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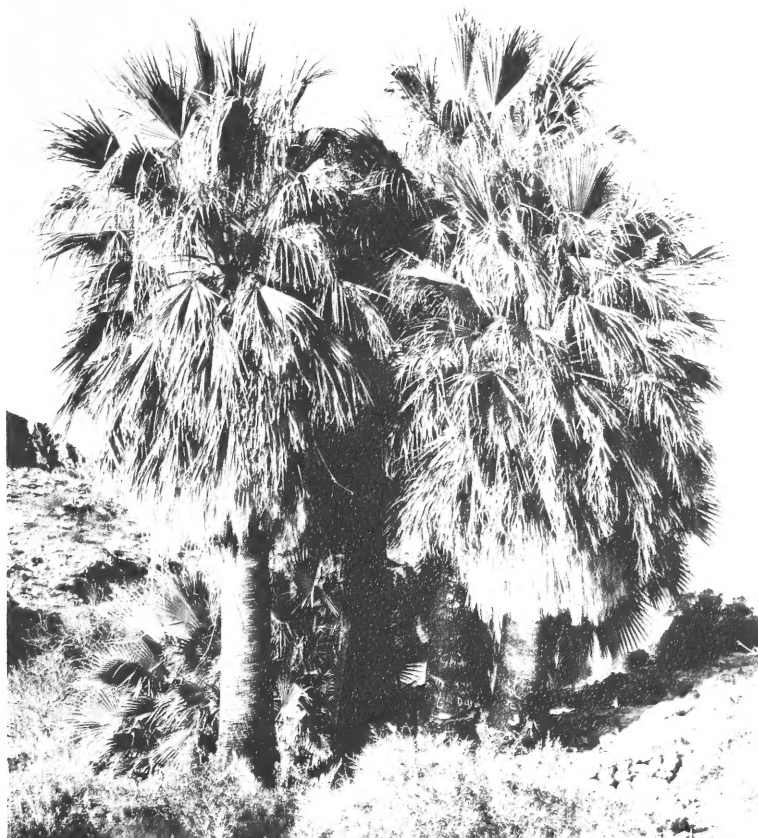
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Ecology of the Desert Kit Fox, *Vulpes macrotis arsipus,* in the Mojave Desert of Southern California

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A field study using live-trapping and radio-telemetry was conducted to learn whether desert kit foxes inhabiting the Rand Open Area in eastern Kern County, California, were being adversely affected by human activities such as use of ORV's, as compared with foxes living in the undisturbed Desert Tortoise Research Natural Area. Individuals were more readily trapped in the Rand Area, and fox populations there were more dense, had a higher rate of reproduction, greater survival, and different sources of mortality as compared with the control population in the Tortoise Area. Except for two foxes shot in the Rand Area, there were no negative effects observed in the ORV study site that could be causally linked to human activities.

The kit fox, *Vulpes macrotis,* is a widely distributed predator in the arid habitats of western North America. Of the eight subspecies named since 1888, *V. m. macrotis,* which was first trapped in Riverside County, California, was extinct by 1910 (Grinnell et al. 1937). In the San Joaquin Valley of California *V. m. mutica* lost a significant portion of its original habitat through increased agricultural, mineral, urban, and industrial developments (Laughrin 1970; Morrell 1972, 1975). This justified its receiving Federal protection as an endangered species following passage of the Endangered Species Protection Act in 1966 (Federal Register, 32: 4001), and its classification as a rare species by the California Department of Fish and Game (State of California 1980).

The status of other subspecies of *V. macrotis* was poorly known. This concerned the Desert Planning Staff of the U.S. Bureau of Land Management (BLM) who was developing comprehensive land-use plans for the deserts of southern California (Anonymous 1980). Without appropriate baseline information it would be difficult, if not impossible, to effectively manage essential habitats necessary for the well-being of the desert kit fox, *V. m. arsipus,* and other potentially vulnerable species of wildlife.

It was known that the kit fox is a relatively unwary animal (Hall 1946; Egoscue 1956, 1962; Laughrin 1970). Highway fatalities are a significant source of reported mortality (Egoscue 1962; Morrell 1972), and kit fox are also vulnerable to being shot at night by predator hunters (Laughrin 1970; Morrell 1972). The use of poisoned grains to control rodents in California poses a potential serious threat because kit fox may become secondary, nontarget victims if they consume either poisoned rodents or bait (Swick 1973; Schitosky 1975). It has also been suggested

that indiscriminate killing and disturbance of kit fox habitats and prey by off-road vehicle (ORV) enthusiasts has a serious, negative effect on the species (Laughrin 1970).

The major goal of this project was to provide BLM with information on the ecological life history requirements of the desert kit fox in the Mojave Desert of southern California that would be useful in their planning document. Specific goals were to: examine habitat preferences, locate and characterize denning sites, determine denning range and movement patterns, and document sources of mortality in undisturbed desert habitats and those being affected by human activities such as ORV use.

Methods

Study Areas

Two study areas were selected in eastern Kern County, California. The first was located on the Desert Tortoise Research Natural Area, approximately 3 km northeast of California City (Fig. 1). This area was partially fenced and access and grazing were restricted. Although the site had a past history of disturbances by sheep grazing and wildfires, it served as a "control" area that was relatively free from contemporary human disturbances.

The second study area was located in the BLM's Rand Open Area which was adjacent to the northeastern boundary of the Tortoise Area. "Indiscriminate" ORV uses were permitted there. It was chronically and heavily grazed by sheep, and in some areas it adjoined agricultural developments. The Rand Area served as the treatment plot where kit fox populations were subjected to periodically intensive human interference.

Both areas had similar elevational gradients (580–900 m). Soils below 610 m were light-textured, while those at higher elevations had coarser texture due to higher concentrations of granitic fragments. Near the ridge lines, soils were shallower and contained larger rock fragments and outcrops.

The dominant vegetation association would have been *Larrea-Ambrosia* with an understory of native forbs and grasses. However, years of grazing have reduced the sites to a *Larrea-Schismus-Erodium* disclimax. The few native winter annuals observed in 1978 were under the canopies of either unpalatable or thorny shrubs. There were few native plants germinating between shrubs. *Ambrosia dumosa* contributed far less to the plant cover than expected, since most individuals had either been eaten or trampled.

Live-trapping

Kit fox were captured using two types of collapsible, wire mesh live-traps: double-door traps measuring 38 × 38 × 107 cm, or single-door traps measuring 30 × 30 × 76 cm. Traps were usually placed at or near kit fox dens, but on a few occasions they were operated near intersections of dirt roads or in washes away from dens. Bait such as sardines in cheesecloth bags, chicken bones, road-killed birds or rodents, or pieces of freshly killed jackrabbits (*Lepus californicus*), was wired to the back door or top of traps.

Captured foxes were handled as quickly and humanely as possible to minimize trauma. A heavy pillowcase was used to distract the fox so that it could be quickly
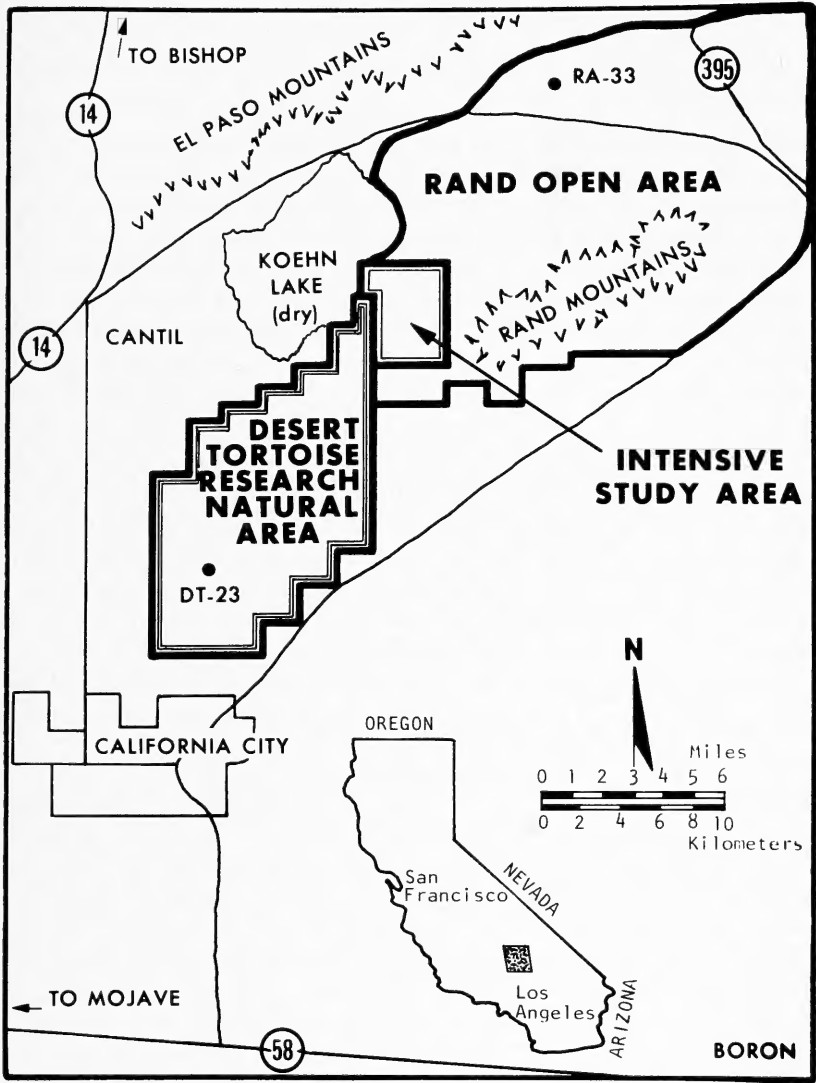
Fig. 1. Location of kit fox study sites in Rand Open Area and Desert Tortoise Research Natural Area, Kern County, California. Dens DT-23 and RA-33 are the first capture and final recovery sites for a dispersing female.

grasped by the nape and withdrawn from the trap. When held by the nape most foxes became submissive and ceased struggling. The animal was placed on the ground with the pillowcase covering its eyes, and its rump and hind legs were firmly held between the knees and legs of the kneeling investigator.

A numbered, Monel metal ear tag supplied by the California Department of Fish and Game was secured to each fox's ear to provide long-term identification of individuals. The right ear was measured from the notch, and observations of the animal's sex, reproductive status, and overall condition were recorded. Fleas and other ectoparasites were observed to determine relative numbers before sam-

ples were taken and preserved in alcohol. Animals were weighed on a portable scale and released at the point of capture.

Radio-telemetry

Selected animals were fitted with lightweight (100 g) radio transmitters (Telonics, Inc., Mesa, AZ) operated at individual frequencies between 150.2 and 151.1 MHz. Each was equipped with an integral, flexible, whip antenna, and was secured to a collar made of a urethane-coated nylon webbing.

Animals were tracked using a multichannel receiver equipped with either an omni-directional antenna, or a multielement, hand-held yagi antenna, and standard radio-telemetry techniques. The directional yagi antenna was also attached to the strut of a Super Cub during aerial surveys to locate animals whose signals were undetectable during routine ground reconnaissance.

Den Descriptions

Kit fox dens were described by observing and recording: number of entrances; elevation; soil type; major vegetation associations; distance to nearest mappable road; and the presence of fresh fox tracks, scats, and prey remains. The den was judged to be either active or inactive based on the freshness of sign. A unique code number was assigned and the location of the den was plotted on a topographic map using compass bearings on prominent land features.

Occupancy of dens, especially by mated pairs, was determined by locating as many radio-collared foxes in their dens as possible each day.

Necropsies

Dead foxes were located as quickly as possible so that information could be gathered on probable cause of death. External measurements, including total length, tail, right hind foot, and right ear from notch, and weight were taken for all animals that were not mummified. External conditions were noted, especially the presence of injuries, blood, ectoparasites, feces, and obvious anomalies. A mid-ventral incision from the larynx to the urogenital openings was made on animals that were not badly decomposed. Each organ and various tissues were observed for gross lesions and evidence of decomposition. The gastrointestinal tract was checked for food items and endoparasites. General condition of reproductive organs was observed.

Results

Live-trapping

Between November 1977 and January 1979, 13 foxes (six males, seven females) were captured 20 times in the Rand Area, for an overall trapping success of 34%. Eight foxes were captured only once, three foxes were recaptured once each, while two foxes were recaptured twice each. Although trapping effort was greater in the Tortoise Area (149 versus 59 trap/nights), trapping success was only 9%. Thirteen individuals (eight males, five females) were captured; none were ever retrapped.

Radio transmitter collars were fitted to six foxes (three males and three females) in the Rand Area, and to all 13 foxes live-trapped in the Tortoise Area. No data were gathered that indicated that the collars were too heavy or interfered with normal activities of the foxes.

Table 1. Number of entrances to kit fox dens observed in the Rand and Desert Tortoise areas, Kern County, California, 1977–1979.

Number of entrances	Rand Area dens (treatment)	Tortoise Area dens (control)
1	5	8
2	7	10
3	7	7
4	1	3
5	2	4
6	2	
7	3	1
8	2	1
9	1	
12	1	
18	1	
22	1	
Total	33	34
Mean (±SE)	5.0 ± 0.8*	2.8 ± 0.3
Median	3	2

* Statistically significant difference between means ($P < 0.05$).

Complete records of trapping information and radio telemetry relocation data were published in Appendix 1 of the study report (O'Farrell and Gilbertson 1979).

Dens

A total of 33 dens were found in the Rand Area. Only seven were found by observers hiking or driving through the area; most were found by tracking radio-collared foxes to new dens (157 radio-fixes). Of 34 dens found in the Tortoise Area, 14 were found by observation, while tracking radio-collared animals revealed 20 new dens (131 radio-fixes).

The average number of entrances to dens was 5.0 ± 0.8 (mean ± standard error) and 2.8 ± 0.3 for the Rand and Tortoise areas respectively (Table 1). The significantly greater ($P < 0.05$) number of entrances to Rand Area dens was also indicated by the fact that 33% of the dens there had more than five entrances, and that the largest dens observed (>10 entrances) were all found there. Only two dens located in the Tortoise Area had more than five entrances.

Mean elevation of dens in the Rand Area was 667 ± 7 m (range 585–770 m), which was significantly lower ($P < 0.05$) than the average elevation of 733 ± 8 m (range 675–830 m) for the Tortoise Area dens. Almost all of the dens were located on gradual, west- to northwest-facing slopes dominated by a *Larrea-Schismus-Erodium* disclimax. Soils were characteristically deep, light-textured, and virtually stoneless to depths of 1.5 m. There was no observable caliche or hardpan layer, and dens were usually placed in well drained sites.

The average distance between dens and the nearest dirt road or jeep trail was 207 ± 42 m and 163 ± 38 m for the Rand and Tortoise areas, respectively (Table 2). Only four dens, two in each area, were located more than 500 m from a road. More than half of the dens on the Tortoise Area were less than 50 m from a road or trail.

Three atypical dens were found. A mated pair in the Rand Area occupied a

Table 2.   Distance from kit fox dens to nearest dirt road or trail in Rand and Desert Tortoise areas, Kern County, California, 1977–1979.

Distance to road (m)	Rand Area dens	Tortoise Area dens
0–25	2	12
26–50	4	6
51–75	3	
76–100	6	2
101–150	3	3
151–200	6	4
201–300	4	1
301–400	1	1
401–500	2	2
501–600		1
601–700		
701–800	1	2
1200	1	
Mean (±SE)	207 ± 42	163 ± 38
Median	150	43.5

single-entrance den placed between horizontal rock layers on the north-facing slope of a small hill at an elevation of 690 m. Another den was located in a culvert under a well-used access road to a recreational vehicle rendevous and camping site in the Rand Mountains. A third den was found next to a steel well casing on the Desert Tortoise Area. The soil adjacent to the casing was eroded in places to a depth of 1.5 m. The fox gained access to a horizontal den opening after dropping down along the casing.

All but four of the 33 dens located in the Rand Area were occupied by radio-collared foxes at some time. Of the occupied dens, 18 were used by single foxes, 10 were used by two foxes (nine by mated pairs, one by two lone foxes), and one was used by three collared foxes (one pair and one lone fox). In the Tortoise Area 14 of 34 dens were never used by foxes carrying radio collars. Of the 20 dens that were used, 14 sheltered only one collared fox each, four were occupied by two foxes (two mated pairs in two dens; two unpaired foxes in each of two dens), and two were occupied by three different foxes (one den used by mated pair; one den used by three lone foxes).

Six foxes in the Rand Area used an average of 7 ± 1.3 dens each with a range of six to nine (Fig. 2). Approximately 42% of the dens were shared by mated pairs. In spite of their proximity, mated pairs appeared to use a series of dens exclusively from their neighbors (Fig. 2). Only one female used more dens alone than with her mate, but most of these were occupied after he was killed.

Three large pupping dens (dens known to have been occupied by mated pairs and their puppies) were located in the Rand Area. They were an average of 2 km apart.

The sizes of dens occupied by mated pairs in the Rand Area, indicated by the number of entrances, differed during and after the breeding season. From January to the end of May, the last time puppies were observed with the pairs, the average
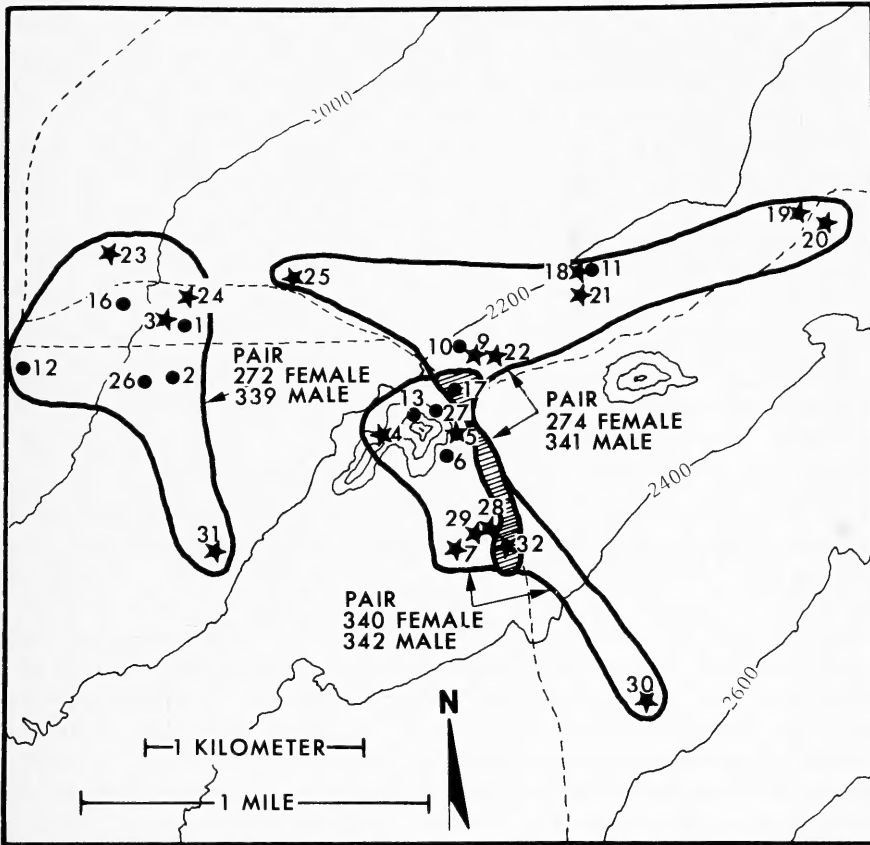
Fig. 2. Locations of dens in Rand Area occupied by mated pairs of kit fox either together (closed circles) or alone (solid stars). Solid line encloses approximate denning ranges. Hatched area indicates only known place where ranges of two pairs may have overlapped. Numbers are den identification codes. Contours are in feet, and dashed lines indicate dirt roads.

number of entrances to shared dens was 8.5 (range 5–18). This was significantly greater ($P < 0.05$) than the average of 3.4 entrances (range 1–8) observed for shared dens occupied between June and December.

Between one and three dens were occupied by the 13 radio-collared foxes in the Tortoise Area, for an average of 2.1 ± 0.8 dens occupied per animal. Only six of the foxes were known to share their dens with other radio-collared foxes; the majority of foxes lived alone or with uncollared mates.

When den sites for six foxes in the Rand Area and for 10 foxes in the Tortoise Area were mapped, the greatest distance between dens used by the individuals averaged 1.6 ± 0.4 km. If the average longest distance were considered to be the estimated diameter of a circular home range, the mean denning range would occupy 200 ha. The denning range was defined as the area enclosing the den sites occupied, usually exclusively, by individual foxes.

Complete descriptions of dens were published in Tables 3 and 4 of the project report (O'Farrell and Gilbertson 1979).

Dispersal

At least two animals moved distances that indicated they were dispersing rather than moving within established home ranges. A male was first caught 2 April 1978 along the west-central border of the Tortoise Area. Over the next eight months he was located aboveground several times, and in a series of dens between the Tortoise Area and California City. The greatest distance between sightings was 4.8 km. A female was found in a den at the base of the El Paso Mountains approximately 32 km northeast of her initial capture point in the Tortoise Area a month earlier (Fig. 1).

Pairing and Reproduction

Three pairs in the Rand Area and one pair in the Tortoise Area were presumed to be mated pairs. The pair in the Tortoise Area was together during March, but both animals died shortly thereafter.

One pair in the Rand Area was together for at least three months, April through June. Puppies were observed in their den in late May. They apparently separated in mid-June, and the male was killed in late July or early August.

Another pair was together throughout the study. They were in common dens from April 1978 through January 1979. Puppies were observed in their dens in late May also. Neither was ever observed in dens with another radio-collared fox.

A third pair was observed to be in the same dens from April through at least late November 1978. At that time they either dispersed far enough to be out of radio range, or their radios both quit 3–4 months prematurely, and they were either untrappable or dead at the termination of the field studies.

Adult males had palpable scrotal testes throughout the year. During January the penises of reproductively active males were obviously engorged with blood. An exception was an unpaired male whose penis was noticeably smaller, un-swollen, and flesh-colored, suggesting that he was not breeding. His weight (2025 g) was comparable with that of breeding males at the time.

Adult females were also reproductively active in January. They had swollen, moist vulvas, and some had already started to make weight gains suggesting that they may have been pregnant. Lactating females with swollen mammae and mat-ted hair around their conspicuous teats were observed in March and April. Puppies were first observed aboveground near their natal dens in late May. None were observed with their parents after that.

Longevity

Longevity was defined as the amount of time foxes were known to be alive. It was calculated from the date of first capture to either the date of the last capture or the date of the last location obtained using radio-telemetry. In the Rand Area the six foxes caught prior to the last trapping session in January 1979, had an average longevity of 10.2 ± 0.8 months with a range of between 8–14. Four of the animals were still alive when the study was terminated. Another whose radio presumably malfunctioned was probably alive as well.

Thirteen foxes in the Tortoise Area had an average longevity of just 2.4 ± 0.7 months. Seven of the animals were known to be alive for 30 days or less, and

Table 3. Observed sources of mortality in kit fox, Kern County, California, 1977–1979.

Area	Number	Probable cause of death
Rand Area (treatment)	2	Shot
Tortoise Area (control)		
Found underground	2	Suffocated; den cave-ins
	3	Emaciated; starved and/or diseased (?)
	3	Unknown
Found aboveground	1	Severe trauma to skull, thorax; predator
	1	Severe trauma to thorax; predator, probably coyote
Both areas		
(tagged Tortoise Area found underground Rand Area)	1	Emaciated, broken hind leg; multiple probable causes

only one animal lived as long as nine months. Average longevity in the Tortoise Area was significantly shorter ($P < 0.05$) compared with average longevity in the Rand Area. None of the animals was known to be alive at the termination of the study.

Mortality

The radio-collars permitted finding 12 dead foxes that were still in a suitable condition to determine probable cause of death, and a dead, untagged animal was found incidentally (Table 3). Two males were found shot to death in the Rand Area. One was on the surface about 150 m from its most recently occupied den. The other, an untagged animal, was found in the entrance to a den formerly used by a mated pair where he had been stuffed by a hunter who had also cut off his tail.

Of the 10 animals found dead in the Tortoise Area, eight were found underground in their dens: three died of unknown causes; three had no food in their stomachs, no subcutaneous or mesenteric fat, and appeared to have starved; two animals were found in collapsed tunnels and probably suffocated in cave-ins.

Two animals were found on the surface. One had its skull crushed and other signs of traumatic death due to a predator; the other had been killed so recently that its body fluids were still near body temperature and the carcass was shipped to the Wildlife Investigations Laboratory, Wildlife Management Branch, California Department of Fish and Game. The examining veterinarian's diagnosis was, "Thoracic trauma, probably dog or coyote. Emaciation . . . ."

The female that dispersed 32 km was also found dead underground. She was also emaciated and had a compound fracture of the right femur. The new den was between two primary roads and she may have been hit by a vehicle. This probably did not kill her directly, however, since there were no signs of internal trauma or hemorrhaging that usually accompany road-kills.

Measurements

Standard measurements (in mm) of foxes found dead in the Tortoise Area were: (three males) total length, 797 ± 9; tail, 320 ± 10; right hind foot, 127 ± 1; right

ear from notch, 86 ± 2; (three females) total length, 772 ± 12; tail, 302 ± 5; hind foot, 125 ± 2; ear from notch, 80 ± 1. Average live weights were: males (15), 2034 ± 78 g; females (13), 1936 ± 64 g.

Fleas

A total of 299 fleas representing five species was identified in 26 collections. The most common were the so-called human fleas, *Pulex irritans* (107 males, 132 females), and the poultry or sticktight fleas, *Echidnophaga gallinacea* (26 males, 27 females). One male *Orchopeas leucopus,* one female *O. sexdentatus,* and two male and three female *Cediopsylla inequalis* were also collected.

Abnormalities

Four abnormalities, none of which resulted from the trapping or tagging operation, were observed: a broken left canine; a hardened scar on a foreleg; a reddish, glazed eye that may have been injured; and a ruptured cornea that also may have been due to a recent injury.

Discussion

Results of the live-trapping efforts were the first indication that populations of foxes in the Rand and Tortoise areas were probably not comparable. Foxes were readily trapped in the Rand area, as shown by the high overall trapping success. Several animals were recaptured, two of them twice each after their initial captures. In spite of increased efforts in the Tortoise Area, the overall trapping success was only 9% and none of the animals were recaptured. Trapping data suggested that the fox population in the Tortoise Area was less dense than in the Rand Area.

Kit fox dens in both areas occupied sites having similar soils, exposure, elevation, and vegetation associations. Soils were always loose-textured and free of rocks or stones. Most authors have associated the kit fox with loose-textured soils (Burt 1934; Hall 1946; Egoscue 1962; Laughrin 1970; Morrell 1972). Morrell (1972) speculated that it might be difficult for kit fox to dig in soils with a hardpan unless other animals, such as badgers, penetrated the impervious layer.

Few of the dens were found in the sandy soils at elevations below 670 m, and none were found at elevations above 820 m where the soils were generally shallow and rocky. The significant difference between mean elevation of den sites on the two study areas probably reflected the fact that optimal textured soils reached lower elevations in the Rand Area compared with the Tortoise Area.

It was anticipated that kit fox would select areas remote from human habitations and disturbances for den sites. Surprisingly, this was not the case, as most dens were within 150 to 200 m of roads and jeep trails, and few were found to be more than 300 m away. It is possible that the human activities conducted on the roads did not disturb the foxes significantly. It is also possible that the dirt roads and trails provided foxes with additional paths along which the foxes had increased visibility for hunting and for remaining vigilant against predators.

Kit fox dens in the Rand Area had a significantly greater number of entrances than dens observed in the Tortoise Area. If the premise is accepted that older, natal, or pupping dens have more entrances than younger, daily-use shelter dens, then the Rand Area provided a more optimal habitat than the Tortoise Area as regards both potential breeding sites and dens to rear puppies. This inference is

further supported by the lack of evidence of successful breeding in the Tortoise Area, and absence of puppies observed there.

In Utah, kit fox dens had between two and seven entrances, although one den had 24 (Egoscue 1962). Dens of *V. m. mutica* in western Kern County had one to 10 entrances, although most had just two (Morrell 1972). When the average number of entrances to dens was compared between subspecies, dens of *V. m. arsipus* in eastern Kern County were more similar to dens of *V. m. nevadensis* in Utah than they were to dens of *V. m. mutica* in nearby western Kern County.

Although kit fox prefer to construct underground dens, they were observed denning adjacent to a well casing and in a culvert. Egoscue (1956) also reported that kit fox occasionally used culverts as dens. The den located between rock layers on a low hill was the most unusual since the single entrance appeared to be in solid rock.

In the Rand Area, 88% of the dens were used by radio-collared foxes. Most of the occupied dens were used either by lone foxes or mated pairs. In the Tortoise Area only 59% of the known dens were ever occupied by collared foxes. Egoscue (1962) also reported that study areas in Utah contained a mixture of occupied and deteriorating dens.

Individual foxes in the Rand Area used more dens than animals on the Tortoise Area. The difference in the average number of dens occupied was probably due to the short duration that radio-collared foxes remained or lived in the Tortoise Area. If more foxes had lived longer there, they may have used as many dens as their neighbors in the Rand Area.

That mated foxes occupied larger dens during the pupping season than during the remainder of the year confirmed Morrell's (1972) finding that San Joaquin kit fox occupied smaller dens during the three months following the breeding season. The importance of the larger natal or pupping dens for successful breeding and survival of the species is only now being appreciated (Egoscue 1962; Morrell 1972).

The three natal or pupping dens occupied by neighboring mated pairs were about 2 km apart. Those in Utah were at least 3.2 km apart (Egoscue 1956, 1962). Spacing of natal or pupping dens may be important in the territorial requirements of the species, especially since data on den-use patterns supported earlier observations that mated pairs used certain sets of dens exclusively (Morrell 1972). This suggests a territorial allocation of available habitat. Egoscue (1975) believed that the maximum carrying capacity of an area for foxes was primarily related to their territorial requirements.

During this study the estimated denning range was 200 ha. This is comparable with Morrell's (1972) estimate of 260 to 520 ha for *V. m. mutica*. Although Morrell called his estimate a home range, an examination of original data (Morrell 1971) showed that he drew boundaries around occupied dens (a denning range), but had no additional information on movements of foxes away from den sites to hunt or maintain territorial boundaries (home range).

The longest dispersal movement recorded was identical in length with two 32-km dispersal movements recorded by Egoscue (1962) in Utah. He showed that puppies did not establish residence in the area of their birth. The dispersal movements recorded in Utah and California may have represented dispersal of juveniles from their natal sites to new ranges.

Timing of reproduction in kit fox in the Rand Area was similar to that described for other subspecies (Egoscue 1956, 1962; Morrell 1972). Adult males had palpable scrotal testes throughout the year. The most conspicuous change in their genitalia occurred in January when their penises were obviously enlarged, red in color, and often appeared to be extended from their sheaths. Females were in estrus in December and January. Evidence based on weight gains of vixens in January, and observations of lactation in March suggested that puppies were born in February or March.

In other studies breeding took place between December and March (Egoscue 1956), and an average of four to five puppies were born between February and March (Egoscue 1956, 1962; Morrell 1972). Puppies did not appear aboveground until they were at least one month old (Morrell 1972).

Kit fox are thought to be essentially monogamous, and may mate for life (Grinnell et al. 1937; Egoscue 1962). Information gathered during this study, as well as the results of previous studies (Egoscue 1962; Morrell 1972) indicated that kit fox employ a flexible strategy as regards reproductive pairing. Some pairs may remain mated for more than one breeding season, while others may change partners frequently. Egoscue (1962) reported that most mated pairs remained bonded but he did observe three cases of polygamy. Morrell (1972) observed that only one of seven mated pairs remained bonded the next breeding season.

Information on longevity provided further evidence that the populations of kit foxes on the two areas were not comparable. In the Rand Area most of the adults tagged at the onset of the study were still alive at its termination. In contrast, most of the foxes in the Tortoise Area were known to be alive for one month or less, and none was alive when the study was terminated. The relatively high turnover of adults in the Tortoise Area, compared with stability of adults in the Rand Area, suggested that the Tortoise Area was not a suitable habitat for the species between 1977 and 1979. The factors responsible for differences in longevity between the two areas were not obvious, but information on sources of mortality suggested tentative answers.

In the Rand Area only two dead foxes were retrieved; both had been shot. The remaining animals were known to be, or were presumably, still alive at the end of the study.

The high proportion of foxes in the Tortoise Area that showed evidence of starvation, plus the absence of similar data in the Rand Area, suggested that food supplies were more dependable in the latter area. Morrell (1972) speculated that starvation was a factor limiting kit fox populations, and he further suggested that the total population may decline in years of low rodent populations. Red fox (*V. vulpes*) also starve during food shortages rather than shifting their territories to sites with more numerous prey (Scott and Klimstra 1955).

Although starvation was the proximate cause of death in several of the kit fox in the Tortoise Area, the ultimate cause of death may have been a contagious disease such as canine distemper. One of the clinical symptoms of this and other viral and bacterial diseases is anorexia and a gradual loss of activity (Armstrong and Anthony 1942; Huff et al. 1974). The loss of almost every animal in the Tortoise Area in a brief period of time, the fact that they died underground, the absence of food in their gastrointestinal tracts, their emaciated overall condition, and the presence of diarrhea and conjunctival secretions provided circumstantial

evidence that a disease may have been the ultimate cause of death. Unfortunately, the animals were not recovered quickly enough to provide tissue samples for histopathological diagnoses.

In the Tortoise Area two adult foxes were dug from their dens after they apparently suffocated in cave-ins. Although the role of accidents as a source of mortality in wild animals is seldom considered, it certainly appeared that the headwalls of both dens collapsed, pinning the animals in chambers. The remaining tunnels appeared to be clear and unaffected by the cave-ins. Natural ground movements, such as earthquakes, plus man-made shocks, such as heavy ORV's bouncing above a den, may play a role in causing cave-ins and mortality of kit foxes.

Two foxes died due to trauma caused by a predator. Teeth on a reference skull of a coyote fit the width of the puncture wound found between ribs of the crushed thoracic cavity of one animal, and the consulting pathologist concluded that at least one of the foxes died of a coyote or dog bite. Coyotes probably killed both animals because there were no feral or domestic dogs observed in the vicinity when the animals were found. Neither animal, however, was eaten by its killer.

Coyotes are considered to be potential predators of kit fox (Goldman 1930; Knapp 1978; Young and Jackson 1951), and Seton (1937) offered the thesis that kit fox used dens to avoid confrontations with coyotes. Egoscue (1962) was unable to provide conclusive evidence that coyotes were, or were not, predators of kit fox. He did, however, relate that a coyote was observed digging into a kit fox den that was found to contain a small puppy. Another coyote was observed stalking a fox family that was aboveground near their den. However, kit fox remains were found in only two of approximately 8357 coyote stomachs examined (Sperry 1941), which suggests that if they kill kit foxes, coyotes seldom if ever consume them.

Animals in both areas were comparable as regards standard measurements and average weights. Standard measurements compared favorably with reported values (Grinnell et al. 1937; Hall 1946), but they failed to confirm that standard measurements of females are 2–7% smaller than those of males (Grinnell et al. 1937). It was also reported that male *V. m. mutica* were 15% heavier than females (Grinnell et al. 1937), and that male *V. m. nevadensis* were 8% heavier than nonpregnant females (Egoscue 1962). There was no significant sexual dimorphism in weights of *V. m. arsipus.*

Fleas were the most conspicuous ectoparasites observed on kit fox. They were found throughout the year, but appeared to be most dense between December and April. They also seemed to be more dense on females than on males, especially during the pupping season. The human flea was the most common and numerous species. It was also found to be the most common flea on kit foxes in Utah (Egoscue 1962).

The sticktight flea was found on 35% of the foxes sampled. It has been found on kit foxes in Arizona (Turkowski 1974), California (Morrell 1972), and Nevada (Beck and Allred 1966), but never on kit foxes sampled in Utah (Egoscue 1962). It is more commonly found on birds.

The few other fleas found were probably prey fleas that transferred to foxes when their preferred host was killed or consumed. *Orchopeas leucopus* is most commonly found on deer mice (*Peromyscus maniculatus*), and harvest mice

(*Reithrodontomys megalotis*); *O. sexdentatus* is usually found on pack rats (*Neotoma* spp.); and *Cediopsylla inequalis* is most often found on lagomorphs, especially cottontails (*Sylvilagus* spp.).

Except for the shooting of two foxes in the Rand Area, there were no significant, immediate negative effects observed in the ecological life history parameters under study that could be causally linked to human activities such as ORV use. Kit fox populations there were more dense, appeared to have a higher rate of reproduction and greater longevity, and did not appear to suffer from either starvation or disease, as compared with the fox population in the relatively undisturbed Tortoise Area.

The choice of the Tortoise Area population as a "control" may have been inappropriate if kit foxes there were being subjected to severe natural stresses, such as low food supplies or infectious diseases, that were not concurrently affecting the Rand population.

The question of how ORV's and other human activities influence kit foxes will not be satisfactorily answered until adequate paired populations are found, and suitable field experiments are designed and executed to apply measured ORV stresses to kit foxes in their dens.

In the meantime, large natal or pupping dens should be protected from adverse human activities or destruction. Results of this and other published studies suggest that natal or pupping dens, used exclusively by mated pairs, may be an important element in the critical habitat of the species.

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A New Species of *Boccardia* (Polychaeta: Spionidae) from the Galápagos Islands and a Redescription of *Boccardia basilaria* Hartman from Southern California

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A new species of *Boccardia* is described from shallow subtidal coral heads of Academy Bay, Santa Cruz Island, Galápagos Islands. The species is a borer and related to other species from the eastern Pacific. *Boccardia basilaria* Hartman, a close relative of the new Galápagos species occurs in subtidal benthic habitats of the southern California continental shelf. The species is redescribed and several deficiencies in its original description are corrected.

As revised by Blake and Kudenov (1978), the genus *Boccardia* Carrazzi is restricted to spionids having branchiae from setiger 2 and two types of major spines in the modified setiger 5. Species having only one type of major spine are now included in the genus *Boccardiella* Blake and Kudenov.

Most of the seventeen known species of *Boccardia* have been well described in a series of papers (Woodwick 1963a, b; Blake 1966, 1979, 1981; Blake and Kudenov 1978; Blake and Woodwick 1971; Rainer 1973; Read 1975). Nine species occur in the eastern Pacific of which eight are endemic.

While examining spionid collections in the U.S. National Museum, an undescribed species of *Boccardia* was discovered among materials from the Galápagos Islands collected during the Southeast Pacific Biological and Oceanographic Program of 1965–66. The new species, described below, is part of an eastern Pacific species group having modified spines in the posterior notopodia. While studying this new form, it was necessary to examine type specimens of the closely related *B. basilaria* Hartman from southern California. Several important characteristics not noted in the original description (Hartman 1961) necessitate a redescription of that species.

Boccardia galapagense new species
Figure 1

Material examined. —GALÁPAGOS ISLANDS, Santa Cruz Island, Academy Bay, *Anton Bruun* Sta. 66128, 0°44.50′S; 90°18.35′W, 23 May 1966, rocky point near Karl Angermeyer's residence, in coral head on rock near steep dropoff to muddy-sand bottom with scattered coral heads, 14 m, coll. S. E. Earle and D. Wallen, SCUBA, holotype (USNM 80487).

Description. —Holotype posteriorly incomplete, large, 22 mm long, 1.2 mm wide for approximately 120 setigers. Color in alcohol: brown, with dark reticulated dorsolateral pigment on prostomium.
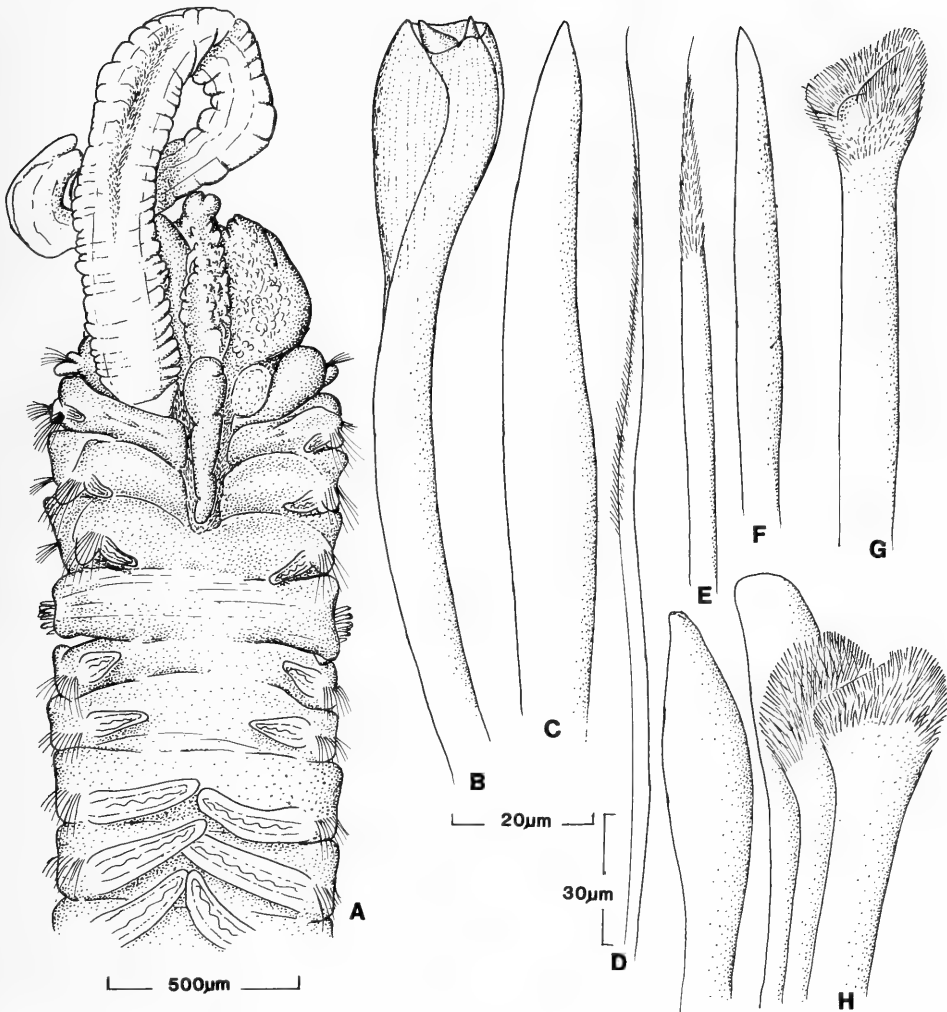
Fig. 1. *Boccardia galapagense.* A, Anterior end in dorsal view; B, Hooded hook of anterior neuropodium; C, Unhooded hook of posterior neuropodium; D, Capillary notoseta of posterior setiger; E, Unworn posterior notopodial spine; F, Worn posterior notopodial spine; G, Bristle-topped major spine from setiger 5; H, Group of two simple, non-bristled and two bristle-topped major spines from setiger 5.

Prostomium narrow, weakly incised anteriorly, followed by narrow, papillated medial portion and with folded caruncle continuing to posterior margin of setiger 3; occipital tentacle lacking, but with anterior edge of caruncle partially elevated, overlying anterior portion of prostomium; without eyes; prominent nuchal cilia present lateral to caruncle (Fig. 1A). Peristomium well developed, slightly inflated; palps thick, with numerous folds along ciliated groove, extending posteriorly for about 12 setigers.

Setiger 1 reduced, lacking notopodium and notosetae; neuropodium short, fingerlike (Fig. 1A). Setigers 2–4, 6 with broad, thin, bladelike elliptical postsetal notopodial lamellae; subsequent notopodia not apparent.

Anterior notosetae and neurosetae of setigers 1–4, 6 short, unilimbate capillaries, arranged in two rows, with setae of first row shortest, with fine granulations on shaft and clear sheath; setae of second row longest, lacking granulations. Notosetae of middle and posterior setigers longer, lacking granulations; posterior notosetae including 5–6 fimbriated capillaries (Fig. 1D) and 2–3 spines; each spine with finely bristled, pointed tips when new (Fig. 1E): with blunted, non-bristled tip when worn (Fig. 1F). Bidentate hooded hooks from neuropodia of setiger 7, numbering 5–6 at first accompanied by 1–2 very fine capillaries; hooks, increasing to 7–8 per neuropodium in middle setigers; anterior hooded hooks with large, expanded hood, having fine striations; with wide angle between main fang and shaft and about 80° angle between apical tooth and main fang (Fig. 1B); hooks of posterior setigers numbering 3–4 per neuropodium losing apical teeth and hoods, becoming straighter and spinelike (Fig. 1C); presence of spines in both noto- and neuropodia of posterior setigers providing distinct armature.

Modified setiger 5 not heavily muscularized, only slightly larger than preceding and succeeding setigers (Fig. 1A); setae including curved row of two types of major spines and neuropodial fascicle of capillaries; no superior capillary fascicle; major spines of two types: 1) dorsal row of 7 smooth, non-bristled, spines with slightly expanded ends; 2) ventral row of 7 bristle topped spines with expanded tips; when viewed dorsally, these spines with apical concavity open to one side with terminal, smooth knob; cavity not seen when viewed from ventral side.

Branchiae present on setigers 2–4, 6 and following setigers to posterior end of fragment. Branchiae of setigers 2–4, 6–7 shortest, increasing to full size by setiger 9 (Fig. 1A); branchiae broad, thin nearly concealing dorsal surface in middle of body segments; posterior branchiae short, fingerlike. Pygidium unknown.

Remarks.—*Boccardia galapagense* is closely related to *B. pugettensis* Blake from British Columbia and Washington, *B. anopthalama* Rioja from western Mexico and *B. basilaria* Hartman from southern California in having posterior notopodial spines. The species is closest to *B. basilaria* in lacking notosetae on setiger 1 and in the manner in which bidentate hooded hooks change to unidentate spinelike setae in posterior setigers. *B. galapagense* differs from *B. basilaria* in having a papillated, narrow, weakly incised prostomium lacking eyes, bristle-topped major spines of setiger 5 with a distinct apical concavity on the posterior side of the expanded bristled tip, and posterior unidentate neuropodial spines lacking hoods. *B. basilaria,* on the other hand, has a more typical strongly incised non-papillated prostomium with four eyes, bristles completely cover the expanded tips of the major spines and the posterior unidentate spines of the neuropodia bear a distinct hood.

Distribution.—*B. galapagense* is known only from the Galápagos Islands where it bores into shallow subtidal coral rock.

Boccardia basilaria Hartman, 1961
Figure 2

Boccardia basilaria Hartman 1961:95–96, pl. 13, figs. 1–7; 1969:89–90, 5 figs.

Material examined.—CALIFORNIA, 8.7 miles from Santa Barbara Point Light, Velero Sta. 5161-57, 34°24′35″N; 119°54′00″W, 2 July 1957, 20.9 m, green mud, Orange Peel Grab, holotype and 50+ paratypes (AHF Poly 0636–7).

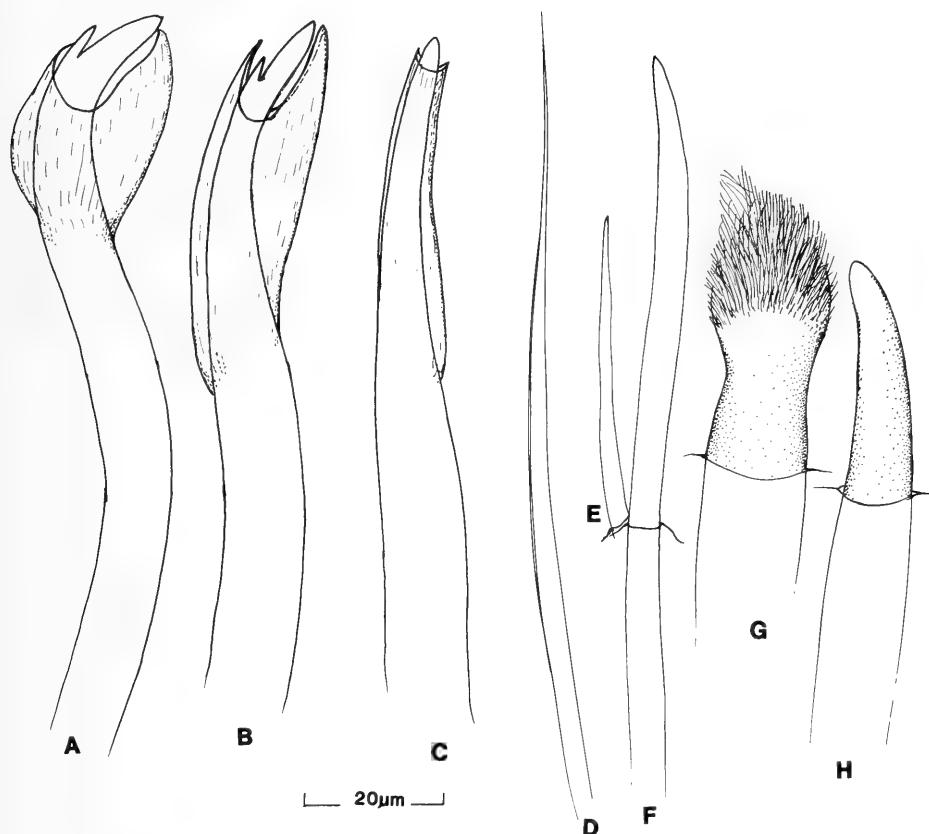*Description.*—Holotype complete 18.5 mm long and 1.2 mm wide for 65 se-

Fig. 2. *Boccardia basilaria.* A, Hooded hook from anterior neuropodium; B, Hooded hook from middle neuropodium; C, Hooded hook from posterior neuropodium; D, Capillary notoseta from posterior row of anterior setiger; E–F, Spines from posterior notopodia; G, Bristle-topped spine from setiger 5; H, Simple major spine from setiger 5.

tigerous segments; most paratypes smaller, incomplete. Color in alcohol: light brown with single medial black pigment spot on 6–10 segments from setiger 5; middle and posterior segments of some specimens with brown reticulated pigment on dorsum and similar pigment on prostomium and anterior ventral areas of some specimens. Body dorsoventrally flattened anteriorly, cylindrical posteriorly.

Prostomium incised anteriorly, forming 2 diverging lobes, continuing posteriorly as caruncle to end of setiger 3; no occipital tentacle, but prostomium with dorsal protuberance at level of setiger 1; with 2 pair of eyes.

Setiger 1 biramous, dorsally elevated; with elliptical neuropodial postsetal lamellae and short, fingerlike notopodial lamellae; setigers 2–4, 6 and subsequent segments with thin, leaflike elliptical noto- and neuropodial postsetal lamellae; notopodial lamellae of middle segments lower, more elongate; neuropodial lamellae less rounded, longer.

Notosetae of setiger 1 simple fascicle of capillaries; setigers 2–4, 6 and following segments with well-developed fascicles of capillary notosetae arranged in two rows with setae of first row shorter, thicker, sharply curved with fimbriated edge; setae

of posterior row longer, straight, without fimbriated edge (Fig. 2D). Posterior notopodial spines present in posterior setigers; spines simple, numbering 1–2 per notopodium (Figs. 2E, F), accompanied by 2–4 long, non-limbated capillaries. Neurosetae of setigers 2–4, and 6 similar in arrangement and form to notosetae. Most capillaries replaced by hooded hooks from setiger 7; hooks numbering 7–8 in a fascicle, accompanied by 1–3 capillaries in ventralmost position; hooks strongly recurved, with inflated hood and with unusually wide angle between main fang and shaft, apical tooth reduced and closely adhering to main fang (Fig. 2A); in middle setigers apical tooth becoming reduced (Fig. 2B) and finally lost in posterior neuropodia (Fig. 2C); hoods of unidentate hooks in posterior setigers reduced, closely applied to shaft. Neuropodial hooks and notopodial spines providing distinct armature to posterior end.

Modified setiger 5 about twice size of preceding and succeeding setigers; setae including curved row of two types of major spines and neuropodial bundle of about fifteen thin capillaries with finely granulated shafts and narrow fimbriated edge; dorsal capillaries lacking. Major spines include dorsal row of 2–3 simple falcate, non-bristled spines (Fig. 2H) and ventral row of 7–8 bristle topped spines with bristles completely enclosing tip (Fig. 2G).

Branchiae present on setigers 2–4, 6 and subsequent segments, absent from last 20 or so setigers; all branchiae, short, widely spaced, located closely to notopodium and nearly fused basally to notopodial postsetae lamellae; anterior branchiae short, barely extending one-quarter of distance across dorsal midline; branchiae reaching full size by about setiger 15, extending about half distance to dorsal midline.

Pygidium with two lappets located ventral to dorsally positioned anal opening.

Remarks. —In the original description of *B. basilaria,* the posterior notopodial spines were not observed (Hartman 1961), although the unidentate nature of the posterior neuropodial hooks was described. The close similarity of *B. basilaria* and *B. galapagense* has already been discussed (see above) and relationships with some other species were considered in an earlier paper (Blake 1979).

Distribution. —Southern California continental shelf.

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Notes on Three European Land Mollusks
Introduced to California

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Cecilioides acicula (Müller 1774) is newly recorded as an introduction in California. *Punctum conspectum* (Bland 1865) is a synonym of *Punctum (Toltecia) pusillum* (Lowe 1831); widely distributed in western North America, it may be both native and introduced. Previous records in California of *Arion circumscriptus* Johnston, 1828, are shown to pertain to *Arion (Carinarion) silvaticus* Lohmander, 1937; the latest documented finding of the species in the state is 1949.

This paper presents information regarding two species of European terrestrial gastropods newly recognized as introductions to western North America or to the state of California and a third which may be both native and introduced. The records added here supplement those in the summary by Hanna (1966) and subsequent papers (Roth 1977, 1982a, 1982b; Roth and Chivers 1980) documenting the continuing discovery and spread of synanthropic snails and slugs in this part of the world.

The following abbreviations are used: CAS—California Academy of Sciences, San Francisco; RMNH—Rijksmuseum van Natuurlijke Historie, Leiden; SBMNH—Santa Barbara Museum of Natural History.

Cecilioides acicula (Müller 1774)

CALIFORNIA: Santa Clara County, garden in Los Altos, on carrots [*Daucus carota*]; J. F. Vedder coll. February 1967 (CAS 036707).

The only previous North American records are in the eastern states—Florida, Maryland, Pennsylvania, and New Jersey (Pilsbry 1946; Dundee 1974). It has been intercepted on numerous kinds of plant shipments originating in both New and Old World ports (Dundee 1974).

The subterranean habit of *Cecilioides acicula* may account for the scarcity of records in western North America. The species may in fact have a much wider distribution in the San Francisco Bay counties, although possibly limited by the availability of calcium-rich soil. With *C. acicula* at the above locality was found *Helicodiscus singleyanus* (Pilsbry 1890), previously known in the San Francisco Bay area from roots and bulbs in a garden in Berkeley (Pilsbry 1948).

Punctum (Toltecia) pusillum (Lowe 1831)
Figures 1–2

This species is a familiar member of the fauna of western North America, where it has gone under the name *Punctum (Toltecia) conspectum* (Bland 1865). This synonymy is new herein.

The range attributed to "*P. conspectum*" includes Alaska, British Columbia, Idaho, Montana, Arizona, and New Mexico, as well as the Pacific Coast states of Washington, Oregon, and California (Pilsbry 1948; Bequaert and Miller 1973). It also occurs in Kamchatka (Dall 1905; Likharev 1963). If *Punctum jaliscoense* (Pilsbry 1926) is a synonym or a subspecies, as it was treated by Baker (1930) and Pilsbry (1948), the species ranges to southern Mexico. No fossil occurrences are known.

I have examined specimens from the following counties in California: Alameda, Butte, Contra Costa, Humboldt, Los Angeles, Mendocino, Merced, Monterey, Nevada, Plumas, San Benito, San Bernardino, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Sonoma, Tehama, Tulare, and Tuolumne. In addition Pilsbry (1948) cited Calaveras, Mariposa, Napa, Orange, San Diego, and Siskiyou counties. Localities are sporadically distributed through the northern and southern California Coast Ranges, Sierra Nevada and Cascade Range (principally the foothills), with a few occurrences in the Transverse and Peninsular Ranges. Many localities are clustered in the San Francisco Bay area and the Los Angeles Basin. It is not possible to say to what extent the gaps in range are real or reflect the uneven distribution of collecting effort.

Specimens in the California Academy of Sciences collection from Alaska, Washington, Oregon, and Idaho are all very similar in shell characters. Specimens from Pasadena and adjacent parts of Los Angeles County, formerly regarded as the subspecies *Punctum conspectum pasadenae* Pilsbry, 1896, have the major radial riblets weakly developed (Fig. 1D). Pilsbry (1948) stated that *P. c. pasadenae* was usually smaller than the nominate subspecies, but shells in lots I have examined (Pasadena, R. Arnold coll. [CAS 036854], and H. N. Lowe coll. [CAS 036855]; bed of Los Angeles River near Los Feliz Bridge, Griffith Park, Los Angeles, M. E. Caruthers coll. [CAS 036856]) actually average about 10 per cent larger in diameter at a given whorl than central California specimens.

Specimens from San Francisco, California (the type locality of *Punctum conspectum*) (Fig. 1C), and elsewhere in the west (Figs. 1D–1F) are very similar to authentic specimens of European *P. pusillum* (Figs. 1A–1B). All have a spirally lirate protoconch of 1.4 whorls (Figs. 1B, E), 5–10 minor radial riblets in the intervals between major radials, flattened whorl shoulder, and low spiral cords corrugating the shell surface (Figs. 2A, B). Typical of *Punctum,* the radial and spiral sculpture are essentially independent (Solem 1977).

The recognized range of *Punctum pusillum* includes the Macaronesian archipelagos and many localities around the Mediterranean, where it has been recorded most often as *Pleuropunctum micropleuros* (Paget 1854). Gittenberger et al. (1980) remarked that its total distribution is poorly known "because the systematic position of many at least closely related nominal taxa has never been thoroughly studied: e.g., *Helix poupillieri* Bourguignat, 1863, from Algeria; *Punctum lederi* (O. Boettger 1880), reported from SE. Azerbaydzhan, U.S.S.R. (Lenkoran) to Israel and Turkey; *Patula atoma* Gredler, 1892, from China, Hunan province; *Pyramidula javana* (Mollendorff 1897) from Java, Bali and Lombok; *Punctum hottentotum* (Melvill & Ponsonby 1891) from southern Africa; etc." Based on a lot from Aomar, Algeria (CAS 036851), I regard *Helix poupillieri* Bourguignat as a synonym of *P. pusillum.* Other material that I find suggestively similar comes
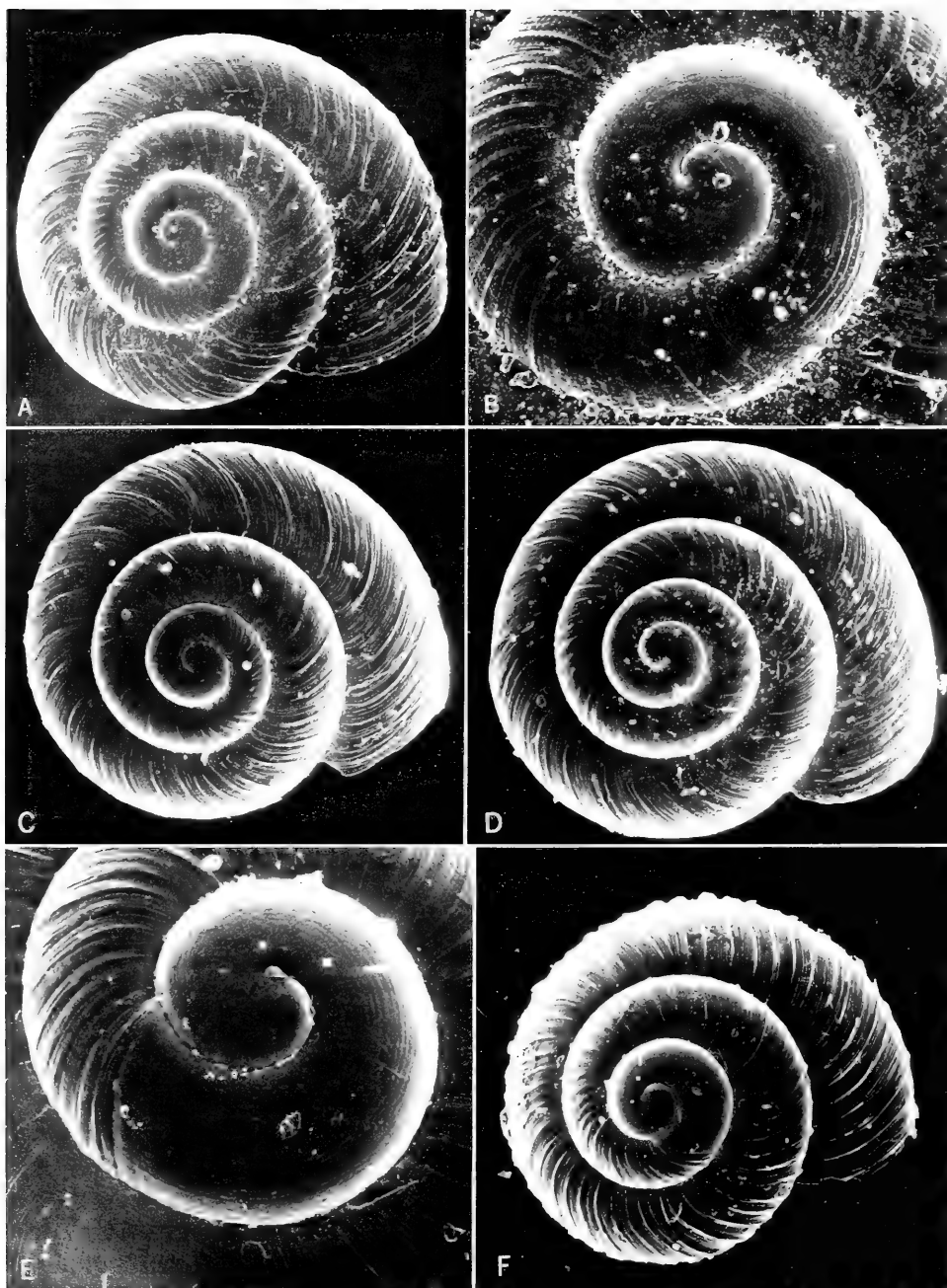
Fig. 1. *Punctum* (*Toltecia*) *pusillum* (Lowe). A, B, Spain: prov. Barcelona, Montjuich, El Marrot, near Miramar, C. Altimira coll. Dec. 1966 (CAS 037053, *ex* RMNH 54890). C, California: San Francisco, Buena Vista Park, B. Roth coll. 2 July 1970 (CAS 037054), virtual topotype of *Helix conspecta* Bland. D, California: Los Angeles, bed of Los Angeles River near Los Feliz Bridge, Griffith Park, M. E. Caruthers coll. (CAS 037055). E, F, California: Plumas County, near Blairsden, A. G. Smith coll. 3 August 1951 (CAS 037056). A, C, D, F, top views, ×25; B, E, sculpture of apical whorls, ×72.
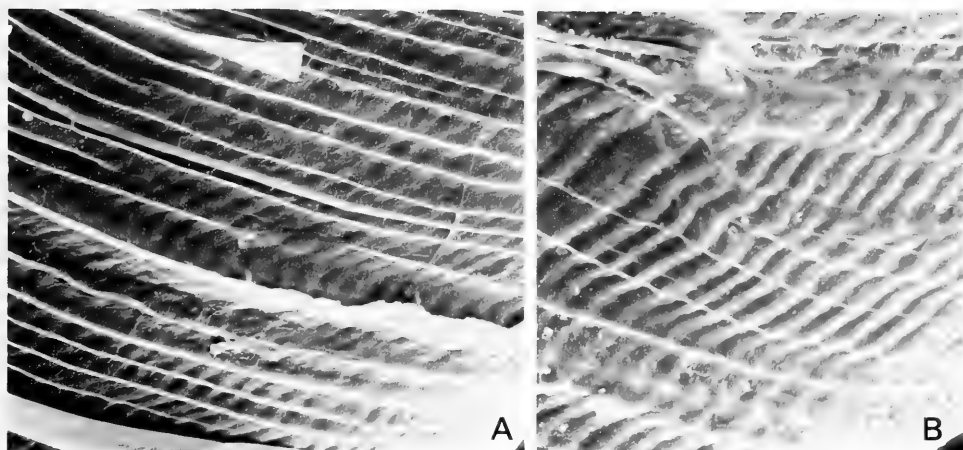
Fig. 2. *Punctum (Toltecia) pusillum* (Lowe), details of sculpture on shoulder of body whorl, ×345. A, California: Plumas County, near Blairsden (CAS 037056). B, Spain, prov. Barcelona, Montjuich, El Marrot, near Miramar (CAS 037053, *ex* RMNH 54890).

from Tonglu, Zhejiang province, China (CAS 036857, originally identified as *Punctum orphana* [Heude]); and Zhililung, near Pujiang, Zhejiang province, China (CAS 036858, "*P. orphana*"). Dr. E. Gittenberger (written comm. 1983) points out that *Zilchogyra cleliae* Weyrauch (1965: pl. 7, fig. 3; not fig. 2 as stated in text) from Argentina and southeastern Brazil may be yet another synonym. The type locality of *Z. cleliae* is a park in Buenos Aires, under the loose bark of eucalyptus trunks, a characteristic type of habitat for an introduced species.

Throughout much of its North American range, *Punctum pusillum* is evidently indigenous: remote localities in Alaska, the mountains of Idaho, Arizona, New Mexico, and other states. However, it also occurs in some situations that are strongly suggestive of an introduced species. For example, it was found in association with *Vitrea contracta, Helix aspersa, Oxychilus cellarius,* and *Arion intermedius* in a landscaped section of San Francisco (Roth 1977); with *Helix aperta, Milax gagates, Deroceras caruanae,* and *Deroceras reticulatum*—all European species—in Richmond, California (Roth and Chivers 1980). It is a common, although inconspicuous, inhabitant of parks and gardens in the San Francisco Bay area. On Santa Cruz Island (southern California) it occurs in a disturbed situation around the University of California field station (SBMNH 33889) but has not yet been discovered in native plant communities on this or any other California island. Other European mollusks, including *Milax gagates, Limax maximus,* and *Limax valentianus,* are similarly restricted to disturbed habitats on Santa Cruz Island.

The far-flung but apparently patchy distribution of *Punctum pusillum* may be a consequence of its "weedy" tendencies. The species is distinctly anthropophilic, but the relative deployment of native versus introduced populations and the source-areas for its urban occurrences will be hard to discover unless some genetic markers or anatomical differences are found. I believe human introduction from Europe must continue to be regarded as a possibility, because of the many parallel instances of Old World mollusks, particularly from the Mediterranean area, becoming successfully established in "civilized" contexts in California. Instances of

North American species introduced to Europe or the Middle East are far fewer in number (Mienis 1977; Kerney and Cameron 1979).

Some recent authors (e.g., Falkner 1974; Gittenberger et al. 1980) treat *Toltecia* Pilsbry, 1926, as a genus. *Toltecia* is distinguished from *Punctum* Morse, 1864, by the presence of "several, usually five or more," minor radial threads in the interspaces between major radials on the last whorl (Pilsbry 1948:649). The type-species of *Punctum, P. minutissimum* (Lea 1841), has, in general, two or three such "microradials" in the interspaces (Solem 1977: figs. 5, 6). This difference is one of numbers, not of basic structure. In *Toltecia* the last ⅓ to ½ whorl before maturity enlarges at a greater rate than previous whorls; the inner lip expands somewhat toward the umbilicus and the plane of the aperture becomes nearly tangent to the face of the body whorl. In *Punctum* this terminal change in growth is absent and the plane of the aperture remains approximately radial (E. Gittenberger, written comm. 1983). Species of both *Punctum* and *Toltecia* have spiral liration on the protoconch; that of *Toltecia* may be slightly stronger. Available anatomical information does not give grounds for separation; compare Baker's (1927: pl. 16, figs. 8, 12) figures of genitalia and pallial organs of *Punctum* (*Toltecia*) *jaliscoense* (Pilsbry)—the type-species of *Toltecia*—with Solem's (1983: fig. 24) of *P. minutissimum*. Pilsbry (1948) ultimately reduced *P. jaliscoense* to a subspecies of *Punctum conspectum*.

In the absence of a phylogenetic revision of the Punctidae addressing these relationships on a worldwide basis, to treat *Toltecia* as a subgenus—as I have done—actually implies more information than is now at hand.

Arion (*Carinarion*) *silvaticus* Lohmander, 1937

CALIFORNIA: San Francisco City and County, Golden Gate Park, near California Academy of Sciences buildings, under leaves; A. G. Smith coll. 4 July 1942 (CAS 025655). Same data but coll. 18 January 1947 (CAS 025653). Same data but coll. 30 April 1949 (CAS 025656).

For many years the distinction between *Arion circumscriptus* Johnston, 1828, *Arion fasciatus* (Nilsson 1823), and *Arion silvaticus*—first pointed out by Lohmander (1937)—was not appreciated by American authors. Most records until about 1969 simply cite *Arion circumscriptus* (e.g., Pilsbry 1948; Hanna 1966). Dissection of the specimens cited above shows them to be *A. silvaticus*. The species is reported in the New World from northeastern North America (Chichester and Getz 1969; Dundee 1974) and from British Columbia (Rollo and Wellington 1975); this is the first record from California.

These specimens were mentioned by Hanna (1966:29) as *A. circumscriptus*. Although *A. silvaticus* persisted in this locality from at least 1942 to 1949, it had disappeared by the time of Hanna's (1966) report. I have not been able to find it subsequently. Lange (1944) collected "*A. circumscriptus*" in Golden Gate Park in 1940 and quoted A. G. Smith (in correspondence) that the species was widespread in the San Francisco Bay region. I have not managed to track down any of Lange's specimens, and the collection of the California Academy of Sciences, which contains most of the slug material handled by A. G. Smith, includes no Bay Area lots beside those cited above.

The several additional reports of *Arion circumscriptus* from California (Gregg 1943; Pilsbry 1948; Ingram 1949; Ingram and Lotz 1950) seem to be restatements

of the same information, referencing either the 1944 Lange publication or personal communication from Smith. The statement by Hill (1951) that *A. circumscriptus* occurs in greenhouses in the San Francisco Bay area is probably also derivative. In summary, although the lots listed here document the former presence of *Arion silvaticus* in this part of California, evidence for its wider occurrence is equivocal or lacking and its continued presence remains problematical.

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The Taxonomic Status of Two North American *Lithurge* (Hymenoptera: Megachilidae)

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Abstract.—Subsequent to my 1983 review of the North American species of *Lithurge,* the type specimen of *L. planifrons* (Friese) has been examined: it is a senior synonym of *L. socorroensis* (Mitchell) (NEW SYNONYMY). The species that I incorrectly believed to be *L. planifrons* is here described as *L. bitorulosa,* no prior name being available. A corrected key to the North American species is included.

In 1983 I reviewed the North American species of the bee genus *Lithurge.* Including one introduced Palearctic species, a total of eight species were recognized. A few Mexican specimens from Jalisco were tentatively identified as *L. planifrons* (Friese), a species otherwise known only from the inadequately described male type. That type, in the collections of the Zoologisches Museum, Humboldt-Universitat, Berlin, has been examined at my request by T. L. Griswold. With the aid of Griswold's notes I have been able to determine that the specimens I had referred to this name were incorrectly identified, and that Friese's name is a senior synonym of *L. socorroensis* (Mitchell). Since no prior name is available for the species that I had called *L. planifrons* it is here named and described as *L. bitorulosa.*

A new key is given to reflect these changes. And, the opportunity is taken to improve the separation of females of *L. echinocacti* and *L. planifrons* (*L. socorroensis* in my previous key).

## *Lithurge* (*Lithurgopsis*) *planifrons* (Friese)

Lithurgus planifrons Friese, 1908:62. ♂.
Lithurgus socorroensis Mitchell, 1938:152–154. ♀. NEW SYNONYMY.
Lithurge (*Lithurgopsis*) *socorroensis*: Snelling, 1983:3, 10. ♀.

The type of *L. planifrons* is in the Berlin Museum and was examined in 1984 by Griswold. His notes on the type make it clear that the male type is not different from males of *L. socorroensis.* It is also clear that the specimens from Jalisco that I (1983) recorded as *L. planifrons* are not that species, but represent one previously undescribed.

The type locality of *L. planifrons* is given as "Jacubaya, Mexico," a misprint for Tacabaya, a suburb of Mexico City. As the name implies, *L. socorroensis* was based on material from Socorro Island in the Revillagigedo Archipelago. The range of *L. planifrons* extends from southern Arizona to Costa Rica.
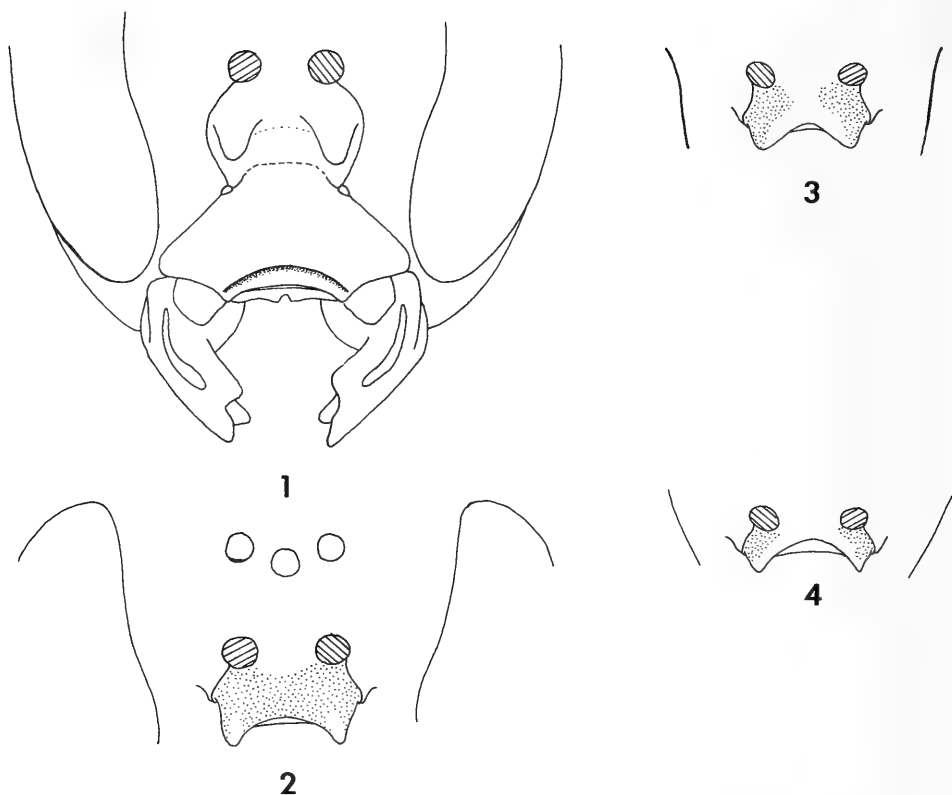
Figs. 1–4. *Lithurge* spp., females: 1, *L. bitorulosa*, frontal view of lower face; 2, *L. bitorulosa*, dorsal view of supraclypeal prominence; 3, *L. planifrons*, same; 4, *L. echinocacti*, same. Stippling indicates extent of punctate areas in Figures 2–4. All Figures drawn to same scale.

Lithurge (*Lithurgopsis*) *bitorulosa*, new species
Figs. 1–2

Lithurge (*Lithurgopsis*) *planifrons*: Snelling, 1983:2, 10. ♂. [Misidentification].

Diagnosis. — Female: First flagellar segment shorter than second; supraclypeal area with large conical protuberance on each side; malar area linear, without posterior pit; upper facet of supraclypeal process conspicuously contiguously to subcontiguously punctate. Male: Tarsal arolia absent; labrum with transverse basal ridge, but without erect spine-like tubercle; supraclypeal area flat, shiny to slightly shiny between contiguous to subcontiguous punctures.

Description. — Female, Measurements (holotype in parentheses): head width 3.54–4.51 (4.51); head length 2.36–2.87 (2.87); wing length 7.5–10.0 (10.0); total length 11.5–15.5 (15.5) mm.

Head: 1.3–1.4 times broader than long; eyes strongly convergent below, upper interocular distance 1.5–1.6 times lower interocular distance. Malar space essentially absent, posterior pit absent. Transverse basal ridge of labrum high in center, with deep median excision. Clypeus with narrow, curved preapical ridge, distad of which clypeus is depressed, shiny; clypeal disc shiny, subpolished between coarse very variably spaced punctures, but with interspaces up to three times

puncture diameter in middle. Supraclypeal area moderately protuberant, with prominent blunt, conical protuberance on each side; lower facet polished and virtually impunctate, upper facet (including area between bases of protuberances) dull to moderately shiny between contiguous to subcontiguous, moderate to coarse punctures that are continuous across midline. Ocellocular distance about 1.3 times interocellar distance. First flagellar segment shorter than pedicel, about as long as second segment; median flagellar segments about one-third broader than long.

Mesosoma: Dorsal portion of mesoscutum coarsely, transversely scabrous anteriorly, becoming more finely, less distinctly transversely scabrous distad. Disc of scutellum finely scabrous.

Pilosity: Hairs mostly whitish; ferruginous hairs present on lower margin of mandible, middle one-third of apical margin of clypeus, and inner side of probasitarsi; meso- and metabasitarsi with brownish hairs on inner side. Sternal scopa somewhat brownish yellow. Marginal pubescent fasciae of metasomal terga 2 and 3 broadly interrupted, those of 4 and 5 complete; tergum 6 wholly covered with dark brownish hairs, the apices of which may be lighter reddish brown; tergal disc with sparse, suberect to erect, simple, brown hairs.

Color: Uniformly blackish brown, but legs (especially femora) lighter, flagellum ferruginous. Wings transparent, weakly brownish.

Male, Measurements: head width 3.64–3.79; head length 2.97–3.08; wing length 7.5–9.0; total length 11.0–13.0 mm.

Head: 1.2–1.3 times broader than long; eyes strongly convergent below, upper interocular distance 1.5–1.6 times lower interocular distance. Labrum with low, rounded basal ridge impressed in middle, but without erect spine. Supraclypeal area mostly flat, but lower portion sloping toward base of clypeus, 1.4–1.5 wider than long; clypeus, supraclypeal area slightly shiny between contiguous to subcontiguous, moderate to coarse punctures, without impunctate median areas. Ocellocular distance about 1.3 times interocellar distance; ocelloccipital distance about 1.3 times interocellar distance. First flagellar segment conspicuously broader than long, shorter than pedicel and about one-third as long as second segment.

Mesosoma: Mesoscutum with moderate, contiguous punctures, sometimes subrugosopunctate. Scutellum with moderate, contiguous punctures.

Pilosity: Similar to that of female, but without ferruginous hairs on mandible and clypeal margins, with yellowish ferruginous hairs on inner side of basitarsi; some brown hairs across occiput and on mesoscutum; metasomal terga 4–6 with continuous distal fasciae, brown hairs of tergal discs longer, last tergum with hairs sparse, some pale hairs at sides.

Color: As described for female, but legs definitely brown.

Type material.—Holotype female, allotype, five female paratypes: 46 mi W Tehuantepec, 2125 ft elev., Oaxaca, MEXICO, 26 June 1961 (University of Kansas Mexican Expedition), on cactus, *Opuntia.* Types in collection of University of Kansas, except one paratype in Natural History Museum of Los Angeles County.

Additional material (Not paratypes).—2 ♂, Estacion Biologia UNAM "Chamela," San Patricio, Jalisco, MEXICO, 1981 (S. H. Bullock; #76); 1 ♂, same data except 21 June 1983 (#1533), in LACM and Estacion Biologia UNAM "Chamela."

Etymology.—Combines the Latin prefix "*bi-*" (two) with the diminutive of *torus* (protuberance or bulge).

Discussion. —The female of *L. bitorulosa* will run to the last couplet in my 1983

key, separating *L. echinocacti* (Cockerell) and *L. planifrons* (as *L. socorroensis*). In all three of these species the supraclypeal area has a pair of sublateral conoid processes. The female of *L. echinocacti* has the supraclypeal area without defined upper and lower facets and with most of its area smooth and shiny between scattered fine punctures; only on the area adjacent to the antennal sockets do the punctures become crowded; the supraclypeal tubercles, in dorsal view, are narrow and acute and the entire supraclypeal area is less strongly protuberant (Fig. 4). The supraclypeal structure of *L. planifrons* more closely resembles that of *L. bitorulosa,* but the shiny, impunctate lower facet extends up and includes all of the area between the tubercles (Fig. 3), while in *L. bitorulosa* the lower facet is confined to the lower one-third of the supraclypeal area, with most of the area between the tubercles subcontiguously punctate (Fig. 2). In both *L. echinocacti* and *L. planifrons,* metasomal terga 2 and 3 possess apical hair bands that are complete across the middle of the segments.

The male, misidentified by me as *L. planifrons* in 1983, will run to that name in my key. Because the labrum lacks an erect spine-like process, the male is most like those of *L. echinocacti* and *L. apicalis*. It differs from both in having the supraclypeal area flat and coarsely and closely punctate along the midline.

The following is a revised version of my 1983 key, reflecting the changes made herein.

Key to North American *Lithurge*

1a. Female, metasoma with six exposed terga 2
  b. Male, metasoma with seven exposed terga 9
2a. First flagellar segment shorter than second; facial prominence, when
    present, not as below (subgenus *Lithurgopsis*) 3
  b. First flagellar segment longer than second; facial prominence high, tri-
    angular in lateral view, its lower portion sloping toward base of clypeus
    (subgenus *Lithurge*) .... *chrysurus* (Fonscolombe)
3a. Supraclypeal protuberance nearly as broad as face, extending laterad of
    subantennal sutures; malar area distinct and with deep posterior pit .. 4
  b. Supraclypeal protuberance, when present, much narrower than width
    of face, not extending laterad of subantennal sutures; malar area linear,
    mandible nearly contiguous with eye, posterior pit usually absent ... 5
4a. Labral tubercle divided in middle only; clypeus with preapical ridge
    which is interrupted in middle .... *apicalis* (Cresson)
  b. Labral tubercle with median and sublateral impressions; clypeus with-
    out preapical ridge .... *littoralis* (Cockerell)
5a. Supraclypeal area distinctly elevated on each side of midline or with a
    single, transverse, bowed elevation 6
  b. Supraclypeal area flat, with no protuberance, shiny and very sparsely
    punctate .... *listrota* Snelling
6a. Supraclypeal area with prominent paired, cone-like elevations; malar
    area without posterior pit 7
  b. Supraclypeal elevation a high, transverse, bowed ridge; malar area with
    broad, shallow posterior pit .... *gibbosa* (F. Smith)
7a. Supraclypeal area very shiny and largely impunctate over one-half or

more of its area (in particular, area between bases of lateral tubercles smooth and shiny); metasomal terga 2 and 3 with complete fasciae ... 8

b. Supraclypeal area mostly contiguously punctate, only narrow lower facet impunctate and shiny; metasomal terga 2 and 3 with apical fasciae broadly interrupted across middle .... *bitorulosa* new species

8a. In dorsal view, supraclypeal area only moderately elevated, and lateral tubercles narrow and acute (Fig. 4); ocelloccipital distance less than interocellar distance .... *echinocacti* (Cockerell)

b. In dorsal view, supraclypeal area strongly elevated and lateral tubercles bluntly conoid (Fig. 3); ocelloccipital distance greater than interocellar distance .... *planifrons* (Friese)

9a. Tarsal arolia present; first flagellar segment shorter than second (subgenus *Lithurgopsis*) 10

b. Tarsal arolia absent; first flagellar segment distinctly longer than second (subgenus *Lithurge*) .... *chrysurus* (Fonscolombe)

10a. Labrum with a single median tubercle, or none 11

b. Labrum with a pair of slender, erect tubercles .... *littoralis* (Cockerell)

11a. Labrum with a low, transverse basal ridge or swelling 12

b. Labrum with a slender, erect, spine-like process 14

12a. Supraclypeal area gently convex, its upper portion sloping toward antennal sockets, and with a definite median area that is less closely punctate than area near subantennal suture or entire supraclypeal area sparsely and irregularly punctate 13

b. Supraclypeal area uniformly flat between clypeal base and antennal sockets, contiguously punctate, punctures coarse and subcontiguous along midline .... *bitorulosa* new species

13a. First flagellar segment, on shortest side, distinctly broader than long, shorter than pedicel; supraclypeal area about 1.4 times wider than long; legs usually reddish .... *echinocacti* (Cockerell)

b. First flagellar segment, on shortest side, about as long as wide, about as long as pedicel; supraclypeal area about 1.8 times wider than long; legs brown .... *apicalis* (Cresson)

14a. Labrum with low, often obsolescent, ridge extending obliquely from basal corner to base of median tubercle 15

b. Labrum deeply concave on either side of tubercle and with short, curved ridge from base of tubercle to midlength of lateral margin ....
.... *planifrons* (Friese)

15a. Supraclypeal area slightly protuberant, densely punctate; ocelloccipital distance greater than interocellar distance .... *gibbosa* (F. Smith)

b. Supraclypeal area flat, sparsely punctate, at least in middle; ocelloccipital distance less than interocellar distance .... *listrota* Snelling

Acknowledgments

indebted to R. W. Brooks who had also examined the *L. planifrons* type and advised me that my earlier interpretation was incorrect.

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Trace Element Composition of Obsidian Butte, Imperial County, California

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Abstract. — Non-destructive energy dispersive x-ray fluorescence analyses were performed on rhyolitic volcanic glass (obsidian) from Obsidian Butte, located at the south end of the Salton Sea in Imperial County, California. Sixteen trace and rare earth element concentrations were measured in parts per million (ppm), and these values compared favorably with analyses employing destructive techniques. The results of the present study demonstrate that archaeological artifacts can be matched reliably to the Obsidian Butte source on the basis of non-destructive quantitative analysis, facilitating the study of prehistoric Southern California obsidian trade and interlaboratory comparison of analytical results.

Obsidian has long been of interest to archaeologists because in regions where it occurs it was the raw material preferred for the manufacture of prehistoric chipped stone tools. Recently, techniques from the physical sciences have provided new ways of deriving information from obsidian artifacts. Using x-ray fluorescence or neutron activation techniques, it is possible to determine the trace and rare earth element composition of volcanic glass (obsidian), and to distinguish between parent geological sources on the basis of contrasts in these elemental constituents. Once the trace element configurations (or "profiles") for obsidian sources in a region are established, it is possible to analyze artifacts from archaeological sites and match them with known obsidian sources on the basis of trace and rare earth element similarities. This procedure, popularly known as "fingerprinting," has been profitably applied to studies of prehistoric trade in western North America (e.g., Jack and Carmichael 1969; Jackson 1974; Jack 1976; Hughes 1983a, b, 1984; Ericson 1981; Nelson 1984).

However, until quite recently, comparatively little research on obsidian trade has been conducted in southern California in part because of the absence of a published quantitative obsidian source data base. Trace and rare earth concentration values have been published for some elements (see Ericson 1981:10; Robinson et al. 1976:table 2), but these have been derived from destructive analyses (i.e., those necessitating crushing and powdering some portion of the sample), which have obvious drawbacks for archaeological studies because of the desirability of analyzing artifacts without sacrificing some portion of them for study. The purposes of this study are to present a series of quantitative trace and rare earth element measurements for Obsidian Butte glass using non-destructive x-ray fluorescence, to compare these values with those generated from previous analyses conducted using destructive methods, and to illustrate the benefits of non-
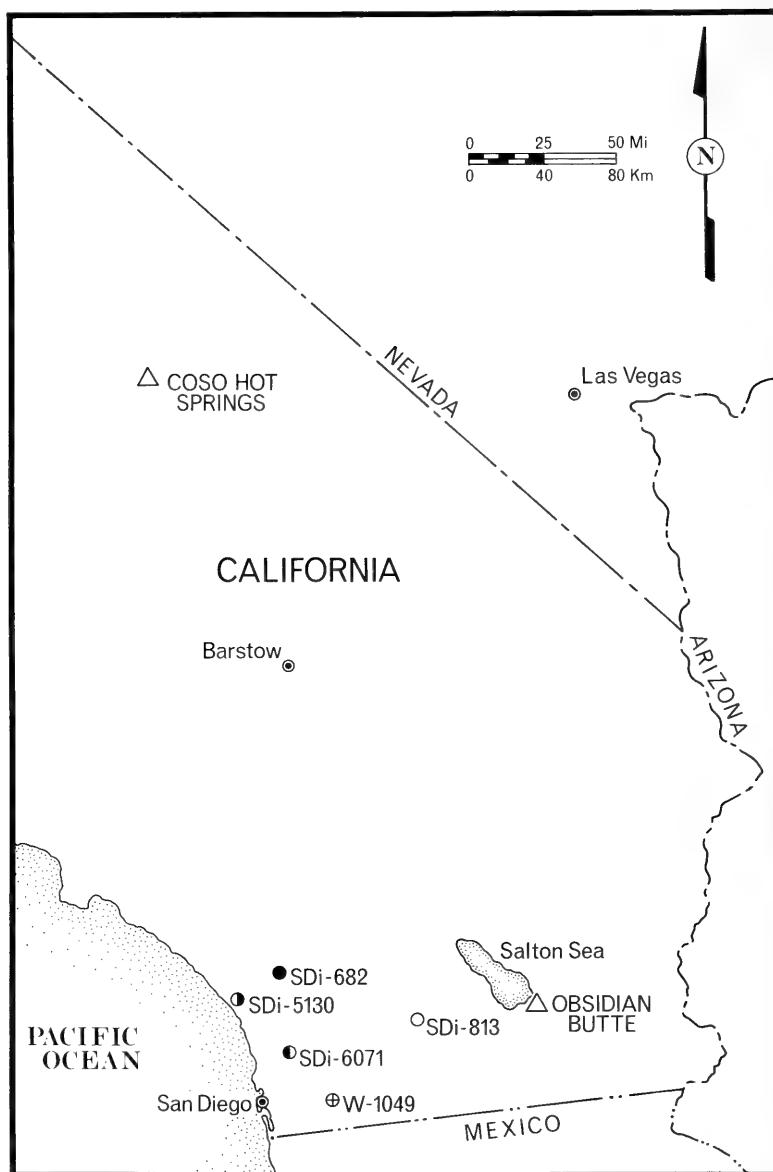
Fig. 1. Map of southern California showing the locations of obsidian sources utilized during prehistoric times (open triangles) and archaeological sites (filled dots) discussed in the text.

destructive quantitative analysis for the study of prehistoric obsidian trade in southern California.

The Setting

The presence of rhyolitic obsidian at Obsidian Butte has been known to geologists for some time (e.g., Rogers 1934; Kelley and Soske 1936). However, Obsidian Butte (Fig. 1) was first brought to the attention of the archaeological community by Treganza (1942:155, fn. 13) and Heizer and Treganza (1944:305), who

noted abundant evidence for its use during prehistoric times as a quarry source for obsidian tools. More than two decades later, Ericson et al. (1976:222) provided a more detailed description of the immediate geological context. Obsidian Butte is actually only one of four volcanoes (Obsidian Butte, Red Island, Rock Hill, and Mullet Island) in the vicinity of the Salton Buttes (see Robinson et al. 1976: fig. 2) where Quaternary volcanic activity produced rhyolitic obsidian and pumice. However, petrochemical analyses indicates no systematic elemental variation between these rhyolitic domes (Robinson, et al. 1976:354). K-Ar ages of ca. 16,000 B.P. (Muffler and White 1969:162) and 33,000 ± 35,000 B.P. (2 σ) (Friedman and Obradovich 1981:40–41) have been reported for Obsidian Butte obsidian.

Methods

To determine whether non-destructive analysis could yield quantitative elemental measurements comparable to those previously published using more time consuming, destructive techniques, analyses were conducted on a sample of 10 unmodified obsidian flakes collected from the southeast side of Obsidian Butte in T11S, R13E, NE ¼ of the NW ¼ of the SE ¼ of Section 32, as depicted on the USGS Obsidian Butte, Calif., 7.5' series quadrangle (1956). No special sample preparation was made, other than rinsing each specimen in distilled water to remove surface contaminants that might effect the analysis.

Laboratory analyses were conducted by the author at the Department of Geology and Geophysics, University of California, Berkeley, on a Spectrace 440 (United Scientific Corporation) energy dispersive x-ray fluorescence machine equipped with a 572 power supply (50 kV, 1 mA), 534-1 pulsed tube control, 588 bias/protection module, 514 pulse processor (amplifier), Tracor Northern 1221 100 mHz analog to digital converter, a Tracor Northern 2000 computer based analyzer with a LSI-11 microcomputer with 24k word capacity, and a Si(Li) solid state detector with 142 eV resolution (FWHM) at 5.9 keV in a 30 mm^2 area. Trace element analyses in the 5–25 keV region of the energy spectrum were conducted using a Rh x-ray tube operated at 30.0 kV, .40 mA pulsed with a .04 mm Rh primary beam filter, while analyses in the 20-60 keV region were conducted using an Am241 100 mCi radioisotope (see Hughes 1983a:fig. 2). All analyses were conducted at 200 seconds livetime. NI (Kα), Cu (Kα), Zn (Kα), Ga (Kα), Pb (Lβ), Th (Lα), Rb (Kα), Sr (Kα), Y (Kα), Zr (Kα), and Nb (Kα) analytical lines were excited by the Rh x-ray tube, while Ba (Kα), La (Kα), Ce (Kα), Pr (Kα), and Nd (Kα) lines were analyzed using the Am241 source. Following excitation, overlapping Kα, Kβ, and L-lines were stripped, yielding the "fingerprints" that appear in Figure 2 (cf. Hampel 1984). Background-subtracted net peak intensities were compared and ratioed to the Rh Kα peak continuum (Franzini et al. 1976), then converted to parts per million using a least squares polynomial fit routine (Schamber 1977; Bice 1980:421–422; Hughes 1983a:25–26).

Results

Most of the quantitative trace and rare earth elemental measurements generated from the present non-destructive study (Table 2) are in agreement with those derived from previous destructive analyses (Table 4), and with recommended values for U.S. Geological Survey international rock standards (Table 1). Pr, Cu,
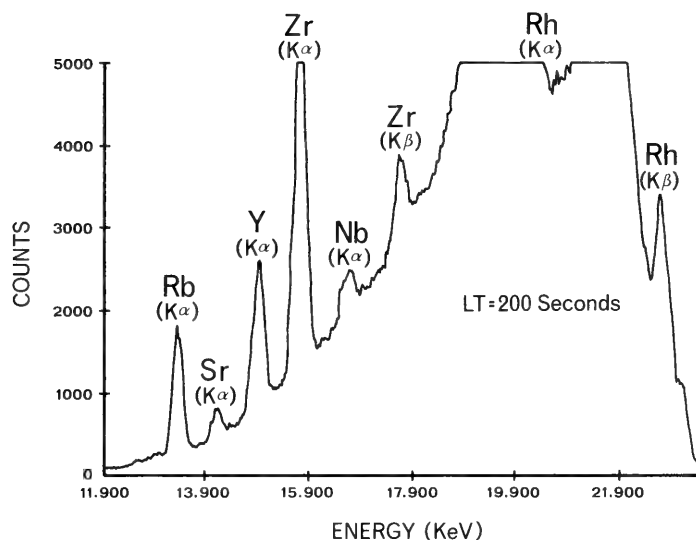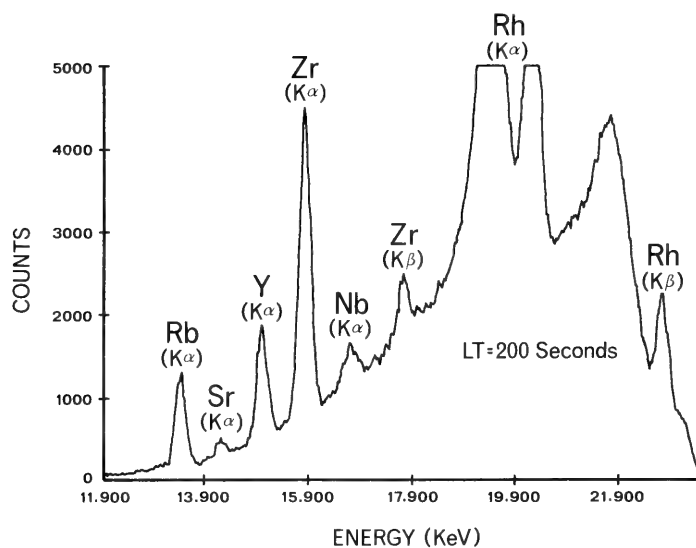
Fig. 2. Energy dispersive x-ray fluorescence "fingerprint" of Obsidian Butte volcanic glass. a) "fingerprint" of pressed powder sample OS-21 (see Table 4); b) "fingerprint" of unmodified obsidian flake sample OB-8 (see Table 2).

and Ni are not measured well by non-destructive x-ray fluorescence, because concentrations for these elements in obsidians often fall below the minimum limits of detection (Vane 1977) at 200 seconds livetime. Computation of coefficients of variation for sample means and standard deviations (Table 3) shows that these measurements vary widely across samples. Th, Nb, and Sr measure-

Table 1. X-ray fluorescence determinations for trace and rare earth element concentrations in three U.S. Geological Survey rock standards compared to recommended values. All values in parts per million. ± = counting error uncertainty (Schamber 1977:249).

U.S. Geological Survey standard	Elements							
	Th	Pb	Nd	Pr	Ce	La	Ba	Nb
W-1 (Flanagan 1976)	2.4	7.8	15.0	3.4	23.0	9.8	160.0	9.5
W-1 (this study)	0.0 ± 0.0	14.0 ± 3.2	15.8 ± 5.4	10.5 ± 5.2	22.8 ± 4.7	12.5 ± 4.1	156.3 ± 7.7	0.0 ± 0.0
GSP-1 (Flanagan 1976)	104.0	51.3	188.0	50.0	394.0	191.0	1300.0	29.9
GSP-1 (this study)	102.5 ± 5.8	52.9 ± 2.8	178.5 ± 11.2	52.8 ± 9.8	393.5 ± 12.5	175.1 ± 9.9	1256.3 ± 22.5	27.8 ± 2.3
G-2 (Flanagan, 1976)	24.2	31.2	60.0	19.0	150.0	96.0	1870.0	13.5
G-2 (this study)	28.2 ± 5.0	33.2 ± 2.6	65.9 ± 9.9	24.0 ± 9.7	149.4 ± 9.1	89.4 ± 8.2	1797.9 ± 28.2	20.9 ± 2.5

U.S. Geological Survey standard	Elements							
	Zr	Y	Sr	Rb	Ga	Zn	Cu	Ni
W-1 (Flanagan 1976)	105.0	25.0	190.0	21.0	16.0	86.0	110.0	76.0
W-1 (this study)	109.0 ± 5.4	22.3 ± 4.5	172.8 ± 6.3	23.8 ± 3.5	14.7 ± 2.8	87.5 ± 6.9	104.5 ± 6.9	69.7 ± 9.2
GSP-1 (Flanagan 1976)	500.0	30.4	233.0	254.0	22.0	98.0	33.3	12.5
GSP-1 (this study)	514.8 ± 5.1	29.4 ± 3.0	238.2 ± 3.9	263.5 ± 4.1	20.4 ± 2.6	95.1 ± 6.8	29.0 ± 2.8	6.8 ± 5.1
G-2 (Flanagan, 1976)	300.0	12.0	479.0	168.0	22.9	85.0	11.7	5.1
G-2 (this study)	309.2 ± 4.9	14.8 ± 3.1	471.5 ± 6.1	170.0 ± 4.0	19.0 ± 2.8	86.1 ± 6.5	5.5 ± 4.9	0.0 ± 0.0

Table 2. Trace element concentration values for 10 source standards from Obsidian Butte. All values in parts per million. ± = counting error uncertainty (Schamber 1977:249).

Element		OB-1	OB-2	OB-3	OB-4A	OB-5	OB-8	OB-13A	OB-14	OB-15A	OB-17
Th		11.6	16.9	18.5	20.3	27.3	20.5	15.3	9.6	16.9	22.7
		±4.9	±4.0	±4.2	±3.9	±4.3	±4.6	±4.8	±5.0	±4.4	±4.5
Pb		19.1	20.3	21.9	20.3	18.3	18.8	14.6	16.9	17.6	23.1
		±2.3	±1.9	±1.9	±1.8	±1.9	±2.0	±2.2	±2.4	±2.0	±2.1
Nd		60.3	56.7	60.7	52.1	59.0	59.4	58.6	70.7	49.1	40.4
		±6.4	±6.6	±5.6	±6.2	±7.2	±6.5	±9.8	±8.0	±7.1	±7.4
Pr		14.8	22.9	21.8	0.0	19.5	8.6	17.4	12.8	11.6	6.8
		±5.8	±5.9	±6.8	±0.0	±6.3	±5.7	±8.6	±6.9	±6.1	±6.7
Ce		103.9	125.8	98.4	112.0	121.3	134.8	113.2	125.8	119.0	107.9
		±5.8	±6.3	±6.7	±5.7	±7.0	±6.2	±8.9	±7.3	±6.7	±7.2
La		55.3	50.0	53.0	46.8	44.3	50.1	40.4	57.7	48.8	63.2
		±4.8	±5.1	±5.8	±4.7	±5.6	±5.0	±7.3	±6.0	±5.5	±5.8
Ba		529.4	454.2	550.9	454.4	443.4	439.6	588.5	516.0	452.1	403.2
		±10.8	±10.6	±13.6	±9.9	±11.7	±10.3	±17.4	±13.1	±11.6	±11.9
Nb		17.1	17.7	18.6	22.9	27.3	21.2	20.1	14.4	21.2	27.7
		±2.7	±2.3	±2.4	±2.2	±2.4	±2.6	±2.7	±2.7	±2.5	±2.5
Zr		294.8	277.4	354.0	326.2	313.3	284.1	343.8	256.5	272.6	301.5
		±5.1	±4.1	±4.6	±4.1	±4.3	±4.5	±5.2	±4.9	±4.4	±4.4
Y		87.5	105.8	95.2	112.0	120.2	111.5	87.6	78.5	107.3	124.2
		±4.1	±3.5	±3.5	±3.4	±3.7	±3.9	±4.0	±4.1	±3.8	±3.9
Sr		37.6	26.2	46.1	35.3	24.6	24.0	45.0	32.1	25.5	19.1
		±2.8	±2.1	±2.5	±2.1	±2.2	±2.4	±2.8	±4.8	±2.3	±2.3
Rb		121.4	129.4	123.0	136.2	151.5	135.2	121.0	111.9	123.7	144.0
		±3.8	±3.2	±3.3	±3.1	±3.4	±3.6	±3.7	±3.7	±3.5	±3.5
Ga		19.7	24.1	23.7	28.0	26.6	23.7	20.8	21.1	23.7	20.9
		±2.7	±2.8	±2.9	±2.6	±2.9	±2.7	±2.8	±3.3	±2.6	±2.7
Zn		55.9	57.5	47.2	55.1	58.6	58.2	62.0	50.3	49.8	63.9
		±4.9	±5.0	±4.9	±4.7	±5.2	±4.8	±5.1	±5.8	±4.7	±4.8
Cu		4.0	3.6	5.7	0.0	3.3	5.0	8.4	0.0	7.5	0.0
		±3.6	±3.6	±3.7	±0.0	±3.8	±3.3	±3.9	±0.0	±3.4	±0.0
Ni		0.0	20.7	8.5	0.0	10.3	0.0	0.0	0.0	0.0	0.0
		±0.0	±5.1	±5.2	±0.0	±5.2	±0.0	±0.0	±0.0	±0.0	±0.0

Table 3. Means ($\bar{X}$), standard deviations (S.D.) and coefficients of variation (CV %) for 16 trace and rare earth elements from Obsidian Butte. Means and standard deviations expressed in parts per million; computed from data in Table 2.

Element		Element		Element		Element	
Th	$\bar{X}$ 17.96	Pb	$\bar{X}$ 19.09	Nd	$\bar{X}$ 56.70	Pr	$\bar{X}$ 13.63
	S.D. 5.18		S.D. 2.47		S.D. 8.07		S.D. 7.19
	CV % 28.85		CV % 12.92		CV % 14.23		CV % 52.79
Ce	$\bar{X}$ 116.21	La	$\bar{X}$ 50.96	Ba	$\bar{X}$ 483.14	Nb	$\bar{X}$ 20.82
	S.D. 11.19		S.D. 6.65		S.D. 59.09		S.D. 4.27
	CV % 9.63		CV % 13.05		CV % 12.23		CV % 20.51
Zr	$\bar{X}$ 302.42	Y	$\bar{X}$ 102.98	Sr	$\bar{X}$ 31.55	Rb	$\bar{X}$ 129.73
	S.D. 31.75		S.D. 15.14		S.D. 9.24		S.D. 11.99
	CV % 10.50		CV % 14.70		CV % 29.29		CV % 9.24
Ga	$\bar{X}$ 23.23	Zn	$\bar{X}$ 55.85	Cu	$\bar{X}$ 3.75	Ni	$\bar{X}$ 3.95
	S.D. 2.66		S.D. 5.39		S.D. 3.05		S.D. 7.08
	CV % 11.45		CV % 9.65		CV % 81.24		CV % 179.14

Table 4.   Trace and rare earth element concentrations for obsidian (OS-21) and whole rock rhyolites from Obsidian Butte. Obsidian Butte and Red Island data from Robinson et al. (1976: table 2); n.m. = not measured; [a] = R. N. Jack, analyst. All values in parts per million.

Element	OS-21[a]	Obsidian Butte			Red Island	
		170-4A	W-772	170-26A	64CMp-107	170-21p
Th	26	n.m.	n.m.	n.m.	n.m.	n.m.
Pb	16	—	—	15	—	10
Nd	62	30	—	70	—	70
Pr	15	n.m.	n.m.	n.m.	n.m.	n.m.
Ce	132	150	—	100	—	150
La	72	70	70	70	30	100
Ba	467	300	700	500	700	500
Nb	31	30	20	20	15	30
Zr	324	300	300	300	300	300
Y	57	100	100	100	100	150
Sr	30	27	50	33	50	25
Rb	144	146	n.m.	137	n.m.	142
Ga	21	30	30	30	50	20
Zn	68	n.m.	n.m.	n.m.	n.m.	n.m.
Cu	6	3	7	7	10	7
Ni	20	n.m.	n.m.	n.m.	—	—
Co	36	—	—	1.5	—	—
Mn	431	n.m.	n.m.	n.m.	n.m.	n.m.
Ti	1074	n.m.	n.m.	n.m.	n.m.	n.m.

ments also are more variable than Pb, Nd, Ce, La, Ba, Zr, Y, Rb, Ga, and Zn, suggesting that they may not be as useful as those remaining elements in distinguishing between obsidian sources (see Hughes 1982:176). However, high "apparent" measurement error (relatively high CV% values) will be registered when the absolute concentration for an element approaches its minimum limits of detection, and when "true" intersource elemental variability exists. In short, it is important to recognize that both instrumental measurement limitations and inherent geochemical variability may be represented in CV% values.

Obsidian Butte trace element concentrations for Ce, Ba, Zr, Y, Sr, and Rb contrast with those for other southern California obsidians (Coso Hot Springs [Jack 1976:table 11.5; Bacon et al. 1981:table 3] Rustler Canyon, San Bernardino County) and Arroyo Matomi, Baja California. These differences between sources can be illustrated using a bivariate scatter diagram (Fig. 3).

In order to test whether the results of the Obsidian Butte analyses could profitably be applied to archaeological research, a sample of 52 obsidian artifacts from five archaeological sites in San Diego County was analyzed and the results were compared to the trace element profiles generated for the known sources in the southern California region (see Fig. 3). As Figure 3 shows, these data fall within the range of trace element concentrations for source specimens from southern California, showing that 39 artifacts match the profile of Obsidian Butte volcanic glass, while the remaining 13 derive from the Coso Hot Springs source. Although these artifacts make up only a part of a larger study of San Diego County obsidian trade (see Hughes and True 1985), they illustrate clearly the potential for employing non-destructive quantitative analyses in archaeological research.
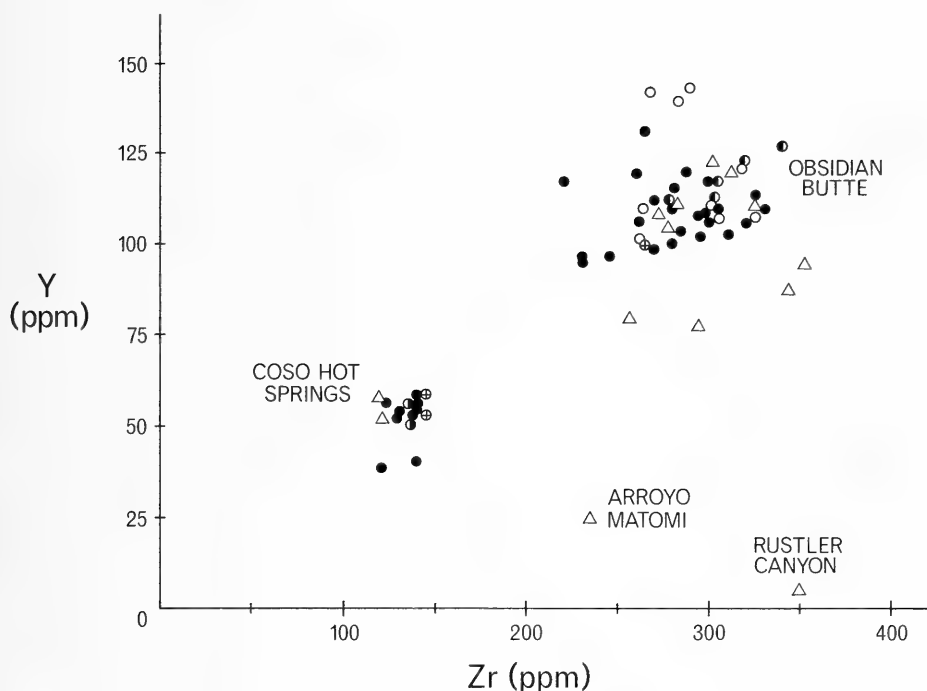
Fig. 3.   Scatter diagram of Y vs. Zr concentrations for obsidian source specimens (open triangles) from southern California and Baja California. Circles represent values for artifacts from archaeological sites SDi-682 (●); SDi-813 (○); SDi-5130 (◐); SDi-6071 (◌) and W-1049 (⊕). Obsidian Butte source standards plotted from data in Table 2; Rustler Canyon and Arroyo Matomi (Baja California) values determined by R. N. Jack using wavelength dispersive x-ray fluorescence.

More generally, the agreement between the present analysis and previous destructive work shows that non-destructive analyses can yield concentration estimates (in parts per million) suitable for use in interlaboratory comparisons. The advantages of reporting the results of archaeometric research in standard measurement units (e.g. weight percent or parts per million) have been recognized for some time (see Bieber et al. 1976); the results of the present study indicate that it is now possible to begin building a quantitative geochemical data base for obsidian source specimens and archaeological artifacts from southern California that can readily be used by researchers at other laboratories.

Acknowledgments

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A New Species of *Heptacarpus* from California, with a Redescription of *Heptacarpus palpator* (Owen) (Caridea: Hippolytidae)

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Abstract.—A new species of *Heptacarpus,* a small shrimp marked with brown dots, is described. It ranges from Santa Rosa Island, California to Guadalupe Island, Mexico. Related to *H. palpator* and *H. brevirostris,* it can be distinguished from them by having only one large distal spine on the first segment of the antennular peduncle, and often having a spine at the distal end of the carpus of the first pereopod. *Heptacarpus palpator* is redescribed and better distinguished from *H. brevirostris. Heptacarpus palpator* ranges from Monterey Bay, California to the south, while *H. brevirostris* usually lives north of Monterey Bay.

Members of the family Hippolytidae, often called broken-back shrimp, are common inhabitants of tidepools, kelp beds, and rocky subtidal bottoms along the coast of California and northern Mexico. *Heptacarpus palpator* (Owen) and *H. brevirostris* (Dana) have been reported often from shallow areas along the coast of California (Schmitt 1921; Johnson and Snook 1955; Ricketts et al. 1968; Carlton and Kuris 1975; Word and Charwat 1976; Chace and Abbott 1980). However, there are only two keys that distinguish between these two species, that given by Schmitt (1921) and the one prepared by Word and Charwat (1976). Both distinguish between the two species on the basis of the length of the antennal scale to that of the telson: equal to the telson or shorter in *H. brevirostris,* or longer than the telson in *H. palpator.*

I tried to use the proportions of the antennal scale to the telson in identifying specimens of *Heptacarpus* spp. from the coast of California. This proved to be unsatisfactory. In many specimens labelled *H. palpator,* the telson was about $0.85 \times$ the length of the antennal scale. To distinguish between the species, careful, time-consuming measurement with calipers was necessary. Schmitt (1921) noted the variability in the rostra of the two species, but made no mention of other parts of the body that might be useful in distinguishing between them.

The original descriptions of *H. palpator* and *H. brevirostris* are very short. The descriptions and illustrations given by Schmitt (1921, as *Spirontocaris palpator* and *S. brevirostris*), and Word and Charwat (1976) also are not extensive. However, Butler (1980) redescribed *H. brevirostris* in detail, with a clear illustration. I was unable to locate the holotype of *H. palpator* for comparison.

To determine for myself the differences between *H. palpator* and *H. brevirostris,* I examined all the specimens designated as these species in the collections of the Allan Hancock Foundation (AHF), University of Southern California, totalling over 200 specimens from 97 stations. I also studied all the specimens of *H. palpator*
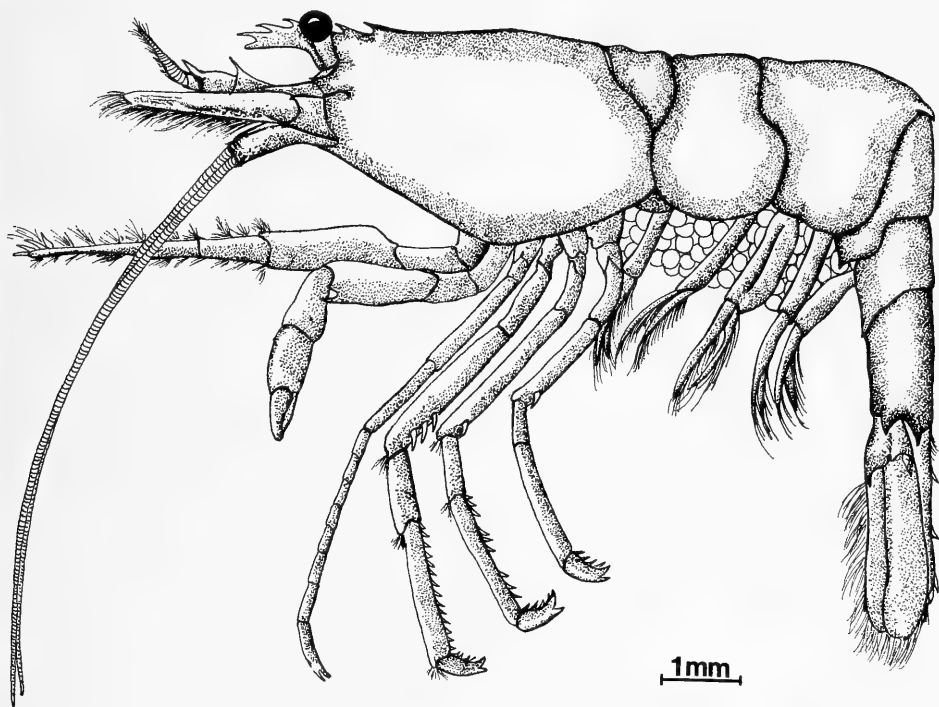
Fig. 1. *Heptacarpus fuscimaculatus.* Ovigerous female, total length in millimeters 14.9. Avalon Harbor, Santa Catalina Island, California; CAS Number 031713.

at the California Academy of Sciences (CAS) as well as specimens labelled *H. brevirostris* from south of San Francisco, a total of 32 specimens from 12 stations.

Comparison of all the specimens revealed differences between *H. palpator* and *H. brevirostris* in the rostrum, spines of the carapace, spines of the pereopods, and ranges in California. However, further examination of the series labelled *H. palpator* disclosed an undescribed species. The new species is described herein, and *H. palpator* is redescribed.

Heptacarpus fuscimaculatus new species
Figs. 1–2

Rostrum straight, with 1–3 (usually 2) spines on carapace and 2–3 spines on dorsal margin proper; 1 or no spines on lower surface. Tip single or bifid. In one specimen, second spine of carapace bifid. Rostrum slightly exceeding first segment of antennular peduncle.

Eyes shorter than rostrum, corneas round and pigmented.

Carapace with large antennal, prominent pterygostomial, and no branchiostegal spines.

Abdominal segments 1–3 rounded at margins. Faint notch of dorsal surface of second segment. Pleura of fourth segment rounded, each with marginal spine posterolaterally. Pleuron of fifth segment with prominent posterolateral spine. Sixth segment about 1.5 × length of fifth segment, with sharp spine on ventrolateral margin and on lateral margin at articulation with telson. Sixth segment slightly shorter than telson.
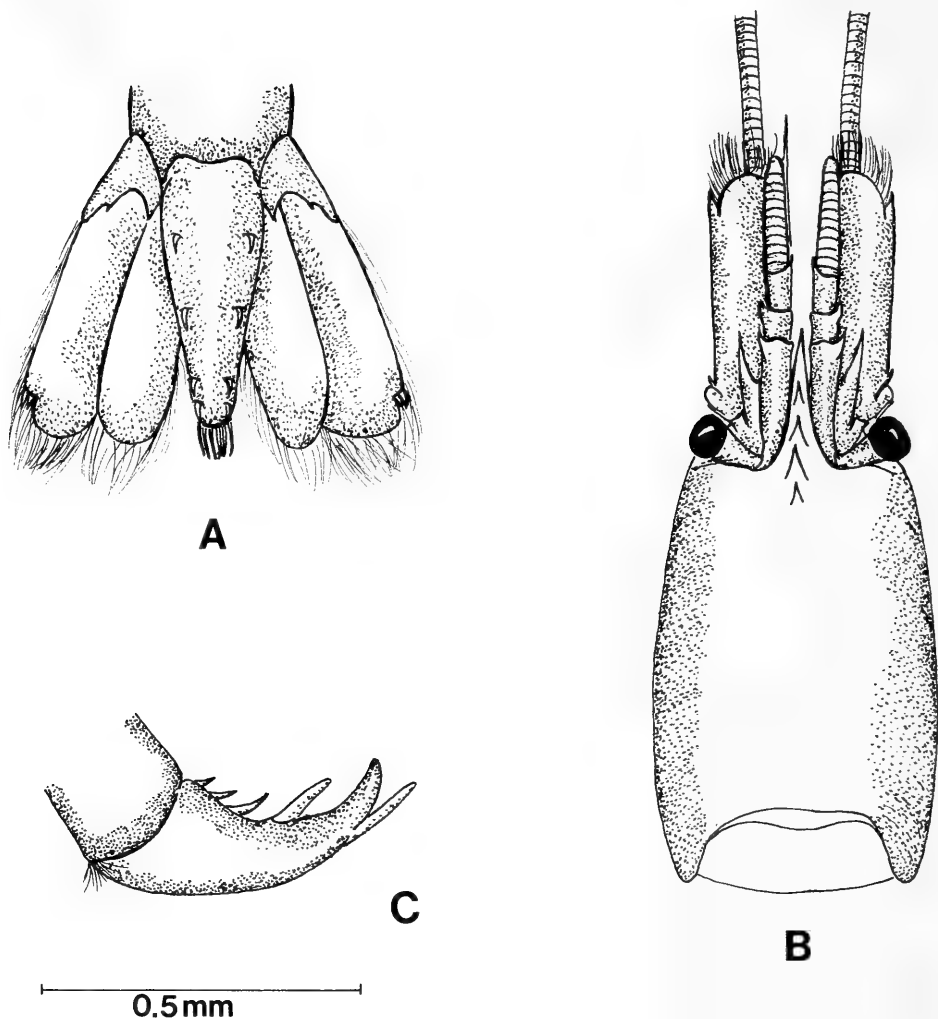
Fig. 2. *Heptacarpus fuscimaculatus.* A, telson and uropods; B, front in dorsal view; C, dactyl of third pereopod.

Telson shorter than uropods; with 3–5 pairs dorsolateral spines and 3 pairs terminal spines with straight setae.

First antenna with prominent, sharp-tipped stylocerite, reaching end of first segment of its peduncle. Latter with large, curved marginal spine, no spinules. Second segment about 0.33× length of first, with sharp terminal spine laterally. Third segment slightly shorter than second, with sharp terminal spine mesially. Inner flagellum stout, with about 12 segments and fringe of setae; outer slim, with at least 15 segments, but often broken during capture.

Second antenna with sharp lower spine on basicerite. Carpocerite about equal to second segment of antennular peduncle. Scaphocerite shorter than antennular flagella, 3× as long as broad; blade shorter than marginal spine, fringed with setae.

Mandible with palp. First maxilla with broad upper endite, small lower endite and bilobed palp. Second maxilla with small lower endite, bilobed upper endite,

well developed palp and scaphognathite. First maxilliped with exopod and bilobed epipod. Second maxilliped with exopod and podobranch. Third maxilliped with epipod, no exopod, longer than scaphocerite. Ultimate segment setose, ending in 3 sharp claws. Penultimate segment about 0.4× length of ultimate, setose. Antepenultimate segment about equal to ultimate, stout, with 2 sharp, stout setae at articulation with penultimate segment.

First pereopod stoutly chelate, with epipod. Dactyl curved, with tuft of setae near tip, about equal to palm of chela. Palm of chela about 0.7× as wide as long. Carpus about equal to length of palm of chela. Merus longer than palm of chela, usually with sharp spine or knob near articulation with carpus. Ischium about 0.4× length of merus.

Second pereopod chelate, with epipod. Palm of chela about 2× length of dactyl. Carpus with 7 segments, that nearest the propodus the longest. Merus about equal to 0.5× carpus, ischium longer than merus.

Third pereopod with epipod. Dactyl stout, about 0.4× as wide as long, with 4 spines. Tip bifid, claw on flexor margin stouter than that at extreme tip. Propodus with about 14 spinules, occurring singly or in pairs; 2.6× length of dactyl. Carpus short, about 0.5× length of propodus, broadly overlapping propodus on distal margin. Merus stout, about 5× as long as wide, with 2–3 large, sharp distolateral spines. Ischium shorter than merus, without spines.

Fourth pereopod without epipod, similar to third, but merus 7× as long as wide and with only 1 or 2 spines. Fifth pereopod without epipod, merus at most 1 spine.

Second pleopods with appendix interna in male, also with appendix masculina.

Uropods longer than telson, fringed with setae. Outer branch with 2 sharp marginal teeth.

HOLOTYPE: Female, total length in millimeters 12.0. Big Fisherman's Cove, Santa Catalina Island, California (33°27′N, 118°28′W), taken by dip net by night light, among low-growing algae on floating dock, 17 July 1982, water temperature 18°C, Mary K. Wicksten, AHF type number 821.

PARATYPES: California, U.S.A.: Becher's Bay, Santa Rosa Island (34°01′N, 120°02′W), 18 m, sand, 2 Aug. 1938, *Velero III* sta. 881-38, 1 specimen.—2.5 mi. E. of S. Pt., Santa Rosa Is. (33°53′45″N, 120°03′40″W–33°53′45″N, 120°03′40″W), 31–33 m, gravel and red algae, 10 April 1941, *Velero III* sta. 1282-41, 2 ovigerous females.—E. of Gull Is., S. of Santa Cruz Is. (33°57′15″N, 119°47′15″W–33°57′30″N, 119°48′05″W), 11–18 m, sand and algae, 31 Oct. 1940, *Velero III* sta. 1197-40, 10 specimens.—E. of Santa Barbara Island (33°29′N, 119°02′W), shoal to 74 m, sand, 12 Aug. 1938, *Velero III* sta. 895-38, 1 ovigerous female.—E. of Santa Barbara Is. (33°28′N, 119°00′W), 46–50 m, sand, 27 May 1938, *Velero III* sta. 975-39, 1 ovigerous female.—E. of Santa Barbara Is., 30 July 1919, *Anton Dohrn,* 2 specimens.—4 mi. E. of Landing, Santa Barbara Is. (33°28′40″N, 119°40′00″W–33°28′35″N, 119°30′00″W), 74 m, 28 Aug. 1941, *Velero III* sta. 1398-41, 1 ovigerous female.—Big Fisherman's Cove, Santa Catalina Island, 17 July 1982, Mary K. Wicksten, 2 specimens other than holotype, private collection of MKW.—Big Fisherman's Cove, Santa Catalina Island, among seaweed, 29 Sept. 1950, F. Ziesenhenne, 1 specimen.—Big Fisherman's Cove, Santa Catalina Island, on dock, 6 Aug. 1984, Mary K. Wicksten, 1 specimen, Catalina Mar. Sci. Center reference collection.—Off Howland's Landing, Santa Catalina
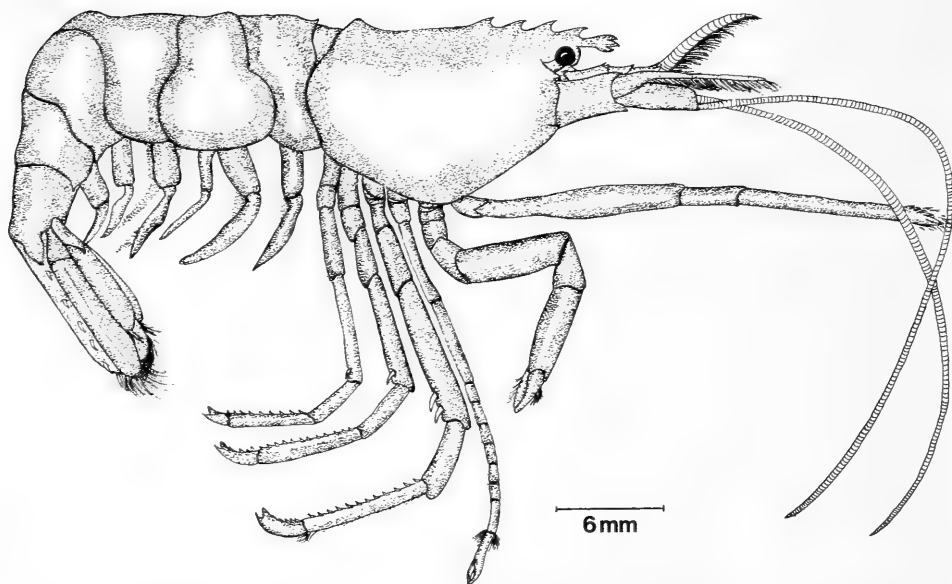
Fig. 3. *Heptacarpus palpator* (Owen). Female, total length in millimeters 44.2. Monterey Municipal Wharf, Monterey, California; CAS Number 034340.

Island (33°29′28″N, 118°33′30″N–33°29′45″N, 118°34′10″W), 240–295 m, mud, 10 Sept. 1940, *Velero III* sta. 1183-40, 1 specimen.—1 mi. NW of White Cove, Santa Catalina Island (33°24′20″N, 118°22′00″W), 4–6 m, among kelp holdfasts, 4 Aug. 1941, *Velero III* sta. 1378-41, 14 specimens.—1 mi. ESE of Willow Cove, Santa Catalina Island (33°22′50″N, 118°19′45″W–33°23′05″N, 118°21′10″W), 63–92 m, 13 Sept. 1941, *Velero III* sta. 1403-41, 1 specimen.—White's Cove, Santa Catalina Island (33°23′N, 118°22′W), 22–28 m, kelp holdfast, 17 Oct. 1948, *Velero IV* sta. 1621-48, 1 ovigerous female.—Avalon, Santa Catalina Island (33°20′45″N, 118°19′45″W), kelp holdfast, 20 Sept. 1938, G. S. Myers, R. L. Bolin and party, CAS, 1 ovigerous female.—BAJA CALIFORNIA, MEXICO: Melpomene Cove, Guadalupe Island (28°N, 118°W), 8 Dec. 1946, Carl Hubbs sta. H46-152, 1 specimen.—S. end of Melpomene Cove, Guadalupe Island, 74–83 m, boat *Orca,* sta. H50-42, 5 specimens. Except as noted, all specimens are in the collection of the Allan Hancock Foundation.

Size range.—8.5–15.5 mm in total length.

Remarks.—*Heptacarpus fuscimaculatus* is related to *H. palpator* and *H. brevirostris* in having epipods on the first three pereopods and having a rostrum shorter than the antennular peduncle. All three species have stout, spiny dactyls on the walking legs, rather than the simple, slender dactyls of *H. stimpsoni,* a species which also has epipods on the first three pereopods. Both *H. brevirostris* and *H. palpator* have spinules at the distal end of the first segment of the antennular peduncle; *H. fuscimaculatus* has only one spine. Neither of the other two species has a spine or tubercle at the end of the merus of the first pereopod. *Heptacarpus fuscimaculatus* often has three spines on the merus of the third pereopod, *H. palpator* usually has two and *H. brevirostris* often has only one. *Heptacarpus fuscimaculatus* usually is found on sandy bottoms or among algae off the islands
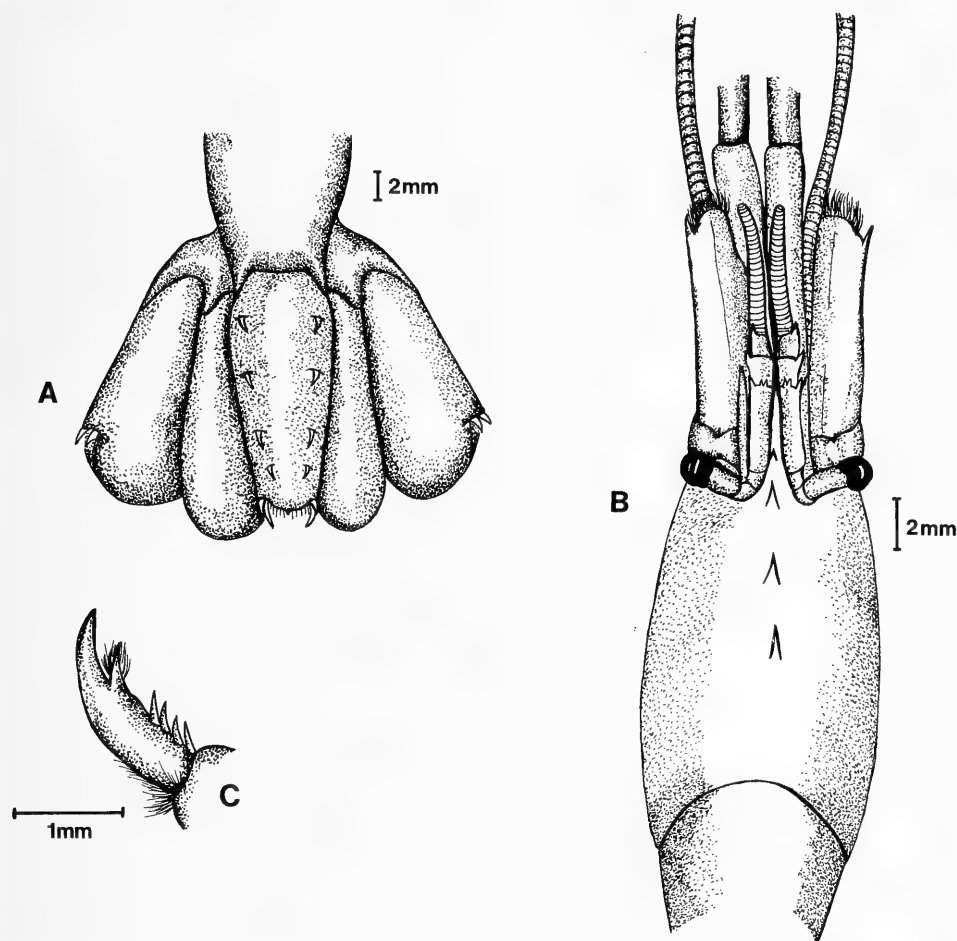
Fig. 4. *Heptacarpus palpator* (Owen). A, telson and uropods; B, front in dorsal view; C, dactyl of third pereopod.

of southern California and northwestern Mexico, rather than along the mainland coast. *Heptacarpus fuscimaculatus* also is usually smaller as an adult than either of the other two species.

All of the specimens that I collected at the type-locality, Big Fisherman's Cove, were clinging to algae on a floating dock after dark. The grass shrimp *Hippolyte clarki* Chace was taken at the same time. In life, three of the animals were translucent with brown spots formed by chromatophores. The species' name refers to these brown spots. The animal taken in 1984 was pale green. A color slide of a living *H. fuscimaculatus* has been deposited in the collection of the California Academy of Sciences.

Heptacarpus palpator (Owen)
Figs. 3–4

Hippolyte palpator Owen 1839:89, pl. 28, fig. 3.
Heptacarpus palpator: Holmes 1900:196, pl. 3, figs. 48, 49.—Holthuis 1947:12.—

Carlton and Kuris 1975:403, pl. 95, figs. 31A, 31B.—Word and Charwat 1976: 122.—Wicksten 1980:205.—Wicksten 1983:26.

Spirontocaris palpator: Rathbun 1904:98.—Schmitt 1921:65, fig. 43.—Ricketts, Calvin and Hedgpeth 1968:163, fig. 137.

Description.—Rostrum straight, variable in length: reaching at least to cornea, often to end of first segment of antennular peduncle or slightly beyond; with 2–3 dorsal spines on carapace and 2–4 dorsal spines on rostrum proper, and 0–2 lower rostral spines; tip usually bifid, sometimes trifid, occasionally single.

Carapace with prominent antennal spine. Pterygostomian spine small, absent in some individuals.

Abdominal segments 1–3 with rounded pleura. Slight dorsal notch in second segment. Third segment without dorsal carina. Pleura of segments 4–5 ending in small, sharp points. Sixth abdominal segment slightly longer than fifth, with 2 sharp lateral points. Telson shorter than uropods, with 4–5 pairs of dorsolateral spines, the most proximal ahead of middle of telson and set further away from other spines than the more distal spines are from each other. Apex of telson pointed, flanked by 5 pair small terminal spines and 1 pair longer spines.

Eyes prominent, cornea pigmented. Eyestalk convex along mesial surface.

First segment of antennular peduncle with 2–3 dorsal spinules and 1 lateral spine. Stylocerite exceeding first segment. Second segment about 0.3× length of first, with sharp lateral spine. Third segment about equal to second, with sharp dorsal spine. Outer flagellum stout, with dense brush of setae; inner flagellum whip-like.

Basicerite of second antenna with sharp ventrolateral spine. Carpocerite exceeding antennular peduncle. Scaphocerite longer than antennular peduncle. Blade of scaphocerite longer than lateral spine, broader proximally than distally, at most, about 2× as long as broad.

Mandible with slender incisor process ending in 4 teeth, with two-lobed palp. Molar process of mandible with numerous spinules. First maxilla with broad upper endite, small lower endite and bilobed palp. Second maxilla with small lower endite, bilobed upper endite, well developed palp and scaphognathite. First maxilliped with exopod and bilobed epipod. Second maxilliped with exopod and podobranch. Third maxilliped longest appendage of body. Inner branch about 2× length of carpace in male, 1.5× length of carapace in female; with epipod, no exopod. Ultimate segment witih 6 dark claws at tip, and with straight setae along its entire length. Penultimate segment about 0.3× length of ultimate, exceeding antennular peduncle. Antepenultimate segment about equal to ultimate, with fine setae.

First pereopod stout, chelate. Fingers of chela about 0.5× length of palm, tipped with tufts of setae. Palm 2× as long as wide. Carpus about as long as fingers of chela. Merus about equal to chela, with lateral row of stout setae. Ischium about 0.3× merus. Epipod present.

Second pereopod slender, chelate, with epipod. Fingers of chela about 0.4× length of palm, with tufts of setae at tip. Carpus with 7 segments, the first the longest. Merus 0.6× length of carpus. Ischium longer than merus.

Third pereopod stout. Dactyl with 2 stout terminal claws and 4 smaller spines, about 2× as long as wide. Propodus 2.5× length of dactyl, with row of small spines on flexor margin. Carpus about 0.5× length of propodus, overhanging
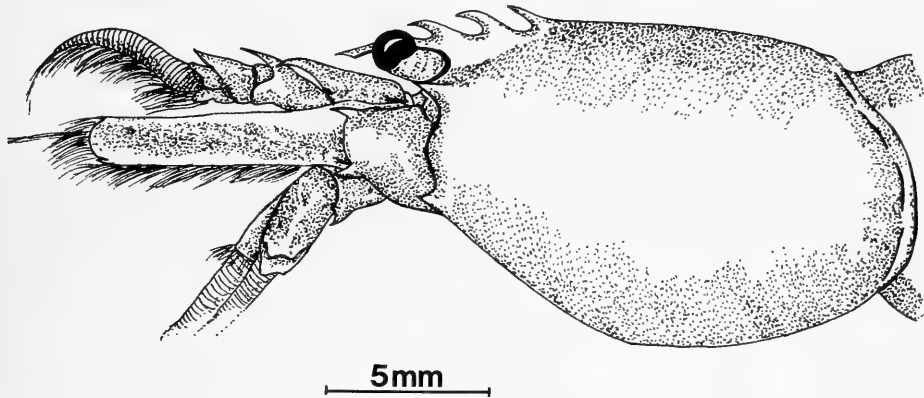
Fig. 5. *Heptacarpus brevirostris* (Dana). Male, total length in millimeters 42.4. North of Salmon Creek, Sonoma County, California; AHF sta. 1627-48. Left, dorsal view of front; right, lateral view of front.

propodus at articulation. Merus about equal to propodus, with usually 2 (rarely 1) sharp ventrolateral spines. Ischium about $0.5 \times$ length of merus.

Fourth and fifth pereopods similar to third, but more slender. One or two spines on merus of each. No epipods present.

Second pleopod with appendix interna; in male, also appendix masculina.

Uropods fringed with fine setae. Outer branch with 2 sharp lateral spines.

NEOTYPE: The original type specimen of *H. palpator* came from Monterey, California. Dr. A. A. Fincham, British Museum (Natural History) informed me that the type cannot be found. The following specimen therefore is designated as a neotype: female, total length in millimeters 38.6. Municipal Wharf, Monterey, Monterey Bay, California (36°37′N, 121°50′W), 8 m, hand net, 2 Feb. 1963, David Powell, CAS number 035671.

Remarks. — *Heptacarpus palpator* often has been confused by biologists with *H. brevirostris,* a very similar species (Fig. 5). Both are found in intertidal and shallow subtidal areas on hard bottoms, have rostra that do not reach the end of the second segment of the antennular penduncle, have stout dactyls on the walking legs with bifid tips, have similar patterns of spines on the carapace and antennae, and have epipods on the first three pereopods. To distinguish between the two species, a combination of features is useful. In *H. palpator,* the scaphocerite is slightly longer than the telson; in *H. brevirostris,* it is equal to or shorter than the telson. In *H. palpator,* the spines on the carapace behind the rostrum are not large relative to those on the rostrum proper; in *H. brevirostris,* the spines on the carapace form a descending series toward the rostrum. The spines on the carapace of *H. brevirostris* are larger than those of the rostrum proper. The rostrum of *H. palpator* often has a bifid or trifid tip, and often exceeds the cornea; in *H. brevirostris,* the tip usually is single and does not exceed the cornea. The meri of the third–fifth pereopods of *H. palpator* usually bear 2, 2, and 1 spines, respectively; in *H. brevirostris,* these meri bear no more than one spine. *Heptacarpus palpator* seems to be slightly smaller than *H. brevirostris:* the largest specimen recorded had a total length of 46.6 mm (Schmitt 1921), while Butler (1980) reported *H. brevirostris* up to a total length of 62 mm.

Heptacarpus palpator has been recorded from San Francisco, California to Bahía San Gabriel, Isla Espíritu Santo, Gulf of California (Wicksten 1983). *Heptacarpus brevirostris* has been reported from Attu, Aleutian Islands to San Francisco (Schmitt 1921; Butler 1980); to south of Carmel, California (Chace and Abbott 1980), and off Santa Catalina Island and Tanner Bank, California (Word and Charwat 1976). The northernmost specimens of *H. palpator* examined by me come from the type locality and nearby, near Monterey, California. The species occurs commonly in tidepools in San Luis Obispo County and along the mainland coast of southern California, from Santa Barbara to San Diego counties. It also occurs along the outer coast of Baja California, Mexico. It has not been collected often on the offshore islands of California and Mexico, but has been taken south of San Miguel Island (*Velero III* sta. 894-38), at Santa Rosa Island (*Velero III* sta. 995-39), Santa Cruz Island (sta. H47-89), Farnsworth Bank, off Santa Catalina Island (11–16 Dec. 1970, AHF collections); off Natividad Island, Baja California (*Velero IV* sta. 1706-49), and between Melpomene Cove and the inner island, Guadalupe Island, Mexico (*Velero IV* sta. 1912-49). There is only one record from the Gulf of California. The species probably rarely ranges south of Magdalena Bay, one of the most southerly areas of upwelling along the west coast of Baja California (Dawson 1951).

Heptacarpus brevirostris seems to prefer colder water than *H. palpator*. It is one of the most common intertidal shrimps along the coast of British Columbia (Butler 1980). The species has been collected often along the coasts of Washington and Oregon, U.S.A. I have observed it in tidepools in Humboldt County, California. It has been taken intertidally and in shallow subtidal waters off Mendocino County, near Bodega Head in Sonoma County, and along the coasts of San Mateo and northern Santa Cruz counties, California. I have been unable to examine the specimens on which Word and Charwat (1976) based their records from southern California.

Heptacarpus palpator often is found on wharf piles, among algae, and in tide pools at lower tide levels and in shallow subtidal areas. The deepest record known to me is 37 m (Santa Monica Bay, California, AHF collections). The color is variable in life, from translucent with brown lines to a uniform deep brown.

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Research Notes

Washingtonia robusta Naturalized in Southeastern California

The natural range of the Mexican fan palm, *Washingtonia robusta,* is limited to northwestern Mexico (McCurrach 1960) and the Baja Peninsula (Shreve and Wiggins 1964). However, in California its use as an ornamental is widespread and the species is the most frequently planted palm in the state (Sunset Editors 1979). It occasionally can be found in disturbed situations immediately adjacent landscaped areas and David Brown (pers. comm.) reports that it is frequently encountered along the Colorado River in Arizona and California. To date, it has not been recorded in undisturbed situations at seeps and springs.

In February 1982 and April 1984, the authors visited a seep in Whipple Wash, San Bernardino County, California, where a lone palm was found. The specimen was unburned, approximately 6.5 m in height and had a slender trunk 40 cm in diameter as measured 1.5 m from the ground. The trunk also flared outward at its base. The petioles were less than 1.2 m in length, formed a cross-hatched pattern around the trunk and hung at an angle. These are all characteristics unique to *W. robusta* as described by McCurrach (1960), Shreve and Wiggins (1964), and Wiggins (1980) and we have concluded that the individual does in fact belong to this species. The palm could have arrived as a seed from the community of Havasu Palms located 9 km down Whipple Wash at the Colorado River. *W. robusta* is an abundant ornamental in this small community and the distance is well within the dispersal potential of birds or the coyote, *Canis latrans* (Cornett 1984). *Cer-*

Fig. 1.   Location of naturalized specimens of *Washingtonia robusta* at undisturbed sites. The upper x designates the lone tree in Whipple Wash; the lower x designates the three individuals at Palm Spring in Anza-Borrego Desert State Park.

cidium floridum, Salazaria mexicana, and *Hyptis emoryi* were growing within 4 m of the palm indicating the site was undisturbed.

This palm was identified in 1975 as *W. filifera* by Brown et al. (1976). However, it probably would not have been of sufficient height at that time to observe the distinguishing characteristics.

On 3 May 1984 the senior author visited Palm Spring in Anza-Borrego Desert State Park. Within historic times, this spring had supported several of the desert fan palms, *W. filifera* (Edwards 1961). However, these were destroyed by early settlers and were gone by 1858. In the late 1950's park rangers attempted to restore the original plant associates of the spring by planting three palms. It had been widely assumed that these were palms of the species *W. filifera* (R. Bloomquist, pers. comm.). However, it has been concluded that these palms also belong to the species *W. robusta* as each of them possesses the characteristics previously described.

In the past three years we have visited over 95% of the palm oases in California, Arizona, and Baja California Norte and these are the only locations where we have found *W. robusta* occurring under relatively undisturbed conditions above latitude 32 degrees north.

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A Microcephalic Cranium from Catalina Island

In the process of transferring stored skeletal materials from the basement of the Catalina Island Museum located on the island of Catalina, a microcephalic skull was discovered among a number of other undocumented skeletal material. While its exact origins are not known, it is likely that the find was native to either the Island or adjacent mainland area. Given the relative rarity of microcephaly in the paleopathological record, the literature is sparse (Guerin 1853; Hrdlicka 1939; Ortner and Putschar 1981) in this area. The skull is virtually complete with only a few facial bones showing some destruction.

It is difficult to assign an exact biological age to this find because of the distortion of the usually reliable age-dependent skeletal markers. Arrested growth of the jaws resulted in the interference of normal tooth eruption which is a prime criterion for aging a subadult. A reasonable estimate is that the individual was between seven and nine years of age. Inasmuch as the individual was immature there is no way to assign a sex to it.

Seckel (1960) set forth several criteria for defining a true microcephalic. Among these are a very small cranium, a markedly receding forehead, projecting nasal bones yielding a "bird-headed" appearance, widely spaced orbits, underdevelopment of the attachment for the neck muscles, a high palate, receding chin etc.

Fig. 1.   Lateral View of the Catalina cranium illustrates the strongly receding frontal bone, which when combined with the elevated nasal structures would produce the "bird-headed" appearance. Bar is 5 cm.

Fig. 2.   Comparison with a normal ten year old skull. Note recession of the forehead and the entire face. Platycephaly, the restricted height of the cranial vault, is readily apparently.

Fig. 3.   Fusion of temporal and parietal bones. Bar is 5 cm.

Fig. 4.   Author's reconstruction of the Catalina cranium.

Employing these criteria, the Catalina cranium clearly demonstrated Seckel's syndrome. The circumference of the cranium is 32 cm measured fronto-occipitally with a cranial capacity of 382 cc employing mustard seed. These measurements are compatible with an approximately three-month postnatal normal child. The frontal bone is markedly receding indicating minimal frontal lobe development (Fig. 1). There is a noticeable keeling in the middle of the forehead. Because of both reduced cranial capacity and acute frontal angulation, the vault of the cranium is low. Comparison with a normal child approximately ten years old serves to emphasize the sharply restricted development of the cranial vault (Fig. 2).

Fusion of the cranial bones is limited to a bilateral obliteration of the suture between the squamosal bone and the parietal bone (Fig. 3). This likely occurred at an early age. With the exception of the anterior part of the sagittal suture and the inferior part of the coronal suture all other sutures are open.

Consistent with either diminutive size or nuchal muscle hypoplasia, the occipital nuchal lines are absent and evidence of strong muscle development is minimal. Because of the underdevelopment of the mandibular ascending ramus, the external auditory meatus is relatively low, which, in turn, would have set the ears in a low position on the head, a feature seen in those with Seckel's Syndrome.

The elevated and projecting nasal bones and the nasal portion of the maxillary bones provide the face with what must have been a very prominent nose in life. In conjunction with the receding forehead, there was likely a well-marked "bird-headed" appearance (Fig. 4). Given the projecting nasal architecture, the orbits are thrown into a slightly lateral position. They also appear relatively large but this is a function of the general hypoplasia of the face (Lim et al. 1973). A relatively

wide distance between the eyes, hypertelorism, an occasional condition of this genetic defect is not observed in this specimen.

The palatal portion of the maxillary bone is noticeably arched with the crowded anterior teeth distorting the dental arch. On both the erupted and unerupted anterior secondary teeth in both jaws there is moderate to marked absence of enamel. This is not observed on the primary dentition or what there is left of them.

The mandible retains both the infantile oblique angle between the horizontal and vertical portion of the jaw as well as the underdevelopment of these elements yielding a slightly micrognathic appearance. Chin recession, noted in all instances of Seckel's Syndrome, is not a conspicuous feature on the Catalina cranium; when reconstructed with soft tissue, however the individual would have had a receding chin.

Given all of the above aberrant osteological features, the Catalina cranium qualifies as a valid example of the rare Seckel's Syndrome which Majewski et al. (1982) believe to be an autosomal recessive condition. Only 17 valid cases of this disease appear in the clinical record.

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First Record of the Dolphin *Steno bredanensis* from the Gulf of California

The cetacean fauna of the Gulf of California, Mexico is quite rich and diverse, but is poorly documented in the literature (Wells et al. 1981). This account is the first recorded occurrence of the rough-toothed dolphin (*Steno bredanensis*) from this body of water. Records of *Steno bredanensis* from the tropical and eastern North Pacific include a few strandings in California, U.S. (Orr 1951; R. Brownell and C. Woodhouse pers. comm.), the Galapagos Archipelago (Orr 1965), and incidental catches in tuna purse-seine nets in the eastern tropical Pacific (Perrin and Walker 1975).

The present specimen was a stranded animal found during an ichthyological collecting trip in the northern Gulf region. The specimen was located above the mean high tide mark approximately 1 km south of the town of El Golfo de Santa Clara, Sonora, Mexico (31°40′N, 114°31′W) on 28 May 1984. The specimen

Fig. 1.   The dolphin *Steno bredanensis* from the Gulf of California.

consisted of a nearly intact rotten carcass which was missing an estimated 15 cm of the tail including the entire flukes. Judging by the condition of the animal and the prevailing climate, I estimated the animal had been dead between one and two weeks. Species identification was based on the following diagnostic characters: 1) in profile, the melon sloped gradually onto the long rostrum (Fig. 1), and 2) the teeth bore numerous fine vertical ridges (Leatherwood et al. 1982). In addition, there was a slight hint of lightly pigmented oval and round patches on the body, especially on the ventral surface, which is typical for adult specimens of *Steno*. The following straight line body measurements, in centimeters, were taken : total length 300 (+15 est.), rostrum to tip of dorsal fin 172, dorsal fin height 19, dorsal fin length at base 33, rostrum to anterior insertion of flipper 57, anterior insertion of flipper to flipper tip 47, axilla to flipper tip 31, rostrum to eye 36, and gape 28.

Due to lack of proper permits, the specimen was not collected but photographs were taken as voucher material (Fig. 1). I wish to thank C. B. Crabtree (UCLA) for assistance in the data collection and for sponsoring the collecting trip.

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The Academy's 1986 Annual Meeting will be held Friday and Saturday, May 2 and 3, at California State University, San Bernardino. In conjunction with it, the Southern California Ocean Studies Consortium and scientists from the Universidad Autonoma de Baja, California Sur, will be presenting their sixth annual U.S.-Mexico Marine Symposium; and the Desert Studies Consortium of California State Universities will be presenting a two-day symposium on Desert Ecology. Southern California Botanists and the American Cetacean Society are also participating in this year's meeting.

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Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus*. J. Mamm., 54:452–458.

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COVER: Desert fan palms, *Washingtonia filifera,* at Mopah Springs in the Turtle Mountains, San Bernardino County, California. Photograph by James W. Cornett, Palm Springs Desert Museum.