, and other management practices on insects. Although prescribed burning seems to benefit the two endangered plants and the host plant for the Lange's by reducing weed populations, its effects on insects are not fully known. Maffei conducted surveys following a controlled burn in 1997. The insect composition along the scraped firebreak changed dramatically within a week after the burn. Chrysidid wasps were fairly common on June 7, 1997 (ten specimens found). By June 14, after the burn, only three individuals were found, with one individual found on successive visits during the following three following weeks. Conversely, the sand wasp, a host for one of the chrysidid wasps became very common and was frequently observed constructing burrows in the loose sand (Maffei 1997). This topic merits additional study.

- The effect of lupine on endangered species. Some experts believe that the nitrogen-fixing lupine might add to the nitrogen load of the soil, to the detriment of the primrose. Others believe primrose do better in the vicinity of lupine (Thompson 1997).

- The effects of gypsum on plant growth and human health.

- The status and identity of endangered plant pollinators.

The Service recognizes the need to collect more data and is currently working on a project to determine the most effective means of controlling nonnative invasive vegetation. The Service will continue to encourage research by non-Service scientists on the Refuge.

Opportunities

Although there are considerable challenges facing the Refuge, it still ranks as a gem of diversity, preserves endemic and listed species, and remains a remnant riverine dune ecosystem. There are many opportunities to work with partners to preserve endangered species habitat. The City of Antioch, with assistance from California Department of Transportation (Caltrans), has worked with the Service to recontour a dune, and will propagate and plant native species, and control nonnative vegetation. Caltrans continues to be an important data-sharing partner and has provided the Service with numerous aerial photographs of the Refuge, as well as labor for dune construction. Chevron Oil Company has worked with the Refuge to recontour three new dunes on the Refuge in the Restored Vineyard area. The Service and PG&E are continuing to pursue a cooperative agreement on PG&E lands. The agreement would improve habitat for endangered species, allow the Service and PG&E to cooperatively manage the Sardis Unit as 27 acres of continuous habitat, and allow the Service to conduct surveys and management activities on PG&E land.

Prescribed burns at the Refuge have dramatically reduced yellow starthistle densities and have resulted in increased cover by native species, although some fire-resistant weeds, such as vetch and filaree, have significantly increased. The Refuge is actively controlling vetch with herbicide and hand-pulling, and will investigate filaree control. At this point, the native plants seem better able to compete with filaree than with yellow starthistle or ripgut brome. Thus, prescribed burning appears to be a useful new tool in weed management on the Refuge.

The unique character of the Refuge has generated a great deal of interest and valuable partnerships over the years. Faculty and staff from various universities and colleges, and local experts continue to provide the Refuge with advice, new information, and important research. The Service and several local universities have conducted research on the Refuge for many years. There are opportunities to analyze data that has been collected, incorporate research results, and develop adaptive management strategies.

Prescribed burn used for nonnative weed control

Chapter 5 - Refuge Vision, Goals, and Objectives

The Refuge preserves a remnant of riverine dune ecosystem with a unique assemblage of plants and animals. This unique ecosystem supports a northern extension of species with Mojave Desert rather than coastal affinities. The importance of the Refuge as a northern California laboratory of desert ecology was unparalleled before travel to the deserts of southern California became as accessible as it is today.

Vision Statement

Our vision is that endangered species management will be incorporated into the overall management of the riverine sand dune ecosystem. Using management actions that mimic natural processes, the Refuge will support self-sustaining populations of Lange's, wallflower, primrose, and other native species.

Through high quality interpretive and environmental education programs, the public will have opportunities to visit and gain appreciation for the unique ecosystem of the Refuge and an understanding of endangered species protection and the role of the National Wildlife Refuge System in recovering endangered species.

Management Philosophy

This is a small refuge with little ability to tolerate catastrophic events -- a catastrophic event at the Refuge could result in the extirpation of one or more species. Because so much of this ecosystem has been destroyed, it is unlikely that enough habitat could be protected or duplicated to sustain the endangered species without active management. Therefore, for the life of this CCP, the Service will concentrate on adaptive management, performing a series of small management studies that are believed to benefit the native species. By monitoring the response of the Refuge resources to these management actions, the Refuge will acquire more data and more tools with which to manage the Refuge. Objectives may be revised based on analysis of the data.

Goals

This section presents long-term guidance for the Refuge in the form of goals, objectives, and strategies.

The Service's planning policy defines a goal as a:

Descriptive, open-ended, and often broad statement of desired future conditions that conveys a purpose but does not define measurable units.

Refuge goals are qualitative statements that support the Refuge purpose and the Refuge System mission by providing a vision of how the Refuge should operate and what the Refuge should be. Goals translate the Refuge purposes into management direction. Each goal is supported by measurable, achievable objectives which are the efforts or action items required to achieve the goals. Refuge objectives provide measurable bench marks that indicate progress towards achieving the Refuge purpose and goals. Objectives are intended to be accomplished within 15 years, however, actual implementation may vary depending on staff and funding levels.

Strategies are specific actions or projects that will lead to the accomplishment of management objectives.

Consistent with the legislative framework, described in Chapter 2, that guides the CCP process, three goals were identified to help guide Refuge planning, development, and management.

Goal 1: To protect, enhance, and maintain habitat for threatened and endangered species, emphasizing species known to inhabit the Refuge, including the Lange's metalmark butterfly, Contra Costa wallflower, and Antioch Dunes evening primrose.

Goal 2: To protect, restore, and manage the Antioch Dunes ecosystem for a diversity of native plant and animal species.

Goal 3: To establish interpretive and educational programs for the public to foster an appreciation of the natural habitats and endangered species supported by the native riverine dune habitat of the Refuge.

Endangered Species

Goal 1: To protect, enhance, and maintain habitat for threatened and endangered species, emphasizing the Lange's metalmark butterfly, Contra Costa wallflower, and Antioch Dunes evening primrose (Service 1984).

The Refuge was established to protect three endangered species that are not found anywhere else in the world. Refuge management options must be weighed carefully to create a management program that best suits the needs of the endangered species. Self-sustaining populations are the ultimate goal of Refuge management.

Objective 1.1: Endangered plants on the Refuge and the host plant for the Lange's will be self-sustaining and propagate naturally from seed within 15 years.

Narrative: Outplanting has been used on the Refuge for many years as an important management technique to prevent the possible extinction of endangered species. No more than 5 percent of the seeds are collected from any individual plant. The long-term objective for the Refuge is to take habitat management actions so that outplantings can be reduced and the species can be self-sustaining. However, outplanting would remain a tool to use against critical population declines.

Strategies:

1.1.1 Propagate and plant the primrose and wallflower on the Refuge when necessary to prevent species extinction until their populations are self-sustaining. Outplant buckwheat as needed, for example, in response to wildfire.

1.1.2 Hand-weed a 1½ foot radius around each outplanted primrose at least once in its lifespan. Greene (1995) found hand-weeding to be very effective at increasing primrose germination rates. Raking could also be beneficial.

1.1.3 Continue to promote research to determine the best means to optimize seed production, viability, germination, seedling survival, and reproduction for the primrose and wallflower.

1.1.4 Encourage genetic diversity by outplanting primrose grown from the seed of plants at the Brannan Island SRA or the Regional Parks Botanic Garden at Tilden Regional Park.

Objective 1.2: Determine the environmental parameters that promote natural regeneration for the primrose, wallflower, and buckwheat.

Narrative: Although much research of these three plant species has been completed, questions remain unanswered. Due to the fragmented nature of the dune ecosystem, the small population sizes, and the limited range of the species, intensive, directed research is needed to assess the effects of management actions and to assure that the population size of endangered species do not drop below critical levels. Research shall be directed toward answering management questions.

Although lack of pollinators is not the primary limiting factor affecting primrose and wallflower population sizes, Pavlik et al. (1988) did find evidence that it may contribute to lower seed production levels for these plants.

Since extensive demographic research has already been undertaken, demographic studies to help determine factors that affect the plants' seed production, viability, germination, seedling survival, vigor, and reproductive success are a lower priority, and should be undertaken if focused on specific management needs.

Strategies:

1.2.1 Encourage additional research to clarify the mechanisms by which competition, water availability, lack of pollinators and other factors limit seedling establishment.

1.2.2 Collect further data to help the Refuge predict how the primrose, wallflower, and buckwheat would be affected by Refuge management practices (such as prescribed burn, herbicide use, disturbance, and public use) and changing conditions.

1.2.3 Encourage researchers to survey adjacent lands with natural vegetation and remnant geomorphology similar to the Refuge as sources of native pollinators and to identify whether activities on adjacent lands (such as pesticide use) affect native pollinators.

1.2.4 Establish a permanent monitoring program with consistent units of area and standardized methodologies and protocols. Permanently mark the areas in the field and record using a global positioning system unit.

1.2.5 Develop a plan to identify and prioritize topics for research.

Objective 1.3: Decrease the amount of invasive nonnative vegetation canopy cover to less than 50 percent overall in the next 10 years. Some areas would be intensively managed and have less than 50 percent canopy cover with invasive nonnative vegetation. Other areas would be less intensively managed and may have more than 50 percent canopy cover.

Narrative: Invasive nonnative vegetation has been identified as the major threat at the Refuge both for endangered species and the ecosystem as a whole. Invasive nonnative vegetation outcompetes native plants and stabilizes the dunes.

Strategies:

1.3.1 Continue ongoing research plots which test various methods of weed control, such as chemical, mechanical (including hand weeding, mowing, and scraping), and fire (burning and flaming) in combination and by themselves. Consider biological controls such as grazing and insects.

1.3.2 Control nonnative vegetation using the most effective combinations of techniques including prescribed fire, herbicide (herbicide application is further described in the EA, Appendix C), and mechanical means, such as mowing and hand weeding.

1.3.3 Since using herbicides kills invasive species but leaves biomass, which increases the organic matter in the soil, experiment with removing dead nonnative vegetation after spraying, by mechanical means.

1.3.4 Burn selected sites periodically. Sites selected for controlled burning will be burned every year for 3 years to remove the nonnative vegetation until the seed bank is decreased. Burning thereafter could be conducted on an as-needed basis and/or would be followed by spot-spraying with herbicide. Sites will be monitored before and after burning to determine the effect of fire on nonnative vegetation, species richness, and endangered species. Burning would be conducted primarily in May or June to kill existing nonnative vegetation prior to setting seed and to decrease the nonnative seed bank. May and June are the best times to burn starthistle because less than 5 percent would be in flower (Service 1997a). The Fire Management Plan is incorporated into the CCP in Appendix I.

1.3.5 Flame or spot spray (with an appropriate herbicide), emerging, resprouting, and surviving nonnative vegetation following prescribed burns consistently. This way, any persistent invasive nonnative vegetation can be eradicated immediately.

1.3.6 Remove woody invasive nonnative vegetation using the cut stump method and/or backhoe to remove biomass. Apply foliar herbicide in the spring on any resprouts or new seedlings.

Objective 1.4: Maintain the Lange’s population size above 500 individuals.

Narrative: Dr. Richard Arnold conducted research at Antioch for many years. The lowest effective Lange’s population size (numbers of Lange’s that reproduce) observed was 400 (Arnold pers com 1999b). Since Lange’s continued to reproduce, Arnold theorized that 400 was a sustainable number. However, geneticists regard 500 individuals per generation as the minimum to guard against loss of heterozygosity (genetic variation) due to inbreeding, genetic drift, and other genetic factors (Arnold 1983a). Therefore, an effective population of 500 Lange’s would be used as the basis for measuring sustainability for the Lange’s.

Strategies:

1.4.1 Provide disjunct habitats to help prevent Lange's extinction by encouraging patches of buckwheat throughout the entire Refuge by planting, nonnative weed removal and/or creating disturbance.

1.4.2 Develop a methodology to calculate population estimates from the Refuge's annual Lange's peak counts. Calculate effective population numbers for the Lange's annually.

1.4.3 Investigate other monitoring protocols that would give us better population esimates.

1.4.4 Enhance habitat for the buckwheat (see strategies for Objective 1.1).

1.4.5 Reduce weed cover (see strategies for Objective 1.3).

Naked-stemmed buckwheat.

Objective 1.5: Promote disturbance over 5 percent of the Refuge every year.

Narrative: The Refuge should be disturbed periodically to provide habitat for primrose, wallflower, and Lange's. Different species react differently to various levels of disturbance. For example, primrose requires newly disturbed sand, periodic disturbance, and an earlier successional stage habitat, while wallflower does not (Roof 1969). Also, prior to Refuge closure in 1986, endemic plants and the Lange's had survived long-term recreational use.

Different life stages of insects require habitat at different successional stages. For example, Lange's populations have shifted location at the Refuge because they require buckwheat in different successional stages (Arnold pers.comm. 1999a). Lange's oviposits (deposits eggs) on the withering lower foliage of mature buckwheat, the same area where larvae pupate. After about 10 years, buckwheat stands begin to die, and require open, active nonweedy sand for reproduction. Therefore, for long-term success, new patches of buckwheat should be planted on cleared substrate (Powell and Parker 1993). Wallflower require less disturbance and later successional stage habitat.

A technical panel held in Antioch on February 2, 1999 generally agreed that primrose grows and germinates well on disturbed sandy soils. Therefore, some substrate disturbance should be incorporated into regular Refuge management protocols. The technical panel indicated that the most effective management regime for the Refuge would be to include a mosaic pattern of management. Areas with self-sustaining populations of each endangered species would be identified and management for that specific species would be emphasized in that specific area. Four levels of disturbance should be incorporated into Refuge management: (1) maximum, disturbance every 5 years; (2) moderate, disturbance every 5 to 15 years; (3) minimum, disturbance every 15 years; or (4) none, for areas such as oak woodland. Natural processes should be facilitated to restore as much ecosystem function as possible.

Strategies:

1.5.1 Create a cycle of disturbance by scraping the soil in a mosaic pattern. Scarify hardpan soils by scraping, rather than discing. Scraping has resulted in less invasive nonnative vegetation and more native plants than discing. Since wallflower are doing well and are self-sustaining at the Refuge, its preferred habitat of north-facing scarps, which are already disturbed, should not be altered. The scraping would be conducted as a series of experiments and monitored and adjusted as results indicate.

1.5.2 Investigate a variety of different measures to introduce controlled sand substrate disturbance on the Refuge. Disturbance mechanisms that could be tried include using 4-wheel drive vehicles on the Refuge, scraping, and incorporating supervised public use on the Refuge to promote controlled disturbance. The disturbance should be in a checkerboard pattern so that entire areas are not disturbed at one time.

California Native Plant Society conducting a survey

1.5.3 All disturbance would be monitored and adaptive management used to refine the tools and techniques.

1.5.4 Encourage research into the habitat structure required by Lange's.

1.5.5 Clear site and plant new patches of buckwheat as needed (Powell and Parker 1993).

Objective 1.6: Develop a step-down management plan for other sensitive plant and animal species within the next 10 years.

Narrative: Antioch Dunes is home to many unique species. Since the Refuge is an isolated habitat, it is important to manage for and protect other species that may be rare and are a part of this unique ecosystem.

Strategies:

1.6.1 Survey the Refuge to develop a comprehensive list of plants, mammals, reptiles, and insects that inhabit the Refuge.

1.6.2 Document locations on a GIS database.

1.6.3 Develop management strategies to protect species that are Federally or State listed, proposed, candidates for listing, vulnerable to localized extirpation, or are locally significant and historically were found at the Refuge. Incorporate the management of these species with those of other species.

1.6.4 Scatter plywood in the upland portions of the Refuge to provide habitat for the llegless lizard.

Objective 1.7: Reduce trespassing.

Narrative: Vandalism and trespassing are serious problems. Trespassers create holes in fences and start fires that have devastating effects on endangered species habitat. While it is recognized that some endangered species require “managed” disturbance, uncontrolled disturbance can damage endangered species populations.

Strategies:

1.7.1 Work with local law enforcement officials, such as the County Sheriff and City Police, to patrol the Refuge once per week.

1.7.2 Acquire additional law enforcement staff (either full-time or collateral duty). The position could be shared with another refuge.

1.7.3 Increase Service presence on the Refuge by having staff or volunteers visit the Refuge more frequently.

1.7.4 Hire additional staff and interns to allow increased presence on the Refuge.

Ecosystem Protection, Restoration, and Management

Goal 2: To protect, restore, and enhance the Antioch Dunes ecosystem for a diversity of native plant and animal species.

The ecosystem goal for the Refuge is restoring, maintaining, and enhancing the plant and animal diversity in the riverine dunes by providing habitat for representative species of the riverine dune habitat using processes as close to natural as possible.

Objective 2.1: Restore habitat disturbance to 5 acres of the Refuge dunes per year to promote open dune conditions, to the extent possible.

Planting on newly constructed dune.

Narrative: Disturbance is an important part of the historic Antioch Dunes ecosystem.

Strategies:

2.1.1 See strategies for Objective 1.5

Objective 2.2: Restore dune habitat on the Refuge by creating dune topography using imported or existing sand.

Narrative: Most of the historic topography of the Antioch Dunes has been lost due to extensive sand mining. Past attempts to restore dune formations include the dunes created in 1991 and 1992 using imported sand, as well as the dunes created in 1999 and 2000 using existing sand. Restoration of the dune topography is seen as an ongoing need. Considerable amounts of sand substrate, as well as labor and expense, is needed to restore the dune habitat over selected parts of the Refuge. Although there has been much discussion among the technical panel (1999) on the

optimal characteristics for imported sand substrate (such as particle size and range of particle sizes), there was general consensus that the overwhelming need is for additional sand as long as it is uncontaminated, clean, and has low silt/organic matter content. The Refuge has begun to investigate sources for clean sand. Sand that has already been dewatered and cleaned is preferred as long as it is suitable. Dredge materials would require the Refuge to construct and lease a dewatering site and materials would need to be barged/relocated twice.

Past dune creation projects have shown that the Sardis pit, even with the additional imported sand, is not exposed to sufficient wind disturbance to be suitable habitat for primrose or wallflower. Also, dunes should be large enough to defend against encroachment by non-native vegetation. New dune construction should focus on experimentation to determine how best to create and maintain dunes that sustain habitat for native plants.

Strategies:

2.2.1 Continue to investigate potential sources for clean sand including Montezuma Wetlands, U.S. Army Corps of Engineers borrow site at Rio Vista, or dredge material from the deepwater ship channel. The preference would be for suitable material that would not require additional processing or dewatering.

2.2.2 Place imported sand on the Refuge in a mosaic pattern. Add sand to create dunes in areas that do not already provide good habitat for endangered species (Figure 11). Dunes constructed with imported sand should cover at least 1 acre and be 15 feet tall.

2.2.3 After creating new dunes, monitor for and control nonnative weeds. Plant native species and monitor the success of the vegetation.

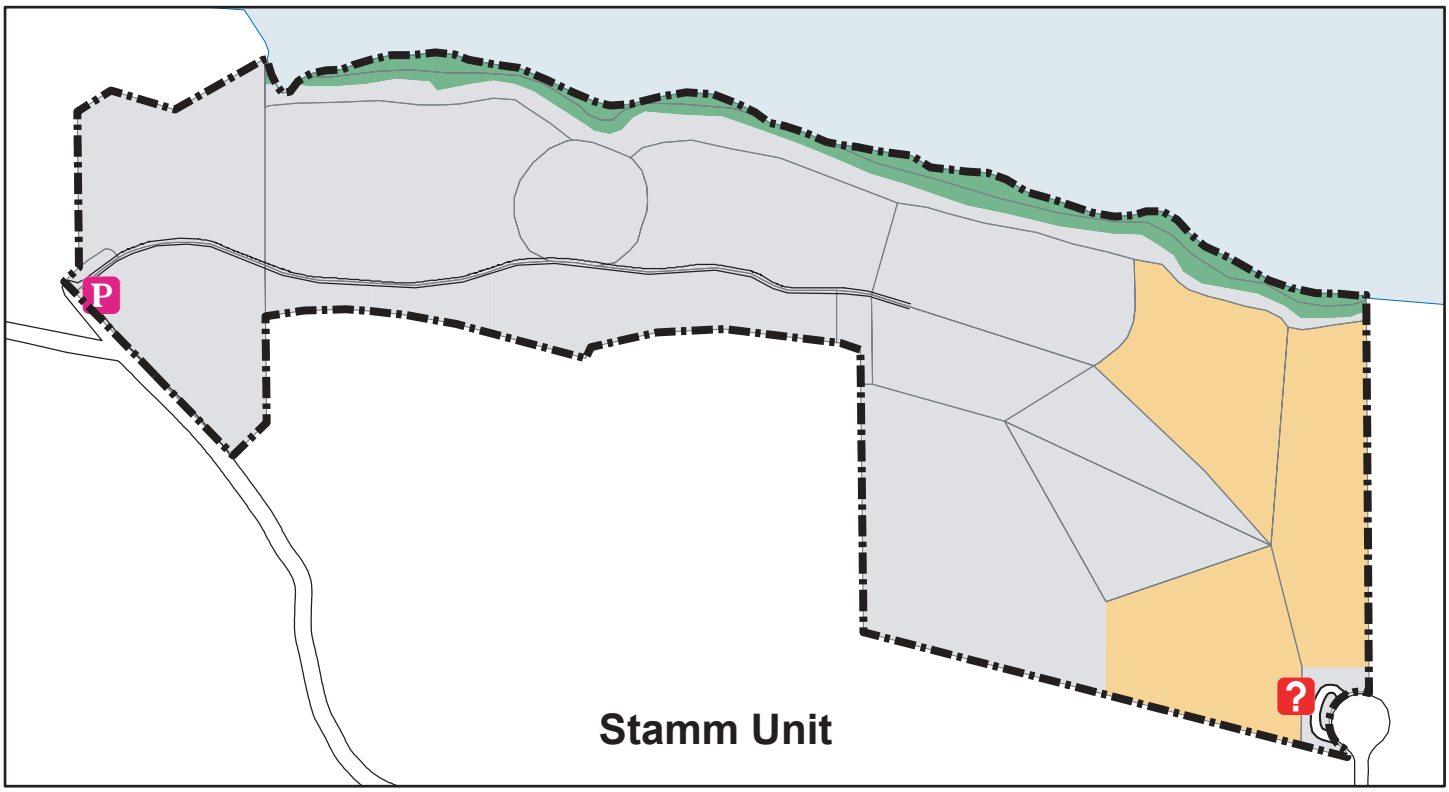
2.2.4 Facilitate natural dune dynamics by placing sand along the river bluff or in other parts of the Refuge that are not sheltered, so that offshore breezes can blow and recontour the dunes.

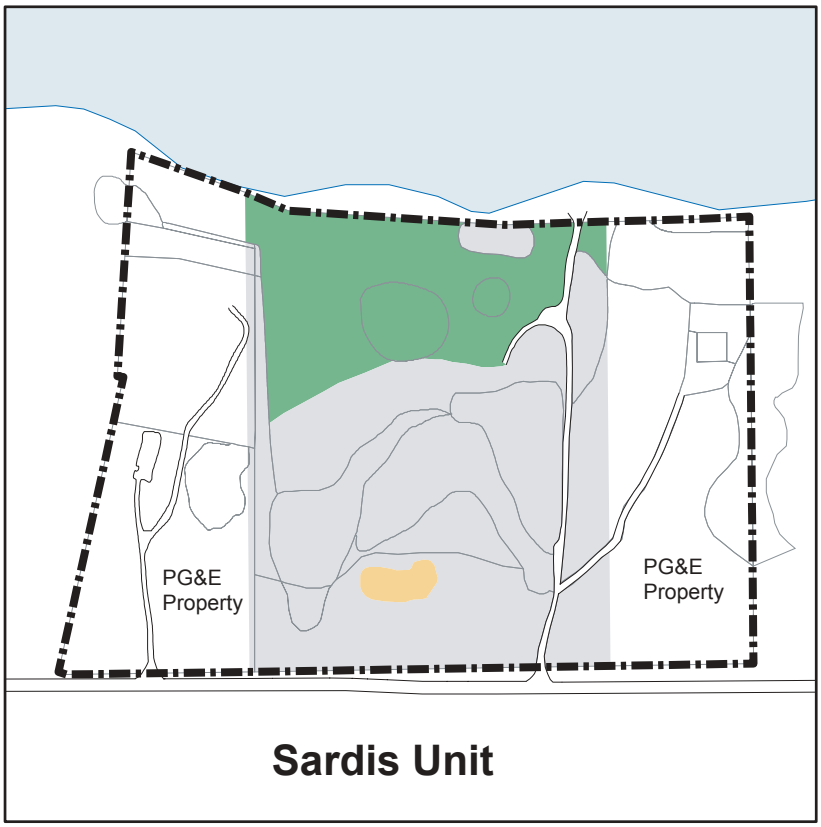
2.2.5 Continue to restore dune topography by contouring dunes using existing sand substrate. Dunes would have steep north facing slopes, which are preferred by the wallflower, and would receive maximum wind action for the primrose and other native dune plants.

Objective 2.3: Increase the amount of native vegetation cover to the extent possible. On the Refuge, at least 50 percent of the plant cover should be native in the next 10 years, focusing special attention on locally significant plant species and species that historically existed.

Narrative: The natural rate of germination and seedling establishment of some native plants has been insufficient for natural revegetation to occur. Therefore, additional plantings are needed to initiate the revegetation and ultimate restoration of the site. Increasing the species richness and abundance of native plants may increase the diversity of native insect species, including pollinators for the endangered and other native plants, assuming there are nearby source populations (Second Technical Panel pers. comm. 1999).

Figure 11. Proposed Management for Antioch Dunes National Wildlife Refuge





Approved Refuge Boundary

Parking

Interpretive Panals

Antioch Dunes Unique Stands with New Dunes

Riparian

Antioch Dunes Unique Stands

100 0 100 200 300 Feet

CA/NV Refuge Planning Office - July 2001

It is difficult to re-create a template of the vegetation that existed at the Refuge prior to industrial development. Furthermore, it may not be desirable to model management according to an historic template. However, over the lifetime of this CCP, the Service should make an attempt to develop a vegetation template, in cooperation with interested scientists, for use as a management tool for the next CCP.

Strategies:

2.3.1 Determine which species historically grew at the dunes and correlate that list with a list of locally significant species. Emphasize management for locally significant species and seek to plant species that were previously found at the Refuge and are historically significant.

2.3.2 Encourage native plants to naturally establish by introducing controlled disturbance and implementing invasive nonnative vegetation control strategies, as listed under Objective 2.4.

2.3.3 Continue to collect seeds of native plants that occur on the Refuge, as well as locally significant plants that historically grew on the Refuge, both on site and, where necessary, off-site but as close to the dunes as possible. Propagate them at a nursery for future outplantings on the Refuge.

2.3.4 Maintain genetic diversity of native plants by continuing to conduct reciprocal transplanting between the Sardis and Stamm Units.

2.3.5 Determine the extent to which particulate emissions from the adjacent gypsum plant affects plant vigor. Individual plants at the Refuge near the gypsum plant, particularly on the Sardis Unit, are usually covered with a layer of gypsum dust. It is not known how this layer of dust affects plant vigor, seed production, and seedling survival. The dust may also deter insect pollinators from using the area. Conduct studies in the greenhouse to determine the effect of gypsum on soil chemistry, photosynthesis, and other factors that might affect the growth of plants on the Refuge.

2.3.6 Work with adjacent landowners to decrease their particulate emissions onto the Refuge. For example, the owners could consider covering more of their operation with a dome, similar to their existing dome, or applying surfactant on the piles.

Objective 2.4: Within 5 years, invasive nonnative vegetation would account for less than 50 percent of the canopy cover.

Strategies:

2.4.1 See strategies for Objective 1.3

Objective 2.5: Continue research and monitoring of various components of native plants and animals to learn more about their response to management practices. Encourage research from outside of the Service. Research topics could include:

- the response of plants and insects to wildfire, prescribed burning, and herbicide,

- the effect of habitat patch size on insect populations,
- an identification of the native plant pollinators and their abundance,
- factors that may affect the growth and viability of native plants such as lack of pollinators and lack of genetic diversity,
- the effect of adjacent land uses on pollinators,
- a census of songbird populations,
- continuing research on effective nonnative weed control,
- response of native plants and invertebrates to imported sand/dune construction,
- the effect of soil sterilizers on reconstructed dunes,
- factors limiting seed germination limiting factors,
- seedling survival, and
- the effect of gypsum on plant viability.

Narrative: Extensive research has been conducted at the Refuge since it was first visited by botanists in the late 1800s. Population trends of primrose, wallflower, and Lange's, as well as the effect of various control methods on nonnative weeds are being monitored. The populations of endangered species are vulnerable to extinction because of the fragmented nature of the Refuge dune ecosystem and their small population sizes. Therefore, intensive, focused research and monitoring is needed to assess the effects of management actions.

Strategies:

2.5.1 Continue investigating historical conditions of the Refuge and the composition of its plant, invertebrate, and reptile communities to guide future restoration efforts.

2.5.2 Encourage research into the effects of management activities and disturbance, such as outplanting native plants, prescribed fires, wildfires, and the effects of scraping on native insects, including insect pollinators and plants.

2.5.3 Expand reptile monitoring. Develop and implement protocols for silvery legless lizards and other species of interest.

2.5.4 Also see Objective 1.2

Objective 2.6: Within 5 years, investigate the best way to protect as much of the remnant dune and riverine ecosystem outside the Refuge boundary as possible, for example, through land acquisition, cooperative agreement, and easement by the Service or others. Maximize contiguous habitat involving both Refuge and adjacent properties by soliciting cooperation of neighboring land owners.

Narrative: Since the Refuge has such a small land base, it is important to consider protecting other lands nearby that contain, or could be feasibly restored to, either a riverine dune or riparian ecosystem. Rare species in the littoral zone along the San Joaquin River, such as Mason's lilaeopsis and Suisun marsh aster, would receive increased protection by incorporation of these lands into the Refuge boundary.

Strategies:

2.6.1 Finalize and maintain a cooperative agreement with PG&E to manage their properties flanking the Sardis Unit.

2.6.2 Develop an initial ascertainment report that identifies land adjacent to or near the Refuge with the potential to provide dune and/or riparian habitat similar to that found on the Refuge. Part of this report could include investigating the Kemwater property to determine the feasibility of incorporating a portion of this property into the Refuge, subject to contaminate remediation.

Suisun marsh aster--rare plant found along riverine habitat.

2.6.3 Seek approval for and conduct land protection planning which includes public outreach. This process, which identifies and prioritizes tracts of land for acquisition, culminates in a land protection plan, conceptual management plan, and NEPA document.

2.6.4 Subject to NEPA documentation and agency approved land protection plan, acquire appropriate adjacent or nearby parcels with dune or riparian habitat, including the portions of the river shore that are not owned by the Refuge in order to protect rare plant species in the littoral zone. Parcels of interest adjacent to the Refuge are limited and small in size, less than 10 acres, in total.

Objective 2.7: Within the next 10 years restore riverine habitat along 5,000 feet of Refuge/San Joaquin River shoreline to pre-European settlement (natural) conditions.

Narrative: The river shore is an important part of the San Joaquin River ecosystem. The river system hosts a variety of candidate and state listed species as well as other rare or unique plant species, including Mason's lilaeopsis, Suisun Marsh aster, and the delta tule pea. Currently part of the Refuge shoreline in the Stamm Unit is covered in revetment.

Strategies:

2.7.1 Determine the natural condition of the shoreline ecosystem.

2.7.2 Remove concrete revetment on and adjacent to Refuge lands along the shoreline in cooperation with State Lands Commission.

2.7.3 Collect cuttings and seeds from native riparian and wetland vegetation and propagate them at a nursery for future outplanting on the Refuge. Plant woody species such as alder, oak, walnut, rose, willow, and cottonwood, in riparian areas of the Refuge.

2.7.4 Remove nonnative plants, such as giant reed, oleandar, tree of heaven, black locust, pampas grass, and pepperweed, from the shoreline.

Objective 2.8: Manage firebreaks so that they support natural ecosystem processes to the greatest extent possible.

Narrative: Firebreaks on the Refuge are required by the county to prevent the spread of wildfire and prescribed fire. Depending on how they are managed, firebreaks can either be detrimental or beneficial to native plants and the ecosystem. For example, colonization by nonnative weeds is more extensive when the firebreaks are disced rather than scraped. Furthermore, scraping can provide open soil for insects if followed by spraying with an emergent herbicide.

Strategies:

2.8.1 Create firebreaks around areas that have few nonnatives and are intensively managed for endangered species. Firebreaks will also form a buffer to reduce the number of nonnative weed seeds dispersing into these areas.

2.8.2 Scrape, rather than disc, firebreaks and maintain open sandy habitat on firebreaks with herbicide or additional scraping.

2.8.3 Prior to conducting a prescribed burn, create individual firebreaks around groups of primrose plants and other species needing protection.

2.8.4 Evaluate steel or masonry walls as firebreaks, along the Southern Refuge boundary of Stamm.

Firebreaks for Antioch Dunes Evening Primrose.

Objective 2.9: Create and foster partnerships, wherever possible, with private individuals, agencies, organizations, businesses, and universities that are mutually beneficial and further the goals of the Refuge.

Narrative: Biologists, universities, environmental organizations, elementary schools, private citizens, and other agencies have expressed an interest in the Refuge. Partnerships provide benefits to the Refuge in the form of research, volunteer labor, staff support, and funding. Partnerships require extensive time to coordinate, develop, and nurture.

Strategies:

2.9.1 Encourage universities to research topics that would facilitate management and fill in data gaps. Research needs identified thus far include those listed under Objective 2.5.

2.9.2 Maintain and enhance existing partnerships with UC Davis, UC Santa Cruz, UC Berkeley, East Bay Regional Parks Botanic Garden at Tilden Regional Park, Mills College, City of Antioch, County of Contra Costa, Los Medanos College, Contra Costa County/Alameda County Weed Management Area, and Napa County Mosquito Abatement District.

2.9.3 Work with other groups or agencies to manage refuge resources more effectively.

Public Use

The Refuge would provide four of the six priority public uses identified in the National Wildlife Refuge System Improvement Act of 1997: (1) environmental education, (2) interpretation, (3) wildlife observation, and (4) photography. These have been determined compatible with the Refuge's purpose (see Appendix A -Compatibility Determinations). Due to the Refuge's limited size and the sensitivity of the species for which it was established, hunting, fishing, and other unmonitored recreational use has been determined incompatible and will not be allowed. The Refuge will be open to staff and educator led public use programs. Because the Refuge is not well known by the local public, the Refuge is interested in conducting outreach efforts in order to educate the local community on the unique Antioch Dunes habitat and species, and to build local support.

Goal 3: To establish interpretive and educational programs for the public to foster an appreciation of the natural habitats and endangered species supported by the Refuge's native riverine dune habitat.

Volunteer helping with native plant revegatation.

Objective 3.1: Develop a volunteer program to recruit and maintain at least 15 to 20 volunteers per year. The volunteers can serve as docents, help with data collection, and/or help with management activities.

Narrative: A volunteer program can be important in several ways. It provides an opportunity for people to help carry out programs that the Refuge would be unable to carry out with existing staff. Volunteers serve as supporters for the Refuge, and share their enthusiasm and knowledge with the staff, other volunteers, and the public. Volunteers also facilitate public outreach and encourage support of the Refuge and its mission.

Strategies:

3.1.1 Write articles for local newsletters, and newspapers such as the local Audubon Society and the California Native Plant Society (CNPS) chapter newsletters to recruit volunteers.

3.1.2 Give talks to local community groups describing the importance and uniqueness of the Refuge.

3.1.3 Establish a docents/friends group that can conduct environmental education programs, interpretive programs, and train new docents.

3.1.4 Develop a program protocol for community service volunteers who work at the Refuge to fulfill community service requirements.

3.1.5 Extend public outreach efforts to recruit volunteers from the local community of Antioch to maximize amount of time at the Refuge and encourage community support. Most volunteers come from the Newark/Fremont area near the San Francisco Bay Refuge Complex office.

3.1.6 Invite Audubon Society volunteers to monitor songbird populations at the Sardis Unit and in other projects.

3.1.7 Invite the CNPS to conduct volunteer plant surveys at the Refuge.

Objective 3.2: Develop a public outreach program to inform the public of the Refuge's role in threatened and endangered species protection and ecosystem management.

Narrative: The Refuge is not well known in the community of Antioch. An outreach program is key to developing awareness so that the public can enjoy and support the Refuge.

Strategies:

3.2.1 Solicit suggestions from local community members for effective community outreach.

3.2.2 Solicit volunteers to assist with the outreach program.

3.2.3 Develop a Refuge brochure.

3.2.4 Give talks to local community groups describing the importance and uniqueness of the Refuge.

Objective 3.3: Develop a group of teachers who use the Refuge for environmental education within the next 5 years. Within 10 years of implementing the CCP, the Refuge would receive five visits by student groups each year.

Narrative: Schools should be encouraged to use the Refuge to teach students about the natural world. Environmental education allows the Refuge to share its unique resources with the public in a controlled fashion. It also fosters public appreciation of the Refuge. Once people realize how special the Refuge and its endangered species are, they would be more likely to support it. If the surrounding community can develop a sense of stewardship for the Refuge, then they are less likely to vandalize it and more likely to discourage or report those who do.

Strategies:

3.3.1 Develop a program to recruit teachers to use the Refuge. Teacher recruitment materials would include: (1) the human history and natural resources of the Refuge, and (2) articles about the Refuge and examples of work from schools that have used the Refuge as part of their curricula.

3.3.2 Focus environmental education efforts on the Stamm Unit. The Stamm Unit is larger, not on a busy street, and has more room for parking than the Sardis Unit.

Objective 3.4: Establish a series of interpretive programs for a variety of audiences that reveal the Refuge's natural and cultural history, endangered species and the riverine dune ecosystem within 5 years of implementation of CCP.

Narrative: Organized, well-managed interpretive programs would greatly enhance the quality of the public's experience of the Refuge. The National Wildlife Refuge System Improvement Act of 1997, recognizes that wildlife-dependent recreational activities are priority uses of the Refuge System, where compatible. Interpretation is included as one of the six priority public uses of the Refuge System.

The Refuge would be opened to guided public use, but would remain closed to unaccompanied visitation.

Strategies:

3.4.1 Provide staff or docent led public tours of the Refuge on specific days.

3.4.2 Develop interpretive programs and events that incorporate Refuge resources and reveal the natural and cultural history of the area.

3.4.3 To provide for safety of the visiting public, remove garbage, rubble, and metal debris throughout the Refuge.

Objective 3.5. Develop signs and publications for a variety of audiences that reveal the Refuge's natural and cultural history, endangered species, and the riverine dune ecosystem within 5 years of implementation of CCP.

Narrative: Currently, there are no signs identifying the name of the Refuge or the unique ecosystem and species that it protects. There is also a need for informative brochures and publications.

3.5.1 Place a Refuge sign at the Entrance of the Stamm Unit.

3.5.2 Develop an automobile pull-out with an interpretive kiosk at the Stamm Unit on Minaker Drive (Figure 11). Use the kiosk to inform visitors about the significance of the Refuge and the role it plays in protecting the three endangered species and the unique ecosystem. Provide contact information so that visitors can arrange to tour the Refuge with staff or a docent.

3.5.3 Place a sign on Wilbur Road at Minaker Dr. directing visitors to the interpretive pullout/viewing area.

3.5.4 Develop interpretive brochures to introduce the importance of the Refuge to visitors and potential visitors. The brochures could be distributed at the San Francisco Bay National Wildlife Refuge Complex visitor center, distributed to volunteers, and sent to conservation groups and teachers in the Antioch area.

Chapter 6 - Funding and Personnel

Refuge objectives are intended to be attained over the next 15 years. Management activities would be phased in over time and implementation is contingent upon and subject to the results of monitoring and evaluation, funding through congressional appropriations and other sources, and staffing.

Funding needed for any refuge includes initial capital outlay for equipment, facilities, labor, and other expenditures, as well as annual, ongoing costs for staff, contracts, supplies, management, maintenance, and other recurring expenses.

Initial capital expenditures for the Refuge would include an interpretive sign and pullout, boundary signs, boundary fencing and gates, vehicles, such as truck, loader, scraper, and trailer (totaling $138,000). In addition, significant capital expenditures ($560,000) would be needed for importing sand and constructing dunes (Table 2). These capital expenditures would not all accrue during the first year of implementation. For example, habitat restoration would be implemented over several years, and some equipment and vehicles could be borrowed from other refuges. The Refuge, however, would incur these costs over the long term.

At full staffing, staff time dedicated to the Refuge would include a Refuge manager, a maintenance worker, a wildlife biologist, and a park ranger. In addition, one intern would be hired to help operate the public use component of this plan. Both the Refuge manager and park ranger would have collateral law enforcement authority. If the proposed Alameda Refuge is established, the Refuge manager, biologist, maintenance worker, park ranger, and intern would be shared between the two refuges. Annual contracts or cooperative agreements would be issued for litter removal, additional law enforcement, weed control, and other activities. All of these recurring costs are expected to total $151,100 per year (Table 3).

Table 2. Estimated Initial Capital Outlay to Implement the CCP

Expenditure	Unit Cost	Unit	Quantity	Total Cost
Replace fence	$16	l.f.	3,000	$48,000
Replace gates	$1,000	ea	3	$3,000
Truck/Jeep	$30,000	ea	1	$30,000
Tractor (includes trailer, sidebar mower, safety cab - share with Alameda)	$60,000	ea	½	$30,000
Interpretive kiosk pullout	$10,000	ea	1	$10,000
Signs (entrance, boundary, and directional)	misc	misc	misc	$5,000
Maintenance equipment	misc	misc	misc	$10,000
Environmental education materials	misc	misc	misc	$2,000
Subtotal				**$138,000**
Cost to acquire sand from Montezuma	$10	yd.^{3}	40,000	$400,000
Dune construction costs	$4	yd.^{3}	40,000	$160,000
Grand Total				**$698,000**

Table 3. Estimated Annual Cost to Implement the CCP

Expenditure	Unit Cost	Unit	Quantity	Total Cost
Salaries and Benefits				
Refuge Manager - GS 12 (share with Alameda)	$70,000	ea	0.5	$35,000
Maintenance Worker/Law Enforcement - WG 8 (Share with Alameda)	$50,000	ea	0.5	$25,000
Biologist - GS 9 (Share with Alameda)	$45,000	ea	0.5	$22,500
Park Ranger - GS 9 (Share with other refuges)	$45,000	ea	0.5	$22,500
Intern (Share with Alameda)	$2,700	ea	0.5	$1,350
Herbicides	$135	gals.	50.0	$6,750
Travel/Training	$2,000	misc	4.0	$8,000
Supplies, space costs, utilities	$25,000	misc	1.0	$25,000
Printing	$5,000	misc	1.0	$5,000
Grand Total				**$151,100**

Chapter 7 - Monitoring and Evaluation

Adaptive management is the process of implementing policy decisions using scientifically driven experiments that test predictions and assumptions about management plans, and using the resulting information to improve management strategies. Management direction is periodically evaluated by a system of applying several options, monitoring the achievement of objectives, and adapting original strategies to reach desired objectives. These periodic evaluations would be used over time to adapt both the management objectives and strategies to better achieve management goals. Such a system embraces uncertainty, enhances management options, and provides new information for future decision-making.

Because monitoring is an essential component of this plan, specific monitoring strategies have been integrated into the goals and objectives. Habitat management activities would be monitored to assess whether the desired effect on habitat components has been achieved. At a minimum, monitoring the number of each endangered species and the reproductive success of the plants would follow established protocols (Table 4). Baseline surveys would be established for other species of plants, animals, and insects for which existing or historical numbers are currently not well known. It would also be important to monitor the effects of public use and disturbance on the endangered species of the Refuge.

Antioch Dunes Evening Primrose seedlings.

Table 4. Monitoring Methods

Study variable	Monitoring methods
Antioch Dunes Evening Primrose	A population count of the entire population of the primrose is undertaken annually during the peak bloom season for this species. The surveys are conducted on all the subunits of the Antioch Dunes National Wildlife Refuge and areas of PG&E land which contain the primrose plants. The survey is conducted by five to ten staff members, Refuge interns and volunteers. A training session is conducted prior to each survey. During the survey, all surveyors start at one end of the subunit and spread themselves 10 to 15 ft apart. They record their observations while walking in a straight line, parallel to one another, communicating with each other to avoid double-counting. Surveyors walk lines back and forth until the subunit has been completely surveyed. All primrose are counted and their status of blooming or non-blooming is recorded. Data is entered into an Access database, and yearly graphs and summaries are written.
Contra Costa Wallflower	A population count of the wallflower is undertaken annually during the peak bloom season for this species. The surveys are conducted on all the subunits of the Antioch Dunes National Wildlife Refuge and areas of PG&E land which contain the Contra Costa Wallflower plants. The same method as used for primrose is used for surveying the Contra Costa Wallflower. Because individual wallflower plants can be difficult to distinguish, surveyors must sometimes follow the stem of the plant to the bottom to determine the number of individual plants. Only the blooming wallflower are documented since first year plants are difficult to see. As with the primrose, data is entered into an Access database, and yearly graphs and summaries are written.
Lange's Metalmark Butterfly	Counts are undertaken as a monitoring method for the Lange's metalmark butterfly. The survey is done once a week during the adult flight season, from the beginning of August through mid-September. The surveys are conducted on all the subunits of the Antioch Dunes National Wildlife Refuge and areas of PG&E land which contain naked-stemmed buckwheat, the host plant for the Lange's. Because Lange's adult stage is only one -two weeks, the survey is not a complete count of the population. Instead the Refuge uses the highest of the weekly counts as the "peak population count," an index to compare the status of the population across years. The survey is conducted by five to ten staff members, Refuge interns, and volunteers. A training session is conducted prior to each survey. During the survey, all surveyors start at one end of the subunit and spread themselves 10 ft apart. They record their observations while walking in a straight line, parallel to one another, communicating with each other to avoid double-counting. Surveyors walk lines back and forth until the subunit has been completely surveyed. As with the primrose, data is entered into an Access database, and yearly graphs and summaries are written.
Effects of prescribed burning on invasive weeds	Prior to initiating prescribed burning on a subunit of the Refuge, at least ten randomized 1m2 plots would be sampled for selected native plants and invasive weeds in the spring. Percent cover would be estimated visually for each of the selected plants. Upon completion of three years of burning, plots would be revisited and resampled to determine effectiveness of the burn program. Data would be entered into a refuge database, and a summary report with graphs completed.
Survival of outplanted plants	Each outplanted primrose is assigned a number. Every year for at least the following three years, the plants would be surveyed to determine survivorship and status (blooming vs non-blooming). The results would be documented in a spreadsheet. For other species, the numbers of plants outplanted into each subunit would be recorded and each one flagged. Once a year for the following three years, the subunits would be counted to determine survivorship rates. A summary report would be completed.
Other proposed management prescriptions	Future management activities such as scraping, importing sand, and creating dune topography would be monitored similarly to the prescribed burning monitoring protocol. Prior to initiating a management action on a subunit of the Refuge, at least ten randomized 1m2 plots would be surveyed for selected native plants and invasive weeds in the spring. Percent cover would be estimated visually for each of the selected plants. Upon completion of the action, plots would be revisited and surveyed in the following spring to determine effectiveness of the action. The Refuge also proposes to increase reptile monitoring. In addition to monitoring vegetation plots in various management units, reptiles would be monitored concurrently. At least five cover boards would be scattered throughout the unit and reptiles found would be counted and identified. All data would be entered into a refuge database, and a summary report with graphs would be completed. To determine the effects of increased public use on native vegetation, an area on the Refuge would be established as an experimental treatment. All educational, interpretive, or volunteer groups visiting the Refuge would be walked through the area as part of their program. Plots in the treatment area would be sampled using the above described methodology, in order to determine the effects of increased foot traffic on an otherwise minimally disturbed dune area. Control plots would also be established in a nearby area for comparison. A summary report would be completed. Due to staff time constraints, some management actions, such as herbicide spraying or hand-weeding, would be monitored by the biologist using a non-quantitative method. The biologist would visually survey the treatment area and estimate level of effectiveness. A summary report will be completed.

Chapter 8 - Compliance Requirements

When implementing this CCP, the Service would comply with the following Federal laws, Executive Orders, and legislative acts:

- Floodplain Management (Executive Order 11988),
- Intergovernmental Review of Federal Programs (E.O. 12372);
- Protection of Historical, Archaeological, and Scientific Properties (E.O. 11593);
- Protection of Wetlands (E.O. 11990);
- Management and General Public Use of the National Wildlife Refuge System (E.O. 12898);
- Hazardous Substances Determinations (Secretarial Order 3127);
- Endangered Species Act of 1973, as amended;
- Refuge Recreation Act of 1962, as amended;
- National Wildlife Refuge Administration Act of 1966, as amended;
- National Environmental Policy Act of 1969, as amended;
- National Historic Preservation Act of 1966, as amended;
- Coastal Zone Management Act of 1972, as amended.

References

Arnold, R.A.
1981. Captive breeding of the endangered Lange's Metalmark butterfly, *Apodemia mormo langei*. Final report for the U.S. Fish and Wildlife Service, Office of Endangered Species, Sacramento, CA.
1983a. Monitoring of the Endangered Lange's Metalmark Butterfly in 1983 at the Antioch Dunes. A final Report for the San Francisco Bay National Wildlife Refuge. US Fish and Wildlife Service Contract No. 10181-9726.
1983b. Ecological studies of six endangered butterflies (Lepidoptera: Lycaenidae): Island biogeography, patch dynamics, and design of habitat preserves. Ph.D. Dissertation, U.C. Berkeley 363 pp.
1985. Private and government funded conservation programs for endangered insects in California. Nat. Areas J. 5:28-39.

Arnold, R.A. and J.A. Powell. 1983. Ecological studies of six endangered butterflies (Lepidoptera: Lycaenidae): Island biogeography, patch dynamics, and design of habitat preserves. University of California Publications in Entomology 99: 1-161.

Arnold, R. A., B. Atwater, R. Bacigalupi, E. Begg, B. Csuti, L.R. Heckard, A. Howard, T. Papenfuss, J. Powell, R. Price, R. Raabe, and J. Roof, July 1983, revised October 1983. Antioch Dunes National Wildlife Refuge Historical Information - a report to the US Fish and Wildlife Service, Prepared under Contract to the US Fish and Wildlife Service.

Atwater, Brian F., A memorandum prepared for the US Fish and Wildlife Service, Branch of Western Region Geology, US Geological Survey, Geologic factors in the prehistoric establishment of organisms endemic to eolian dunes near Antioch, California, November 1982.

BAAQMD (Bay Area Air Quality Management District).
1999a. Toxic Air Contaminant Control Program 1999 Annual Report. http://www.baaqmd.gov/
1999b. Annual Bay Area Air Pollution Summary for 1999. http://www.baaqmd.gov/

Bolton, H. E., 1933. Font's Complete Diary, translated in by H. E. Bolton. University California Press Berkeley. From the ADNWR history.

CALFED
1999. Bay-Delta Program, Ecosystem Restoration Program Plan, Vol. 1 - Ecological Attributes of the San Francisco Bay-Delta Watershed., Draft Programmatic EIS/EIR Technical Appendix, June 1999.
2001. CALFED Bay-Delta Homepage. http://calfed.ca.gov/

California Department of Fish and Game & US Fish and Wildlife Service. Water Resources. 1980. Sacramento/San Joaquin Delta Wildlife Habitat Protection and Restoration Plan. Published report.

California Department of Water Resources. 1995. Sacramento San Joaquin Delta Atlas.

Carpenter, E.J. and S.W. Cosby. 1939. Soil Survey, Contra Costa County, California. USDA, Bureau of Chemistry and Soils.

Clark and Witham, Inc., November 1999. Phase I and II Environmental investigation at Antioch Dunes National Wildlife Refuge report prepared for the Service.

Davidson, George, 1907. Discovery of San Francisco Bay.

Endangered Species Information System. 1996. Draft Taxonomy Species Wallflower, Contra Costa, Species Id ESIS701018, 13 Mar 1996. Fish and Wildlife Information Exchange, Virginia Tech, Virginia. http://fwie.fw.vt.edu/WWW/esis/lists/e701018.htm

Essig Museum of Entomology. 2000. University of California, Berkeley, California Endangered Insects, Lange's Metalmark Butterfly. http://shanana.berkeley.edu/essig/endins/metalmk.htm.

Fernandez, Erin. 1997. Restoration Work at Antioch Dunes National Wildlife Refuge, Tideline, Winter 1997.

Fish and Wildlife Service
1978. Environmental Assessment Land Acquisition Ascertainment Report Lange's Metalmark Butterfly (*Apodemia mormo Langei)*.
1984. Recovery Plan for Three Endangered Species Endemic to Antioch Dunes, California.
1987. Antioch Dunes National Wildlife Refuge Management Plan.
1997a. Service, Intra-Service Section 7 Evaluation Form Consultation/Conference/ Concurrence, February 20, 1997.
1997b. Final Environmental Assessment, Prescribed Burn Program, June 1997.
1998. Memo regarding the Antioch Dunes Evening Primrose Census for 1998.

Greene, E.L. 1896. Studies in Cruciferae. Pittonia 3:117-138.

Greene, Julie A. 1995. *Three reproductive Ecology Studies in the Narrow Endemic Oenothera deltoides spp. Howellii*, master's thesis, 7 April 1995, Claremont Graduate School, Claremont, California.

Howard, Alice Q. and R. A. Arnold, 1980. *The Antioch Dunes — Safe at Last?* Fremontia

Johnson, A. F. 1978. Report on Antioch Dunes threatened plant species. California Dept. of Fish and Game, Sacramento. Unpublished paper.

Jones and Stokes Associates. 2000. Soil Evaluation for Contra Costa Wallflower, Antioch Dunes Evening Primrose, and Naked-Stemmed Buckwheat, Antioch Dunes National Wildlife Refuge, Antioch, California. Prepared for the U.S. Fish and Wildlife Service. January 2000.

Maffei, W. A. 1997. Progress Report: Survey of Antioch Dunes National Wildlife Refuge for 17 Listed Taxa, unpublished report for the US Fish and Wildlife Service.

Niehaus, T. 1977. Rare plant status report, Erysimum capitatum (Dougl. ex Hook.) Greene var. angustatum (Greene) G. Rossb., Contra Costa wallflower. Unpublished report on file at: Office of Endangered Species, Washington, D.C.

Pavlik, B. M.

1988a. With N. Ferguson, and E. Manning. Demographic Studies of Endemic Plants at the Antioch Dunes National Wildlife Refuge. II. Seedling Demography, Seed Production and Seed Bank Dynamics. Prepared for the Endangered Plant Project, California Department of Fish and Game, funded by California Endangered Species Tax Check-off Funds. December 1988.

1988b. With N. Ferguson, E. Manning and M. G. Barbour. Demographic Studies of Endemic Plants at the Antioch Dunes National Wildlife Refuge. I. Seed Production and Germination. Prepared for the Endangered Plant Project, California Department of Fish and Game, funded by California Endangered Species Tax Check-off Funds. May 1988.

1993. With E. Manning. Assessing Limitations on the Growth of Endangered Plant Populations, I. Experimental Demography of *Erysimum capitatum* spp. *Angustatum* and *Oenothera deltoides* ssp*. Howellii.* Biological Conservation 1993, 65: 257-265.

1993. With N. Ferguson, and M. Nelson. Assessing Limitations on the Growth of Endangered Plant Populations, II. Seed Production and Seed Bank Dynamics of *Erysimum capitatum* spp. *Angustatum* and *Oenothera deltoides* ssp*. Howellii.* Biological Conservation 1993, 65: 257-265.

Powell, J.A.

1999. A December 16, 1999 letter addressed to the Service.
1992. Microlepidoptera of the Antioch Dunes National Wildlife Refuge. A Report to the U.S. Fish and Wildlife Service. January 1992.
1983. Changes in the Insect Fauna of a Deteriorating Sand Dune Community During 50 Years of Human Exploitation. Unpublished ms.

Powell, J.A. and Parker, M. W. 1993. Lange's Metalmark, *Apodemia mormo langei* Comstock. From Conservation Biology of Lycaenidae. Edited by T.R. New.

Roof, J.B. 1969. In memoriam: the Antioch dunes. The Four Seasons, 3(1):2-4.

Rossbach, G.B. 1958. A new taxa and new combinations in the genus Erysimum in North America., Aliso, 1958:115-124.

Rusmore, J. 1999. Antioch Dunes Invasive Weed Control Report. Unpublished ms for the Service.

Sawyer, J. O. and T. Keeler-Wolf, 1995, *A Manual of California Vegetation.*

Thompson, D. 1997. Preliminary results of seedling survival and demographic studies, unpublished ms.

Personal Communication

Arnold, R. A., Entomologist.
2001. May 4, 2001.
1999a. First Technical Panel, 2 February 1999.
1999b. Second Technical Panel, 16 November 1999.

Buffa, Joelle, Personal Communication, June 2001.

DeBecker, Sally, PG&E, Personal, April 12, 2001.

Loredo, Ivette, Personal Communication, November 17, 1999.

Loredo, Ivette, Personal Communication, 3/2000.

Loredo, Ivette, Personal Communication, April 2000.

Loredo, Ivette, Personal Communication, 1 September, 2000.

Maffei, W, Napa County Mosquito Abatement District, Personal Communication, June 8, 2000.

Morton, Chuck, Caltrans, comments on the CCP, November 2000.

Parker, Mike. USFWS, Personal Communication, November, 2000.

Powell, Jerry UC Berkeley, Personal Communication, February 1999.

Randy Riblet, Park Ranger, Personal Communication, Brannan Island State Recreation Area, January 5, 2000.

Richardson, Aaron, BAAQMD, Personal Communication, April 30, 2001.

Second Technical Panel, November 16, 1999, Personal Communication.

Slowik, Tory, Personal Communication, Service, February 23, 1999.

Technical Panel, February 2, 1999, personal communication.

Valentine, Nick, Archeologist, Service, January 21, 2000.