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ENVIRONMENTAL EFFECTS OF SOLAR THERMAL POWER SYSTEMS

ECOLOGICAL OBSERVATIONS DURING CONSTRUCTION OF THE BARSTOW 10-MWe PILOT STPS

OCTOBER 1981

PREPARED FOR

U.S. DEPARTMENT OF ENERGY

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Frederick B. Turner

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Laboratory of Biomedical and Environmental Sciences
University of California, Los Angeles
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Los Angeles, California 90024

MGW

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Abstract

The prospective heliostat field and the environment downwind (east) of the site of Solar One were examined during 1978 and 1979--before construction began. Observations then continued between October 1979 and August 1981, during construction of the power plant. As expected, clearing and grading the heliostat field in the fall of 1979 removed essentially all plants and animals from the area. Before the field was cleared, we recorded about 25 kinds of annual plants, with an aggregate density of from 3000 to 8900 plants per m^2 and an aggregate dry weight standing crop of from 670 to 930 $kg \cdot ha^{-1}$. In the spring of 1980, about six months after clearing, the field appeared barren from a distance. However, 25 different kinds of plants were found in areas not subject to heavy use. About half of these were non-native species and a number of these were pests (e.g., Bermuda grass, Russian thistle). Before construction the field sustained at least 20 different kinds of birds. During the first half of 1981 only ten species were observed and most of these were simply flying over the field. The only bird commonly seen on the ground within the heliostat field was the Horned Lark. Regular inspections of heliostats in all four quadrants of the field in 1981 showed that birds in these areas behaved normally. No birds were seen on pedestals or heliostats, or around the periphery of the core area. One dead bird (Say's Phoebe) was found in March 1981. Some reptiles and rodents survived clearing of the field and a few snakes were seen around buildings in the spring of 1980. We judge that few of these animals were still present in 1981.

Off-field observations were made at varying distances from the fence along the eastern margin of the field. The principal environmental effect observed in these areas was the transport and deposition of sand and other soil particles into areas northeast and east of the cleared area. This arc of displaced material was clearly visible in aerial photographs to a distance of around 100-125 m. Measured changes in heights of sand dunes between October 1979 and January 1980 ranged from 25 cm at a point 35 m from the edge of the field to 1-2 cm between 85 and 100 m from the edge. Sand continued to accumulate between January 1980 and May 1981. This material was not deposited uniformly, but formed localized deposits around shrubs and other obstructions to air flow.

Baseline temperature profile measurements were made at two sites near the heliostat field between November 1980 and July 1981. The experimental site was directly downwind of the heliostat field, where we would expect maximal effects of the power plant on wind and temperature profiles. The control site was 700 m north of this site, in an area where prevailing westerly winds would not be affected by power plant structures. Statistically significant differences in air temperature were observed at these sites, and relationships were affected by time of year. The differences were small, but their potential biological significance cannot be discounted. These differences are not necessarily associated with construction activities, and can best be viewed as background with which future measurements during testing and operation may be compared.

In areas where sand was deposited, some elements of annual vegetation were affected. In areas 125 m from the heliostat field total numbers of species were reduced (in 1981) relative to numbers recorded in four more distant plots. Aggregate density of annual plants in one of the close-in plots was relatively more reduced in 1981. Grass (Schismus arabicus) growing in new sand was more sparse than in undisturbed areas, but individual plants were larger. Individuals of Erodium cicutarium were both fewer in number and smaller in sandy areas within 100 m of the field in April 1981. In the spring of 1980 significantly more whiptailed lizards were counted along a line 50 m east of the field than along lines 360 and 610 m from the field; by the spring of 1981 counts along this line were comparable to those made on lines farther downwind. We suspect that other indirect biological effects of this nature occurred but were not measured. In any event, the zone of disturbance on the downwind side of the heliostat field was apparently only 100-125 m wide--representing a very small area when contrasted with the area of the heliostat field itself.

Measurements of air quality made ∿2 km south and ∿1 km southeast of the solar site revealed violations of both state (10 pphm) and federal (12 pphm) ozone standards during the spring and summer of 1980. We do not believe that amounts of ozone in the air were influenced by construction activites. Measurements of NO_2 and NO were always below relevant standards. Amounts of airborne particulates collected downwind of the site were not unusual except during periods of high winds, and there was no reason to suspect any effects of construction.

Vegetative growth and reproduction by three species of shrubs were contrasted in plots 100, 400 and 800 m downwind of the field in 1980 and 1981. We detected only a few statistically significant differences among a variety of measured parameters, and none could be logically related to construction of Solar One. Analyses of populations of kangaroo rats and ground squirrels occupying areas 150 and 600 m downwind of the field showed similar time trends in densities and mean body weights. Analyses of the relative abundance of juveniles of theses species in these two areas in July of 1979, 1980 and 1981 showed no evidence that reproduction in the close-in area was affected. Similarly, estimates of densities of horned larks in areas 300-600 m and 1.9-4.5 km east of the field and counts of gridiron-tailed lizards along lines 50, 360 and 610 m east of the field between 1979 and 1981 showed no changes attributable to construction activities.

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1. Introduction

The goal of the Solar Thermal Energy Systems Division of the U.S. Department of Energy (DOE) is to support and accelerate development of a self-sustaining solar thermal industry. Construction and operation of demonstration facilities to validate technical and economic feasibility, as well as to confirm environmental acceptability of the technology, is an important element of DOE strategy. The DOE, together with the Southern California Edison Company (SCE), the California State Energy Commission, and the Los Angeles Department of Water and Power, is constructing a 10 MWe solar thermal power system (STPS) near Barstow, in San Bernardino County, California (Fig. 1). This project, Solar One, represents the first large central receiver-type solar facility for generating electricity constructed in this country. The Laboratory of Biomedical and Environmental Sciences (LBES), acting for DOE, was assigned responsibility for assessing environmental consequences of constructing Solar One.

Solar energy is generally perceived as ecologically benign, but it is important to confirm this perception by observations made during the construction, testing and operation of a solar thermal power plant. Possible environmental impacts of solar thermal power systems have been discussed in a number of earlier reports and papers (Pritchett 1975, Energy Research and Development Administration 1977, Environmental Improvement Agency 1977, Black and Veatch and Electric Power Research Institute 1977, Davidson and Grether 1977, Patten 1978, Energy and Environmental Analysis 1979, Turner 1980, Strojan 1980, Bhumralkar et al. 1980, and Lindberg and Perrine 1981). These deal principally with potential effects of operating such power plants, and less so with impacts of construction activities.

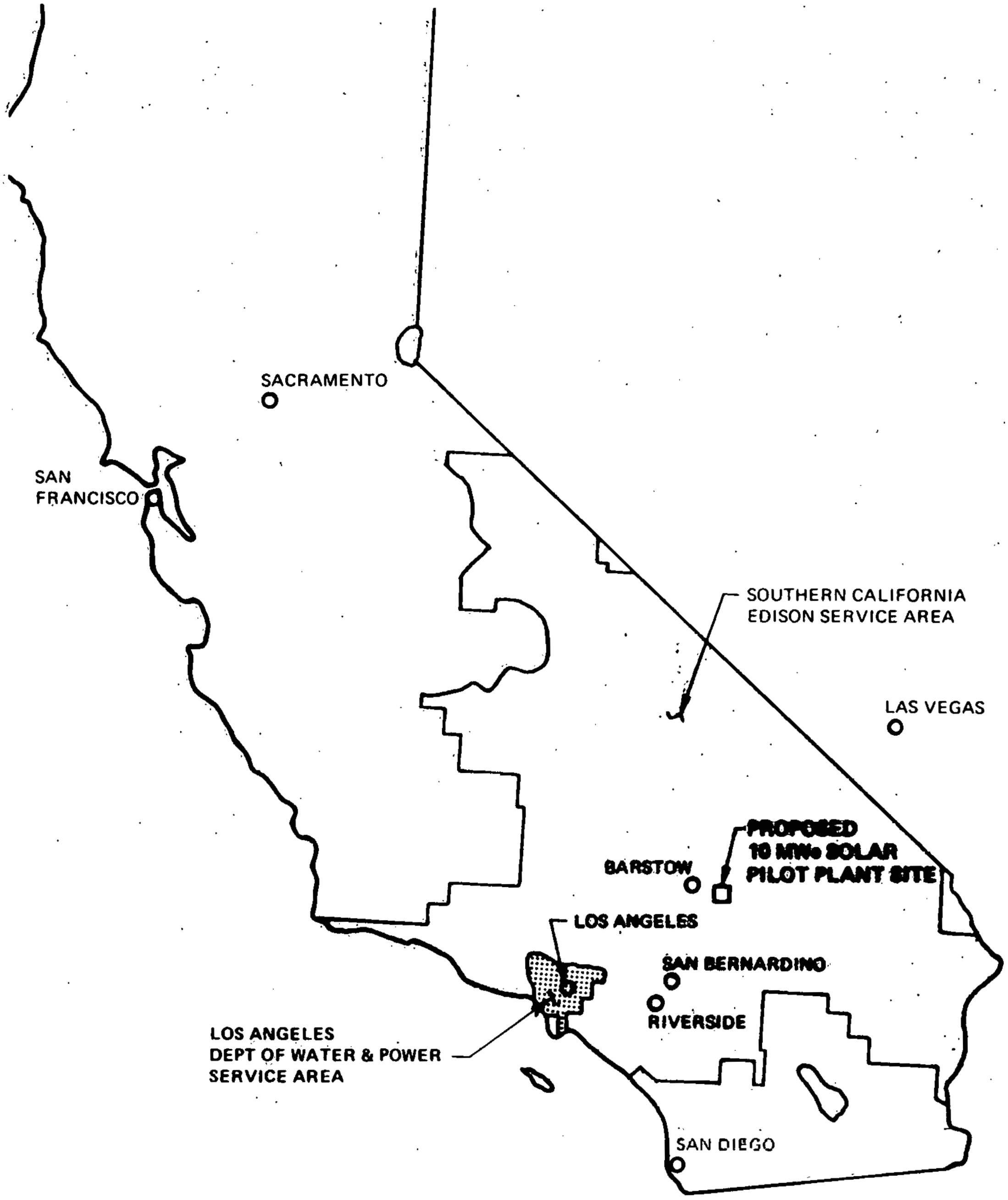


Figure 1. General area map showing Barstow, California, and proposed site of 10 MWe solar thermal power plant (EIA, 1977).

Nevertheless, we believe that an appraisal of the latter, under real-life conditions, is a valuable opportunity--and one which will serve to promote commercial development of the technology.

Solar One is being built about 19 km east of Barstow, California, on land owned by SCE (Fig. 2). The site is at an elevation of 590 m and in the western portion of the Mojave Desert on the ancient flood plain of the Mojave River. A detailed discussion of site geology and hydrology was developed in the environmental impact analysis. The plant site receives about 3500 hours of sunshine annually. The perennial vegetation of the site and environs is composed mainly of three shrubs: bursage (Ambrosia dumosa), saltbush (Atriplex polycarpa) and creosotebush (Larrea tridentata). The heliostat field was originally cleared of natural vegetation in 1953 and crops grown until 1956. After the field was abandoned natural processes of recovery began, and in 1979 the predominant shrub on the mirror field was saltbush. Farther east the most common shrubs are creosotebush and bursage. Annual plants and animals occupying the area are typical of the Mojave Desert. Lists of species may be found in the original impact analysis and in a pre-construction site description conducted in 1978 and 1979 (Environmental Improvement Agency 1977, Turner 1979).

The purpose of the pre-construction observations was to i) establish normal attributes of the ecosystem, ii) evaluate seasonal variations in these attributes, and iii) identify selected species or groups of species whose status could be conveniently monitored during construction. The purpose of observations during the construction phase was to determine whether the environment east (downwind) of the construction area was deleteriously affected in any way.

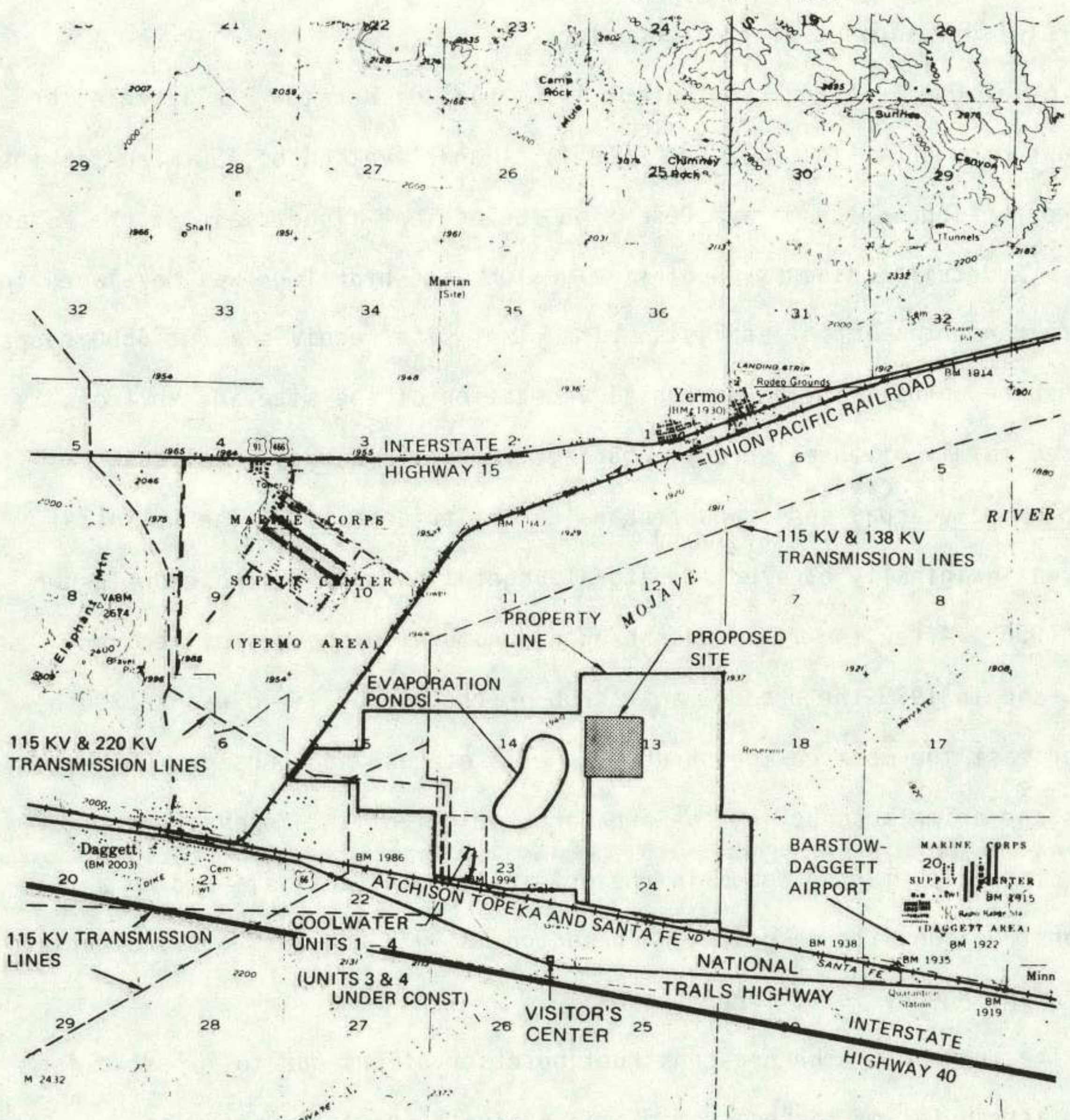


Figure 2. Map of Southern California Edison's Cool Water property near Barstow, California, showing proposed site of solar thermal power plant (EIA, 1977).

2. A general plan of environmental monitoring

In setting up a plan of monitoring we did not adopt a total ecosystems approach. As Suter (1981) has pointed out, there are often good reasons not to do this because it is so difficult to bring general ecological theory to bear on project-specific issues. More important, the evaluation of a comprehensive array of variables (e.g., many micrometeorological parameters, static and dynamic features of many different kinds of plants and animals) is not economically feasible. We simply made comparisons of a few key meteorological variables and changes in the states of a limited array of "indicator" species or assemblages of species of plants and animals. Indicator species were numerically abundant and possessed attributes amenable to convenient and reliable evaluation--whether of growth, reproduction, or numbers. Indicator species also exhibited pre-construction similarity in areas adjoining (but not within) and at a distance from the mirror field. The areas of interest were those i) immediately east (downwind) of the mirror field, and ii) from 300 m to 4 km east of the field--the distance depending on what was compared and evaluated.

We were also influenced in our planning by the expectation that the program would continue not only through the period of construction of Solar One, but also during testing and operation of the facility. Many of the physical measurements we made downwind of the sites were more logically related to operational than construction phases of the project.

We expected that large amounts of dust and sand would be blown into areas (downwind) of the heliostat field when the area was cleared and graded in the fall of 1979. This sort of unconsolidated material is important not only because of its possible effects on the off-field environment, but also because it could interfere with successful operation of the facility. Large amounts of loose sand outside the heliostat field could be remobilized by winds blowing from the east and carried back into the field. Whether this is really an important point can only be ascertained by actual operating experience.

Ambient air quality in the vicinity of the solar site has been analyzed by Environmental Applications, Inc. (1980), where there is a good discussion of the general influences of pollutants from the Los Angeles Basin. More locally, the primary source of pollutants is Southern California Edison's Cool Water Generating Station. Through 1978 the station consisted of two gas-burning units. Early in 1979 a third unit went on line, and a fourth unit was completed during the summer of 1979. These last two units burn a distillate resembling jet fuel. The central receiver of a solar thermal power plant becomes so hot (ca. 500° C) during operation that various chemical reactions are catalyzed in the air next to the receiver wall. For example, nitrogen and oxygen in the air combine to form NO_x. It is considered doubtful that amounts of NO_x formed in this way would be at all significant in terms of local air quality. However, there is merit in determining present amounts of NO_x in the environs of the solar site.

Meteorological monitoring within the heliostat field will be carried out by MDAC (McDonnell Douglas Astronautics Co. 1979). The measurements proposed bear on operation of the facility and analysis of its performance. The highest priority measurements have been defined as direct insolation, wind speed, cloud shadow pattern, wind direction, dry bulb temperature, dew point temperature, and hail formation. Lower priority measurements include circumsolar radiation, atmospheric turbidity, barometric pressure, precipitation, and global insolation. In this scheme precipitation is a low priority variable, and rainfall data are important only as they may bear on the cleansing of heliostats. It is also important to understand how changes in the microclimate of the heliostat field may influence conditions beyond the boundaries of the plant site.

Some qualitative predictions of micro- to mesoclimatic changes in a heliostat field have been based on assumed alterations of albedo coupled with effects of heliostats on normal air flow (Energy Research and Development Administration 1977, Energy and Environmental Analysis, 1979). Other more quantitative forecasts have been based on computer simulations (Davidson and Grether 1977, Bhumralkar et al. 1980). All of these evaluations have involved very large systems ($\geq$ 100 MWe), and not all are in agreement. One assessment expressed the view that the net albedo of the heliostat field would be about 56%, almost twice as high as the natural albedo of the environs. It was further stated that the "...increased reflectivity [of the field] could cause an appreciable cooling of air flowing over the mirror field during...daytime hours" (Energy Research and Development Administration 1977). This would imply, then, some daytime cooling of the area downwind of the field. These views were reiterated in the environmental impact statement for the Barstow project (Environmental Improvement Agency 1977), and were also among those suggested by Bhumralkar et al. (1980). None of these evaluations took into account the effects of clearing vegetation from the mirror field. Because of the removal of these plants the dissipation of heat by transpiration is eliminated. Davidson and Grether (1977) considered that the albedo of the mirror field would be reduced, and in a "global analysis" of climatological effects of one million

100 MWe plants assumed the "darkening" of 3 million km^2 of land. We need to analyze the off-field environment on the downwind side carefully so as to determine i) whether air temperature profiles are altered by the existence and operation of the STPS and ii) if so, to what distance such an effect may be expressed.

The biological indicator species selected for particular attention are described briefly below. Of the woody perennials, bursage (Ambrosia dumosa) is a small shrub, widely distributed between 1000 and 1900 m from southeastern California and Sonora into southern Nevada, southwestern Utah and southern Arizona and New Mexico (Benson and Darrow 1954). It is often numerically dominant in associations with creosotebush. Desert saltbush (Atriplex polycarpa) grows on alkaline soils below 1700 m from southeastern California, adjoining portions of Sonora, and southern Nevada into extreme southwest Utah and southern Arizona (Benson and Darrow 1954). It is often associated with disturbed soils. Creosotebush (Larrea tridentata) ranges from southeastern California and Sonora across southern Nevada, southwestern Utah, Arizona, New Mexico and into western Texas. It generally occurs below 1700 m and is the dominant species of many desert communities in southwestern U.S. (Valentine and Gerard 1968, Munz 1974).

In terms of overall structure and total biomass, annual plants are of much less importance than the larger shrubs. However, these smaller plants represent a volatile and dynamic component of the desert community and may be extremely important as sources of food and water for animals. Only five species were consistently and commonly represented in our study areas: a small boraginaceous annual (Cryptantha angustifolia), a species of buckwheat (*Eriogonum trichopes*), a non-native but long established herb (*Erodium cicutarium*), desert gold (*Geraea canescens*), and a non-native annual grass (*Schismus arabicus*). We focused primarily on numbers of annual plots, their individual dry weights, and estimates of aggregate dry weights (standing crops) of all annual species.

Species of vertebrates judged to be good indicators were Merriam's kangaroo rat (*Dipodomys merriami*), the roundtail ground squirrel (*Spermophilus tereticaudus*), the horned lark (*Eremophila alpestris*), the western whiptail lizard (*Cnemidophorus tigris*), and the gridiron-tailed lizard (*Callisaurus draconoides*).

Merriam's kangaroo rat is a nocturnal granivorous, heteromyid rodent, active year-around in this part of the Mojave Desert. The species is one of the more abundant and widely distributed of the kangaroo rats, extending from northwestern Nevada through southeastern California, most of Arizona, and southwestern New Mexico well into central Mexico (Burt and Grossenheider 1952). Adult males weigh about 38 g, females slightly less. The roundtail ground squirrel is a diurnal sciurid, which is inactive most of the winter months. The species occurs only in southeastern California, western Arizona and adjoining portions of Baja California and Sonora (Burt and Grossenheider 1952). Adults weight about 120 g.

The western whiptail lizard is a diurnal, insectivorous lizard, with a relatively brief period of above-ground activity (late April-August) by adults (Turner et al. 1969). The species is widely distributed in western U.S., ranging from southern Oregon and Idaho throughout California, Nevada and Utah, most of Arizona, and as far east as southern Colorado and western

Texas and south into Mexico (Stebbins 1966). Adults weigh around 16 g. Females lay one or two clutches of eggs in the spring and hatchlings appear in late August and may be active into early October. The gridiron-tailed lizard is also diurnal, insectivorous, and inactive during the winter. The species occurs from northern Nevada through southeastern California and southern Arizona into Baja California and Sonora (Stebbins 1966). Adult males weigh around 17 g, females 13. Eggs are laid in the spring and the hatchlings appear in late August or September.

The horned lark breeds widely in western North America. It is a resident species in the vicinity of the STPS, breeding in April-May. The nest is a grass-lined depression on the ground and two clutches of 3-5 eggs are usually laid (Peterson 1969). These larks feed on grass seeds and forbs taken at or near ground level. We expect considerable public interest in possible effects of plant structures on birds. An appreciable literature dealing with bird mortality around man-made towers has grown up during the past 20 years (e.g., Ganier 1962, Laskey 1963, Caldwell and Wallace 1966, Stoddard and Norris 1967, Crawford 1974, Avery et al. 1978).

The tower at Barstow is not tall (100 m) when contrasted with others studied, but the Barstow tower and associated heliostats may cause some mortality of migrants and resident species. For example, seasonal bird mortality in the vicinity of a 366-m tower in North Dakota was estimated at over 1,000 individuals (Avery et al. 1978). At Barstow, it is also possible that birds may roost on heliostats, or even attempt to nest within the panel supports. Whether heliostats may become significantly fouled by excrement remains to be determined.

A major problem in interpreting biological observations in the vicinity of Solar One is that populations of desert organisms experience natural changes from one year to the next. Owing to differences in rainfall and temperature, such changes include growth and production of shrubs, numbers and kinds of annual plants germinated, and densities of various populations of animals. Therefore, a series of observations in a single area will shed little light on possible influences of the STPS because such effects are confounded by natural fluctuations. This problem was met by making comparisons over time in paired plots shown to be similar before construction of the STPS. Such a design assumes that if construction of the facility affects conditions beyond the mirror field the effects will be more strongly expressed in areas near the field than in those at a distance. The detection and interpretation of divergences in paired areas was the basic rationale of the off-field monitoring program.

3. History of construction activities

The specific site selected for Solar One was northeast of SCE's Cool Water Generating Station evaporating ponds and south of the dry course of the Mojave River. Construction of the power plant began in the fall of 1979 when a roughly circular area of about 53 ha was cleared and graded. Later drainage ditches were dug around a portion of the prospective heliostat field, a perimeter road was constructed, and the entire field fenced. Excavation for bases of 1,818 heliostats began in March 1980. Figure 3 shows the status of the project at about this time. After pedestals were poured and supporting pylons erected, attachment of heliostats began in mid-February 1981. This work was completed by the end of September 1981. A 100-m central receiver tower was completed in the spring of 1981 and the receiver was erected during July 1981. Other activities included construction of an aboveground thermal storage system (began in July 1980), fabrication of a single 3-cell cooling tower (begun in September 1980 and completed in August 1981), the construction of a control center and installation of the turbogenerator in mid-June 1981.

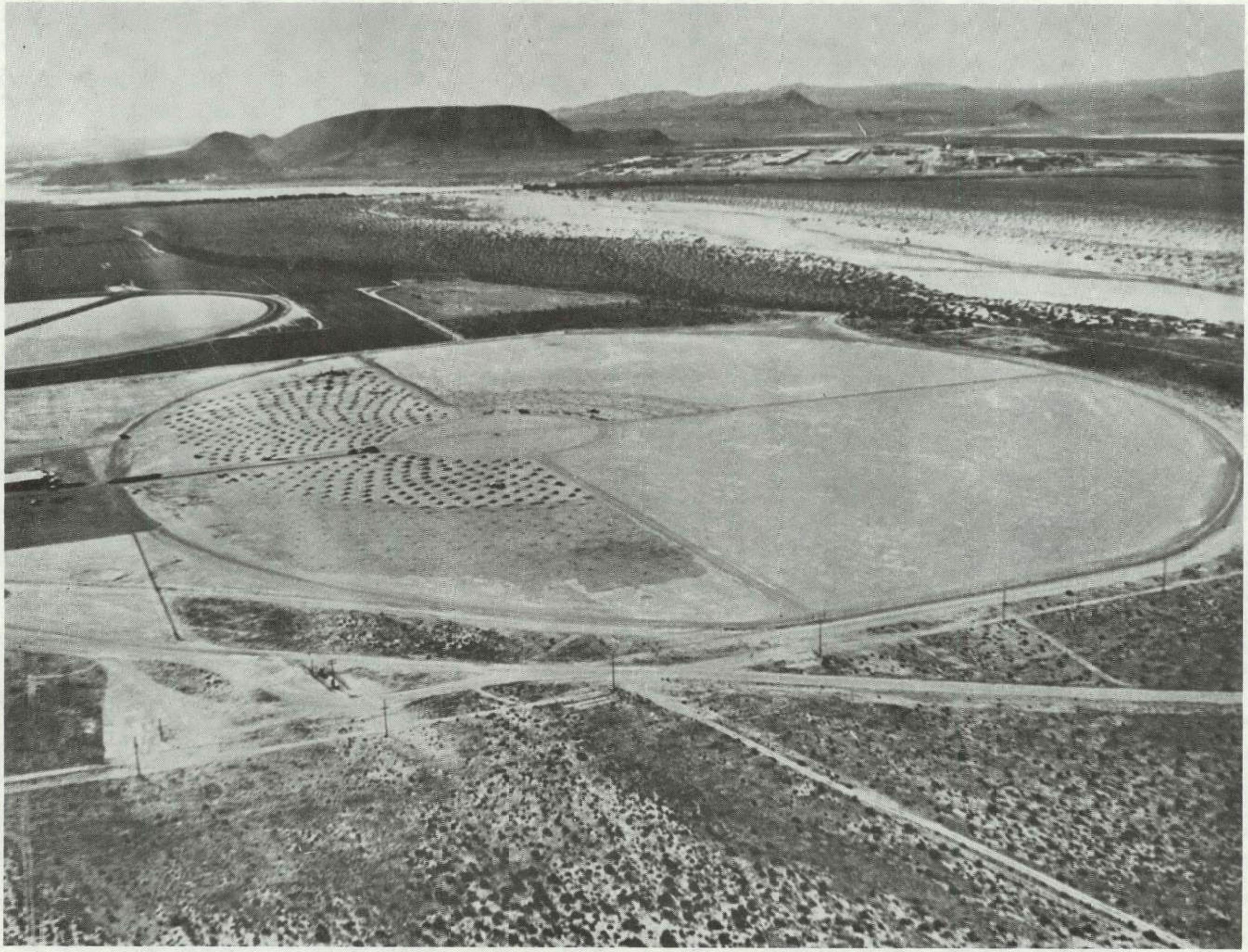


Figure 3. Looking northwest across the heliostat field, spring 1980. Work on heliostat pedestals has begun south (left) of the core area. Off-field observations were to east (lower right) of field.

4. Observations during construction period

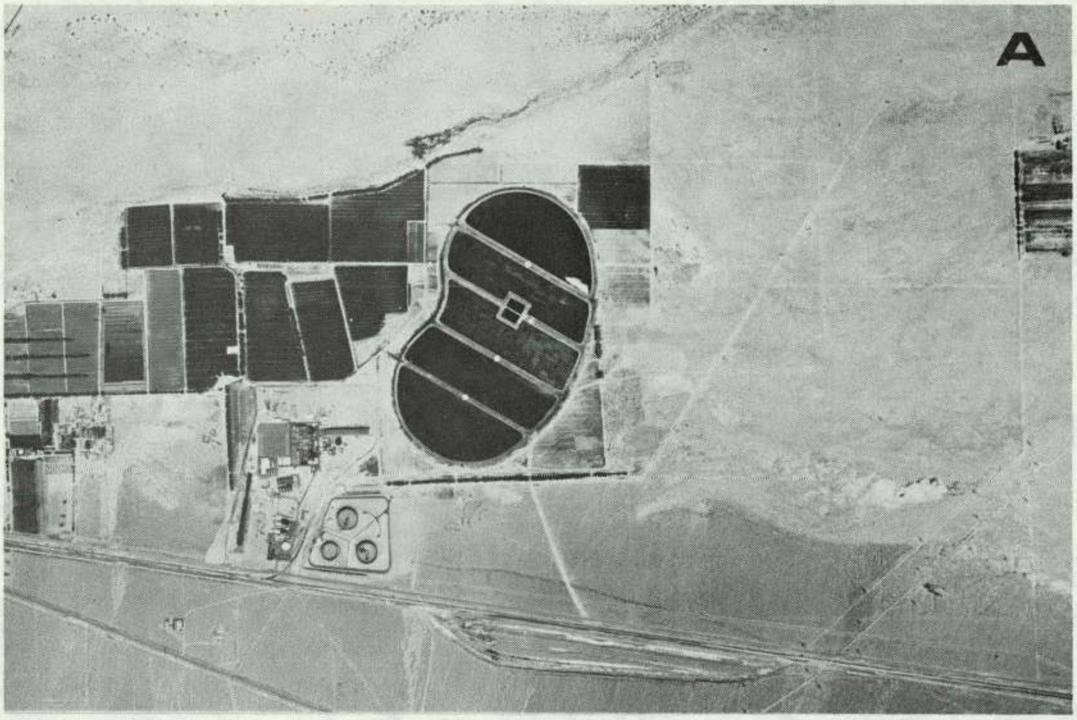
4.1. Aerial photography

A program of aerial photography was begun in June 1979 and continued with photographs taken in December 1979, and June and November 1980. Pictures were taken by Metrex Corporation at three exposures using multi-spectral infra-red film. The first two sets of photographs were analyzed by the Medical Imaging Science Group at the University of Southern California, emphasizing change detection based on computerized digital image processing (Frei et al. 1979).

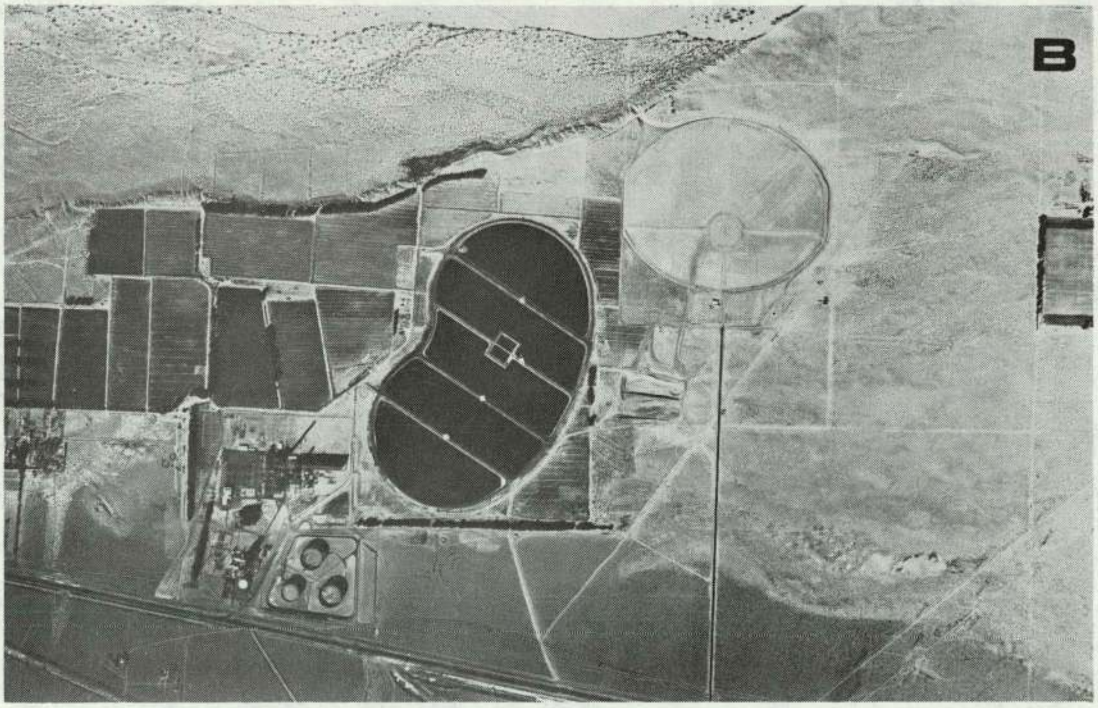
Figures 4 and 5 illustrate various stages in the development of the solar thermal power plant. Figure 4A shows SCE's Cool Water Generating Station and adjoining areas in July 1979, several months before construction began. Figure 4B (December 1979) shows the cleared and graded heliostat field lying northeast of the large evaporating pond. Here we may note the light colored area east of the field where sand blown off the surface of the cleared field was deposited. Figure 5A was taken in June of 1980 and shows further differentiation of the core area (lower center of field). Figure 5B, taken in November 1980, shows the tower in the core area and heliostat pedestals and/or mounted heliostats in the northeast and southeast quadrants. Areas of wind-deposited sand are still clearly visible to north and east of the heliostat field.

Figure 6 illustrates the technique of digital image processing, comparing photographs taken in July (Fig. 4A) and December 1979 (Fig. 4B). In Figures 6A and 6B we see the original views. Fig. 6C was produced by computerized comparisons of the foregoing views, indicating areas of change

Figure 4

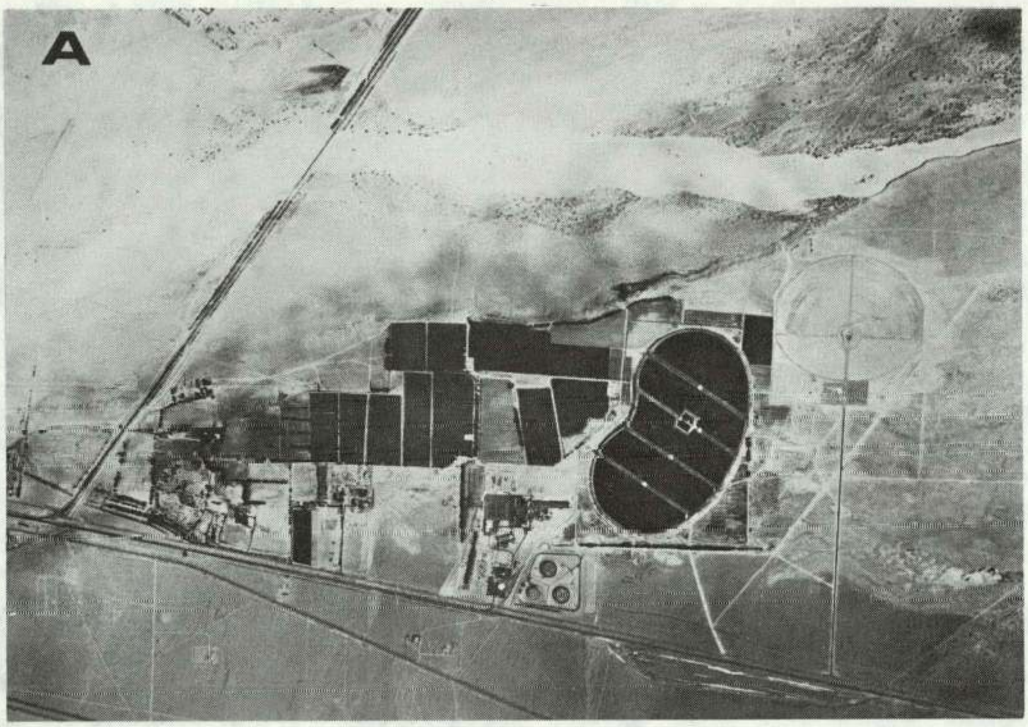


Southern California Edison's Cool Water Generating Station (left center) in July 1979. Large kidney-shaped area is composed of evaporating ponds. Dark rectangular areas are agricultural fields. The site of the prospective solar thermal power plant is in right center.

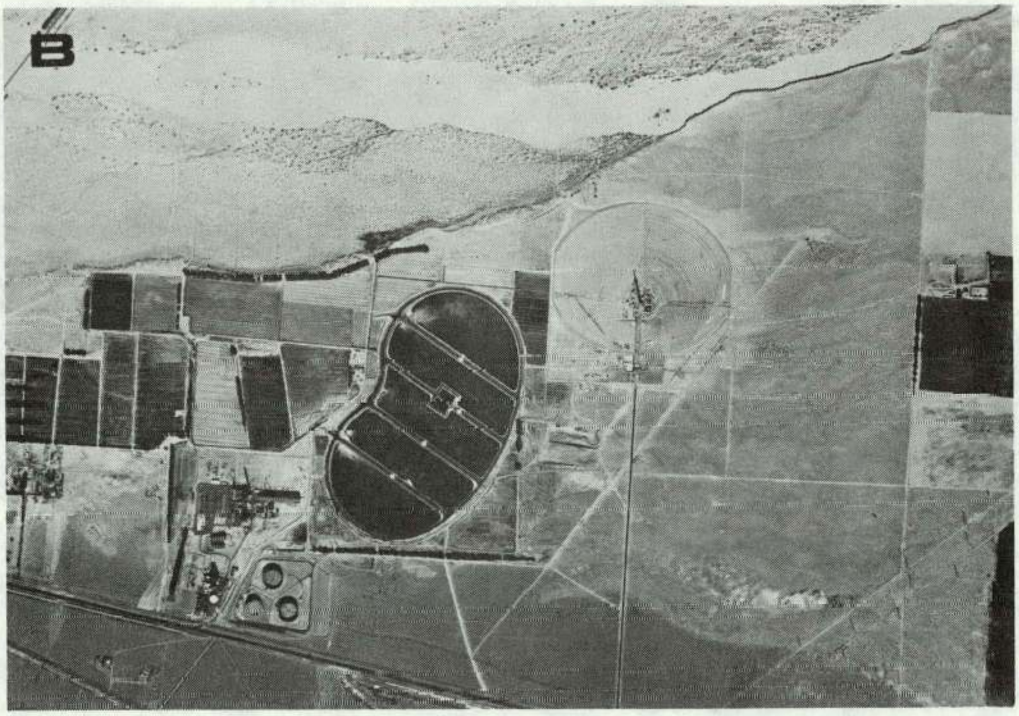


The Cool Water Generating Station in December 1979, showing the cleared heliostat field northeast of the evaporating ponds. Note the arc of sand blown to the east of the cleared field. These deposits are conspicuous to a distance of 100 m downwind of the clearing.

Figure 5

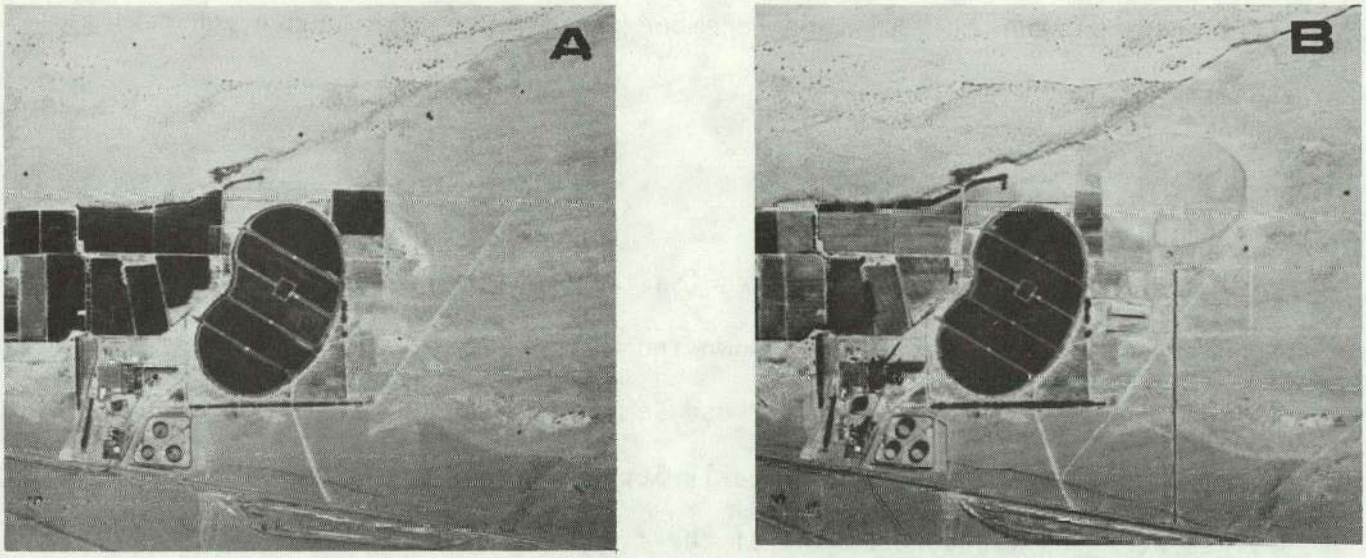


The Cool Water Generating Station in June 1980. Some of the pedestals for heliostats have been put in place and some construction has begun in central core area (lower center of heliostat field).



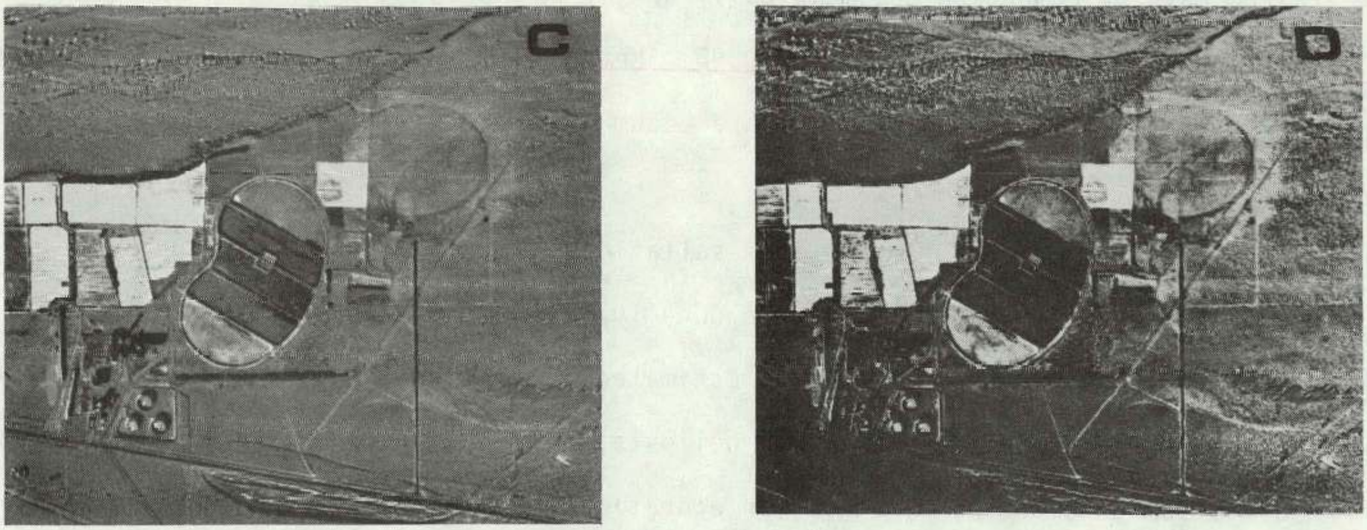
The Cool Water Generating Station in November 1980. Heliostat pedestals show clearly in right half of field. Work has begun on thermal storage system and receiver tower in the core area.

Figure 6



Cool Water Generating Station and prospective solar thermal power plant site in July 1979

The solar thermal power plant site in December 1979, showing the cleared heliostat field northeast of the evaporating ponds



Original "change image" based on July and December 1979 photographs

Enhanced change image, emphasizing heliostat field, coronoa of wind-blown sand east of field, new road, and site of old cultivated field by whitening. Fig. 6D is the final enhanced change image, in which differences between the July and December photographs have been given maximal emphasis.

4.2. Saltation meter measurements

Two special collecting devices (saltation meters) designed by Lawrence Livermore Laboratory were placed downwind of the prospective heliostat field in mid-June 1979. The design of these samplers was illustrated in a previous report (Turner 1979: p. 18). In early September 1979 four more of these devices were positioned downwind of the field. Stations 1 and 2 were, respectively, 100 m and 60 m east of the eastern edge of the heliostat field. Station 3 was about 200 m north of Station 2. Stations 4-6 were about 600 m east of the field, in a north-south line. These devices measured fluxes of windblown sand at five levels above the ground (from 1 to 36 cm). The width of the device was 0.95 cm, so one can estimate mean daily sand flows across a 1-cm path by computing the mean daily weight of sand collected (total weight divided by days) and dividing by 0.95. Meters were examined periodically and when significant amounts of sand had accumulated the material was removed and weighed.

Amounts of sand removed from saltation meters at various stations downwind of the solar site between June 1979 and May 1981 are summarized in Appendix 1. Table 1 abstracts estimated fluxes for a 77-day period prior to clearing and grading the heliostat field, and for three periods after commencement of construction operations in September 1979. Fluxes were low at Stations 1 and 3 during the summer of 1979, then increased dramatically at Stations 1 and 2 after clearing and grading began. These two stations were just east of the field. Station 3 was apparently

Table 1. Fluxes of sand ($g \cdot cm^{-1} \cdot day^{-1}$) along 1-cm paths at stations downwind of the solar field between June 1979 and May 1981. Weights of sand (g) collected in meters are given in parentheses. No observations (n.o.) were made at Stations 2, 4, 5 and 6 before September 2, 1979.

Dates	Stations 1	 2	 3	 4	 5	 6
June 16-Sept 1, 1979 (77 days)	0.048* (3.5)	n.o. -	0.025* (1.9)	n.o. -	n.o. -	n.o. -
Oct 22, 1979-Feb 29, 1980 (131 days)	10.8 (1344.1)	>20.2 (2513.9)	0.14 (17.4)	0.001 (0.12)	0.02 (2.49)	0.05 (6.22)
Mar 1-June 15, 1980 (106 days)	0.25 (25.4)	0.75 (75.4)	0.07 (6.6)	0.24 (24.5)	0.04 (3.7)	0.08 (8.2)
Mar 29-May 10, 1981 (43 days)	0 (0)	1.54 (63.1)	0 (0)	0 (0)	0 (0)	0 (0)

* These data were erroneously transposed in the report of baseline studies (Turner 1979: p. 19).

too far north to be so conspicuously affected. Stations 4, 5 and 6 were so far east of the site that high fluxes were never measured there (except at Station 4 during the spring of 1980). Analyses of the vertical distribution of sand fluxes presented in earlier quarterly reports showed that most of the sand moved near the ground--within 1 cm of the surface.

Movement of sand off the newly cleared heliostat field was substantial during the late fall of 1979. In fact, so much sand moved across Station 2 during this time that the meter overflowed on several occasions. Later the surface of the field stabilized somewhat and fluxes between March 1 and June 15, 1980, were much lower (at Stations 1 and 2) than measured during the previous 4-1/2 months. After June 1980 there were barely detectable collections of material in saltation meters until the spring of 1981, when sand was again collected at Station 2. This period of collection coincided with a period of higher than usual winds, suggesting that some material on the surface of the heliostat field was still susceptible to mobilization 18 months after clearing.

Dr. Richard Hunter attempted to estimate the amount of sand blown off the heliostat field between October 1979 and the end of February 1980. He assumed the diameter of the heliostat field to be 800 m, and loss rates based on measurements at Stations 1 and 2. Hunter estimated that roughly 160 metric tons of sand were removed during this time. If all of this had been evenly deposited in a sector extending to 100 m from the field's eastern edge, new deposition would have been about 11 metric $\text{tons}\cdot\text{ha}^{-1}$.

However, sand deposited downwind of the field was not uniformly dispersed, but formed mounds in wind shadows of shrubs (Fig. 7). Mound heights were measured downwind of the prospective field in 1979 so we were able to estimate increases in sand depths as a result of construction activities. Post-construction measurements were made in January 1980 and again in May 1981 (Table 2). Most of the observed increases in sand depth took place immediately following the clearing and grading of the heliostat field (as reflected in the 1980 measurements), but sand continued to accumulate between January 1980 and May 1981.

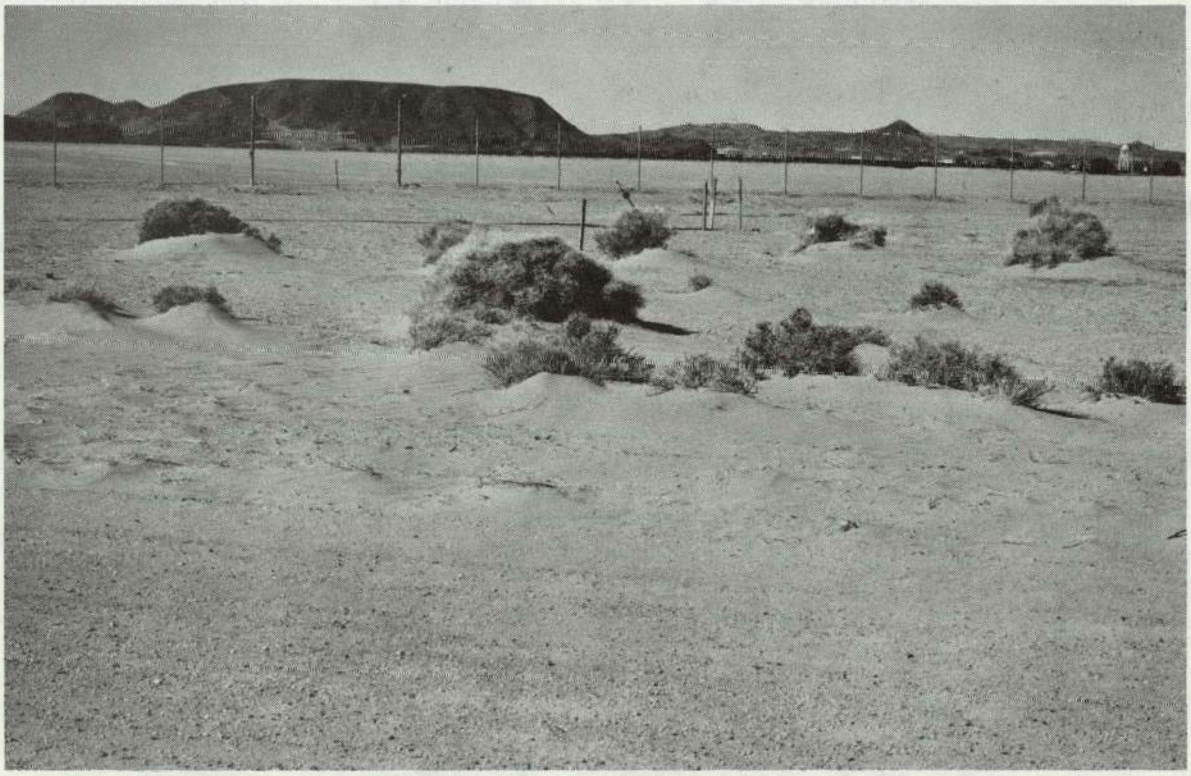


Figure 7. Newly deposited sand just east of the cleared heliostat field in the spring of 1980. Largest fence posts indicate location of East Gate.

Table 2. Depths of accumulated sand at 20 points between 33 and 98 m downwind of the eastern edge of the heliostat field, January 1980 and May 1981.

Distance from edge of field (m)	Number of sampling points	Dates	Mean increases (cm) in height (± one s.e.)	Ranges of measured increases (cm)
33 - 36	3	Jan 1980	24.7 ± 4.2	20 - 33
		May 1981	37.0 ± 3.5	33 - 44
44 - 49	4	Jan 1980	16.5 ± 1.0	14 - 19
		May 1981	17.0 ± 1.6	13 - 20
53 - 57	3	Jan 1980	9.7 ± 3.8	4 - 17
		May 1981	15.3 ± 5.5	6 - 25
87 - 88	5	Jan 1980	1.2 ± 0.2	1 - 2
		May 1981	2.0 ± 0.3	1 - 3
91 - 98	5	Jan 1980	2.0 ± 1.3	0 - 6
		May 1981	3.2 ± 0.6	2 - 5

Material blown off the heliostat field remained well localized and appreciable new deposits were only observed within 100 m of the downwind perimeter. As we shall see later, this new material had some effects on plants growing in these areas. Furthermore, the displaced sand downwind of the field may constitute a source from which material could be blown west across the array of heliostats. Whether this occurs will depend on i) how quickly the displaced material stabilizes, and ii) the occurrence and velocity of winds from the east.

4.3. Airborne particulates

Beginning in August 1979, airborne particulates were measured every 6 days by personnel of the Statewide Air Pollution Research Center at the University of California, Riverside, at a site about 1 km southeast of the solar site. UCR used a Sierra Instruments Hi-Vol Air Sampler mounted about 3.8 m above the ground. Although the UCR station is not directly downwind of the solar site, we have used their air sampling data for the period August 1979 to May 1980 because no other measurements are available for this period.

In July 1980 we installed a Sierra Instruments Model UV-1 High Volume Sampling System 100 m east (downwind) of the solar site. The instrument was positioned 1.2 m above the ground. Measurements were made every 6 days through August 1981. Net weights of material on filters were converted to estimates of $\mu g \cdot m^{-3}$ of air flow.

Table 3 gives estimated mean masses of airborne particulates ($\mu g \cdot m^{-3}$) measured between August 1979 and August 1981. Monthly means were generally between around 20 to 80 $\mu g \cdot m^{-3}$, and only during November 1980 and May and June 1981 was this range exceeded. These higher means were owing to unusual winds, often (as in November 1980) resulting from a single very high sample. Measurements taken at the UCR station during clearing and grading of the heliostat field (September-October 1979) were not unusual, but we emphasize that this station was not directly downwind of the solar site. As indicated above, unusually high monthly means observed subsequent to grading and clearing were associated with windstorms and not to any construction operations.

Table 3. Airborne particulates measured east (UCLA) and southeast (UCR) of the solar site between August 1979 and August 1981. Measurements until May 1980 were made by UCR; thereafter by UCLA.

Month and year	Numbers of samples taken	Mean mass of particulates ($\mu g \cdot m^{-3}$)	Standard error of the mean	Range
Aug 1979	6	66.1	4.9	49.3-76.8
Sept	5	77.9	1.4	74.9-83.0
Oct	5	83.7	14.2	46.6-108.2
Nov	5	56.1	3.8	44.3-63.7
Dec	3	72.6	16.0	44.8-100.0
Jan 1980	5	28.3	4.2	18.3-43.9
Feb	5	27.8	4.3	15.2-38.2
March	5	65.6	22.3	22.2-141.0
Apr	5	76.8	11.6	57.4-120.8
May	5	73.9	11.2	49.5-110.9
Aug	2	37.7	13.8	23.9-51.5
Oct	2	62.2	25.4	36.8-87.7
Nov	4	250.9	164.7	46.0-741.3
Dec	5	83.5	17.2	41.7-142.2
Jan 1981	4	38.7	6.4	30.7-60.7
Feb	4	20.2	1.4	16.6-22.7
March	5	28.4	10.0	5.5-65.2
Apr	5	42.4	10.4	16.8-67.5
May	4	100.1	45.7	31.1-233.5
June	4	96.0	47.7	13.5-233.0
July	4	69.1	7.0	52.5-80.0
Aug	5	67.6	10.9	41.7-105.9

4.4. Atmospheric pollutants

Since the summer of 1979, C. R. Thompson and Gerrit Kats, of the Statewide Air Pollution Research Center at the University of California, Riverside, have measured amounts of ozone, nitric oxide and nitrogen dioxide in air downwind of the solar site. The UCR station is about 1 km southeast of the heliostat field. For a one-year period beginning in the fall of 1979, Southern California Edison made similar measurements about 2 km south of the solar site, south of the highway between Needles and Barstow (see Fig. 2). The SCE data were taken to establish baseline conditions in support of an application to site a coal gasification facility at Cool Water, and have been summarized by Environmental Applications, Inc. (1980).

Table 4 presents, on a quarterly basis, observations between November 1979 and October 1980. December, January and February are winter months,

Table 4. Mean concentrations (pphm) of gases measured south and east of Solar One between November 1979 and October 1980.

Time of year	Ozone		NO_2		NO	
	SCE	UCR	SCE	UCR	SCE	UCR
Fall	3.4	2.6	1.7	1.2	0.9	2.6
Winter	2.4	2.4	1.4	0.05	1.1	1.9
Spring	4.4	3.6	1.2	0.01	0.4	0.7
Summer	5.9	5.3	1.4	0.07	0.3	0.4

March-May are spring months, June-August are summer months, and September-November represent autumn. Measurements of ozone at the two sites were in good agreement, with highest values in spring and summer. Measurements at both the SCE and UCR sites showed that times of maximal concentrations of ozone were always in the afternoon, ranging from around 1300-1400 in the winter to as late as 1700 during the summer. Seasonal changes closely followed total insolation. Both California (10 pphm) and federal (12 pphm) ozone standards were violated at times during the spring and summer. Mean quarterly concentrations of NO_2 were consistently higher at the SCE sampling site (Table 4), but amounts of oxides of nitrogen were low at both stations. The maximum NO_2 concentration reported for the SCE site was 9.5 pphm during the fall. The California standard is 25 pphm. The average annual NO_2 concentration at the SCE site was 1.4 pphm, while the federal standard is 5 pphm. Times of highest concentration of NO_x were almost always early in the morning, ordinarily from 0300 to 0700.

It has been suggested that changing patterns of fuel combustion at the Cool Water Generating Station may influence amounts of some gases measured downwind of the station. Units 1 and 2 burn natural gas or fuel oil. Units 3 and 4 burn turbine fuel (although these units are being modified to burn alternate fuels). Joe Reeves and Kermit Rosenthal (SCE) provided fuel use figures for the period August 1979 to October 1980. During this time the combustion of gas was fairly uniform. The mean monthly use was around 700 million cubic feet, and except for April and May of 1980 (275 and 308 million ft^3, respectively), the monthly consumption was never less than 534 million ft^3 nor more than 971 million ft^3. On the other hand, no fuel oil at all was burned during the summer of 1980, while up to 50,000 barrels were used in January of that year. Turbine fuel use ranged from essentially zero (May-June 1980) to over 300,000 barrels in November 1979 and February 1980.

Multiple regression analyses were made of mean monthly levels of NO and NO_2 (for 14 months) measured at the UCR station. Independent variables used were amounts of the three fuels burned, monthly rainfall, and mean monthly air temperature. The climatological records were based on measurements at the Barstow-Daggett airport. Oil consumption was significantly (and inversely) correlated ($\underline{r} = -0.7$) with air temperature, simply because a lot of oil was burned during the winter of 1979-80 and none during the summer of 1980. There were no other significant intercorrelations between independent variables. Table 5 summarizes simple correlation coefficients for five independent variables, and gives multiple R^2 values for the multiple regression analyses.

Table 5. Results of multiple regression analyses of mean monthly levels of NO and NO_2 downwind of the solar site, August 1979-October 1980.

Independent variables	NO	NO_2
Gas	0.32	0.46
Oil	0.37	-0.32
Turbine fuel	0.36	-0.11
Rainfall	-0.11	-0.36
Mean air temperature	-0.56*	0.46
Multiple R^2 (and number of variables entered)	0.77* (5)	0.39 (5)

*Significant at 5% level

Although the R^2 value for NO is statistically significant, it is not immediately obvious how to interpret the outcome of the analysis. The first independent variable to enter was mean air temperature ($R^2 = 0.31$), the second was combustion of gas (multiple $R^2 = 0.57$), and the third was rainfall (multiple $R^2 = 0.73$). The inclusion of the other two variables had no significant effect on the total R^2. These analyses are of limited relevance because the focus was so coarse--i.e., based on monthly means. The approach could be sharpened by using daily concentrations of gases and daily records of fuel consumption and air temperatures.

In summary, we can detect no effects of construction activities on concentrations of ozone and NO_x, nor would we expect to see such effects. Questions have been raised in the past as to whether the high temperatures and high solar intensity adjacent to the receiver of an operating solar thermal power plant could catalyze the production of significant amounts of air pollutants (e.g., NO_x). This issue has been explored by Perrine et al. (1981), assuming a facility rated at 430 MW_e with 61,000 heliostats. Their worst case analyses--based on chemical equilibria, chemical kinetics, mass emission rates, transport and dispersion--indicated "that some air pollutants may be produced...in quantities sufficient to be of regulatory concern. However, these authors continued: "In all likelihood the quantities produced will be small, and fully merit for solar its general recognition as a benign energy technology." On the basis of this study, we do not consider this problem an environmental issue with Solar One.

4.5 Micrometeorology

In keeping with the rationale that the heliostat field may have subtle micrometeorological and ecological influences outside of the immediate field environment, baseline temperature profile measurements were made at two sites near the heliostat field between November 1980 and July 1981. One site (X-1) was established 50 m east of the fence around the heliostat field, on an east-west line with the receiver tower. We considered this the "experimental" site because, with prevailing west winds, micrometeorological patterns of this area are most likely to show effects of the field and associated structures. The control site (X-2) was about 700 m north of X-1 and about 200 m northeast of the field, where prevailing winds are relatively unaffected by power plant structures.

Two-meter masts were erected at each site, each mast supporting four shielded thermocouples at 2, 10, 50 and 200 cm. Thermocouples were also buried 5 cm below the surface at each site. Hourly temperature profiles were measured at the two sites for 24-hour periods every month but January. Soil surface and deep sky temperatures were recorded with a Barnes Engineering PRT-10 IR thermometer. Shortwave irradiation was measured with a Licor light meter each hour. Air temperatures were measured with an Omega 2175A Digital Thermometer and mean temperatures computed from 5-10 measurements made within intervals of 1-2 seconds. Measurements were made by switching successively to input leads for the eight thermocouples. Temperatures at the X-2 (control) site were compared with temperatures at the X-1 (experimental) site by paired _t_-tests. Daytime average temperatures were computed as means of all temperatures taken at any one height for all hours in which solar radiation values were recorded. Mean peak daytime temperatures were obtained from the three warmest hours of the day--based on temperatures at 2 m. Night average temperatures were based on values for all hours in which no solar radiation was recorded and night minimum temperatures were based on the three coldest hours. Peak average temperatures were examined to insure that any significant differences between sites would be observed, and to determine the magnitude of such differences at critical temperature periods during the day.

Representative data for the two sites taken during December 1980 and July 1981 are summarized in Appendix 2. Similar data were acquired during November 1980 and between February and June 1981.

Average air temperatures ranged from 10° C in December 1980 to around 35° C in June and July 1981. In general, temperature height profiles showed typical lapse conditions during the day and inversions at night at both sites (Figs. 8 and 9). Daytime temperature height profiles showed no consistent pattern of differences at the two sites. However, except during December, night temperatures at the control site (X-2) were cooler than at the experimental site (X-1).

Daytime average temperatures and peak average temperatures at 2 m were from 1.3 to 0.2° C warmer at the control site (X-2) between November 1980 and March 1981. Conversely, between April and July 1981 these temperatures were generally from 0.2 to 0.75° C cooler at the X-2 site (Fig. 10). Night average and minimum temperatures at X-2 (2 m) were generally cooler by 0.8 to 0.1° C (Fig. 11).

Daytime average and peak average temperatures at 2 cm were consistently warmer (up to 5.8° C) at the control site (X-2) and, except during November, mean night and night minimum temperatures at this height were consistently

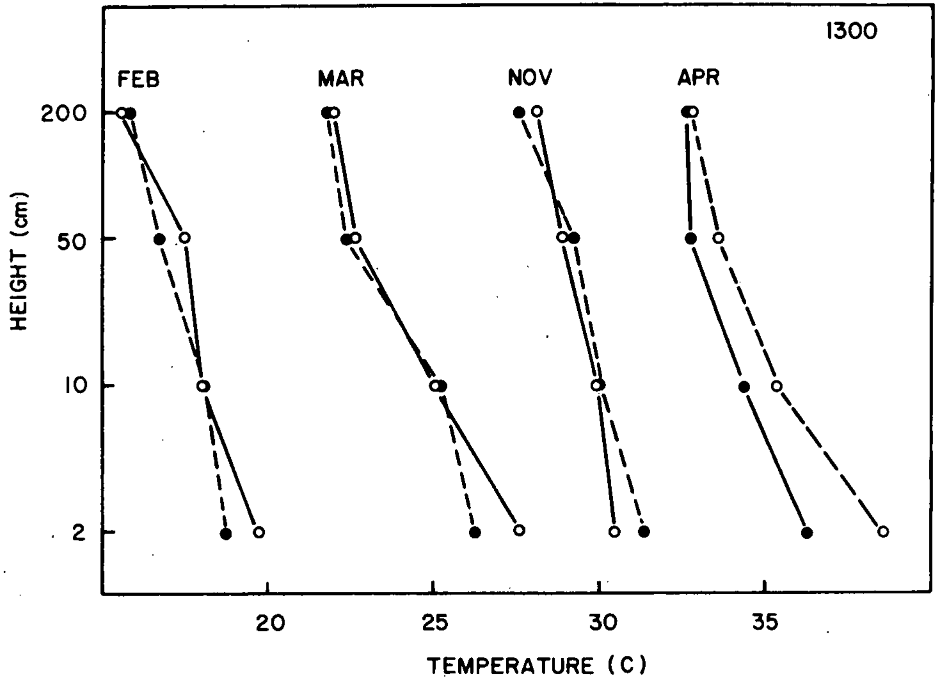


Figure 8. Air temperature profiles (at 1300 hours) at two sites near the heliostat field between November 1980 and April 1981. Open circles: experimental site (directly downwind of the heliostat field); solid circles: control site.

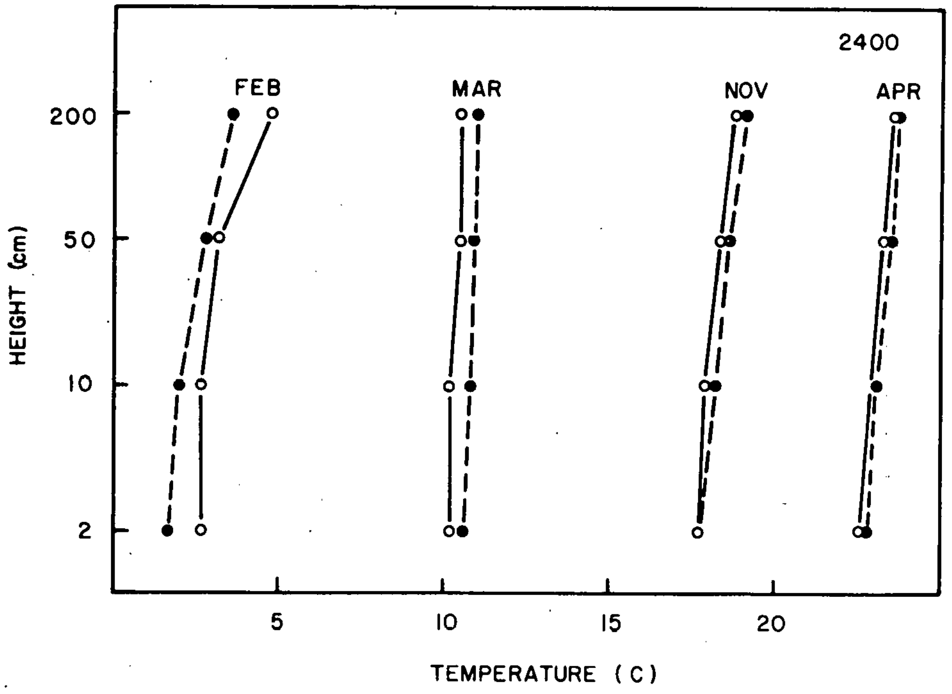


Figure 9. Air temperature profiles (at 2400 hours) at two sites near the heliostat field between November 1980 and April 1981. Symbols as in Figure 8.

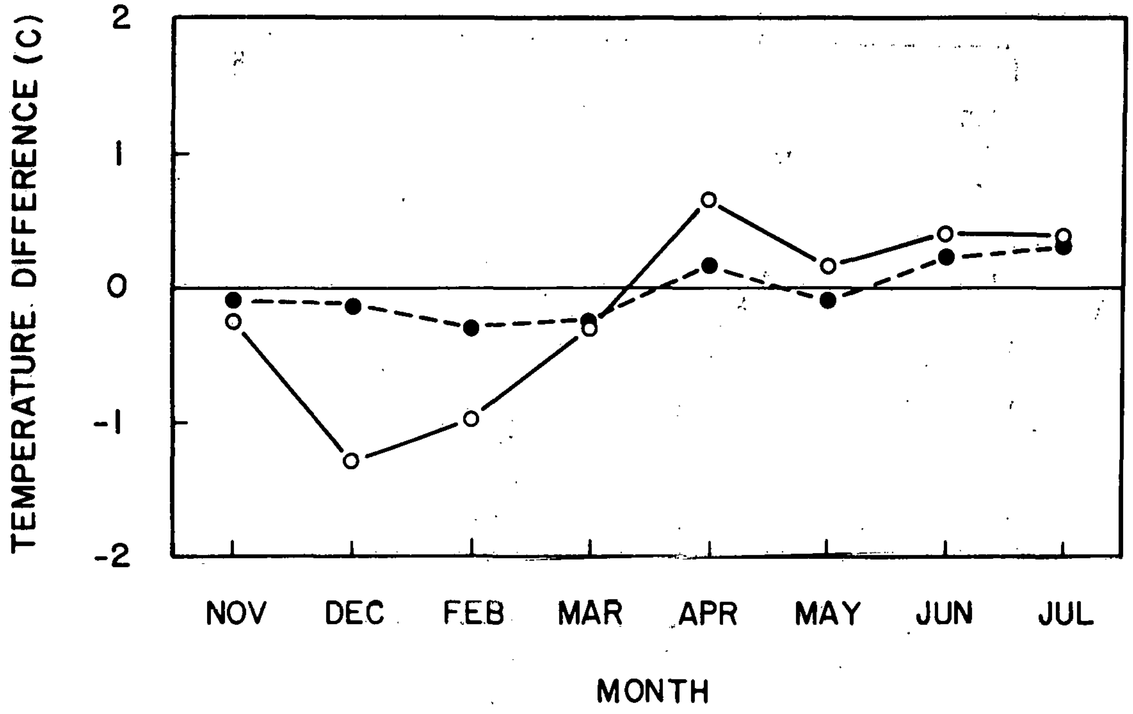


Figure 10. Differences between mean temperatures (at 2 m) at two sites near the heliostat field between November 1980 and July 1981. Open circles: mean daytime peak temperature differences; solid circles: mean daytime temperature differences.

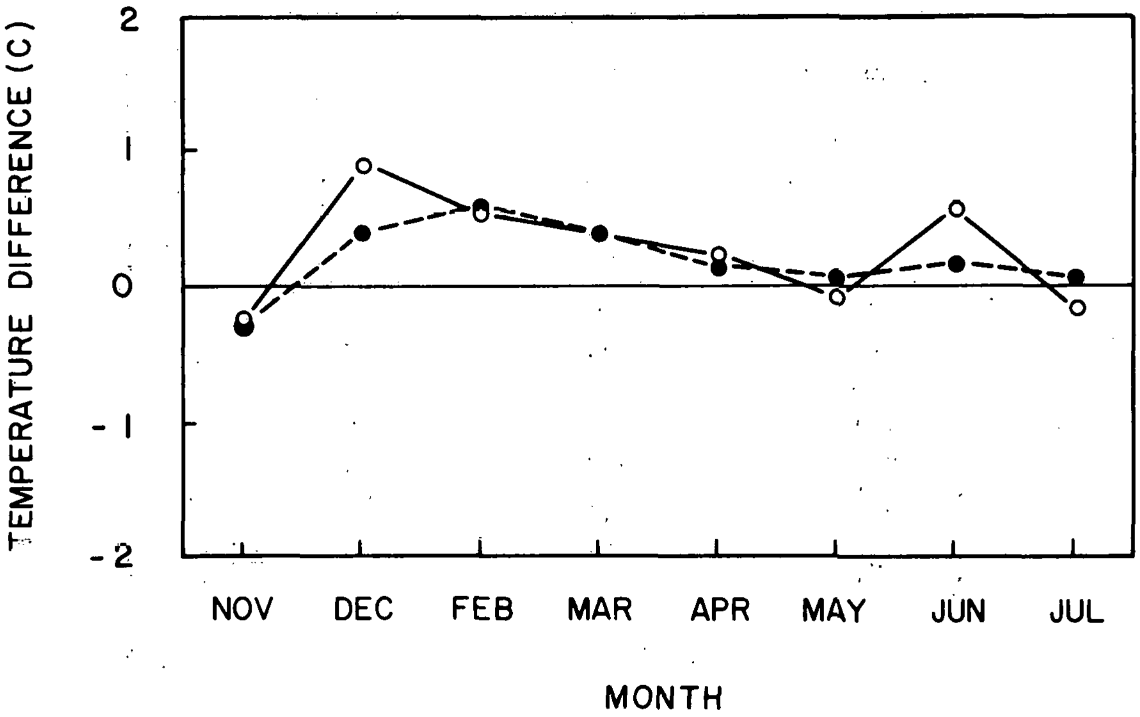


Figure 11. Differences between mean temperatures (at 2 m) at two sites near the heliostat field between November 1980 and July 1981. Open circles: mean nighttime minimum temperature differences; solid circles: mean nighttime temperature differences.

cooler (up to 0.8^{o} C) at the control (X-2) site (Table 6).

Table 6. Differences (^{o}C) between mean temperatures recorded at 2 cm at two sites near the heliostat field between November 1980 and July 1981. Differences were obtained by subtracting means at the experimental site (X-1) from those at the control site (X-2).

Attributes	Months							
	Nov	Dec	Feb	Mar	Apr	May	Jun	Jul
Mean daytime temperature	-0.2	-0.9	0.0*	-1.1	-1.2	-0.4	-0.3	-3.2
Mean daytime peak	-0.1*	-2.5	-0.1*	-1.4	-1.8	-0.4	-0.8	-5.8
Mean nighttime temperature	-0.2	0.8	1.0	0.4	0.4	0.1	0.4	0.8
Mean nighttime minimum	-0.3	1.3	0.4	0.4	0.4	0.1*	0.6	0.8

* no statistically significant difference (95% confidence level)

We expected temperature patterns at 2 cm to be more susceptible to influence by characteristics of energy exchange at the soil surface. On the other hand, temperatures at 2 m are certainly more affected by advected energy. This, in turn reflects the influence of upwind energy exchange conditions (Oke 1978). It is possible that the shift in daytime temperature differences between March and April 1981 at 2 m resulted from construction activities in the heliostat field. The sometimes dramatic differences between the control (X-2) and experimental (X-1) sites at 2 cm may have resulted from changes in the soil surface composition. The experimental site (X-1) is in the area where new sand was deposited and where a high proportion of the surface is covered with fine sand. The control site, however, has a more typical ground surface consisting of desert pavement interspersed with open areas.

The data from which the temperature differences at the two sites were derived (Figs. 10, 11; Table 6) were not all significantly different (based on paired t-tests). Daytime average temperatures at 2 m were not significantly different from one another in December 1980, April 1981 and May 1981. Day peak average temperatures at 2 m were not significantly different from one another im March and May 1981. Night average and night peak average temperatures were not significantly different from one another in May and July 1981. At 2 cm, day average temperatures (February 1981), day peak average temperatures (November 1980 and February 1981), and night peak average temperatures (May 1981) were not significantly different. In spite of the foregoing we believe the general site relationships described are supported by the overall body of our data.

The magnitude of temperature differences between control (X-2) and experimental (X-1) sites at 2 m (up to 1.3^{0} C but usually $\sim$0.5^{0} C) is modest, and is not likely to augur important biological or ecological problems. However, ecosystems can be affected by very small temperature differences when expressed over extensive areas and for long periods of time (e.g., Nobel 1980). The temperature differences between control (X-2) and experimental (X-1) sites at 2 cm (up to 5.8^{0} C) are of greater ecological interest--if indeed these differences represent effects of construction. The soil surface, and the zone just above it, are an important region for small animals and plant germination and growth. Temperature differences of 5-6^{0} C could influence these biological processes, although the intensity of the effect will be modified by the timing of various biological events.

We have shown small but statistically significant differences between air temperature attributes at a site directly downwind of the heliostat field and another site where downwind effects of construction would be less likely. We have also shown that some of these differences--particularly those observed near ground level--could have ecological significance. We have not, however, established that the differences are associated with construction activities. No profile measurements were made at these sites before construction, and we have no data with which to compare the measurements made between November 1980 and July 1981. However, the measurements reported here could be an important element in the interpretation of similar data acquired after testing and operation begin.

On July 9 and 10, 1981 a series of measurements of albedo were made within the cleared heliostat field and in undisturbed areas surrounding the field. These measurements were made with a Lambda Instruments 200S pyranometer held about 0.8 m above the ground. Measurements were made at 0610, 0815, 1005, 1200, 1430 and 1640 hours at sites east and west of the core area within the field, and at points east, northeast and north of the field itself.

Twelve measurements made inside and 18 measurements outside of the field were grouped by time and examined by factorial analysis of variance: two locations and six times of day. Table 7 summarizes means of these measurements.

Table 7. Mean measurements of albedo made within the cleared heliostat field and in areas outside the field, July 1980.

Solar time	Inside heliostat field	Outside heliostat field
0610	0.358	0.354
0815	0.347	0.338
1005	0.322	0.312
1200	0.312	0.306
1430	0.326	0.327
1640	0.344	0.358

The analysis of variance showed, as expected, a highly significant effect owing to time of day ($\underline{F} = 11.6$, $\underline{F}_{0.01} = 3.4$), but no other effects. The $\underline{F}$-value for location was 0.2 ($\underline{F}_{0.01} = 7.2$). Albedo, as we measured it, did not differ in the cleared heliostat field and in undisturbed areas beyond. However, because the instrument was less than a meter above ground the effect of the absence of vegetation was not really registered--i.e., at 0.8 m the instrument measured the reflected radiation from bare ground in both denuded and vegetated areas. Had measurements been made from the air, we would expect a higher albedo for the exposed surface of the heliostat field because the instrument's field of view would be greatly increased and the absence of vegetation would then register as an increase in surface radiation reflection.

4.6 Annual plants in off-field plots

Six 1-ha plots (100 x 100 m) were established east (downwind) of the prospective heliostat field early in 1979. Two of these (1-2) lay about 125 m east of the eastern margin of the field. Plot 3 was 300 m northeast of the edge. Plots 4, 5 and 6 were 730, 740 and 930 m northeast of the eastern edge of the field. Annual plants were counted in quadrats in these plots in the spring of 1979, 1980 and 1981. Plot 1 contained 49 quadrats, Plot 2 had 50, Plot 3 had 36, Plot 4 had 37, Plot 5 had 36, and Plot 6 had 36. Permanent marks were placed so that we could reposition quadrats in the same places each year. Common species of annual plants were harvested and dried so that we could estimate mean dry weights of various species. These means were then combined with estimates of densities of various kinds of annual plants so as to estimate dry weight standing crops in plots.

We computed a diversity index based on the relative densities and dry weight standing crops of various species of annuals. If the overall density of annual plants was $\underline{D}$, the overall standing crop $\underline{B}$, and $\underline{d}_i$ and $\underline{b}_i$ the density and biomass of the $\underline{i}_{th}$ species, then the relative density and relative biomass of the $\underline{i}_{th}$ species were computed as $100\underline{d}_i/D$ and $100\underline{b}_i/B$, respectively. These two values were summed for each species to give a series of "importance values" ($\underline{I}_i$). Diversity was computed as:

$$\Sigma(I_i/\Sigma I)^2$$

A flora consisting of but one species would have a diversity index of one. A very rich flora, with all species exhibiting the same importance values, would have a diversity index approaching zero.

In order to make comparisons between observations in plots we used two kinds of tests. The first was a simple non-parametric rank correlation test, as described by Snedecor (1956: p. 190). One compares the ranking of, say, densities or biomass in various plots in successive years to determine whether significant reordering in rank has occurred. The statistic r_s may range from -1.0 (complete disaccord) to +1.0 (complete accord). One tests the hypothesis (H_o) that there is no correlation between rankings in different years. For six cases (6 plots), the critical r_s values for rejecting H_o are $>+0.886$ and <-0.886. We also examined ratios of change in various attributes between years, by dividing the mean value observed in year $n+1$ by that observed in year n. Because we computed standard errors of the means of variables for different years, we could estimate the standard errors of these ratios. Given that we have a mean value for year $n+1$ ($\bar{x}$), an estimate of s.e.$_{\bar{x}}$, a mean value for year $n(\bar{y})$ and an estimate of s.e.$_{\bar{y}}$, one may estimate the standard error of $\frac{\bar{x}}{\bar{y}}$ as:

$$\text{s.e.} = \left[\frac{(\text{s.e.}_{\bar{x}})^2}{\bar{y}^{2}} + \frac{(\text{s.e.}_{\bar{y}})^2 (\bar{x}^{2})}{\bar{y}^{4}} \right]^{\frac{1}{2}}$$

We can compare ratios in different areas by first computing the difference between ratios ($r_1 - r_2$) and estimating the standard error of the difference as:

$$se_d = (se_{r_1}^{2} + se_{r_2}^{2})^{\frac{1}{2}}$$

Then $(r_1 - r_2)/se_d$ is a Z-statistic, approximately normal in distribution with a mean of zero and a standard deviation of one.

About 90 kinds of annual plants were identified in the downwind environs of the solar site. However, the greatest number of different species ever registered in any of the six plots under study was 47 (Plot 4, 1979). Generally, we recorded from around 25 to 35 kinds of annuals in plots in 1979. Following the low rainfall winter of 1980-81, we only registered from 9 to 16 kinds of annuals in plots during the spring of 1981.

General attributes of spring floras in 1979, 1980 and 1981 are set forth in Appendix 3. Standard errors of means are based on variations registered in the different quadrats inspected in plots. Year-to-year changes in estimated abundances of these five species are given in Appendix 4. Appendix 5 gives estimated dry weight standing crops of three species in 1979, 1980 and 1981. The 1979 data originally presented by Turner (1979: pp. 24 et seq.) were later revised, so some of the figures presented here differ from those in the earlier report.

Appendix 3 shows, as expected, that annual floras downwind of the solar site underwent pronounced changes between the 1979 and 1981 growing seasons. Aggregate densities of plants almost doubled between 1979 and 1980, while dry weight biomass declined about 25%. Although there were many more plants in 1980, they were much smaller than those in 1979, and the 1980 plants grew little, dried out and died quickly. Numbers of species observed in plots were generally stable between 1979 and 1980. By the spring of 1981, however, annual floras were conspicuously impoverished in all plots. Numbers declined to around 25% of their 1979 level, while biomass dwindled to about 10% of the 1979 standing crop.

Numbers of species observed in 1981 were around 30-50% of those present in previous years. It is interesting to note that the diversity index computed from sampling data showed a slight increase between 1979 and 1980, and again between 1980 and 1981. Diversity is not to be confused with species-richness. Diversity takes into account the relative abundance of different kinds of species. The point is that we wish to be able to distinguish between a flora composed of, say, one species represented by 1,000 individuals and 15 other species, each represented by a single individual. Such a flora is clearly less diverse than one composed of 16 equally abundant species.

Appendixes 4 and 5 show that the commoner species of annuals were not equally abundant in all plots, and that standing crops also differed between plots. Because Plot 1 was very sandy, certain plants (e.g., _Schismus arabicus_ and _Erodium cicutarium_) were more common--often much more so--in this plot. All of Plot 2 and about half of Plot 1 lay within the area which was cleared of all vegetation in 1953, and some of the differences between these plots and the others are related to this past experience. The local abundance of desert gold was more or less complementary to densities of _Schismus_ and _Erodium_. Appendixes 4 and 5 also show that individual species did not necessarily follow the broad patterns of change described in connection with overall annual floras. Because _Schismus arabicus_ composed such a large fraction of all plants counted in quadrats, its year-to-year changes set the general tone for changes in aggregate densities. However, densities of desert gold and _Cryptantha angustifolia_ declined throughout the study in all plots. In 1981 _Erodium cicutarium_ contributed most substantially to the total standing crop of annuals. Other species exhibited different patterns of change in different plots. It is against this backdrop of natural variation, including the conspicuous year-to-year changes in annual floras, that we must seek evidence of effects of construction of Solar One.

Table 8 gives observed ranks of four collective attributes of annual plants in plots between 1979 and 1981.

Table 8. Observed ranks of attributes of annual floras in six plots downwind of the solar site, 1979-1981.

		Plots					
Attribute	Year	1	2	3	4	5	6
Numbers of different species observed	1979	3	2	5	1	6	4
	1980	2	3	6	4	5	1
	1981	6	5	2	3-4	3-4	1
Aggregate density	1979	2	1	4	3	5	6
	1980	2	1	5	3	6	4
	1981	4	6	1	2	5	3
Aggregate biomass	1979	5	6	4	1	2	3
	1980	1	5	3	4	2	6
	1981	2	5	3	1	4	6
Diversity	1979	1	2-3	2-3	5	6	4
	1980	1	2	3	4	6	5
	1981	6	3-4	5	3-4	2	1

Table 9 gives similar rankings for densities and standing crops of selected species of annuals between 1979 and 1981. Table 10 gives values of $\underline{r}_s$ based on data in Tables 8 and 9. Here, we generally compared 1979-80 and 1980-81, but we have also included two comparisons of 1979 and 1981. With three exceptions, rankings between 1979 and 1980 were more similar than between 1980 and 1981. Apparently, the drastic reduction in numbers and kinds of species during the very poor season of 1981 altered the

Table 9. Observed ranks of densities and dry weight standing crops of species of annuals in six plots downwind of the solar site, 1979-1981.

Species and attribute	Year	Plots					
		1	2	3	4	5	6
Cryptantha angustifolia							
density	1979	3	2	1	5	6	4
	1980	2	3	1	5	6	4
	1981	6	4	3	2	5	1
standing crop	1979	4	2	1	5	6	3
	1980	4	3	1	5	6	2
	1981	6	4-5	2	3	4-5	1
Eriogonum trichopes							
density	1979	2	5	1	4	6	3
	1980	2	5	1	6	4	3
	1981	3	4-5	1	6	4-5	2
Erodium cicutarium							
density	1979	1	2	4	3	5	6
	1980	1	2	4	3	5	6
	1981	1	3	4	2	5	6
standing crop	1979	1	2	4	3	5	6
	1980	1	2	4	3	5	6
	1981	2	5	3	1	4	6
Geraea canescens							
density	1979	5	6	3	4	1	2
	1980	5	6	3	4	1	2
	1981	2	4	5-6	5-6	1	3
Schismus arabicus							
density	1979	1	2	5	3	4	6
	1980	3	2	5	1	6	4
	1981	6	5	1	4	3	2
standing crop	1979	5	6	4	1	2	3
	1980	4	6	2	3	1	5
	1981	4	6	1	2	3	5

Table 10. Values of $\underline{\Sigma d^2}$ and $\underline{r_s}$ based on rankings of various collective attributes of annual floras and of individual species densities in six plots downwind of the solar site, 1979-1981. Statistically significant values of $\underline{r_s}$ are indicated by asterisks.

Attribute or species	Years compared	$\underline{\Sigma d^2}$	$\underline{r_s}$
Number of	1979-80	22	0.37
different species	1980-81	38.5	-0.10
Aggregate	1979-80	6	0.83
density	1980-81	48	-0.37
Aggregate	1979-80	36	-0.03
biomass	1980-81	14	0.60
Diversity	1979-80	2.5	0.93*
	1980-81	63.5	-0.81
C. angustifolia			
density	1979-80	2	0.94*
	1980-81	40	-0.14
standing crop	1979-80	2	0.94*
	1980-81	14.5	0.59
Density of	1979-80	8	0.77
E. trichopes	1980-81	2.5	0.93*
E. cicutarium			
density	1979-80	0	1.00*
	1980-81	2	0.94*
	1979-81	2	0.94*
standing crop	1979-80	0	1.00*
	1980-81	16	0.46
Density of	1979-80	0	1.00*
G. canescens	1980-81	22.5	0.36
S. arabicus			
density	1979-80	16	0.54
	1980-81	56	-0.60
	1979-81	68	-0.94*
standing crop	1979-80	14	0.60
	1980-81	6	0.83

inter-plot associations observed during the first two years. We should also bear in mind, however, that far fewer annuals were counted during the 1981 sampling, and this may have had some effect on the apparent rankings.

Only 10 of 26 values of $\underline{r}_s$ in Table 10 were statistically significant (i.e., >0.886 or <-0.886) so, in general, the hypothesis of no correlation between rankings was not rejected. The easiest situations to interpret are those in which patterns were unaltered throughout the course of the study, e.g., the density of *Erodium cicutarium*. In other instances densities or standing crops were similar between 1979 and 1980 but not between 1980 and 1981. Note that between 1979 and 1981, based on sampling data available, the relative abundance of *S. arabicus* was almost perfectly reversed, i.e., the plots with high densities in 1979 had low densities in 1981, and vice versa.

Does lack of rank correlation in successive years have anything to do with the construction of Solar One? If this were so, one might expect reordering in ranks to show changes in relationships between the plots close to the solar site (1-3) and those farther east (4-6). Several examples may be given to show how this did not occur: number of different species, 1979-80; aggregate density, 1979-80; density of *E. trichopes*, 1979-80. In all of these cases, ranks among the three closest plots and the three more remote plots were rearranged. These sorts of changes are very unlikely to imply an anthropogenic disturbance. In other instances, however--generally between 1980 and 1981--rankings were more drastically reordered. Diversity in the close-in plots and the relative abundances of *C. angustifolia* and *S. arabicus* were all reshuffled so that original rankings were altered.

These last types of changes can only be advanced as possible effects. If the deposition of new sand in Plots 1 and 2 during the fall of 1979 was a disturbing influence, why did we not see more evidence of change when the 1979 and 1980 seasons were compared? In attempting to evaluate the rank correlation tests, we need to take into account several points bearing on the interpretation of such data. First, the estimates we are ranking are subject to error. Second, there are clearly differences between individual species in terms of their susceptibility to disturbance and/or natural influences. Third, effects of anthropogenic (or non-natural) perturbations may be masked during favorable conditions and only expressed when natural stresses are intensified. This point could be related to the apparent differences in the 1980 and 1981 seasons described above.

We may also look at directions and degree of change in attributes of floras, or densities and standing crops of species, from one year to the next. An inspection of year-to-year changes in densities of individual species in six plots (Appendix 4) led us to select Schismus arabicus, Geraea canescens, Cryptantha angustifolia and Erodium cicutarium for such analyses. Numbers of these species followed similar trends in all plots between 1979 and 1981. Densities of Schismus increased between 1979 and 1980, then decreased in 1981. Densities of Erodium tended to increase throughout the study. Densities of the other two species declined in both years. Table 11 gives ratios of changes for these four species. The table also gives associated standard errors for these ratios, based on the standard errors of the numerators and denominators used to compute ratios.

Table 11 . Ratios of changes (± standard errors) in densities of four species of annual plants (year *n*+1/year *n*) in six plots downwind of the solar site, 1979-1981.

Years	Plots	*Cryptantha angustifolia*	*Erodium cicutarium*	*Geraea canescens*	*Schismus arabicus*
1979-80	1	0.88 ± 0.31	3.71 ± 1.07	0.39 ± 0.24	1.85 ± 0.47
	2	0.45 ± 0.13	2.08 ± 0.96	0.64 ± 0.20	2.00 ± 0.34
	3	0.87 ± 0.28	2.08 ± 0.97	0.48 ± 0.24	2.05 ± 0.34
	4	0.96 ± 0.46	6.34 ± 3.49	0.94 ± 0.46	2.38 ± 0.51
	5	0.64 ± 0.35	3.54 ± 2.45	0.53 ± 0.16	1.89 ± 0.46
	6	1.02 ± 0.36	3.27 ± 3.34	0.43 ± 0.17	2.42 ± 0.51
1980-81	1	0.002 ± 0.0008	0.99 ± 0.26	0.20 ± 0.20	0.07 ± 0.020
	2	0.009 ± 0.004	0.94 ± 0.52	0.28 ± 0.30	0.08 ± 0.190
	3	0.047 ± 0.017	4.32 ± 2.00	0.037 ± 0.026	0.19 ± 0.027
	4	0.52 ± 0.48	2.22 ± 1.18	0.041 ± 0.036	0.10 ± 0.025
	5	0.014 ± 0.006	4.64 ± 2.80	0.043 ± 0.020	0.17 ± 0.041
	6	0.19 ± 0.10	28.3 ±22.8	0.027 ± 0.016	0.16 ± 0.033

Table 12 gives ratios of changes in standing crops of three species. Table 13 gives similar data pertaining to four collective attributes of annual floras. We now inquire as to whether ratios in different plots differed significantly

Table 12 . Ratios of changes (+ standard errors) in standing crops of three species of annual plants (year n+1/year n) in six plots downwind of the solar site, 1979-1981.

Plots	Cryptantha angustifolia	Erodium cicutarium		Schismus arabicus
	1979-80	1979-80	1980-81	1979-80
1	0.66 ± 0.27	7.08 ± 2.05	0.17 ± 0.05	0.77 ± 0.20
2	0.46 ± 0.15	3.79 ± 1.93	0.19 ± 0.11	0.61 ± 0.12
3	1.15 ± 0.42	9.31 ± 6.99	1.49 ± 0.94	0.83 ± 0.19
4	0.66 ± 0.33	3.01 ± 2.32	1.33 ± 0.58	0.48 ± 0.10
5	0.74 ± 0.46	8.67 ± 7.51	1.69 ± 1.15	0.76 ± 0.16
6	1.08 ± 0.47	∞	27.5 ± 22.0	0.58 ± 0.15

and, if so, what this may mean. Ratios were compared for all 15 pairs of plots in each set of six plots given in Tables 11, 12 and 13. These calculations showed that none of the ratios pertaining to G. canescens differed. This was also true of ratios of changes in densities of E. cicutarium (both years), of densities and standing crops of S. arabicus and C. angustifolia between 1979 and 1980, of standing crops of E. cicutarium between 1979 and 1980, and of changes in aggregate density between 1979 and 1980. The other 10 comparisons indicated some significant differences between ratios.

Table 13. Ratios of changes (± standard errors) in four collective attributes of annual floras (year n+1/year n) in six plots downwind of the solar site, 1979-1981.

Years	Plots	Number of species per quadrat	Aggregate density	Aggregate dry weight biomass	Diversity
1979-80	1	0.90 ± 0.09	1.83 ± 0.43	1.53 ± 0.29	0.83 ± 0.05
	2	1.03 ± 0.09	1.76 ± 0.29	0.83 ± 0.14	0.91 ± 0.06
	3	0.86 ± 0.07	1.77 ± 0.26	0.92 ± 0.17	0.96 ± 0.07
	4	0.61 ± 0.06	2.34 ± 0.49	0.57 ± 0.11	0.84 ± 0.04
	5	1.20 ± 0.11	1.83 ± 0.43	0.78 ± 0.15	0.97 ± 0.03
	6	0.91 ± 0.09	2.32 ± 0.45	0.64 ± 0.12	1.01 ± 0.05
1980-81	1	0.47 ± 0.04	0.12 ± 0.02	0.10 ± 0.03	1.26 ± 0.08
	2	0.34 ± 0.03	0.09 ± 0.02	0.08 ± 0.03	1.07 ± 0.07
	3	0.63 ± 0.05	0.19 ± 0.03	0.12 ± 0.04	1.04 ± 0.06
	4	0.54 ± 0.06	0.13 ± 0.03	0.25 ± 0.07	0.96 ± 0.06
	5	0.61 ± 0.06	0.19 ± 0.04	0.08 ± 0.03	0.78 ± 0.04
	6	0.71 ± 0.07	0.17 ± 0.03	0.07 ± 0.02	0.79 ± 0.05

Table 14 gives absolute values of *Z*-statistics (i.e., differences between ratios were both positive and negative, but negative signs have been dropped). Again, we need to look for evidence of significant changes in Plots 1 and 2 relative to the other plots. Inspection of ratios of change (Tables 11-13) and associated *Z*-statistics (Table 14) indicates the following points:

Table 14. Z-statistic values for pairs of plots downwind of the solar site, 1979-81. Values of Z exceeding 1.96 are statistically significant at 5% level (*); values exceeding 2.58 are significant at the 1% level (**).

Plot pairs	Species per quadrat 1979-80	Species per quadrat 1980-81	Aggregate density 1980-81	Aggregate biomass 1979-80	Aggregate biomass 1980-1	Diversity 1979-80	Diversity 1980-81	Densities of species, 1980-81 *Cryptantha*	Densities of species, 1980-81 *Schismus*	Standing crop of *Erodium* of 1980-81
1-2	1.02	2.60**	1.07	2.19**	0.48	1.02	1.67	1.60	0.36	0.17
1-3	0.35	2.50*	1.94	1.79	0.40	1.51	2.20**	2.64**	3.53**	1.40
1-4	2.69**	0.97	0.28	3.10**	1.97*	0.16	3.00**	1.07	3.00**	2.00*
1-5	2.11*	1.94	1.56	2.27*	0.48	2.41*	5.39**	2.05*	2.17*	1.32
1-6	0.08	2.96**	1.39	2.93**	0.83	2.53*	5.00**	1.95	2.43*	1.24
2-3	1.49	5.00**	2.77**	0.41	0.80	0.54	0.33	2.18*	3.30**	1.38
2-4	3.89**	2.99**	1.11	1.44	2.23*	0.97	1.41	1.05	0.65	1.93
2-5	1.20	4.03**	2.10*	0.24	0	0.90	3.56**	0.69	2.01*	1.30
2-6	0.94	4.87**	2.22*	1.03	0.28	1.28	3.26**	1.88	2.16*	1.24
3-4	1.63	1.15	1.43	1.75	1.61	1.48	0.94	0.98	2.45*	0.14
3-5	2.61**	0.26	0	0.61	0.80	0.13	3.61**	1.84	0.41	0.13
3-6	0.44	0.93	0.48	1.33	1.12	0.58	3.20**	1.47	0.72	1.18
4-5	4.72**	0.82	1.20	1.02	2.23*	2.60**	2.50*	1.04	1.46	0.23
4-6	2.78**	1.85	0.95	0.43	2.47*	2.66**	2.18*	0.66	1.50	1.14
5-6	2.04*	1.09	0.40	0.73	0.28	0.69	0.16	1.83	0.19	1.17

1. The increase in mean number of species per quadrat in Plot 5 in 1980 differed significantly from changes observed in all but one of the other five plots.

2. The reduction in mean numbers of species per quadrat in Plots 1 and 2 in 1981 was generally more severe than in any of the other plots.

3. Aggregate density declined significantly more in Plot 2 in 1981 than in three other plots.

4. Plot 1 sustained its level of biomass significantly better than four other plots between 1979-80. This was because of unusually high net production by *Erodium cicutarium* in Plot 1. Reduction in aggregate biomass in Plot 4 was less than in other plots between 1980-81.

5. Diversity increased significantly in Plots 5 and 6 relative to Plots 1 and 4 in 1980. Diversity generally increased between 1979 and 1980 because biomass production was more evenly distributed among the various species. In 1979 the biomass of *Schismus arabicus* was more predominating. Ten of 15 inter-plot comparisons showed significant differences in changes in diversity between 1980-81. Plots 1-3 exhibited greater losses in diversity than Plots 5 and 6.

6. Density of *Cryptantha angustifolia* was better sustained in Plot 3 relative to Plots 1 and 2 between 1980-81. Plots 1 and 5 also differed.

7. Reductions in densities of *Schismus arabicus* in Plots 1 and 2 between 1980 and 1981 were significantly greater than in other plots.

8. The reduction of standing crop of *Erodium cicutarium* in Plot 1 between 1980 and 1981 differed significantly from the increase in standing crop in Plot 4. In fact, as we will see, the reductions of biomass of *Erodium* in both Plots 1 and 2 between 1980 and 1981 were apparently a response to

continued accumulation of new sand in portions of these plots.

Of these changes, we judge 2, 3, 7 and 8 to be associated with deposition of sand in Plots 1 and 2. We do not believe that 1, 4 and 6 have anything to do with construction of Solar One, and it is not clear how to interpret 5.

In order to investigate more directly possible effects of new sand on densities and sizes of plants in areas close to the heliostat field, we laid out four 200-m lines running east from the fence around the field in the spring of 1981. On April 3, 1981, we established 1 m^2 quadrats every 20 m along these lines. We then counted and measured the heights of all Schismus arabicus and Erodium cicutarium in these quadrats. These were the only two species present in significant numbers. Table 15 gives mean counts and heights of plants (± standard errors) in 40 quadrats between 0-100 and 100-200 m east of the fence.

Table 15. Mean heights (cm) and numbers (± standard errors) of two species of annuals between 0 and 200 m east of the heliostat field, April 1981.

Species	Distance from field (m)	Number of quadrats	Mean counts per quadrat	Mean heights (cm)
Erodium cicutarium	0 - 100	20	8 ± 4	27 ± 6
	100 - 200	20	116 ± 44	77 ± 20
Schismus arabicus	0 - 100	20	280 ± 73	2.4 ± 0.5
	100 - 200	20	218 ± 70	9.1 ± 4.5

Counts and measurements of S. arabicus do not differ significantly, while those pertaining to E. cicutarium do (p = <0.05). Whereas both size and numbers of Erodium were reduced in areas close to the heliostat field, observations of Schismus in areas of newly deposited sand in 1980 showed that although numbers were reduced those plants germinating achieved somewhat larger sizes (Fig. 12). We interpreted this as owing to reduced competition. Although mean numbers and sizes of Schismus at different distances from the field do not differ in Table 15 , the means vary in directions consistent with the 1980 observations. These kinds of differences are not always supported by

Figure 12 . Area of deposition of new sand downwind of the solar site in the spring of 1980. Notice the lower density (but larger size) of grasses (Schismus arabicus) growing in newly deposited sand.

measurements in the six plots. For example, 1980 measurements of numbers and standing crops of Schismus imply no differences between Plots 1 and 2 and the other plots. However, not all quadrats in close-in plots were affected by sand, and overall plot means may have masked differences expressed in individual quadrats. The effects shown in Table 15 and Figure 12 were observed within 100 m of the heliostat field and were often (as in Fig. 12) highly localized.

The collective implications of all of the data reviewed are that construction activities at the solar site influenced some elements of annual vegetation in Plots 1 and 2. The one conspicuous factor was deposition of sand blown from the surface of the cleared heliostat field. Not every species of plant was affected. As pointed out above, the effects we observed were localized--within 100-125 m of the edge of the field. While disturbances of this nature may affect some species adversely, they often shift delicate competitive relationships to the advantage of other species. The overall effect of such perturbations is to alter the relative abundance of certain species and, in particularly unfavorable years, to reduce species-richness.

4.7. Annual plants in the heliostat field

Sampling of annual plants along three lines within the prospective mirror field in the spring of 1978 showed that aggregate numbers and standing crops in this previously disturbed area considerably exceeded densities and standing crops measured in areas outside (downwind) of the prospective field. For example, estimated aggregate densities ranged from around 3000 to $8900 \cdot m^{-2}$, and aggregate biomass from 670 to 930 $kg \cdot ha^{-1}$. The flora was not particularly rich in terms of different species recorded (ca. 25), but was more diverse

(Simpson indexes from 0.49 to 0.67) than areas downwind of the prospective heliostat field (Turner 1979: p. 24).

On April 26, 1980, about six months after the heliostat field had been cleared and graded Richard Hunter inspected several areas of the field. The ground where pedestals had been installed was virtually bare, but plants were growing in other areas which had been leveled and compacted. Numbers were sparse, but at least 21 kinds of annual plants and 4 species of perennials were observed (Table 16).

Table 16. Annual plants and herbaceous perennials growing in heliostat field in April 1980.

Introduced species	Native species
Bromus tectorum (grass)	_Astragalus didymocarpus_
B. wildenovii (grass)	_Cryptantha angustifolia_
Capsella bursa-pastoris	_Descurainia pinnata_
Chenopodium album	_Eremalche exilis_
Cynodon dactylon (Bermuda grass)*	_Eriogonum trichopes_
Erodium cicutarium	_Euphorbia_ sp.
Hordeum glaucum (grass)	_Geraea canescens_
H. vulgare (grass, barley)	_Hesperocallis undulata_*
Plantago major	_Lupinus shockleyi_
Salsola paulsenii	_Oenothera_ sp.
Schismus arabicus	_Palafoxia linearis_*
Sisymbrium irio	_Plantago insularis_
	_Stephanomeria pauciflora_*

*herbaceous perennial

In June 1981, Herbert Hill observed _Stephanomeria pauciflora_, _Tiliqua plicata_ (herbaceous perennial), _Cryptantha angustifolia_, _Sisymbrium irio_, _Schismus arabicus_ and _Salsola paulsenii_ in the mirror field. Plants which have survived within the field can in no way be considered a natural "flora," and some are viewed as pests. However, the presence of these species on a "volunteer" basis may serve as a guide to future attempts to foster revegetation of portions of the heliostat field.

4.8. Shrubs

Growth and reproduction by shrubs were evaluated at varying distances downwind of the heliostat field during 1980 and 1981. Six plots were located 100, 400 and 800 m east of the field, with two plots at each distance. We worked with the three most common shrubs in the area: creosotebush, bursage and saltbush.

The performance of shrubs was assessed with techniques used in earlier studies in southern Nevada (Turner and Edney 1977, Turner and Vollmer 1980). Measurements were made twice yearly--before and after the growing season. Production of flowers and fruits depends on numbers of nodes or shoot tips, so counts of the latter were an indispensable common denominator for comparisons between shrubs. Counts of reproductive structures were made at times of peak flowering and fruiting, as determined by observations of phenology.

Flowers of creosotebush are produced at young nodes near shoot tips. Any shoot bearing leaves was considered a viable shoot tip, and flowering and fruiting success was evaluated in terms of numbers of potential sites. The inflorescences of bursage are extensions of shoot tips. Counts of shoot tips give a good indication of reproductive potential of a given branch. Flowering stalks grow indeterminately so we estimated numbers of heads on stalks. We simply measured lengths of inflorescences from first to last flower heads. Fruit production was estimated similarly. Saltbushes are dioecious (i.e., shrubs are either male or female). Monitoring of this species was restricted to mature (15+ years) female plants. Flowers are produced on inflorescences growing from stem tips, but we restricted our work to counts of the conspicuous winged fruits.

Ten shrubs of each species were selected in each plot. On each subject shrub five branches were tagged, and the vegetative growth and reproduction associated with these branches were the bases for comparisons. At the beginning of each growing season we measured "growth potential" variables to determine whether shrubs selected for study in different plots had comparable potential for growth and reproduction: i) numbers of tips or nodes per branch, ii) number of tips or nodes per shoot, and iii) lengths of shoots. As the growing seasons progressed we made further counts or measurements relating to shoot elongation, growth of new shoots, and production of fruits and flowers. Experience in Nevada has shown that most of these variables are not normally distributed. Typical distributions are negatively skewed, with a concentration of values at the low end of the scale. We made inter-plot comparisons using Friedman's non-parametric test, which is based on rankings of observations in various plots (Sokal and Rohlf 1969).

Appendix 6 shows selected pre-season growth variables for three kinds of shrubs in 1980 and 1981. Data from the pairs of plots at each distance were combined so means are based on measurements of 20 shrubs. Appendix 6 also summarizes means of various pre-season variables observed in 1980 and 1981, and gives associated X^2 values based on Friedman tests. None of these values showed statistically significant differences in pre-season states of shrubs selected for study.

Tables 17 and 18 show results of measurements of growth and reproduction during the 1980 and 1981 seasons. The 1981 season was so poor that we were not able to make measurements of some reproductive parameters. Values of _p_ with asterisks are statistically significant (* = 5% level, ** = $\leq$1% level). In four cases in Tables 17 and 18 X^2 values are statistically significant, indicating a difference between plots. In all four cases, the difference lies in the plots 400 m downwind of the site. Means for plots close to (100 m) and remote from (800 m) the site were almost identical. It is highly unlikely that the differences observed at an intermediate distance were in any way related to construction activities.

Table 17: Measurements of vegetative growth and reproduction by three kinds of shrubs in areas downwind of the solar site in 1980.

Species	Variable	Distances (m)			X^2	p
		100	400	800		
Ambrosia dumosa	Inflorescences per shoot	1.3	1.1	1.0	0.64	0.73
	Lengths of shoot inflorescences (mm)	14.2	23.9	10.5	8.44	0.01**
	New shoots per branch	5.0	4.9	5.0	0.46	0.80
	Lengths of new shoots (mm)	56.1	49.9	49.4	0.59	0.75
Larrea tridentata	Nodes per shoot tip	4.7	4.8	4.5	0.10	0.95
	Shoot lengths (mm)	218	189	193	4.94	0.08
	Flowers per branch	32.3	26.3	31.6	11.11	0.004**
	Fruits per branch	21.2	18.0	21.9	5.99	0.05*
Atriplex polycarpa	New shoots per branch	2.8	2.7	2.8	0.74	0.72
	Lengths of new shoots (mm)	176	113	138	0.31	0.86
	Reproductive indexes (per branch)	1.5	0.7	1.4	5.66	0.06

Table 18 . Measurements of vegetative growth and reproduction by three kinds of shrubs in areas downwind of the solar site in 1981.

		Distances (m)				
Species	Variable	100	400	800	X^2	p
Ambrosia dumosa	Inflorescences per shoot	none	none	none	-	-
	New shoots per branch	1.3	1.5	1.7	2.94	0.23
	Lengths of new shoots (mm)	15.5	24.5	20.7	4.25	0.12
Larrea tridentata	Nodes per shoot tip	4.1	3.7	4.2	0.95	0.62
	Shoot lengths (mm)	67.9	58.8	67.2	6.32	0.04*
	Flowers per branch	9.8	9.2	10.2	3.35	0.19
	Fruits per branch	4.4	4.5	5.7	1.69	0.43
Atriplex polycarpa	New shoots per branch	4.6	4.3	3.4	3.19	0.20
	Lengths of new shoots (mm)	70.4	68.9	50.5	3.61	0.16
	Reproductive indexes	not measured			-	-

4.9. Birds

Observations of birds within the prospective heliostat field and in areas downwind of the field were made between September 1978 and September 1979--before construction began. Later observations were restricted to areas downwind of the solar site until January 1981, when a program of observations within the heliostat field was established. This included one transect 450 m long, which completely encircled the innermost ring of heliostats, four 150 m transects (one in each quadrant of the field) around the outermost ring of heliostats, and four 100 m transects (one in each quadrant) midway between the innermost and outermost ring of heliostats. Observations and counts were made in these areas in January, April, May and July of 1981. Arrangements were also made for the collection and preservation of birds found dead in the construction area by SCE and/or DOE employees.

Pre-construction observations in 1978-79 used the Emlen (1971, 1977) transect method to make density estimates within the prospective heliostat field and areas downwind of the field. Transects ranged from 800 to 1600 m in length. The observer walked these lines during the 2 1/2-3 hours after sunrise at about 1 km hr, recording all visual and auditory detections along each side of a line. Converting these counts to estimates of density was based on estimates of the widths of strips in which detections of various species could be made. Some species were detected over greater distances than others. Estimated strip widths were 60 m for most of our species, but were as high as 120 m for some types (e.g., Say's Phoebe, Yellow-rumped Warbler, Savannah Sparrow), and even 500 m for the Western Kingbird. For some species, strip widths varied with season and amount of vegetative cover. No strip widths were estimated for wide-ranging species (e.g., falconiforms, ravens), and densities of these species were not estimated. Other habitats in the vicinity of the solar site were inspected and simple lists of birds observed were maintained. Such observations were made in adjoining alfalfa fields, along tamarisk windbreaks, and in the vicinity of evaporation ponds.

Pre-construction observations of birds were described earlier (Turner 1979). More than 80 kinds of birds were observed during 1978 and 1979. Subsequent observations increased the list of species to 108, with 70 of these seen in the vicinity of evaporating ponds. Here, waterfowl were predominant in winter while shorebirds were common in fall and spring. The Horned Lark (Eremophila alpestris) was the most common species in the prospective heliostat field, although its importance diminished during winter when migrant sparrows predominated.

Table 19 summarizes pre-construction observations of birds within the prospective heliostat field and also gives counts of birds seen there during the first half of 1981--after most of the heliostat pedestals and some of the heliostats were in place. The post-construction fauna was obviously diminished--both in terms of species richness and diversity. Most of the Horned Larks were observed on the ground, and most were in the northwest quadrant of the field. This was apparently owing to the proximity of an alfalfa field. All species except the Horned Lark, the American Kestrel and the Mountain Bluebird were observed above pedestal height. Swallows and Ravens fed or hunted over the field, whereas blackbirds were seen flying between feeding and roosting areas. No birds were observed on pedestals, heliostats, or around the periphery of the core area. Birds within the heliostat field displayed normal behavior and

Table 19. Birds observed in prospective heliostat field (September 1978, January, March and May 1979) and after installation of some heliostats in 1981. Pre-construction data record presence of species (+) or a range of estimated densities ($n \cdot km^{-2}$) if species was observed at different times. Post-construction data give numbers of birds seen during six (January), four (April), ten (May) and five (July) counting periods. Dashes indicate that species were not observed.

Species	September 1978-May 1979	1981 Jan	Apr	May	July
Turkey Vulture	+	-	-	-	-
Marsh Hawk	+	-	-	-	-
American Kestrel	-	2	-	-	-
Prairie Falcon	+	-	-	-	-
Killdeer	+	11	-	-	-
Burrowing Owl	+	-	-	-	-
Western Kingbird	0.1	-	-	-	-
Say's Phoebe	1.0	-	-	-	-
Horned Lark	50 - 540	0	1	73	53
Rough-winged Swallow	-	-	-	-	1
Barn Swallow	+	-	-	3	-
Cliff Swallow	-	-	-	2	-
Common Raven	+	1	-	3	-
Loggerhead Shrike	1.0 - 2.1	-	-	-	-
Yellow-rumped Warbler	2.1	-	-	-	-
Mountain Bluebird	-	2	-	-	-
Western Meadowlark	4.2 - 7.3	-	-	-	-
Starling	+	-	-	-	-
Red-winged Blackbird	0.4	-	-	4	-
Brewer's Blackbird	+	-	-	15	-
Savannah Sparrow	3.1	-	-	-	-
Lark Sparrow	4.2	-	-	-	-
White-crowned Sparrow	9.1	-	-	-	-
Song Sparrow	10.4	-	-	-	-

only one dead bird was found. A Say's Phoebe (Sayornis saya) was found dead at the base of a building in late March 1981.

Between September 1978 and May 1981 densities of birds were estimated from transect data in an area 300-600 m downwind of the eastern edge of the heliostat field. Appendix 7 summarizes these estimates, together with indications of the presence of some species whose densities were not estimated. Our principal concern, however, is with time changes in numbers of Horned Larks in this area and their comparisons with numbers in other areas farther from the heliostat field. Table 20 summarizes estimates of densities of Horned Larks in the plot 300-600 m east of the field and in three other areas in which transect counts were made.

Table 20. Estimates of densities ($n \cdot km^{-2}$) of Horned Larks downwind of the solar site between September 1978 and May 1981. Dashes indicate that no observations were made in areas.

Dates	Distances downwind (m) from eastern edge of field			
	50	300 - 600	1900 - 2200	4100 - 4450
Sept 1978	92	100	-	-
Jan 1979	4.2	4.2	-	-
March	63	37	-	-
May	108	44	-	-
Sept	-	20.8	-	-
Jan 1980	-	4.5	3.0	-
Apr	-	20.8	-	41.7
May	-	34.2	-	30.7
Sept	-	14.6	-	18.8
Jan 1981	-	16.4	-	0
Apr	-	15.6	-	10.4
May	-	39.6	-	17.7

We initially established a control area between 1.9 and 2.2 km east of the field, but later moved to another area (4.1 - 4.5 km east of the field) because it was more comparable to the close-in site. Given the mobility of birds, about all that can be said of the sampling data between January 1980 and May 1981 is that there were no obvious indications of effects of construction on larks 300-600 m east of the edge of the field. Estimated densities in this area were generally higher than those observed farther east (except in April 1980). Larks were present in the easternmost area in January 1981, but were only seen in flight over the plot. The higher density in the 300-600 m area in May 1981 was due to the proximity of a recently mowed alfalfa field.

4.10 Rodents

Small rodents were trapped both on the prospective heliostat field and in areas downwind of the field between September 1978 and July 1979 before construction began (Turner 1979: 43 et seq.). Mammals occupying the solar site were typical of the northern Mojave Desert: coyotes, kit foxes, jackrabbits, cottontails, pocket gophers, kangaroo rats, pocket mice, deer mice, grasshopper mice, three kinds of ground squirrels and various bats.

Beginning in October 1979 we focused on two areas east of the heliostat field: Plot 21 was about 150 m east of the eastern edge of the field; Plot 22 was about 600 m east of the field. Each of these grids was composed of 100 trapping stations arranged in a 10 x 10 15-m grid. We used two Sherman-type live traps per station and one Tomahawk live trap for ground squirrels. All three traps were used at night and the Tomahawk traps during the day. Rodents captured were weighed, marked by toe-clipping, and released. After five nights of trapping most of the animals captured were marked. Traps were then shifted to assessment lines and operated for four nights. Assessment lines extended beyond the boundaries of the trap grids, and captures of rodents along these lines were used to estimate the actual area trapped by the 10 x 10 grids. Trapping records pertaining to four sex-age groups of each species were analyzed separately, to yield density estimates for each group. These components were summed to provide an estimate of the total population. The method of analyzing capture-recapture data has been described by O'Farrell et al. (1977). Live weights of rodents were determined in the field using a Pesola spring balance.

Table 21 summarizes estimates of density of kangaroo rats (Dipodomys merriami) and ground squirrels (Spermophilus tereticaudus) in the two areas between September 1978 and July 1981. Ground squirrels were not active during the winter months, and only one individual was trapped in October 1979.

Table 21. Estimated densities ($n \cdot ha^{-1}$) of kangaroo rats and ground squirrels in two plots downwind of the solar site, 1979-1981.

Dates	Kangaroo rats Plot 21	 Plot 22	Ground squirrels Plot 21	 Plot 22
Sept 1978	82.3	74.7	1.8	1.1
Jan 1979	46.1	36.5		
May	25.7	21.0	6.3	6.2
July	35.7	24.0	7.6	9.7
October	18.4	10.5		
Jan 1980	10.9	5.4		
April	9.4	5.3	8.0	4.0
July	9.4	9.3	16.1	14.3
Sept	13.3	4.0	4.4	1.3
Apr 1981	5.2	9.1	9.6	9.5
July	4.7	4.7	3.5	2 5

Time trends in apparent numbers of ground squirrels in the two areas were almost identical, giving no reason to suspect that the general status of the more proximal population was deleteriously affected. The significance of the kangaroo rat data are less clear, although it is immediately obvious that numbers of Dipodomys in the two plots decreased dramatically during the 34 months of observation. When estimated densities ($\underline{d}$) in the two plots were regressed on time ($\underline{t}$, in months) we obtained the results set forth in Table 22.

Table 22. Results of linear regression analyses of densities of kangaroo rats in two plots downwind of the solar site, 1979-1981.

	Plot 21	Plot 22
Regression equation	$\underline{d} = -1.81\underline{t} + 53.7$	$\underline{d} = -1.49\underline{t} + 43.3$
Correlation coefficient	-0.82	-0.75
$\underline{F}$-value for test of non-zero slope	18.8	11.4
Standard error of regression coefficient	0.42	0.44

The intercepts estimated by these analyses indicate that Plot 21 (closest to the heliostat field) supported somewhat higher densities of kangaroo rats than Plot 22 before any construction began. This difference was fairly well sustained throughout the period of construction, although it was not manifested in the 1981 sampling. The difference in the regression coefficients (indicating the slope of the decline in numbers in the two plots) may be tested by estimating the standard error of the difference:

$$\underline{s}_d = (s.e._1{}^2 + s.e._2{}^2)^{1/2}$$

and comparing the difference between the regression coefficients with $\underline{s}_d$. The value of $\underline{s}_d$ is 0.608 and the difference between the regression coefficients is 0.32 (1.81 - 1.49). Then 0.32/0.608 (or 0.53) is a $\underline{Z}$-statistic with a mean of zero and unit standard deviation. Clearly the regression coefficients fitted to data from the two plots do not differ significantly. We see, then, no evidence that numbers of kangaroo rats and ground squirrels in the proximal plot were adversely affected by construction activities. The decline in numbers of kangaroo rats in Plot 21 was matched by observations in Plot 22, and was apparently owing to a sequence of conditions unfavorable for reproduction and/or survival of young.

Reproductive success of kangaroo rats and ground squirrels in the two plots was evaluated by comparing the relative numbers of juveniles trapped in the two areas during July of 1979, 1980 and 1981 (Table 23). Numbers of juveniles and adults in Plots 21 and 22 were compared by X^2 tests (with corrections for continuity). Table 23 gives values of X^2 for these comparisons. With one exception, these tests showed that relative numbers of juvenile rodents in the two areas were insignificantly different. In July 1980 the proportion of young ground squirrels in Plot 21 was significantly greater than that observed in the control area (Plot 22). There was no evidence that reproductivity by kangaroo rats and ground squirrels in the plot closest to the solar site was deleteriously influenced by construction activities.

Table 23. Numbers of juvenile and adult kangaroo rats and ground squirrels trapped in two plots downwind of the solar site, 1979-1981. Value of $X^2_{0.05}$ is 3.84.

Species	Date	Plot	Juvenile	Adult	X^2
<u>Dipodomys merriami</u>	July 1979	21	45	66	<0.01
		22	39	60	
	July 1980	21	13	9	0.63
		22	18	22	
	July 1981	21	1	16	1.41
		22	5	21	
<u>Spermophilus tereticaudus</u>	July 1979	21	12	18	0.68
		22	4	13	
	July 1980	21	45	25	5.16*
		22	15	23	
	July 1981	21	2	19	0
		22	1	10	

Table 24 gives mean live weights for adult male and female kangaroo rats in the two plots between September 1978 and July 1981. These data show a slight difference between the sexes and peak body weights during the spring, (see also Turner and Chew 1981, p. 219), but give no indication of any differences between the plots.

Table 24. Mean live weights (g) of adult kangaroo rats occupying two plots downwind of the solar site between September 1978 and July 1981.

Dates	Plot 21		Plot 22	
	males	females	males	females
Sept 1978	39.0	37.0	39.7	37.7
Jan 1979	37.0	35.0	37.0	34.7
March	44.0	41.3	43.7	41.7
July	37.7	35.7	38.0	35.3
Oct	36.3	34.7	36.0	34.0
Jan 1980	37.7	33.3	39.3	34.7
Apr	44.3	43.3	44.3	45.7
July	41.0	37.3	39.0	39.0
Sept	36.7	35.0	32.7	34.7
Apr 1981	40.3	36.7	38.0	33.7
July	38.3	36.3	37.5	35.4
Overall means	38.4	36.4	37.6	35.6

4.11. Reptiles

The following kinds of reptiles were observed in the vicinity of the solar site: gridiron-tailed lizards, western whiptailed lizards, leopard lizards, desert iguanas, horned lizards, long-tailed brush lizards, glossy snakes, sidewinders, red racers, bullsnakes, long-nosed snakes, and the desert tortoise.

Lizards were counted along lines across the prospective mirror field and in areas downwind of the field in the spring and summer of 1979 before construction began (Turner 1979: p. 47 et seq.). In the spring of 1980 we made counts of lizards along three 800 m north-south lines downwind of the heliostat field: Line 20 (50 m east of the field), Line 31 (360 m east) and Line 32 (610 m east). Lines were walked in the morning, usually between 0700 and 1200--the normal period of peak activity of lizards occupying the area.

The two most abundant species were gridiron-tailed lizards (_Callisaurus draconoides_) and whiptailed lizards (_Cnemidophorus tigris_), and we report observations of these species. Turner (1979: p. 48) showed that the apparent incidence of _Callisaurus_ was about the same between early May and late July, with no evidence of a seasonal effect on counts. Counts of _Cnemidophorus_, however, were highest early in the season and diminished significantly towards the end of July.

Table 25 gives mean numbers of these two species counted on three lines in 1979 (prior to construction activities) and in 1980 and 1981.

Table 25. Mean numbers of lizards counted (per walk) along 800 m lines downwind of the solar site, 1979-1981. Total lizards counted are given in parentheses.

Species	Year	Line 20	Line 31	Line 32
Callisaurus draconoides	1979	1.40 (105)	1.25 (96)	0.94 (72)
	1980	0.34 (26)	0.18 (14)	0.40 (31)
	1981	0.02 (1)	0.05 (3)	0.28 (18)
Cnemidophorus tigris	1979	1.35 (101)	1.79 (138)	1.79 (138)
	1980	2.74 (211)	1.40 (108)	1.16 (89)
	1981	0.97 (62)	0.78 (50)	0.47 (30)

The general points to emphasize here are i) the decline in apparent abundance of Callisaurus on all lines between 1979 and 1981, and ii) the conspicuously greater abundance of Cnemidophorus along Line 20 in the spring of 1980. Because the means in Table 25 are based on counts made during the entire season, we present some of the counting data pertaining to these species in greater detail in Tables 26 and 27 . There is no question as to the reality of the decline in apparent abundance of gridiron-tailed lizards between 1979 and 1981, for this was observed in other parts of the Barstow region as well. For our purposes it is more important to consider possible differences between lines. Table 26 shows that, in general, 1979 counts of these lizards did not differ as a function of distance from the prospective heliostat field (although the July counts along

Table 26. Mean counts (± one standard error) of gridiron-tailed lizards along three lines downwind of the solar site during June and July 1979, 1980 and 1981.

Counting periods	Lines 20	31	32
June 12 - 16, 1979	1.29 ± 0.37	1.32 ± 0.24	0.85 ± 0.21
June 9 - 11, 1980	0.42 ± 0.19	0.33 ± 0.14	0.50 ± 0.15
June 8 - 10, 1981	0	0.08 ± 0.08	0.08 ± 0.08
June 19 - 28, 1979	1.55 ± 0.31	1.05 ± 0.28	0.89 ± 0.26
June 16 - 18, 1980	0.50 ± 0.19	0.17 ± 0.17	0.33 ± 0.19
June 23 - 25, 1980	0.25 ± 0.13	0.08 ± 0.08	0.33 ± 0.14
June 15 - 17, 1981	0.08 ± 0.08	0	0.33 ± 0.19
June 22 - 24, 1981	0	0	0.50 ± 0.20
July 9 - 14, 1979	1.25 ± 0.28	1.75 ± 0.32	0.94 ± 0.19[1]
June 30 - July 2, 1980	0.50 ± 0.23	0	0.08 ± 0.08
July 7 - 9, 1980	0.08 ± 0.08	0.25 ± 0.18	0.50 ± 0.15[2]
June 29 - July 1, 1981	0	0.08 ± 0.08	0.25 ± 0.13

[1] significantly less than Line 31

[2] significantly greater than Line 20

Line 32 were lower than those along Line 31). The situation was generally unchanged in 1980, except that the July counts along Line 32 were higher than those along Line 20. It is harder to judge the 1981 observations because counts were so low along all lines, but the virtual absence of these lizards along Line 20 is worthy of note, particularly since the reduction in numbers was not so drastic along Line 32.

Table 27 shows a general similarity of counts of whiptailed lizards along lines in 1979, except that counts in early June were significantly less along Line 20 than on Lines 31 and 32. The really distinct differences reflected in Table 27 are the counts of whiptailed lizards on Line 20 during

Table 27. Mean counts (± one standard error) of whiptailed lizards along three lines downwind of the solar site during June and July 1979, 1980 and 1981.

Counting periods	Lines 20	 31	 32
June 12 - 16, 1979	0.53 ± 0.21[1]	1.47 ± 0.33	1.35 ± 0.33
June 9 - 11, 1980	2.67 ± 0.38[2]	1.42 ± 0.45	0.92 ± 0.42
June 8 - 10, 1981	0.42 ± 0.15	0.67 ± 0.28	0.42 ± 0.15
June 19 - 28, 1979	0.85 ± 0.15	1.16 ± 0.23	1.05 ± 0.21
June 16 - 18, 1980	2.00 ± 0.33[2]	0.42 ± 0.15	0.58 ± 0.34
June 23 - 25, 1981	2.33 ± 0.36[2]	0.42 ± 0.26	0.42 ± 0.19
June 15 - 17, 1981	0.75 ± 0.13	0.67 ± 0.26	0.58 ± 0.26
June 22 - 24, 1981	0.58 ± 0.29	0.67 ± 0.23	0.25 ± 0.18
July 9 - 14, 1979	1.00 ± 0.24	0.94 ± 0.21	1.63 ± 0.33
June 30 - July 2, 1980	2.92 ± 0.61[3]	1.75 ± 0.33	1.33 ± 0.36
July 7 - 9, 1980	1.83 ± 0.37[3]	1.00 ± 0.39	0.83 ± 0.27
June 29 - July 1, 1981	0.47 ± 0.23	0.17 ± 0.11	0.33 ± 0.14

[1] significantly less than Lines 31 and 32

[2] significantly greater than Lines 31 and 32

[3] significantly greater than Line 32

the summer of 1980. The contrast between lines in 1980 is heightened by the fact that the 1981 counts did not differ significantly.

We believe that construction activities in some way influenced numbers of whiptailed lizards counted on Line 20 during the spring and summer of 1980. We can eliminate the possibility of an increase in numbers owing to improved reproduction and/or survival of lizards--the response was simply too rapid. There are several other possible explanations: i) lizards moved into the area as a result of clearing and grading the heliostat field, ii) lizards moved into the area from areas farther east, and iii) deposition of new sand along Line 20 made whiptailed lizards more conspicuous and readily counted. The last explanation is doubtful because, as we showed previously, new sand entered close-in areas during the spring of 1981 as well as 1980.

The idea of animals moving out of the disturbed heliostat field into adjoining areas is superficially attractive, but not strongly supported by counts of other kinds of lizards. Counts of desert iguanas in 1980 were conspicuously higher along Line 20 than in 1979, but so were counts along Lines 31 and 32. On the other hand, counts of gridiron-tailed lizards and horned lizards declined along <u>all</u> lines between 1979 and 1981. Rodent trapping during the spring of 1980 gave no evidence of increased numbers in the plot closest to the heliostat field, but we must recall that this plot was about 300 m east of the field, while Line 20 was only 50 m downwind. It is also important to bear in mind that when clearing and grading began in the fall of 1979, adult whiptailed lizards were dormant and underground. There is no way of knowing how well these animals survived early construction operations in the heliostat field. It is possible that some of these lizards survived, emerged in the spring of 1980, and quickly moved off the open surface of the field into less disturbed environments. We can neither prove nor refute this premise. We consider it very unlikely that whiptailed lizards moved into areas along Line 20 from locales farther east (downwind) of the heliostat field, but again we cannot disprove this possibility.

4.12. Sensitive species

The general area of the Barstow STPS was surveyed in 1972 in connection with the permitting process for the Cool Water Combined Cycle Project, and the site of Solar I was examined in April 1977 (Environmental Improvement Agency 1977). These surveys reported no rare or endangered species of plants or animals on the site. A fuller and more recent discussion of this aspect of the general area of the solar site has been developed for the SCE Coal Gasification Demonstration Project to be constructed south of Solar I. Several sensitive species of plants and animals are listed as possible inhabitants of the area. The California Native Plant Society has proposed a classification of "rare" for *Dalea arborescens*, *Linanthus arenicola* and *Astragalus jaegerinus*, and a status of "endangered" for *Eriophyllum mohavensis*. The U. S. Department of Interior has proposed *Chorizanthe spinosa* and *Salvia columbariae ziegleri* as "rare." Of these plants, we have observed only *Linanthus arenicola* in study plots east of the solar site. We have, however, identified in our study areas another species--*Muilla coronata*--which is classified as "rare" by the California Native Plant Society. This species is not listed federally.

Four fully protected species of vertebrates either occur, or may occur, near the Solar I site. The desert tortoise (*Gopherus agassizii*) is under consideration for federal listing as threatened in California. Tortoises have been observed by DOE and SCE employees in the vicinity of the STPS, and we recorded one tortoise about 800 m east of the site. This species is apparently not common in the area, but does occur there. The Prairie Falcon (*Falco mexicanus*) and Golden Eagle (*Aquila chrysaetos*) occur around the site and "...are known to nest within eight miles of the ...area," according to comments in the draft version of the Gasification Demonstration Project Environmental Impact Report.

The most interesting problem involving sensitive species is that of the status of the ground squirrels (*Spermophilus* spp.) occupying the area downwind of the solar site. Two closely related species (*S. tereticaudus* and *S. mojavensis*) occur in the northwestern corner of the Mojave Desert. The latter species, the Mojave ground squirrel, is classified as "Rare" by the California Department of Fish and Game (Hoyt 1972, Wessman 1977). The ground squirrels in the vicinity of Solar One have, at various times in the past, been identified as both species. In the course of our work we trapped ground squirrels which could not be definitely identified. We supported a special study by David Hafner during the summer of 1981 to resolve this issue, and Hafner's findings will be reported separately. The general nature of Hafner's conclusions are as follows: i) on the basis of conventional morphological criteria morphs of *both* species of ground squirrels occupy the area downwind of the solar site, ii) the *S. mojavensis* morphs were trapped in areas with gravelly soils, the *S. tereticaudus* morphs were trapped in more sandy areas--a distinction which has been typically true of past experience, iii) all ground squirrels downwind of the solar site have chromosome numbers of 36, and chromosome morphologies were identical, iv) on the basis of karyotypic data (i.e., chromosome counts and morphology) the squirrels should be considered *S. tereticaudus*.

5. Discussion

If it is generally acknowledged that solar power plants are ecologically "benign", why is it necessary to conduct any sort of environmental monitoring program at Solar One? The answer to this question is partly based on public perceptions of "solar energy", which are generally related to small dispersed systems rather than to large central receiver-type power plants. More importantly, provisions of the National Environmental Policy Act strongly imply the need for assessments extending beyond the stages of initial project planning (Council of Environmental Quality 1978). There is nothing more destructive to an emerging technology than the post facto discovery of unforeseen environmental problems.

Our observations during construction of Solar One are reassuring in that off-field environmental effects were apparently highly localized. Wind removal of loose sand from the cleared heliostat field and ensuing indirect effects on some species of plants and animals occupying close-in areas were the only impacts identified.

How effective, in retrospect, was the environmental monitoring program during construction of Solar One? First of all, we could have placed our study plots more strategically. Judging from our findings, observations should have been concentrated in an area lying in an arc 100-200 m downwind of the eastern edge of the heliostat field. None of our observations indicated effects at greater distances. We point out, however, two problems bearing on the siting of these areas: i) some uncertainty as to where, exactly, the eastern edge of the field would lie, and ii) the lack of any precedents upon which to base the positions of close-in and remote plots. The distribution of effort in on-field and off-field areas was, in our view, appropriate for the period of observation involved. Had work continued into testing and operational phases, our planned programs of bird work and documentation of recolonization of the heliostat field would have matured. Our measurements of micrometeorological variables clearly emphasized the need for automated systems--and such capacity was developed during the last 9 months of observations. We would not, given another opportunity of this nature, make observations of large woody perennials. Our observations at Barstow, coupled with earlier experience in Jackass Flats, Nevada (Turner and Edney 1977, Turner and Vollmer 1980), indicate that measurements of the sort we made are sensitive only to major differences in regimens of rainfall, and possibly temperature. Given a program of, say, 5-10 years duration, the measurements we made might indicate statistically significant responses. In the shorter term, we would only be able to measure reactions to very drastic disturbances. We also believe that observations of birds in off-field situations are unlikely to be instructive. Because birds are so mobile it is difficult to find areas of potential impact and similar control areas where changes in apparent abundance of indicator species can be confidently interpreted. Based on experience at Barstow, annual plants, rodents and reptiles emerged as the most suitable animal groups. A carefully limited analysis of selected species of arthropods is another possibility.

Temperature is, of course, one of the most influential physical factors which affects biological and ecological processes. These processes, mediated by the physical structure and behavior of organisms, influence temperatures of plants and animals. For at least one group of desert perennials, plant surface temperature differences of only 0.1°C influenced population changes

(Nobel 1980). Thus, air temperature differences of the nature we observed 2 m and 2 cm above the ground at two sites located near the heliostat field could influence organism function. As pointed out earlier, however, the observed temperature differences have not been related to heliostat field construction or presence.

The overall areal extent of air temperature differences has not yet been established, so the importance of the differences in terms of total area affected is poorly known. Finally, no attempt has been made to examine the coupling between air temperature differences and temperatures of organisms occupying the downwind ecosystem. When monitoring was begun we expected that further data collection during operation and testing of the power plant would help answer these questions.

The general approach to biological monitoring depended on detection of changes in the size and composition of populations of organisms. Hence, subtle changes in physiological states of individuals were not detected unless these disturbances influenced survival and/or reproduction. There was also the risk that the indicator species were unaffected while other unmonitored species were affected. Our plan assumed that if construction and operation of the facility affected organisms beyond the heliostat field, the effects would be more conspicuously expressed in areas adjoining the field than at greater distances. Our plan could not discriminate between non-divergence owing to lack of effects and non-divergence because of equivalent impacts in areas immediately next to, and at a distance from, the field. Finally, the plan was vulnerable to purely random differences in performances of populations under observation, even though such performances were unaffected by construction of the power plant. This problem would exist in almost any program, and all of our interpretations of divergences were tempered by general experience with biota of the Mojave Desert.

If a larger solar thermal power plant should be constructed, and if there were an associated program of environmental monitoring, how could the program be improved? This question should be considered because SCE is already planning the construction of a 100MWe STPS somehwere in the Mojave Desert. Judging from our findings at Barstow, the problem of windblown sand should receive primary emphasis. We measured this in two ways at Solar One--with saltation meters and by measurements of increased depth of sand at selected sampling sites. In our view, the latter is preferable. The procedure is direct, and avoids problems associated with extrapolating amounts of sand collected through small apertures, as well as failure of meters to accommodate total fluxes. It is not immediately clear how measurements should be scaled up from a 10 MWe plant to one of 100 MW, but the sampling grid should be designed to give an adequate measure of the geographic heterogeneity of new sand deposition. Is it possible to develop a model of sand transport and deposition based on physical characteristics of the heliostat field substratum and local meteorology? Can any predictions be made as to the ultimate stabilization of transported sand?

Transport and deposition of new sand may impose indirect effects on plants and animals occupying downwind environments. Based on experience at Barstow, it would be wise to plan experiments to gauge effects of sand deposits on germination, growth and survival of selected species of annual plants. Such assessments would be very difficult to accomplish in field situations, but could be carried out in the greenhouse. Another ecological problem has to do with the possible displacement of animals from the area cleared for heliostats and other structures. Such an effect was suggested, but not proven, by observations of whiptailed lizards downwind of the Barstow solar site. Impacts of this nature could be evaluated by experiments involving marking and release of animals occupying the prospective heliostat field.

We commented earlier on our expectation of continued environmental monitoring at Solar One during testing and operation of the power plant. Although such work will not be carried out, it is worth reviewing the program we envisioned in a general manner. In June 1981 a meeting was held under the aegis of the San Francisco Operations Office of DOE to consider a continuing program of environmental monitoring at Solar One. The principal outcome of this meeting was a prioritized ranking of prospective monitoring endeavors. Little interest was evinced in the problem of deposition of drift water from the cooling towers of the power plant or in the problem of NO_x production around the wall of the receiver. The environmental problems judged to have the greatest importance were i) effects of the receiver tower and other plant structures on birds, ii) possible effects of birds on the reflective surfaces of heliostats, and iii) the possible dangers to birds from heliostat beams focused on the central receiver.

Other problem areas accorded high priorities were i) continued meteorological measurements downwind of the heliostat field, and coordination of these measurements with related observations within the field, ii) measurements of wind speed profiles and air turbulence upwind of the heliostat field and in the wake of the field, iii) observations of recolonization of the heliostat field by plants and animals, and iv) continued "biological measurements" in the downwind environment. We have already discussed how these last observations should be revised in terms of recent experience.

References

Avery, M. L., P. F. Springer and J. F. Cassel. 1978. The composition and seasonal variation of bird losses at a tall tower in southeastern North Dakota. American Birds 32: 1114-1121.

Benson, L. and R. A. Darrow. 1954. The trees and shrubs of the southwestern deserts. Univ. Arizona Press, Tucson.

Bhumralkar, C. M., A. J. Slemmons and K. C. Nitz. 1980. Numerical study of local/regional changes caused by a large solar central receiver power plant. U.S. Department of Energy Report DOE/CS/20537-1, SRI International, Menlo Park, CA.

Black and Veatch, Electric Power Research Institute. 1977. Environmental assessment of solar energy power plants. EPRI Report RP955-1.

Burt, W. H. and R. P. Grossenheider. 1952. A field guide to mammals. Houghton Mifflin Co., Boston.

Caldwell, L. D. and G. J. Wallace. 1966. Collections of migrating birds at Michigan television towers. Jack-Pine Warbler 44: 117-123.

Crawford, R. L. 1974. Bird casualties at a Leon County, Florida TV tower: October 1966--September 1973. Tall Timbers Res. Sta. Bull. No. 18. 27 pp.

Davidson, M. and D. Grether. 1977. The central receiver power plant: an environmental, ecological, and socioeconomic analysis. Lawrence Berkeley Laboratory Report LBL-6329, University of California, Berkeley.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88: 323-342.

Emlen, J. T. 1977. Estimating breeding season bird densities from transect counts. Auk 94: 455-468.

Energy and Environmental Analysis, Inc. 1979. Draft programmatic environmental assessment of the U.S. Department of Energy's solar thermal power systems program. Energy and Environmental Analysis, Inc., Arlington, VA.

Energy Research and Development Administration. 1977. Solar program assessment: environmental factors. U.S. Energy Research and Development Administration Report ERDA 77-47/4.

Environmental Applications, Inc. 1980. Southern California Edison--Coolwater Site meteorological and air quality monitoring program. Annual Report. Volume One--Discussion and data summary. Environmental Applications, Inc., La Jolla, CA.

Environmental Improvement Agency. 1977. Environmental Impact Assessment/Environmental Impact Report. Environmental Improvement Agency, San Bernardino County, Calif.

Frei, W., T. Shibata and G. C. Huth. 1979. Environmental change detection in digitally registered aerial photographs. In: "Applications of Digital Image Processing III." Society of Photo-Optical Instrumentation Engineers Vol. 207, Bellingham, WA.

Ganier, A. F. 1962. Bird casualties at a Nashville TV tower. Migrant 33: 58-60.

Hoyt, D. F. 1973. Mohave ground squirrel survey. Calif. Dept. Fish and Game, Special Wildlife Investigation, Project W-54-R-4. 10 pp.

Laskey, A. R. 1963. Casualties at WSIX TV tower in autumn. Migrant 34: 15.

Lindberg, R. G. and R. L. Perrine. 1981. Environmental effects of solar thermal power systems. Environmental considerations in siting a solar-coal hybrid power plant. I. Environmental assessment. U.S.

Department of Energy Report UCLA 12/1282, University of California, Los Angeles.

McDonnell Douglas Astronautics Company. 1979. Meteorological station requirements specification (RADL Item 7-19), Department of Energy Report SAN/0499-26, Huntington Beach, CA.

Munz, P. A. 1974. A flora of southern California. Univ. Calif. Press, Berkeley.

Nobel, P. S. 1980. Influences of minimum stem temperatures on ranges of cacti in southwestern United States and central Chile. Oecologia 47: 10-15.

O'Farrell, M. J., D. W. Kaufman and D. W. Lundahl. 1977. Use of line-trapping with assessment line method for density estimation. J. Mammal. 58: 575-582.

Oke, T. R. 1978. Boundary layer climates. J. Wiley and Sons, New York.

Patten, D. E. 1978. Solar energy conversion: an analysis of impacts on desert ecosystems. Final Report to the U.S. Department of Energy. Arizona State Univ., Tempe. 66 pp + Appendixes.

Perrine, R. L., L. M. Libby and M. Simpson. 1981. The potential production of air pollutants near STPS receiver surfaces. U. S. Department of Energy Report UCLA 12-1313, University of California, Los Angeles.

Peterson, R. T. 1969. A field guide to western birds. Houghton Mifflin Co., Boston.

Prichett II, Wilson. 1975. Solar Power Plant Impacts. A study of the environmental and economic implications of large scale solar thermal-electric power generation in the Southwestern United States. M.A. Thesis, Univ. Virginia, Charlottesville.

Snedecor, G. W. 1956. Statistical methods. Iowa State Univ. Press, Ames.

Sokal, R. R. and F. J. Rholf. 1969. Biometry. W.H. Freeman and Co., New York.

Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co., Boston.

Stoddard, H. L. and R. A. Norris. 1967. Bird casualties at a Leon County, Florida TV tower: an eleven-year study. Tall Timbers Res. Sta. Bul. No. 8. 194 pp.

Strojan, C. L. 1980. Environmental aspects of solar energy technologies. Solar Energy Research Institute Report SERI/TP-743-826, Golden, CO.

Suter, G. W. II. 1981. Ecosystem theory and NEPA assessment. Bull. Ecol. Soc. Amer. 62: 186-192.

Turner, F. B. (ed.). 1979. Ecological base line studies at the site of the Barstow 10 MWe pilot solar thermal power system. U.S. Department of Energy Report UCLA 12-1223, University of California, Los Angeles.

Turner, F. B. 1980. Environmental issues and solar thermal power systems. Pp. 430-434 in: Proceedings 26th Annual Meeting, "Life Cycle Problems and Environmental Technology." Institute of Environmental Sciences, Philadelphia.

Turner, F. B., P. A. Medica, J. R. Lannom, Jr. and G. A. Hoddenbach. 1969. A demographic analysis of the whiptail lizard, Cnemidophorus tigris, in southern Nevada. SWest. Nat. 14: 189-202.

Turner, F. B. and E. B. Edney. 1977. Ecological effects of coal fly ash on desert plants and animals. Southern California Edison Research and Development Series 77-RD-114. 118 pp.

Turner, F. B. and A. T. Vollmer. 1980. Ecological effects of precipitator ash on desert plants. Southern California Edison Research and Development Series Report 80-RD-106, Rosemead, CA.

Turner, F. B. and R. M. Chew. 1981. Production by desert animals. Pp. 199-260 in: "Arid Lands IBP Synthesis Volume 2," D. W. Goodall and R. E. Perry (eds.). Cambridge University Press.

Valentine, K. A. and J. B. Gerard. 1968. Life-history characteristics of the creosotebush, Larrea tridentata. New Mexico State Univ. Agri. Expt. Station Bulletin 526. 32 pp.

Wessman, E. V. 1977. The distribution and habitat preferences of the Mojave ground squirrel in the southeastern portion of its range. U.S. Bureau of Land Management, Wildlife Management Branch, Administrative Report 77-5: 1-15.

Appendix 1

Weights (g) of sand collected by saltation meters downwind of solar site between June 16, 1979, and May 10, 1981. No observations (n.o.) were made at Stations 2, 4, 5 and 6 before September 1, 1979.

	Stations					
Dates	1	2	3	4	5	6
Jun 16, 1979	0.35	n.o.	1.85	n.o.	n.o.	n.o.
Sep 1	3.14	n.o.		n.o.	n.o.	n.o.
Oct 31	144.64	1051.00				
Nov 3			5.03			
Nov 10		30.70				
Nov 24		75.58				
Dec 1	181.69	209.15				
Dec 8			11.15			
Dec 22	350.61	872.25				
Jan 12, 1980	653.52					
Jan 19		241.28				
Feb 29	13.63	34.0	1.24	0.12	2.49	6.22
Mar 8		2.72			1.17	0.12
Mar 15		7.20		0.15		
Mar 22					0.02	
Mar 29	8.15	21.69				
Apr 12		0.30				
May 10		0.94				
May 31	7.79	23.96	3.82	21.50		
Jun 15	9.45	18.59	2.83	2.85	2.51	8.08
Mar 29, 1981		43.36				
May 10		19.76				
Grand Totals	1371.9	2653.8	25.9	24.6	6.2	14.4

Appendix 2

Comparisons of air temperature profile differences at two sites adjoining Solar One in 1980 and 1981

Dates	Hours	Height (cm)	*n*	Mean temperature difference (°C)	Deep sky temperature (°C)	Total insolation $(W \cdot m^{-2} \cdot day^{-1})$	Values for paired *t*-tests	*p*
Dec 14-15	0700-1610	-5	100	-0.12	-15.6	5,302	1.42	>0.10
		2	100	-0.87			5.57	<0.01
		10	100	-0.63			4.91	<0.01
		50	100	-0.35			3.73	<0.01
		200	100	-0.13			1.49	>0.10
	1710-0600	-5	140	-0.94	-23.4	night	24.14	<0.01
		2	140	0.78			9.38	<0.01
		10	140	0.40			3.89	<0.01
		50	140	0.44			4.36	<0.01
		200	140	0.41			4.70	<0.01
July 21-22	0600-2000	-5	150	-1.11	not measured	21,130	6.71	<0.01
		2	150	-3.23			15.70	<0.01
		10	150	-0.17			2.08	<0.05
		50	150	0.23			2.91	<0.01
		200	150	0.31			4.04	<0.01
	2100-0500	-5	80	0.83	not measured	night	29.34	<0.01
		2	80	0.80			10.59	<0.01
		10	80	0.19			2.91	<0.01
		50	80	0.11			1.56	>0.10
		200	80	0.04			0.44	>0.50

Appendix 3

Mean attributes (and standard errors) of annual floras in six plots downwind of the solar site, 1979-1981. Attributes are 1) total species observed, 2) numbers of species per quadrat, 3) aggregate density ($n \cdot m^{-2}$), 4) aggregate dry weight biomass ($kg \cdot ha^{-1}$) and 5) Simpson diversity index.

		Plots					
Year	Attribute	1	2	3	4	5	6
1979	1	32	34	26	47	25	31
	2	6.42 (0.43)	6.69 (0.37)	7.03 (0.40)	8.46 (0.57)	4.71 (0.34)	6.87 (0.42)
	3	1016 (187)	1063 (107)	741 (72.5)	775 (88.9)	606 (124)	576 (78.4)
	4	154 (23.2)	143 (13.6)	157 (17.3)	245 (26.6)	226 (27.0)	170 (20.7)
	5	0.75 (0.03)	0.76 (0.03)	0.67 (0.03)	0.92 (0.02)	0.93 (0.02)	0.85 (0.03)
1980	1	33	31	25	29	28	34
	2	5.76 (0.39)	6.87 (0.42)	6.06 (0.36)	5.16 (0.42)	5.64 (0.35)	6.27 (0.49)
	3	1859 (273)	1868 (238)	1314 (144)	1816 (322)	1112 (125)	1335 (188)
	4	235 (27.9)	119 (17.1)	145 (22.2)	140 (21.5)	177 (27.9)	108 (14.6)
	5	0.62 (0.03)	0.69 (0.03)	0.73 (0.03)	0.77 (0.04)	0.90 (0.02)	0.86 (0.03)
1981	1	9	10	14	12	12	16
	2	2.71 (0.17)	2.33 (0.18)	3.83 (0.23)	2.78 (0.24)	3.43 (0.25)	4.42 (0.21)
	3	214 (32.7)	171 (30.9)	248 (18.7)	235 (30.9)	207 (39.7)	221 (26.5)
	4	24.0 (5.2)	9.0 (3.8)	18.5 (5.5)	35.2 (8.6)	13.6 (4.3)	6.7 (1.8)
	5	0.78 (0.03)	0.74 (0.03)	0.76 (0.03)	0.74 (0.03)	0.70 (0.03)	0.68 (0.03)

Appendix 4

Estimated densities ($n \cdot m^{-2}$) of five species of annual plants in six plots downwind of the solar site, 1979-1981.

		Plots					
Species	Year	1	2	3	4	5	6
Cryptantha angustifolia	1979	93.3	170	171	21.5	18.2	64.4
	1980	82.6	76.3	149	20.6	11.7	65.9
	1981	0.14	0.67	7.0	10.6	0.16	12.8
Eriogonum trichopes (buckwheat)	1979	0.51	0.32	1.6	0.34	0.22	0.38
	1980	2.0	0.41	2.2	0.28	0.49	0.78
	1981	0.07	0.03	0.52	-	0.03	0.09
Erodium cicutarium (filaree)	1979	26.9	17.4	2.4	3.2	1.1	0.10
	1980	99.9	36.2	5.0	20.3	3.9	0.36
	1981	98.5	34.2	21.6	45.1	18.1	10.2
Geraea canescens (desert gold)	1979	0.28	0.11	0.79	0.36	3.0	1.9
	1980	0.11	0.07	0.38	0.34	1.6	0.82
	1981	0.022	0.019	0.014	0.014	0.070	0.022
Schismus arabicus (non-native grass)	1979	892	875	564	744	577	509
	1980	1653	1754	1154	1770	1093	1231
	1981	115	135	218	175	188	197

Appendix 5

Estimated dry weight standing crops (kg·ha^{-1}) and standard errors, of three species of annual plants in six plots downwind of the solar site, 1979-1981.

Species	Year	Plots					
		1	2	3	4	5	6
Cryptantha angustifolia	1979	10.4 (3.2)	15.6 (3.8)	19.2 (5.0)	3.8 (1.5)	3.1 (1.9)	10.6 (3.0)
	1980	6.9 (1.9)	7.2 (1.6)	22.1 (5.8)	2.5 (0.8)	2.3 (0.6)	11.5 (3.8)
	1981	0 -	0.01 (0)	0.07 (0.02)	0.02 (0.01)	0.01 (0)	0.11 (.03)
Erodium cicutarium	1979	18.4 (4.2)	10.6 (4.6)	0.9 (0.5)	7.7 (5.3)	0.8 (0.5)	0 -
	1980	130 (23)	40.2 (10.7)	8.1 (3.8)	23.2 (8.0)	6.5 (3.6)	0.2 (0.1)
	1981	21.7 (5.2)	7.8 (0.4)	12.1 (5.1)	30.9 (8.2)	11.0 (4.3)	4.4 (1.8)
Schismus arabicus	1979	126 (23)	117 (12)	137 (17)	233 (26)	220 (27)	159 (21)
	1980	97 (17)	71 (11)	114 (21)	112 (19)	167 (28)	94 (15)
	1981	2.3 (0.9)	1.2 (0.3)	6.1 (1.6)	4.1 (1.1)	2.6 (0.7)	2.2 (0.4)

Appendix 6

Mean pre-season vegetative states of three kinds of shrubs in plots downwind of the solar site, 1980 and 1981.

Species	Variable	Year	Distances (m) 100	400	800	X^2	*p*
Ambrosia dumosa	Numbers of nodes per branch	1980	14.4	14.3	14.8	1.86	0.41
		1981	12.7	12.7	12.8	0.79	0.68
	Number of nodes per shoot tip	1980	2.8	2.5	2.6	2.65	0.27
		1981	2.6	2.7	2.6	1.52	0.47
Larrea tridentata	Number of nodes per branch	1980	36.5	37.5	39.0	5.86	0.051
		1981	38.7	39.2	39.1	0.91	0.64
	Number of nodes per shoot tip	1980	2.3	2.4	2.5	1.67	0.43
		1981	3.2	3.4	3.2	1.37	0.51
	Length of shoot tips (mm)	1980	45.4	44.3	48.7	4.50	0.11
		1981	53.7	52.6	54.4	2.14	0.34
Atriplex polycarpa	Number of nodes per branch	1980	23.0	21.9	22.7	1.19	0.57
		1981	28.8	28.4	28.9	1.99	0.37

Appendix 7

Presence and/or estimated abundance ($n \cdot km^{-2}$) of birds in a plot 300-600 m downwind of the solar site between September 1978 and May 1981

Species	Sept 78	Jan 79	Mar 79	May 79	Sept 79	Jan 80	Apr 80	May 80	Sept 80	Jan 81	Apr 81	May 81
Turkey Vulture	+	-	-	-	-	-	-	0.1	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	0.1	-	-	-	-
Prairie Falcon	+	-	-	-	-	-	-	-	-	-	-	-
Mourning Dove	+	-	-	-	1.0	-	-	1.7	-	-	-	7.8
Common Flicker	-	-	-	-	-	1.5	-	-	-	-	-	-
Burrowing Owl	+	+	-	+	-	-	0.2	-	-	-	-	-
Vaux Swift	-	-	-	-	-	-	-	0.3	-	-	-	-
Costa's Hummingbird	-	-	-	-	-	-	-	2.3	-	-	-	-
Western Kingbird	-	-	-	-	-	-	1.0	-	-	2.1	7.3	-
Say's Phoebe	-	-	-	-	1.0	1.5	-	0.6	1.0	0.7	-	-
Barn Swallow	+	-	-	-	-	-	-	-	-	-	-	-
Violet-green Swallow	-	-	-	-	-	-	0.4	-	-	-	-	-
Common Raven	+	-	-	-	-	-	1.8	-	-	-	-	-
Loggerhead Shrike	2.1	-	-	-	-	-	-	0.7	-	-	-	-
Orange-crowned Warbler	-	-	-	-	-	-	2.8	-	-	-	-	2.1
Yellow-rumped Warbler	-	6.3	-	-	-	-	-	-	-	-	4.2	1.0
Yellow Warbler	-	-	-	-	-	-	-	-	-	-	2.1	-
Wilson's Warbler	-	-	-	-	2.8	-	-	-	-	-	-	-
Western Meadowlark	2.1	-	-	-	-	-	-	-	-	-	-	-
Red-winged Blackbird	2.1	-	-	-	-	-	-	-	-	-	-	-
LeConte's Thrasher	-	-	-	-	-	-	-	-	-	-	-	-
House Finch	2.1	2.1	-	1.4	-	-	1.8	-	1.0	-	-	-
Sage Sparrow	-	18.8	-	-	-	-	-	-	-	-	-	-
Chipping Sparrow	-	2.1	-	-	-	-	-	-	-	-	-	-
Brewer's Sparrow	12.5	-	-	-	-	1.5	-	-	4.2	-	-	-
White-crowned Sparrow	-	47.9	-	-	-	14.9	4.2	-	-	25.8	-	-
Song Sparrow	-	33.3	10.4	-	-	-	-	-	-	-	-	-
Savannah Sparrow	-	-	-	-	-	5.9	-	-	-	7.4	-	-
Lark Sparrow	-	-	-	-	6.3	-	-	-	-	-	-	-