CHANGES IN THE INSECT FAUNA OF A DETERIORATING RIVERINE SAND DUNE COMMUNITY DURING 50 YEARS OF HUMAN EXPLOITATION

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INTRODUCTION

The sand dune formation east of Antioch, Contra Costa County, California, comprised the largest riverine dune system in California. Biogeographically, this formation was unique because it supported a northern extension of plants and animals of desert, rather than coastal, affinities. Geologists believe that the dunes were relicts of the most recent glaciation of the Sierra Nevada, probably originating 10,000 to 25,000 years ago, with the sand derived from the supratidal floodplain of the combined Sacramento and San Joaquin Rivers.

The ice age climate in the area is thought to have been cold but arid. Presumably summertime winds sweeping through the Carquinez Strait across the glacial-age floodplains would have picked up the fine-grained sand and redeposited it to the east and southeast, thus creating the dune fields of eastern Contra Costa County. Then the river cut into this deposit in more recent times, leaving a narrow ridge of sandhills with vertical cliffs (Atwater, 1982a and 1983 *in litt*.), which were 35-38 meters in height east of the Antioch townsite.

It is likely that the sheet of eolian sand between the Mt. Diablo foothills and the western margin of the Sacramento-San Joaquin delta remained isolated from other dune fields in central California, such as along the coast (Atwater, 1982a,b). Hence, the resultant biological 'island' probably was an isolated, northern outpost of a desert biogeographical element that extended along the western side of the San Joaquin Valley, associated with riverine floodplain sands and fossil beaches from inland seas of Pleistocene to mid-Pleistocene times. Moreover, if the foregoing model applies generally to

Quaternary ice ages, the cyclic nature of late Pleistocene climate implies that dunes could have formed near Antioch several times. According to Axelrod (1967), the driest part of the Tertiary occurred in mid- to late-Pliocene, when many members of the Madro-Tertiary Geoflora ranged well into California. Thus, corridors of arid habitat may have existed periodically since the orogenic rise of the Coast Ranges in late Pliocene, enabling a long history of west valley desert elements. Hence, plants and insects of desert affinities at Antioch could have colonized from relatively short distances during succeeding inter-glacial periods (e.g., Doyen and Opler, 1973).

The Speculation by Howard and Arnold (1980) that this desert biota moved northward during the Xerothermic period, 5000-8000 years ago, is based on an assumption that formation of the Antioch dune system occurred after opening of the San Joaquin-Golden Gate Seaway 10,000 years ago. However, the San Joaquin and Sacramento rivers first reached the sea via the Carquinez Strait at least 400,000 years ago, as evidenced by volcanic ash of that age interbedded with deposits of Sierra Nevadan origin at several places near San Francisco, according to Atwater (1983 _in litt_.). Hence this alleged recentness of the Antioch dune system and its plants and insects as well as the scenario for a riverine origin of the sands (e.g., as described by Roof, 1969) appear to be minor factors in the history of the community.

Natural processes during the last postglacial era and agricultural grazing practices, especially the latter, during the past 1.5 century, reduced this desert-like habitat to small, scattered patches. The Antioch dunes possessed one of the northernmost and biologically best known of these communities; they were sufficiently large to resist conversion to agricultural or industrial use until biologists could sample the fauna and flora.

The greatest extent of this sand dune formation is unknown, but in historic times a narrow berm of sandhills extended along the shore about 3.5 km east of the town of Antioch (U.S.G.S., Collinsville Quadrangle, 1918 ed., surveyed in 1906-07); estimates range up to 9 km along the river (Roof, 1969). The sand was spread in diminishing quantities and effects to soil composition, extensively southeastward, into areas that were converted to agriculture long before any insect collecting took place (Carpenter & Crosby, 1939). Probably there were elements of the fauna and flora beyond the present town of Oakley to Knightsen and eastward in areas of the Delta later modified by dredging. By the 1930's, when entomological survey began in earnest, extensive sand-mining had already decimated parts of the sandhills. At that time they occupied a narrow arc, 0.1-0.3 km wide, bordered inland by vineyards, a railroad, and grazed land.

The sandhills supported a stabilized vegetation when first recorded by botanists in the 1880's, including scattered oaks (*Quercus agrifolia*) and a diverse mantle of woody shrubs and spring-flowering annuals (Howard & Arnold, 1980). After mining activities had greatly increased the extent of active sand, summer visitors 50 years ago encountered "rolling dunes with large open sand areas, and scattered oaks, both east and west of the park" [Oak Park, 3.2 km east of Antioch] (R. M. Bohart, A. E. Michelbacher, pers. communications). Most of the insect groups discussed here are characteristic inhabitants of sandy habitats such as active dunes, riverbanks, and desert areas. The changes indicated by the data summarized in this report are associated with the loss of that kind of habitat, rather than directly with loss of plant species or increased weediness, which of course are correlated with destruction of the active sand habitat.

HISTORY OF EXPLOITATION

Large scale industrial development at the Antioch dunes took place during a several year period following World War II. A gradual and increasingly severe destruction of the habitat has occurred over a much longer period, however, and the disappearance of insect species (Table 6) tends to corroborate the notion that no single event or brief era destroyed the community. A brief chronology of the exploitation is as follows.

Pre-1910: Two brickyards were established near the western end of the dune system in the 1880's (Benyo, 1972), and sand-mining for bricks and concrete began at other sites before and shortly after the turn of the century. Surveys in 1906-07 showed two railroad spurs crossing the dunes to the river edge. One of these (1.2 km east of the dune terminus at Antioch) dissected the lower, western part of the dune ridge, leading to a boat landing at the Holland Brick Company. This site later became the eastern end of the Stamm property and ultimately a part of the National Wildlife Refuge (SP area of this report). The eastern railroad spur extended through a tunnel to a pier servicing a quarry (USGS, Collinsville Quadrangle, 1918) at the Golden Gate Brick Company. The latter site, later popularly known as "Little Corral," became the eastern of the two parcels in the refuge (LC of this report).

1920's: Several companies were said to be running sand-mining operations, moving from site to site as leases expired (Howard & Arnold, 1980). The Report of the State Mineralogist for 1927 includes a photograph of a sandpit mine that was operated near the present LC area. Remnants of similar structures were still standing at LC when I first visited the site in 1954.

1931: (U.S. Army aerial photo AC 28 30 113). Two tall towers, built in 1909 and 1927 on formerly lower (ca 17 m elevation) areas between the highest parts of the dune ridge, flank the former Golden Gate Brickyard railroad spur

(LC area). The western tower, built as a substation by the Great Western Power Company, was accompanied by several buildings, with around-the-clock work shifts and permanent residents who introduced ornamental plants. Purchase of this property by PG&E was concluded in 1936, several years after construction of the second tower, to the east. Five huge sandpits, each with a railroad spur, are in operation; three are east of the towers in the formerly highest dune sector, which has been largely excavated; one is between the towers, and one just west of the towers. The last is starting to encroach into the remaining highest dune. Deposits of active sand occur along the lee slopes subtending the dune ridge, more extensively so towards the western (windward) end, where brickyard and shipyard construction had been developed long before. No doubt much of the active sand of this era had been freed for wind movement by quarry operations; thus the early entomological investigations (1931-39) took place on artificially disclimax dunes. The western part of the sandhills remained vegetated in 1939.

1949: (USGS Antioch North Quadrangle, 1953, 1906-07 survey modified by aerial photographs of 1949). A tremendous increase in sand-mining and industrial development during and following the war is evidenced by flat, sand areas 0.5 km wide on either side of the powerline towers, which now stand on 18 m high bluffs flanked by 3-5 m flats where there had been sandhills 35 m (west) and 38 m (east) in height. Contours of the western and easternmost, lower sand ridges, 18-25 m high remained relatively unchanged, but the eastern flanks of the former dunes (area of Marsh Landing) now have large fuel storage tanks and a PG&E substation.

1952: (Aerial photograph, Fairchild survey, AV 86-01-15). There is extensive sand-mining in the area west of the power lines and a quarry has resumed operation at LC between the towers. Huge industrial developments

(Fiber Board - Crown-Zellerbach) now occupy the 0.5 km west of the PG&E substation, eliminating the last of the eastern half of the sandhills.

1954-55: The area west of the power lines, no longer actively quarried, has become a partially vegetated sand flat, with low, active dunes, flanked to the south by fragments of unexcavated ridges with natural vegetation (Samuelson, 1956). Similar conditions existed in the LC area; these and the intervening power lines bluff were the disturbed "dunes" where most insect survey took place in the early 1950's.

1958: Large scale mining of the remaining sand ridge to the west was well advanced. A city sewage disposal plant was constructed in 1956, involving extensive grading of surrounding areas south of the dunes. Some of the entomological work of the late 1950's was carried out in disturbed parts of this western area (e.g., Ferguson, 1962; Powell & Chemsak, 1959). The east end of the remaining ridge (SP area) was relatively undisturbed, with several oaks (JAP field notes).

1965: A final surge of sand-mining enlarged the excavation area at LC, scraping bare the floor of the whole pit (W. J. Turner photos).

1968-1972: Massive industrial development during the 1950's is graphically seen in the revised USGS Antioch North Quadrangle, compiled from aerial photographs taken in 1968. Industries included the Kaiser Gypsum plant in the excavated area west of the power lines, and all the areas east of them. Roof (1969) reported that the last of the Antioch dunes were being trucked away; by May, 1972 a low ridge ca 8 m high with one oak tree provided a lee slope for sand deposit by prevailing wind (JAP photos). During this time increased stabilization by weediness and grazing by horses converted the *Eriogonum*-dominated natural vegetation at the PG&E power line corridors, particularly severely so where a cyclone fence was built to enclose all of the highest remaining hill at the PG&E-McCullough property boundary.

1973-76: Annual disking of all level parts of PG&E and LC properties encourages complete replacement of natural vegetation with weeds. A fire in June, 1976 denuded the PG&E eastern hill, further encouraging weediness.

1978: A final surge of sand-mining at SP removed the last remnant sand ridge, leaving the eastern portion of the property exposed to prevailing winds, without a lee slope to enhance sand deposit. A small fire along east edge of SP destroyed some of the remaining native vegetation.

1980-82: Cessation of sand-mining and exclusion of vehicles following purchase of SP and LC results in weed cover of sand roads and paths, further reducing sources of active sand. *Eriogonum*, *Guterrezia* and *Senecio* continue to senesce and die without replacement, evidently because seedlings fail to persist in stabilized, weedy vegetated areas.

HISTORY OF ENTOMOLOGICAL INVESTIGATIONS

S. E. Flanders and F. H. Wymore collected 4 widespread species of Pompilidae, Sphecidae, and Tenebrionidae on 4 dates, Sept. 1922 to Feb. 1923. Machine-printed "Antioch" labels were used, suggesting that considerable numbers of specimens were involved then or on earlier dates, but such material was not discovered in the families surveyed. It is not known whether these collections were made at the dunes area east of Antioch, but in any case, they did not result in a flurry of interest in the insect fauna there. No further records are known before 1929.

Beginning in October, 1929, E. C. Van Dyke of the California Academy of Sciences (CAS), began a series of visits to the Antioch dunes that spanned 13 years. He was the most important collector of the early era. Independently, A. E. Michelbacher and E. O. Essig of the University of California, Berkeley

(UCB), discovered the site and began collecting at Antioch in 1932. In June, 1933, Essig took a group of students in the summer field course to Oak Park (Sweeney's Beach) in the eastern end of the dunes; included were M. A. Cazier and R. M. Bohart, who made many return visits and stimulated those by other UCB students (G. E. Bohart, E. G. Linsley, J. W. MacSwain, E. S. Ross and others) during the 1930's. R. M. Bohart recalls that most of these collections were made at a site "where a railroad spur ran down into a low area, at the top of the hill" on the county road, because there was a fee at Oak Park. This was the Golden Gate Brick Co. site (USGS Collinsville Quadrangle, 1918) that later became known as LC and was the primary collecting area of 1948-54 era. Bohart's visits spanned 45 years and probably outnumbered those of any other collector until the present era.

The insect fauna, with its many large and colorful species of desert affinities, was so exotic to Bay Area entomologists, that Antioch attracted remarkable attention. In the 1930's many species of wasps and flies, particularly the giant flower-loving fly, Rhaphiomydas trochilus, were completely new to collectors of this region, so that discovery of this fauna must have been analogous to a major expedition to the Mojave Desert or Arizona, during an era when travel in the desert was still difficult and the depression curtailed travel generally. As a result, Antioch was given attention unprecedented in the annals of western insect survey. Probably no locality of limited size has had so many visits by insect collectors over so long a period, and thus it offers an unique opportunity to document changes in the fauna.

Since 1929, at least one collection of the insect families considered here has been made at Antioch in every year except 1931, 1943, 1970, and 1980; insects have been collected on more than 590 dates during the 54 years.

The greatest concentrations of effort, judged by frequency of visits in 5 years, were in 1935-39 (113 dates), 1952-56 (103 dates), and 1975-79 (71 dates). The periods of lowest interest occurred in 1942-46 (11 dates), 1960-1964 (12 dates), and 1969-73 (8 dates). Thirty or more visits were made in 1936, 1938, 1952, and 1965. Often, if not usually, trips were made by two or more collectors, particularly in earlier eras when travel was less efficient.

During the 1930's Antioch began to appear on the entomological map as new species were described (Table 5), and towards the end of that era, considerable attention was directed to study of biologies and interrelationships of some of the insects, particularly wasps (Bohart & MacSwain, 1939, 1940a, 1940b; Cazier, 1941; Ross, 1941).

Following World War II, there was a second flurry of effort in sampling the insect fauna, and many smaller and/or nocturnal species overlooked by the 1930's collectors, were added to the inventory. P. D. Hurd made a series of visits during 1947-1965, particularly in 1947-53, and many students at the University worked at Antioch during this era (e.g. Barnes, Ferguson, Gillaspy, MacNeill, Rozen, Wasbauer).

Awareness of the unique insect community grew, as 8 new species were described from Antioch material in 1943-55 (Table 5) and biological studies were continued (e.g. Hurd, 1951, 1956; Linsley & MacSwain, 1954; Ross, 1953). Appreciation of the unique interrelationships culminated with the 1955 publication in Life Magazine of "The Life of Insects," containing a 6-page section entitled, "Communal life on the dunes," that described the plant and animal community at Antioch, primarily through paintings by Walter Linsenmaier. This was reprinted in the Life Nature Library Book, "The Land and Wildlife of North America," (Farb, 1964: 44-49).

Most collectors of the early eras felt that the habitat was destroyed during the postwar industrial expansion, and their visits ceased after 1954. However, a new generation of us who had not seen the pre-industrial dune community, continued the tradition, and more than 140 visits were made during 1955-1965. This era included research associated with several biological studies and theses (Ferguson, 1962; Linsley & MacSwain, 1958; Powell, 1964a, 1964b; Powell & Chemsak, 1959; Powell & Stage, 1962; Rentz 1973; Stage, 1966; Turner, 1966).

During the late 1960's and early 1970's there was another period of relative neglect, with only diminishing remnants of dunes left at LC and SP. Following a survey trip in May, 1972, I began to accumulate records of the entomological history, queried many of the collectors of earlier eras, and in 1974-75 corresponded and met with PG&E and University of California personnel in a futile attempt to have the powerline parcels designated as a natural preserve in the U.C. Natural Lands & Water Reserve System. Insect collecting increased in 1974-76, primarily by students at U.C., Davis (UCD) (L. Siri, N. J. Smith and others), and I began my recent era survey in July, 1976, after the area had been proposed as endangered habitat, with one butterfly and two plants designated in 1976 as endangered species.

INSECT FAUNA

Methods. -- An attempt was made to survey the insect fauna at the dune remnants east of Antioch in 1976-82. Collections were made on 94 dates -- I made 70 visits, J. B. Johnson made several visits with me and two separately in 1977; students and staff of UCD made 17 visits in 1976-79, and W. Pulawski (CAS) made 4 visits in 1981-82. I surveyed in every month, at least twice in each month except January, March and December, but 70% of all dates during this era were August-September; only 18% were in April-July. The seasonal distribution in effort is similar to that of past collectors but is exaggerated for late summer-fall, with proportionately about twice as many visits in August-September and correspondingly fewer in spring and early summer (Table 3). (15% vs. 26%; 40% in 1930s, '40s)

An assessment of the present insect community at the remnant Antioch dunes was carried out by comparison of species in selected families collected in 1976-82 with those of earlier eras. An insect community such as existed in the Antioch area prior to man's disturbance might consist of 4,000-5,000 species, thorough survey and taxonomic assessment of which would require an army of specialists working around the calendar for several years. As a result, there is no complete list of insects, or of even one major order of insects, that occurred at Antioch, or for any other locality in the western United States. Thus, the only feasible means of assessment is that of selected groups.

A pilot survey to assess the state of diurnal insects was made during 17 visits between July, 1976 and October, 1977. Usually two sites, the eastern portion of the Stamm property and the PG&E-Sardis property (SP and LC respectively, Map 1) were sampled for 2-4 hrs each. General collection methods believed to be those used in the 1930's and 1940's were employed. More recently developed techniques, such as blacklights, flight traps, and pheromone traps, were not used. About 2,000 specimens were processed and sorted to taxa and a preliminary comparison to older collections was made.

Fourteen families (Table 1) were chosen that include species characteristic of sand dune communities. The ecological roles within the community vary among these families, but the emphasis is on sand-nesting or sand-burrowing predators. Bees of families other than Halictidae were collected, but identifications of recent collections have not been obtained. The 1976-77 material represents about 350 species/date records for these groups.

Insects that might have been better indicators of some aspects of the community, such as phytophagous species associated with particular native plants, are omitted because they were not sampled in earlier eras (e.g. leaf beetles, aphids, moths), or because reliable identifications of species are not available. I did not sample at night, so adequate comparison with earlier collections cannot be made for some groups (e.g. ant lions, scarab beetles).

I made additional collections in August 1978 and 1979, as a by-product to field population studies of Apodemia mormo langei, comprising about 175 records. Finally, 30 visits were made between August 1981 and October 1982, emphasizing less thoroughly sampled taxa within the 14 families, especially bees and smaller flies and wasps. In addition, pitfall trapping was carried out during this time because crepuscular and nocturnal Mutillidae and Tiphiidae had been sampled in the 1950's but not in 1976-79 and because Tenebrionidae were emphasized by Van Dyke and others in the 1930's but not in later years.

The 1981-82 collections, consisting of over 3,000 specimens, and ultimately representing about 420 species/date records, were prepared, sorted and sent to taxonomic specialists, along with material from prior years of my survey as well as specimens exhumed from undetermined or questionably identified museum collections. Some of this work was supported by Fish and Wildlife funding, but the primary use of the funding was to canvass collections, record data and process data. We attempted to locate every specimen of these 14 families that had been collected at Antioch and deposited in the California Academy of Sciences (CAS), University of California, Davis

(UCD), and the Essig Museum at U.C. Berkeley (UCB). A few records from the literature or from other collections, for which voucher specimens were not seen, were incorporated, but no attempt was made to canvass other museum collections. I think these 3 institutions house the vast majority of extant Antioch specimens, at least for the 3 primary eras assessed. No attempt was made to document abundance by numbers of specimens.

Altogether, we tallied about 3,000 species/date records, of which about 500 were duplicates (two collectors or two institutions). The records were incoded in a d-Base II program on an Apple computer, proofread then corrected and transferred to a Winchester disc for manipulation. Analysis of the insect fauna and its history of records are based on this data bank; the 376 species represent perhaps 10% of the total fauna, but probably the data include a much higher proportion of available specimens from Antioch because the taxa selected include some of the most popular insects with general collectors.

Eras selected for analysis. -- On the basis of intensity of sampling effort, three 7-year eras were selected for comparison of insect faunal composition: 1933-39, 1948-54, and 1976-82. Data for the families examined represent 136, 121, and 94 dates, respectively. The 1930's represent an early phase of human impact, with prior and concurrent sand-mining having largely eliminated the highest dune ridge and extensively increased active sand by removal of stabilized vegetation. Probably insects characteristic of active sand habitats were favored during this phase, and populations of many sand-nesting wasps, some of their predators, and sand burrowing beetles ~~and flies~~ such as _Coelus gracilis_, apiocerid and therevid flies, were more abundant than before, possibly vastly so.

The second, post-war era, was an intermediate stage in deterioration of the dunes, with industrial building encompassing large parts of the area and fragmenting the remainder into two islands with relatively low sandhills. Finally, the recent era has been a late phase of the habitat decimation, with removal of the last active sand dunes and stabilization of remnant patches by weediness.

Biological island size. -- An approximation of biological island area at the beginning of each era, based on habitat length x width (right angle), using aerial photographs and USGS maps, is: 2.17 km^2 in 1931, 1.71 km^2 in 1949 and 0.26 km^2 in 1976. The "islands" were defined by encroachment of land converted to agricultural or industrial uses, other than sand-mining. Essentially no portion of the habitat was completely undisturbed by the 1920's, and the actual island size, represented by patches of vegetation dominated by native plants, was much smaller than the above estimates. The "native" habitat continued to diminish within each era, increasingly so during the later two.

Inventory of species. -- Altogether, 376 species were recorded in the 14 families examined (Table 2), but 97 (26%) were recorded only once. Among the remaining 279, most were collected during only one part of the past half century, the result of either biological phenomena (extinctions, new colonists) or sampling error (by collectors or by subsequent loss from collections). Because there are no other studies of 50-year, 600 visit samples, it is unknown whether any aspects of the Antioch faunal sampling or changes are unusual. If, for example, there were such a study in a stable community, one could speculate on the degree of influence by habitat deterioration upon faunal composition, such as uniquely recorded species.

There are several reasons for a large part of the inventory having been recorded once (or a few times): 1) resident species disappear from the community after one collection; 2) resident species are overlooked by all collectors but one; 3) wandering insect individuals enter the area only occasionally; 4) wandering collectors sample occasionally outside the dune habitat (e.g., adjacent marshland or littoral environment); 5) specimens are mislabelled or misidentified. An effort was made to eliminate misidentifications and nomenclatural changes as a source of error in species diversity, by having contemporary specialists examine older identifications of uniquely recorded species.

The percentage of uniques declined from 26% of the total species collected in the 1930's to 23% in era II and 18% in era III. Presumably part of the difference in these figures can be attributed to (1) above, early extinction of species (prior to 1948), coupled with incomplete sampling in the early era. Possibly some of the 18% in the recent era represent first records of new colonists, such as species favored by weedy habitat. However, the majority of species recorded only once or twice probably were nonresident.

I assume that overall diversity in the insect fauna has declined with the gradual loss of natural habitat and native plant species and with the drastic reduction in size of the dune "island." The data, however, do not demonstrate this, whether or not species recorded only once are included (Table 4). There is no significant difference in the number of species recorded in the 3 eras, 208, 205, and 214. Although a decline in diversity is evident in a few groups (nyssonine Sphecidae, Therevidae, Meloidae, Tenebrionidae), the reverse appears to have occurred in other taxa (e.g. Pompilidae, Bombyliidae). The 3 most obvious reasons that a decline in diversity is not documented are: a) failure of 1930's collectors to sample thoroughly; b) loss of species from the collections surveyed, which was not a factor in recent era material; and c) establishment of new colonist species in the area.

The most obvious evidence that the first two of these are important factors is the increase in number of species records per collection date, with the recent average nearly double that of earlier eras (Table 4). The influence of casual collections, one or a few species on a given date, is much greater in earlier data. Such records originate in two ways, the collector has little interest or time for the taxa considered here (e.g. a butterfly collector casually takes a colorful bombyliid or robber fly that has captured a butterfly), or larger collections are fragmented and only a few specimens remain in local museums. Like the fossil record, probability of preservation increases for specimens in progressively younger collections. Losses by damage in handling or by insect pests, mould, etc., is particularly prevalent in private collections before they are deposited in museums. After deposit in an institution, specimens sometimes are discarded if damaged or poorly prepared. A more important source of loss, however, is dispersal of material borrowed by taxonomists. Frequently holdings of whole genera or families are loaned, and some or all of the specimens are held indefinitely and eventually find their way to another institution. For example, Painter and Hall (1960) recorded 3 species of Poecilanthrax (Bombyliidae) at Antioch on 4 dates in the 1930's, collected by A. E. Michelbacher or G. E. & R. M. Bohart, presumably borrowed from UCD or UCB. None of these were deposited there or CAS; one was located at U.C. Riverside, the others probably went with the Painter collection to the U.S. National Museum. An accurate appraisal of this kind of redistribution of specimens is not available, but at any given time, an estimated 10% of the Essig Museum collection, in excess of 300,000 specimens, is on loan. Thus, a comparison of historical collections based on local institutions inevitably will include bias that increases with age.

My first visit to Antioch, on September 5, 1954, provides an example of poor documentation in earlier eras, due to inexperienced and casual collectors, and by subsequent loss of specimens, as contrasted to recent survey visits. More than a dozen butterfly collectors spent several hours at the LC area that day in 1954 (Opler & Powell, 1962), and with undergraduate student field experience, I sampled various insects. The following year, ants destroyed part of my private collection, including bombyliids and other insects from Antioch. Seven species (all large insects) appear in the present data, 6 from my collecting, one from another student. If other relevant material was taken, the specimens have been destroyed or deposited or retained elsewhere. By contrast, my visits in early September, 1977, 1978, and 1981 (two dates combined) produced 31, 23, and 36 species, respectively in the 14 families discussed here.

Evidence that collectors of early eras actually sampled incompletely, irrespective of subsequent attrition of specimens, is shown by paucity of records in smaller insects. Examples include: the microbombyliids (*Empidideicus*, *Mythicomyia*, *Phthiria*) -- no records in the 1930's, one record in 1954, 27 records of 6 species in 1977-82; small asilids (*Metapogon*, *Stichopogon*) -- no 1930's collection, 2 of 2 species in era II, 6 of 3 species in the recent era; and pemphredonine sphecids -- 1 record in 1936, 3 records of one species in 1948-54, 28 records of 8 species in 1976-82. While some of these may represent new colonists associated with weediness or other community change, it seems certain that smaller insects generally were overlooked by earlier era collectors, particularly in the 1930's.

Probably the 3 periods included successively fewer relatively inexperienced collectors, but perhaps more importantly, the 1930's fauna at Antioch featured a much greater diversity of larger, conspicuous insects and species exotic to the Bay Area. As a result, I imagine that even experienced collectors could satisfactorily spend their non-specialist sampling time mostly on larger species. In September, 1936, collectors encountered miles of secondarily deposited, active sand dunes supporting a rich flora of fall-flowering native plants. They collected 98 species representing the 14 families recorded, a diversity greater than that taken in any month until 1977. In addition to a wide array of desert wasp genera, the September fauna in the 1930's included the giant flower-loving fly, *Rhaphiomydas trochilus*, large bombyliid flies such as *Ligyra gazophylax* and *Lordotus striatus*, the picture-winged *Exoprosopa* (3 spp) and *Poecilanthrax* (3 spp), colorful *Thereva* (2 spp), the large velvet ants, *Dasymutilla flammifera* and *D. sackenii*, none of which exists at Antioch now. It is not surprising that nobody noticed the tiny black pemphredonine wasps or near microscopic bombyliids that surely must have been present. As a result, meaningful comparison of diversity cannot be made from the data, and decline of diversity can be measured only by the disappearance of species, discussed below.

Endemism. -- Entomological literature is not organized in a manner enabling retrieval of type localities, but there are at least 27 species or subspecies of which the holotype was collected at Antioch (Table 5). At least 2 others included allotypes from Antioch. Among these, 11 species were known at the time or subsequently have been found to occur at distant sites, including several of desert affinities; 9 others are recorded from similar sandy habitats in the Central Valley; and two are of uncertain taxonomic status but are suspected to be synonyms of widespread species. The remaining 8, 5 species and 3 subspecies, are known only from Antioch. Sufficient sampling in recent years has been carried out to indicate that 4 of these are extinct at the type locality: *Neduba extincta* (Tettigoniidae), *Anthicus antiochensis* (Anthicidae), *Philanthus nasalis* (Sphecidae), and *Perdita hirticeps luteocincta* (Andrenidae). Three others, *Idiostatus middlekauffi*

also Coelus gracilis & [illegible] are now known elsewhere

(Tettigoniidae), Dysticheus rotundicollis (Curculionidae), and Colletes turgiventris (Colletidae) belong to taxa that have not been adequately surveyed and/or studied in recent years, and their status is uncertain. Finally, Apodemia mormo langei (Riodinidae) persists in annually diminishing numbers (Arnold & Powell, 1983 and unpubl. data).

Extinctions. -- Among 376 species recorded at Antioch, only 219 (58%) were collected during the recent 7-year survey. Disregarding the 97 species recorded only once, 69% of the others were present in the recent era. Probably some inconspicuous species that persist in low numbers were overlooked, but it is obvious that many species which were collected often in earlier years are gone.

A chronology of the last known collection (Table 6) reveals a surprising uniformity in the parade of species passing from the picture when the best sampled 7-year periods are compared: 35 species were collected for the last time in the 1930's, 34 in 1947-53, 45 in 1954-59, and 22 in the 1960's. Rather than an abrupt increase in disappearances coinciding with the industrial buildup of 1947-53, many extinctions preceded World War II and many followed 5-10 years after the industrialization. Measured against sampling effort, there was an increase in the extinction rate, 0.26 species/collecting date in 1933-39, 0.32 in 1947-53, 0.42 in 1954-60, and a slight decrease to 0.35 in 1962-68.

About 157 species (71 that had been recorded only once), were not observed in the recent 7-year survey and presumably have disappeared from the community. A marked increase in last records appears for 1977-78 (Table 6), but some or most of this is artifactitious, with only cursory August sampling in 1978-79 and the 1981-82 survey available to document these possible extinctions. Sampling in 1981-82 emphasized Tenebrionidae, Mutillidae, bees and smaller sand wasps and flies and was not thorough for larger wasps. Nonetheless, several conspicuous species, that were observed in 1976-79 apparently did disappear or decline markedly in abundance. Noteworthy extinctions include the following:

Apioceridae: *Apiocera* were commonly observed (several per day) in 1976-78, but the two species, *A. barri* and *A. chrysolasia* are not distinguishable in the field and were not described until later (Cazier, 1982), and few vouchers were taken. These included 4 records of *barri*, 2 of *chrysolasia*. By 1982 these flies were scarce, only 5 or 6 observed in 8 August-October visits, and the 4 vouchers were all *barri*.

Rhaphiomydas trochilus, perhaps the most conspicuous insect characteristic of desert sand dune affinities, was not observed in 1976-82. It was collected on at least 16 occasions prior to 1950, but there were only 3 records after the industrial buildup, in 1955, 1967, and July 18, 1974.

Asilidae: Two species disappeared in the post-industrial years; *Efferia cana* (9 records), and *Machimus occidentalis* (13 records) were both collected from 1933 to 1959. The largest robberfly of the Antioch fauna, *Proctacanthus occidentalis*, has long been conspicuous (40 records, 1933-1967) and was often seen in 1976-79 (vouchers for 7 dates). Only one individual was observed in 1981-82.

Bombyliidae: All of the larger bombyliids have disappeared, with the exception of *Chrysanthrax atrata*, a parasite of *Bembix occidentalis* (Bohart & MacSwain, 1939). Both the wasp and *C. atrata* were observed in diminishing numbers during 1976-82. The picture-winged *Exoprosopa* were last collected in 1939 (*E. divisa*, one record), 1941 (*E. dodrina*, 3 prior records), 1954 (*E. eremita*, 9 prior records), 1965 (*E. jonesi*, 2 prior records), 1978 (*E. xanthina*, 3 prior records), and 1979 (*E. doris*, 4 prior records). The largest bombyiid, *Ligyra gazophylax*, was collected only in 1937-41; *Lordotus striatus*, a species of desert affinities, used to be common at Antioch (25 records 1933-1959), but only 2 were taken after 1960, the last on September 14, 1966. The colorful *Poecilanthrax*, cutworm parasites, evidently were doomed by decimation of stabilized natural flora during the early sand-mining era; there are 6 records for 3 species, all before 1937.

Chrysididae: Most cuckoo wasps have been recorded too sporadically to provide conclusive evidence of extinction, presumably because their populations exist in low density, and many species are small and overlooked by non-specialist collectors. Among the larger species recorded in earlier eras, *Ceratochrysis trachypleura* was taken 6 times, the last in 1952, and 8 species of *Chrysis* (24 records) were not seen after 1977. *C. derivata* (4 records) and *C. vagabunda* (5 records) were taken once in 1977, *C. coloradica* 5 times in 1937-54. One of the *coloradica* was reared from an anthidiine bee (Megachilidae) in 1937, and this *Chrysis* was reared from *Anthidium collectum* Huard at Antioch by Ferguson (1962). Twelve species of anthidiine bees are recorded at Antioch by Grigarick and Stange (1968), including 9 collected in May, 1949; my survey showed only 3 species in 1976-82. These resin bees usually are pollen-gathering specialists associated with *Lotus*, *Phacelia* or Asteraceae and often they require fibrous material from a different plant in nest building.

Mutillidae: Disappearance of the larger diurnal velvet-ants is an obvious dwindling in the arenicolous entomofauna; of 5 *Dasymutilla* in the 1930's, only the two smaller species remain. *D. aureola* and *D. flammifera* (10 records) were last recorded in 1939, while *D. sackenii*, with 65 records 1932-1958, was taken once in 1979. Although some of these species are primarily crepuscular and may have been overlooked in 1976-78, none appeared in 1981-82 pitfall traps, which caught many *D. coccineohirta*, *Pseudomethocha* and nocturnal mutillids.

Pompilidae: Spiderwasps apparently were present in greater diversity in recent years than in former times, but one species, *Anoplius clystera* that used to be commonly observed (25 records 1936-1977, including 6 in 1977) was not collected in 1978-82. Two congeners, *A. californiae* (3 records to 1938) and *A. imbellis* (two records 1951-52) may have disappeared early.

Scoliidae: The 3 large sc~~h~~oliids persisted into the recent era, but only one male of *Campsomeris pilipes* was taken, in July 1977. Females of *C. tolteca* and *Campsoscolia alcione* were occasionally observed (and tallied as sight records) in 1981-82, despite the fact that no likely host is known at Antioch. These wasps are thought to be parasites of large scarab beetle grubs, such as *Polyphylla*, none of which has been recorded at Antioch since 1968. The two *Campsomeris* were recorded more than 40 times in earlier eras, often in April-June, but I did not see any in spring months. *C. alcione*, by contrast, was collected only three times previously, in 1937-38 and 1954. X

Tiphiidae: *Myzinum frontale* (5 records) disappeared after 1948, and *M. maculata*, which was formerly abundant (10 records, some in long series in the 1930's) was collected only 4 times in the recent era. These and *Brachycistis*, which was not adequately sampled (i.e. at lights) except in the 1950's, are also suspected to be scarab grub parasites. Twelve species of Scarabaeidae were taken in my survey, but most are too small to serve as hosts of scoliids and tiphiids. *Cyclocephala longula* LeC. and *Serica oliveri* Saylor, both formerly common, were taken in low numbers and are potential hosts at least for *Brachycistis*.

Sphecidae: Many of the smaller species have been too poorly surveyed to permit documentation of their histories. Among larger sphecids, several species that were sufficiently recorded to document residency disappeared before or during the industrial building era, while several others appeared to diminish markedly during recent years.

In the first group are 4 species of grasshopper-hunting *Tachytes*, with 17 records prior to 1950, the last in 1938 (*T. fulviventris*), 1942 (*T. obscurus*), and 1949 (*T. californicus* and *T. amazonus*). One congener, *T. distinctus* persists in this niche. *Steniolia duplicata* was collected in 1938-55 (4 records); Bombyliidae are its preferred prey, virtually all of larger of which have disappeared.

Stizoides renicinctus, an exotic looking genus for this part of California, was seen during the same era (10 records, the last in 1958). The species is a cleptoparasite of *Prionyx* (Sphecinae), and therefore probably more vulnerable than the less specialized hunting wasps; but two species of *Prionyx* were fairly common at Antioch until recently (33 records in 1976-82.). Among caterpillar hunters, *Podalonia communis* (5 records), *Ammophila pruinosa* (12), *A. boharti* (12), were not recorded after 1956. *Philanthus nasalis*, an endemic species that presumably preyed on small bees, was collected only between 1948-59 (8 records).

In the recent era, several larger sphecids apparently died out: *Chalybion californicum*, which had been recorded sporadically since 1933, was commonly observed in 1976-77 at both SP and LC (5 voucher dates) but was not seen in 1981-82; *Chlorion aerarium*, a brilliant blue-green species that provisions with crickets, was collected 7 times since 1935, the last on July 31, 1977 (possibly a transient). *Palmodes dimidiatus* was commonly encountered (25 records 1932-65), but I saw it only once, in 1979. Its competitor katydid- and tree cricket-hunters were the two largest sphecids of the fauna, *Sphex ichneumoneus* and *S. pennsylvanica*; they were collected sporadically before 1976 (11, 6 records respectively) and were seen occasionally in 1976-77 but only once or twice in 1981-82. The large caterpillar hunters, Ammophila macra and A. procera, were observed frequently in 1976-77, particularly at LC (8 voucher dates) but seemed to disappear (1 SP record in 1982), although there was no apparent change in the presumed prey sources (Sphingidae on Salix, or possibly Notodontidae on Quercus). Both were collected often in the past (9, 12 records 1936-74).

Halictidae: Probably there has been considerable reduction in diversity of bees accompanying losses of annual flowering plants, but in Halictidae most species are small and were not thoroughly sampled (11 of 35 species were recorded only once, Table 2). Among halictids collected more than twice, 5 species were not recovered during the recent era: Agapostemon femoratus, 1936-1954 (11 records); Evylaeus kinkaidi 1936-1975 (7); Halictus rubicundus, 1949-1972 (7); Nomia melanderi, 1947-1962 (5); and Sphecodes sp. #1, 1937-1958 (3). None of these is known to be oligolectic; 3 of them were collected from Layia platyglossa or Phacelia in the 1930's, spring flowers that are no longer extant at Antioch in numbers sufficient to be factors in bee bionomics.

Meloidae: Only two of 9 recorded species of blister beetles persist at Antioch; most of the others were collected too few times to document their residence. However, Eupompha elegans, a desert species, was recorded 4 times, the last in 1940.

Tenebrionidae: Coelus gracilis, a flightless burrowing beach beetle, presents one of the most puzzling extinctions. Originally described from Antioch on the basis of a 1938 series, it was collected 5 times, the last in 1941. The species was presumed extinct until we discovered it at 4 places along the western margin of the San Joaquin Valley in the 1970's (Doyen, 1976). These sites, which are presumed to be relictual from beaches of

Pleistocene inland seas, are small, two of them less than 500 m^2 in extent. The only explanation for the early disappearance of *C. gracilis* at Antioch seems to be that nobody looked for it after 1941 (tenebrionids generally were ignored during the post war era -- only 19 records for 9 species in 1948-54) until Doyen and I attempted sand-screening in 1974-76 without success. During the interim, the habitat occupied by the *Coelus* colony, which may have been restricted to one portion of the dunes, must have been eliminated. Only one other tenebrionid that had been recorded more than once in the past was not recovered during the recent 7-year era, *Helops californicus* (6 records 1939-1959).

probably winter active associated with dead wood

Species restricted to one of the two refuge parcels. -- Differences in habitat composition at LC and SP are sufficient to restrict the occurrence of some insect species, according to 1976-82 data. Predictable examples include phytophagous insects such as Lepidoptera feeding on *Quercus* restricted to LC, and species that are dependent upon active sand, such as mutillids, at SP. There were also a number of examples for which there were no obvious environmental restrictions. Table 7 lists 34 species, recorded more than twice during the recent era, exclusively at either LC or SP, in the 14 families compared for all eras and in Lepidoptera. Among these, 15 species occurred only at LC, 19 at SP.

The most interesting instances of restriction are the beetle-hunting philanthine wasps. Five species of *Cerceris* and *Eucerceris* occupy only one area, 2 at LC, 3 at SP, while a sixth species, *C. vanduzeei*, was common at both sites. Two other species were recorded during these years, *C. acanthophila* (2 records in 1976) and *C. convergens* (1 record in 1977) but are suspected to be no longer resident.

Prey selection by any *Cerceris* species usually is restricted to beetles of one family, even over widespread geographic areas, although various genera may be preferred by individual females or in different locations (Krombein, 1979; Scullen & Wold, 1969). Among the extant Antioch species, 3 are weevil-hunters, one selects buprestids, and prey of the two smallest species are unknown. By segretating the female wasps into size categories, a division of the hunting niche, by prey size, is perceived. Thus, C. frontata, a large wasp, 17-19 mm in length, catches large weevils at SP, probably Lixus, which is one of the previously recorded prey that was observed at Antioch in 1981-82. Eucerceris ruficeps (9-12 mm) also occurs at SP but does not compete with C. frontata for prey, capturing small curculionine weevils, Sitona and Dysticheus (Linsley & MacSwain, 1954; one Disticheus prey record May 1982). A third weevil-hunter, C. sextoides (13-15.5 mm) also provisions with Sitona (Krombein, 1979; specimen record Antioch, 1952, UCB), but the Antioch population is restricted to LC, displacing E. ruficeps there.

Cerceris californica occurs at SP and avoids competition with its congeners by provisioning with Buprestidae. In a chaparral situation in southern California, this species took buprestids of 22 species in 4 genera, primarily Acmaeodera (Linsley & MacSwain, 1956), while a series of females taken near Tracy, San Joaquin County, is associated with Chrysobothris (UCB). It is remarkable that californica has survived at Antioch because buprestids are not abundant there. I observed Acmaeodera on several occasions in May and early July, at Oenothera flowers and on Lupinus, and collected one female C. californica with an Acmaeodera victim May 28, 1982. This wasp may also depend upon Agrilus, which were common on Salix in late May. Most records for californica at Antioch are mid-May to July 2, but it was collected in late September, 1938, so a sequence of prey species may have been used.

There are no prey records for the remaining two species, C. cockerelli and C. vanduzeei, which are much smaller wasps (6-9 mm). Related species (Group I of Scullen, 1965) are known to capture tiny Chrysomelidae, Bruchidae, or Curculionidae, and C. blakei of the eastern U.S. is recorded taking very small weevils, a chrysomelid and a tenebrionid (Krombein, 1979). Thus, the two Antioch species may use different beetle families at LC, and if either of them uses weevils, their size prevents competition with C. sextoides (LC) and C. frontata (SP).

It is further interesting that the cercerine wasp fauna at Antioch has lost competitors of each of these size guilds. Cerceris bicornuta (17-22 mm) is as large as frontata and is recorded using large weevils (Eupagoderes and Sphenophorus) elsewhere. There were 6 records of bicornuta at Antioch in 1937-48, about half as many as for frontata in the 1930's and 40's, suggesting that the more abundant of the two persisted when industrial development restricted the habitat area. In the mid-size range, C. nigrescens (10-13 mm) was collected at Antioch from 1938 to 1975 (7 records); elsewhere it is recorded as preying on Sitona and other small curculionine weevils. Evidently C. sextoides and Eucerceris ruficeps, which were collected 4 or 5 times more frequently than was nigrescens, were better adapted to exploiting the diminishing habitat.

Two small Cerceris also disappeared: C. convergens (3 records, 1938-77), and C. finitima (2 records, 1938, 1953), for which there is one record of bruchid and chrysomelid prey, respectively. Presumably they could not share the tiny beetle niche with the much more abundant C. vanduzeei (35 records prior to 1976, despite its small size) and C. cockerelli, which appears to have colonized the area after 1955.

Possible Recently Colonized Species. -- Insects that were recorded at Antioch only during recent years may have been overlooked by earlier collectors, or specimens may have been dispersed to museums not surveyed in this study. Alternatively, some species may have colonized the area despite or ~~even~~ because the habitat changed to a more stabilized, weedy situation. Such colonizers would be expected most commonly among introduced insects or native species that feed on weedy plants. Examples include the alkali mallow-feeding skipper butterfly, Pyrgus scriptura (Boisduval), which is believed to have invaded the Central Valley via weedy habitats and was discovered in the Delta area in 1956-57, and a polyphagous tortricid moth, Platynota stultana (Walsingham), which expanded its range in northern California in recent decades, and was first observed at Antioch in 1967 (Powell, 1983). Most of the insects in the 14 families discussed here, however, are more characteristic of native habitats, and presumably colonizations in a deteriorating natural community are fewer. In each example, an assumption has to be formulated on the basis of size of individuals, biological role and geographical distribution of the species, and specialization of past collectors.

For example, it is difficult to imagine that four species of Mythicomyia have moved into the area in recent years. Rather, it seems likely that these tiny flies, which are characteristic of native, arid habitats and not weedy ones, were overlooked by collectors in former eras. Similarly, Stichopogon, a tiny robberfly requiring specialized searching and collecting effort, was recorded only three times prior to my recent survey, the first in 1952. It seems likely that a population has been present all along, but entomologists of the 1930's, 1940's, 1960's, and early 1970's did not know or care. Metapogon fergusoni, a similar asilid, probably was not recorded before 1977 for the same reason.

There are 36 species that were collected for the first time at Antioch in 1976-82. Among these, however, 24 were taken only once, possibly as strays from adjacent habitats. Most of the remainder are small insects of the kinds likely to be overlooked. Nonetheless, there are a number of insects in the Antioch fauna that must have colonized or became more abundant subsequent to the industrial building era (Table 8). These species are of a size or frequency that it does not seem likely they could have been overlooked by earlier collectors. This is most obvious in the Pompilidae, where records indicate that overall diversity has increased, despite the fact that P.D. Hurd and M. S. Wasbauer, who specialized in spider wasps, often collected at Antioch in the 1947-1954 era.

INSECTS ASSOCIATED WITH ERYSIMUM AND OENOTHERA

I did not conduct a detailed survey of the insects associated with the two endangered plants, *Erysimum capitatum* var. *angustatum* and *Oenothera deltoides* var. *howellii*, but sporadic observations during the spring months yielded some information on pollinators and predators.

Pollinators. -- A wide variety of insects visits *Erysimum capitatum*, including bees of many genera, butterflies, and flies. Most visitors are nectar-seekers that may occasionally transfer pollen incidentally, while polylectic bees apparently sometimes collect the pollen. At Antioch, samples on 4 dates between March 13 and May 28, 1982, included halictid bees of 6 genera: *Agapostemon texanus*, *Dialictus brunneiventris*, *D. perichlarus*, *D. tegulariformis*, *Evylaeus nigrescens*, *Halictus ligatus*, *Lasioglossum pavonotum*, and Sphecodogastra aberrans[1]. Among these, D. tegulariformis (1♀) and L. pavonotum (3♀) carried pollen loads, on April 21. Both large (Anthophora, Bombus) and small (Ceratina) apids, particularly males, commonly visit Erysimum. None of the larger females carried pollen, but several males had the faces covered with pollen. One Ceratina female collected April 21 had a partial load of pollen. Hence it seems probable that if insect vectors are a normal means of pollination in Erysimum, a variety of polylectic bees serve the purpose at Antioch.

Oenothera deltoides, by contrast, is an evening-flowering species that is believed to be adapted to hawkmoth (Sphingidae) pollination (Linsley et al., 1963). The flowers do not crumple until midday, and hence provide residue pollen for polylectic bees and several oligolectic species that are adapted morphologically to carry the pollen and behaviorally to forage during evening or early morning (Linsley et al., 1963, 1973). Various species of Andrenidae and Halictidae occur in different parts of the plant's broad geographic distribution, including Sphecodogastra aberrans. Nesting and foraging activities of this bee were studied in detail at Antioch by Turner (1966), who found that pollen-collecting regularly occurred both in the evening after flowers first opened and in early morning. Crepuscular activity began 65 to 18 minutes before sundown and terminated an average of 28 min. after, while matinal activity took place from 48 min. before to a mean termination 100 min.

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[1] Identified by P. D. Hurd, Jr. (in 1952-1965) and G. Eickwort (in 1982). Presumably the same halictid has been identified as an undescribed species closely related to Evylaeus galpinsiae Cockerell by G. E. Bohart (Linsley et al., 1973:7; Bohart & Youssef, 1976:196). I did not have specimens studied by Bohart to provide for comparison by Eickwort.

Later described as a new species (McGinley 2003) Sphecodogastra antiochensis after sunrise.

S. aberrans was fairly common (20+ observed) at SP on June 14, 1982, during my only early morning visit. Females were active until 1.5 hrs after sunrise, but none was observed with pollen after 0630, 35 min after sunrise.

A smaller species of halictid, Dialictus sp. A., was active at Oenothera flowers on the same morning (June 14, 0630-0800), and one female was taken with pollen between 0700-0730.

Another bee, Hesperapis regularis (Cresson) (Melittidae), which used to be abundant at Antioch, was a common Oenothera visitor and may have been a factor in its pollination, although it is believed to be primarily an oligolege of Clarkia unguiculata at this site (Stage, 1966). Hundreds of males were observed sleeping in the flowers of Oenothera in May, 1958 (Linsley & MacSwain, 1958), and aggregations of nests and sleeping males were seen by Stage in 1963 and by Turner in 1965. I observed H. regularis only once, when both sexes including pollen-laden females were taken in Oenothera flowers on May 25, 1977; in 1982 my spring survey may have overlooked this bee, but if present it is rare compared to former years. I searched Clarkia flowers only on June 15, which is at the end of the flight period of H. regularis (Stage, 1966).

Pollination by small bees such as S. aberrans has been shown to be possible, but the total effect on a plant population may be insignificant (Linsley, et al. 1963; Turner 1966). Turner did not observe any hawkmoth activity during the 1965 season and suggested that pollination of Oenothera may be effected by diurnal bees that scavenge residual pollen. Among these, he mentioned Agapostemon texanus and Bombus (bumblebees). I collected pollen-laden A. texanus at Oenothera in May 1977, and in 1982 I found Lasioglossum pavonotum with pollen, and 3 genera of Apidae, Ceratina, Bombus, and *Apis mellifera* (honeybees) visiting *O. deltoides* in the morning after *S. aberrans* had ceased foraging.

It is possible that a large colony of a sphingid moth such as *Hyles lineata* (L.) existed at the Antioch dunes prior to human intervention and acted on the primary pollinator of *Oenothera deltoides*. Certainly populations of this and other hawkmoth species exist in suburban and agricultural situations in the vicinity, so that occasional individuals could fly to the *Oenothera* flowers at LC and SP. However, the only known observation of sphingids at Antioch was made by Alice Howard, who discovered a few full grown larvae of *H. lineata* feeding on *O. deltoides* in late May, 1983. Hence, although sphingids probably act as occasional pollinators of the Antioch evening primrose, our observations tend to corroborate those of Turner in the 1960's, indicating that hawkmoths are not abundant at the site. Therefore, pollination probably depends upon pollen-collecting females of *Sphecodogastra aberrans* and scavenger-nectar visits by larger, polylectic bees later in the morning.

Predators. -- Crucifers generally are exploited by specialists among the phytophagous insects and are unpalatable to generalists. There are four Lepidoptera that can or do feed on *Erysimum capitatum* var. *angustatum*. The primitive moth, *Chalceopla simpliciella* (Walsingham) (Incurvariidae) has been collected from flowers of *Erysimum* at LC, but not SP, in April, 1957, 1965, 1967, 1977, and 1982. The female of this small, bronze-colored, diurnal moth is equipped with a piercing ovipositor, by which eggs are inserted into the ovules. Young larvae feed in the developing seed, leaving after several are consumed to make portable cases (based on observations of a related species on *Arabis* in the Berkeley Hills, JAP 63F5). Later instars probably live on the ground and may eat dead leaves. A second microlepidopteran, the ubiquitous diamond-back moth, Plutella xylostella (L.), feeds on all kinds of crucifers, native and introduced, and probably lives primarily on Hirschfeldia (Brassica) at Antioch, although I reared it only from Lepidium latifolium (JAP 77K3 at LC). Probably leaves of Erysimum serve as a larval food in spring for this multivoltine species.

E. capitatum also may serve as a larval host of two pierid butterflies, Euchloe ausonides Lucas and Pieris protodice Bdv. & LeC., but no larvae were observed. The latter species is not a continuous resident, but in most years it is present after mid-summer. In 1977 the multivoltine P. protodice persisted at Antioch throughout the season and in such years could feed on Erysimum in spring. Euchloe flies only in spring, deposits its eggs on inflorescences of crucifers, and the larvae feed primarily on immature seed pods. At Antioch the population could be primarily dependent on adventive Hirschfeldia. In 1982 the butterflies were observed from March 13 to May 28 and were present both at LC and SP.

One additional potential predator (exploiter) of Erysimum, the harlequin cabbage bug, Murgantia histrionica Hahn (Pentatomidae), becomes abundant on Hirschfeldia by late summer, both at LC and SP. It was not observed on E. capitatum, however, and spring feeding nymphs may not travel far from the Hirschfeldia where eggs are laid in fall.

Oenothera deltoides var. howellii has at least three specialist predators, two small moth species that probably are inconsequential, and a leaf feeding beetle that appears to be devastating the plant, in addition to sporadic defoliation by the sphingid, Hyles lineata, mentioned above.

The white-lined sphinx, Hyles lineata, a widespread species which is found occasionally throughout the San Francisco Bay area, is polyphagous on low growing herbaceous plants in the caterpillar stage. Larvae sometimes occur in epidemic outbreaks, especially in desert areas, where Oenothera is one of the host plants.

Mompha eloisella (Clemens) (Gelechioidea) is a widespread species that is dependent upon Oenothera; larval feeding occurs in the lumen of the flowering stalks. Whether effects of this feeding are detrimental to the plants is unknown. Larvae and pupae were collected in March in dry stalks from the preceding season (JAP 82C13). They were abundant, but many larvae and emerging adults were destroyed by pyemotid mites which occurred in the stem colonies in the field. Adults of M. eloisella have been collected at LC and SP in April 1956 and 1982, May 1967, and July, 1965, so there may be more than one generation per season.

A second species of Mompha, seen only at SP, feeds as a leaf- or bud-miner. One adult was reared from O. deltoides in April, 1978 (JAP 78D86) and one larva suspected to be the same species was found in a bud in March, 1982. Adults were observed on Oenothera flowers in June, 1982.

Described as "a sea of white" in 1965 (Turner, 1966), the flowering of Oenothera had declined to ca 50 plants at LC in June 1982; and there were ca 120 plants in bloom in the eastern area of SP. The sparseness seems attributable primarily to loss of suitable seedling habitat, due to sand removal and increased weediness, but also to feeding by adults and larvae of a chrysomelid beetle, Altica lasulina LeConte. A widespread specialist on Onograceae, this beetle becomes more abundant as the season progresses, such that virtually all vegetative parts of older plants and many adjacent Oenothera seedlings are completely skeletonized by mid-July or early August, after which flowering is essentially finished. By contrast, Turner (1966) stated that flowering and bee activity continued into mid-September and blooming through October. There are 1950's specimen records of Sphecodogastra *aberrans* in October (UCB).

Turner did not mention deleterous effects of this chrysomelid, and the UCB collection does not have specimens of it collected in 1965 or earlier. However, there is a long series of apparently the same species in CAS without hostplant data, collected by Van Dyke in September, October, and February 1937-1941. It was common by the time I began the recent survey in July, 1976, suggesting that subsequent to the 1960's some imbalance in its bionomics occurred to enable buildup of high population densities. It is possible that the beetle-hunting wasp, *Cerceris finitima*, which was collected at Antioch in 1938 and 1953 and is recorded preying on a chrysomelid in Ohio, hunted *Altica lasulina*; and it is possible that one of the two remaining small *Cerceris*, *cockerelli* or *vanduzeei* provisions nests with this beetle. As noted above, *C. cockerelli* evidently has colonized and become common at LC since 1958, coincidentally, perhaps, with the increase of abundance of *Altica* on *Oenothera*.

SUMMARY

A suvey of insects at the remnant riverine dunes east of Antioch, Contra Costa Co., CA, was made during 1976-1982 by compiling records from 94 visits representing all months. Fourteen families (Table 1) were selected to represent the sand-based fauna, and dates of all species labelled Antioch, 1 mi E, and 2 mi E of Antioch were recorded from CAS, UCD, and UCB. Those representing 1933-39 and 1948-54 (135, 121 visits respectively) were compared separately to the recent 7-year era. The three eras represent early (extensive sand-mining), middle (extensive industrial buildup), and late (final sand-mining and extensive weediness) in the deterioration of the dune habitat. The maximum "biological island" is estimated to have declined from ca 2.2 km^2 to 0.25 km^2.

Altogether, 376 species of the 14 families are recorded (Table 2), of which 97, or 26%, were collected on only one date. Because collectors of early eras did not sample thoroughly, there is no significant difference between the diversity (number of species) recorded in the 3 selected eras. The data indicate that 1930's workers overlooked small insects and nocturnal species, while those of the postwar era overlooked small species to a lesser degree and tended to ignore Bombyliidae and Tenebrionidae (Table 4)

Decline in diversity is best documented by disappearance of species, especially larger insects. About 157 species of those recorded earlier were not collected in 1976-82 and are presumed extinct at this locality (Table 6). The parade of passing species began surprisingly early -- 35 species were last seen in the 1930's -- and showed no marked acceleration correlated with an exploitation event, prior to 1976. Rather, there has been a gradual loss of species until the present era, when it appears that the extinction rate rapidly increased. Loss of diversity seems most obvious in Therevidae, diurnal Mutillidae, larrine and nyssonine Sphecidae, and Meloidae. Probably it has been dramatic in Bombyliidae and Chrysididae, but collectors of earlier eras also recorded less than 50% of the total species diversity because smaller species were overlooked. By contrast, Asilidae, Pompilidae, the larger sphecids, and Tenebrionidae have been less affected, with more than 60% of the known species extant into the recent era.

Among 27 species or subspecies having Antioch as the type locality, 8 are not known elsewhere (Table 5), and 9 others are known only from similar sandy habitats in the Central Valley, many of which have been destroyed. Four of the endemics appear to be extinct at the type locality, and three are too poorly collected or known taxonomically to document. The remaining one, _Apodemia mormo langei_ survives in declining numbers.

At least 34 species in the 14 families recorded and in Lepidoptera appear to be limited to one of the two refuge parcels. In philanthine sphecid wasps, which are beetle-hunters, restriction in 5 species appears to be the result of competitive displacement.

A number of insects appear to have colonized the drastically altered habitat since the early 1950's industrial buildup. This would be expected of species that occupy weedy habitats, but even in the flies and wasps discussed here, which are characteristic of native situations, several newcomers are recorded. This is best documented in spider wasps where the diversity clearly increased after specialists collected the fauna 30 years ago.

RECOMMENDATIONS FOR RECOVERY MANAGEMENT

Most of the insects discussed here are characteristic of active sand habitats. Their larvae live in loose sand as active predators or scavengers, or the adults dig burrows in loosely to well compacted sand where their offspring are housed in cells, or they are cuckoo-associates, cleptoparasitic, or predators of such burrowing species. In addition to the 14 families compared, I conducted a survey of small moths, primarily by larval collections, and compiled literature and collection records from Antioch. These microlepidoptera feed on plants, and although there are no Antioch records of them prior to the 1950's, they provide one index of present diversity of the phytophagous insect fauna. At Antioch there are 69 species for which foodplants are known, of which 2 are polyphagous, 8 feed on weedy native and introduced plants (*Lepidium*, *Hirschfeldia*, grasses etc.), and the remainder (85%) are host specific on native plants -- 22 species feed on *Quercus*, 7 on *Lupinus albifrons*, 7 on *Salix*, 4 on *Heteromeles*, 3 on *Senecio*, 3 on *Ambrosia psilostacha*, 2 each on *Baccharis*, *Oenothera*, *Lotus*, and one each on Croton, Eriogonum, Erysimum, Psoralea, Grindelia, Gutierrezia, and Heterotheca. In addition a noctuid moth, Schinia mortua, is specific to Grindelia camporum, and the Antioch population is believed to be the northernmost known.

Based on my observations of the sand-dwelling and native plant-feeding insects and the decline of them and their hostplants during the past 10 years, I believe that loss of abundance and diversity in many insect taxa is directly related to loss of active sand. Unless a substantial source of sand is provided, the habitat will continue to stabilize through weediness, and the diversity of native plants will continue to decline. Although some plants such as Quercus, Lotus, Lupinus albifrons, Heteromeles, Grindelia camporum, and possibly Erysimum are able to persist in weedy habitats, most of the natives mentioned cannot. As their individuals senesce, they are not replaced because seedlings cannot compete with stabilized weed cover or in artificially disturbed weedy situations such as that promoted by annual rototilling.

It appears to me that Eriogonum, Senecio, Gutierrezia and Chrysopsis are dying out for lack of open sand. These are four of the most important nectar sources during summer and fall. Oenothera deltoides has suffered similarly but appears to persist in less obviously active sand. Senecio and Erysimum seem to be dependent upon hillslopes, and neither has been successful in colonizing areas where sand excavation has left extensive level areas. The same is true of Eriogonum, which appears to require deep, loose sand not necessarily hills, for survival of seedlings after the first year.

An added problem for maintenance of the two endangered plants, Erysimum capitatum and Oenothera deltoides is continuance of stable populations of their pollinators. My observations in 1982 indicated that several species of polylectic bees (at least 7 Halictidae of 5 genera; 2 or 3 Anthophoridae) visit Erysimum at Antioch, as do various other nectar seeking insects; hence its pollination, if primarily dependent on insects, probably will not be a limiting factor. Oenothera deltoides, by contrast appears to be primarily pollinated by a matinal and crepuscular bee, Sphecodogastra aberrans, the abundance of which has declined with that of the plant. Casual visitors include several other species of Halictidae, and Hesperapis regularis (Melittidae), but Oenothera abundance has declined drastically and their role in pollination is believed to be minor. The flowers of O. deltoides are primarily hawkmoth-adapted, and moths may effect pollination at Antioch, but there are no observations of moth visits of Sphingidae at the sites.

Following are procedures that could aid in the maintenance and/or recovery of some of the faunal and floral elements.

Short term recovery. -- I recommend that disking at the vineyard at SP be resumed. Annual disking and weed removal in the vineyard maintenance provided a source of active sand that created a wind blown sandy area to the east of it. That site became stabilized with weeds soon after the weed cover developed in the vineyard in 1982. The area could be disked and the loose sand pushed into two or three parallel, north-south ridges, to provide suitable slopes for deposit of wind blown sand and for establishment of Senecio and Eriogonum.

At LC, similar use of a bulldozer could provide one or two north-south ridges on the frontage parcel, and if PG&E could be convinced to cooperate, on the southern half of each of the powerlines corridors. PG&E might provide the equipment as a public relations benefit. The immediate several meters along the PG&E-LC margin adjacent to the highway, should be cleared and treated with herbicide as a fire prevention measure and as a means of reducing conflict with the district fire marshal.

Some of the alien plants should be removed. It would be feasible to cut and remove all the *Ailanthus* and *Robinia* at LC, and it would be possible, perhaps by volunteer aid from Boy Scouts or Native Plant groups, to remove all the iceplant, *Carpobrotus* (*Mesembryanthemum*) at both sites. Although initially the areas opened thusly would be susceptible to colonization by annual weeds, eventually they could be manipulated by sand movement and planted with natives. At present they are stabilized and exclusive of natural vegetation.

Some removal or suppression by herbicide spot treatment of other alien plants, especially Russian thistle and yellow-star thistle ought to be attempted. These plants are relatively easily removed (as compared to annual grasses), yet form extensive ground cover preventing seedling establishment by native plants and stabilize active sand. This is particularly evident at SP in areas formerly kept open by trail bike activity.

Long term recovery. -- A large volume of sand has to be imported. It is unrealistic to believe that sufficient wind-blown sand will accumulate from natural sources before total weedcover eliminates the remaining native plants. The proposed deposit of river dredgings by the U.S. Army Corps of Engineers may provide an economically feasible means of sand import. Whether dredging spoils will generate fine-grained sand capable of wind movement is not known. Based on the results of such deposits at Rio Vista, it appears that coarse grained residue that is not readily colonized by native plants will be the product, at least initially. Nevertheless, without any alternative sand source, the dredging proposal seems worthy of trial. If the process is realized, I strongly recommend that the material be deposited in the middle of the excavated area on the west parcel. I think use of the LC basin for this dumping is unlikely to produce useful results because the site is shielded from prevailing winds, so little sand movement could occur, and any that did occur would result in redeposit on properties east of the Wildlife Refuge. Rather, it seems likely a basin of deeper, solidified material soon to be covered with weeds would result. Moreover, filling the LC basin would destroy several native insect populations associated with Grindelia camporum, Salix, and the only tidal-free marsh habitat on the refuge.

After the dredging fill dries, its surface should be treated with monocot-specific pre-germination herbicide to prevent establishment of alien annual grasses and stabilization before wind action can begin to activate its surface. Planting of some elements of native flora would be desirable, if economically possible, especially Eriogonum, Senecio, and Chrysopsis. Judging from results of sand-mining at SP in the 1950's, I think Lupinus, Oenothera, Croton, Gutierrezia, and Heterotheca would invade the replenished habitat naturally if weed cover were prevented.

If a sufficiently high hill (5-10 m ?) of sand was produced, eventually redeposit sand should accumulate to its lee side and begin to produce a natural sequence of active sand mounds that are initially invaded by Eriogonum, Oenothera and Croton, as we have seen in the former road bed area at SP during 1978-82.

Eventually, if either or both approaches to providing active sand are realized, planting of native annuals could be carried out by scattering seed. Eschscholzia, Platystemon, Phacelia, and Layia are examples of annuals that must have been more extensive in the past, judging from labels on insect specimens collected in the 1930's and 1940's. There seems to be a sufficiently diverse native bee fauna in the area that pollination would be effective (18 species of Halictidae and more than 40 non-parasitic species of other families collected in 1976-82, besides Bombus and Apis).

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APPENDIX 1.

Table 1. Biological roles and number of species recorded from Antioch in 14 insect families (species collected only once in parentheses)

DIPTERA		
Apioceridae	larvae believed to be free-living predators in sand; adults nectiferous or non feeding	3
Asilidae	larvae predaceous in sand, rotting wood, etc.; adults predaceous	15 (5)
Bombyliidae	larvae specialized predators in sand, wood; adults nectiferous	46 (18)
Conopidae	larvae internal parasitoids, of bees or wasps; adults nectiferous (?)	10 (2)
Therevidae	larvae predators in sand; adults non-feeding?	8 (3)
HYMENOPTERA		
Chrysididae	larvae specialized (cuckoo) parasitoids of wasps, bees	35 (12)
Mutillidae	larvae parasitoids of aculeate wasp and bee larvae or pupae	19 (1)
Scoliidae	larvae believed to be external parasitoids of scarab grubs adults nectiferous	3
Tiphiidae	believed to be larval parasitoids of burrowing beetle grubs	8 (1)
Pompilidae	adults hunt spiders, one per offspring and burrow; adults nectiferous	39 (9)
Sphecidae	adults specialized hunters of particular insects or spiders, usually several to many prey per offspring; adults nectiferous	123 (28)
Halictidae	larvae provisioned with pollen in ground burrows; adults oligolectic or polylectic, nectiferous, solitary or semisocial	35 (11)
COLEOPTERA		
Meloidae	larvae specialized parasitoids; adults phytophagous	9 (3)
Tenebrionidae	larvae and adults detrivorous or phytophagous scavengers in sand, rotted wood, etc.	23 (4)
TOTAL		376 (97)

Table 2. Systematic list of 376 insect species recorded at Antioch, 1922-1982, with year of last known collection. (*) denotes 92 species recorded only once (24%)

DIPTERA

Apioceridae	
Apiocera barri Cazier	1982
Apiocera chrysolasia Cazier	1977
Rhaphiomidas trochilus (Coquillett)	1974
Asilidae	
Dicolonus simplex Loew*	1937
Efferia albibarbis (Macquart)	1982
Efferia antiochi (Wilcox)	1981
Efferia cana (Hine)	1959
Holopogon atrifrons Cole*	1938
Machimus occidentalis (Hine)	1959
Machimus ?sestertius Martin*	1977
Metapogon fergusoni Wilcox*	1977
Metapogon hurdi (Wilcox)	1981
Nicocles aemulator Loew	1951
Proctacanthus occidentalis Hine	1982
Stenopogon breviusculoides (Bromley)	1982
Stenopogon obscuriventris (Loew)	1982
Stichopogon n. sp. near fragilis Back	1982
Triorla interrupta (Macquart)*	1946
Bombyliidae	
Anthrax irroratus irroratus Say*	1933
Anthrax melanopogon (Bigot)*	1959
Aphoebantus conurus Osten Sacken	1940
Aphoebantus mus Osten Sacken	1978
Aphoebantus n. sp. nr. obtectus Melander	1982
Aphoebantus sp. nov. nr. eremicola Melander	1959
Aphoebantus tardus Coquillett	1977
Chrysanthrax atrata (Coquillett)	1982
Chrysanthrax cautor (Coquillett)*	1965

Bombyliidae (continued)

Conophorus nigripennis (Loew)	1982
Empidideicus sp. nov.	1981
Exoprosopa divisa (Coquillett)*	1939
Exoprosopa dodrina Curran	1941
Exoprosopa doris Osten Sacken	1979
Exoprosopa eremita Cresson	1954
Exoprosopa jonesi Cresson	1965
Exoprosopa xanthina Painter	1978
Geron parvidus Painter	1972
Hemipenthes lepidota (Osten Sacken)*	1978
Hemipenthes sp. nr. curta (Loew)*	1948
Hemipenthes sp. nr. morio (L.)*	1982
Hemipenthes sinuosa jaennickeana (Osten Sacken)*	1938
Heterostylum robustum (Osten Sacken)	1978
Lepidanthrax inauratus (Coquillett)*	1935
Ligyra gazophylax (Loew)	1941
Lordotus striatus Painter	1966
Mythicomyia n. sp. Hall 82	1981
Mythicomyia armipes Cresson	1981
Mythicomyia cruralis Melander*	1982
Mythicomyia polygena Melander	1981
Paracosmus edwardsii (Loew)	1962
Paravilla edititicoides (Painter)*	1959
Paravilla fulvicoma (Coquillett)*	1941
Paravilla syrtis (Coquillett)	1978
Phthiria loewi Painter*	1965
Phthiria sp.	1977
Poecilanthrax colei Johnson & Johnson	1936
Poecilanthrax pilosus (Cole)	1936
Poecilanthrax varius Painter & Hall*	1935
Toxophora virgata (Osten Sacken)*	1950
Villa fulviana (Say)*	1942
Villa lateralis (Say)	1982
Villa molitor (Loew)*	1982
Villa (Thyridanthrax) nugator (Coquillett)	1982

Bombyliidae (continued)

Villa pretiosa (Coquillett)	1982
Villa semifulvipes Painter*	1977

Conopidae

Dalmannia pacifica Banks*[1]	1950
Myopa perplexa Camras	1939
Myopa willistoni Banks*	1937
Physocephala texana (Williston)	1982
Physoconops fronto (Williston)	1981
Thecophora propinqua (Adams)	1978
Zodion americanum Wiedemann	1982
Zodion fulvifrons Say	1982
Zodion intermedium Banks	1939
Zodion obliquefasciatum (Macquart)	1978

Therevidae

Acrosathe otiosa (Coquillett)	1982
Arenigena sp. nov. Irwin '78 (marcida gr.)	1982
Ozodiceromyia costalis (Loew)	1965
Ozodiceromyia laevigata (Loew)	1976
Pherocera sp.*	1982
Tabuda planiceps (Loew)	1967
Thereva fucata Loew*	1936
Thereva sp. nr. johnsoni Coquillett*	1936

HYMENOPTERA

Chrysididae

Argochrysis armilla Bohart	1959
Argochrysis mesillae (Cockerell)	1978
Ceratochrysis collega Bohart	1982
Ceratochrysis perpulchra (Cresson)*	1954
Ceratochrysis trachypleura Bohart	1952
Chrysis astralia Bohart*	1937
Chrysis coerulans Fabricius*	1949
Chrysis coloradica Bohart	1954

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[1] Based on one specimen cited by Camras & Hurd (1957) (not located)

Chrysididae (continued)

Chrysis derivata Buysson	1977
Chrysis fuscipennis Brullé*	1982
Chrysis lauta Cresson	1940
Chrysis lucifera Bohart	1977
Chrysis snowi Viereck	1958
Chrysis vagabunda Bohart	1977
Chrysis venustella Bohart	1958
Hedychridium amabile Cockerell*	1958
Hedychridium dimidiatum (Say)	1962
Hedychridium fletcheri Bodenstein	1972
Hedychridium solierellae Bohart & Brumley	1965?
Hedychrum boharti French	1982
Hedychrum parvum Aaron	1982
Holopyga hora Aaron	1982
Minymischa arenicola Kimsey	1982
Omalus (Diplorrhos) variatus (Aaron)	1982
Omalus (Diplorrhos) telfordi Bohart & Campos*	1981
Omalus (Omalus) iridescens (Norton)*	1950
Omalus (Pseudomalus) purpuratus (Provancher)*	1952
Omalus (Pseudomalus) trilobatus Bohart & Campos*	1952
Omalus glomeratus (Buysson)*	1981
Omalus janus (Haldeman)*	1965?
Parnopes edwardsii (Cresson)	1979
Parnopes fulvicornis Cameron	1981
Pseudolopyga carrilloi (Bohart & Brumley)	1966
Pseudolopyga taylori (Bodenstein)*	1966
Trichrysis doriae (Gribodo)*	1939

Mutillidae

Chyphotes (Chyphotes) mandibularis (Mickel)	1953
Chyphotes (Pitanta) mickeli mickeli Buzicky	1982
Dasymutilla abdita Mickel	1982
Dasymutilla aureola (Cresson)*[1]	1939

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[1] Based on one specimen in Swisher collection (ID by Swisher)

Mutillidae (continued)

Dasymutilla californica (Rad.)	1981
Dasymutilla coccineohirta (Blake)	1982
Dasymutilla flammifera (Mickel)	1939
Dasymutilla sackenii (Cresson)	1979
Odontophotopsis sp. #1 (Group Mellicausa)	1982
Odontophotopsis sp. #2 (Group Mellicausa)	1982
Pseudomethoca dentifrontalis Bradley	1968
Pseudomethoca anthracina (Fox)	1982
Sphaeropthalma (Micromutilla) difficilis (Baker)	1982
Sphaeropthalma (Photopsis) angulifera (Schuster)	1952?
Sphaeropthalma (Photopsis) edwardsii (Blake)	1954
Sphaeropthalma (Photopsis) orestes (Fox)	1982
Sphaeropthalma (Photopsis) triangularis (Blake)	1956
Sphaeropthalma (Photopsis) unicolor (Cresson)	1982
Typhoctes p. peculiaris (Cresson)	1982

Scoliidae

Compsomeris pilipes (Saussure)	1977
Campsomeris tolteca (Saussure)	1982
Campsoscolia alcione (Banks)	1981

Tiphiidae

Brachycistis agama Dallatorre	1956
Brachycistis imitans (Malloch)	1982
Brachycistis ioachinensis Bradley	1981
Brachycistis petiolata Fox*[1]	1950's?
Myzinum frontale (Cresson)	1948
Myzinum maculata (Fabricius)	1981
Paratiphia nevadensis (Cameron)	1982
Tiphia n. sp. nr. nevadana, Wasbauer '83	1977

Pompilidae

Ageniella blaisdelli (Fox)	1979
Agenioideus biedermani (Banks)*	1955
Anoplius aethiops (Cresson)	1982
Anoplius (Lophopompilus) cleora (Banks)*	1978

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[1] Based on Wasbauer (1966:41) "There is a single record from Antioch" (specimen not located).

Pompilidae (continued)

Anoplius californiae Evans	1938
Anoplius clystera (Banks)	1977
Anoplius imbellis (Banks)	1952
Anoplius insolens (Banks)	1982
Anoplius nigritis (Doubleday)	1982
Anoplius toluca (Cameron)	1981
Aporinellus basalis Banks	1982
Aporinellus completus Banks	1982
Aporinellus fasciatus (Smith)	1978
Aporinellus medianus Banks	1981
Aporinellus taeniatus taeniatus (Kohl)*	1954
Aporinellus yucatanensis (Cameron)	1981
Aporus luxus (Banks)*	1954
Auplopus architectus metallicus (Banks)	1977
Ceropales maculata caenosa Townes	1954
Ceropales nigripes Cresson*	1938
Cryptocheilus hesperus (Banks)	1977
Entypus unifasciatus californicus Townes	1981
Episyron biguttatus californicus (Banks)	1981
Episyron conterminus posterus (Fox)	1982
Episyron quinquenotatus hurdi Evans	1982
Episyron snowi (Viereck)	1938
Evagetes hyacinthinus (Cresson)	1977
Evagetes mohave (Banks)	1954
Evagetes padrinus padrinus (Viereck)	1982
Evagetes subangulatus (Banks)*	1978
Hemipepsis ustulata ochroptera Stal*	1978
Pepsis pallidolimbata smithi Hurd*	1977
Pepsis thisbe Lucas	1982
Poecilopompilus interruptus semiflavus Evans	1981
Pompilus arctus Cresson*	1937
Pompilus phoenix Evans	1977
Pompilus scelestus Cresson	1978
Sericopompilus neotropicalis (Cameron)	1982
Tachypompilus unicolor unicolor (Banks)	1982

Sphecidae -- subfamily Ammophilinae	
Ammophila aberti Haldeman	1981
Ammophila azteca Cameron	1981
Ammophila boharti Menke	1956
Ammophila californica Menke	1981
Ammophila cleopatra Menke	1978
Ammophila kennedyi (Murray)	1978
Ammophila macra Cresson	1982
Ammophila nasalis Provancher	1978
Ammophila parapolita (Fernald)	1981
Ammophila placida Smith*	1937
Ammophila procera Dahlbom	1977
Ammophila pruinosa Cresson	1958
Podalonia communis (Cresson)	1955
Podalonia luctuosa (F. Smith)	1965
Podalonia sericea Murray	1981
Sphecidae -- subfamily Astatinae	
Astata bakeri Parker*	1942
Astata nubecula Cresson*	1953
Diploplectron beccum Parker*	1954
Dryudella caerulea (Cresson)	1981
Dryudella rhimpa F. Parker	1982
Sphecidae -- subfamily Crabroninae	
Belomicrus cladothricis Cockerell*	1981
Belomicrus eriogoni Pate	1981
Crabro argusinus Bohart*	1949
Crabro pleuralis Fox	1955
Crossocerus chromatipus Pate*	1977
Crossocerus sp. (not chromatipus)*	1981
Ectemnius (Clytochrysus) lapidarius (Panzer)*	1950
Ectemnius (Hypocrabro) spiniferus (Fox)	1981
Ectemnius continuus (F.)*	1977
Oxybelus californicus Bohart & Schlinger	1981
Oxybelus exclamans Viereck	1977
Oxybelus uniglumis (L.)	1977

Sphecidae -- subfamily Larrinae

Ancistromma bradleyi Bohart & Bohart*	1981
Ancistromma capax W. Fox	1981
Bothynostethus sp.*	1950
Larropsis tenuicornis (Smith)	1981
Liris argentatus (Beauv.)	1981
Liris beata (Cameron)*	1936
Miscophus (Nitelopterus) californicus (Ashmead)	1962
Pisonopsis birkmanni Rohwer	1981
Pisonopsis clypeata W. Fox	1978
Plenoculus davisi Fox	1972
Solierella albipes (Ashmead)	1958
Solierella blaisdelli (Bridwell)	1958
Solierella levis Williams*	1958
Tachysphex aequalis Fox	1981
Tachysphex alpestris Rohwer	1981
Tachysphex amplus Fox*	1965
Tachysphex antennatus Fox	1958
Tachysphex apicalis fusus Fox	1972
Tachysphex ashmeadii W. Fox	1981
Tachysphex clarconis Viereck	1973
Tachysphex psammobius Kohl*	1955
Tachysphex texanus (Cresson)	1978
Tachytes amazonus Smith	1949
Tachytes californicus Bohart	1949
Tachytes chrysopyga obscurus Cresson	1942
Tachytes distinctus distinctus Smith	1981
Tachytes fulviventris fulviventris Cresson	1938
Trypargilum californicum (Saussure)	1947

Sphecidae -- subfamily Nyssoninae

Bembix americana comata Parker	1981
Bembix amoena Handlirsch*	1936
Bembix occidentalis Fox	1981
Bicyrtes capnoptera (Handlirsch)	1953
Bicyrtes ventralis (Say)	1981
Foxia secunda (Rohwer)	1959

Sphecidae -- subfamily Nyssoninae (continued)

Glenosticta pulla (Handlirsch)	1978
Gorytes angustus (Provancher)	1965
Gorytes canaliculatus Packard*	1951
Gorytes provancheri Handlirsch	1952
Gorytes simillimus Smith*	1935
Hoplisoides confertus (W. Fox)*	1936
Hoplisoides dentatus (W. Fox)	1982
Hoplisoides hamatus (Handlirsch)*	1951
Hoplisoides spilopterus (Handlirsch)	1976
Hyponysson bicolor Cresson*	1952
Microbembex californica Bohart	1982
Microbembex nigrifrons (Provancher)	1977
Nysson chumash Pate	1962
Nysson recticornus Bradley*	1959
Steniolia duplicata (Provancher)	1955
Steniolia scolopacea scolopacea Handlirsch	1981
Stizoides (Tachystizus) renicinctus (Say)	1958
Zanysson texanus fuscipes (Cresson)*	1941

Sphecidae -- subfamily Pemphredoninae

Diodontus crassicornis Viereck	1981
Diodontus fraternus Rohwer*	1981
Diodontus occidentalis (Fox)	1982
Diodontus vallicolae Rohwer*	1977
Mimesa sabina Gittins	1978
Passaloecus armeniacae Cockerell*	1960
Spilomena sp.	1981
Stigmus fulvipes W. Fox	1981
Timberlakena yucaipa Pate	1981

Sphecidae -- subfamily Philanthinae

Cerceris acanthophila Cockerell	1976
Cerceris bicornuta Guerin	1948
Cerceris californica Cresson	1982
Cerceris cockerelli Viereck	1981
Cerceris convergens Viereck & Cockerell	1977

Sphecidae -- subfamily Philanthinae (continued)

Cerceris finitima Cresson	1953
Cerceris frontata Say	1982
Cerceris nigrescens F. Smith	1975
Cerceris sextoides Banks	1981
Cerceris vanduzeei Banks	1982
Clypeadon californicus (Bohart)	1982
Eucerceris ruficeps Scullen	1982
Philanthus crotoniphilus Vier. & Ckll.*	1935
Philanthus gibbosus (Fabricius)	1981
Philanthus multimaculatus Cameron	1981
Philanthus nasalis Bohart	1959
Philanthus pacificus arizonae Dunning	1982
Philanthus ventilabris (Fabricius)	1981
Philanthus ventralis (Mickel)	1981

Sphecidae -- subfamily Sceliphroninae

Chalybion californicum (Saussure)	1977
Chlorion aerarium Patton	1977
Sceliphron caementarium (Drury)	1977

Sphecidae -- subfamily Sphecinae

Isodontia elegans Smith	1981
Palmodes dimidiatus (DeGeer)	1979
Prionyx atratus (Lepeletier)	1954
Prionyx parkeri Bohart and Menke	1981
Prionyx thomae (F.)	1981
Sphex (Ammobia) ichneumoneus (L.)	1982
Sphex (Ammobia) pennsylvanica (L.)	1982
Sphex (Fernaldina) lucae (Saussure)	1979

Halictidae

Agapostemon femoratus Crawford	1954
Agapostemon texanus Cresson	1982
Dialictus sp. A of Eickwort 82*	1982
Dialictus sp. B of Eickwort 82	1982
Dialictus brunneiventris (Crawford)	1982
Dialictus diversopunctatus (Ellis)	1939

Halictidae (continued)

Dialictus incompletus (Crawford)	1977
Dialictus longicornis (Crawford)*	1954
Dialictus megastictus (Cockerell)	1950
Dialictus perichlarus (Cockerell)	1982
Dialictus punctatoventris (Crawford)*	1982
Dialictus tegulariformis (Crawford)	1982
Dufourea sandhouseae sandhouseae (Michener)*	1952
Evylaeus argemonis (Cockerell)*	1937
Evylaeus aspilurus (Cockerell)*	1941
Evylaeus kincaidii (Cockerell)	1952
Evylaeus nigrescens (Crawford)*	1982
Evylaeus sp. 1 of Eickwort '82	1937
Evylaeus sp. 2 of Eickwort '82	1957
Evylaeus sp. 8 of Eickwort '82*	1950
Evylaeus sp. near inconditus (Cockerell)*	1938
Halictus farinosus Smith	1978
Halictus ligatus Say	1982
Halictus rubicundus (Christ)	1972
Lasioglossum pavonotum (Cockerell)	1982
Lasioglossum titusi (Crawford)*	1954
Lasioglossum tripartitus (Cockerell)	1981
Nomia (Acunomia) melanderi Cockerell	1962
Nomia nevadensis angelesia Cockerell	1982
Sphecodes sp. #1 of Eickwort 82	1958
Sphecodes sp. #2 of Eickwort 82	1982
Sphecodes sp. #3 of Eickwort 82	1982
Sphecodes sp. #4 of Eickwort 82	1977
Sphecodes sp. #5 of Eickwort 82*	1958
Sphecodogastra aberrans (Crawford)	1982

COLEOPTERA

Meloidae

Epicauta californica (Werner)*	1951
Epicauta fallax (Horn)	1965
Epicauta puncticollis Mannerheim	1965

Meloidae (continued)

Eupompha elegans perpulchra (Horn)	1940
Lytta funerea (Fall)*	1951
Lytta moerens moerens (LeConte)	1953
Lytta vulnerata (LeConte)	1982
Nemognatha lurida apicalis LeConte	1982
Nemognatha scutellaris LeConte*	1930's

Tenebrionidae

Anchomma costatum LeConte*	1956
Anepsius delictatulus LeConte	1982
Apocrypha anthicoides Eschscholtz	1956
Apsena rufipes Eschscholtz	1982
Auchmobius subboreus Blaisdell	1981
Blapstinus pulverulentus Mannerheim	1982
Coelus gracilis Blaisdell	1941
Conibius seriatus LeConte	1982
Coniontis sanfordi Blaisdell	1982
Coniontis sp. #1	1982
Eleodes (Blapylis) littoralis Eschscholtz	1956
Eleodes armata LeConte	1982
Eleodes gigantea Mannerheim	1982
Eleodes omissa LeConte	1982
Eleodes tuberculatus Eschscholtz*	1933
Helocrinus blaisdelli Casey	1977
Helops californicus Mannerheim	1959
Lepidonemoplatia sericea Horn	1967
Metapoloba pruinosa Horn*	1933
Metaponium convexicolle LeConte	1982
Notibius puncticollis LeConte*	1958
Nyctoporis aequicollis Eschscholtz	1982
Triorophus subpubescens Horn	1982

Table 3. Number of dates by month on which insects of 14 selected families (Table 1) were collected at Antioch during three 7-year eras

	1933-39	1948-54	1976-82	Total
January	1		1	2
February	5		2	7
March		6	1	7
April	11	13	3	27
May	11	23	4	38
June	13	12	7	32
July	14	15	3	32
August	27	20	41	88
September	34	16	25	75
October	18	15	4	37
November	1		2	3
December		1	1	2
TOTAL	135	121	94	350

Table 4. Number of species recorded in 14 insect families and number of species per family in 3 selected 7-year eras

	1933-1939	1948-1954	1976-1982	1930-1982
DIPTERA:				
Apioceridae	2	3	2	3
Asilidae	9	11	9	15
Bombyliidae	23	11	22	46
Conopidae	6	6	6	10
Therevidae	7	5	4	8
HYMENOPTERA:				
Chrysididae	16	16	15	35
Halictidae	18	20	18	35
Mutillidae	14	15	12	19
Pompilidae	16	18	29	39
Scoliidae	3	3	3	3
Sphecidae -- Ammophilinae	11	13	10	15
Sphecidae -- Astatinae	2	4	2	5
Sphecidae -- Crabroninae	3	6	9	12
Sphecidae -- Larrinae	10	14	11	28
Sphecidae -- Nyssoninae	15	16	9	24
Sphecidae -- Pemphredoninae	1	1	8	9
Sphecidae -- Philanthinae	15	15	14	19
Sphecidae -- Sceliphroninae	3	2	3	3
Sphecidae -- Sphecinae	7	6	7	8
Tiphiidae	4	4	5	8
COLEOPTERA:				
Meloidae	5	6	2	9
Tenebrionidae	18	9	14	23
TOTAL SPECIES	208	205	214	376
Approx. species/date records	800	796	1140	
Dates	135	121	94	594
$\bar{x}$ Species records/visit	5.9	6.6	12.1	

Table 5. Insects Originally Described from Antioch, Contra Costa Co., CA

	Valid taxa by present concepts				
	Antioch Endemic	Occurs in Other Central Vy. Areas	Widespread	Probable Synonyms of Widespread Species	Last Known Collection at Antioch
ORTHOPTERA:					
Neduba extincta Rentz, 1977	1				1937
Idiostatus middlekauffi Rentz, 1973	1				1965
NEUROPTERA:					
Brachynemurus infuscatus (Adams, 1956)		1			1950
COLEOPTERA:					
Anthicus antiochensis Werner, 1976	1				1953
Coelus gracilis Blasidell, 1939		1			1941
Dysticheus rotundicollis Van Dyke, 1953	1				1982
LEPIDOPTERA:					
Apodemia mormo langei Comstock, 1938	1				1982
Phyllonorycter antiochella (Opler, 1971)			1		1982
DIPTERA:					
Efferia antiochi Wilcox, 1966		1			1981
Cophura hurdi Hull, 1960				(X?)	1939
Metapogon hurdi Wilcox, 1964		1			1981

Myopa perplexa Camras, 1953			1		1939
Eumachronychia persolla Reinhard, 1965			1		1958
Thaumatomyia rubrivittata Sabrosky, 1943			1		1936
HYMENOPTERA:					
Chyphotes mandibularis Mickel, 1967 (allotype)			1		1953
C. mickeli Buzicky, 1941 (allotype)			1		1982
Sphaeropthalma edwardsii flammifera Schuster, 1958		1			1952
Myrmusula pacifica (Mickel, 1940)		1		(?)	1952
Microdynerus arenicolus (Bohart, 1955)			1		1981
Polistes dorsalis californicus Bohart, 1949			1		1978
Episyron quinquenotatus hurdi Evans, 1950			1		1981
Eucerceris ruficeps Scullen, 1948		1			1982
Philanthus nasalis Bohart, 1972	1				1959
Colletes turgiventris Timberlake, 1951			1		1937
Melissodes hurdi LaBerge, 1961		1			1981
Perdita scitula antiochensis Timberlake, 1960	1				1982
Perdita ciliata Timberlake, 1958		1			1981
Perdita hirticeps luteocincta Timberlake, 1960	1				1936
Andrena (Cnemidandrena) luteihirta Donovan, 1977			1		1969
TOTALS	8	9	11	1	

Table 6. Chronology of last known collection date for 211 insect species at Antioch, 1930-1978. (*) designates species collected only once. (LC = Little Corral area; SP = Stamm Property area).

1933/05/26	Tenebrionidae	Eleodes tuberculatus Eschscholtz*
1933/06/08	Bombyliidae	Anthrax irroratus irroratus Say*
1933/08/19	Tenebrionidae	Metapoloba pruinosa Horn*
1935/09/04	Sphecidae, Sphecinae	Palmodes californicus Bohart & Menke*
1935/09/04	Bombyliidae	Poecilanthrax varius Painter and Hall*
1935/09/09	Sphecidae, Nyssoninae	Gorytes simillimus Smith*
1935/09/09	Bombyliidae	Lepidanthrax inauratus (Coquillett)*
1935/09/15	Sphecidae, Philanthinae	Philanthus crotoniphilus Vier. & Ckll.*
1936/04/18	Sphecidae, Larrinae	Liris beata (Cameron)*
1936/05/18	Sphecidae, Nyssoninae	Hoplisoides confertus (W. Fox)*
1936/08/23	Sphecidae, Nyssoninae	Bembix amoena Handlirsh*
1936/09/	Therevidae	Thereva fucata Loew*
1936/09/	Therevidae	Thereva sp. nr. johnsoni Coquillett*
1936/09/09	Bombyliidae	Poecilanthrax pilosus (Cole)
1936/09/10	Bombyliidae	Poecilanthrax colei Johnson & Johnson
1937/04/11	Pompilidae	Pompilus arctus Cresson*
1937/04/25	Conopidae	Myopa willistoni Banks*
1937/05/	Halictidae	Evylaeus argemonis (Cockerell)*
1937/05/11	Asilidae	Dicolonus simplex Loew*
1937/09/26	Sphecidae, Ammophilinae	Ammophila placida Smith*
1937/10/17	Chrysididae	Chrysis astralia R. Bohart*
1938/08/20	Asilidae	Holopogon atrifrons Cole*
1938/08/21	Pompilidae	Episyron snowi (Viereck)

1938/08/31	Bombyliidae	Hemipenthes sinuosa jaennickeana (O.S.)*
1938/09/09	Pompilidae	Anoplius californiae Evans
1938/09/09	Pompilidae	Ceropales nigripes Cresson*
1938/10/23	Sphecidae, Larrinae	Tachytes fulviventris fulviventris Cresson
1938/10/23	Halictidae	Evylaeus sp. near inconditus (Cockerell)*
1939/04/02	Conopidae	Myopa perplexa Camras
1939/04/02	Conopidae	Zodion intermedium Banks
1939/06/01	Bombyliidae	Exoprosopa divisa (Coquillett)*
1939/06/07	Chrysididae	Trichrysis doriae (Gribodo)*
1939/08/22	Halictidae	Dialictus diversopunctatus (Ellis)
1939/09/17	Mutillidae	Dasymutilla aureola (Cresson)*
1939/10/10	Mutillidae	Dasymutilla flammifera (Mickel)
1940/05/21	Chrysididae	Chrysis lauta Cresson
1940/06/02	Bombyliidae	Aphoebantus conurus Osten Sacken
1940/09/09	Meloidae	Eupompha elegans perpulchra (Horn)
1941/04/13	Halictidae	Evylaeus aspilurus (Cockerell)*
1941/07/	Bombyliidae	Paravilla fulvicoma (Coquillett)*
1941/07/27	Sphecidae, Nyssoninae	Zanysson texanus fuscipes (Cresson)*
1941/07/27	Tenebrionidae	Coelus gracilis Blaisdell
1941/08/10	Bombyliidae	Ligyra gazophylax (Loew)
1941/08/10	Bombyliidae	Exoprosopa dodrina Curran
1942/06/04	Bombyliidae	Villa fulviana (Say)*
1942/08/23	Sphecidae, Astatinae	Astata bakeri Parker*
1942/08/23	Sphecidae, Larrinae	Tachytes chrysopyga obscurus Cresson
1946/07/15	Asilidae	Triorla interrupta (Macquart)*
1947/08/09	Sphecidae, Larrinae	Trypargilum californicum (Saussure)
1948/08/	Tiphiidae	Myzinum frontale (Cresson)

1948/08/21	Sphecidae, Philanthinae	Cerceris bicornuta Guerin
1949/04/09	Chrysididae	Chrysis coerulans Fabricius*
1949/05/21	Sphecidae, Crabroninae	Crabro argusinus R. Bohart*
1949/06/04	Sphecidae, Larrinae	Tachytes amazonus Smith
1949/10/01	Sphecidae, Larrinae	Tachytes californicus Bohart
1950/04/29	Chrysididae	Omalus (Omalus) iridescens (Norton)*
1950/04/29	Conopidae	Dalmannia pacifica Banks*
1950/05/08	Sphecidae, Ammophilinae	Podalonia communis (Cresson)
1950/05/08	Sphecidae, Crabroninae	Ectemnius (Clytochrysus) lapidarius (Panzer)*
1950/05/08	Halictidae	Dialictus megastictus (Cockerell)
1950/05/08	Halictidae	Evylaeus sp. 8 of Eickwort 82*
1950/06/	Bombyliidae	Toxophora virgata (Osten Sacken)*
1950/08/11	Sphecidae, Larrinae	Bothynostethus sp.*
1951/03/16	Asilidae	Nicocles aemulator Loew
1951/04/20	Sphecidae, Nyssoninae	Gorytes canaliculatus Packard*
1951/04/20	Sphecidae, Nyssoninae	Hoplisoides hamatus (Handlirsch)*
1951/09/23	Meloidae	Epicauta californica (Werner)*
1951/09/23	Meloidae	Lytta funera (Fall)*
1952/04/05	Halictidae	Dialictus longicornis (Crawford)*
1952/04/05	Halictidae	Dufourea sandhouseae (Michener)*
1952/05/17	Sphecidae, Nyssoninae	Hyponysson bicolor Cresson*
1952/08/	Mutillidae	Sphaeropthalma (Photopsis) angulifera (Schuster)
1952/08/09	Sphecidae, Nyssoninae	Gorytes provancheri Handlirsch
1952/08/09	Chrysididae	Omalus (Pseudomalus) trilobatus Bohart & Campos*
1952/09/09	Chrysididae	Ceratochrysis trachypleura Bohart
1952/10/	Pompilidae	Anoplius imbellis (Banks)
1952/10/04	Chrysididae	Omalus (Pseudomalus)purpuratus (Provancher)*

1952/10/15	Halictidae	Evylaeus kincaidii (Cockerell)
1953/04/21	Meloidae	Lytta moerens moerens (LeConte)
1953/06/29	Sphecidae, Nyssoninae	Bicyrtes capnoptera (Handlirsch)
1953/10/05	Mutillidae	Chyphotes (Chyphotes) mandibularis (Mickel)
1953/10/15	Sphecidae, Astatinae	Astata nubecula Cresson*
1953/10/15	Sphecidae, Philanthinae	Cerceris finitima Cresson
1954/05/	Chrysididae	Chrysis coloradica Bohart
1954/07/08	Sphecidae, Astatinae	Diploplectron beccum Parker*
1954/07/08	Bombyliidae	Exoprosopa eremita Cresson
1954/07/08	Chrysididae	Ceratochrysis perpulchra (Cresson)*
1954/07/08	Halictidae	Agapostemon femoratus Crawford
1954/07/08	Pompilidae	Aporinellus taeniatus taeniatus (Kohl)*
1954/09/22	Pompilidae	Aporus luxus (Banks)*
1954/09/26	Mutillidae	Sphaeropthalma (Photopsis) edwardsii (Blake)
1954/10/	Pompilidae	Ceropales maculata caenosa Townes
1954/10/	Pompilidae	Evagetes mohave (Banks)
1954/10/14	Sphecidae, Sphecinae	Prionyx atratus (Lepeletier)
1954/10/14	Halictidae	Lasioglossum titusi (Crawford)*
1955/04/12	Sphecidae, Larrinae	Tachysphex psammobius Kohl*
1955/08/	Pompilidae	Agenioideus biedermani (Banks)*
1955/10/25	Sphecidae, Crabroninae	Crabro (Crabro) pleuralis Fox
1955/10/25	Sphecidae, Nyssoninae	Steniolia duplicata (Provancher)
1956/03/29	Tenebrionidae	Anchomma costatum LeConte*
1956/03/29	Tenebrionidae	Apocrypha anthicoides Eschscholtz
1956/04/05	Tenebrionidae	Eleodes (Blapylis) littoralis Eschscholtz
1956/05/	Tiphiidae	Brachycistis agama Dallatorre
1956/06/27	Mutillidae	Sphaeropthalma (Photopsis) triangularis (Blake)

I collected this species about 1963-1965. Would be amazed if it is not still there - occupies weedy habitat.

1956/07/04	Sphecidae, Ammophilinae	Ammophila boharti Menke
1957/03/06	Halictidae	Evylaeus sp. 2 of Eickwort 82
1958/04/28	Sphecidae, Larrinae	Tachysphex antennatus Fox
1958/05/15	Tenebrionidae	Notibius puncticollis LeConte*
1958/09/27	Sphecidae, Ammophilinae	Ammophila pruinosa Cresson
1958/09/27	Sphecidae, Nyssoninae	Stizoides (Tachystizus) renicinctus (Say)
1958/10/03	Sphecidae, Larrinae	Solierella albipes (Ashmead)
1958/10/03	Sphecidae, Larrinae	Solierella blaisdelli (Bridwell)
1958/10/03	Sphecidae, Larrinae	Solierella levis Williams*
1958/10/03	Chrysididae	Chrysis snowi Viereck
1958/10/03	Chrysididae	Chrysis venustella Bohart
1958/10/03	Chrysididae	Hedychridium amabile Cockerell*
1958/10/03	Halictidae	Sphecodes sp. #1 of Eickwort 82
1958/10/03	Halictidae	Sphecodes sp. #5 of Eickwort 82*
1959/01/17	Tenebrionidae	Helops californicus Mannerheim
1959/04/10	Asilidae	Machimus occidentalis (Hine)
1959/04/24	Sphecidae, Nyssoninae	Nysson recticornus Bradley*
1959/05/	Asilidae	Efferia cana (Hine)
1959/07/31	Sphecidae, Nyssoninae	Foxia secunda (Rohwer)
1959/07/31	Bombyliidae	Anthrax melianopogon (Bigot)*
1959/07/31	Bombyliidae	Aphoebantus n. sp. nr. eremicola
1959/09/25	Bombyliidae	Paravilla edititicoides (Painter)*
1959/10/25	Sphecidae, Philanthinae	Philanthus nasalis R. Bohart
1960/05/28	Sphecidae, Pemphredoninae	Passaloecus armeniacae Cockerell*
1962/06/17	Bombyliidae	Paracosmus edwardsii (Loew)
1962/06/17	Sphecidae, Larrinae	Miscophus (Nitelopterus) californicus (Ashmead)
1962/06/17	Sphecidae, Nyssoninae	Nysson chumash Pate

1962/06/17	Chrysididae	Hedychridium dimidiatum (Say)	
1962/08/19	Halictidae	Nomia (Acunomia) melanderi Cockerell	
1965/07/28	Bombyliidae	Phthiria loewi Painter*	
1965/08/19	Bombyliidae	Chrysanthrax cantor (Coquillett)*	
1965/08/19	Sphecidae, Larrinae	Tachysphex amplus Fox*	
1965/08/28	Meloidae	Epicauta puncticollis Mannerheim	
1965/09/01	Sphecidae, Nyssoninae	Gorytes angustus (Provancher)	
1965/09/01	Bombyliidae	Exoprosopa jonesi Cresson	
1965/09/01	Meloidae	Epicauta fallax (Horn)	
1965/10/23	Sphecidae, Ammophilinae	Podalonia luctuosa (Smith)	
1965 (?)	Chrysididae	Hedychridium solierellae (Bohart & Brumley)	
1965 (?)	Chrysididae	Omelus janus (Haldeman)*	
1966/05/20	Chrysididae	Pseudolopyga taylori (Bodenstein)*	
1966/07/13	Chrysididae	Pseudolopyga carrilloi (Bohart & Brumley)	
1966/09/14	Bombyliidae	Lordotus striatus Painter	
1967/04/08	Therevidae	Tabuda planiceps (Loew)	
1967/05/16	Tenebrionidae	Lepidonemoplatia cericea Horn	
1967/05/16	Therevidae	Arenigena sp. (nov of Irwin 78) (marcida gr.)	
1968/02/02	Mutillidae	Pseudomethoca dentifrontalis Bradley	
1972/05/28	Sphecidae, Larrinae	Plenoculus davisi Fox	
1972/05/28	Bombyliidae	Geron parvidus Painter	
1972/05/28	Chrysididae	Hedychridium fletcheri Bodenstein	
1972/05/28	Halictidae	Halictus rubicundus (Christ)	(SP)
1972/05/28	Sphecidae, Larrinae	Tachysphex apicalis fusus Fox	(LC)
1973/05/14	Sphecidae, Larrinae	Tachysphex clarconis Viereck	
1974/08/18	Apioceridae	Rhaphiomidas trochilus (Coquillett)	
1975/08/16	Sphecidae, Philanthinae	Cerceris nigrescens F. Smith	

1976/07/25	Sphecidae, Nyssoninae	Hoplisoides spilopterus (Handlirsch)	
1976/08/17	Therevidae	Ozodiceromyia laevigata (Loew)	
1976/09/02	Sphecidae, Philanthinae	Cerceris acanthophila Cockerell	
1977/02/18	Tenebrionidae	Helocrinus blaisdelli Casey	
1977/07/02	Sphecidae, Philanthinae	Cerceris convergens Viereck & Cockerell	(LC)
1977/07/02	Asilidae	Machimus ? sestertius Martin*	(LC)
1977/07/02	Bombyliidae	Villa semifulvipes Painter*	(LC)
1977/07/02	Chrysididae	Chrysis vagabunda Bohart	(LC)
1977/07/02	Scoliidae	Camposomeris pilipes (Saussure)	(LC)
1977/08/10	Sphecidae, Crabroninae	Oxybelus exclamans Viereck	(SP)
1977/08/10	Apioceridae	Apiocera chrysolasia Cazier, 1982	(LC)
1977/08/10	Pompilidae	Pompilus phoenix Evans	(SP)
1977/08/31	Sphecidae, Pemphredoninae	Diodontus vallicolae Rohwer*	(LC)
1977/08/31	Sphecidae, Sceliphroninae	Chalybion californicum (Saussure)	(LC)
1977/08/31	Sphecidae, Sceliphroninae	Chlorion aerarium Patton	(LC)
1977/08/31	Bombyliidae	Aphoebantus tardus Coquillett	(LC)
1977/09/02-09	Halictidae	Sphecodes sp. #4 of Eickwort 82	(LC)
1977/09/02-09	Pompilidae	Cryptocheilus hesperus (Banks)	(LC)
1977/09/02-09	Pompilidae	Pepsis pallidolimbata smithi Hurd*	(LC)
1977/09/03	Sphecidae, Nyssoninae	Microbembex nigrifrons (Provancher)	(SP)
1977/09/03-08	Sphecidae, Ammophilinae	Ammophila procera Dahlbom	(LC)
1977/09/03-08	Sphecidae, Crabroninae	Crossocerus chromatipus Pate*	(LC)
1977/09/03-08	Sphecidae, Crabroninae	Ectemnius continuus (F.)*	(LC)
1977/09/03-08	Sphecidae, Crabroninae	Oxybelus uniglumis (L.)	(LC)
1977/09/03-08	Sphecidae, Sceliphroninae	Sceliphron caementarium (Drury)	(SP)
1977/09/03-08	Pompilidae	Anoplius clystera (Banks)	(LC)
1977/09/03-08	Pompilidae	Auplopus architectus metallicus (Banks)	(LC)

1977/09/03-08	Pompilidae	Evagetes hyacinthinus (Cresson)	(LC)
1977/09/03-08	Tiphiidae	Tiphia n. sp. Wasbauer '83	(LC)
1977/09/15	Chrysididae	Chrysis derivata Buysson	
1977/09/23	Chrysididae	Chrysis lucifera Bohart	
1977/10/11	Asilidae	Metapogon fergusoni Wilcox*	(SP)
1977/10/11	Bombyliidae	Phthiria sp.	(SP, LC)
1977/10/11	Halictidae	Dialictus incompletus (Crawford)	(SP)
1978/08/09	Chrysididae	Argochrysis mesillae (Cockerell)	
1978/08/15	Bombyliidae	Exoprosopa xanthina Painter	(LC)
1978/08/17-23	Sphecidae, Ammophilinae	Ammophila kennedyi (Murray)	(SP)
1978/08/17-23	Sphecidae, Larrinae	Pisonopsis clypeata W. Fox	(SP)
1978/08/17-23	Sphecidae, Nyssoninae	Glenosticta pulla (Handlirsch)	(SP)
1978/08/17-23	Pompilidae	Anoplius (Lophopompilus) cleora (Banks)*	(SP)
1978/08/17-23	Pompilidae	Aporinellus fasciatus (Smith)	(SP)
1978/08/17-23	Conopidae	Zodion obliquefasciatum (Macquart)	(LC)
1978/08/17-23	Halictidae	Halictus farinosus Smith	(SP)
1978/08/20	Pompilidae	Evagates subangulatus (Banks)*	(SP)
1978/08/20	Pompilidae	Pompilus scelestus Cresson	(SP)
1978/08/20	Sphecidae, Larrinae	Tachysphex texanus (Cresson)	(SP)
1978/08/28-30	Pompilidae	Hemipepsis ustulata ochroptera Stal*	(SP)
1978/08/29	Bombyliidae	Aphoebantus mus Osten Sacken	(LC)
1978/08/29-30	Sphecidae, Pemphredoninae	Mimesa ? Sabina Gittins	(SP)
1978/08/29-30	Bombyliidae	Heterostylum robustum (Osten Sacken)	(SP)
1978/09/01	Sphecidae, Ammophilinae	Ammophila cleopatra Menke	(LC)
1978/09/01	Sphecidae, Ammophilinae	Ammophila nasalis Provancher	(LC)
1978/09/01	Bombyliidae	Hemipenthes lepidota (O.S.)*	(LC)
1978/09/01	Bombyliidae	Paravilla syrtus (Coquillett)	(LC)
1978/09/01	Conopidae	Thecophora propinqua (Adams)	(LC)

[illegible] Species recorded more than twice in 1976-82
only at LC or SP (number of voucher dates)

	LC	SP
DIPTERA		
Asilidae: Proctacanthus occidentalis	6	
Stichopogon n. sp. near fragilis	4	
Bombyliidae: Mythicomyia n. sp.	9	
Mythicomyia polygena	4	
Villa nugator		7
Conopidae: Physocephala texana	*	10
Physoconops fronto	*	5
HYMENOPTERA		
Chrysididae: Parnopes edwardsii		4
Parnopes fulvicornis		3
Mutillidae: Dasymutilla coccineohirta		15
Chyphotes mickeli		6
Sphaeropthalma orestes		5
Pompilidae: Pepsis thisbe		3
Sericopompilus neotropicalis		4
Sphecidae: Ammophila procera	3	
Oxybelus californicus	3	
Hoplisoides dentatus		3
Microbembex californica		12
Steniolia scolopacea	4	
Spilomena sp.	4	
Cerceris californica		3
Cerceris cockerelli	19	
Cerceris frontata		6
Cerceris sextoides	10	
Clypeadon californicum		9
Eucerceris ruficeps		5
Philanthus gibbosus	5	**
Halictidae: Sphecodogastra aberrans		5
COLEOPTERA		
Meloidae: Lytta vulnerata		6
Tenebrionidae: Eleodes gigantea	7	
LEPIDOPTERA		
Noctuidae: Schinia mortua	6	
Pyralidae: Homeosoma electellum	3	
Tortricidae: Phaneta amphorana	4	
Incurvariidae: Chalceopla simpliciella	3	

* 1 LC record in 1977
** 1 SP record in 1981

Table 8. Possible recently colonized species: repeatedly observed insects that were not recorded until after the industrial building era (number of date records in parentheses)

Bombyliidae	
Aphoebantus n. sp., 1977-82	(4)
Villa lateralis, 1954-82	(7)
Chrysididae	
Hedychrum boharti, 1958-82	(21)
Halictidae	
Dialictus sp. B, 1954-82	(5)
Sphecodes spp. #2, 3, 4, 5, 1958-82	(13)
Pompilidae	
Ageniella blaisdelli, 1959-79	(5)
Aporinellus basalis, 1978-82	(5)
Episyron conterminus, 1977-82	(4)
Tachypompilus unicolor, 1975-82	(13)
Pepsinae (3 spp. *Hemipepsis*, *Pepsis*), 1977-82	(5)
Sphecidae	
Sphex lucae, 1974-79	(4)
Cerceris cockerelli, 1958-82	(22)
Tachysphex texanus, 1956-78	(7)
Tenebrionidae	
Conibius seriatus, 1965-82	(5)

APPENDIX 2

STATUS OF 15 INSECTS LISTED IN NOTICE OF REVIEW BY THE U.S. FISH AND WILDLIFE SERVICE, 1980 and 1982

ORTHOPTERA:

Idiostatus middlekauffi Rentz, 1973. This species is known only from the type specimens collected at Antioch between 1937-1965. The specialized techniques used to collect nocturnal shield-backed katydids, such as this and the following species, were not employed during my survey.

Neduba extincta Rentz, 1977. Known only from a single specimen collected at Antioch in 1937, the species was assumed to be extinct at the time of its description.

COLEOPTERA:

Anthicus antiochensis Werner, 1976. This sand dune beetle, an unusually large anthicid, was recorded at Antioch on 4 dates between June 1952 and October 1953, by Werner. My sand screening and pitfall trap surveys in 1976-1982 and subsequent ones by K.S. Hagen did not reveal its presence at Antioch, but *A. antiochensis* is known at Rio Vista and other delta sites.

Coelus gracilis Blaisdell, 1939. A flightless, burrowing beach beetle, *C. gracilis* was collected at Antioch on 5 dates between 1938-1941. It was presumed extinct until John Doyen and I discovered it at 4 localities in Fresno and Kings Counties along the western margin of the San Joaquin Valley in 1972-1976 (Doyen, 1976). These sites, which are presumed to be relictual beaches of Pleistocene inland seas, are small, two of them less than 500 m^2 in extent. Larger islands of active sand existed at Antioch when we first attempted sand-screening, but the species evidently had become extinct there by the mid 1970's.

Dysticheus rotundicollis Van Dyke, 1953. The taxonomic and geographical status of this weevil, which was collected originally from Antioch in 1952, has not been assessed recently. There is a series in UCB taken at Antioch on Gutierrezia in 1952. (det. Kissinger). Specimens that appear to be this species were taken during diurnal surveys in 1977, 1981, and 1982, incidentally from vegetation, in pitfall traps, and as prey of the sand wasp Eucerceris ruficeps (itself a NOR listed species).

DIPTERA:

Rhaphiomydas trochilus (Coquillet), 1892. Originally described from Merced, CA, this giant flower-loving fly has been recorded at several Central Valley localities characterized by riverine sand deposits, from Tulare County north to Antioch. Most of the known specimens were collected at Antioch in the 1930's. After the industrial expansion there, only 3 R. trochilus were recorded, in 1955, 1967, and 1974. The species was found at Oakdale, Stanislaus Co. in 1961 and near Ripon, San Joaquin County in 1968, so localized populations may persist at sandy sites in the Central Valley, but R. trochilus appears to be extinct at Antioch.

Cophura hurdi Hull, 1960. This name was based on a single specimen collected at Antioch in 1939. Unfortunately, the whereabouts of that type specimen is unknown, and the taxonomic status of C. hurdi is uncertain. Hull stated that the type was returned to California, but neither the California Insect Survey, University of California, Berkeley, nor the California Academy of Sciences has a record of having received it. From the description, the late Joseph Wilcox (pers. communication) suspected that C. hurdi may have been based on a female Nicoles species.

Efferia antiochi Wilcox, 1966. Although named for its type locality, this robberfly is known from the Central Valley south to Fresno. It was recorded at Antioch many times between 1933 and 1959, but during my survey it was collected only on two dates, in September, 1981.

Metapogon hurdi Wilcox, 1964. This species, like the preceeding, was described from Antioch and recorded also at Fresno. M. hurdi has remained poorly known because the adults fly in November. They were observed at SP on one of my two November visits, in 1981.

HYMENOPTERA:

Perdita hirticeps luteocincta Timberlake, 1960. This race is known only from the type specimens collected at Antioch in 1936. Not all the Perdita taken in my survey have been identified by a specialist, but it appears that no luteocincta were encountered.

Perdita scitula antiochensis Timberlake, 1960. Described from Antioch and nearby Oakley, this subspecies was taken in September, 1977-1982, primarily at LC at flowers of Gutierrezia, less commonly at Lessingia and other composites. A few were collected at SP. A third Perdita described from Antioch, P. interserta ciliata Timberlake, 1958, was abundant on Eriogonum and occurred occasionally on Heterotheca and other composites, from August to October.

Myrmosula (Mymosa) pacifica (Mickel), 1940. This name is based on one specimen collected at Antioch in 1938. Wasbauer (1974) considered it likely to be a synonym of M. exaggerata (Krombein) a widespread species. No Myrmosula were taken during 1981-82 in my pitfall trap survey, which recorded wingless females of 10 other species of nocturnal Tiphiidae and Mutillidae.