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Invertebrates

Franciscan Brine Shrimp

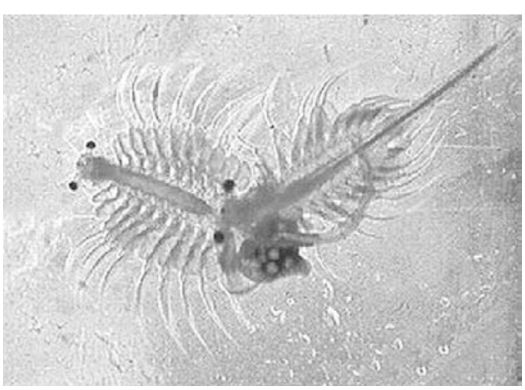
Artemia franciscana Kellogg

Brita C. Larsson

General Information

The Franciscan brine shrimp, *Artemia franciscana* (formerly *salina*) (Bowen et al. 1985, Bowen and Sterling 1978, Barigozzi 1974), is a small crustacean found in highly saline ponds, lakes or sloughs that belong to the order Anostraca (Eng et al. 1990, Pennak 1989). They are characterized by stalked compound eyes, an elongate body, and no carapace. They have 11 pairs of swimming legs and the second antennae are uniramous, greatly enlarged and used as a clasping organ in males. The average length is 10 mm (Pennak 1989). Brine shrimp commonly swim with their ventral side upward. *A. franciscana* lives in hypersaline water (70 to 200 ppt) (Maiss and Harding-Smith 1992).

In the Bay area, the optimum temperature for *A. franciscana* is 21-31°C. In the winter, when temperatures fall below this range, brine shrimp populations decline and their growth becomes stunted (Maiss and Harding-Smith 1992). Other environmental factors such as wind, salinity, and the quantity and quality of phytoplankton may also affect Bay area populations of *A. franciscana* and their effects on this species are currently being investigated (Maiss and Harding-Smith 1992).



Reproduction, Growth, and Development

Artemia franciscana has two types of reproduction, ovoviviparous and oviparous. In ovoviviparous reproduction, the fertilized eggs in a female can develop into free-swimming nauplii, which are set free by the mother. In oviparous reproduction, however, the eggs, when reaching the gastrula stage, become surrounded by a thick shell and are deposited as cysts, which are in diapause (Sorgeloos 1980). In the Bay area, cysts production is generally highest during the fall and winter, when conditions for *Artemia* development are less favorable. The cysts may persist for decades in a suspended state. Under natural conditions, the lifespan of *Artemia* is from 50 to 70 days. In the lab, females produced an average of 10 broods, but the average under natural conditions may be closer to 3-4 broods, although this has not been confirmed. Each brood contains from 30 to 100 offspring which mature in 10-25 days (Maiss and Harding-Smith 1992). The larva grows and differentiates through approximately 15 molts (Sorgeloos 1980).

Food and Feeding

Artemia franciscana feed on phytoplankton and blue-green algae that occur in Bay area salt ponds (Maiss and Harding-Smith 1992).

Distribution

Artemia franciscana occurs in highly saline waters throughout western North America, Mexico, and in the Caribbean (Bowen et al. 1985). In California, *A. franciscana* occurs from sea level to 1,495m and in many parts of the state, but its distribution is spotty because of this species salinity requirements (Eng et al. 1990). Historically in the Bay area they were found in salt pannes and sloughs were hypersaline conditions occurred. Currently they occur in salt ponds in the northern and southern portion of San Francisco Bay that are used for the commercial production of salt. Salt ponds cover approximately 111 km and in the North bay 36 Km off the Bay's shoreline (Lonzarich 1989). The distribution of *Artemia* in these salt ponds is limited by the salinity of the ponds. The optimum salinity range for *Artemia* is 70 ppt to 175 ppt (Carpelan 1957). They do not occur where the salinity is above 200 ppt.

Population Status and Influencing Factors

Commercial salt production in San Francisco Bay is currently an active industry, so habitat for *A. franciscana* is not limited and populations are large due to ample amounts of habitat. Donaldson et al. (1992) sampled a 496 acre salt pond in the San Francisco Bay National Wildlife Refuge and estimated the highest winter adult population at 40 billion and the lowest winter population at 4.5 billion. Brine shrimp populations are lowest in the winter and peak in the summer months when their optimal temperatures occur so these numbers are conservative for a maximum population value for the pond. Current populations of the brine shrimp probably far exceed historic populations because the salt ponds in which they occur are manmade. Salt ponds occurred naturally and there is even some evidence that the Ohlone Indians manipulated a portion of the Bay shoreline for salt production but never was there as much salt pond habitat for brine shrimp as currently occurs in the Bay area.

Trophic Level

Artemia franciscana is a primary consumer.

Proximal Species

Anderson (1970) lists sightings of 55 bird species using salt ponds in San Francisco Bay. Mallards, California gulls, whimbrels, Wilson's phalarope, eared grebes and American avocets are several species which feed on *A. franciscana*. Western and least sand pipers, willets, greater yellow legs and Bonaparte's gulls are commonly seen roosting and feeding in the salt pond environment and most likely feed on *Artemia* in these ponds (Maiss and Harding-Smith 1992).

Good Habitat

Brine shrimp occur in salt ponds adjacent to San Francisco Bay that have salinities ranging from 70 to 200 ppt but are most common when the range is between 90 and 150 ppt (Maiss and Harding-Smith 1992). Harvey et al. (1988) reported that up to 46% of the 23,465 acres of active salt ponds in South Bay are within the 70-200 ppt salinity range in the summer and contain brine shrimp.

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California Vernal Pool Tadpole Shrimp

Lepidurus packardi Simon

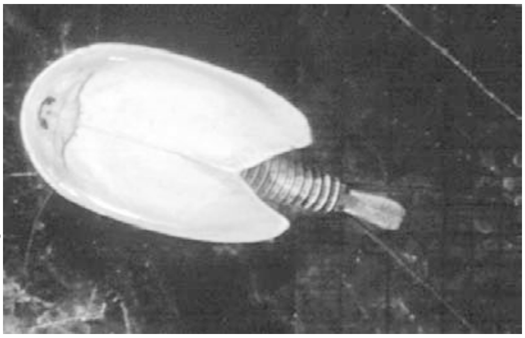
Brita C. Larsson

General Information

The California vernal pool tadpole shrimp is a small crustacean found in ephemeral freshwater pools that belong to the order Notostraca. They are characterized by sessile compound eyes, a shield-like carapace covering the head and much of the trunk, and a telson that is a flat and paddle-shaped protuberance. They can reach a length of 50 mm and have approximately 35 pairs of legs and two long cercopods (Pennak 1989). Tadpole shrimp are primarily benthic organisms that swim with their legs down. They can also climb or scramble over objects and plow through bottom sediments (Federal Register 1994). Information about the biology of this species is limited and incomplete (Ahl 1991).

Reproduction, Growth, and Development

Much of what is known about the reproduction, growth, and development of *L. packardi* comes from studies by Ahl (1991) and Longhurst (1955). Their life history is dependent on ephemeral freshwater pools. In California, vernal pools are generally hydrated during the rainy season, which extends from winter to early spring. Populations of tadpole shrimp are reestablished from diapaused eggs when winter rains rehydrate vernal pools. Once a pool rehydrates, the eggs hatch over a three week period, some hatching within the first four days. It takes another three to four weeks for the tadpole shrimp to become sexually reproductive. Populations consist of both males and females, though late in the season, pools are often dominated by males. After copulation, fertilized eggs descend into the foot capsule of the female (Desportes and Andrieux 1944). The eggs are sticky and when they are deposited they adhere to plant matter and sediment particles (Federal Register 1994). A female can have up to six clutches of eggs, totaling about 861 eggs during her lifetime (Ahl 1991). Depending on the depth and persistence of water in a pool, some eggs hatch immediately. The remainder inter diapause and lie dormant in the sediment during the dry portion of the year (Ahl 1991).



Dr. J.L. King

Food and Feeding

Tadpole shrimp feed on organic detritus and living organisms such as fairy shrimp and other invertebrates (Pennak 1989, Fryer 1987).

Distribution

L. packardi is endemic to vernal pools in the Central Valley, coast ranges and a limited number of sites in the Transverse Range and Santa Rosa Plateau (Federal Register 1994). The distribution of this species is not well known for the Bay area. Recently, *L. packardi* was collected at the Warm Springs Seasonal Wetland which is a part of the Don Edwards San Francisco Bay National Wildlife Refuge (Caires et al 1993). Other populations have been found north of the eastern half of Potrero Hills in the North Bay (S. Forman, Pers. obs.). Seasonal wetlands occur sporadically in both the North and South Bay and may provide additional habitat for this species. Surveys in seasonal wetlands surrounding San Francisco Bay may contribute and increase information on the distribution of this species.

Population Status and Influencing Factors

Current status of the population of tadpole shrimp in the Bay area is not known. Loss of seasonal wetland habitat in the Bay area may be significantly affecting the population of this species especially since distribution information for the Bay area is so limited.

Trophic Level

Lepidurus packardi is most likely a secondary consumer.

Proximal Species

Waterfowl, western spadefoot toad, and tadpoles.

Good Habitat

Lepidurus packardi inhabits vernal pools. They have been found in pools ranging in size from 5 square meters to 36 hectares. The water in the pools can be clear to turbid. The pools often have low conductivity, TDS, and alkalinity (Federal Register 1994, Eng et al. 1990). The pools dry up in the late spring and are dry in the summer and fall then fill with rain water in the winter and early spring. Vernal pool formations occur in grass bottomed swales of grasslands in old alluvial soils, underlain by hardpan or in mud bottomed pools (Federal Register 1994). Pools with cobblely hardpan bottoms also serve as habitat (Gallagher 1996). Gallagher (1996) found that the depth, volume, and duration of inundation of a pool was important for the presence of *L. packardi* in vernal pools when compared to the needs of other branchiopods. He found *L. packardi* did not reappear in ponds that dried and rehydrated during the study period, while other Branchiopod species did. *L. packardi* needs deeper and longer-lasting pools if they are to persist over a rainy season in which both wet and dry periods occur. Temperature variation in pools where *L. packardi* have been found to vary from 3 to 23°C (Gallagher 1996). Salinity, conductivity, dissolved solids, and pH of the water in vernal pools are also important in determining the distribution of tadpole shrimp (Federal Register 1994).

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Reticulate Water Boatman

Trichocorixa reticulata Guerin

Wesley A. Maffei

Description and Systematic Position

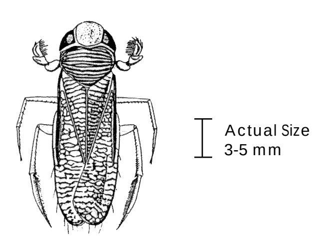
Trichocorixa reticulata is a small hemipteran, approximately 3-5mm in length, that belongs to the family Corixidae. This insect, also known as the salt marsh water boatman, can be recognized by the fine network of lines on its hemelytra (outer wing covers), the 10-11 dark transverse bands on the pronotum, and the pala of front legs not exceeding two-thirds the width of an eye along the ventral margin (**Figure 3.1**).

Distribution

Sailer (1948) states that this insect is found along the Pacific Coast from northern San Francisco Bay south to Peru. Populations from Kansas, New Mexico, Texas, Florida, and the Hawaiian Islands have also been recorded. One isolated record was reported in China but this has been unconfirmed. Within the San Francisco Bay environs this water boatman can be found in mid to upper marsh tidal pools and man-made salt ponds. **Figure 3.2** shows the locations around the Bay Area where *T. reticulata* have been collected, and **Table 3.1** shows the collection dates.

Suitable Habitat

T. reticulata prefers saline environments. Cox (1969) found this insect in southern California coastal salt ponds with salinities ranging from brackish up to 160 ‰ and Jang (1977) states that this water boatman can occur in ponds with salinities up to 170 ‰. Carpelan (1957) found the Alviso population in Cargill salt ponds that ranged from 23 ‰ up to 153 ‰. In all instances it was found that the greatest numbers of individuals and the most reproduction occurred in saline environments with a salinity range of 35-80 ‰.



Wes Maffei

Figure 3.1 Reticulate Water Boatman – *Trichocorixa reticulata*

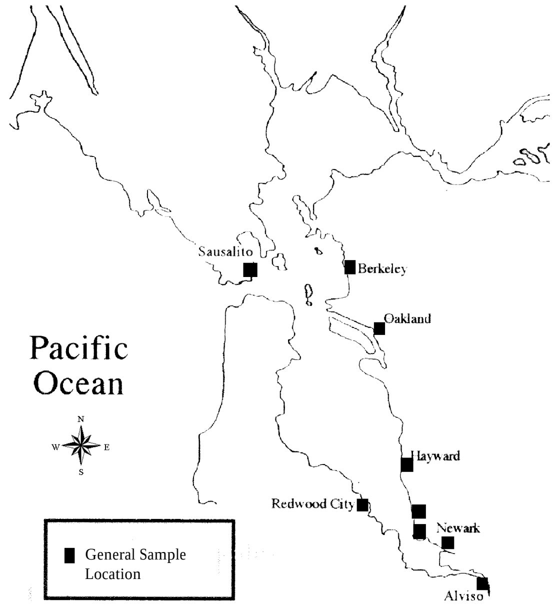


Figure 3.2 Known *Trichocorixa reticulata* Localities Within San Francisco Bay Tidal and Diked Marshes

Table 3.1 Known Collection Sites For *Trichocorixa reticulata* [1]

Location	Date Specimen(s) Collected
Sausalito	29 Oct 1921
Redwood City	15 Jun 1922, 24 Apr 1923, 8 May 1923
Berkeley	18 Apr 1962
Oakland	14 Apr 1930
Baumberg Tract, Hayward	8 Oct 1989
Coyote Hills Park	25 Oct 1988, 11 May 1989
Mowry Slough	25 Sep 1997
Alviso (Coyote Creek)	12 Aug 1980

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, University of California Berkeley Essig Museum, University of California Bohart Museum, San Jose State University Edwards Museum, San Mateo County Mosquito Abatement District Insect Collection, and private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

Biology

Sailer (1942) believes that all species of *Trichocorixa* over winter as adults. Scudder (1976) states that Tones (unpub.) has found that in Saskatchewan, *Trichocorixa verticalis interiores* over winters in the egg stage.

Eggs are laid singly on submerged vegetation or objects on the bottom substrate. Developmental time for eggs and immatures can very considerably with temperature.

Adult water boatman are both herbivorous and predatory feeding on algal cells and various microorganisms. Although Corixids are aquatic in all life stages, the adults are capable of leaving the water and dispersing by flight. Maffei (unpub.) has noted that south San Francisco Bay populations are attracted to dark colored objects, with adults landing in large numbers on the hoods of green or burgundy colored vehicles while adjacent white vehicles had few if any specimens.

Reproduction

Cox (1969) and Carpelan (1957) have noted that peak reproduction occurs in saline environments with salinities ranging between 35 ‰ and almost 80 ‰. Egg laying is continuous during spring, summer and fall with the greatest number of nymphs occurring during April and May. Cox (1969) has also found that crowding of adults led to increased egg production in females.

Balling and Resh (1984) have reported, that the number of generations per year for the Petaluma Marsh population was at least in part dependent on the longevity of the tidal ponds. They found that ponds which dried during late summer contained over wintering, non-reproducing adults while water filled ponds would produce another generation. Reproduction does occur year-round but Cox (1969) states that salinity and adult densities influence the number of eggs laid and the maturation rates of the immature stages. Balling and Resh (1984) noted that the time between generations of the Petaluma Marsh population was also affected by variable egg development times, variable instar development rates, and inter-pond differences in recruitment of adults. In general, it has been determined that environmental conditions can cause water boatmen to either accelerate or delay their development and production of subsequent generations.

Significance to Other Wetlands Taxa

This insect is considered an important prey item for shore birds. Howard (1983) studied the esophageal contents of 35 Ruddy Ducks, *Oxyura jamaicensis*, at the Alviso salt ponds and found that this water boatman comprised 12.6% of the total food volume. Howard also examined the gizzard contents of 53 Ruddy Ducks and found that 25.5% of the total food volume was water boatmen. Anderson (1970) analyzed the stomach contents of 10 Ruddy Ducks and found that water boatman, snails and Widgeon grass seeds were the primary components of their diet. He also found Least Sandpipers, Wilson's Phalarope and Northern Phalarope's utilized this insect as part of their diets.

Conservation Needs and Limiting Factors

Salinity and the length of time tidal marsh ponds contain water seem to be the primary driving forces affecting both developmental rates and reproduction.

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Invertebrates

Tiger Beetles

Cicindela senilis senilis, C. oregona,
and *C. haemorrhagica*

Wesley A. Maffei

Description and Systematic Position

Cicindela senilis senilis, *C. oregona*, and *C. haemorrhagica* are moderate sized beetles, approximately 10-15mm in length, that belong to the family Cicindelidae (F**igure 3.3**). These beetles, also known as tiger beetles, can be easily identified by their large, bulging eyes and long, sickle-shaped mandibles that bear small teeth. Adults of *C. senilis* and *C. oregona* are usually shining metallic blue to green on the ventral surface with the dorsum dull coppery brown and bearing small yellowish-white irregular markings. *Cicindela haemorrhagica* is similar in appearance to both *C. senilis* and *C. oregona* except that the ventral surface of the abdomen is usually bright red. The larvae are S-shaped, yellowish-white, have the head and the first thoracic segment flattened, an enlarged hump on the fifth abdominal segment with hooks, and large mandibles that are similar to the adults.

Distribution

Historically the San Francisco Estuary, including the beaches just outside of the Golden Gate Bridge, was home to four species of tiger beetles. These were: *Cicindela haemorrhagica, C. hirticollis, C. oregona oregona* and *C. senilis senilis.* Only two species, *C. haemorrhagica* and *C. senilis senilis* are present today with *C. haemorrhagica* in decline within or near the tidal areas of the San Francisco Bay Estuary. *Cicindela oregona oregona* may still be present within the estuary but the last known population was destroyed in 1996.

The dominant tiger beetle, *C. senilis senilis,* is currently found throughout the south and central portions of the estuary with one population having been identified from Grizzly Island in 1991. Museum records in-

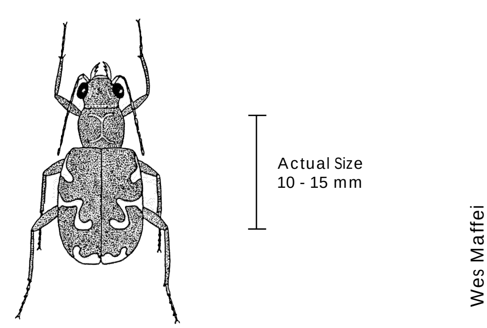

Figure 3.3 Tiger Beetle – *Cicindela senilis senilis*

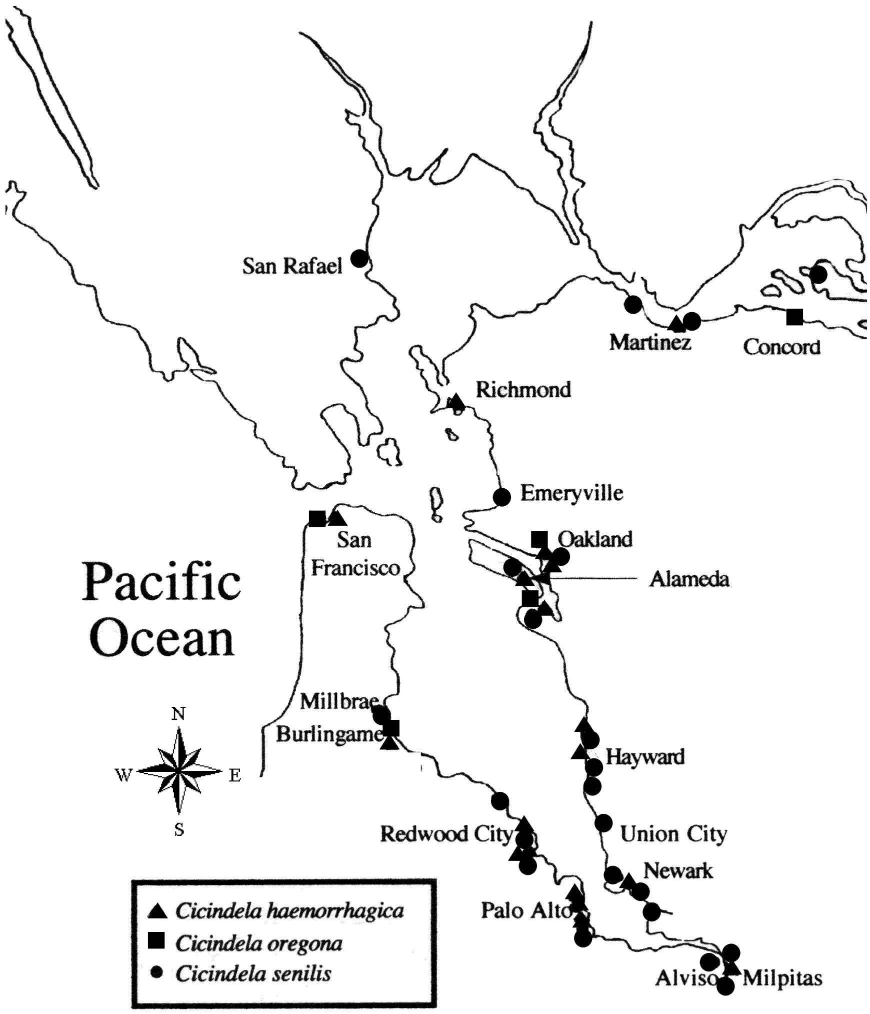

Figure 3.4 Known Tiger Beetle Localities Within San Francisco Bay Tidal and Diked Marshes

dicate that this beetle was also found in San Rafael, Martinez and Port Costa but these sites have not been sampled in over 40 years. *C. haemorrhagica*, has become increasingly scarce as its habitat continues to be altered for human needs. This beetle is currently found at Trojan Marsh (San Leandro), Hayward Landing (Hayward), Salt Ponds west of Newark and the Richmond Field Station (Richmond). Historically this beetle had a broader distribution with sites as far north as Martinez and south throughout most of the south San Francisco Bay. The populations at Alameda, Bayfarm Island and Oakland no longer exist and other sites identified from museum records have apparently not been sampled in at least three or more decades (Maffei, unpub.). *C. oregona* is probably no longer present within the tidal and diked marshes of the San Francisco Bay. The last known population was at Bayfarm Island and was extirpated in 1996 when the site was graded in preparation for development. **Figure 3.4** shows the locations around the Bay Area where *C. senilis senilis*, *C. oregona*, and *C. haemorrhagica* have been collected, and **Table 3.2** shows the collection dates.

Suitable Habitat

San Francisco Bay tiger beetles are commonly found along open, muddy margins of creeks and streams and also along the muddy margins of salt pannes that are occasionally inundated by high tides. High, dry banks of channels and open areas of levees associated with salt ponds and muted tidal marshes tend to be favored sites for *C. senilis senilis*. Habitat utilized by both adults and larvae can be characterized as having extensive areas of fine silt or sandy clay-like soil, exposed to full sun, with minimal to moderate vegetation, and being located near water. *C. haemorrhagica* and *C. oregona oregona* have shown a preference for wet, sandy beach-like areas that may or may not be influenced by fresh water from creeks and canals.

Biology

The specific biology of San Francisco Bay tiger beetles is not well known. The information that follows is a general-

Table 3.2 Known Collection Sites for Tiger Beetle Populations[1]

Location	Date Specimen(s) Collected
Cicindela haemorrhagica	
Martinez	28 Aug 1959, 21 Sep 1959
Richmond Field Station	24 Apr 1993
Alameda	23 Aug 1930, 24 Aug 1930, 4 Jul 1932
San Francisco	31 Jan 1944 (***)
Burlingame	7 Oct 1969
Lake Merritt	Jul 1906
Oakland	15 Aug 1902
Redwood City (nr Yt. Harbor)	15 Jun 1952
Redwood City (Saltmarsh)	31 Jul 1951
Palo Alto Yacht Harbor	29 Jun 1969
East Palo Alto	31 Jul 1951
Milpitas	15 Jul 1966, 26 Jul 1966
Newark (2 mi west of)	25 Jun 1975, 24 Jul 1980
Bayfarm Island	21 Jun 1990
Russell Salt Marsh, Hayward	30 Jul 1996, 27 May 1997
Trojan Marsh	2 Aug 1997
Cicindela oregona	
San Francisco Beach	14 Apr 1957
Burlingame	22 May 1952
Bayfarm Island	11 Apr 1972, Jul 1989, 21 Jun 1990, Jul 1993, Aug 1993, 12 Apr 1993, 1 Sep 1995
Oakland (*)	Jun 1906, 16 Aug 1902
Concord (*)	27 Apr 1935
Cicindela hirticollis (data from Graves 1988)	
Oakland	no date
San Francisco	1907?

Location	Date Specimen(s) Collected
Cicindela senilis senilis	
San Rafael (*)	23 May 1941, 20 May 1951
Milbrae	1 Sep 1912, 2 Jun 1912, 3 Oct 1914
San Mateo	24 Oct 1952
Redwood City (Salt Marsh)	16 Sep 1951, 15 Jul 1951, 15 Jun 1952
Redwood City (Harbor)	15 Jun 1952
Redwood City	15 Apr 1952, 26 Sep 1952
Bair Island	9 Mar 1997
East Palo Alto (Marsh)	13 Jul 1951
Palo Alto (Salt Marsh)	23 May 1921
Grizzly Island (wildlife area)	10 Oct 1991
Port Costa	21 Sep 1947
Martinez	28 Aug 1955, 28 Sep 1955
Emeryville	20 Aug 1936
Lake Merritt	4 Oct 1904, 9 Oct 1904, 12 Sep 1907, 12 Apr 1909
Alameda	Jun 1901, 16 Aug 1902, 9 May 1907
Bayfarm Island	May 1939
Oliver Salt Ponds, Hayward	5 Aug 1989, 2 Jul 1990
Whale's Tail Marsh (Hayward)	12 Apr 1993, 8 Apr 1993, 11 Mar 1993
Baumberg Salt Ponds	Mar 1989, 1 Apr 1990, 13 Jun 1989, 11 Mar 1997
Patterson Hill Marsh, Fremont	11 Apr 1989
Newark (2 mi west of)	25 Jun 1975, 24 Jul 1980
Dumbarton Bridge (Newark)	9 May 1952
Newark Salt Flats	17 Jun 1966
W. End Mowry Slough	19 Sep 1997
Brinker Marsh	Mar 1989, 10 Mar 1997
E. End Albrae Slough, Fremont	12 Mar 1997
Dixon Rd, Milpitas	23 Jun 1956
Milpitas (wet sand)	1 May 1966, 12 Oct 1966
Alviso	21 Mar 1947, 22 Mar 1947, 27 Mar 1947, 12 Apr 1947, Apr 1954, 14 Apr 1955, 15 Apr 1955, 12 May 1959, 19 May 1959, 8 Jun 1980

* May or may not be within the confines of the Ecosystem Goals Project.

*** Probably a dubious record, suspect mislabeled specimen.

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, University of California Berkeley Essig Museum, University of California Bohart Museum, San Jose State University Edwards Museum, San Mateo County Mosquito Abatement District Insect Collection, and private collections of Dr. J. Gordon Edwards and Wesley A. Maffei

ized biology for these insects drawn from the studies of other species and a summary article by Pearson (1988).

Adults of these beetles are active on hot, sunny days and are exceedingly quick both in flight and on the ground. When approached these insects will run away or fly for a short distance, land, and then face their pursuer. Larvae and adults are predators, feeding on other insects. Prey items for San Francisco Bay tiger beetles include but are not limited to the Brine Flies *Ephydra cinerea*, *Ephydra millbrae*, *Lipochaeta slossonae*, and *Mosillus tibialis*, and various beetles belonging to the families Carabidae and Tenebrionidae. Pearson and

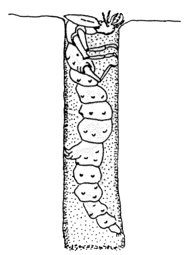

Figure 3.5 *Cicindela senilis senilis* Larva in Burrow

Mury (1979) found that adults of some species of tiger beetles also fed on dead organisms. Faasch (1968) and Swiecimski (1956) found the adults located live prey visually while dead prey were found tactilely. Adult beetles tend to frequent the muddy margins of their habitat where prey items are readily encountered while the immature stages tend to be found in the drier areas.

The eggs, larvae and pupae are subterranean, with the larvae living in vertical burrows and waiting near the top to seize any prey that passes by (**Figure 3.5**). Prey items are captured with the mandibles and pulled down to the bottom of the burrow where it is ingested. Faasch (1968) found that a dark object against a light background released the prey-catching behavior. Burrows are enlarged by loosening the soil with the mandibles and using the head and pronotum to push the soil to surface. At the surface, the soil is flicked off by flipping the head and pronotum backward (Shelford 1908, Willis 1967). The depth of larval tunnels has been found to range between 15 and 200 cm depending on the age of the larva, the species of tiger beetle, the season and soil type and conditions (Criddle 1910, Willis 1967, Zikan 1929).

Larvae undergo three molts with the time for development lasting one to four years and averaging about two years (Willis 1967). Pearson and Knisley (1985) found that the availability of food effected rate of development and was therefore a limiting resource in the life cycle of tiger beetles. They found that ample prey shortened the developmental time from egg to adult with 60 days total developmental time having been observed for some laboratory reared beetles. Prior to pupation, the last instar larva plugs the tunnel entrance and excavates a chamber or pupal cell. The period for pupation is usually short, lasting no more than 30 days.

Larvae can be found throughout the year while adults are present from March through October. Peak adult activity for the south San Francisco Bay *Cicindela senilis senilis* populations is from late April through June (Maffei, unpub.). Blaisdell (1912) noted that adults of *C. senilis* , which emerged in the fall, would hibernate. *C. haemorrhagica* do not emerge until mid to late June and are usually present through September.

Reproduction

Males initiate copulation by approaching a female in short sprints which is similar to the intermittent sprinting used when foraging. Once close enough to a potential mate, the male leaps onto their back, grasping the thorax with his mandibles and the elytra with his front and middle legs. The male's hind legs remain on the ground and the coupling sulci of the female receives his mandibles. Males frequently mount both males and females of any tiger beetle species present. Females try to dislodge intruding males by rolling on their backs, lurching and then running out into bright sunshine. It is believed that the fit of the male mandibles into the female sulci may be species specific and that this feature allows other males, and females of other species, to rid themselves of unwanted mates (Freitag 1974).

Oviposition usually occurs when the female touches the ground with her antennae and bites the soil with her mandibles. The ovipositor is then extended and with a thrusting motion of the abdomen a hole up to 1 cm is excavated. One egg is deposited in the hole and it is then covered over so that no evidence of disturbance exists. The choice of soil type for oviposition has been found to be extremely critical for many species (Knisley 1987, Leffler 1979, Shelford 1912, Willis 1967).

Availability of prey has been found to directly affect female mortality and the number of eggs produced. Adult beetles in prey poor habitats were only found to approach maximum fecundity during years of high rainfall and high prey populations (Pearson and Knisley 1985). Prey availability for larvae was found to affect the size of later instars, which ultimately affected the size of the adults produced and individual fecundity (Hori 1982a, Pearson and Knisley 1985).

Significance to Other Wetlands Taxa

These beetles may be a potential prey item for shore birds. Cramp and Simmons (1983) cite a stomach content analysis study of the European race of Snowy Plover, *Charadrius alexandrinus alexandrinus*, in Hungary which revealed the presence of 28 tiger beetles. Swarth (1983) noted that these beetles were occassionally eaten by Snowy Plovers found at Mono Lake. Marti (1974) found tiger beetle parts in burrowing owl pellets that were studied in the northeastern part of Larimer County, Colorado.

Conservation Needs and Limiting Factors

Nagano (1982) has stated that some tiger beetles are considered to be good indicators of coastal wetlands disturbance, with the least disturbed habitats having the greatest species diversity. San Francisco Bay tidally influenced wetlands appear to have two species of tiger beetle, with those sites that have had minimal disturbance or that have not seen much human activity for long periods of time having the highest populations (Maffei, unpub.). Unfortunately, few sites exist that have not been subjected to human activity. This has resulted in a loss of species diversity, with potential tiger beetle habitat usually having only a single species present and having small disjunct populations. Historically, there were sites that had more than one species present within a given habitat (ie. Lake Merritt, Bayfarm Island and Burlingame).

San Francisco Bay populations of *Cicindela senilis senilis* and *C. haemorrhagica* prefer to be near permanent or semi-permanent bodies of water utilizing tidal pannes with sizable unvegetated flats and/or nearby minimally vegetated levees. *Cicindela haemorrhagica* has shown a preference for sandy beach-like sites but can utilize dry, fine silty sites as is evidenced by the population at Russell Salt Marsh, Hayward. Both species of beetles need to have fine silty clay-like or sandy clay soils, that are unvegetated or sparsely vegetated, within in which to breed. Bright sunshine and minimal flooding are also important factors.

The immature stages of other species of tiger beetles have been found to inhabit a smaller range of the habitat than the adults and are not capable of tolerating as much variation in physical factors such as soil moisture, soil composition and temperature (Hori 1982b, Knisley 1987, Knisley 1984, Knisley and Pearson 1981, Shelford 1912, Shelford 1908). The length and duration of flooding can also be important, although what the specifics of these parameters are for San Francisco Estuary tiger beetles is not clear.

Larochelle (1977) found that many species of adults are readily attracted to lights. What impact this might have on San Francisco Bay Tiger Beetles with respect to dispersal and survival is unknown.

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Western Tanarthrus Beetle

Tanarthrus occidentalis Chandler

Wesley A. Maffei

Description and Systematic Position

Tanarthrus occidentalis is a small beetle, approximately 3-5mm in length, that belongs to the family Anthicidae (**Figure 3.6**). The head, pronotum, legs and abdomen are reddish-orange and the elytra are usually brown or black with the apical and basal third sometimes reddish or yellowish in color. This beetle can be separated from similar bay area Anthicid beetles by noting the distinct medial constriction of the eleventh antennal segment. It can further be separated from *Formicilla* spp., a similar appearing bay area Anthicid of marshes and grasslands, by examining the posterior margin of the mesepisternum which lacks a posterior fringe of long hairs.

Chandler (1979) has indicated that this beetle is very similar to *T. iselini*, which is found only in central New Mexico, but can readily be separated by antennal morphology.

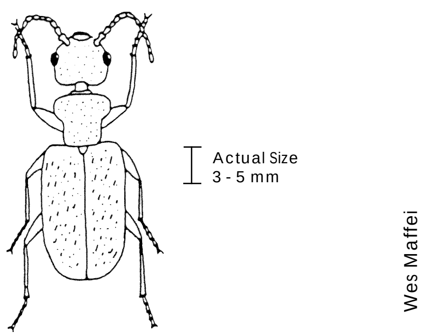

Figure 3.6 Western Tanarthrus Beetle – *Tanarthrus occidentalis*

Distribution

Tanarthrus occidentalis was first collected in 1976 and subsequently described as a new taxon by Chandler in 1979. Specimens were collected from the Cargill salt pans, now part of the San Francisco Bay National Wildlife Refuge, adjacent to Dum-barton Bridge, Alameda County, California. Additional populations have been identified from the salt pans of the Baumberg tract, Hayward, California, and from Bayfarm Island, Alameda, California. In 1996 the Bayfarm Island population was extirpated due to modification of their habitat in preparation for anticipated development. Surveys of the south and central San Francisco Bay area have revealed no other populations at this time (Maffei, unpub.). **Figure 3.7** shows the locations around the Bay Area where *T. occidentalis* specimens have been collected, and **Table 3.3** shows the collection dates.

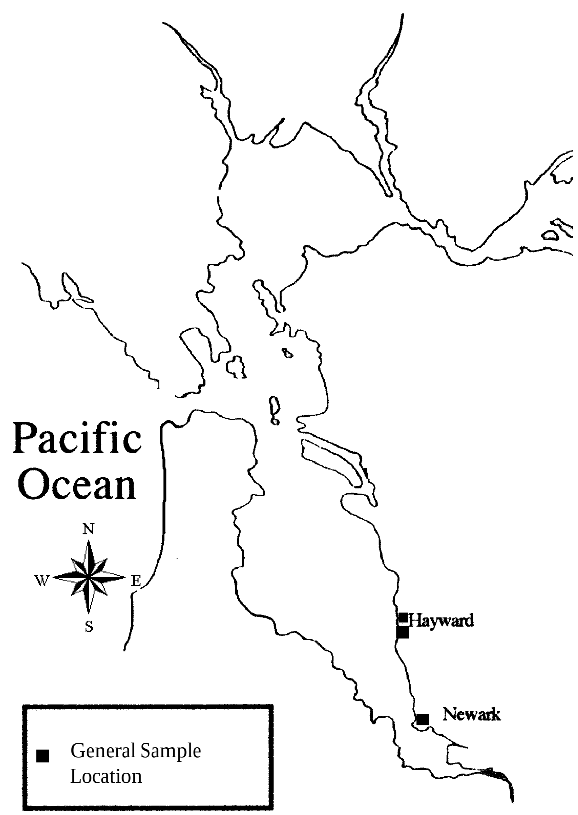

Figure 3.7 Known *Tanarthrus occidentalis* Localities Within San Francisco Bay Tidal and Diked Marshes

Invertebrates

Table 3.3 Known Collection Sites For *Tanarthrus occidentalis* [1]

Location	Date Specimen(s) Collected
2 mi W. Newark, off Dumbarton Bridge (salt Pans)	27 May 1976, 15 May 1978
Oliver South #2 Salt Pond, Hayward	5 Aug 1989
Baumberg Salt Pond #11, Hayward	2 Jun 1989, 13 Jun 1989, 5 Aug 1989, 8 Aug 1989, 10 Jul 1997

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, the University of California Berkeley Essig Museum, the University of California Bohart Museum, the San Jose State University Edwards Museum, the San Mateo County Mosquito Abatement District Insect Collection, and the private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

Invertebrates

Suitable Habitat

Tanarthrus occidentalis has been found in no other locality except for abandoned crystallizer ponds and salt pannes of southern San Francisco Bay. In all instances these sites remain dry for most of the year except during late winter when temporary pools of rainwater form. Habitat can be characterized as having extensive areas of salt crystals interspersed with open areas of fine silt and very little or no vegetative cover.

Biology

The biology of this beetle is not fully understood. Maffei (unpub.) has observed the Baumberg tract population and found that the adults commonly occur out on inactive, salt encrusted crystallizer ponds. These beetles were observed feeding on the carcasses of the brine flies *Ephydra cinerea* and *Lipochaeta slossonae* (family Ephydridae) which were still in the webs of unidentified Dictynid spiders. They appeared to function as "house cleaners" being able to move freely about the web site unmolested by the resident spider. Peak adult activity is May through September.

The immature stages of this beetle have not been located at this time. Larvae of other members of the beetle family Anthicidae feed on detritus and one species has been recorded as a predator.

Reproduction

Unknown.

Significance to Other Wetlands Taxa

This beetle has been identified as part of the immature Snowy Plover Diet (Page et al. 1995, Feeney and Maffei 1991). Its relationship to other taxa, other than Dictynid spiders, that utilize abandoned salt crystallizers is unknown at this time.

Conservation Needs and Limiting Factors

The conservation needs and limiting factors associated with this beetle are not very clear. Its association only with salt encrusted areas, other than the margins of salt ponds, that remain dry for most of the year appears to be the primary limiting factor.

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Inchworm Moth

Perizoma custodiata

Wesley A. Maffei

Description and Systematic Position

Perizoma custodiata is a small moth, with a wingspan of approximately 22-29mm, that belongs to the family Geometridae. This moth, commonly known as a measuring worm or inch worm moth, has an alternating pattern of vertical light and dark bands on the fore wings with plain, pale tan hind wings (**Figure 3.8**). The variation in width and intensity of the fore wing banding has caused different entomologists to describe this moth as a new taxon on four different occasions (Guenee 1857, Hulst 1896, Packard 1876). Wright (1923) noted the difficulty in separating examples of the "different species" of the Pacific Coast recognized at that time, stating that they intergrade so much that he found it difficult to tell one from another.

Larvae are a uniform light green or tan in color and attain a maximum size of approximately 30mm.

Distribution

Coastal areas from central northern California south along the coast of Baja California and including the Gulf of California. Found throughout San Francisco Bay tidal and diked salt marshes. **Figure 3.9** shows the locations around the Bay Area where *Perizoma custodiata* have been collected, and **Table 3.4** shows the collection dates.

Suitable Habitat

Upper middle to high marsh that has berms or levees with adequate populations of Alkali Heath (*Frankenia salina*).

Biology

Adults are on the wing from March through November, with peak adult populations occurring during late spring and early summer.

Larvae have been observed feeding on *Frankenia salina* (Maffei, unpub.) and Packard (1876) has noted that the larvae of other members of the genus *Perizoma* live on low growing plants with the pupa being subterranean. Caterpillars have been observed on Alkali Heath that was inundated by high tides of 6.3 or greater at the Whale's Tail Marsh, Hayward, California. The eggs and larvae have not been found during the winter months, and it is presumed that these moths over winter as pupae.

Reproduction

The number of generations per season and the number of eggs per female is apparently unknown for San Francisco Bay populations.

Significance to Other Wetlands Taxa

Snowy plovers have been observed consuming adult moths at the Baumberg Tract in Hayward, California (Feeney and Maffei 1991). This insect may also be a part of other shore bird and passerine bird diets.

The digger wasp, *Ammophila aberti*, has been observed provisioning its nests with the larvae of this moth (Maffei, unpub.).

Adult moths are pollinators of *Frankenia salina* and are probably pollinators for many of the other flowering plants within diked and tidal marshes.

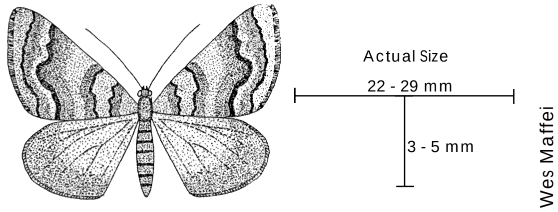

Figure 3.8 Inchworm Moth – *Perizoma custodiata*

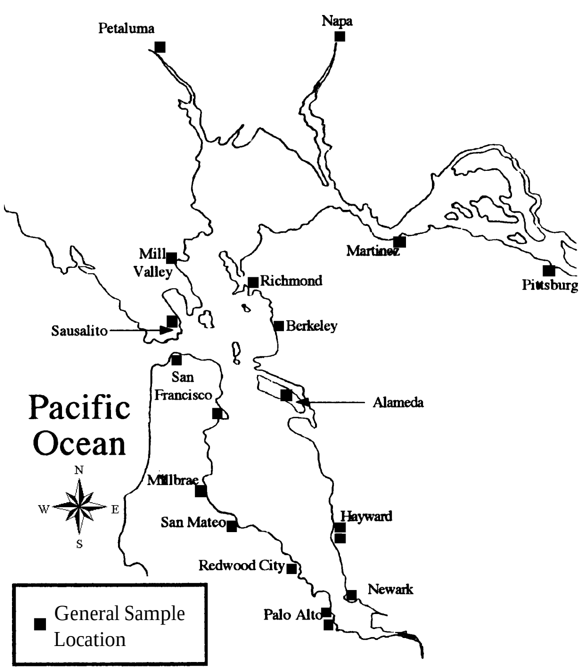

Figure 3.9 Known *Perizoma custodiata* Localities Within San Francisco Bay Tidal and Diked Marshes

Table 3.4 Known Collection Sites For *Perizoma custodiata* [1]

Location	Date Specimen(s) Collected
West Pittsburg	15 Feb 1957, 21 Mar 1957, 19 Sep 1957
Martinez	30 Aug 1962
Richmond	18 Jun 1956, 12 Apr 1959
Berkeley	11 Mar 1923, 3 Nov 1923
Berkeley (Bayshore)	27 Jul 1916, 16 May 1955
Alameda	12 May 1918, 13 May 1920
Dumbarton Marsh	22 Jul 1968, 20 Sep 1968, 22 Nov 1968
Shoreline Int. Ctr. (Hwyd)	2 Jul 1990
Baumberg Tract (Hayward)	24 Feb 1990, 1 Apr 1990
Napa	5 May (no year)
Petaluma	13 May 1936, 15 May 1938 17 Apr 1939, 12 May 1940
Mill Valley (Slough)	17 Jun 1950
Mill Valley	23 Mar 1920, 5 Sep 1923, 26 Nov 1924, 3 Oct 1926
South Marin Co. Shore	12 Apr 1950
San Francisco	1 Sep 1909, 25 Sep 1909, 9 Oct 1909, 15 Jun 1919, 5 Oct 1919, 21 Oct 1919, 9 Nov 1919, 30 Sep 1920, 4 Oct 1920, 22 Oct 1920, 24 Oct 1920, 11 Dec 1920, 30 Dec 1920, 4 Jan 1921, 6 Sep 1921, 17 Oct 1921, 26 Oct 1922, 14 Jul 1925, 15 Sep 1925
San Francisco (Dunes)	7 Apr 1961
Millbrae	10 Sep 1914
San Mateo	3 Oct 1920
Palo Alto	12 Jun 1933, 27 Jun 1933, 22 Jul 1933, 11 Aug 1933, 26 Apr 1954
E. Palo Alto	May 1978
Bair Island	1 Mar 1987, 9 Mar 1997

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, University of California Berkeley Essig Museum, University of California Bohart Museum, San Jose State University Edwards Museum, San Mateo County Mosquito Abatement District Insect Collection, and private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

Conservation Needs and Limiting Factors

Frankenia salina has been identified as the larval host plant for this moth (Maffei, unpub.). Upper middle to high marsh areas with small dense patches of this plant support fairly high numbers of this organism. Its wide distribution along the Pacific Coast would seem to preclude this organism from any immediate danger of extirpation.

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Pygmy Blue Butterfly

Brephidium exilis Boisduval

Wesley A. Maffei

Description and Systematic Position

Brephidium exilis, also known as the Pygmy Blue, is a small butterfly, with a wingspan measuring approximately 13-20mm (**Figure 3.10**). Adult butterflies have the dorsal surface of the wings brown with the basal third to half light blue. The ventral surface of the wings are grayish white with pale brown bands and a row of iridescent black and silver spots along the outer edge of the hind wing. The eggs are flattened, light bluish-green in color, and have a fine raised white mesh on the surface. Larvae are pale green or cream colored and have a finely punctate surface with white tipped tubercles, a yellowish white dorsal line, and a bright yellow substigmatal line (**Figure 3.11**). Some specimens may lack the lateral substigmatal line but all mature larvae have a frosted appearance which resembles the ventral surface of salt bush leaves or the flower heads of pigweed. The pupae can be quite variable in color but are usually light brownish yellow, have a dark brown dorsal line, and have the wing pads pale yellowish green in color sprinkled with brownish dots.

Three subspecies of this butterfly have been recognized with *Brephidium exilis* noted as the western subspecies (Scott 1986).

Distribution

Brephidium exilis is found from southwestern Louisiana and Arkansas westward to California and south to Venezuela (Howe 1975, Scott 1986). Strays have been noted as far north as Kansas and Idaho. This butterfly is widely distributed throughout the San Francisco Bay, being particularly abundant in salt marshes (Tilden 1965). **Figure 3.12** shows the locations around the Bay Area where *B. exilis* have been collected, and **Table 3.5** shows the collection dates.

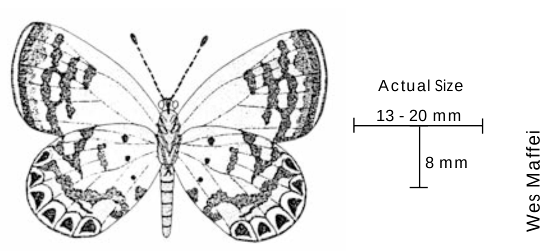

Figure 3.10 Adult Pygmy Blue Butterfly – *Brephidium exilis.*

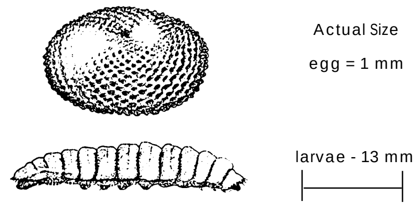

Figure 3.11 *Brephidium exilis* Egg and larva (from Comstock 1927)

Suitable Habitat

Prefers lowland areas such as alkali flats, salt marshes, vacant lots, roadsides and desert prairie with various Chenopodiaceae and Aizoaceae.

Biology

The adult flight period for San Francisco Bay populations is late February through October, with peak abundance occurring in September (Comstock 1927, Garth and Tilden 1986, Tilden 1965).

Larvae feed on most parts of the host plant. Recorded larval hosts are: *Atriplex canescens, A. coulteri, A. serenana, A. leucophylla, A. patula hastata, A. semibaccata, A. rosea, A. cordulata, A. hymenelytra, A. coronata, A. lentiformis breweri, Suaeda fruticosa, S. californica, S. torreyana, Salicornia virginica, Chenopodium album, C.*

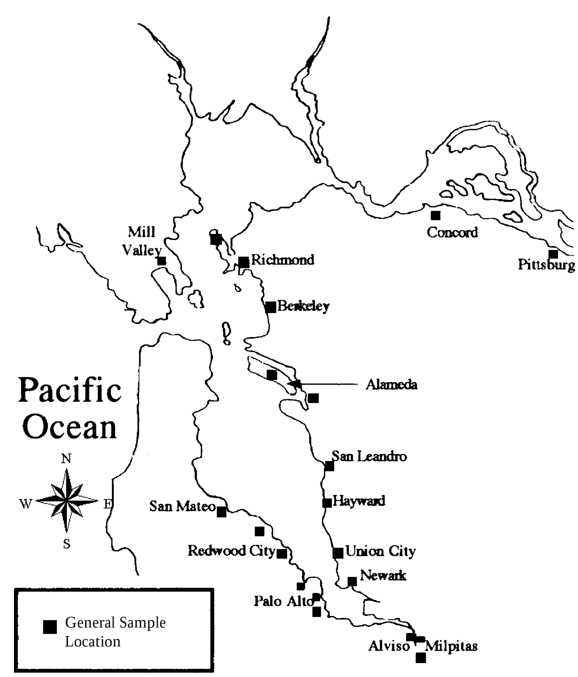

Figure 3.12 Known *Brephidium exilis* Localities Within San Francisco Bay Tidal and Diked Marshes

Table 3.5 Known Collection Sites For *Brephidium exilis*[1]

Location	Date Specimen(s) Collected
West Pittsburg	15 Apr 1957
Avon	27 Aug 1972
Richmond Point	3 Oct 1964
Richmond	10 Aug 1953
Berkeley (Shoreline)	8 Jun 1915, 22 Jun 1989, 18 Oct 1995
West Berkeley	20 Jun 1987, 31 Oct 1987, 23 Nov 1987, 25 Jun 1988, 23 Jun 1990
Alameda	12 May 1918, 17 May 1918
Larkspur	20 Sep 1958
Oakland	8 Apr 1938
San Leandro	14 Aug 1935
Milpitas	29 Nov 1974
Alviso	1 Nov 1985, 11 Jun 1986
Palo Alto	4 Oct 1908, 8 Jun 1909, 1 Oct 1935, Aug 1937, 10 Jul 1967
East Palo Alto	14 Jun 1952
Menlo Park	20 Sep 1958, 9 Oct 1958
Redwood City	28 Jul 1963
San Mateo	4 Oct 1955, 10 Oct 1955
San Carlos Airport	11 Aug 1977

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, University of California Berkeley Essig Museum, the University of California Bohart Museum, San Jose State University Edwards Museum, San Mateo County Mosquito Abatement District Insect Collection, and private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

leptophyllum, *Salsola iberica*, *S. kali tenuifolia*, *Halogeton glomeratus*, *Trianthema portulacastrum*, and *Sesuvium verrucosum* (Comstock 1927, Garth and Tilden 1986, Howe 1975, Scott 1986, Tilden 1965).

Nagano and coworkers (1981) found this butterfly to be an indicator of saline soils.

Reproduction

This butterfly has many generations within one season, with one generation often overlapping the next (Howe 1975). Scott (1986) states that males patrol all day over the host plants in search of females. Eggs are laid singly and can be found anywhere on the host plant, but are usually on the upper surfaces of leaves. The number of eggs produced per female is unknown.

Significance to Other Wetlands Taxa

Most likely a prey item for birds utilizing the marshes of the estuary. Larvae may also be a food item for insectivorous vertebrates. South bay populations of this butterfly are parasitized by the small black tachinid fly *Aplomya theclarum* (Maffei, unpub.).

Conservation Needs and Limiting Factors

None.

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Summer Salt Marsh Mosquito

Aedes dorsalis (Meigen)

Wesley A. Maffei

Description and Systematic Position

The summer salt marsh mosquito, *Aedes dorsalis*, is a medium sized mosquito measuring approximately 5-6 mm in length. Freshly emerged adults are one of the most brightly colored marsh mosquitoes found within the San Francisco Estuary. These insects are brilliant gold in color, have a dorsal white band running the length of the abdomen and have broad white bands on the tarsal segments of the legs. Older specimens may be yellow or yellowish-brown in color and the markings on the abdomen may be incomplete if the scales have been rubbed off. The immature stages can be identified by insertion of the siphon tuft at or beyond the middle of the siphon tube, a broadly incomplete anal saddle, presence of a weak saddle hair and moderate to short anal papillae. The presence of single upper and lower head hairs has been used as an additional diagnostic feature but this can be inconsistent, especially in later instar larvae.

The similarity of this mosquito to *Aedes melanimon* Dyar has resulted in some confusion with early efforts to identify both adults and larvae. Detailed studies of different populations of both of these mosquitoes have helped to clarify and verify the systematic position of both of these insects (Bohart 1956, Chapman and Grodhaus 1963).

Distribution

This mosquito can be found throughout most of the United States, southern Canada, Europe and Asia (Carpenter and LaCasse 1955, Darsie and Ward 1981). Within California, this mosquito can be found in coastal salt marshes and the brackish waters of the Sacramento and San Joaquin Delta (Bohart 1956, Bohart and Washino 1978).

Suitable Habitat

Larvae are found in a variety of brackish and freshwater habitats throughout their world range (Carpenter and LaCasse 1955). Within San Francisco Bay *A. dorsalis* are usually encountered in temporarily flooded tidal marsh pannes, heavily vegetated ditches and brackish seasonal wetlands. Adults prefer open habitats such as grasslands, open salt marsh and the edges of woodlands.

Biology

Adults are aggressive day biting mosquitoes that have been found capable of traveling distances of more than 30 miles (Rees and Nielsen 1947). Flights of adults in Alameda County have been known to disperse distances of more than five miles from their larval source (Maffei, unpub.). Garcia and Voigt (1994) studied the flight potential of this mosquito in the lab and found that the adults exhibited strong flight characteristics which they believed helped them to adapt to the strong winds encountered in their preferred open habitats. Females are readily attracted to green, grassy fields and will rest there waiting for available hosts (Maffei, unpub.).

Host studies have shown that large mammals are preferred, especially cattle and horses (Edman and Downes 1964, Gunstream et al. 1971, Shemanchuk et al. 1963, Tempelis et al. 1967). The effects of adult feeding activity on livestock can be severe resulting in reduced feeding and in some instances injury to animals attempting to evade severe attacks. Recent adult activity within the San Francisco Estuary has impacted outdoor school activities, businesses and residents, resulting in at least two instances where medical attention was required for people reacting to multiple bites (Maffei, unpub.).

Eggs are deposited individually on the mud along the edges of tidal pools or the receding water line of brackish seasonal wetlands. Winter is passed in the egg stage and hatching occurs with the first warm weather of spring. Additional hatches occur with subsequent refloodings of the larval habitat. Eggs can remain viable for many years with only part of any given brood hatching during any single flooding event.

The larval stage can last from four to fourteen days with duration being primarily dependent on temperature. Other factors that can regulate rate of larval development include competition for space and quality and availability of nutrients. Rees and Nielsen (1947) found larvae that completed their development in saline pools of the Great Salt Lake with salt concentrations as high as 120 ‰. Washino and Jensen (1990) reared larvae, from Contra Costa County salt marshes, in solutions simulating 0, 10, 50 and 100% concentrations of seawater and found that survivorship improved as salt content approached that of seawater.

Total developmental time, from egg to adult, has been observed to occur in less than one week (Maffei, unpub.).

Reproduction

Male mating swarms have been observed occurring over low growing bushes, prominent objects and open fields (Dyar 1917, Garcia et al. 1992). Both observations noted that swarming activity began at sunset and that the swarms were not more than two to three meters above the ground. Swarming and mating usually occurs on the marsh within a few days of adult emergence and is followed by random dispersal of host seeking adults.

The number of gonotrophic cycles and eggs produced per female remains unclear for San Francisco Bay populations. Early work by Telford (1958) found that 12 broods and approximately eight generations occurred during one breeding season at Bolinas in Marin County. The number of generations per year does vary with respect to weather and tidal conditions.

Significance to Other Wetlands Taxa

This species of mosquito is commonly found in association with the tidal pool brine fly *Ephydra millbrae* and the water boatman *Trichocorixa reticulata*. Both the brine fly and the water boatman have been identified as food sources for shorebirds and waterfowl (Anderson 1970; Feeney and Maffei 1991; Howard 1983; Maffei, unpub.; Martin and Uhler 1939). The larvae of this mosquito may also be a food source for these birds and adults may be a food source for swallows.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal or tidal wetlands. Sites that drain poorly will create habitat that can readily produce very large numbers of aggressive biting adults. Plans for long term maintenance of seasonal and tidal wetlands should include resources for mosquito control as the need arises. The dynamic nature of these types of habitats coupled with human activities can easily convert a non-breeding site into a major mosquito producing source.

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Winter Salt Marsh Mosquito

Aedes squamiger (Coquillett)

Wesley A. Maffei

Description and Systematic Position

Aedes squamiger is a medium-sized to large mosquito, measuring approximately 6-9mm in length, that belongs to the fly family Culicidae (**Figure 3.13**). Adults have a distinctive black and white speckled appearance and large, flat scales along the wing veins which separates this fly from other San Francisco Bay mosquitoes. Larvae can be identified by the presence of an incomplete anal saddle, a siphon tuft distal to the pecten row, an anal saddle hair as long or longer than the anal saddle, and upper and lower head hairs that are usually branched (**Figure 3.14**).

This mosquito was described as a new taxon by Coquillett in 1902 from specimens collected from the cities of Palo Alto and San Lorenzo, California. Bohart (1948) differentiated the larvae and pupae of *Aedes dorsalis* and *Aedes squamiger* thereby providing a means of separating the immature stages of these two species which are very similar in appearance. In 1954, Bohart described and provided keys to the first stage larvae of California *Aedes* and further clarified the differences between these two mosquitoes.

Distribution

This mosquito is found along the Pacific Coast region from Marin and Sonoma counties, California, south to Baja California, Mexico (Bohart and Washino 1978, Carpenter and LaCasse 1955, Darsie and Ward 1981, Freeborn and Bohart 1951). **Figure 3.15** shows the distribution of *Aedes squamiger* in 1950. The current distribution within the San Francisco Bay area is very similar, with additional sites having been identified along the shoreline of the East Bay.

Suitable Habitat

Preferred habitat consists primarily of coastal pickle weed tidal and diked marshes, especially salt marsh pools that are diluted by winter and early spring rains. Cracked ground of diked wetlands and old dredge disposal sites are also a favorite habitat for deposition of eggs and development of larvae. This mosquito prefers brackish or saline habitats and has not been found in truly fresh water marshes. Bohart, et. al. (1953) found larvae of various stages in pools with salinities ranging from 1.2 ‰ to 35 ‰. Studies by Garcia and coworkers (1992, 1991) indicated that optimal larval development occurred at salinities between 5 ‰ and 15 ‰.

Biology

Eggs hatch as early as late September and can continue to hatch with the accumulation of rainfall from each successive storm event. Maffei (unpub.) found larvae that hatched from the incidental flooding of a marsh by a duck club as early as late September. Bohart, et. al. (1953) states that three to six major hatches of eggs occur during the fall months. It is believed that only part of the eggs laid during the prior spring season hatch with a decreasing percentage of the remaining eggs hatching during successive years. Garcia, et al. (1991) found that as many as four floodings were necessary to hatch all of the eggs from field collected samples. Bohart and Washino (1978) state that the eggs are usually dormant from April through September and that this obligatory diapause is terminated by the decreasing fall temperatures that fall below 7°C. Garcia et al. (1991) found that hatching does not occur until the eggs have been exposed to temperatures that are less than 10°C. Voigt (pers comm.) believes that once the eggs have been thermally

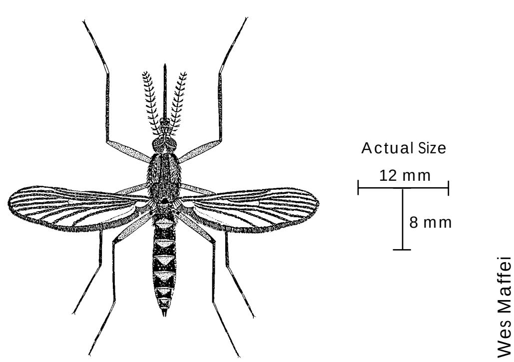

Figure 3.13 Adult Winter Salt Marsh Mosquito – *Aedes squamiger*

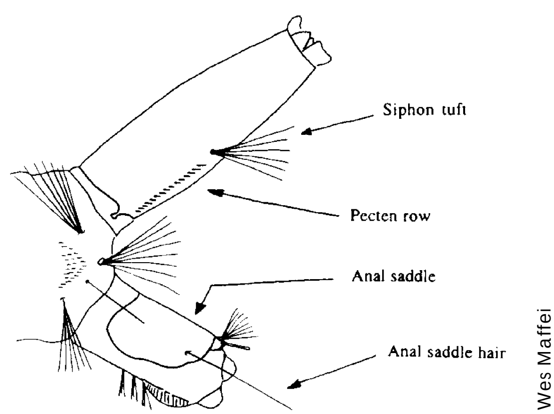

Figure 3.14 Terminal Abdominal Segment of a Fourth Instar Larva

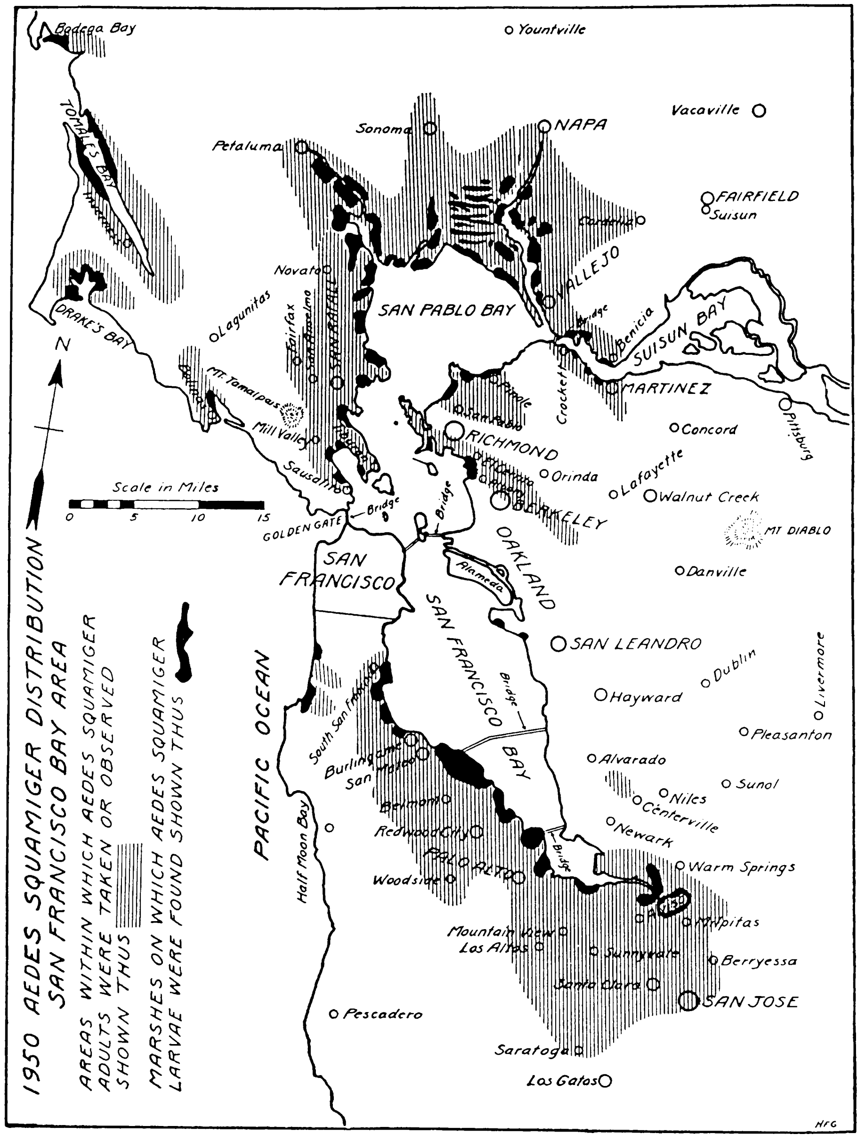

Figure 3.15 *Aedes Squamiger* Distribution in the San Francisco Bay Area, 1950

From Aarons, 1954

conditioned that hatching can then occur anytime in the future following submersion. This may possibly help to explain summer hatches following flooding of sites by inadvertant human activity (Maffei, unpub.).

Larvae are principally found in salt marsh pools that are diluted by fall and winter rainfall. Bohart and coworkers (1953) found that a minimum of 48 days were required for the development of the aquatic stages before adult emergence, with the first pupae having been found during the first week of February. Under "normal" conditions pupae are usually found from the last two weeks of February through the beginning of March. Estimates of the number of larvae per acre vary from 1.65 million to 1.45 billion depending on environmental factors (Aarons 1954, Aarons et al 1951, Lowe 1932). Larvae are capable of remaining submerged for extended periods of time where they browse on vegetation and mud. Garcia, et al (1990) calculated the minimum developmental threshold for development of larvae to the adult stage to be 4.4°C. Additional studies by Garcia and coworkers (1991) found that first and second instar larvae had developmental thresholds that were 2-4°C lower than the later instars. From these data , they concluded that the lower developmental thresholds of the earlier instars allowed larvae from later hatching installments to emerge as adults in closer synchrony with those larvae that hatched earlier in the season. They also noted that larvae and pupae could survive in the mud at sites that underwent periodic draw-down of the water. Garcia, et al. (1990) also studied the diapause habit of the last instar larvae and concluded that this interesting trait probably contributed in some degree to the partial synchronous emergence of the adults.

Adults usually emerge during the last week of February through the end of March. Emergence of adults in April has occurred from unusually heavy late winter and early spring rains that have caused late egg hatches with rapid larval development. Adults usually fly to areas away from their breeding sites, using ravines and natural or man made waterways from the marshes to the local hills as passageways. From these passageways the adults spread laterally into the wind protected areas of the surrounding community (Freeborn 1926). It is believed that at these protected sites adults mate and and seek blood meals (Telford 1958). Gray (1936) noted that this mosquito flew the longest distance of any California mosquito from its larval source. Aarons (1954) noted that adults were found in Saratoga, some 10 miles from the nearest known larval source. Other workers have found that adults of this mosquito are capable of traversing distances of more than 15 miles from any possible larval site (Aarons, et. al. 1951, Krimgold and Herms 1934, Lowe 1932, Stover 1931, Stover 1926). Biting activity begins in April and usually ends by early June. Rabbit baited traps in the east bay have collected adults from 16 March to 28 June (Garcia et al. 1983). Adults are known to be aggressive day and early dusk biting mosquitoes. This species along with the Summer Salt Marsh Mosquito, *Aedes dorsalis*, were the first mosquitoes to become the primary focus of organized mosquito control efforts in California. The first mosquito control campaigns were undertaken at San Rafael in 1903 and also at Burlingame in 1904. The earliest written record of what is believed to be the attacks of *Aedes squamiger* and *Aedes dorsalis* on humans was in a diary entry of Father Juan Crespi in April of 1772 (Bolton 1927). In his diary he describes the vicious attacks of mosquitoes that sorely afflicted his party while traveling along the eastern side of San Francisco Bay. Aarons, et al. (1951) states that there is reason to believe that the salt marsh mosquitoes made certain times of the year almost unbearable for the early Indians.

Females oviposit in those parts of the marshes that are not under water. Eggs are laid on plants and along the muddy margins of ponds close to the water line. Most of the eggs are located in these higher areas of the marshes and will therefore not hatch without a combination of tides and rainfall. For diked marshes, at least a few inches of rainfall must occur to inundate the eggs and stimulate hatching. Maffei (unpub.) has found that the runoff of as little as one inch of rainfall from city streets into marshes used as flood control basins can flood a marsh sufficiently to hatch eggs and produce larvae. Females that oviposit in late spring will deposit eggs in the lower portions of the marshes and it is these eggs that hatch first with tidal activity only or ponding of early rain water runoff.

Reproduction

Observations on mating swarms have shown that *Aedes squamiger* tends to swarm approximately one hour before to one-half hour after sunset (Garcia et. al. 1992). Swarms can consist of a few to several thousand individuals that hover over prominent objects such as trees or large bushes and can occur at heights ranging from six to approximately 50 feet (Bohart and Washino 1978, Garcia et. al. 1992). Garcia et al. (1992, 1983) found that adults traveled back and forth to the marshes quite readily producing a new batch of eggs with each trip. He also found that the highest parous condition observed was seven, with average parity rates ranging between 3 and 5.4. Garcia, et al. (1992) found a direct correlation between wing length and the number of eggs produced with larger females producing more eggs. The maximum number of eggs produced per female was less than 250. Garcia, et al. (1990) also found that temperature played an important role in longevity, ovarian development and oviposition. Females held at 15°C were still alive 50 days after their last blood meal and average longevity was about 35 days when kept at 20°C. The minimum temperature threshold for ovarian development or oviposition was found to be about 15°C.

Significance to Other Wetlands Taxa

Aedes squamiger larvae are frequently found in association with larvae of the Summer Salt Marsh Mosquito, *Aedes dorsalis,* and the Winter Marsh Mosquito, *Culiseta inornata*. The adults of these mosquitoes may be a possible food source for swallows and the larvae may be a food source for waterfowl.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal or tidal wetlands. Sites that drain poorly will create habitat that can readily produce very large numbers of aggressive biting adults. Plans for long term maintenance of seasonal and tidal wetlands should include resources for mosquito control as the need arises. The dynamic nature of these types of habitats coupled with human activities can easily convert a non-breeding site into a major mosquito producing source.

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Washino's Mosquito

Aedes washinoi Lansaro and Eldridge

Wesley A. Maffei

Description and Systematic Position

Aedes washinoi was described as a new taxon by Lanzaro and Eldridge in 1992 and was determined to be a sibling species of *Aedes clivis* and *Aedes increpitus*. Prior to 1992, all three species of mosquitoes were known as *Aedes increpitus*. Adults of this mosquito are almost impossible to separate from its sibling species, when using morphological features, and can also sometimes be confused with *Aedes squamiger*. The easiest way to distinguish *Ae. squamiger* and *Ae. washinoi* is to examine the wing scales. *Aedes squamiger* has very broad, flat, plate-like scales on the wings whereas *Ae. washinoi* will have the usual thin, pointed wing scales. The wings of *Ae. washinoi* will also tend to be uniformly dark with a concentration of pale scales on the anterior wing veins. In all other respects, both *Ae. squamiger* and *Ae. washinoi* share a similar black and white speckled appearance. The larvae of this mosquito can be difficult to separate but Darsie (1995) has provided additions to Darsie and Wards 1981 keys to facilitate identification.

Distribution

This mosquito is found from Portland, Oregon south to Santa Barbara, California and eastward into the lower Sierra Nevada mountains. Populations of this mosquito have also been found along the eastern Sierra Nevada Range at Honey Lake.

Suitable Habitat

Within the San Francisco Estuary the preferred habitat is shallow ground pools and upland fresh to slightly brackish water sites that are next to salt marshes or in riparian corridors. These habitats also tend to be dominated by willow or cotton wood trees and/or black berry vines.

Biology

Larvae usually hatch during early winter after a series of successive storm events has filled ground depressions with water. Additional hatches of larvae can occur if late winter and early spring rains refill drying larval sites. Larvae of this mosquito also exhibit a late fourth instar diapause and partial synchronous adult emergence similar to that observed in *Aedes squamiger*. Adults emerge during late winter and early spring and can persist through early June, depending on weather conditions.

Females are aggressive day biting mosquitoes that tend not to travel far from their larval sources. Maffei (unpub.) found that adult mosquitoes traveled a maximum distance of one and one-half miles from their larval habitat and that local, man made canals were used as a passageway into the surrounding community.

Eggs are deposited in the muddy margins adjacent to the receding water line of the larval habitat and hatch the following winter when reflooded.

Reproduction

Adults have been observed swarming under or near the tree canopy of their larval habitat (Garcia, et al. 1992).

Significance to Other Wetlands Taxa

Unknown.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal wetlands or riparian corridors. Sites that have shallow ground pools and willow or cotton wood trees or blackberry vines will create habitat that can readily produce very large numbers of aggressive biting adults. The restoration of historical willow groves should not occur if homes are within two miles of the project site.

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Western Encephalitis Mosquito

Culex tarsalis Coquillett

Wesley A. Maffei

Description and Systematic Position

The western encephalitis mosquito is a medium sized mosquito measuring approximately 5-6 mm in length. This fly was described in 1896 as a new taxon by Coquillett from specimens gathered in the Argus Mountains of Inyo County, California (Belkin et al. 1966).

Adults can be identified by using the following morphological features: legs with bands of pale scales overlapping the tarsal joints; femur and tibia of the hind legs with a pale stripe or row of pale spots on the outer surface; proboscis with a complete median pale band; ventral abdominal segments with v-shaped patches of darkened scales; and the inner surface of the basal antennal segment with patches of pale scales. The larvae can be recognized by the four to five pairs of ventrally located siphon tufts that are nearly in line with each other (**Figure 3.16**) and the 3-branched lateral abdominal hairs found on segments III to VI.

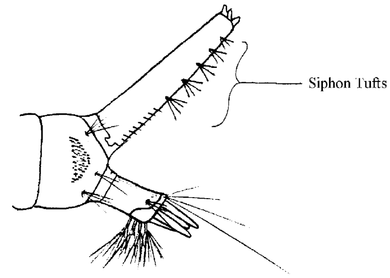

Figure 3.16 Terminal Abdominal Segment of *C. tarsalis larva*

Invertebrates

Distribution

This mosquito has been found in central, western and southwestern United States, southwestern Canada and northwestern Mexico (Carpenter and LaCasse 1955, Darsie and Ward 1981). Within California, this fly has been found in every county from elevations below sea level to almost 10,000 feet (Bohart and Washino 1978, Meyer and Durso 1993).

Suitable Habitat

The immature stages are found in all types of fresh water habitats except treeholes. Poorly drained pastures, rice fields, seepages, marshes and duck club ponds are especially favored as breeding habitat for this mosquito. Telford (1958) found larvae in salt marsh pools with salinities up to 10 ‰. Urban sources include poorly maintained swimming pools, ornamental ponds, storm drains, flood control canals, ditches, waste water ponds and most man made containers (Beadle and Harmston 1958, Bohart and Washino 1978, Harmston et al. 1956, Meyer and Durso 1993, Sjogren 1968).

Adults rest by day in shaded or darkened areas such as mammal burrows, tree holes, hollow logs, under bridges, in caves, in eves and entry ways of residences, brush piles and in dense vegetation (Mortenson 1953, Loomis and Green 1955, Harwood and Halfill 1960, Price et al. 1960, Rykman and Arakawa 1952).

Biology

Adult females of this species usually feed at night. Precipitin tests indicate a wide variety of hosts consisting of various birds and mammals with an occasional reptile or amphibian (Anderson et al. 1967, Edman and Downe 1964, Gunstream et al. 1971, Hayes et al. 1973, Reeves and Hammon 1944, Rush and Tempelis 1967, Shemanchuk et al. 1963, Tempelis 1975, Tempelis et al. 1967, Tempelis et al. 1965, Tempelis and Washino 1967). Reeves (1971) states that host availability and season are probably the most important considerations in the adult host feeding pattern. The availability of nesting birds during spring and early summer may account for the preponderance of identified, early season, avian blood meals. With the progression of the summer season, availability and behaviour of bird hosts varies and a switch to mammal hosts occurs (Hammon et al. 1945, Hayes et al. 1973, Reeves and Hammon 1944, Reeves et al. 1963, Tempelis et al. 1967, Tempelis and Washino 1967). Adults pass the winter months in facultative diapause which is triggered by short day length and low ambient temperatures. In the warmer parts of southern California adults are active year round while in San Francisco Bay populations inactivity usually occurs from December through February. Additional periods of low temperatures or unseasonably warm winters can vary the time spent in diapause.

Flight range studies indicate that this mosquito will readily disperse from its larval source. Reeves et al. (1948) found that adults generally dispersed two miles or less, although prevailing winds helped to distribute marked females up to three miles. Bailey et al. (1965) studied the dispersal patterns of Yolo County, California populations and found that prevailing winds were important to adult dispersal with significant numbers of adults having traveled seven miles within two nights. The maximum distance traveled was recorded at 15.75 miles. From their studies they concluded that the likely dispersal distance of Sacramento Valley populations was probably about 20-25 miles. It was further concluded that most locally controlled mosquito sources are repeatedly reinfested during the summer because these mosquitoes travel so readily with the wind.

The larval stages feed on a wide variety of microorganisms, unicellular algae and microscopic particulate matter. The amount of time required to complete development from egg to adult varies depending on water temperature, availability of food and crowding. Bailey and Gieke (1968) found that water temperatures of 69°F to 86°F were optimal for larval development. Beyond 86°F, the larval stage lasted about eight days but mortality was very high. Mead and Conner (1987) found the average developmental rates from egg to adult to be 18.7 days at 67°F and 7.4 days at 88°F.

Reproduction

Male mating swarms occur shortly before to just after sunset. Harwood (1964) found that initiation of the mating swarm was related to changes in the light intensity and that light levels of approximately 7 foot candles would initiate crepuscular flight activity. He further found that lab colonized males could be induced to swarm when abrupt changes in light intensity occurred.

Lewis and Christenson (1970) studied female ovipositional behaviour and found that the initial search for oviposition sites by females occurs close to the lowest available surface. Groups of eggs, also known as egg rafts, are deposited directly onto the water with the average number of eggs per raft varying between 143 to 438 (Bock and Milby 1981, Buth et al. 1990, Reisen et al. 1984). Environmental factors such as water temperature, crowding and availability of food have been found to affect development of the immature stages, which in turn, affects the size of the female mosquito and ultimately the number of eggs and egg rafts produced. Logan and Harwood (1965) studied the effects of photoperiod on ovipositional behaviour of a Washington strain of *Culex tarsalis* and found that peak oviposition occurred within the first hour of darkness and light.

Autogeny, or the development of eggs without a blood meal, does occur with this mosquito. Moore (1963) found that autogenous *Culex tarsalis*, from Sacramento Valley, California, produced an average of 116 eggs per female with an observed maximum of 220. He also found that the level of autogeny decreased from spring to summer. Spadoni et al. (1974) also studied autogeny in *Culex tarsalis* populations from the same region finding similar results and detecting autogeny as early as April. They further found that no autogenous egg development was observed in overwintering females from November through February and that the mean number of eggs produced per autogenous female was 144.

Significance to Other Wetlands Taxa

This mosquito is the primary vector of Western Equine Encephalitis (WEE) and Saint Louis Encephalitis (SLE) viruses for most of the western United States (Brown and Work 1973, Longshore et al. 1960, Reeves and Hammon 1962, Work et al. 1974). Rosen and Reeves (1954) have also determined that this fly is an important vector of avian malaria.

Larvae of the Winter Marsh Mosquito, *Culiseta inornata*, are frequently found with the immature stages of this mosquito during fall and spring. The larvae of this insect may be a possible food source for waterfowl.

Conservation Needs and Limiting Factors

Sound water management practices should include consultations with local public health and mosquito or vector control agencies to prevent or at least minimize the production of this mosquito from managed, restored or newly created wetlands. Adequate resources need to be provided in all short and long term management plans to help protect humans and horses from the encephalitis viruses that can be vectored by this mosquito.

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Winter Marsh Mosquito

Culiseta inornata (Williston)

Wesley A. Maffei

Description and Systematic Position

The winter marsh mosquito was described from specimens collected in the Argus Mountains, Inyo County, California, in 1893 (Belkin, et al 1966). This insect is one of California's largest mosquitoes, measuring approximately 8-10 mm in length. Adults are generally light brown to reddish-brown in color and lack any unusual or distinctive markings. Diagnostic features of the imagines include: tip of the abdomen bluntly rounded; wings with the radial and medial cross veins nearly in line with each other; anterior wing veins with intermixed light and dark scales; and wings without distinct patches of dark scales (**Figure 3.17**). Larvae can be identified by the presence of only one tuft of hairs inserted near the base of the pecten row on the siphon and by having the lateral hairs of the anal saddle distinctly longer than the anal saddle (**Figure 3.18**).

Distribution

This mosquito can be found throughout the United States, southern Canada and northern Mexico over a wide range of elevations and habitats (Carpenter and LaCasse 1955). Populations of the winter marsh mosquito have been found throughout California except in Mariposa County (Meyer and Durso 1993).

Suitable Habitat

The immature stages can be found in a wide variety of habitats ranging from duck club ponds, ditches, seepages, rainwater pools, salt marshes and manmade containers. Telford (1958) found larvae in Marin County marshes with salinities ranging from 8 ‰ to 26 ‰.

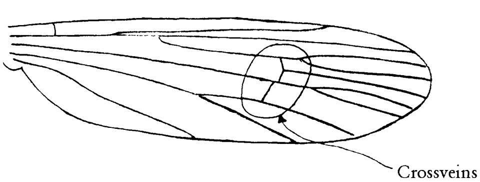

Figure 3.17 Wing of an Adult *Cs. inornata*

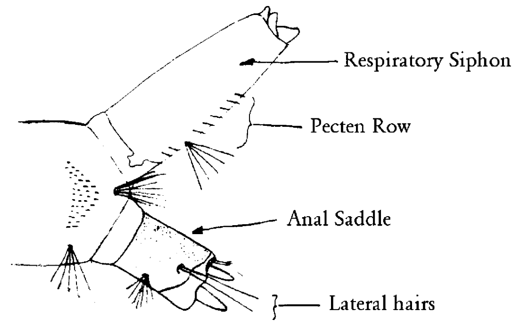

Figure 3.18 Terminal Abdominal Segment of a Fourth Instar Larva

Adults are usually found resting near their larval habitats during their breeding season while summer aestivating adults are presumed to utilize animal burrows in upper marshes and adjacent uplands (Barnard and Mulla 1977, Shemanchuk 1965).

Biology

Adults are present fall, winter and spring and enter facultative diapuase in the summer as a means of surviving the hot, dry California summers. Aestivating females are thought to emerge from mammalian burrows and shelters in the fall following decreased temperatures and the first fall rains. Meyer, et al. (1982a, 1982b) found that optimal flight activity occurred between temperatures of 48°F and 64°F, with a sharp decrease below 43°F and above 64°F. Washino, et al. (1962) studied populations of this mosquito in Kern County, California and found that small numbers of adult females persisted throughout the summer period.

Adult female mosquitoes feed primarily on large domestic mammals although populations associated with brackish marshes have been significantly pestiferous to humans within the San Francisco Estuary (Bohart and Washino 1978; Maffei, unpub.). Precipitin tests have shown that the primary hosts are cattle, sheep, horses and pigs (Bohart and Washino 1978, Edman and Downe 1964, Edman et al. 1972, Gunstream et al. 1971, Reeves and Hammon 1944, Shemanchuk et al. 1963, Tempelis 1975, Tempelis et al. 1967, Tempelis and Washino 1967, and Washino et al. 1962).

Flight range studies have found that the maximum distance traveled was 14 miles (Clarke 1943). Adults of San Francisco Bay populations tend to stay close to their larval source, usually traveling less than two miles for a blood meal. Wind and proximity of available hosts are probably important factors affecting adult dispersal and may help account for the variability observed between different populations of this mosquito.

Adults can be attracted to lights. Bay area mosquito abatement Districts monitor adult populations of this mosquito by using New Jersey light traps. Barnard and Mulla (1977) found that the trapping efficiency of New Jersey light traps could be improved by incresing the intensity of the incandescent light bulbs used from 25W to 100W.

Studies of lab colonized females by Owen (1942) found that the average life expectancy for adults was about 97 days with a maximum of 145 days. Weather conditions, specifically temperature and humidity, and availability of nutrients will affect adult longevity.

Total developmental time from egg to adult has been studied by Shelton (1973) and Mead and Conner (1987) and both found that water temperatures above 78°F were lethal to larval development. Average developmental times ranged from 48 days at 51°F to 13 days at 74°F. Shelton (1973) also noted that as water temperature increased beyond 68°F, average body weight and adult survivorship decreased markedly.

Invertebrates

Reproduction

Rees and Onishi (1951) found that adults usually do not swarm and that freshly emerged females are mated by waiting males. Copulation usually occurs end to end vertically, with the female above the male, and is completed in about 3.5 to 6.5 hours.

Groups of eggs, also known as egg rafts, are deposited directly on the water. Buxton and Breland (1952) studied the effects of temporary dessication and found that eggs were still viable after three to four days exposure in damp leaves at various temperatures. They also found that the eggs tolerated exposure to temperatures as low as 17.6°F and had a hatch rate as high as 98%. The survival of larvae hatched from eggs exposed at 17.6°F was low varying from 50% to 100% mortality following 24 and 48 hours exposure respectively.

Significance to Other Wetlands Taxa

Winter Marsh Mosquito larvae are frequently found in association with larvae of *Aedes squamiger* and the Encephalitis Mosquito, *Culex tarsalis*. The larvae of this mosquito may be a possible food source for waterfowl.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be exercised when managing, altering or restoring seasonal wetlands. Sites that pond water will produce very large numbers of adults. Care must be exercised when manipulating water levels in diked marshes. The fall flooding of these types of wetlands for waterfowl management can produce enormous numbers of adults. The proximity of human habitation or recreational facilities can be seriously affected by the biting activity of these mosquitoes.

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Brine Flies

Diptera: Ephydridae

Wesley A. Maffei

Description and Systematic Position

There are numerous species of brine flies (Diptera: Ephydridae) that can be found within the confines of the San Francisco Bay region. Three are exceptionally numerous within the bay's tidal and diked seasonal wetlands. These are: *Ephydra cinerea, Ephydra millbrae* (**Figure 3.19**), and *Lipochaeta slossonae* (**Figure 3.20**). Adults can readily be recognized by the following features: head—lacking oral vibrissae, having a swollen protruding face, and having small diverging postvertical setae; wings -with the costa broken near the subcosta and humeral crossvein, and lacking an anal cell.

Adult flies are small in size (*E. cinerea* 2-3 mm in length, *E. millbrae* 4-5 mm in length, and *L. slossonae* 2-3 mm in length) and have unpatterned wings. The coloration for each is as follows: *E. cinerea*—opaque bluish-grey with a greenish tinge and legs with knees and most tarsal segments yellow; *E. millbrae*- brownish grey with brown legs; and *L. slossonae*—whitish grey with a black-brown thoracic dorsum and legs having yellow tarsal segments.

The immature stages are small yellowish-white larvae bearing eight pairs of ventral prolegs with two or three rows of hooks. The last pair of prolegs are enlarged and have opposable hooks and the last abdominal segment bears elongate respiratory tubes with terminal spiracles. The puparium is similar in shape to the last larval stage and is generally dark yellow to brown in color (**Figure 3.21**).

Distribution

Ephydra millbrae is found throughout the San Francisco Bay Area in mid to upper marsh tidal pools that are infrequently affected by the tides. *E. cinerea*

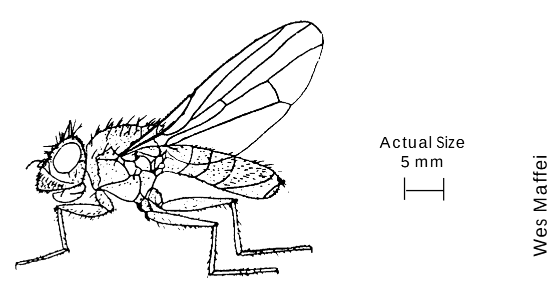


Figure 3.19 Adult *Ephydra millbrae* (Adapted from Jones (1906) and Usinger (1956))

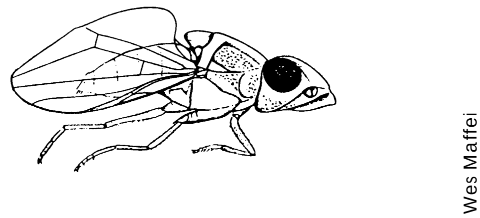


Figure 3.20 Adult *Lipochaeta slossonae* (Adapted from Jones (1906) and Usinger (1956))

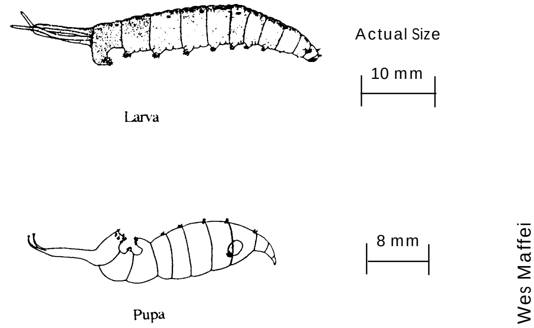


Figure 3.21 *Ephydra millbrae* Larva and Pupa (Adapted from Jones (1906) and Usinger (1956)

is closely associated with hypersaline environments, especially salt ponds of the south and north bay. *Lipochaeta slossonae* is commonly found in or near crystallizer ponds of the south bay and possibly also in salt ponds with salt concentrations somewhat above that of sea water in other parts of the San Francisco Bay region. **Figure 3.22** shows the locations around the Bay Area where brine flies have been collected, and **Table 3.6** shows the collection dates.

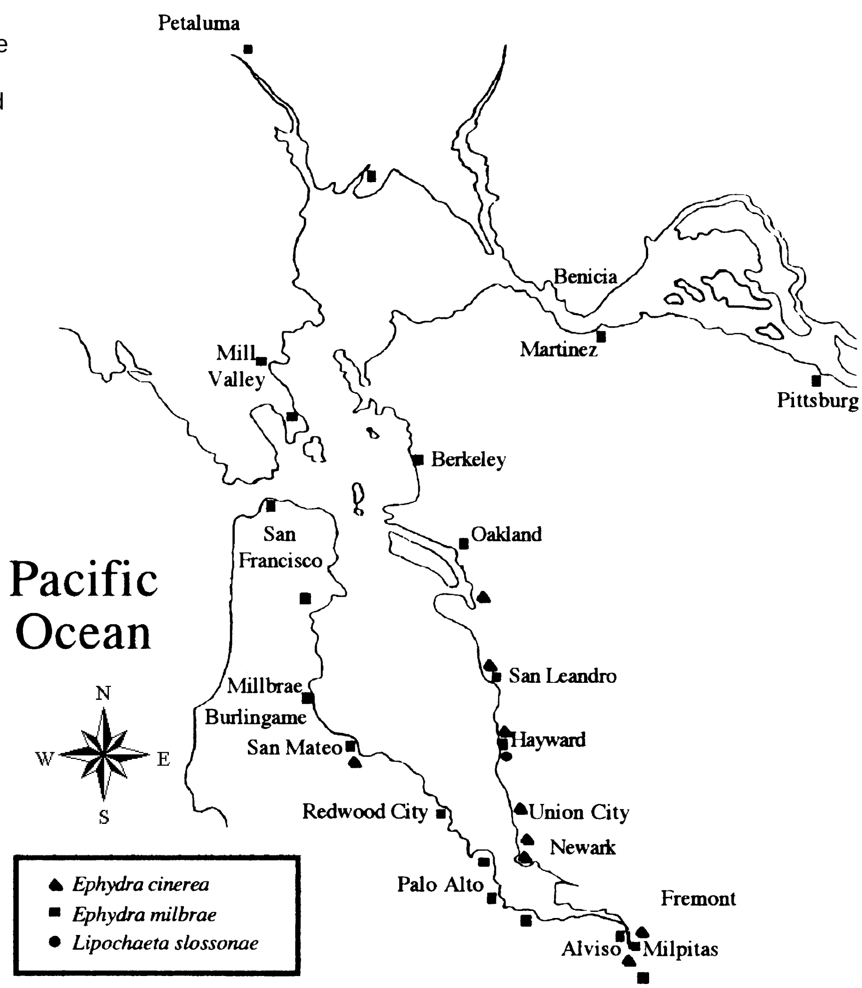
Suitable Habitat

Saline and hypersaline environments.

Biology

Simpson (1976) has summarized marine Ephydrid fly biology and a modified portion of that is presented here. Eggs are deposited in the water and hatch after one to

Figure 3.22 Known Brine Fly Localities Within San Francisco Bay Tidal and Diked Marshes



five days. The larva immediately begins feeding and will pass through three instars. First and second instar larvae shed their cuticles in order to pass on to the next larval stage. The cuticle of the last larval instar is not shed but instead forms the protective pupal covering, also known as the puparium. Adults emerge three to ten days after the onset of pupation by inflating a balloon-like ptilinum inside their heads. The ptilinum forces a circular cap off of the front of the puparium allowing the adults to emerge. Deflation of the ptilinum and attainment of normal adult coloration occurs within 0.5 to 1.5 hours. Total developmental time from deposition of eggs to emergence of adults ranges from two to five weeks.

Adults are generally reluctant to fly and when disturbed will usually fly very close to the ground for very short distances (Simpson 1976 and Wirth 1971). *Lipochaeta slossonae* adults have the peculiar habit of resting with the wings and legs held very close to the body, giving the appearance of a tube or torpedo. Should the wind cause them to lose their footing, they simply roll freely across the substrate until stopped by some object such as large salt crystals of crystallizer ponds or a spiders web. Dictynid spiders frequently build webs on crystallizer ponds collecting large numbers of these flies (Maffei, unpub.).

Precise food habits have been determined for only a few species of Ephydrids with adults of *E. cinerea* known to feed on masses of blue-green algae and the alga *Enteromorpha sp.* while *L. slossonae* utilizes various diatoms and dinoflagellates. Cheng and Lewin (1974) observed that *L. slossonae* would fluidize the silt or sandy substrate by vigorously shaking their bodies, thereby freeing some of the microorganisms upon which they feed.

Invertebrates

Table 3.6 Known Collection Sites For Brine Flies [1]

Location	Date Specimen(s) Collected
Ephydra cinerea	
Oakland (Tide Flat)	20 Jul 1937
San Leandro	19 Nov 1947
Baumberg Tract (Hayward)	25 May 1989, 2 Jun 1989, 8 Jun 1989
Fremont (Mouth of Coyote Hills Slough)	15 Jul 1976
Dumbarton Marsh	4 Jul 1968, 19 Jul 1968, 3 Aug 1968, 17 Aug 1968, 20 Aug 1968, 15 Sep 1968, 20 Sep 1968, 3 Oct 1968, 4 Nov 1968, 9 Nov 1968
Newark	13 Aug 1930
Alvarado	2 Aug 1931
Alviso (Artesian Slough)	1 Jun 1980
Alviso	2 Oct 1969, 18 Nov 1971
Milpitas	29 Nov 1974
San Mateo	3 Oct 1920, 4 Aug 1925, 10 May 1931
Lipochaeta slossonae	
Oliver Salt Ponds (Hayward)	5 Aug 1989
Baumberg Tract (Hayward)	4 Jun 1989

Location	Date Specimen(s) Collected
Ephydra millbrae	
Sears Pt. (Solano Co.)	29 Jun 1951
Mill Valley (Slough)	17 Apr 1950
Tiburon	5 Jul 1927
San Francisco	22 May 1915
Colma (Colma Creek)	5 May 1974
Millbrae	20 Mar 1908, 1 Sep 1912
San Mateo	3 Oct 1920
Foster City	20 Mar 1973
Redwood City	Apr 1923, 10 Apr 1923
Menlo Park	31 Jul 1955
Dumbarton Dr. (San Mateo Co.)	30 Dec 1947
Palo Alto	28 Jul 1894, 6 Aug 1894, 30 Jun 1915
Palo Alto (Salt Marshes)	2 Apr 1906
Mountain View	12 May 1915, 18 May 1915, 12 Jul 1924
Pittsburg	25 Nov 1923
Martinez	31 Aug 1962
Berkeley	29 Mar 1929, 26 Sep 1947
Oakland	20 Jun 1949
San Leandro	19 Nov 1947
Baumberg Tract (Hayward)	29 May 1989, 24 Feb 1990
Alviso	29 Mar 1942, 10 Apr 1969
Alviso Yacht Harbor	26 Feb 1971
Milpitas	29 Nov 1974
San Jose	21 Oct 1977

[1] Information assembled from specimens contained within the California Academy of Sciences Insect Collection, the University of California Berkeley Essig Museum, the University of California Bohart Museum, the San Jose State University Edwards Museum, the San Mateo County Mosquito Abatement District Insect Collection, and the private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

Larvae apparently feed on the same organisms as the adults (Brock, et al. 1969).

The known salinity tolerances for the different brine flies varies. Jones (1906) observed that *E. millbrae* will occur in salt water pools with salinities up to 42 ‰. *Ephydra cinerea* and *L. slossonae* seem to prefer saline environments much higher than 42 ‰ but are not entirely restricted to these hypersaline habitats (Maffei, unpub.).

Nemenz (1960) studied the ability of immature *E. cinerea* to maintain proper water balance in high saline environments and found that the larvae had a normal osmotic pressure of 20.4 atmospheres in their haemolymph. He concluded that the adaptation to highly concentrated salt solutions was partly due to a relatively impermeable cuticle and probably also to active osmotic regulation.

Reproduction

Females begin laying eggs one to two weeks after they emerge. *Ephydra cinerea* has been observed to walk down stems of aquatic vegetation or emergent objects to oviposit underwater. The other Ephydrid flies oviposit on the water surface, where the eggs quickly sink to the bottom. Jones (1906) states that the eggs of *E. millbrae* are deposited on the floating mats of its puparia. Females deposit between 10 and 60 eggs and may require up to 20 days to complete deposition of their eggs.

Significance to Other Wetlands Taxa

These insects are an important prey item of shore birds and game ducks (Martin and Uhler 1939). Feeney and Maffei (1991) observed Snowy Plovers and Maffei (unpub.) observed California Gulls, Black Necked Stilts and American Avocets charging through large assemblages of brine flies catching disturbed adults as they attempted to fly away. Murie and Bruce (1935) have observed populations of the Western Sandpiper, *Calidris mauri*, feeding on Brine Flies near the Dumbarton bridge. Anderson (1970) found Lesser Scaups, Dunlins, Avocets, Western Sandpipers and Northern Phalaropes feeding on *Ephydra cinerea* in the salt ponds of southern Alameda County.

These flies are a common prey item of spiders, especially the Dictynidae and Salticidae. The tiger beetle, *Cicindela senilis senilis*, will catch these flies, and the adults of the Anthicid beetle, *Tanarthrus occidentalis*, utilizes the carcasses of these flies as a food source.

Conservation Needs and Limiting Factors

Ephydra cinerea seems to prefer the hypersaline environs of salt ponds and has shown poor ability to adapt to the tidal pools of mid elevation tidal marshes. The larvae of this fly are also easily out competed by *E. millbrae* in salt marsh tidal pools.

The frequency of flooding and duration of flooding or drying periods limits the reproductive success of *E. millbrae*.

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Jamieson's Compsocryptus Wasp

Compsocryptus jamiesoni Nolfo

Wesley A. Maffei

Description and Systematic Position

Compsocryptus jamiesoni is a moderate sized wasp, approximately 15-25mm in length, that belongs to the family Ichneumonidae, tribe Mesostenini. Overall body ground color is rusty red-brown with the middle of the face, vertex and occiput of the head, apical third of the antennae, and the thoracic sutural markings black. The wings are light brownish-yellow with three dark brown transverse bands, the apical pair of bands merging near the posterior margin of the wing (**Figure 3.23**). Females have an ovipositor measuring approximately 6mm in length and the base of the third abdominal tergite black. Nolfo (1982) has indicated that this wasp is very similar to both *Compsocryptus calipterus brevicornis* and *Compsocryptus aridus*, which have been found within the confines of the San Francisco Bay Region exclusive of its salt marshes. Males of this wasp are very similar to *Compsocryptus calipterus brevicornis* but can readily be separated by the absence of any dark markings on the apex of the hind femur. Females are similar to *Compsocryptus aridus* but differ in having the body color rusty red-brown rather than brownish-yellow and the dark markings of the wings broader.

Distribution

This wasp was first collected in 1981 and subsequently described as a new taxon by Nolfo in 1982 from specimens collected at the salt marshes in Alviso, Santa Clara County, California. Additional populations have been identified from the salt marshes of the eastern San Francisco Bay as far north as San Leandro, California (Maffei, unpub.). Surveys for this wasp from other parts of the San Francisco Estuary have not been done at this time. **Figure 3.24** shows the locations around the Bay Area where *Compsocryptus jamiesoni* have been collected, and **Table 3.7** shows the collection dates.

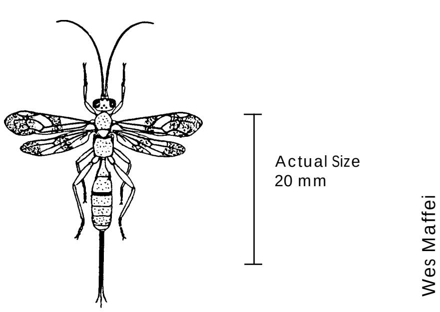

Figure 3.23 Jamieson's Compsocryptus Wasp – *Compsocryptus jamiesoni*

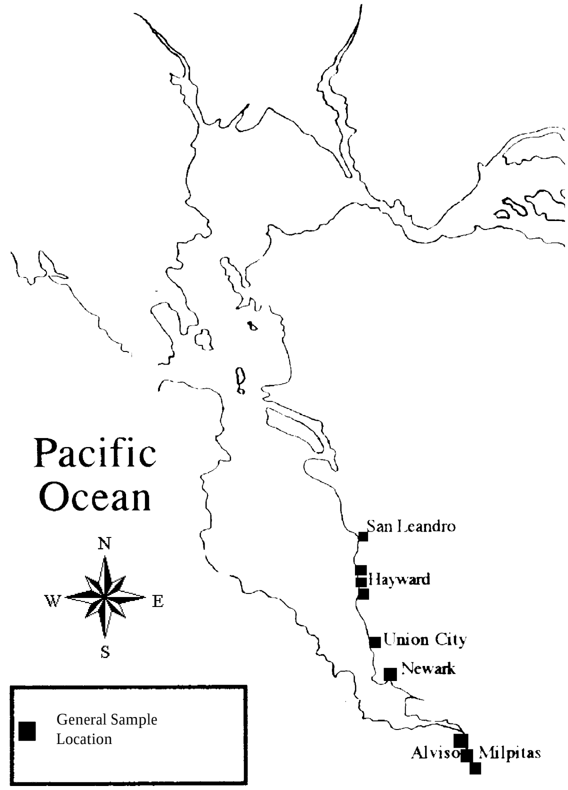

Figure 3.24 Known *Compsocryptus jamiesoni* Localities Within San Francisco Bay Tidal and Diked Marshes

Suitable Habitat

Compsocryptus jamiesoni have only been found on short grass or herbage in or near tidal and muted tidal marshes.

Table 3.7 Known Collection Sites For *Compsocryptus jamiesoni* [1]

Location	Date Specimen(s) Collected
Trojan Marsh (San Leandro)	11 Sep 1997
Oliver Salt Ponds (Hayward)	23 Sep 1989
Baumberg Tract (Hayward)	4 Jun 1989
Shoreline Int. Ctr. (Hwyd)	1 Jul 1990, 2 Jul 1990
Ecology Marsh	24 Aug 1994
Hetch-Hetchy Marsh	16 Jul 1997
Alviso (Triangle Marsh)	3 Jun 1980
Santa Clara (Topotype)	2 Sep 1928
San Jose (Topotype)	16 Aug 1982

1 Information assembled from specimens contained within the California Academy of Sciences Insect Collection, University of California Berkeley Essig Museum, University of California Bohart Museum, San Jose State University Edwards Museum, San Mateo County Mosquito Abatement District Insect Collection, and private collections of Dr. J. Gordon Edwards and Wesley A. Maffei.

Biology

Little is known concerning the biology of this wasp. Other members of the tribe Mesostenini are known to be parasitic in cocoons of lepidoptera and other ichneumonids, puparia of diptera and other wasps, and the egg sacs of spiders (Townes 1962). Adults regularly utilize dew or rainwater from foliage and nectar from flowers when available and can be found from April through October. The peak flight period for *C. jamiesoni* is June through August (Maffei, unpub.).

Reproduction

Unknown.

Significance to Other Wetlands Taxa

Unknown.

Conservation Needs and Limiting Factors

Unknown.

References

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Invertebrates

A Note on Invertebrate Populations of the San Francisco Estuary

Wesley A. Maffei

The study of San Francisco Bay invertebrate populations and their interrelationships has usually been given low priority or altogether neglected during the planning and implementation of enhancement or restoration projects. Environmental assessments of habitat quality and health have frequently forgotten about the terrestrial or semi-aquatic invertebrates that are usually very sensitive to environmental changes. Arthropods, especially insects, are sensitive indicators of environmental disturbance or change (Lenhard and Witter 1977, Hellawell 1978, Hawkes 1979).

A survey of the literature shows that few studies have been done on the biology and ecology of the terrestrial and semi-aquatic invertebrates within the San Francisco Estuary. What is known about these organisms generally comes from studies of invertebrate populations well outside of this geographic area. For many of the common species, this is probably adequate. Unfortunately, little information exists about what species are found within the different wetland habitats, and less still is known about the impacts of wetlands projects on the existing invertebrate populations. Those species that are pests (i.e., mosquitoes) are fairly well known, while taxa such as Jamieson's compsocryptus wasp or the western tanarthrus beetle, which were described as new to science within the last twenty years, have poorly known or completely unknown biologies. This lack of basic information, specifically what species exist where, coupled with an understanding of their basic biologies, warrants careful consideration and research. The fact that unknown populations of organisms, or unique, sensitive, or threatened and endangered taxa do exist within or near the tidal reaches of the Bay suggests that more care should be taken when planning enhancement or restoration projects. The relationship of some invertebrate species to the success of other organisms (i.e. plants or invertebrates) needs to be clarified.

Some invertebrates are known to play a significant role in the life cycles of other organisms. Functioning as pollinators, herbivores, scavengers, predators, and prey, terrestrial and semi-aquatic invertebrates are a significant component of any habitat or community. It became apparent through the course of the Goals Project that the experts on many of the key species of fish and wildlife were not always clear about the roles played by invertebrates with respect to the survival of their target species or communities. This prompted the construction of some graphic displays, in this case food webs, by which to illustrate what little is known about the roles performed by the largest and most easily overlooked group of organisms in our estuary, the invertebrates.

Food webs are frequently used to illustrate the complex relationships between organisms within a given area or habitat. Unfortunately, they cannot hope to tell the entire story. Factors such as the seasonality of the organisms, length of time and time of year the studies were performed, the limited number of organisms that can be included in the web, and the complexity of the habitat or ecosystem being studied tend to result in webs that over generalize what actually exists or has been observed.

The following sample invertebrate webs are undoubtedly incomplete. They have been assembled from many hours of field observation in the southern portion of the San Francisco Estuary, and from an exhaustive search of the literature. The most notable feature of all of these webs is the delicate relationships that exist between all of the organisms involved. The potential reduction or loss of one member of the web clearly illustrates how its associates could be impacted. It should be noted that not all of the organisms that have been found or studied are represented. The organisms included in these webs are those routinely found in association with the plant or plants that are indicated by the boxes with the thickened black borders. **Figures 3.25**, **3.26**, and **3.27** are examples of partial webs developed to illustrate the relationship of some of the organisms associated with the plant species alkali heath (*Frankenia salina*), common pickleweed (*Salicornia virginica*), and willow (*Salix lasiolepis*), respectively. **Figures 3.28** and **3.29** are examples of partial webs that illustrate the relationships of organisms within mid-marsh pans and crystallizer pond habitats. The web for the organisms associated with old crystallizer ponds was included to illustrate that even in this inhospitable habitat, webs of life can and do exist. When known vertebrate relationships for most of the webs have been included. **Table 3.8** is a brief summary of the descriptions and biologies of some of the invertebrates from the alkali heath web. **Table 3.9** is a listing of the scientific names associated with a major common name category. It is hoped that these tables might help the reader better visualize the nature of the relationships shown for the different organisms included in the webs.

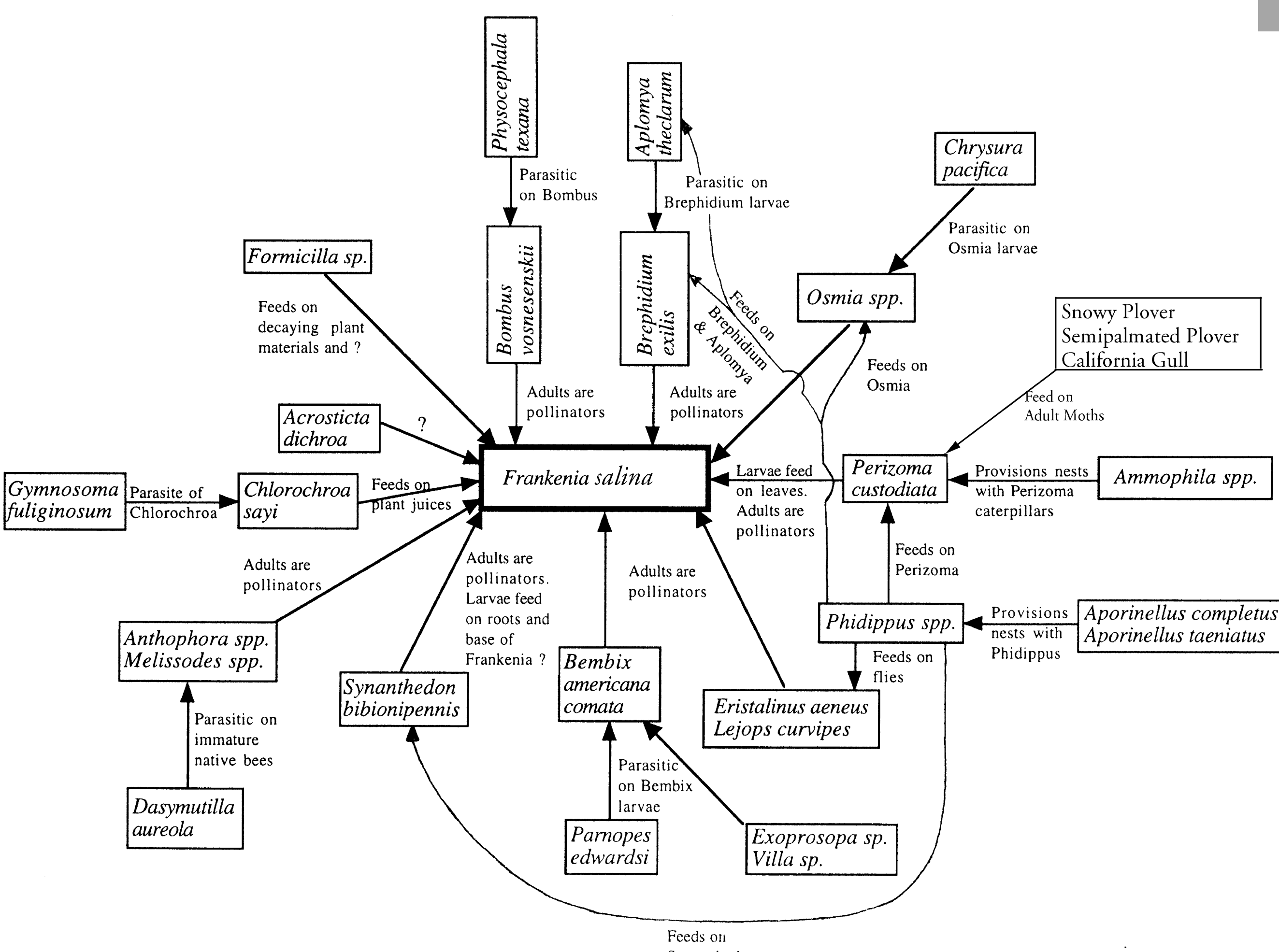

Figure 3.25 A Partial Web of the Organisms Associated With Alkali Heath (*Frankenia salina*) in San Francisco Tidal Marshes

Table 3.8 Partial Summary of Organisms Associated with Alkali Heath.

Bees and Wasps

Bombus vosnesenskii – A moderate to large sized bumblebee that is mostly black with a small amount of yellow on the thorax and posterior portion of the abdomen. Adults tend to nest in abandoned rodent burrows along levees and adjacent upland habitat.

***Anthophora* spp.** – A moderate sized native bee, belonging to the family *Anthophoridae*, that is light brown to grayish brown in appearance and has long antennae. Adults collect pollen from flowers, are solitary, and dig fairly deep burrows in the ground. Burrows are usually lined with a waxy substance. Frequently visited plants are *Brassica* spp., *Frankenia* sp. and hemlock.

***Melissodes* spp.** – A small to moderate sized native bee, belonging to the family *Anthophoridae*, which is grayish in color. Pollen collecting habits are similar to *Anthophora* spp.

***Osmia* spp.** – A bluish–black bee with smoky colored wings, that belongs to the family of bees known as leaf cutting bees, or *Megachilidae*. This genus of bees is commonly known as mason bees because of their habit of building small earthen cells on or under stones, in abandoned burrows, in holes in boards, twigs and logs, and in plant galls.

***Ammophila* spp.** – A long, slender solitary digger wasp belonging to the family *Sphecidae*. These wasps build simple, vertical burrows, that are provisioned with moth caterpillars. Nests usually occur in fine, silty or sandy soil with minimal vegetation.

Aporinellus completus and ***Aporinellus taeniatus*** – Small black spider wasps (family *Pompilidae*) that provision their nests with jumping spiders (genus *Phidippus*).

Chrysura pacifica – A small iridescent bluish–purple to bluish–green wasp, measuring up to 10mm in length. This wasp parasitizes the leaf cutting bee *Osmia*.

Parnopes edwardsi – A moderate sized brilliant light green wasp, measuring about 10–13mm, that parasitizes the sand wasp *Bembix americana*.

Bembix americana – A large sand wasp that is bluish gray in color with pale white markings on the abdomen. The eyes are usually bright yellow to yellowish–green in color. Adult wasps provision their ground nests with adult flies.

Dasymutilla aureola – A golden yellow to bright orange insect known as a velvet ant. These insects are not closely related to ants but do have the appearance of looking like an ant. Velvet ants provision their burrows with ground nesting bees and wasps.

Beetles

***Formicilla* sp.** – A very small, brown to tan colored beetle, known as an Ant–like flower beetle. These beetles are known to feed on decaying vegetation and can sometimes be very common at the bases of *Frankenia* sp.

Stink Bugs

Chlorochroa sayi – A moderately sized (one–half inch) stink bug that is pale to deep green in color. This insect is known for releasing a foul smelling odor when disturbed or threatened.

Butterflies and Moths

Perizoma custodiata – A moderate sized moth belonging to the family of moths known as measuring worms, or *Geometridae*. Adults are tan gray or brown in color and have dark geometric bands across the forewings. Larvae are about one inch long, light green in color and feed on the leaves of *Frankenia*. Adults are present throughout the year, with peak populations occurring from spring through fall.

Brephidium exilis – A very small brown and blue butterfly that is a frequent visitor of *Frankenia*.

Synanthedon bibionipennis – A small moth, belonging to the family of moths known as clear wing moths, or *Sesiidae*. Adults emerge in late May to early June and can be found through late September. These insects are frequently associated with *Frankenia* sp. It is believed that the larvae may feed on the roots and the bases of *Frankenia* sp. plants. Currently, this is the only clear wing moth known to inhabit the levees of mid to upper tidal marshes within the San Francisco Estuary.

Flies

Gymnosoma fuliginosum – A small, bright orange and black fly that is parasitic on the green stink bug, *Chlorochroa sayi*.

Physocephala texana – A bright red and black fly, about one–half an inch long, that parasitizes the bumblebee *Bombus vosnesenskii*.

Aplomya theclarum – A very tiny black fly, with a bright silver face, that parasitizes the larvae of the pygmy blue butterfly.

Acrosticta dichroa – A small, bright green and red fly with one brown spot at the tips of the wings. This fly is frequently seen walking up and down the stems of *Frankenia* holding it's wings outstretched and rotating them in opposite directions. Biology unknown.

***Exoprosopa* spp.** and ***Villa* spp.** – Small to moderate sized, fuzzy looking flies that are commonly known as bee flies. *Villa* spp. is light brown in color with clear wings and *Exoprosopa* spp. is brown and white banded with brightly patterned brown and clear wings. Both species of flies are parasites of immature sand wasps of the genus *Bembix*.

Eristalinus aeneus –A moderate sized, shiny olive green fly that is commonly known as a hover fly or flower fly. The larvae of this fly are known as rat–tailed maggots and are found in somewhat saline or brackish pools of tidal marshes. Adult flies are an important food source for *Bembix* sand wasps and spiders.

Lejops curvipes – A moderate sized flower fly, measuring about 10–15mm, that is bright reddish–orange, with a central black stripe on the abdomen and mostly black legs.

Spiders

***Phidippus* spp.** – Two species are common within our marshes. One is solid black with the top of the abdomen bright red and can reach a size up to one–third of an inch. The other is dark gray with variegated white lines and reaches a size of about a quarter of an inch.

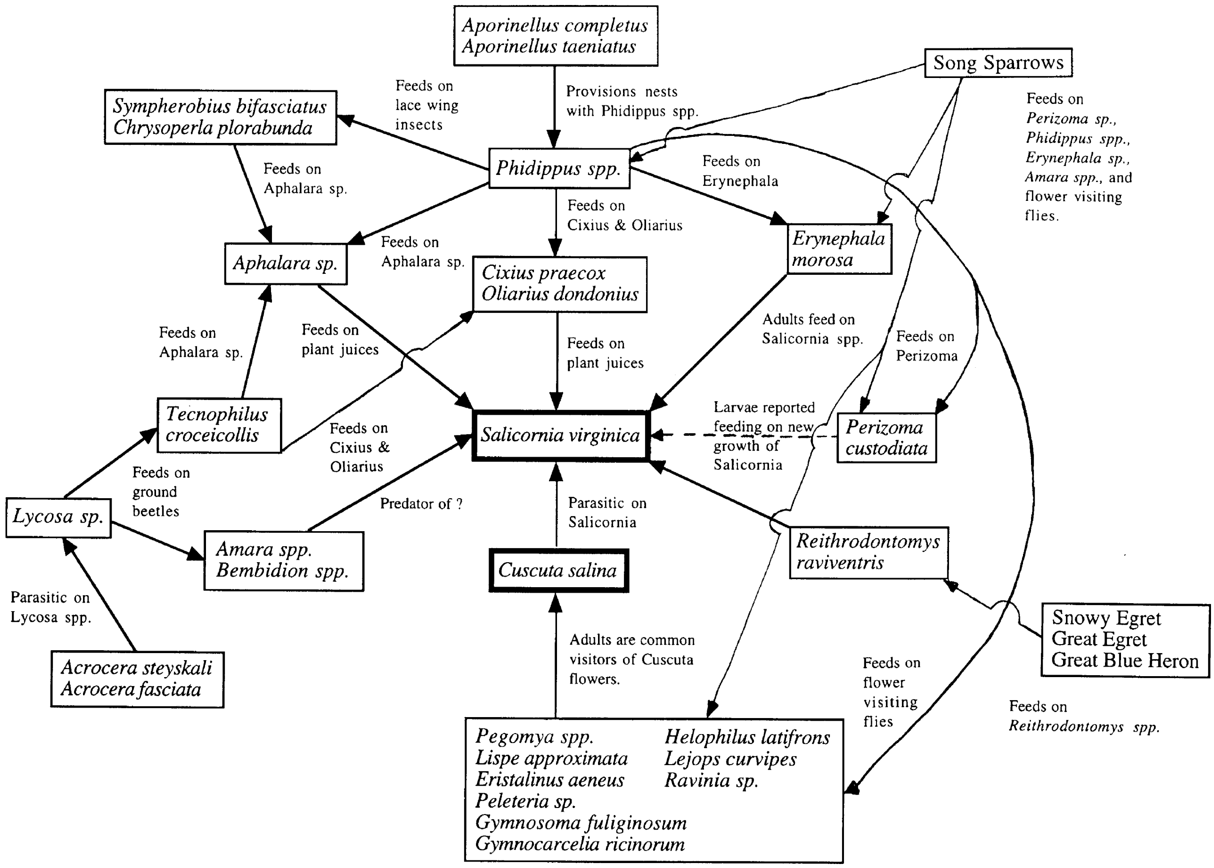

Figure 3.26 A Partial Web of the Organisms Associated With Common Pickleweed (*Salicornia virginica)* in San Francisco Bay Lower High Tidal Marshes

The need for terrestrial invertebrate surveys has become more apparent with the increase in wetland enhancement and restoration projects. The conversion of one habitat type to another "more valuable" or "more improved" habitat type can and usually does have significant impacts on the often-unnoticed invertebrate populations that exist within them. In some cases these impacts can be positive, while in other instances the opposite is true. **Table 3.10** lists by site and date(s) those known terrestrial and semi-aquatic invertebrate surveys or species studies.

It is hoped that these preliminary illustrations and discussions will shed a small amount of light on the complexity of the commonly overlooked micro fauna that exists within the tidal and diked habitats of our estuary. It is further hoped that this glimpse might stimulate others to investigate further the biology and ecology of the terrestrial micro fauna within these habitats. We must improve our understanding of the importance of invertebrates to the survival of the other bayland organisms if we are to make better-informed decisions about the future of habitats and organisms of the San Francisco Bay.

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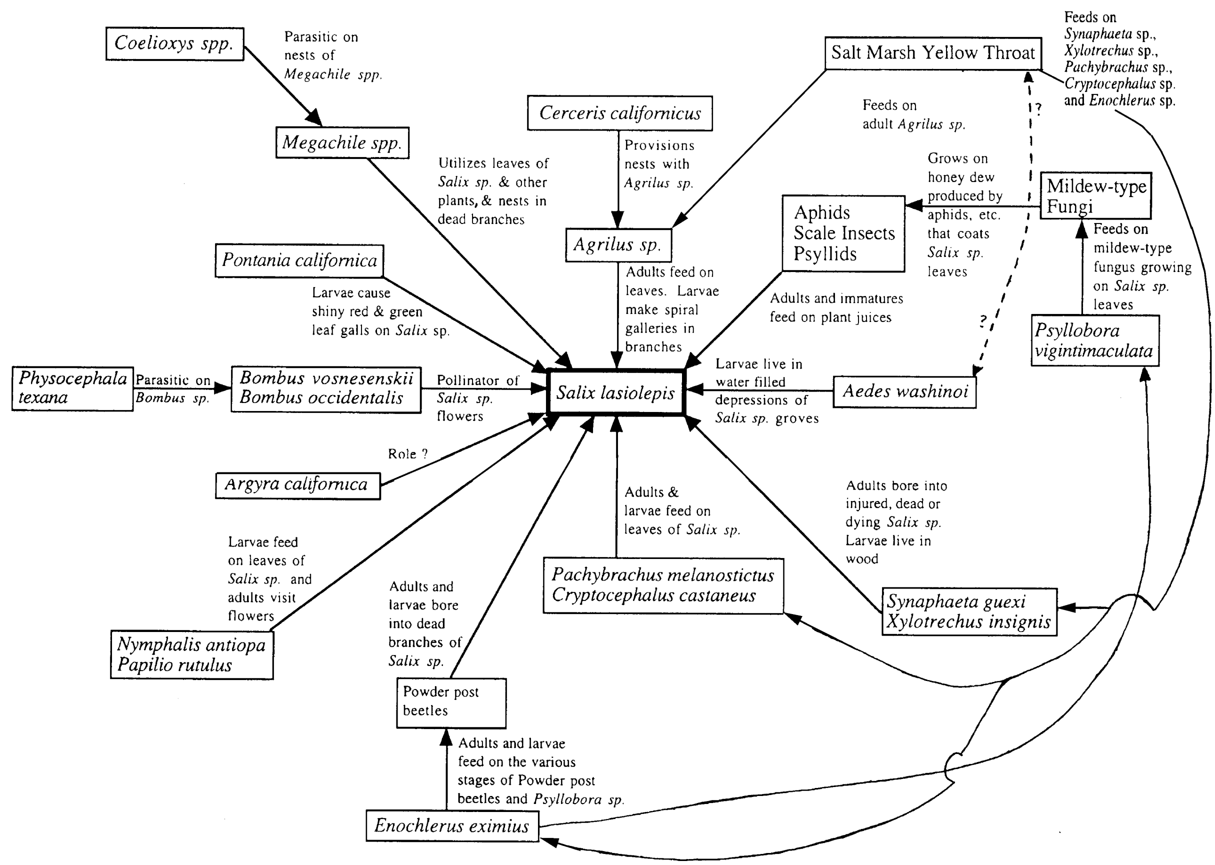

Figure 3.27 A Partial Web of the Organisms Associated With Willow (*Salix lasiolepis*)

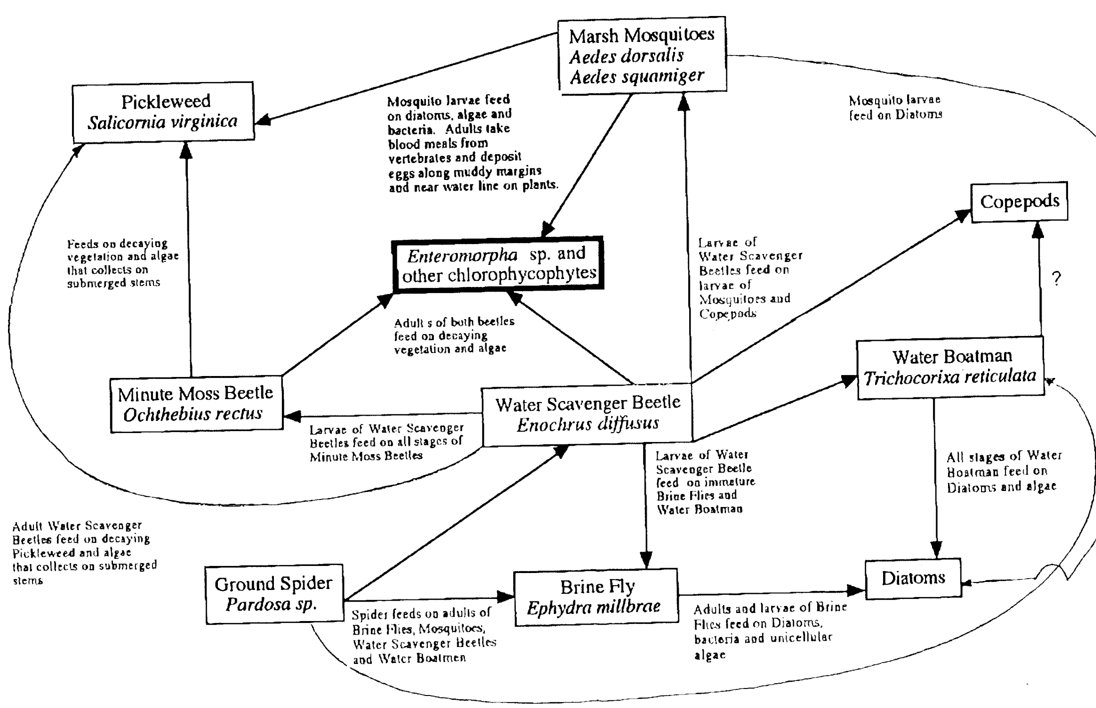

Figure 3.28 Partial Web of Organisms Associated With Mid-Tidal Marsh Pans

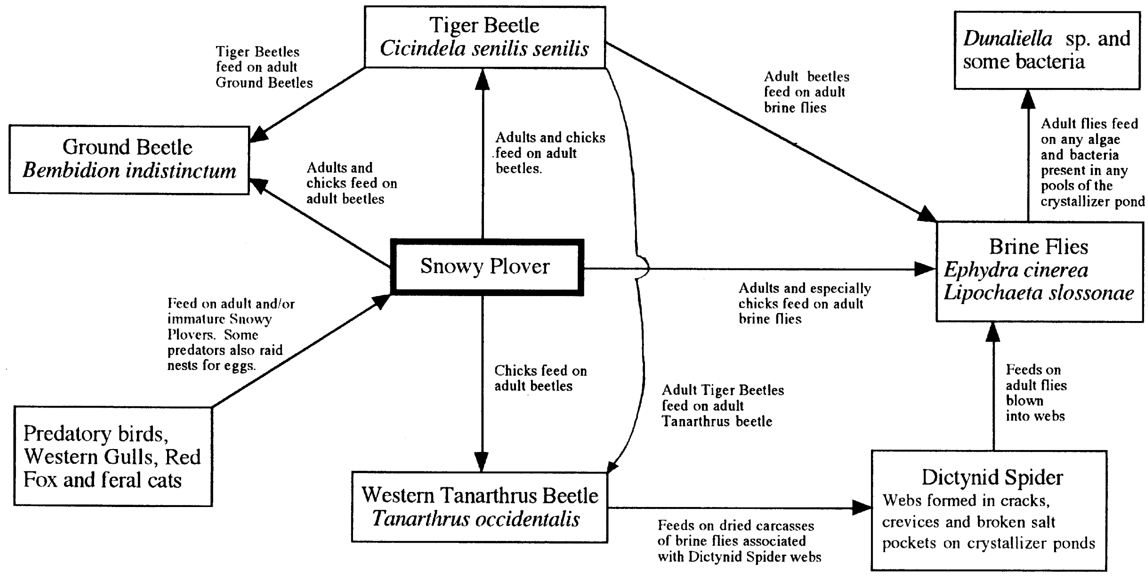

Figure 3.29 A Partial Web of the Organisms in the Baumberg and Oliver Brothers Salt Crystallizer Ponds, Hayward, California

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Table 3.9 Food Web Taxa by Major Common Name Category

Butterflies and Moths
Brephidium exilis
Nymphalis antiopa
Papilio rutulus
Perizoma custodiata
Synanthedon bibionipennis

Hoppers and Psyllids
Aphalara sp.
Aphids
Cixius praecox
Oliarius dondonius
Psyllids
Scale Insects

Flies
Acrocera steyskali
Acrocera fasciata
Acrosticta dichroa
Aedes dorsalis
Aedes squamiger
Aedes washinoi
Aplomya theclarum
Argyra californica
Ephydra millbrae
Eristalinus aeneus
Exoprosopa spp.
Gymnocarcelia ricinorum
Gymnosoma fuliginosum
Helophilus latifrons
Lejops curvipes
Lipochaeta slossonae
Lispe approximata
Pegomya spp.
Peleteria sp.
Physocephala texana
Ravinia sp.
Villa spp.

Beetles
Agrilus sp.
Amara spp.
Bembidion spp.
Cicindela senilis senilis
Cryptocephalus castaneus
Enochlerus eximius
Enochrus diffusus
Erynephala morosa
Formicilla spp.
Ochthebius rectus
Pachybrachus melanostictus
Powder post Beetles
Psyllobora vigintimaculata
Synaphaeta guexi
Tanarthrus occidentails
Tecnophilus croceicollis
Xylotrechus insignis

Ants, Wasps and Bees
Ammophila spp.
Anthophora spp.
Aporinellus completus
Aporinellus taeniatus
Bembix americana comata
Bombus vosnesenskii
Bombus occidentalis
Cerceris californicus
Chrysura pacifica
Coelioxys spp.
Dasymutilla aureola
Megachile spp.
Melissodes spp.
Osmia spp.
Parnopes edwardsi
Pontania californica

Bugs
Chlorochroa sayi
Trichocorixa reticulata

Lacewings
Chrysoperla plorabunda
Sympherobius bifasciatus

Spiders
Dictynid Spider
Lycosa spp.
Pardosa sp.
Phidippus spp.

Birds
Great Blue Heron
Great Egret
Salt Marsh Yellow Throat
Snowy Egret
Snowy Plover
Song Sparrows
Western Gull

Mammals
Feral Cat
Red Fox
Reithrodontomys raviventris

Plants
Cuscuta salina
Dunaliella sp.
Enteromorpha sp.
Frankenia salina (= *grandifolia*)
Salicornia virginica
Salix lasiolepis

Fungi
Mildew type fungus

Fowler, B.H. 1977. Biology and life history of the salt marsh snail, *Assiminea californica*, (Tryon, 1865) (Mesogastropoda: Rissoacea). Unpubl. M.A. thesis, San Jose State Univ., San Jose, Calif. 143 pp.

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Table 3.10 Known Terrestrial or Semi-aquatic Invertebrate Surveys or Studies of Selected Invertebrate Taxa[1]

Locale	Date of Study	Reference(s)
Alviso Salt Ponds, Charlston to Alviso Slough	1951-1952	L.H. Carpelan (1957)
Outer Coyote Creek Tributary	1980	J. Anderson, et. al. (1980)
Warm Springs Seasonal Wetlands, Fremont	1993	T. Caires, et. al. (1993)
	1995	W. Maffei, (unpub. field notes)
Dumbarton Point Marsh, Fremont	1968	R.S. Lane (1969)
Coyote Hills Marsh, Fremont	1983-1984	E.A. Bergey, et. al. (1992)
Ecology Marsh, Fremont	1994	C. Daehler and D. Strong (1995)
	1996-1996	W. Maffei (unpub. field notes)
Baumberg and Oliver Salt Ponds	1989-1990	L. Feeney and W. Maffei (1991)
	1997-1997	W. Maffei (unpub. field notes)
Oakland Airport, Burrowing Owl Mitigation Area	1995	L. Feeney, et al.. (1996)
Richmond Field Station	1992-1994	J.A. Powell (unpub. Paper, 1994)
Petaluma Marsh	1977-1978	S. Balling and V. Resh (1991, 1982) M. Barnby and V. Resh (1980) V. Resh and S. Balling (1983)
	1980-1980	S. Balling and V. Resh (1984)
	1979	S. Balling (1982)
	1981-1981	M. Barnby (1985)
Cullinan Ranch, USGS Survey	1995(?)	M. Paquin (unpub.)
Suisun Marsh, Between Cutoff and Suisun Sloughs	1978-1979	S. Balling (1982) S. Balling and V. Resh (1982) V. Resh and S. Balling (1983)
Suisun Marsh	1972-1973	A.M. Shapiro (1975a, b, 1974)

[1] The studies shown pertain primarily to insects and arachnids and do not include the numerous biological studies on mosquitoes.

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4

Amphibians and Reptiles

California Tiger Salamander

Ambystoma californiense

Mark R. Jennings

General Information

The California tiger salamander (Family: Ambystomatidae) is a large (75-125 mm SVL) terrestrial salamander with several white or yellow spots or bars on a jet-black field (Stebbins 1985). Although often referred to as a subspecies of the more widespread tiger salamander (*A. tigrinum*; e.g., see Frost 1985, Stebbins 1985, Zeiner et al. 1988), the California tiger salamander is currently recognized as a full species (Jones 1989, Shaffer et al. 1993, Barry and Shaffer 1994). In 1992, the California tiger salamander was petitioned for listing as an endangered species (Long 1992) based on concerns about population declines due to the extensive loss of habitat, introductions of non-native aquatic predators, and interbreeding with introduced salamanders originally brought in as live fish bait (Long 1992; see also Jennings and Hayes 1994). The U.S. Fish and Wildlife Service ruled that the petition was warranted but precluded by pending listing actions on higher priority species (Sorensen 1994).

Reproduction

Most adults probably reach sexual maturity in two years, but some individuals may take longer during periods of unfavorable conditions such as annual droughts (Shaffer et al. 1993). Adults migrate during the night from subterranean refuge sites (small mammal burrows) to breeding ponds after the onset of relatively warm winter rains (late November-early March) where courtship and egg deposition occurs (Twitty 1941, Barry and Shaffer 1994, Loredo and Van Vuren 1996). Males may precede females to breeding ponds (Shaffer et al. 1993, Loredo and Van Vuren 1996) and distances travelled by adults from refuge sites to breeding sites may be up to 1.6 km (Austin and Shaffer 1992). Females lay single or small groups of 2-4 eggs (8.5-12 mm in diameter) on detritus, submerged vegetation, or on the benthos of relatively shallow rain pools (Storer 1925). The number of eggs laid per female is unknown. During periods of low rainfall, California tiger salamanders may not reproduce (Jennings and Hayes 1994). After reproducing, adults return to subterranean refuge sites, some to the same small mammal burrows they emerged from earlier in the year (Shaffer et al. 1993).

Brad Shaffer

Growth and Development

Eggs hatch after 2-4 weeks (Storer 1925, Twitty 1941), and gilled aquatic larvae take a minimum of at least 10 weeks to successfully reach metamorphosis (Anderson 1968, Feaver 1971). Larvae lack legs upon hatching at 10.5 mm total length, but quickly grow four legs within 1-2 weeks. Larvae generally are about 75 mm in total length and weigh about 10 grams at metamorphosis into juveniles, although they may remain in water (for up to six months) and grow to much larger sizes with a better chance of survival after metamorphosis (Jennings and Hayes 1994). Overwintering of larvae, which is common with several species of *Ambystoma* (see Stebbins 1985), is unusual with *A. californiense* because of the temporary nature of its natural breeding habitat (Shaffer et al. 1993). All records of overwintering or aseasonal metamorphosis are based on salamanders in artificially-created habitats (Jennings, unpubl. data).

Upon metamorphosis (usually early May-through July), juveniles disperse in mass at night away from desiccating breeding ponds into terrestrial habitats (Zeiner et al. 1988, Loredo and Van Vuren 1996, Loredo et al. 1996). Juveniles have also been known to disperse during periods of unfavorable conditions (e.g., August) re-

Amphibians & Reptiles

sulting in mass mortality (Holland et al. 1990). Both adults and juveniles seek refuge in small mammal burrows (especially those of California ground squirrels (*Spermophilus beecheyi*) and Botta's pocket gophers (*Thomomys bottae*) [Barry and Shaffer 1994, Loredo et al. 1996]) and spend most of the year underground until the onset of cooler and wetter surface conditions (Jennings and Hayes 1994). Juveniles probably feed on invertebrates in subterranean mammal burrows and grow throughout the year. During the winter months however, both juveniles and adults emerge from burrows and forage at night on the surface for extended periods of time, although adults appear to do all their foraging after completing their reproductive activities (Shaffer et al. 1993).

California tiger salamanders are relatively long-lived animals, reaching ages of 20 years or more in captivity (Jennings, unpubl. data). The average life span of adults in the wild is unknown.

Food and Feeding

Larval California tiger salamanders subsist on aquatic invertebrates (Oligochaetes, Cladocera, Conchostraca, Ostracoda, Anostraca, Notostraca, Chironomids, *etc.*), as well as the larvae of western spadefoots (*Scaphiopus hammondii*), California toads (*Bufo boreas halophilus*), and Pacific treefrogs (*Hyla regilla*), if the latter are present in breeding ponds (Anderson 1968; Feaver 1971; Jennings, unpubl. data). Larval salamanders are also highly cannibalistic (Jennings, unpubl. data). Good numbers of food organisms in breeding ponds appear to be important for the survival and rapid growth of salamander larvae to metamorphosis (Jennings, unpubl. data).

Juvenile and adult salamanders subsist on terrestrial invertebrates (Oligochaetes, Isopoda, Orthoptera, Coleoptera, Diptera, Araneida, Gastropoda, *etc.*; Stebbins 1972; Morey and Guinn 1992; Jennings, unpubl. data). There is no evidence of adult salamanders feeding in aquatic environments (Jennings, unpubl. data).

Distribution

The historical distribution of the California tiger salamander ranged from the vicinity of Petaluma, Sonoma County and Dunnigan, Colusa-Yolo County line (Storer 1925) with an isolated outpost north of the Sutter Buttes at Gray Lodge, Butte County (Hayes and Cliff 1982) in Central Valley, south to vernal pools in northwest Tulare County, and in the South Coast Range south to ponds and vernal pools between Bulleton and Lompoc in the Santa Ynez drainage, Santa Barbara County (Jennings and Hayes 1994). The known elevational range extends from 3 m-1054 m (Shaffer et al. 1993). The species has disappeared from about 55% of its historic range (Jennings and Hayes 1994).

In the Bay Area, California tiger salamanders have disappeared from almost all of the lower elevation areas (<50 m), save one small site on the San Francisco Wildlife Refuge near Fremont, Alameda County (Jennings, unpubl. data). There are scattered populations currently inhabiting vernal pool and stockpond habitats in hills surrounding the South Bay (Jennings, unpubl. data), to the nort of Coyote Hills in Suisun, and in northern Contra Costa. A group of relict populations is also present in the North Bay region in vernal pool habitats near Petaluma (Shaffer et al. 1993) (**Figure 4.1**).

Current Status and Factors Influencing Population Numbers

Based on the data presented in Shaffer et al. (1993) and Jennings and Hayes (1994), California tiger salamanders appear to have disappeared from approximately 58% and 55% (respectively), of their historic range in the state (Sorensen 1994). This salamander is most affected by land use patterns and other anthropogenic events which fragment habitat and create barriers between breeding and refuge sites (Jennings and Hayes 1994). Some of the more important factors negatively influencing salamander populations include: conversion and isolation of vernal pool habitats (and surrounding oak woodland and grasslands) to agriculture and urbanization (Barry and Shaffer 1994); lowering of the groundwater table by

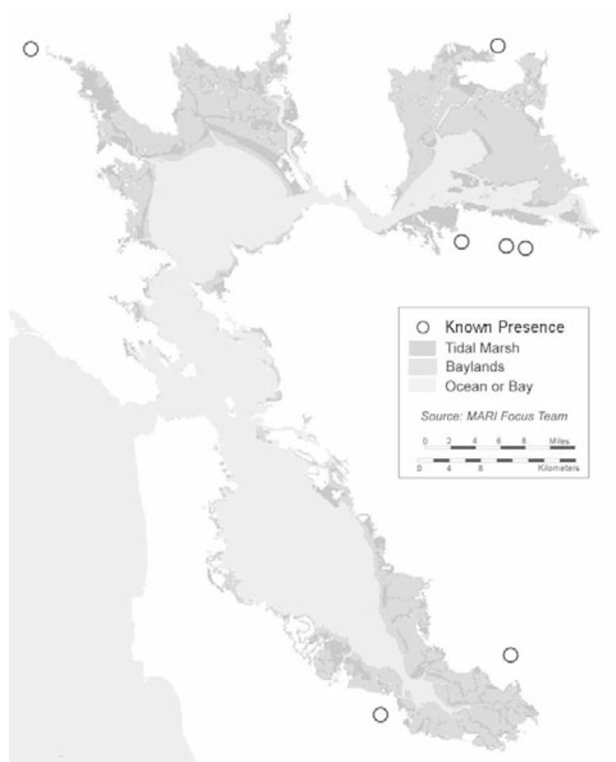

Figure 4.1 California Tiger Salamander – Some Current Locations

overdraft (Jennings and Hayes 1994); mortality of juvenile and adult salamanders by vehicles on roads (Twitty 1941); the introduction of non-native predators such as mosquitofish (*Gambusia affinis*), bullfrogs (*Rana catesbeiana*) and crayfish (specifically *Procambarus clarkii*) into breeding habitats (Shaffer et al. 1993); the widespread poisoning of California ground squirrels and other burrowing rodents (Loredo et al. 1996); and interbreeding with introduced salamanders originally brought in as live fish bait (Shaffer et al. 1993). Juvenile and adult salamanders have also been found in a number of human-created habitats such as septic tank lines, pipes, wells, wet basements, and permanent irrigation ponds (Jennings and Hayes 1994). Such habitats may not be suitable for the long-term survival or successful reproduction of local salamander populations.

Trophic Levels

Larval and post-metamorphic life stages are secondary consumers.

Proximal Species

Predators: Common [=San Francisco] garter snake, Coast garter snake, Central Coast garter snake, California red-legged frog, bullfrog, shrews, striped skunk, opossum, herons, and egrets. Ducks and predacious aquatic insects prey on larvae only.
Prey: Oligochaetes, snails, and terrestrial insects. Zooplankton and aquatic insects are prey for larvae.
Habitat: California ground squirrel and valley pocket gopher (maintain tiger salamander's terrestrial habitats)

Good Habitat

The best habitats for California tiger salamanders are vernal pool complexes with colonies of California ground squirrels or Botta's pocket gophers within the complex or nearby (Shaffer et al. 1993). Such habitats are normally associated with grasslands or oak woodlands (Barry and Shaffer 1994). Additionally, there needs to be abundant invertebrate resources and other native amphibian larvae in the vernal pools used by breeding salamanders.

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California Toad

Bufo boreas halophilus

Mark R. Jennings

General Information

The California toad (Family: Bufonidae) is a moderate-sized (62-125 mm SUL) toad with prominent oval parotoid glands and a light middorsal stripe (Stebbins 1985). Dorsal coloration is normally dusky, gray, or greenish, with warts set in black patches (Storer 1925). Natural intergrades with boreal toads (*B. b. boreas*) in northern California and hybrids with Yosemite toads (*B. canorus*) in the Sierra Nevada have been recorded (Storer 1925, Karlstrom 1962).


Rick Fridell

Reproduction

California toads breed between January and July with higher altitude populations delaying breeding until June or July (Storer 1925). At lower elevations, toads are active all year, but at higher elevations adults emerge from hibernation sites immediately before reproducing (Stebbins 1951). Males and females congregate at night around aquatic breeding sites such as stockponds, temporary roadside pools, cement water reservoirs, and the margins of flowing streams where males call, amplexus occurs, and females lay up to 16,500 eggs in two long strings wrapped around vegetation at water depths <150 mm (Storer 1925, Livezey and Wright 1947). Eggs strings are about 5 mm in diameter and the inclusive eggs 1.7 mm in diameter (Storer 1925). After reproducing, adults generally disperse back into the surrounding terrestrial habitats such as meadows and woodlands where they use almost any sort of cover (e.g., trees, low vegetation, beds of leaves, small mammal burrows, rocks, pieces of concrete, downed logs, etc.) that provides a slight amount of moisture and protection from the drying effects of the sun and wind (Storer 1925).

Growth and Development

Eggs hatch within four days to a few weeks (depending on the prevailing water temperature; Storer 1914) and the resulting larvae normally comprise schools composed of one or more clutches (Jennings, unpubl. data). Larvae grow rapidly and usually metamorphose in 2-3 months (from April-August) at 19-52 mm (Storer 1925, Wright and Wright 1949). Recent metamorphs are 12-15 mm in total length (Wright and Wright 1949) and are often observed around the immediate margin of the breeding pond under any cover that protects them from the wind and sun (Storer 1925). The number of newly metamorphosed toads at such breeding sites can number in the thousands (Storer 1925). Young toads grow rapidly and probably reach sexual maturity in two years at lower elevations and somewhat longer at mid-higher elevations (Stebbins 1951). Both juveniles and adults are largely crepuscular, although an occasional individual will be observed during the day in wet or overcast conditions (Storer 1925).

Adults may live 10 years or more in captivity (Bowler 1977) but the longevity of toads in the wild is unknown.

Food and Feeding

Larvae are thought to be algal grazers (Stebbins 1951), but the foraging ecology of larval California toads is unknown. Juveniles and adults feed on a wide variety of terrestrial and flying invertebrates including: Oligochaetes, Isopoda, Diplopoda, Orthoptera, Plecoptera, Dermaptera, Hemiptera, Homoptera, Coleoptera, Trichoptera, Lepidoptera, Diptera, Arachnids, and Gastropoda (Storer 1914; Eckert 1934; Stebbins 1951, 1972; Morey and Guinn 1992; Jennings, unpubl. data). Cannibalism can also occur (Stebbins 1972).

Distribution

California toads are found over most of California (except for the northernmost counties where they are replaced by boreal toads, and almost all of the Mojave and Colorado deserts where they are replaced by other toad species) from sea level to over 3,050 meters in the Sierra Nevada (Stebbins 1972). This toad is replaced at higher elevations in the central and southern Sierra Nevada by the Yosemite toad (*Bufo canorus*) [Karlstrom 1962]. California toads are widespread in the Bay Area (Stebbins 1959) (**Figure 4.2**) and are still relatively common in stockponds and other aquatic habitats in the surrounding foothills (Jennings, unpubl. data).

Current Status and Factors Influencing Population Numbers

California toads are still present throughout most of their native range in California, although they are now rare in many urban areas where they were formerly common (such as in the Los Angeles Basin; Jennings unpubl. data). The possible reasons for the localized declines are insecticides used in eradicating introduced Mediterranean fruit flies (*Ceratitis capitata*), changing land use patterns by agriculture and urban communities which now leave less sites containing permanent water and areas of dense vegetation (such as tule-lined canals, low ground cover, *etc.*), and habitat fragmentation by roads and dense regions of urbanization (Jennings, unpubl. data). In the Bay Area, California toads are still relatively abundant in natural and moderately-altered habitats (Stebbins 1959; Jennings, unpubl. data). The factors most associated with toad survival include local breeding ponds that last for at least two months, and sufficient cover (vegetative and small mammal burrows) that provide places for toads to feed and grow, as well as escape predators and desiccating conditions.

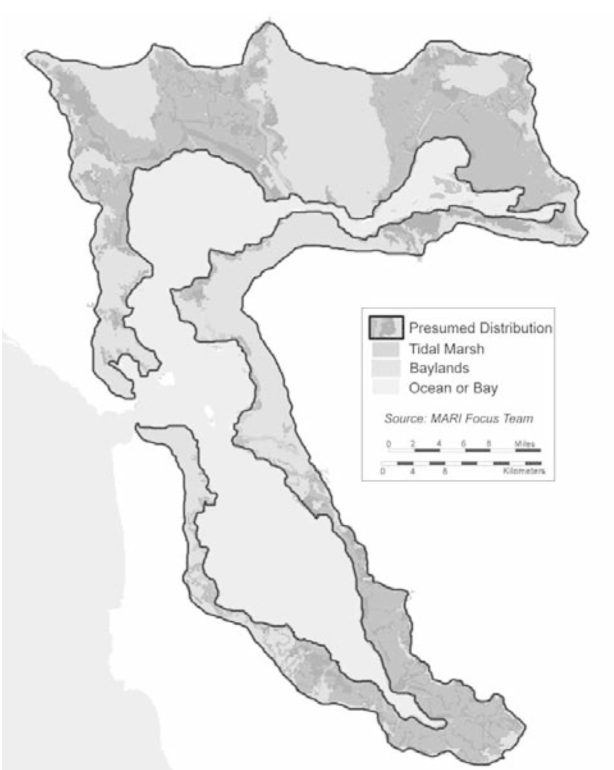

Figure 4.2 California Toad – Presumed Bay Area Distribution

Trophic Levels

Larval stages are primary consumers and post-metamorphic life stages are secondary consumers.

Proximal Species

Predators: Common [=San Francisco] garter snake, coast garter snake,central coast garter snake, bullfrog, introduced predatory fishes, herons, egrets, raccoon, striped skunk, and opossum. Predacious aquatic insects prey on larvae.
Prey: Aquatic insects, Oligochaetes, Gastropoda, Isopoda, and terrestrial insects.
Habitat: Willows, cattails, tules, sedges, blackberries, riparian vegetation.

Good Habitat

California toads inhabit grasslands, woodlands, meadows, gardens, golf courses, and parks—in fact, anywhere where a permanent source of moisture is present and breeding ponds of at least two months duration are available (Storer 1925). The largest populations of toads seem to be found around stockponds or reservoirs that have an abundance of invertebrate prey, many small mammal burrows and objects (or vegetation) that are available for cover, and a lack of introduced predators (fishes and bullfrogs [*Rana catesbeiana*]) in aquatic habitats.

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Pacific Treefrog

Hyla regilla

Mark R. Jennings

General Information

The Pacific treefrog (Family: Hylidae) is a small (19-50 mm SUL) frog with toe pads and a black eye stripe (Stebbins 1985). The dorsal coloration is highly variable—green, tan, reddish, gray, brown, or black—sometimes with dark dorsal spots (Wright and Wright 1949, Resnick and Jameson 1963, Stebbins 1972); however green or shades of brown are the usual colors observed (Nussbaum et al. 1983). For a time, these treefrogs were lumped with chorus frogs of the genus *Pseudacris* (see Hedges 1986). However, recent work has shown that Pacific treefrogs are not chorus frogs, hence the reversion to the old genus *Hyla* (Crocroft 1994).

This frog has the most notable voice of the frog world as its call has been used as a natural background sound in innumerable movies produced by Hollywood (Myers 1951).

Reproduction

Pacific treefrogs can become sexually mature in one year, but most become sexually mature in two years (Jameson 1956). At lower elevations, treefrogs are active all year, but at higher elevations adults emerge from hibernation sites immediately before reproducing (Stebbins 1951). From late November to July (beginning with the first warm rainfall), males congregate at night around any suitable shallow pond of water (or at the shallow edges of deep water ponds or reservoirs) and chorus to attract receptive females (Storer 1925, Brattstrom and Warren 1955, Schaub and Larsen 1978, Nussbaum et al. 1983), and also call to space themselves from one another (Snyder and Jameson 1965, Allan 1973). Groups of two or three males tend to call in sequence during these choruses and the sequence is consistently started by one frog known as the bout leader (Whitney and Krebs 1975).

The choruses may continue into daylight hours (Jameson 1957) and can be deafening if hundreds or thousands of calling males are involved (Stebbins 1959; Jennings, unpubl. data). Females attracted to these calls usually select the bout leader to mate with (Whitney and Krebs 1975). Upon amplexus, females lay approximately 20-25 packets containing 9-70 (usually 22-25) eggs on submerged aquatic vegetation or on the bottom of shallow pools (Smith 1940, Livezey and Wright 1947), generally at depths >100 mm (Storer 1925). Egg masses are normally laid close together, one against another, or separated by <25 mm (Stebbins 1951). The eggs are about 1.3 mm in diameter and females may lay from 500 to 1,250 total eggs (Storer 1925, Smith 1940). After egg deposition, males and females remain the vicinity of the breeding pond for up to one and three months respectively, and then return to surrounding terrestrial habitats (Jameson 1957, Nussbaum et al. 1983). Females may also breed up to three times during the year (Perrill and Daniel 1983).

Growth and Development

Eggs hatch in four days to two weeks, depending on the prevailing water temperatures and the resulting larvae (6.0-7.5 mm total length) grow rapidly (Storer 1925). Larvae are also known to aggregate into large groups of several hundred individuals (Brattstrom and Warren 1955). Metamorphosis is generally within two months at anytime between February-late August (Storer 1925; Jennings, unpubl. data), at total lengths between 45 and 55 mm (Storer 1925, Wright and Wright 1949). Post-metamorphs are about 12-15 mm and grow rapidly within the first two months often doubling their size (Jameson 1956). For the first few months, post-metamorphs remain in the immediate vicinity of the breeding pond utilizing almost any cover present (rocks, vegetation, leaves, *etc.*) for protection from the drying effects of the sun and wind (Jameson 1956). After several months, juveniles disperse out into surrounding terrestrial habitats and seek places that contain moisture and are protected by the elements. Such places include small mammal burrows, rock fissures, tree cavities, dense vegetation, piles of debris, buildings, artificial drains, *etc.*, that may be 0.8 km or more from the nearest standing water (Storer 1925, Jameson 1957).

Adults may live four years or more in captivity (Jennings, unpubl. data). Longevity in the wild is apparently somewhat over three years (Jameson 1956).

Food and Feeding

Larvae are thought to be algal grazers (Storer 1925), but the foraging ecology of larval Pacific treefrogs is unknown. Juveniles and adults feed on a wide variety of terrestrial and flying invertebrates including: Oligochaetes, Oniscidea, Orthoptera, Hemiptera, Homoptera, Coleoptera, Lepidoptera, Diptera, Hymenoptera, Arachnids, and Gastropoda (Needham 1924; Stebbins 1951; Brattstrom and Warren 1955; Nussbaum et al. 1983; Morey and Guinn 1992; Jennings, unpubl. data).

Distribution

Pacific treefrogs are found over most of California (except drier parts of the Mojave and Colorado deserts) from sea level to around 3,670 m in the Sierra Nevada (Stebbins 1972, 1985). In the Bay Area they are very abundant (Stebbins 1959; Jennings, unpubl. data), and found throughout the region (**Figure 4.3**).

Current Status and Factors Influencing Population Numbers

Pacific treefrogs have always been abundant throughout most of their native range (e.g., see Storer 1925, Stebbins 1951, Nussbaum et al. 1983), and they still remain so even in the Sierra Nevada (Jennings 1996, *contra* Drost and Fellers 1996). Treefrogs are especially common in the Bay Area (Stebbins 1959) because of their ability to utilize habitats created by humans—especially in urban areas. Although populations are negatively influenced by the premature drying of breeding ponds and continued loss of many individuals through predation,

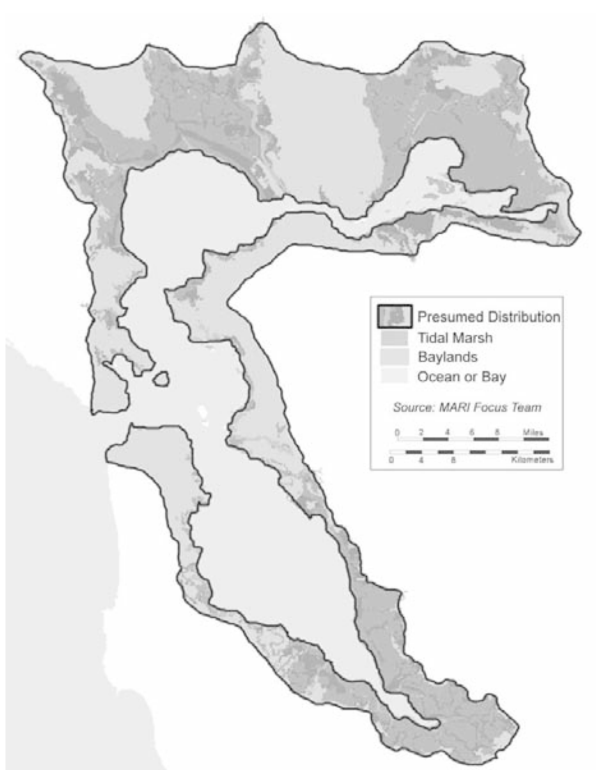

Figure 4.3 Pacific Treefrog – Presumed Bay Area Distribution

treefrogs are able to successfully reproduce in numbers to overcome these set backs (Jameson 1956, 1957).

Trophic Levels

Larval stages are primary consumers and post-metamorphic life stages are secondary consumers.

Proximal Species

Habitat: Willows, cattails, tules, and sedges.
Predators: Common [=San Francisco] garter snake, Coast garter snake, Central Coast garter snake, California red-legged frog, bullfrog, introduced predatory fishes, herons and egrets, raccoon, striped skunk, and opossum. California tiger salamander and various predacious aquatic insects prey on larvae only.
Prey: Aquatic and terrestrial insects.

Good Habitat

Pacific treefrogs can essentially inhabit almost any place that contains sufficient moisture and protection from the wind and sun, and has suitable nearby breeding sites. They can reproduce in temporary aquatic environments as small as a jar of water as long as the water remains present for two months or more (Jennings, unpubl. data) and the water temperature is below 35-38°C (Schechtman and Olson 1941). The largest populations seem to be present in complexes of shallow ponds (lacking fishes and other aquatic predators) surrounded by growths of tules (*Scirpus* sp.) and other aquatic vegetation (Jameson 1956, 1957), although Pacific treefrogs also seem to do well in golf courses, city parks, and other places that have permanent aquatic habitats and places with riparian vegetation (Jennings, unpubl. data).

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California Red-Legged Frog

Rana aurora draytonii

Mark R. Jennings

General Information

The California red-legged frog (Family: Ranidae) is a large (85-138 mm SUL) brown to reddish brown frog with prominent dorsolateral folds and diffuse moderate-sized dark brown to black spots that sometimes have light centers (Storer 1925, Jennings and Hayes 1994a). The species is the largest native frog in the state and there are data to support elevation as a separate species from the northern red-legged frog (*R. a.aurora*) [see Hayes and Miyamoto 1984, Green 1985]; however, there is also large zone of intergradation along the Pacific slope of the North Coast Range (Hayes and Kremples 1986). In 1993, the California red-legged frog was petitioned for listing as an endangered species by the U.S. Fish and Wildlife Service (Sorensen 1993) based on a significant range reduction and continued threats to surviving populations (Miller 1994). The frog was subsequently listed as Threatened by the U.S. Fish and Wildlife Service (Miller et al. 1996).

Dan Holland

Reproduction

Adults generally reach sexual maturity in their second year for males and third year for females (Jennings and Hayes 1985), although sexual maturity may be reached earlier during years of abundant food resources (Jennings, unpubl. data). During extended periods of drought, frogs may take 3-4 years to reach maturity (Jennings and Hayes 1994a). Reproduction generally occurs at night in permanent ponds or the slack water pools of streams during the winter and early spring (late November-through April) after the onset of warm rains (Storer 1925, Hayes and Jennings 1988, Jennings and Hayes 1994a). California red-legged frogs can only successfully reproduce in aquatic environments with water temperatures $\leq 26^{\circ}$C and salinities $\leq 4.5\%$ as developing embryos cannot tolerate conditions higher than this (Jennings, unpubl. data). Larvae can tolerate somewhat higher water temperatures and salinities (Jennings, unpubl. data). Males generally appear at breeding sites from 2-4 weeks before females (Storer 1925). At breeding sites, males typically call in small, mobile groups of 3-7 individuals that attract females (Jennings and Hayes 1994a). Females amplex with males and attach egg masses containing approximately 2,000-6,000 moderate-sized (2.0-2.8 mm diameter) eggs to an emergent vegetation brace at depths usually from 75-100 mm (Storer 1925). Egg masses are normally laid at the surface of the water (Livezey and Wright 1947). California red-legged frogs are explosive breeders, usually depositing their egg masses within 3-4 week period after large rainfall events (Hayes and Miyamoto 1984). After reproduction, males usually remain at the breeding sites for several weeks before removing to foraging habitats, while females immediately remove to these foraging habitats (Jennings, unpubl. data). There is no evidence of double clutching with this species (Jennings, unpubl. data).

Growth and Development

Eggs hatch after 6-14 days (depending on the prevailing water temperature), and the resulting larvae (8.8-10.3 mm total length) require 3.5-7 months to attain metamorphosis at 65-85 mm total length (Storer 1925; Jennings, unpubl. data). Larvae, which are solitary and almost never overwinter, typically metamorphose between July and September (Storer 1925, Jennings and Hayes 1994a).

Juvenile frogs are 25-30 mm total length at metamorphosis and commonly sun themselves during the day at the edge of the riparian zone next to the breeding site. As they grow, they gradually shift from diurnal and nocturnal periods of activity, to largely nocturnal activity (Hayes and Tennant 1986). During periods of rainfall, both juveniles and a few adults may disperse away from breeding sites and may be found some distance (up to

0.8 km) away from the nearest water (Jennings, unpubl. data). Along the lower reaches of streams on the Central Coast of California which tend to almost completely dry up during the late summer, subadult and adult frogs have been found to occupy small mammal burrows under leaf litter or dense vegetation in the riparian zone (Rathbun et al. 1993). These frogs make overland trips every few days or so to isolated stream pools to rehydrate themselves although one frog remained in riparian habitat for 77 days (Rathbun *in litt.* 1994 as cited in Miller et al. 1996). Based on these observations, frogs found in coastal drainages appear to be rarely inactive, whereas those found in interior sites probably hibernate (Storer 1925).

Based on limited field data, California red-legged frogs appear to live about 8-10 years in the wild (Jennings, unpubl. data).

Food and Feeding

Larvae are thought to be algal grazers (Storer 1925), but the feeding ecology of larval California red-legged frogs is unknown. Juvenile and adult frogs have a highly variable animal food diet that includes: Amphipods, Isopods, Orthoptera, Isoptera, Hemiptera, Homoptera, Neuroptera, Coleoptera, Lepidoptera, Diptera, Hymenoptera, Arachnids, Gastropoda, small fishes, amphibians, and small mammals (Stebbins 1972, Hayes and Tennant 1985, Baldwin and Stanford 1987). Most prey that can be swallowed that are not distasteful are eaten, with larger frogs capable of taking larger prey (Jennings and Hayes 1994a). Small red-legged frogs, Pacific treefrogs (*Hyla regilla*), and California mice (*Peromyscus californicus*) may contribute significantly to the diet of subadults and adults (Arnold and Halliday 1986, Hayes and Tennant 1985).

Distribution

Historically, California red-legged frogs were found throughout the Pacific slope drainages from the vicinity of Redding, Shasta County (Storer 1925), inland and at least to Point Reyes, Marin County (Hayes and Kremples 1986), California (coastally) southward to the Santo Domingo River drainage in Baja California, Mexico (Linsdale 1932). They also historically occurred in a few desert slope drainages in southern California (Jennings and Hayes 1994b). California red-legged frogs generally occurred below 1370 m in the Sierra Nevada foothills (Jennings 1996) and 1520 m in southern California, although some of the populations toward the upper limit of the range of this frog may represent translocations (Jennings and Hayes 1994a). In the Bay Area, this frog was historically abundant enough to support an important commercial fishery just before the turn of the century (Jennings and Hayes 1985) and up to the 1950s it was still considered to be present in much of the San Francisco Bay region (Stebbins 1959). However, earlier overexploitation, subsequent habitat loss from agriculture and urbanization, and the introduction of exotic aquatic predators have presently reduced red-legged frog distribution to scattered locations in the foothills and mountains of the San Francisco Bay region (Jennings, unpubl. data) (**Figure 4.4**).

Current Status and Factors Influencing Population Numbers

Based on the data presented in Jennings and Hayes (1994a, 1994b), California red-legged frogs appear to have disappeared from approximately 70-75%, of their historic range in the state (Miller et al. 1996). This frog is most affected by land use patterns and other anthropogenic events which fragment high quality habitat and create environments unsuitable for the continued survival of the species (Jennings and Hayes 1994a, 1994b). Some of the more important factors negatively influencing frog populations include: conversion and isolation of perennial pool habitats (and surrounding riparian zones) to agriculture; reservoir construction projects; urbanization; lowering of the groundwater table by overdraft; overgrazing by domestic livestock; extended drought; mortality of juvenile and adult frogs by vehicles on roads; and the introduction of non-native predators such as mosquitofish (*Gambusia affinis*), bullfrogs (*Rana*

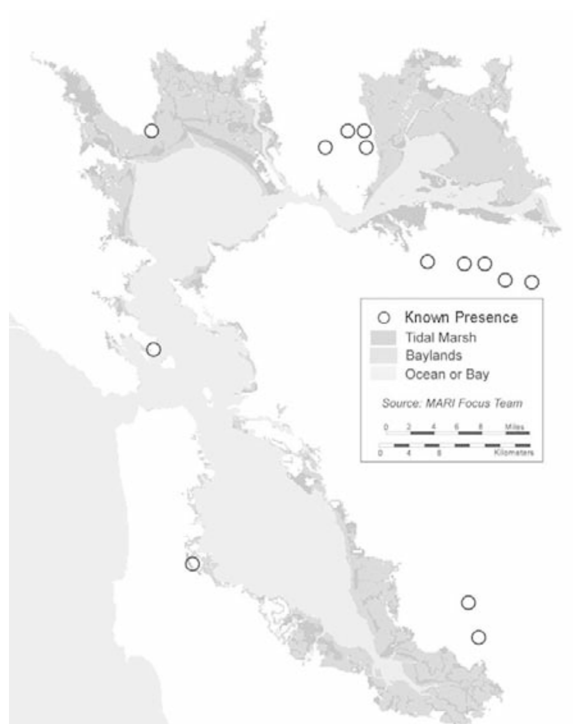

Figure 4.4 California Red-Legged Frog – Some Current Locations

catesbeiana) and crayfish (specifically *Procambarus clarkii*) into breeding habitats (Miller et al. 1996). Juvenile and adult frogs have also been found in a number of human-created habitats such as irrigation canals, golf course ponds, sewage treatment ponds, gravel pits, and intermittent irrigation ponds (Jennings and Hayes 1994a; Jennings, unpubl. data). Such habitats may not be suitable for the long-term survival or successful reproduction of local frog populations, especially near urban areas where predators such as bullfrogs and raccoons (*Procyon lotor*) are able to build up large populations as a result of human activities (Jennings, unpubl. data).

Trophic Levels

Larval stages are primary consumers and post-metamorphic life stages are secondary/tertiary consumers.

Proximal Species

Predators: Common [=San Francisco] garter snake, Coast garter snake, Central Coast garter snake, bullfrog, heron, egret, raccoon, and introduced predatory fishes. Predacious aquatic insects prey on larvae only.

Prey: California tiger salamander, Pacific treefrog, California mouse, bullfrog, and aquatic and terrestrial insects.

Habitat: Willows, cattails, tules, sedges, and blackberries.

Good Habitat

Although California red-legged frogs can occur in ephemeral or artificially-created ponds devoid of vegetation, the habitats that have been observed to have the largest frog populations are perennial, deep (>0.7 m) water pools bordered by dense, shrubby riparian vegetation (Jennings 1988, Hayes and Jennings 1986). This dense riparian vegetation is characterized by arroyo willows (*Salix lasiolepis*) intermixed with an understory of cattails (*Typha* sp.), tules (*Scirpus* sp.), or bulrushes (*Scirpus* sp.) [Jennings 1988].

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Western Pond Turtle

Clemmys marmorata

Mark R. Jennings

General Information

The western pond turtle (Family: Emydidae) is a moderate-sized (120-210 mm CL), drab brown or khaki-colored turtle often lacking prominent markings on its carapace (Bury and Holland, in press). Carapace coloration is usually dark brown or dull yellow-olive, with or without darker streaks or vermiculations radiating from the centers of the scutes (Ernst et al. 1994, Jennings and Hayes 1994).

There are two poorly differentiated subspecies of the western pond turtle (*C. m. marmorata* and *C. m. pallida*) with a wide zone of intergradation in central California (Bury 1970). Based on a morphological evaluation, Holland (1992) found three distinct evolutionary groups within this taxon. However, Gray (1995) found through DNA fingerprinting of *C. marmorata* samples from the extreme southern and northern edges of its range support the original designation of two distinct subspecies. Bury and Holland (in press) indicate that more comprehensive genetic studies are currently underway to determine the taxonomic status of this taxon.

In 1992, the western pond turtle was petitioned for listing as an endangered species (Sorensen and Propp 1992) based on concerns about widespread population declines due to the extensive loss of habitat, overexploitation, introductions of non-native aquatic predators (Sorensen and Propp 1992; see also Jennings and Hayes 1994). The U.S. Fish and Wildlife Service subsequently ruled that the petition was not warranted (USFWS 1993) and this turtle remains a candidate 2 species (Drewry 1994).

Reproduction

In California, sexual maturity in western pond turtles occurs at between seven and 11 years of age at approximately 110-120 mm CL with males maturing at slightly

Joe DiDonato

smaller sizes and ages than females (Jennings and Hayes 1994). Sexual maturity is delayed in turtles that experience drought conditions and in more northerly populations (Jennings and Hayes 1994). Adult turtles typically mate in late April or early May, although mating can occur year-around (Holland 1985a, 1992). The nesting season is from late April to early August (Storer 1930, Buskirk 1992, Rathbun et al. 1992, Jennings and Hayes 1994, Goodman 1997a). Females emigrate from the aquatic habitats to an unshaded, upland location that may be a considerable distance (400 m or more) from riparian zones to nest (Storer 1930; Rathbun et al. 1992; Bury and Holland, in press). However, most nest locations are close to riparian zones if nesting substrates and exposures are suitable (Jennings, unpubl. data). Once a suitable site is located, females deposit from 1-13 eggs that have a thin, but hard (calcified) outer shell in a shallow (ca. 10-12 cm deep) nest (Rathbun et al. 1992, 1993)—usually in well-drained clay or silt soils (Jennings and Hayes 1994). Eggs laid in excessively moist substrates have a high probability of failing (Feldman 1982). Females can lay more than one clutch of eggs a year and may dig several "false" nests lacking eggs to deter potential predators (Rathbun et al. 1993, Goodman 1997b).

Growth and Development

Young turtles hatch at lengths of 25-29 mm CL (Ernst et al. 1994) after an incubation period of 3-4.5 months (Buskirk 1992; Bury and Holland, in press) and are thought to overwinter in the nest because there are only a few records of hatchling turtle emergence in the early fall in southern and central California (Buskirk 1992, Jennings and Hayes 1994). Most hatchling turtles are thought to emerge from the nest and move to aquatic sites in the spring (Buskirk 1992) where they typically double their length the first year and grow relatively rapidly over the next 4-5 years (Storer 1930, Holland 1985a). Young turtles spend most of their time feeding in shallow water dominated by relatively dense vegetation of submergents, short emergents, or algal mats (Buskirk 1992, Jennings and Hayes 1994). Juveniles and adults prefer slack- or slow-water aquatic habitats with basking sites such as rocks and logs (Bury 1972, Reese 1996). Water temperatures >15°C markedly increase turtle activity so many western pond turtles are probably active year around in coastal locations (Reese and Welsh 1998) and only active from March or April-October or November in interior locations (Bury and Holland, in press). Juveniles and adults seem to remain in pond environments except when ponds dry up or at higher elevations when turtles may disperse into terrestrial environments to hibernate (Jennings and Hayes 1994; Goodman 1997a, Bury and Holland, in press). In stream environments, juveniles and adults show considerable variation with regards to movements and the timing of movements into terrestrial environments (Rathbun et al. 1993, Reese and Welsh 1998). Some turtles will leave the stream during the summer when water conditions are low and water temperatures are elevated (>35°C), while others will not. However, almost turtles seem to leave streams during the winter months when large flood events are common (Rathbun et al. 1993). Additionally, some turtles will move considerable distances (e.g., 350 m) to overwinter in terrestrial habitats such as leaf litter or under the root masses of trees (Rathbun et al. 1992, 1993). Some individual turtles have displayed site fidelity for hibernation sites from year to year (Bury and Holland, in press).

Western pond turtles often move about from pool to pool in stream situations, sometimes on a daily basis during seasons of activity (Bury 1972, Reese and Welsh 1998). Distances moved along streams can be up to 5 km (Bury and Holland, in press). These turtles also have the ability to move several kilometers if their aquatic habitat dries up (Reese 1996) and they can tolerate at least seven days without water (Jennings and Hayes 1994; Bury and Holland, in press).

Western pond turtles are known to live over 42 years in the wild (Jennings and Hayes 1994) although most individuals have a much shorter life span of around 20-25 years (Bury 1972).

Food and Feeding

Juvenile and adult western pond turtles feed largely on the same items although juveniles feed more on smaller aquatic invertebrates (Bury 1986). Food items found in turtle stomachs include: algae, aquatic plants, Nematomorpha, Cladocera, Decapoda, Isopoda, Ephemeroptera (nymphs only), Odonata (nymphs only), Orthoptera, Hemiptera (nymphs and adults), Neuroptera (larvae only), Coleoptera (larvae and adults), Trichoptera (larvae only), Diptera (larvae and adults), Araneae, Gastropoda, fishes, and amphibians (Carr 1952, Holland 1985b, Bury 1986, Ernst et al. 1994, Goodman 1997a). These turtles are dietary generalists and highly opportunistic (Ernst et al. 1994). They will consume almost anything that they are able to catch and overpower. The relatively slow pursuit of these turtles results in their diet being dominated by relatively slow-moving aquatic invertebrates and carrion, although aquatic vegetation may also be eaten (Evenden 1948, Bury 1986, Baldwin and Stanford 1987), especially by females having recently laid eggs (Jennings and Hayes 1994).

Distribution

The western pond turtle historically occurred in most Pacific slope drainages from Klickitat County, Washington along the Columbia River (Slater 1962) south to Arroyo Santa Domingo, northern Baja California, Mexico (Jennings and Hayes 1994). Isolated populations are also known from Carson, Humboldt, and Truckee drainages in western Nevada (LaRivers 1962, Banta 1963). In California the species is known from most Pacific slope drainages between the Oregon and Mexican borders below 1430 m (Jennings and Hayes 1994). Turtle observations from above this elevation are thought to be introductions (Jennings and Hayes 1994). Western pond turtles are present throughout the Bay Area (Stebbins 1959) (**Figure 4.5**), although at much lower numbers and at fewer localities than previously—especially in urban areas (Jennings, unpubl. data).

Current Status and Factors Influencing Population Numbers

The western pond turtle is declining in population size and numbers throughout its range, particularly in southern California and the San Joaquin Valley (Bury and Holland, in press). Many turtle populations in these areas of decline are now composed almost entirely of old adults without any successful recruitment (Jennings and Hayes 1994). The reasons for these declines are largely due to urbanization, agricultural development, flood control projects, exotic diseases, exploitation for the food and pet trade, extended drought, and the introduction of exotic predatory species such as largemouth bass (*Micropterus salmoides*) and bullfrogs (*Rana catesbeiana*) which also compete for the availability of prey items—especially with young turtles (Brattstrom 1988; Buskirk 1992; Jennings and Hayes 1994; Reese 1996; Goodman 1997a; Bury and Holland, in press). Turtle nests and gravid females moving overland are especially vulnerable to predation by raccoons (*Procyon lotor*), whose populations have greatly increased in many rural areas due to the increase in human populations in these areas (Bury and Holland, in press; Jennings, unpubl. data). Additionally, some of the largest turtle populations in the Central Valley and southern California are found in sewage treatment ponds. Unfortunately, such habitats are probably unsuitable for the long term survival of the species because of the lack of suitable habitat for nest sites and increased vulnerability of adult turtles to predation by humans, raccoons, and other animals (Jennings, unpubl. data).

Trophic Levels

Young turtles are essentially secondary consumers; adults are primary and secondary consumers.

Proximal Species

Predators: Raccoon, bullfrog, black bear, humans, and introduced predatory fishes. Striped skunk and opossum prey on eggs and hatchlings, and herons and egrets prey on young turtles.

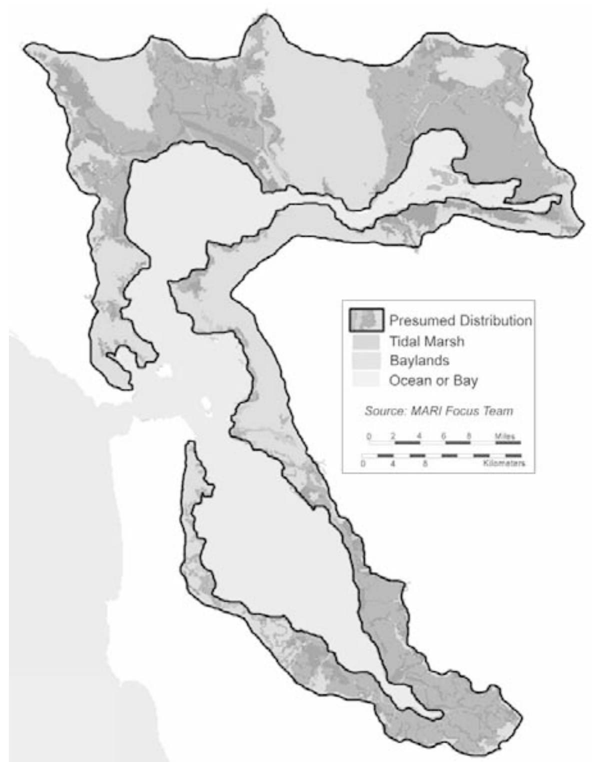

Figure 4.5 Western Pond Turtle – Presumed Bay Area Distribution

Prey: Aquatic Insects, aquatic vegetation, and California tiger salamander larvae.
Habitat: Aquatic vegetation.

Good Habitat

The largest western pond turtle populations have been observed in warm water (15-35°C), slack- or slow-water habitats, which have abundant basking sites and underwater refugia. The presence of dense stands of submergent or emergent vegetation, and abundant aquatic invertebrate resources, as well suitable nearby nesting sites and the lack of native and exotic predators, are also important components (Bury 1972; Jennings and Hayes 1994; Bury and Holland, in press).

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California Alligator Lizard

Elgaria multicarinata multicarinata

Kevin MacKay
Mark R. Jennings

General Information

The California alligator lizard (Family: Anguidae) is a large (100-125 mm SVL) alligator lizard with a broad head, keeled scales, and a reddish-blotched dorsum marked with nine or more dusky crossbands between the head and hindlimbs (Stebbins 1959, 1985). The top of the head is often mottled (Fitch 1938). There is a longitudinal stripe or row of dashes down the middle of each scale row on the belly (Stebbins 1985).

All alligator lizards in the western United States were formerly placed in the genus *Gerrhonotus* (e.g., Smith 1946; Stebbins 1958, 1959, 1972, 1985; Lais 1976). However, recently revised alligator lizard systematics places these species in the genus *Elgaria* (Waddick and Smith 1974; Gauthier 1982; Good 1987a, 1987b, 1988).

Reproduction

California alligator lizards are egg layers (Smith 1946) that probably reach sexual maturity in two years at about 73 mm SVL for males and about 92 mm SVL for females (Goldberg 1972). Mating apparently occurs over a relatively long period (up to 26 hours or more), but most copulation events are considerably shorter than this (Fitch 1935). Based on data from closely related *E. m. webbii* in southern California, adults emerge from hibernation and mate from late February-late May to August-mid September, and eggs are probably laid in small mammal burrows (Stebbins 1954) or under rocks from June-mid July (Goldberg 1972) or later into August (Stebbins 1954) or early September (Burrage 1965). Clutch sizes are 5-41 (average 13) and females can lay more than one clutch a year (Burrage 1965).

Jens V. Vindum, Academy of Sciences

Growth and Development

Based on data from closely related *E. m. webbii* in southern California, incubation of the eggs probably takes 42-57 days (Atsatt 1952, Burrage 1965) and hatchlings appear from mid August-early October at 30-36 mm SVL and 0.5-0.6 g (Burrage 1965, Goldberg 1972). Juveniles grow rapidly the next season, reaching sexual maturity after about 18 months (Goldberg 1972). The longevity of California alligator lizards in the wild is unknown, but marked lizards have been recaptured after four years (Jennings, unpubl. data).

Both juveniles and adults are active in the daytime, at dusk, and at night, and have a relatively low preferred temperature range (Brattstrom 1965, Cunningham 1956, Kingsbury 1994). Because of this, they do not bask. Instead, they prefer very dense cover and often position themselves under warmed objects such as rocks or pieces of wood during certain times of the day (Kingsbury 1994). Alligator lizards frequent riparian zones where their prehensile tails are used in climbing trees and other vegetation in pursuit of prey (Cunningham 1955; Stebbins 1959, 1972). They are also found under debris such as woodpiles, brush heaps, old logs, *etc.* (Stebbins 1954).

Food and Feeding

California alligator lizards probably consume the same food items taken by *E. m. webbii*. Food items recorded in the latter include: Isopoda, Orthoptera, Isoptera, Hemiptera, Homoptera, Coleoptera (larvae and adults), Lepidoptera (larvae and adults), Diptera (larvae and adults), Scorpionida, Araneida [including the egg cases and adults of the black widow spider (*Latradectus mactans*)], Gastropoda, lizards (*Sceloporus occidentalis*, *S. graciosus*, and *E. multicarinata*), small mammals, and the eggs and young of small birds (Fitch 1935, Cowles 1937, Stebbins 1954, Cunningham 1956).

Distribution

California alligator lizards are found in the Sacramento Valley and surrounding foothills, from Shasta County south through the North Coast Range (Mendocino-Marin counties), the San Francisco Bay region and the South Coast Range to Ventura County (Fitch 1938). The elevational range is from sea level to around 1830 m in the Sierra Nevada (Basey and Sinclear 1980). This lizard is apparently absent from most of the San Joaquin Valley proper, but it is found on the northern Channel Islands (Fitch 1938). It intergrades with the *E. m. scincicauda* in Mendocino and Trinity counties in the north and *E. m. webbii* in Ventura County in the south and El Dorado County in the east (Stebbins 1985). They are found throughout the Bay Area (Stebbins 1959) (**Figure 4.6**).

Current Status and Factors Influencing Population Numbers

California alligator lizards are still present in good numbers over almost all of their historic range because of their ability to survive (and even thrive) in urban environments. The most important predator of these lizards in such modified habitats is the domestic cat (*Felis cattus*). In more natural habitats, alligator lizards are eaten by a number of reptile, avian, and mammal predators (Fitch 1935). They are still very abundant in the foothills of the Bay Area (Jennings, unpubl. data).

Trophic Levels

California alligator lizards are secondary/tertiary consumers.

Proximal Species

Habitat: Pickleweed, riparian vegetation, blackberries, willows.
Predators: Domestic cat, striped skunk, opossum, raccoon, heron, egret, hawks, coyote, red fox, bullfrog, common garter snake, and Coast garter snake.
Prey: Terrestrial insects, oligochaetes, and arachnids.

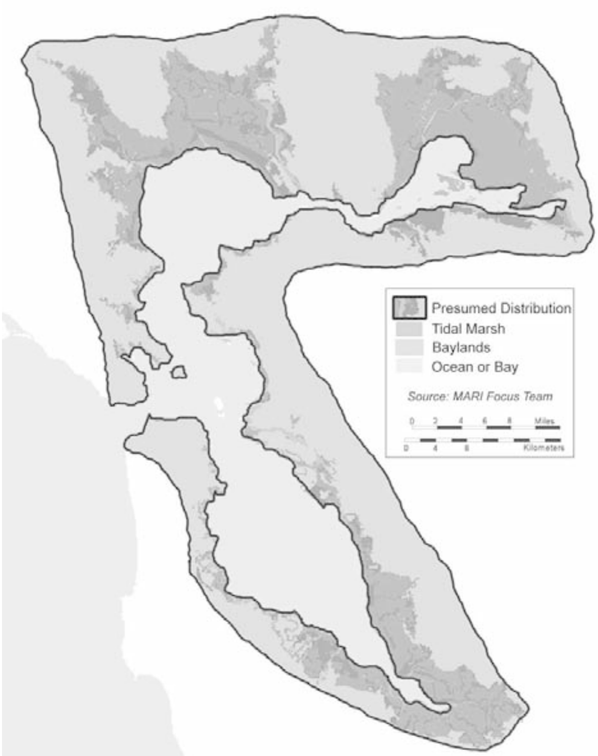

Figure 4.6 California Alligator Lizard – Presumed Bay Area Distribution

Good Habitat

California alligator lizards occupy many habitats from pickleweed flats to open grasslands, to oak woodlands, to mixed coniferous forest, to urban environments (Fitch 1935; Lais 1976; Stebbins 1954, 1985). However, the largest observed populations are in the riparian zones of oak woodlands and in coastal sage scrub near beaches (Jennings, unpubl. data).

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Central Coast Garter Snake

Thamnophis atratus atratus

Mark R. Jennings

General Information

The central coast garter snake (Family: Colubridae) is a medium-sized (60-102 cm TL) garter snake with eight upper labial scales and a highly variable dorsal color throughout its range (Bellemin and Stewart 1977). Snakes usually have a dark olive to black dorsum and single yellow to orange dorsal stripe and sometimes lateral stripes of pale yellow (Stebbins 1985). The throat is a bright yellow. Both *T. a. atratus* and *T. e. terrestris* have similar dorsal and ventral colorations in habitats occupied along the central coast of California (Bellemin and Stewart 1977, Stebbins 1985). Boundy (1990) considers what is currently *T. a. atratus*, to be be actually composed of two different subspecies. However, his proposed subspecies from the mountains of the East Bay region and the South Coast Range (south of Santa Cruz County) has not been formally published.

Garter snake taxonomy has undergone a considerable number of revisions during this century, especially during the past 40 years. The snake *T. a. atratus* is often referred to as *T. elegans atratus*, or *T. couchii atratus* in the literature (e.g., see Fitch 1940, 1984; Fox 1948a, 1948b, 1951; Stebbins 1954, 1972; Fox and Dessauer 1965; Lawson and Dessauer 1979). Rossman and Stewart (1987) were the first to convincingly elevate *T. atratus* as a separate species and this arrangement has been followed by others (e.g., see Lawson 1987).

Reproduction

Central coast garter snakes are live-bearers. Females give birth from 4-14 (or more) young (ave. 8.6) in the fall (August-September) [Fox 1948a, 1948b]. Adults probably mate annually during the spring (March-April) [Fox 1948b, 1952a], but females have the ability to store sperm for up to 53 months (Stewart 1972).

Denise Loving

Growth and Development

Unknown. If similar to other garter snakes on the central coast of California, neonates are present from late August through November (Rathbun et al. 1993) and juveniles grow rapidly during the first year of their lives (Fox 1948a). Sexual maturity is reached in about 2-3 years (Fox 1948a). Longevity in the wild is unknown, but adults probably live for at least 4-5 years (Jennings, unpubl. data).

Food and Feeding

Juvenile and adult snakes feed almost entirely on fishes (e.g., *Gasterosteus aculeatus*, *Hesperoleucus symmetricus*, and *Cottus* spp.), newts (larvae and adults of *Taricha torosa*), toads (*Bufo boreas halophilus*), and frogs (e.g., larvae, juveniles, and adults of *Hyla regilla*, *Rana aurora draytonii*, *R. boylii*, and *R. catesbeiana*) [Fitch 1941; Fox 1951, 1952b; Bellemin and Stewart 1977; Boundy 1990; Barry 1994; Jennings, unpubl. data].

Distribution

Central coast garter snakes inhabit small streams, ponds, and other aquatic habitats in the San Francisco Peninsula and the East Bay Hills, Contra Costa County (south of the Sacramento River), southward through the South Coast Range to Point Conception, Santa Barbara County, and east to the western edge of the San Joaquin Valley (Fox 1951, Bellemin and Stewart 1977). Snakes north of San Francisco Bay are *T. a. aquaticus* (Fox 1951, Stebbins 1985). Their elevational distribution is from near sea level to 1290 m on Mount Hamilton (Fox 1951). They are relatively common East Bay and South Bay regions of the San Francisco Estuary (Stebbins 1959; Jennings, unpubl. data) (**Figure 4.7**).

Current Status and Factors Influencing Population Numbers

Central coast garter snakes are negatively affected by habitat alteration, especially by agriculture and urbanization which often results in intermittent aquatic habitats unsuitable for this species. These snakes are also probably negatively affected by the introduction of exotic predators such as bullfrogs (*Rana catesbeiana*) and largemouth bass (*Micropterus salmoides*), which are known to eat garter snakes (Schwalbe and Rosen 1988). However, these central coast garter snakes are still relatively abundant in aquatic habitats located in the foothills surrounding the Bay Area where urban development is less intrusive (Jennings, unpubl. data).

Trophic Levels

Central coast garter snakes are tertiary consumers.

Proximal Species

Predators: Racoon, herons, egrets, hawks, and bullfrogs.
Prey: threespine stickleback, sculpins, Pacific treefrog, California toad, foothill yellow-legged frog, California red-legged frog, bullfrog, coast range newt.

Good Habitat

Coast garter snakes are most abundant in riparian habitats with shallow ponds containing abundant numbers of native fishes and amphibians, and dense thickets of vegetation nearby (Jennings, unpubl. data). Such habitats are most common in natural sag ponds and artificial stock ponds (Barry 1994).

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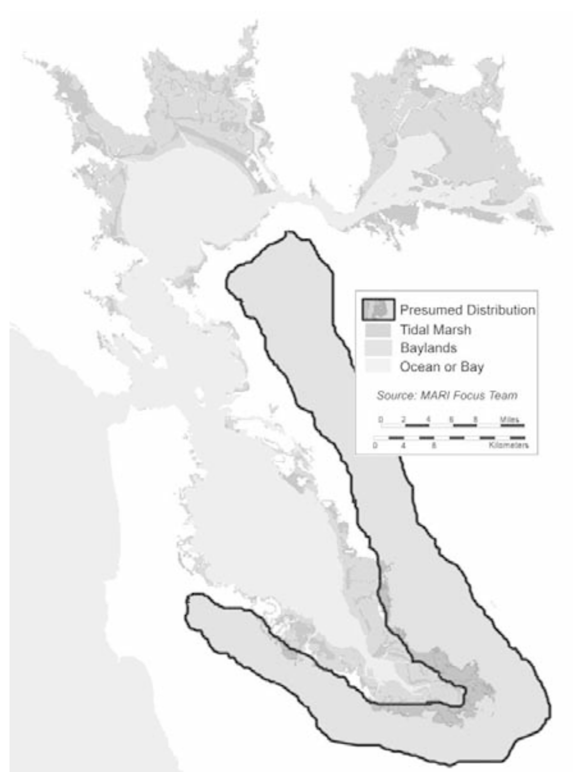

Figure 4.7 Central Coast Garter Snake – Presumed Bay Area Distribution

Boundy, J. 1990. Biogeography and variation in southern populations of the garter snake *Thamnophis atratus*, with a synopsis of the *T. couchii* complex. Unpubl. M.A. Thesis, San Jose State Univ., San Jose, Calif. 105 p.

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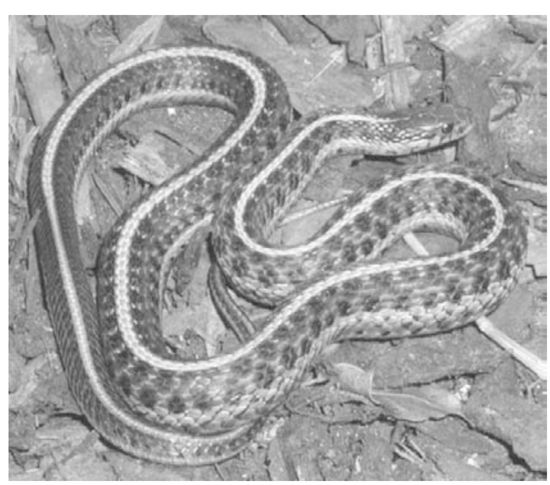
Coast Garter Snake

Thamnophis elegans terrestris

Kevin MacKay
Mark R. Jennings

General Information

The coast garter snake (Family: Colubridae) is a medium-sized (45-107 cm TL) garter snake with eight upper labial scales and a highly variable dorsal color throughout its range (Bellemin and Stewart 1977, Stebbins 1985). Snakes usually have a reddish to solid black dorsum (sometimes with a checkerboard of dark spots or bars), and single pale to bright yellow dorsal stripe, and two lateral stripes of yellow to salmon (Fitch 1983, Stebbins 1985). The throat and belly are usually tinged with orange flecks (Fox 1951). Both *T. a. atratus* and *T. e. terrestris* have similar dorsal and ven-



Dr. Alan Francis

Amphibians & Reptiles

tral colorations in habitats occupied along the central coast of California (Bellemin and Stewart 1977, Stebbins 1985).

Reproduction

Coast garter snakes are live-bearers. Females give birth to from 4-14 young (average 8.6) in the fall (August-September) [Fox 1948, Stebbins 1954]. Adults probably mate annually during the spring (March-July) [Fox 1948, 1952a, 1956], but females have the ability to store sperm for up to 53 months (Stewart 1972).

Growth and Development

Unknown. If similar to other garter snakes on the central coast of California, neonates are present from late August through November (Rathbun et al. 1993) and juveniles grow rapidly during the first year of their lives (Fox 1948). Sexual maturity is reached in about 2-3 years (Fox 1948). Longevity in the wild is unknown, but adults probably live for at least 4-5 years (Jennings, unpubl. data).

Food and Feeding

Coast garter snakes subsist largely on slugs (Arion sp., *Ariolimax columbianus*, and others), California slender salamanders (*Batrachoseps attenuatus*), ensatinas (*Ensatina eschscholtzii*), arboreal salamanders (*Aneides lugubris*), Pacific treefrogs (*Hyla regilla*), western fence lizards (*Sceloporus occidentalis*), California voles (*Microtus californicus*), deer mice (*Peromyscus maniculatus*), young brush rabbits (*Sylvilagus bachmani*), harvest mice (*Rheithrodontomys* spp.), nestling white-crowned sparrows (*Zonotrichia leucophrys nuttalli*), and nestling song sparrows (*Melospiza melodia*) [Fitch 1941; Fox 1951, 1952b; James et al. 1983; Barry 1994]. Fox (1951) also records at least one instance of cannibalism in the wild. There is a heavy preference for slugs, rodents, and nestling birds in some areas inhabited by this snake (Fox 1951, 1952b; James et al. 1983). Coast garter snakes will also eat a wide variety of fishes and amphibians if the occasion arises (see Fox 1952b).

Distribution

Coast garter snakes inhabit the North and South Coast Ranges from just north of the Oregon border, south to Point Conception, Santa Barbara County (Fox 1951, Bellemin and Stewart 1977, Stebbins 1985). They intergrade with *T. e. elegans* at mid-elevations of the North Coast Range (Stebbins 1985). The elevational range is from near sea level to around 350 m (Fox 1951). Coast garter snakes are widely distributed in the Bay Area (Stebbins 1959) (**Figure 4.8**).

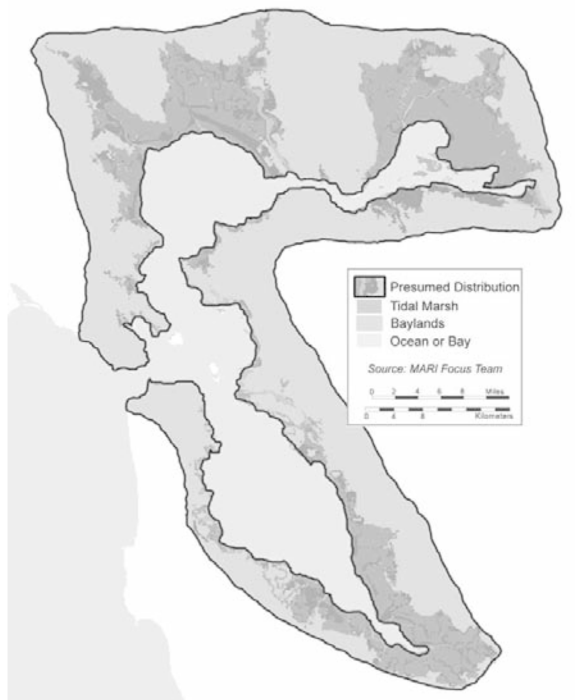


Figure 4.8 Coast Garter Snake – Presumed Bay Area Distribution

Current Status and Factors Influencing Population Numbers

Coast garter snakes are negatively affected by habitat alteration, especially by agriculture and urbanization which often results in disturbed or open habitats unsuitable for this species. Because these snakes do not require permanent aquatic habitats for long term survival like other garter snake taxa in the Bay Area, they are less affected overall by human activities. Coast garter snakes are still relatively abundant in terrestrial habitats located in the foothills surrounding the Bay Area (Jennings, unpubl. data).

Trophic Levels

Coast garter snakes are tertiary consumers.

Proximal Species

Predators: Raccoon, herons, egrets, hawks, California kingsnake, and bullfrog.
Prey: Pacific treefrog, California red-legged frog, bullfrog, Coast Range newt, oligochaetes, California mouse, California vole, white-crowned sparrow, brush rabbit (young only), shrews, slugs.

Good Habitat

Coast garter snakes inhabit meadows (such as grasslands) and clearings with second growth in the fog belt and also chaparral (Stebbins 1972). They are often abundant in canyons with coast live oaks (*Quercus agrifolia*), California bay (*Umbellularia californica*) and numerous shrubs, as well as riparian zones or other areas of dense vegetation (such as blackberries (*Rubus discolor* and *R. ursinus*), thimbleberries (*R. parviforus*) and Baccharis (*Baccharis* spp.)) next to more open areas (Fox 1951).

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Stewart, G.R. 1972. An unusual record of sperm storage in a female garter snake (genus *Thamnophis*). Herpetology, 28(4):346-347.

San Francisco Garter Snake

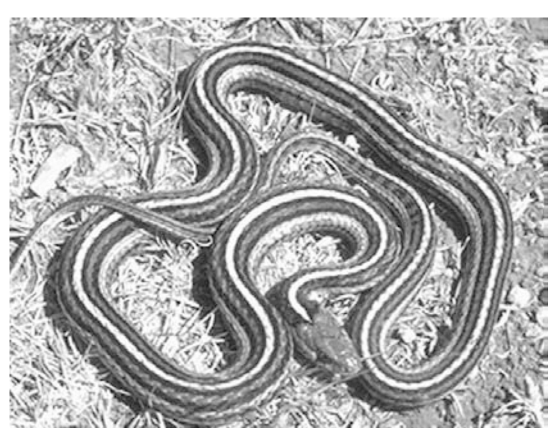
Thamnophis sirtalis tetrataenia

Mark R. Jennings

General Information

The San Francisco garter snake (*Thamnophis sirtalis tetrataenia*; Family Colubridae) is a medium sized (46-122 cm TL), snake with seven upper labial scales and a wide dorsal stripe of greenish yellow edged with black, bordered on each side by a broad red stripe followed by a black one (Barry 1978, Stebbins 1985). The belly is a bright greenish blue (often turquoise) and the top of the head is red (Stebbins 1985, Barry 1993). This snake was one of the first reptiles to be listed as Endangered by the U.S. Fish and Wildlife Service in 1967 (U.S. Fish and Wildlife Service 1985).

Although the name of this snake has been stable since Fox (1951) solved the mystery regarding the original collection of *T. s. tetrataenia* in 1855, Boundy and Rossman (1995) recently proposed that the nomenclature of *T. s. tetrataenia* be revised because the holotype of *T. s. infernalis* was found to actually be a specimen of *T. s. tetrataenia*. This proposal of substituting *T. s. infernalis* for *T. s. tetrataenia* and *T. s. concinnus* for *T. s. infernalis* (*sensu lato* Fox 1951), has been followed by Rossman et al. (1996). However, a petition has been



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received and published by the International Commission on Zoological Nomenclature to conserve the usage of *T. s. infernalis* and *T. s. tetrataenia* and designate a neotype for *T. s. infernalis* (Barry and Jennings 1998). Thus, the existing usage of the Fox (1951) nomenclature should be followed until a ruling is made on the case.

Reproduction

San Francisco garter snakes are live bearers which mate during the spring (March-April) and also during the fall (September-November), the latter often in breeding aggregations of several males and one female (Fox 1952a, 1954, 1955). Neonates (18-20 cm total length) are normally born in litters of 1-35 (average 16) during late July to early August (Fox et al. 1961; Cover and Boyer 1988; Barry 1993, 1994), although a few litters are born as late as early September (Larsen 1994). Females have the ability to store sperm for up to 53 months (Stewart 1972).

Growth and Development

Snakes are most active from March to September although they can be observed during any month of the year (Wharton 1989, Barry 1994, Larsen 1994). Juveniles grow rapidly during their first year, spending much of their time feeding in riparian zones or aquatic habitats (Barry 1994). Males and females probably reach sexual maturity in two years (at about 46 cm and 55 cm total length respectively), although some slower growing snakes reach sexual maturity in three years (Barry 1994). During the summer months, subadult and adult snakes may disperse away riparian areas into adjacent habitats to feed on amphibians in rodent burrows (Barry 1993). During the winter months, juvenile and adult snakes hibernate in small mammal burrows in adjacent upland habitats (Larsen 1994). Some snakes can move large distances (>2 km) over short periods of time (Wharton 1989), but limited radio tracking data indicate that most movements are considerably shorter than this distance (Larsen 1994).

Food and Feeding

Subadult and adult San Francisco garter snakes feed largely on the larvae and post-metamorphic life stages of Pacific treefrogs (*Hyla regilla*) and California red-legged frogs (*Rana aurora draytonii*). California toads (*Bufo boreas halophilus*), introduced bullfrogs (*R. catesbeiana*), introduced mosquitofish (*Gambusia affinis*), and threespine sticklebacks (*Gasterosteus aculeatus*) are also taken (Fox 1951, Wharton 1989, McGinnis 1984, Barry 1994). Juvenile snakes feed largely on newts (*Taricha* spp.), earthworms, and Pacific treefrogs (Barry 1993) and will refuse other most non-amphibian items offered to them (Fox 1952b, Larsen et al. 1991). Adult snakes rarely eat California voles (*Microtus californicus*), even when they are abundantly available (Barry 1993).

Distribution

San Francisco garter snakes are a Bay Area endemic that are essentially restricted to San Mateo County, California (Stebbins 1959, Barry 1978) (**Figure 4.9**). Historically, they occurred in aquatic habitats and adjacent uplands along the San Andreas Rift Zone from near Pacifica, southeast to the Pulgas Water Temple, and along an arc from the San Gregorio-Pescadero highlands, west to the coast, and south to Point Año Nuevo (Barry 1978, 1994; McGinnis 1984). At least two recent records just south of Point Año Nuevo—from the mouth of Waddell Creek, Santa Cruz County—are questionable (Barry 1993, 1994). Intergrades with *T. s. infernalis* have been recorded in eastern San Mateo County (southeast of the Pulgas Water Temple) and extreme western Santa Clara County (Fox 1951, Barry 1994).

Current Status and Factors Influencing Population Numbers

San Francisco garter snakes have disappeared from significant portions of their native range due to habitat loss from agriculture and urbanization—especially from housing developments and freeway construction (Medders

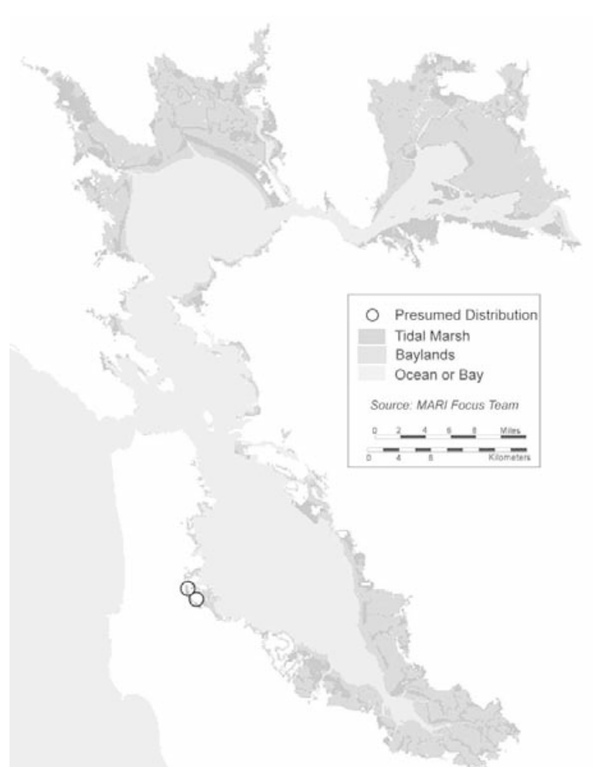

Figure 4.9 San Francisco Garter Snake – Current Known Location Restricted to San Mateo County

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1976; USFWS 1985; Barry 1978, 1993). Historically, the largest known population of snakes was at a series of sag ponds (locally referred to as the "Skyline Ponds") along Hwy 35 in the vicinity of Pacifica, Daly City, San Bruno, and South San Francisco (Barry 1978, 1993, 1994; USFWS 1985). Today, this complex of ponds has been completely covered by urbanization. The large Bay Area population of snakes studied by Wharton (1989) has extensively declined due to the loss of several prey species from saltwater intrusion into the marsh (see Larsen 1994) and this population may now be close to extinction (Jennings, unpublished data). Besides the above, declines also resulted from large numbers of snakes being collected for the pet trade (especially overseas) and *T. s. tetrataenia* continues to be illegally collected for pets despite stiff penalties for doing so (e.g., see Bender 1981). Today, about 70% of the current remaining San Francisco garter snake habitat is composed of artificially constructed aquatic sites such as farm ponds, channelized sloughs, and reservoir impoundments (Barry 1993). Such habitats are often managed in ways that are detrimental to the snake and its preferred prey, the California red-legged frog (Barry 1993, 1994; Larsen 1994).

Current estimates put the number of San Francisco garter snakes at about 65 "permanent" reproductive populations of around 1500 total snakes >1 year of age (Barry 1993). About half the known populations are protected to some extent by refuges such as water preserves or state parks (Barry 1993). The key to preserving the species is to set aside adequate amounts of habitat and manage these areas for *T. s. tetrataenia* and its prey, especially California red-legged frogs (Barry 1993, Larsen 1994).

Amphibians & Reptiles

Trophic Levels

San Francisco garter snakes are tertiary consumers.

Proximal Species

Prey: Coast Range newt, California red-legged frog, threespine stickleback, Pacific treefrog, bullfrog.
Predators: Hawks, herons, egrets, bullfrog, striped skunk, opossum, and raccoon.

Good Habitat

San Francisco garter snakes are most abundant in natural sag ponds or artificial waterways that have been allowed to develop a dense cover of vegetative (Barry 1993). This is due to the presence of large amphibian populations (=prey base) and many basking sites for juvenile and adult snakes which are relatively secure from potential predators (Barry 1994). The presence of adjacent upland areas with abundant numbers of small mammal burrows are also important as hibernation sites for snakes during the winter (Larsen 1994).

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5

Mammals

Salt Marsh Harvest Mouse

Reithrodontomys raviventris

Howard S. Shellhammer

Life History

Salt marsh harvest mice (SMHM) are small, native rodents which are endemic to the salt marshes and adjacent diked wetlands of San Francisco Bay and are listed as an endangered species by the U.S. Fish and Wildlife Service and the State of California (Shellhammer 1982). They range in total length from 118 to 175 millimeters and in weight from 8 to 14 grams. They are vegetarians that can drink water ranging from moderately saline to sea water. They swim calmly and well. They do not burrow, but will build ball-like nests of dry grasses and other vegetation on the ground or up in the pickleweed (Fisler 1965). Their behavior is placid, so much so that their behavior is used as a secondary criterion in identifying them to the species level.

Historical and Modern Distribution

SMHM are composed of two subspecies. The northern subspecies, *R. r. haliocoetes*, is found on the upper portions of the Marin Peninsula; in the Petaluma, Napa and Suisun marshes; as well as a disjunct series of populations on the northern Contra Costa County coast. The southern subspecies, *R. r. raviventris*, is found in the more highly developed portions of the Bay from the Richmond area, down around the South San Francisco Bay (primarily south of a line between Redwood City and Hayward), and a disjunct series of small populations on the Marin Peninsula. Some modern distributions are indicated in **Figure 5.1** and a listing of available trapping data are included in **Appendix 5.1.**

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Their chromosome number and morphology have been studied by Shellhammer, and the two subspecies show some differences in chromosome shape indicating that genetic isolating mechanisms are beginning to form between them. No recent and modern genetic studies have been completed at the present time, hence nothing is known about the genetic variability of this species and whether or not it faces problems of inbreeding and random genetic drift as its average population size decreases.

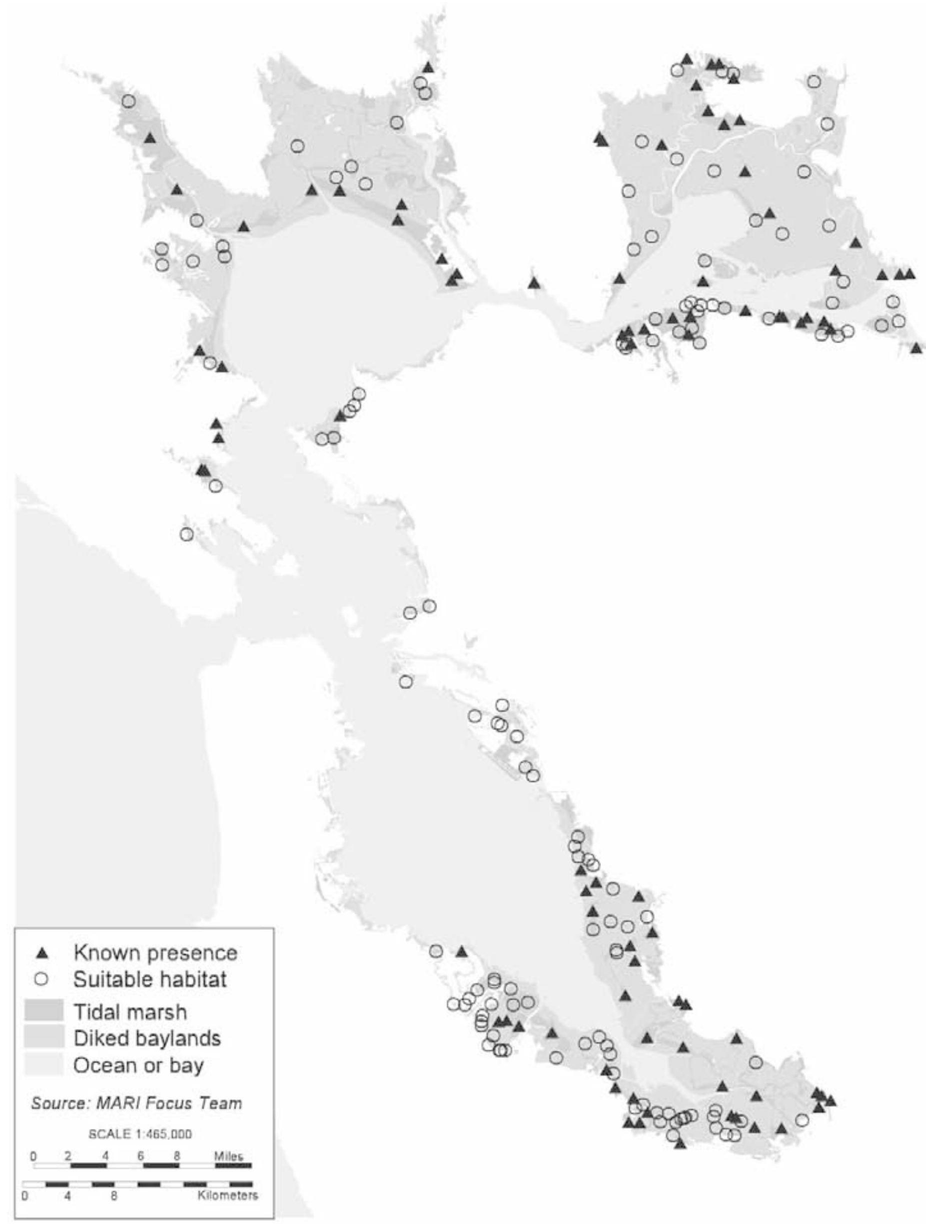
The major threats to their habitat include filling, diking, subsidence, and changes in water salinity (Shellhammer 1982, 1989). Various estimates have been made that at least 75% of all the tidal marshes around the Bay have been filled in or otherwise destroyed over the last 150 years. Most of the remaining marshes have been back-filled or diked-off, and hence most of the remaining tidal marshes are narrow strips along the bay side of the levees. Those strip marshes and most of the remaining larger marshes have lost their upper and part of their middle zones, such that there is little escape cover from high tides available. In the southern end of the South San Francisco Bay, the combination of subsidence caused by water drawdown and the freshening of that part of the Bay by massive amounts of non-saline, treated sewage effluent has changed the saline vegetation of that area to brackish and freshwater species such as bulrushes (*Scirpus sp.*), cattails (*Typha sp.*), and peppergrass (*Lepidium latifolium*), species not used by SMHM (Duke et al. 1990; Shellhammer 1982, 1989).

Because of these influences, SMHM has disappeared from many marshes and is present in very low numbers in most others. The highest consistent populations are found in relatively large marshes along the eastern edge of San Pablo Bay and in old dredge spoil

Mammals

Figure 5.1 Salt Marsh Harvest Mouse – Some Current Locations and Suitable Habitat

Note: Mice are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Mice may also be present in other areas.



disposal ponds on former Mare Island Shipyard property; most of these marshes are in or will be included in the San Pablo Bay unit of the San Francisco Bay National Wildlife Refuge (Bias and Morrison 1993, Duke et al. 1995). Other areas supporting large populations include some parts of the Contra Costa County coastline (Duke et al. 1990, 1991), some parts of the Petaluma Marshes, and the Calaveras Point Marsh in the South San Francisco Bay (Duke et al. 1990), although the latter area is deteriorating because of the declining salinity and correlated changes in vegetation.

Diked wetlands adjacent to the Bay have grown in importance as the tidal marshes bayward of their outboard dikes have decreased in size and quality (Shellhammer 1989). Most of such diked marshes in the South San Francisco Bay are being threatened by urban and industrial development along their borders. In addition, most of these diked marshes are not managed to provide adequate vegetative cover of halophytic species or to maintain their salinity over time (Duke et al. 1990, Shellhammer 1989).

Suitable Habitat

SMHM are dependent on the thick, perennial cover of salt marshes and move in the adjacent grasslands only in the spring and summer when the grasslands provide maximum cover (Fisler 1965). Their preferred habitats are the middle and upper portions of those marshes, i.e., the pickleweed (*Salicornia virginica*) and peripheral halophyte zones, and similar vegetation in diked wetlands adjacent to the Bay (Shellhammer et al. 1982, 1988). Some areas of known suitable habitat are shown in **Figure 5.1**.

Conservation and Management

There are many questions that need to be addressed in order to properly manage the SMHM. They include the following: (1) Little is known about the degree of genetic heterozygosity and polymorphism of this species. Is it variable, and hence is the SMHM resistant to increasing isolation, genetic drift, and potential increased inbreeding, or is it a species that has survived a series of genetic bottlenecks and become monomorphic and lacks resilience? Without information on its population genetics, the only prudent course of action is to argue for the largest possible population sizes of SMHM. Much more needs to be known about the population genetics of this species if it is to be properly managed over the long run. (2) It is not known how much upland edge constitutes enough of a buffer to protect SMHM from alien predators (especially cats) and human disturbance. The U.S. Fish and Wildlife Service Endangered Species biologists recommend 100 feet, but 100 feet of grassland, for example, may not be enough of a barrier to keep out dogs, cats, red foxes, or humans. (3) The impact of introduced red foxes is not known, but they have had a great impact on the California clapper rail, which is found in the same marshes with SMHM.

Control of red foxes is being carried out in those marshes in which there are rails and mice, but not in all marshes potentially containing SMHM alone. Actually, very little is known about the effects of predators on the SMHM, including the effects of the rail. (4) Little is known of the interactions between various species of rodents in diked marshes. Geissel et al. (1988) demonstrated seasonal displacement of SMHM from optimal habitat by California voles. Elaine Harding of U.C. Santa Cruz is studying (as of 1997-98) rodent interactions and has concerns that certain management practices in diked wetlands might work against SMHM. (5) Little is known about the impact of peppergrass on SMHM numbers. SMHM remain in mixed pickleweed-peppergrass communities (Duke et al. 1990, 1991), but no studies have been carried out in areas of 100% peppergrass, a condition that is becoming increasingly common in the southern end of the South San Francisco Bay. (6) Lastly, there is the strong possibility that youthful pickleweed marshes are more productive of SMHM than older ones. That is certainly the case reported by Bias (1994) and Bias and Morrison (1993) at Mare Island Naval Shipyards and in the marshes bordering the adjacent San Pablo Bay, a marsh that has been growing actively by accretion for decades. The effect of the relative youth of marshes (or possible the lack of their senescence), needs to be looked at along with the potential effects of toxics, the depth of buffer zones when marshes are bordered by either urban and industrial development, and other concerns spelled out previously in this document.

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Appendix 5.1 Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Alameda County						
Albrae Slough		100	2	0.02	1974, 1975	Cummings, E.
Albrae Slough		2600	15	0.006	1983	Shellhammer, H.
Albrae Slough		200	4	0.02	1984	Shellhammer, H.
Audubon Marsh		2700	4	0.001	1984	Shellhammer, H.
Audubon Marsh		300	7	0.023	1985	
Baumberg Tract			9		1985	
Cabot Boulevard		1046	6	0.006	1989	
Calaveras Point	Coyote Cr	100	0	0	1974, 1975	Cummings, E.
Calaveras Point	north of	100	0	0	1974, 1975	Cummings, E.
Calaveras Point		400	22	0.055	1990	Duke, R.
Calaveras Point		1000	104	0.104	1990	Duke, R.
Coyote Creek	Newby Isl	300	0	0	1985	
Coyote Creek	east	892	2	0.002	1990	Duke, R.
Coyote Creek		500	0	0	1990	Duke, R.
Coyote Hills		710	17	0.024	1975	Zetterquist
Coyote Hills		100	4	0.04	1980	Gilroy, A.
Coyote Hills Slough		100	0	0	1974, 1975	Cummings, E.
Coyote Hills Slough		400	0	0	1983	Shellhammer, H.
Coyote Hills Slough	area A	200	2	0.01	1983	Shellhammer, H.
Coyote Hills Slough	area D	200	0	0	1983	Shellhammer, H.
Coyote Hills Slough	area CH	200	0	0	1964	Shellhammer, H.
Coyote Hills Slough	area A	200	6	0.03	1984	Shellhammer, H.
Coyote Hills Slough	area PA	200	0	0	1984	Shellhammer, H.
Coyote Hills Slough	area CH	200	1	0.005	1984	Shellhammer, H.
Coyote Hills Slough		400	7	0.018	1984	Shellhammer, H.
Coyote Hills Slough		400	6	0.015	1985	Shellhammer, H.
Coyote Hills Slough	area 4	200	3	0.015	1985	Shellhammer, H.
Drawbridge		100	0	0	1974, 1975	Cummings, E.
Drawbridge		0	4		1978	
Dumbarton		25	3	0.12	1971	Schuat, D.B.
Dumbarton	railroad	100	0	0	1974, 1975	Cummings, E.
Dumbarton		400	13	0.033	1978	Leitner
Dumbarton		200	0	0	1980	Gilroy, A.
Dumbarton		500	6	0.012	1990, 1991	
Durham Road Marsh		200	0	0	1980	Gilroy, A.
EBRPD SMHM Preserve		540	4	0.007	1983	Kobetich
EBRPD SMHM Preserve		600	10	0.017	1984	Kobetich
EBRPD SMHM Preserve		725	7	0.01	1985	Kobetich
Emeryville Crescent		540	6	0.011	1982	Olsen, D.
Emeryville Crescent		1500	0	0	1986	
Fremont Redevelopment		900	13	0.014	1985	Kobetich
Hayward	Caltrans	300	1	0.003	1985	Jennings, V.R.
Hayward Marsh		900	21	0.023	1982	Shellhammer, H.
Hayward Marsh		1075	40	0.037	1990	
Ideal Marsh		100	1	0.01	1974, 1975	Cummings, E.
Ideal Marsh		200	0	0	1980	Gilroy, A.
Irvington STP		200	1	0.005	1985	Kobetich
Johnson Landing		900	21	0.023	1982	Kobetich
Johnson Landing		1950	15	0.008	1983	Kobetich
Leslie-Lincoln		200	0	0	1985	Jennings, V.R.
Leslie Quarry Site		300	2	0.007	1985	Shellhammer, H.

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Alameda County (continued)						
Mayhew's Landing		1200	41	0.034	1985	
Mayhew's Landing		7410	23	0.003	1988	Shellhammer, H.
Mayhew's Landing		3120	36	0.012	1988-89	Johnson, V.
Meadow Gun Club		200	2	0.01	1985-	Shellhammer, H.
Mowry Slough	north of	75	2	0.027	1971	Schaub, D.B.
Mowry Slough	north of	100	0	0	1974, 1975	Cummings, E.
Mowry Slough	northeast	200	1	0.005	1980	Gilroy, A.
Mowry Slough	northwest	400	0	0	1980	Gilroy, A.
Mowry Slough	north	300	2	0.007	1985	
Mt. Eden Creek		400	5	0.013	1985	Shellhammer, H.
Mt. Eden Creek		871	9	0.01	1985	
Mud Slough	e. of Dra	200	4	0.02	1985	Jennings, V.R.
Mud Slough	w. of Dra	300	0	0	1986	Anderson, J.
Munster Site		1350	34	0.025	1985	Shellhammer, H.
Newark Slough		600	9	0.015	1978	
Newark Slough	central	200	0	0	1980	Gilroy, A.
Newark Slough	east	100	0	0	1980	Gilroy, A.
Newark Slough	headquart	365	1	0.003	1980	Gilroy, A.
Newark Slough		950	36	0.038	1982	Newcomer, M.
Newark Slough	SFC	300	4	0.013	1983	Shellhammer, H.
Newark Slough		5850	20	0.003	1983	Shellhammer, H.
Newark Slough		600	0	0	1984	Shellhammer, H.
Newark Slough		800	6	0.008	1985	Shellhammer, H.
Oakland Airport		1350	0	0	1985	Kobetich
Oakland Airport		1350	0	0	1985	Shellhammer, H.
Oakland Airport		500	0	0	1990	Xucera, T.E.
Old Alameda Creek		100	0	0	1974, 1975	Cummings, E.
Old Alameda Creek		200	0	0	1980	Gilroy, A.
Old Alameda Creek	Whale's T	400	3	0.008	1980	Gilroy, A.
Old Alameda Creek		300	2	0.007	1985	
Old Fremont Airport		900	5	0.006	1985	Kobetich
Old Fremont Airport		2400	27	0.011	1986	
?? Gun Club		200	2	0.01	1985	Shellhammer, H.
Roberts Landing		817	2	0.002	1983	Shellhammer, H.
Roberts Landing		817	2	0.002	1983	Kobetich
Roberts Landing		4350	126	0.029	1987	Shellhammer, H.
Roberts Landing		1240	28	0.023	1990	
Sulphur Creek		300	0	0	1985	
Sulphur Creek		200	1	0.005	1985	Shellhammer, H.
Thornton Ave.	Caltrans	200	1	0.005	1985	Jennings, V.R.
Turk Island		100	0	0	1974, 1975	Cummings, E.
Union City 511 Areas		1020	17	0.017	1986	
Union City Marsh	area B	600	2	0.003	1983	Shellhammer, H.
Union City Marsh		600	2	0.003	1984	Shellhammer, H.
Union City Marsh		1000	5	0.005	1985	Shellhammer, H.
University Ave	E. Palo A	160	0	0	1985	Jennings, V.R.
Warm Springs Mouse Pas	King and Ly	900	1	0.001	1985	Shellhammer, H.
Warm Springs Mouse Pas	King and Ly	450	7	0.016	1989	Foerster, K.
Warm Springs Seasonal		900	13	0.014	1985	Shellhammer, H.
Warm Springs Seasonal		1350	0	0	1988	Klinger, R.C.
Whistling Wings Duck Club		200	2	0.01	1985	Shellhammer, H.

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Contra Costa County						
Antioch Point			21		1985	
Castro Creek Marsh		672	51	0.076	1981	Mishaga, R.
Concord Naval Weapons		150	12	0.08	1971	Schaub, D.B.
Concord Naval Weapons		123	4	0.033	1979	
Concord Naval Weapons		447	19	0.043	1979	Shellhammer, H.
Concord Naval Weapons		1800	22	0.012	1985	Shellhammer, H.
Concord Naval Weapons		2890	200	0.069	1991	Shellhammer, H.
Hastings Slough		1200	37	0.031	1988	Shellhammer, H.
Hoffman Marsh		80	0	0	1976	
Martinez East		200	0	0	1980	Simons, L.
Payten Shough		900	22	0.024	1988	Shellhammer, H.
Pittsburg		2800	64	0.023	1978	
Pittsburg East		100	0	0	1980	Simons, L.
Pittsburg West		100	0	0	1980	Simons, L.
Point Edith			25		1987	Botti, F.
Point Edith		800	5	0.006	1988	Shellhammer, H.
Point Edith		800	5	0.006	1988	Shellhammer, H.
Richmond Dump		200	1	0.005	1980	Simons, L.
San Pablo Creek		125	13	0.104	1971	Schaub, D.B.
San Pablo Creek		100	0	0	1974, 1975	Cummings, E.
San Pablo Creek		2480	81	0.033	1986	
Shell marsh		2270	6	0.003	1988	Shellhammer, H.
Shell marsh		800	1	0.001	1990	
Stockton Ship Channel	CWWS #22	400	0	0	1980	Shellhammer, H.
Stockton Ship Channel	CWWS #20	200	0	0	1980	Shellhammer, H.
Stockton Ship Channel	CWWS #21	200	6	0.03	1980	Shellhammer, H.
Stockton Ship Channel	CWWS #24	400	0	0	1980	Shellhammer, H.
Marin County						
Bahia	south	930	31	0.033	1984	Shellhammer, H.
Bahia	south, no	3000	68	0.023	1987	Shellhammer, H.
Bahia	north	300	3	0.01	1989	Duke, R.
Black John Slough	Mahoney S		16		1987	Bott, F.
China Camp State Park		200	2	0.01	1980	Simons, L.
Corte Madera		100	3	0.03	1971	Schaub, D.B.
Corte Madera		100	6	0.06	1974, 1975	Cummings, E.
Corte Madera		100	0	0	1976	
Corte Madera		200	2	0.01	1980	Simons, L.
Corte Madera		672	19	0.028	1981	Mishaga, R.
Corte Madera		1412	0	0	1983	Shellhammer, H.
Corte Madera		750	0	0	1990	Freas, K.E.
Gallinas Creek	north ban	100	1	0.01	1974, 1975	Cummings, E.
Gallinas Creek	south ban	100	1	0.01	1974, 1975	Cummings, E.
Gallinas Creek		672	34	0.051	1981	Mishaga, R.
Hamilton Air Force Base		300	1	0.003	1982	Newcomer, M.
John F. McInnis Park		1050	4	0.004	1986	
Larkspur ferry Marsh		480	0	0	1988	Shellhammer, H.
Muzzi Marsh	south	430	0	0	1986	
Novato Creek		100	1	0.01	1974, 1975	Cummings, E.
Petaluma Creek		200	0	0	1980	Simons, L.
Petaluma Sewage Treatm		100	0	0	1974, 1975	Cummings, E.
Pickleweed Park: San Rafael		1094	37	0.034	1990	Bias, M.A.

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Marin County (continued)						
Spinnaker Lagoon		1200	11	0.009	1990	
Spinnaker Lagoon		1200	0	0	1991	
Marin/Sonoma County						
Petaluma River Mouth		100	0	0	1974, 1975	Cummings, E.
Napa County						
Coon Island	south end	200	2	0.01	1980	Simons, L.
Fagan Marsh	northeast	100	14	0.14	1980	Simons, L.
Deman Slough		100	0	0	1980	Simons, L.
Napa Slough	w of brid	100	1	0.01	1980	Simons, L.
San Mateo County						
Bair Island		500	3	0.006	1971	Schaub, D.B.
Bair Island	east	100	1	0.01	1974, 1975	Cummings, E.
Bair Island	Corkscrew	100	0	0	1974, 1975	Cummings, E.
Bair Island	southwest	100	1	0.01	1974, 1975	Cummings, E.
Bair Island	east	300	7	0.023	1985	
Bair Island	Corkscrew	300	3	0.01	1985	
Bair Island	southwest	220	19	0.086	1988	Botti, F.
Bay Slough		200	0	0	1980	Gilroy, A.
Belmont Slough		100	0	0	1974, 1975	Cummings, E.
Bird Island		100	1	0.01	1974, 1975	Cummings, E.
East Third Street		150	3	0.02	1989	McGinnis, S.M.
Foster City	marina si	116	0	0	1978	Johnston, D.S.
Foster City		900	0	0	1985	Shellhammer, H.
Foster City Marina Sit		900	0	0	1985	Duke, R.
Greco Island		100	2	0.02	1971	Schaub, D.B.
Greco Island		100	0	0	1974, 1975	Cummings, E.
Greco Island	south	150	0	0	1980	Gilroy, A.
Greco Island	north	150	3	0.02	1980	Gilroy, A.
Ideal Cement Marsh		250	5	0.02	1976	
Ideal Cement Marsh		900	0	0	1984	Shellhammer, H.
Ideal Cement Marsh		800	1	0.001	1985	Shellhammer, H.
Ideal Cement Marsh		978	42	0.043	1989-90	
Laumeister Marsh		100	0	0	1974, 1975	Cummings, E.
Laumeister Marsh		500	8	0.016	1990, 1991	
Palo Alto Yacht Harbor		200	1	0.005	1980	Gilroy, A.
Phelps Slough		100	0	0	1974, 1975	Cummings, E.
Ravenswood Slough		100	0	0	1974, 1975	Cummings, E.
Redwood Shores		100	0	0	1974, 1975	Cummings, E.
San Rafael Canal		1344	37	0.028	1990	Flannery, A.W.
Santa Clara County						
Alviso	south of	100	0	0	1975	Malenson, M.A.
Alviso Dump		200	0	0	1975	
Alviso Marina		100	0	0	1974, 1975	Cummings, E
Alviso Slough	west	100	0	0	1974, 1975	Cummings, E
Alviso Slough	east	100	4	0.04	1974, 1975	Cummings, E
Artesian Slough		200	0	0	1986	Anderson, J.
Calabazas Creek	south of	100	0	0	1975	Malenson, M.A.
Coyote Creek		900	11	0.012	1985	Shellhammer, H.
Coyote Creek		200	6	0.03	1990	Duke, R.
Crittenden Marsh		300	0	0	1985	
Emily Renzel Marsh	ITT marsh	4200	54	0.013	1988	Johnson, V.

Mammals

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Santa Clara County (continued)						
New Chicago Marsh		100	2	0.02	1974, 1975	Cummings, E
New Chicago Marsh		1152	14	0.012	1975	Zetterquist,
New Chicago Marsh		300	0	0	1978	
New Chicago Marsh		400	0	0	1980	Gilroy, A., a
New Chicago Marsh		392	11	0.028	1985	Shellhammer, H.
New Chicago Marsh		2820	65	0.023	1986	Shellhammer, H.
New Chicago Marsh	Sammis si	1400	4	0.003	1987	Duke, R.
New Chicago Marsh		705	8	0.011	1988	Shellhammer, H.
Owens Corning Landfill		800	6	0.008	1990	Duke, R.
Palo Alto Baylands		40	1	0.025	1971	Schaub, D.B.
Palo Alto Baylands		2058	196	0.095	1972	Wondolleck, E
Palo Alto Baylands		100	0	0	1974, 1975	Cummings, E
Palo Alto Baylands		300	1	0.003	1985	
Palo Alto Baylands		1500	32	0.021	1990	
Palo Alto Flood Basin		100	0	0	1974, 1975	Cummings, E
Palo Alto Flood Basin		220	1	0.005	1975	Zetterquist,
Palo Alto Flood Basin		100	0	0	1975	Malenson, M.A.
Ravensweed Area		800	1	0.001	1990	Duke, R.
Sunnyvale		1200	3	0.003	1990	Duke, R.
Sunnyvale Baylands Park		540	0	0	1987	
Triangle Marsh	Grey Goos	20	0	0	1971	Schaub, D.B.
Triangle Marsh		4376	71	0.016	1974	Rice, V.C.
Triangle Marsh		100	23	0.23	1974, 1975	Cummings, E
Triangle Marsh		200	0	0	1976	
Triangle Marsh		922	12	0.013	1977-1978	Shellhammer, H.
Triangle Marsh		300	2	0.007	1983	Shellhammer, H.
Triangle Marsh		182	0	0	1984	Shellhammer, H.
Triangle Marsh		384	2	0.005	1985	Shellhammer, H.
Triangle Marsh		300	2	0.007	1986	Anderson, J.
Triangle Marsh		600	5	0.008	1986	Anderson, J.
Triangle Marsh		500	10	0.02	1990	Duke, R.
Triangle Marsh		1500	35	0.023	1990	Duke, R.
Solano County						
ACME Landfill Site		1200	9	0.008	1989	Foster, J.
Benicia	Marine Te	160	2	0.013	1979	Michaels, J.L.
Benicia State Park		200	0	0	1980	Simons, L., a
Chabot Creek Outfall M		483	4	0.008	1989	Ford, K.
Collinsville		1296	32	0.025	1978	Envirodyne En
Collinsville		1296	32	0.025	1978	Envirodyne En
Collinsville		1536	8	0.005	1979	
Collinsville		2350	2	0.001	1980	
Collinsville, Rail Cor		640	0	0	1979	
Cordelia Dike		150	0	0	1980	Shellhammer, H
Cullinan Ranch	S. Dutchm	2385	5	0.002	1983	Shellhammer, H
Denverton Highway		150	0	0	1980	Shellhammer, H
Ehaann Duck Club		800	3	0.004	1988	Shellhammer, H
Figueras Tract		100	2	0.02	1974, 1975	Cummings, E.
Figueras Tract		100	2	0.02	1974	Lindeman, E.
Gentry/Pierce Property		1800	10	0.006	1986	Duke, R.
Gold Hills Road Overcr		500	3	0.006	1990	
Grizzly Bay 1		300	5	0.017	1980	Shellhammer, H

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Solano County (continued)						
Grizzly Bay 2		300	2	0.007	1980	Shellhammer, H.
Grizzly Island		74	19	0.257	1971	Schuab, D.B.
Hill Slough	Windmill	150	0	0	1980	Shellhammer, H.
Hill Slough	Dump	150	0	0	1980	Shellhammer, H.
Hill Slough	wildlife	200	11	0.055	1981	
Hill Slough		300	1	0.003	1985	
Island #1		98	20	0.204	1971	Schuab, D.B.
Jackspine Wetland		150	0	0	1980	Shellhammer, H.
Joice Island		50	9	0.18	1971	Schuab, D.B.
Joice Island	powerline	300	1	0.003	1980	Shellhammer, H.
Joice Island	footbridge	300	0	0	1980	Shellhammer, H.
Joice Island		300	2	0.007	1985	
Leslie Intake	west bank	100	12	0.12	1974, 1975	Cummings, E.
Leslie Intake		150	20	0.133	1976	
Opes Road Marsh		420	0	0	1990	
Uco Slough		300	3	0.01	1986	
Mare Island Naval Ship		100	2	0.02	1974, 1975	Cummings, E.
Mare Island Naval Ship		1384	296	0.214	1985	Kovach, S.D.
Mare Island Naval Ship		2114	140	0.066	1986	Kovach, S.D.
Mare Island Naval Ship		1764	240	0.136	1987	Kovach, S.D.
Mare Island Naval Ship		14672	1005	0.068	1989	Bias et al.
Mare Island Naval Ship		9383	336	0.036	1990	Bias et al.
Mare Island Naval Ship		20502	1427	0.07	1991	Bias et al.
Meins Landing		300	2	0.007	1980	Shellhammer, H.
Meins Landing Mound		300	2	0.007	1980	Shellhammer, H.
Montezuma Site		1296	32	0.025	1978	
Montezuma Site		1800	17	0.009	1978	
Montezuma Site		1200	21	0.018	1991	Duke, R.
Morrow Island		300	0	0	1980	Shellhammer, H.
Napa River			3		1972	Rollins, G.
Nurse Slough		150	0	0	1980	Shellhammer, H.
Nurse Slough		400	7	0.018	1986	
Park Place		880	0	0	1987	
Park Place Shopping Ce		980	0	0	1987	
Rayer Island		30	1	0.033	1985	Kovach, S.D.
Roe Island		800	6	0.008	1988	Shellhammer, H.
Roe Island (east)		90	8	0.089	1985	Kovach, S.D.
Roe Island (west)		90	3	0.033	1985	Kovach, S.D.
Sears Point 1		800	21	0.026	1982	Newcomer, M.
Simmons Island		50	7	0.14	1971	Schuab, D.B.
Simmons Island	3 areas	600	4	0.007	1980	Shellhammer, H.
Simmons Island		1200	1	0.001	1985	Shellhammer, H.
Southern Solano Annexa		1109	30	0.027	1987	
Southhampton Bay (outb		375	2	0.005	1986	
Southhampton Marsh		700	18	0.026	1990	
Stockton Ship Channel	Brown's Is	400	0	0	1980	Shellhammer, H.
Stockton Ship Channel	Ryer Is	400	0	0	1980	Shellhammer, H.
Suisun Marsh Club No. 2	Bryan Par	195	6	0.031	1980	
Suisun Slough		300	4	0.013	1985	
Sulphur Springs Creek		600	0	0	1990	
Teal Boathouse		300	0	0	1980	Shellhammer, H.

Appendix 5.1 (continued) Important Data Sets for Salt Marsh Harvest Mouse (1971 - 1991). Compiled by Elaine Harding from a USFWS database.

Location	Subarea	Trap Nites	Mice	Mice Per Trap Nite	Year	Author
Solano County (continued)						
Teal Slough		300	2	0.007	1980	Shellhammer, H.
Vennink	Building	150	0	0	1980	Shellhammer, H.
Vennink	Stockgate	300	3	0.01	1980	Shellhammer, H.
Vennink	Decoy	300	0	0	1980	Shellhammer, H.
Vennink	Bayside	150	0	0	1980	Shellhammer, H.
West Grizzly Island		300	0	0	1985	
Wildwings Duck Club (M		800	7	0.009	1988	Shellhammer, H.
Sonoma County						
Lower Tubbs Island		100	9	0.09	1971	Schaub, D.B.
Lower Tubbs Island		100	4	0.04	1974, 1975	Cummings, E.
Lower Tubbs Island		256	5	0.02	1979	Moss, J.G.
Lower Tubbs Island		100	0	0	1980	Simons, L.
Mare Island Naval Ship		672	80	0.119	1988	Stroud, M.C.
Petaluma Creek		100	7	0.07	1971	Schaub, D.B.
Petaluma River	1 m. upst	100	0	0	1974, 1975	Cummings, E.
Petaluma River Mouth		100	1	0.01	1980	Simons, L.
Sonoma Creek	east	100	2	0.02	1974, 1975	Cummings, E.
Sonoma Creek	mouth	100	2	0.02	1980	Simons, L.
Sonoma Creek		200	12	0.06	1982	Newcomer, M.
Tolay Creek Mouth		100	4	0.04	1980	Simons, L.
Tubbs Island 1		750	33	0.044	1982	Newcomer, M.
Tubbs island Accessory		205	8	0.039	1980	Simons, L.

California Vole

Microtus californicus

William Z. Lidicker, Jr.

Life History

California voles are common inhabitants of the San Francisco Bay wetlands. They are vegetarians, feeding extensively on *Salicornia* and other marsh vegetation. They make runways through the vegetation, burrow extensively in non-flooded areas, and often utilize driftwood for cover. They are critically important prey species for a wide variety of mammalian and avian predators.

The population dynamics of voles has been studied intensively in adjacent upland grasslands (Cockburn and Lidicker 1983; Krebs 1966; Lidicker 1973; Pearson 1966, 1971; Salvioni and Lidicker 1995), but little is known about marsh populations. It is not known, for example, if most marsh populations are merely extensions of upland ones or independent demographic units. An exception is the San Pablo Creek vole; see below. Grassland populations around the Bay exhibit annual or multi-annual cycles in numbers, but the demographic behavior of salt marsh populations is unknown. Similarly, we know that grassland voles breed mainly in the wet season, and especially intensely from February through May. Voles in marshes may well be different, perhaps breeding mostly in the summer and very little during the flood-prone winters.

California voles are keystone species in grassland communities by virtue of their importance as a major prey species (Pearson 1985) and their potentially great effect on vegetation (Lidicker 1989). Thus, if similar roles are played in San Francisco Bay wetlands, these rodents may be vital to the health of the wetland communities. Because they are known to exhibit strong fluctuations in numbers (four orders of magnitude), suitable habitat patches must be large enough for the species to survive low-density bottlenecks. These voles are also known to exhibit strong non-trophic interactions with other species of mammals. The introduced house mouse (*Mus musculus*) is strongly affected negatively by the presence of voles (DeLong 1966, Lidicker 1966). Interactions with Western harvest mice (*Reithrodontomys megalotis*) are more complex (Heske et al. 1984). At moderate *Microtus* densities harvest mice are positively influenced, presumably because the harvest mice make effective use of vole runways. However, at high vole densities, the *Reithrodontomys* are strongly negatively impacted. It is possible that salt marsh harvest mice (*Reithrodontomys raviventris*) may interact in a similarly complex way with voles. Geissel et al. (1988) demonstrated seasonal displacement of salt marsh harvest mice by voles. More subtle indirect effects may also be important. For example, if voles sustain populations of red fox (*Vulpes vulpes*), an indirect negative effect on clapper rails (*Rallus longirostris obsoletus*) may be manifest.

J.K. Clark; Courtesy UC IPM Project

Historical and Modern Distributions

The taxonomic status of San Francisco Bay voles is complex. Marsh inhabiting voles from Point Isabel (Contra Costa County) south on the east side of the Bay and around to the west side as far north as Redwood City have been described as the subspecies *paludicola*. Thaeler (1961) examined these populations in detail and concluded that at least the East Bay populations could not be distinguished from the upland subspecies *californicus*. Voles from the Marin County side of the Bay are placed in *M.c. eximius*, and those from Grizzly Island (Solano County) and eastward into the Delta represent the large, dark subspecies *aestuarinus*. Of special interest and concern, Thaeler (1961) described the vole population inhabiting the marshes around the mouth of San Pablo Creek (Contra Costa County) as *M.c. sanpabloensis*. This subspecies is viewed as a species of special concern by the State of California (Williams 1986). It is darker and yellower than the adjacent populations of *M.c. californicus*. Further, its palatines are deeply excavated along their posterior borders, the rostrum is narrow, and the auditory bullae relatively inflated.

Suitable Habitat

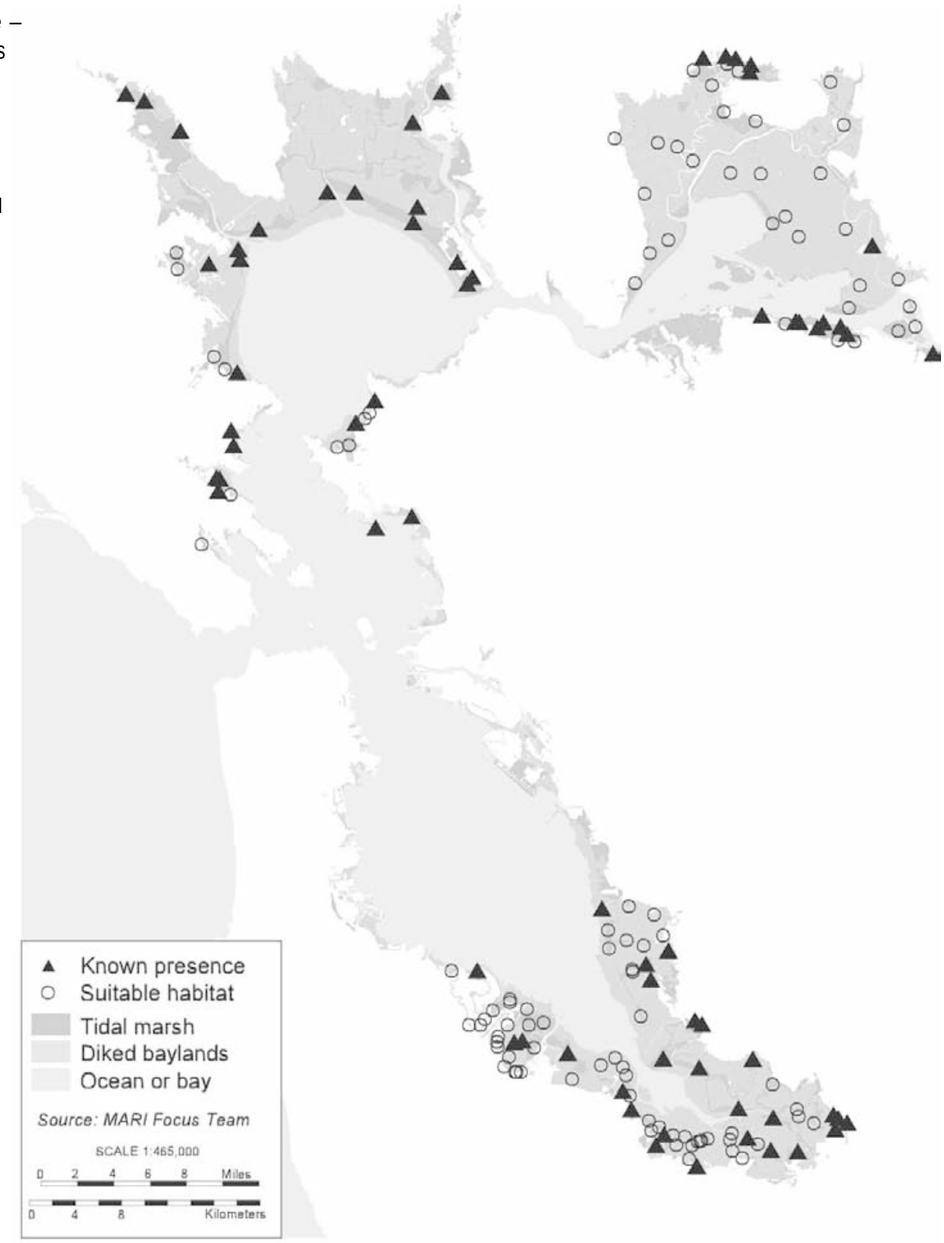
Habitat use extends from adjacent upland grasslands into both salt and freshwater marshes, at least into those where flooding does not occur regularly. Voles are good swimmers, however, and can survive occasional inundation. Some known current locations and potential suitable habitats are shown in **Figure 5.2**.

Conservation and Management

Efforts to conserve wetlands should be aware of the endemic form *M.c. sanpabloensis* and attempt to achieve

Figure 5.2 California Vole – Some Current Locations and Suitable Habitat

Note: Voles are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Voles may also be present in other areas.



Mammals

representation of the other three currently recognized subspecies in the Bay Area as well. Because of their role as a major prey species, California voles are likely keystone species in the health of Bay Area wetland communities.

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Salt Marsh Wandering Shrew

Sorex vagrans haliocoetes

Howard S. Shellhammer

Life History

The salt marsh wandering shrew (SMWS) appears to have some of the most restrictive food and habitat requirements of any mammal inhabiting the marshes of the greater San Francisco Bay Region—far more, for example, than the endangered salt marsh harvest mouse (*Reithrodontomys raviventris*). While little is known of the SMWS subspecies, shrews in general are insectivores which are born in the spring and become sexually mature the following winter. SMWSs have gestation periods of about 21 days (Owen and Hoffman 1983). Many shrew species have only one litter, and adults die after the young are weaned (Jameson and Peeters 1988).

Historical and Modern Distribution

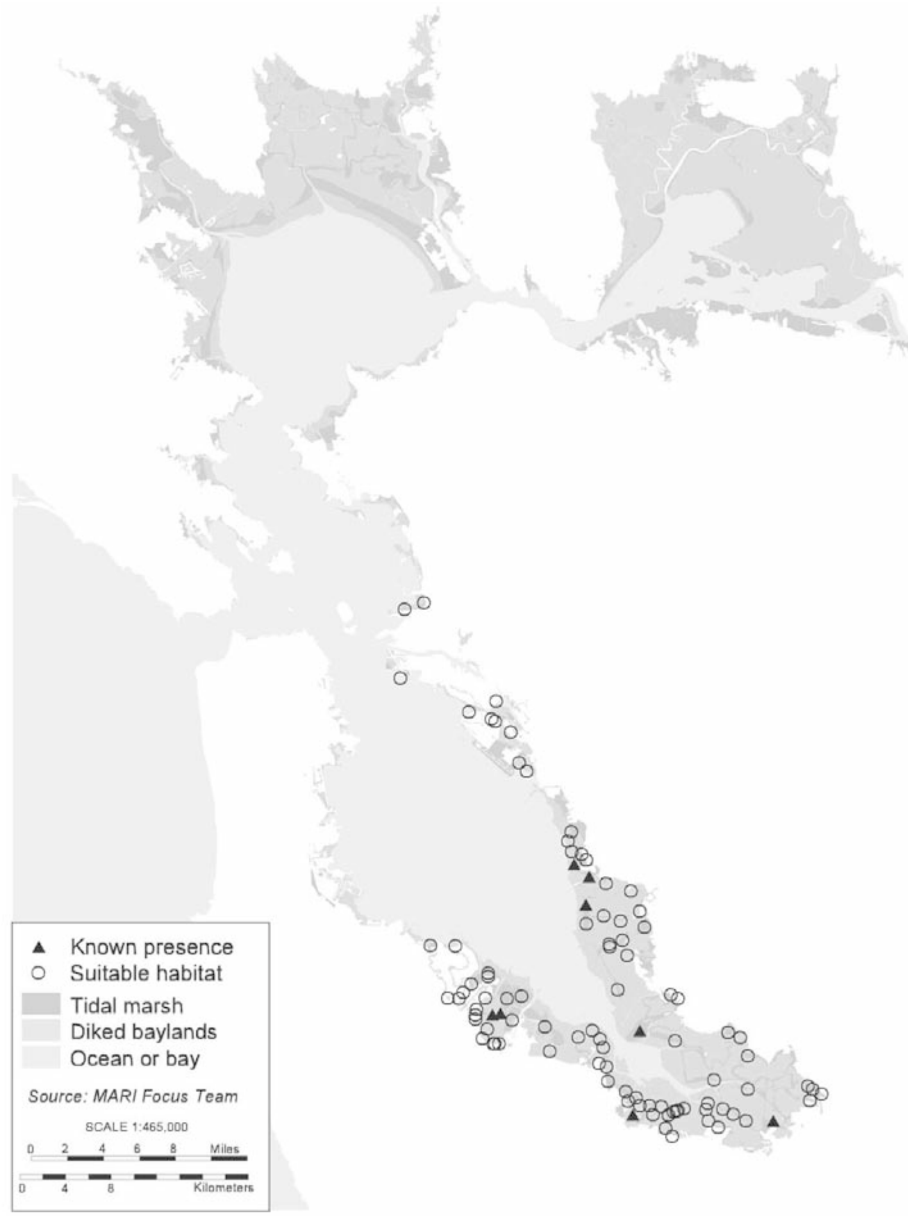
The historical range of the SMWS extended from the northern end of the San Francisco Peninsula, down through the marshes of the South San Francisco Bay, and up through the marshes of western Contra Costa County to about the Benicia Straits.

Johnston and Rudd (1957) suggested that between 1951 and 1955 shrews represented about 10% of the small mammals of the marshes. They were far less numerous in the 1970s and 80s, at least in the southern part of its range (Shellhammer, pers. obs.). Known or suspected populations as of 1986 included marshes south of Foster City and Hayward and in the San Pablo marshes of the San Pablo Bay (WESCO 1986). This subspecies of vagrant shrew is currently confined to the salt marshes of the South San Francisco Bay **(Figure 5.3)**. It exists in a narrow band of tidal salt marsh and does not seem to be present in diked marshes.

Dr. Richard B. Forbes

Figure 5.3 Salt Marsh Wandering Shrew – Some Current Locations and Suitable Habitat

Note: Shrews are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Shrews may also be present in other areas.



Suitable Habitat

The SMWS's habitat is wet, medium high salt marshes. It is best described by D. Williams (1983) in a draft report for the California Department of Fish and Game using material primarily from Johnston and Rudd (1957): "[Salt marsh wandering shrews] frequent areas in the tidal marshes providing dense cover, abundant food (invertebrates), suitable nesting sites, and fairly continuous ground moisture. Their center of activity is in the 'medium high marsh,' about 6 to 8 feet above sea level, and in lower marsh areas not regularly inundated. Suitable sites are characterized by abundant driftwood and other debris scattered among pickleweed (*Salicornia)*. The pickleweed is usually one to two feet in height. The detritus preserves moisture and offers refuge in dry period to amphipods, isopods and other invertebrates, and resting sites for shrews. Nesting material consists of plant material, primarily *Salicornia* duff. The higher marsh, 8 to 9 feet in elevation, is too dry and offers only minimal cover—few to no shrews occupy this zone. The lower cordgrass (*Spartina*) zone is subjected to daily tidal floods and has cover too sparse for shrews."

Some potential suitable habitat locations are shown in **Figure 5.3**.

Conservation and Management

Johnston and Rudd's 1957 paper represents the last scientific work on the subspecies, per se. The rest of the reports (Williams 1983; WESCO 1986; this present effort) are all based on that study and that of Rudd 1955.

Many changes have taken place since the early 1950s and little to nothing is known as to how such changes have affected the prey or habitat requirements of this shrew. The southern part of the San Francisco Bay has been greatly freshened by hundreds of millions of gallons of treated sewage outflows per day, and this freshening has brought about changes in plant species composition. Until point source reductions were placed on industrial sewage in the 1980s, large amounts of heavy metals, as well as polychlorinated biphenyls and petroleum hydrocarbons were poured into the Bay. In addition, the storm runoff and inflows of creeks and small rivers carried unknown amounts of pesticides, petroleum compounds, and other toxic substances. It is not known how decreased salinity and increased toxicity in the South Bay may have impacted the shrews, either directly, or indirectly, through changes in the amount and diversity of their prey. In addition to salinity, vegetation changes, and toxics, many of the marshes of the South Bay have subsided, and the *Salicornia* bands have become more degraded and more heavily inundated. Again little is known as to the effects on this shrew of such changes.

The SMWS is currently listed as "Mammalian Species of Special Concern" by the California Deptartment of Fish and Game and as a candidate species for listing in Category 2 by the U.S. Fish and Wildlife Service. Neither classification offers legal protection to its habitat. Little recent biological information is available to support its classification as a protected species, a status it merits.

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Suisun Shrew

Sorex ornatus sinuosis

Kevin MacKay

Life History

The Suisun shrew is a small (95-105 mm in total length), dark, insectivorous mammal with a long, pointed nose, and a well-developed scaly tail (37-41 mm). Suisun shrews are carnivores and predators feeding primarily upon amphipods, isopods, and other invertebrate species (WESCO 1986, Hays 1990). The shrews may also occasionally serve as prey for several large predators such as the short-eared owl (*Asio flammeus*), northern harrier (*Circus cyaneus*), and black-shouldered kite (*Elanus caeruleus*) (WESCO 1986).

The reproductive period of the Suisun shrew extends from late February through September, with the majority of breeding occurring from early spring through May. A second breeding period occurs in late summer when the young born the previous spring are mature and able to mate for the first time.

Shrews typically construct domed, cup-like nests composed of small paper scraps and dead material from plants such as pacific cordgrass (*Spartina foliosa)*, pickleweed (*Salicornia virginica)*, and salt grass (*Distichlis spicata)*. The nests are usually placed directly on the soil surface under driftwood, planks, or wood blocks, and are situated above the high tide line to escape flooding (WESCO 1986). Runways enter from the sides and from beneath, and are not opened until two to three weeks after the birth of the young (Johnston and Rudd 1957). After the young have dispersed, the nests may be used by other small mammals such as the endangered salt marsh harvest mouse (*Reithrodontomys raviventris*) (WESCO 1986).

There are no published data on the gestation period of the Suisun shrew, but the salt marsh wandering shrew and other small shrews have a gestation period of about 21 days (Owen and Hoffmann 1983, WESCO 1986). Litter size ranges from four to six individuals, with a survival rate of 55 to 60 percent from near birth to just after weaning (Johnston and Rudd 1957). Causes of mortality include drowning from high tides, death of the mother, starvation, exposure, and predation (WESCO 1986). The young remain in the nest for up to five weeks and then move into adjacent areas (Rudd 1955).

Suisun shrews seldom reach their maximum life expectancy of 16 months, and populations turn over on an annual basis. Populations in the early spring typically consist of adults born the previous year. These individuals gradually die off during the summer months, and by fall have been almost completely replaced by young born the previous spring (Owen and Hoffmann 1983).

Activity patterns vary according to season and reproductive condition in the Suisun shrew, but the subspecies is predominately nocturnal, especially during the breeding season. Sexually mature shrews are very active in the spring, concurrent with the breeding season, but are less active during the early summer. Young-of-the-year born in early spring become sexually mature by late summer, and their activity patterns peak during this second breeding season. Others, born later in the season are still sexually immature by late summer and remain comparatively inactive during this period (Owen and Hoffmann 1983).

Hays (1990) found that during the non-breeding season, shrews lived in loose social groups of 10 to 15 individuals. These groups contained only one adult male, and one such group occupied 0.07 ha. In the spring other adult males invade these groups, disrupting the stable structure by competing among themselves.

Territorial behavior in shrews has not been well documented in the field. However, Rust (1978) noted territorial patrolling in observations of breeding captive Suisun shrews.

Historical and Modern Distribution

One of the nine subspecies of ornate shrew that occur in California, the Suisun shrew is a relatively rare inhabitant of the salt marsh ecosystem of San Pablo and Suisun Bays (WESCO 1986). Johnston and Rudd (1957) estimated that the shrews represent approximately 10 percent of the mammalian fauna present in marsh habitats, and were less abundant than mice (*Mus sp.)*, rats (*Rattus sp.)*, voles (*Microtus sp.)*, and harvest mice (*Reithrodontomys sp.)*.

The historical extent of the Suisun shrew distribution is unknown (WESCO 1986) **(Figure 5.4)**. According to Rudd (1955) the subspecies historically inhabited the tidal saline and brackish salt marsh communities of northern San Pablo and Suisun bays, ranging from the mouth of the Petaluma River, Sonoma County on the west, eastward through Southampton and Grizzly Island to approximately Collingsville, Solano County (WESCO 1986, Rudd 1955, Williams 1983). The western extent of the range was redefined by Brown and Rudd (1981) as they identified the shrews inhabiting the marshes west of Sonoma Creek and Tubbs Island as *S. o. californicus* (WESCO 1986, Williams 1983).

However, surveys completed by Grinnell (1913) discovered Suisun shrews only at Grizzly Island. Researchers (WESCO 1986) have speculated that, at that time, the shrew was restricted to the greater Grizzly Island area because of the lack of suitable habitat throughout the rest of the historic range. The 1914 soil survey of the San Francisco Bay Area identifies most of the Napa Marsh as low tidal mud flats, a habitat that would be consistently inundated by tidal waters and thus uninhabitable by Suisun shrews or other small mammals. Once these areas were diked, and suitable habitat created, the shrew may have expanded its historic range into these adjacent areas (WESCO 1986).

There are no data available which directly measures the current densities of Suisun shrew populations. The number of individuals within a population appears to vary with season and habitat type. Newman (1970) estimated that the most favorable habitat supported shrew densities of as many as 111 individuals per hectare. A related species, the dusky shrew (*Sorex obscurus*), has overlapping home ranges averaging 0.037 ha in size, with a density of 37 to 42 individuals per hectare. These latter figures are probably a more accurate depiction of Suisun shrew populations as the amount of favorable habitat is limited throughout most of its range (WESCO 1986).

The Suisun shrew is currently limited in its distribution to the scattered, isolated remnants of natural tidal salt and brackish marshes surrounding the northern borders of Suisun and San Pablo bays (WESCO 1986).

Rudd (1955) identified four distinct populations of Suisun shrews: the Grizzly Island population, found throughout the marshlands east of Suisun Slough; a peripheral population found west of Suisun Slough and on Morrow Island; the Southampton population, restricted to the Benicia State Recreation Area; and the Sears Point Road population located in the Napa marshes.

No Suisun shrews were captured in either of the two most recent population studies (Williams 1983, WESCO 1986) that attempted to assess the current distribution of the shrew. This lack of trapping success can possibly be attributed to the extremely high rainfall in 1982 and 1986. Most of the low-lying marshes were flooded for extended periods of time, adversely affecting the small mammal populations. Additional trapping efforts for salt marsh harvest mice occasionally yielded *Sorex* captures; however, only one capture, at Cullinan Ranch on South Slough, was identified as *S. o. sinuosis* (WESCO 1986).

WESCO (1986) plotted all known *S. o. sinuosis* captures to delineate extant populations. Only two individual areas were identified that support populations of Suisun shrews: Grizzly Island and Solano Island Number 1. Nine additional marsh areas were also identified as having a high probability of supporting Suisun shrew populations: Skaggs Island, Appleby Bay/Coon Island, Steamboat Slough, Vallejo, Morrow Island, Cordelia Slough South, Hammond Island, Simmons/Wheeler Islands, and Collingsville (WESCO 1986).

Suitable Habitat

Suisun shrews typically inhabit saline and brackish tidal marshes characterized by pacific cordgrass (*Spartina foliosa*), pickleweed (*Salicornia virginica*), gumplant

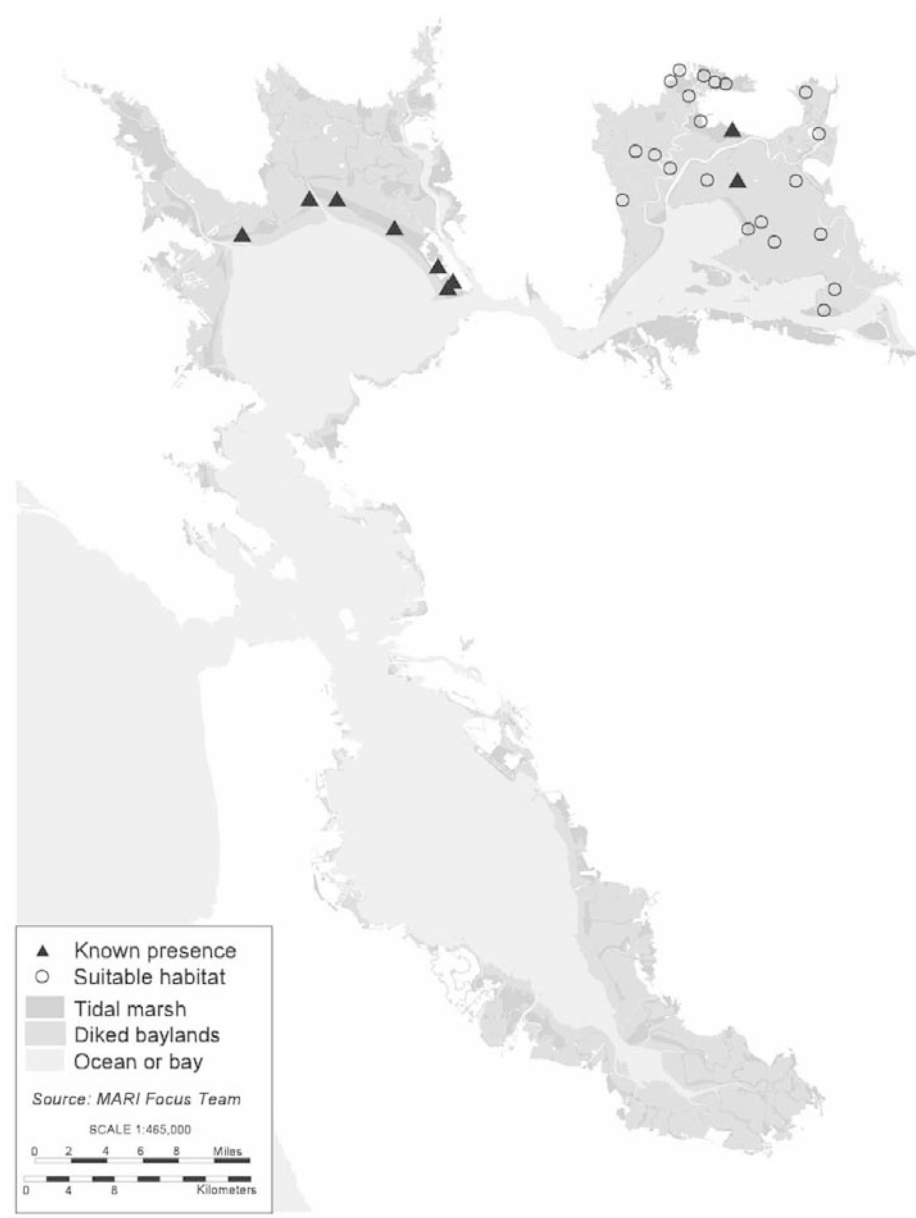

Figure 5.4 Suisun Shrew – Some Current Locations and Suitable Habitat

Note: Shrews are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Shrews may also be present in other areas.

(*Grindelia humulis*), California bulrush (*Scirpus californicus*), and common cattail (*Typha latifolia*). However, shrew occurrence appears to be more strongly associated with vegetation structure rather than species composition. Suisun shrews prefer dense, low-lying vegetation which provides protective cover and suitable nesting sites, as well as abundant invertebrate prey species (Owen and Hoffmann 1983). Driftwood, planks, and other debris found above the high-tide line also affords the shrew with valuable foraging and nesting sites. In addition, adjacent upland habitats provide essential refuge areas for Suisun shrews and other terrestrial animals during periods of prolonged flooding (Williams 1986). Some areas of potentially suitable habitat for the Suisun Shrew are shown in **Figure 5.4**.

Conservation and Management

Williams (1986) identified the lack of an adequate elevational gradient of marsh vegetation and adjacent upland habitats as the principal obstacles to the recovery of Suisun shew populations in San Pablo and Suisun bays. However, as the Suisun shrew does not seem to make use of upland grasslands (Hays 1990), and because of evidence of interbreeding with *S. o. californicus*, future marsh management practices should include the provision of elevated sites that flood only occasionally, but not include upland grassland, which would encourage contact with *californicus*.

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Ornate Shrew

Sorex ornatus californicus

Elaine K. Harding

Life History

Ornate shrews are small insectivores weighing on average five grams and with a tail short relative to the length of the head and body (Owen and Hoffmann 1983). There are nine subspecies of ornate shrew found throughout California and Mexico, and three of these are currently candidates for federal listing (USFWS 1989). *Sorex ornatus californicus* is not considered a sensitive species, although very little information is known about this subspecies, as is the case with most shrews. This subspecies may coexist with the Suisun shrew (*Sorex ornatus sinuosis)* in the marshes of San Pablo and Suisun bays. The pelage of the ornate shrew is grayish brown dorsally to a pale gray ventrally, which differentiates it from the Suisun shrew's darker pelage (Rudd 1955).

Shrews reproduce from late February through September, with peaks in late spring and summer. There is little information on this species' litter size or survival, but embryo counts ranged from four to six (Owen and Hoffmann 1983). A few young-of-the-year born in spring may mature by summer and reproduce. These shrews live no longer than 12 to 16 months. Their extremely high metabolism requires that they eat high energy foods often throughout the course of a day. *S. o. californicus* is a predator of invertebrates and may find food and cover in low, dense, moist vegetation. In wetland areas, amphipods are known to be important sources of food for shrews, but the diet of this shrew has not been thoroughly investigated.

Historical and Modern Distribution

S. ornatus californicus' range is from the Sacramento Valley southwest to the Central Coast, including the San Francisco Bay except for the southwestern portion of San Pablo Bay. A thorough account of its current range within the San Francisco Bay is not available due to a lack of identification to the species level when found incidentally during other studies. Some known and potential habitats, however, are indentified in **Figure 5.5**.

The ornate shrew may hybridize with the Suisun shrew in particular parapatric zones in North San Pablo Bay marshes. Rudd (1955) described populations at Grizzly Island and Sears Points which exhibited intermediate morphological characters between *S. o. californicus* and *S. o. sinuosus*. More recently Brown and Rudd (1981) concluded that populations at other locations once considered hybrids of the Suisun shrew (*S. o. sinuosus)* and the salt marsh wandering shrew (*S. vagrans)* are only

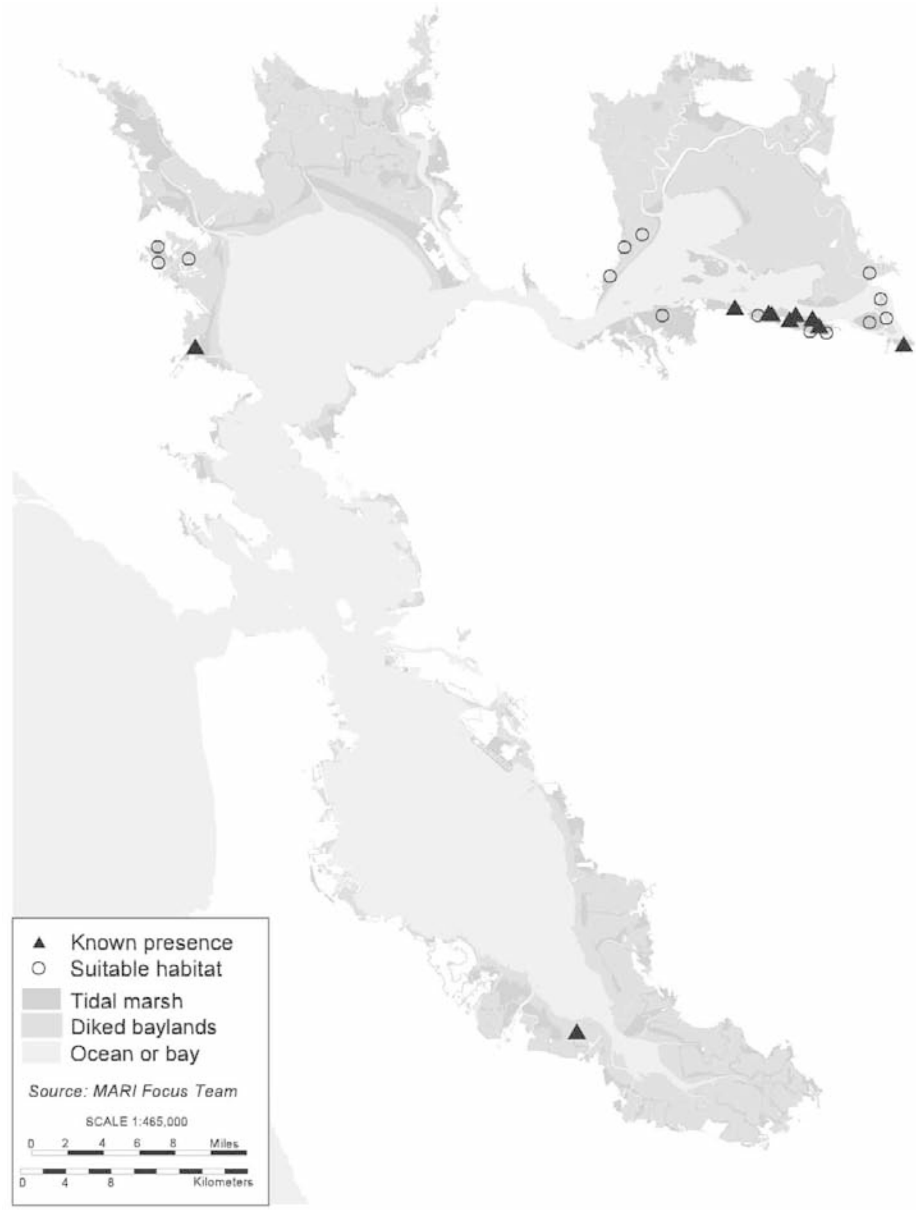

Figure 5.5 Ornate Shrew – Some Current Locations and Suitable Habitat

Note: Shrews are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Shrews may also be present in other areas.

slightly differentiated populations of *S. o. californicus*. However, further discrimination of the taxonomic status between *S. o. californicus* and *S. o. sinuosus* is needed as the two subspecies have identical karyotypes (Brown 1971).

Suitable Habitat

The ornate shrew prefers semi-arid, grassland and riparian habitats. Despite this preference, it is also found in brackish and saltwater marshes in San Pablo Bay and perhaps in other marshes throughout the Bay Area (**Figure 5.5**) based on records of identification only to the genus *Sorex*.

Conservation and Management

The ornate shrew is an uncommon inhabitant of the upland transition zones and marshes in the San Francisco Bay. Although it is not currently endangered, its local population status may be a general indicator of the health of an ecosystem, particularly as shrews are very good barometers of contaminant loads. Because they prey on a variety of invertebrates, they often bioaccumulate more rapidly than other species of similar size. It is important to monitor the status of this species and to research their potential as an indicator of wetland health.

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North American River Otter

Lutra canadensis

Michael L. Johnson

Life History

Adult river otters can range in size from 900 mm to almost 1,300 mm, and can weigh from 5 to 14 kg. Clinal variation in size is present, with otters becoming smaller from north to south, especially along the Pacific Coast. Sexual dimorphism is present, with females being smaller than males. Litter sizes vary with location from 1-5, with the average litter being 2-3. Females may become pregnant every year or may become pregnant only in alternate years, depending on local conditions. Pups grow rapidly and typically emerge from the den at two months, and are weaned at about three months. Dispersal of offspring typically occurs at about one year (Melquist and Hornocker 1983), and there are reports of yearlings dispersing up to 200 km (125 mi), although typical dispersal distances are about 32 km (20 mi) (Hornocker et al. 1983). Both sexes typically mature at two years of age, and can live up to 12-15 years in the wild. Captive otters have lived as long as 25 years.

River otters are the top carnivore in riverine systems and eat a wide variety of prey. Otters are most often cited as feeding primarily on fish and secondarily on crustaceans, mammals, reptiles, birds, amphibians, and insects (Table 36.2 in Toweill and Tabor 1982, Table 5 in Melquist and Dronkert 1987). A study of food habits of river otters in the Suisun Marsh performed by scat analysis (Grenfell 1974) indicated that crayfish were the most frequent prey item, and birds and fish were alternately the second most frequent prey item, depending on season. Although individual species identification of the fish was not attempted, scales and teeth indicated that the most probable prey items were the carp (*Cyprinus carpio*), Sacramento squawfish (*Ptychocheilus grandis*), the tule perch (*Hysterocarpus traskii*), and the striped bass (*Morone saxatilis*). Mammals, plants, and reptiles appeared to be taken opportunistically, as their frequency of occurrence in scats was never higher than 10 percent.

Historical and Modern Distribution

The North American river otter is a member of the Family Mustelidae Subfamily Lutrinae Tribe Lutrini. Formerly abundant throughout much of Northern California, they are placed into the subspecies *L. c. pacifica* Rhoads (Stephens 1906, Ingles 1965, Deems and Pursley 1978). Alternate subspecies designations placed otters from California's Sacramento and San Joaquin drainages into a separate subspecies, *L. c. brevipilosus* Grinnell (Anthony 1928, Grinnell 1933) with the type locality being Grizzly Island, Suisun Bay, Solano County, California (Grinnell 1933). Although there were 18 subspecies at one time, currently there are six. It was recently proposed that these be placed into a single species with the South American river otter, and placed into a New World genus *Lontra* (Van Zyll De Jong 1987).

Northern river otters were once found in all major drainages throughout North America, possessing one of the largest geographic ranges of all mammals. The present distribution over North America extends from 25° north latitude in Florida to over 70° north latitude in Alaska, and from eastern Newfoundland to the Aleutian Islands (Toweill and Tabor 1982). In California, the distribution of river otters early in the 20th century included the Sacramento, San Joaquin and North Coast river drainages, eastward from the coast to the Sierra crest and to the Warner Mountains of Modoc County, and from the San Joaquin River east to the Sierra crest (Belfiore 1996). Grinnell placed the center of species abundance in the Sacramento-San Joaquin Delta (Grinnell 1933). Intensive trapping for pelts occurred during the latter half of the century (Ingles 1965, Duplaix 1978, Mason 1989, Halbrook et al. 1994). Recent declines are also blamed on habitat destruction or alteration as well as the deterioration in water quality (Deems and Pursley 1978, Mason 1989). The California Fish and Game Commission imposed a ban on trapping in 1969. Despite meager evidence, furbearer status reports indicated that the populations were increasing throughout California (Schrempf and White 1977), and in the early

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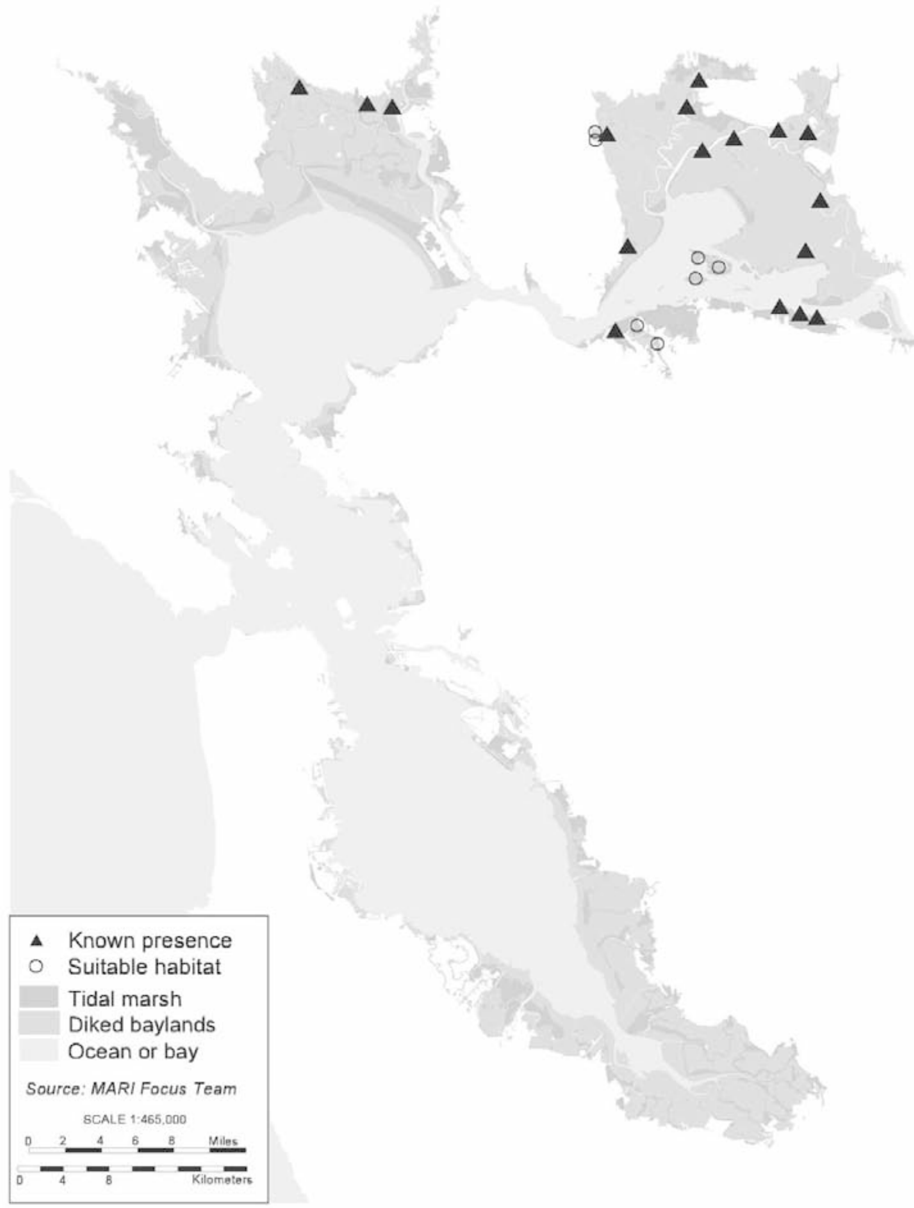

Figure 5.6 North American River Otter – Some Current Locations and Suitable Habitat

Note: Otters are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Otters may also be present in other areas.

1980s the California Department of Fish and Game proposed an open river otter trapping season. However, the lack of evidence for population recovery led to maintenance of the ban in 1984 (Belfiore 1996). River otters are currently classified by U.S. Fish and Wildlife as a Class II species according to the Endangered Species Act.

The highest densities of river otters are currently found in the Klamath-Trinity River drainage, and in the Sacramento River drainage (Schrempf and White 1977). Although historical distributions do not place otters east of the Sierra crest, there are recent reports of otters in Mono and Inyo counties (Schrempf and White 1977). In the San Francisco Bay region, most river otter sitings have been in the Suisun region (**Figure 5.6**).

Suitable Habitat

Otters are found in freshwater habitats throughout northern California, as well as in brackish, salt marsh and other marine locations (Grinnell 1933, Schrempf and White 1977). Distributions are primarily associated with good river bank cover, but are not specific to any particular vegetation type (**Figure 5.6**). Otters are found at elevations as high as 9,000 feet, but prefer lower altitudes due to food preferences (Schrempf and White 1977).

Conservation and Management

Habitat loss and degradation continues to be a major problem in maintaining viable populations of river ot-

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Zoological Society of Milwaukee County

ters. Additionally, river otters are almost entirely aquatic, and therefore are at risk from contaminants that they directly contact and that may bioconcentrate through the food chain. A recent review of the association between the status of mink and otter populations and exposure to organochlorine chemicals in the Great Lakes indicates that there may be an association between higher levels of chemicals and lower harvest rates (Wren 1991), although the association needs further documentation.

Loads of chemical contaminants in the Bay-Delta system are sufficient to be toxic to invertebrates (Bailey 1993, Bennett et al. 1995). The river otter would be expected to bioaccumulate persistent, water-borne contaminants from their prey items (Ropek and Neely 1993). In fact, the San Francisco Estuary Project recommended monitoring of the river otter in the Bay-Delta system as a sentinel species for providing information about the extent of exposure incurred by wildlife in general (Bailey et al. 1995, Belfiore 1996).

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Southern Sea Otter

Enhydra lutris nereis

David G. Ainley
Robert E. Jones

Life History

Individual adult sea otters show very little movement, being resident the year round where they occur. Males and females occupy home ranges of about 35 and 80 hectares, respectively. Subadult bachelor males disperse much more widely and comprise the vanguard as the population slowly expands to recolonize its former range. Pupping can occur year round, but mainly occurs December through March.

Sea otters feed mainly on benthic invertebrates, such as bivalves, abalone, urchins, cephalopods, and crustaceans, but they also eat fish. Lacking a layer of blubber, they must eat voraciously to maintain body heat, and consume 15-35% of their body weight daily (Leet et al. 1992). Their dense fur is their only insulation against the cold waters that they frequent.

Historical and Modern Distribution

The historic range of the sea otter in the eastern North Pacific extended along the coast from central Baja California, Mexico, north through the Aleutian Islands. Presently, however, owing to intensive hunting for fur in the 18th and 19th centuries, the range is much restricted and is centered around two populations, one in the Aleutian Islands and Southeast Alaska (south to Vancouver) and one in California. Each population is considered to be subspecifically distinct; the southern (or California) sea otter is listed as threatened under the Endangered Species Act (state and federal). The southern population, currently numbering a little over 2,200 animals, has grown from a few dozen animals that resided in a refugium near Pt. Sur early in this century.

In San Francisco Bay, sea otters once occurred abundantly in the central part at least as far inland as the mouth of Sonoma Creek, Sonoma/Marin County. The population in the Bay was likely in the low thousands but, for their pelts, all were hunted to extinction by the early-1800s (Skinner 1962). Sea otter teeth are very abundant in the middens of early Americans that are scattered around the Bay shores (e.g., Emeryville; Broughton 1999).

Jimmy Hu

It has taken several decades for the population to spread from the focus near Pt. Sur north to San Mateo County (and south to Pismo Beach, Ventura County). In the San Francisco Bay Area, otters are regularly seen north to Pt. Reyes, Marin County; the northern most extent of the breeding population is at Pacifica, San Mateo County. Until recently, no documented sightings of sea otters in the Bay had been made, although sightings existed for the outer portion of the Golden Gate. During the 1990s, however, several sightings were confirmed in the Bay, including ones near Strawberry Point, north of Sausalito, and in Richardson Bay (McHugh 1998) (**Figure 5.7**).

Suitable Habitat

Sea otters occur in shallow, usually protected, nearshore waters to about 15 m deep. Throughout the range, which is more or less linear and continuous in California, sea otters prefer, but are not restricted to, rocky substrates near points of land (Kenyon 1969, Leet et al. 1992). The promontories provide protection from ocean swells and lush growths of kelp usually occur in these areas. The otters normally do not come to land but use the kelp for resting, support, and protection from predators (sharks). The kelp in turn is maintained by the otters through their predation of kelp grazers such as sea urchins (Dayton 1975). Thus, the invasion of rocky habitat by sea otters is followed by a recovery of the kelp forest, if not present already.

Conservation and Management

In addition to the suitable habitat described in the preceding section, the return of otters to the Bay is contingent upon the continued growth and expansion of the coastal population outside the Bay, the lack of oil pollution (oil destroys the insulating properties of sea otter pelage), and the availability of food. Other than the passage of time, as the population continues to expand, oil pollution, even low-level chronic pollution, is problematic for recolonization of the Bay by this species.

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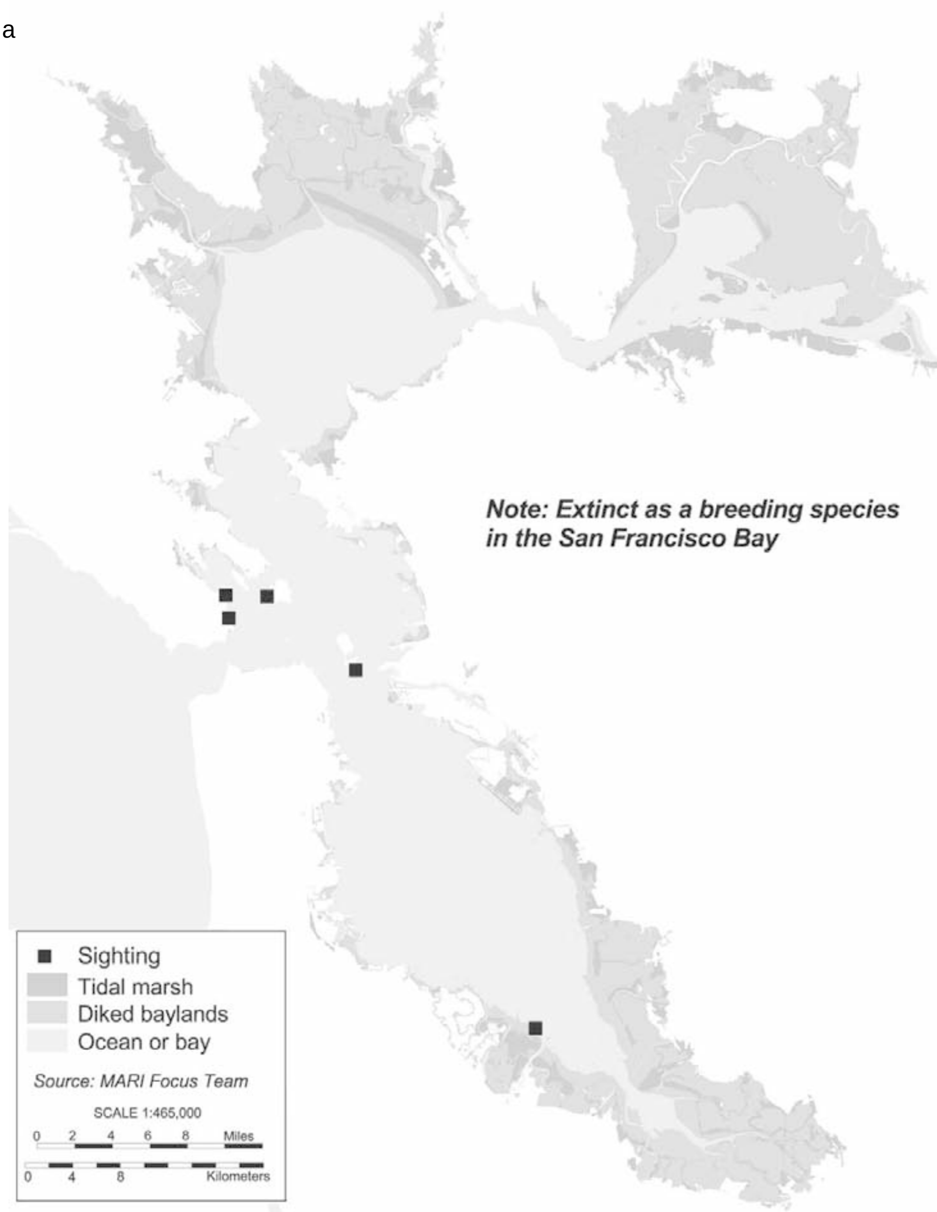
Figure 5.7 Southern Sea Otter – Some Current Locations



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Harbor Seal

Phoca vitulina richardsi

William Z. Lidicker, Jr.
David G. Ainley

Life History

Harbor seals are the only marine mammals that are permanent residents in San Francisco Bay. During the recent past, California sea otters (*Enhydra lutris nereis*), known from numerous Indian middens, and harbor porpoises (*Phocoena phocoena*) were widespread in the Bay (Skinner 1962). Seasonally resident California sea lions (*Zalophus californianus*) use the Central Bay in the vicinity of the Golden Gate. See Ainley and Jones' accounts of the sea otter and sea lion.

Eight stomachs with food examined from individuals taken outside the Bay, but close to it, contained a variety of fish and a few octopus (Jones 1981). The most commonly taken fish were from the families Embiotocidae (surf perch) and Zoarcidae (eelpouts). Harvey and Torok (1995) identified 14 species of fish and one cephalopod from 215 fecal samples collected from seals at seven haul-out sites around the Bay in 1991-92. Five species of fish made up more than 93% of the dietary weight, and one introduced species yellowfin goby (*Acanthogobius flavimanus),* constituted more than 54% of the total number of prey items found. Diet changed seasonally, with the goby and staghorn sculpin (*Leptocottus armatus*) predominating in the fall and winter, and plainfin midshipman (*Porichthys notatus*) and white croaker (*Genyonemus lineatus*), with jacksmelt (*Atherinopsis californiensis*) and the goby, predominating during spring and summer. Diet also differed regionally. In the extreme South Bay, the goby, sculpin, and croaker predominated; in the Central Bay, the mid-shipman predominated, comprising 91% of the diet. Curiously, no herring otoliths were found in the fecal samples.

An analysis of data from 59 radio-collared individuals revealed that frequency of diving (feeding) was greater at night (Harvey and Torok 1995). Pups are born in the spring, and a complete molt follows in early summer.

Courtesy of CCCR

About 30% of San Francisco Bay seals have reddish fur (Allen et al. 1993). This is a higher proportion than found anywhere else in the species' range (Kopec and Harvey 1995). The reddish discoloration is apparently caused by an accumulation of iron deposits (rust) on the fur, and develops rapidly following the early summer molt. The condition appears to cause the fur to become brittle, and it has been associated with shorter vibrissae and patchy fur loss (Kopec and Harvey 1995). Allen (pers. comm.), however, reports that only a few seals have shorter vibrissae and most of the fur loss occurs around orifices such as the mouth and eyes. It has been suggested that heavy metal contamination, most likely selenium, predisposes hairs to the rust accumulation (Kopec and Harvey 1995), but direct evidence for this is lacking. The speculation that the red condition is contaminant based is opposed by the fact that some seals develop red coloration while living on the outer coast (Allen, pers. comm.).

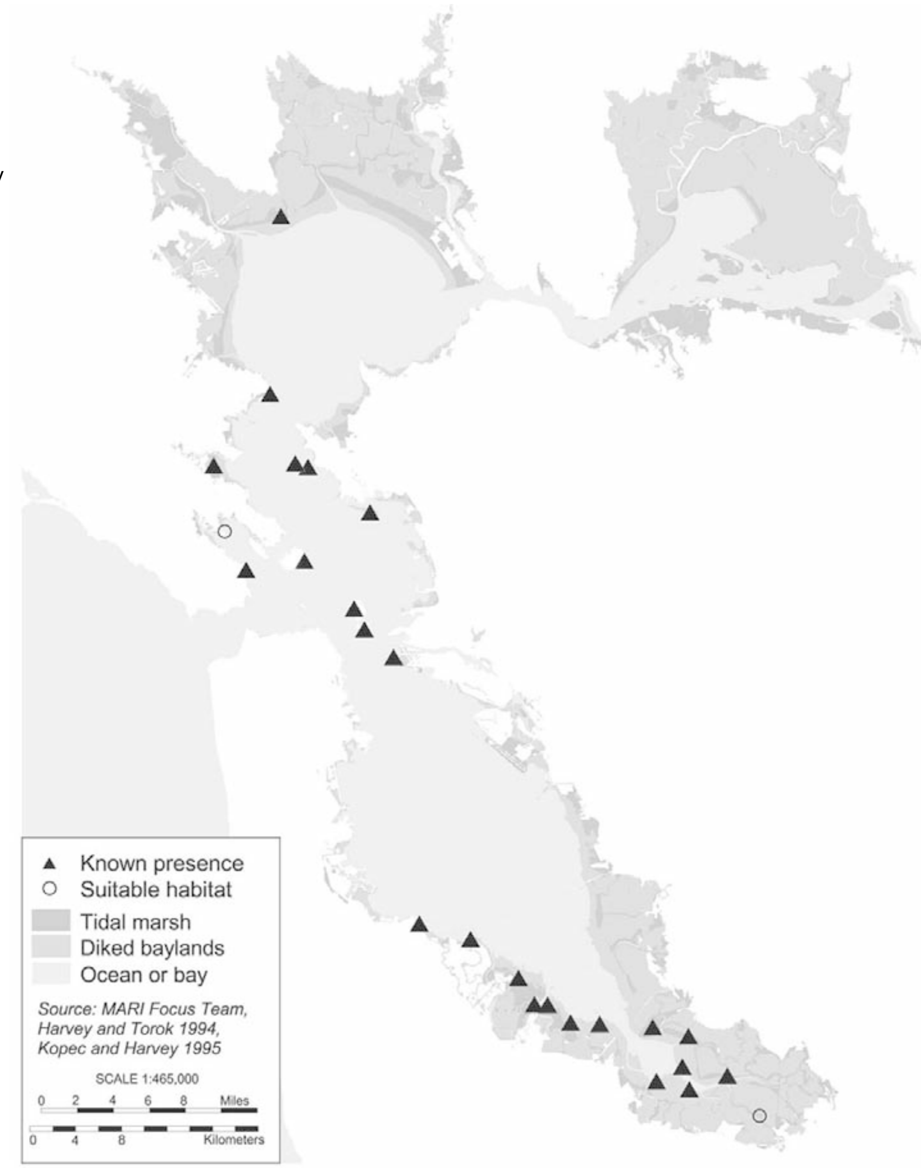
Historical and Modern Distribution

Harbor seals have been observed as far upstream as Sacramento, but little regular use is evident north of the Suisun Bay. Northerly sites are at Tubbs Island (Sonoma County) and Sister's Island (Marin). The haul-out sites associated with the Central Bay feeding area include (see Allen 1991, Harvey and Torok 1995): Sister's Island in Muzzi Marsh (a levee breached in two places to form an island), Castro Rocks, Brooks Island, Strawberry Spit (no longer used), a floating abandoned dock near Sausalito, Angel Island, Yerba Buena Island, and a breakwater at the Oakland entrance into Alameda Harbor. Included in this complex may be sites in the Golden Gate itself: Point Bonita and Land's End. Haul-out sites associated with the South Bay feeding area include: Coyote Point, Seal Slough, Belmont Slough, Bair Island, Corkscrew Slough, Greco Island, Ravenswood Point, Hayward Slough, Dumbarton Point, Newark Slough, Mowry Slough, Calaveras Point, Drawbridge, and Guadalupe Slough. **Figure 5.8** shows the locations of known current haul-out sites plus a few potential sites.

Seals may pup at any haul-out site but, generally, pupping sites are more traditional and are the least disturbed of all sites used. During the early 1990s, there were eight known pupping sites around the Bay, although more than four pups were born at only three sites: Castro Rocks, Newark Slough, and Mowry Slough (Kopec and Harvey 1995). In 1992, there were a third again as many pups born at Mowry Slough (67) than at all other sites combined (48; see also Riseborough et al. 1980). However, the previous year, there were only 39 at Mowry Slough but double (26) the 1992 number at Castro Rocks. Current counts from 1999 include 243 seals (78 pups) at Mowry Slough, 107 seals (21 pups) at Castro Rocks, and 72 seals (3 pups) at Yerba Buena Is-

Figure 5.8 Harbor Seal – Some Current Haul-out Locations and Suitable Habitat

Note: Seals are very possibly present in areas identified as "suitable" habitat based on current information regarding habitat types. Seals may also be present in other areas.



Mammals

land (Green et al. 1999, Green pers. com.). Historically, there was a large rookery near Alviso (Skinner 1962); this site most likely was Mowry Slough, given a description by Fancher (1979) (Allen, pers. comm.). If Skinner's Alviso site is not Mowry Slough, then the question becomes: did the seals move the few kilometers from "near Alviso" to Mowry Slough?

Censusing harbor seals is difficult, in the Bay or anywhere, because of the changes in numbers as a function of year, season, tide, time of day and human disturbance, and frequent movements of individuals throughout the Bay and even onto the adjacent outer coast. Nevertheless, numbers in the Bay apparently did not change significantly between 1982 and 1999 (Kopec and Harvey 1995, Green et al. 1999). A census taken in 1987 tallied 524 individuals in the Bay system (Hanan et al. 1988), and censuses in 1999 tallied 641 in the Bay (D. Green, pers. com). This population stability is in marked contrast to a steady increase during recent decades in the numbers of seals at sites along the coast, especially of Marin County (cf. Allen et al. 1989). Radio-tagged seals from San Francisco Bay have moved north to Point Reyes and south to Pescadero (Kopec and Harvey 1995). Allen (1991) believes that disturbance may be discouraging more seals from using the Bay and, thus, may be responsible for the lack of growth in the Bay. Pollutants may also be affecting the reproductive success of seals within the Bay (Kopec and Harvey 1995).

Suitable Habitat

Harbor seals feed in the deeper waters of the Bay. Kopec and Harvey (1995) identified two principal feeding areas. The first includes the area from the Golden Gate east to Treasure Island, northwest to the Tiburon Peninsula, and with a spur southward from Yerba Buena Island. Richardson's Bay, which is adjacent to this area, has been used extensively for feeding in the past, although not as much at present; feeding in Richardson's Bay may be contingent upon the presence of Pacific herring (*Clupea pallasi*; Allen 1991). This Central Bay feeding area is surrounded by nine haul-out and/or breeding sites (see above). The second major feeding area includes open Bay waters from the San Mateo Bridge southward. On the basis of the study by Kopec and Harvey (1995), this area is partitioned into five sub-areas, the largest being just west of Hayward. This South Bay feeding area is surrounded by 14 haul-out and/or breeding sites (see above).

Haul-outs must have gently sloping terrain, have deep water immediately nearby, and be free of disturbance, either by boats or by land (Allen 1991). An average of two haul-out sites are occupied by an individual seal each day, more so in the fall and winter and more so in the South Bay (Harvey and Torok 1995). Between-site movement is less frequent during the spring and summer, and is less frequent among seals in the deeper Central Bay. Haul-out sites used for pupping tend to be ones that are the most protected from disturbance. The use of such sites are persistent (traditional), and seals are slow to discover and utilize potential new pupping sites (Allen 1991).

Certain sites may be used as haul-outs at either low or high tide, e.g., seals appear to use Muzzi (Corte Madera) Marsh at high tide, but switch to Castro Rocks, 8 km away, at low tide (Allen 1991). In this case, Muzzi Marsh is separated from deep water by mud flats 2 km wide at low tide, but Castro Rocks are always surrounded by deep water.

Conservation and Management

The long association of harbor seals with humans (native Americans) in the Bay, including being actively hunted until about 1890, has made them extremely wary. They will flush from haul-out sites at 300 meters (Paulbitsky 1975, Allen et al. 1984). This makes them susceptible to harassment by persons on shore and boaters and kayakers from the Bay. Allen (1991) monitored the gradual abandonment of Strawberry Spit by seals during the 1970s and 1980s as a result of encroachment by humans and in spite of attempts for mitigation. An engineered haul-out site nearby has yet to be accepted by seals. Haul-out sites and especially pupping sites are needed that are protected from frequent human disturbances.

Allen (1991) also noted that harbor seals of the Central Bay reduced their use of winter haul-outs in and around Richardson's Bay and used the ones farther south more frequently (i.e., Treasure and Yerba Buena islands) when the herring ceased spawning in Richardson's Bay (and spawned more along the San Francisco waterfront). Therefore, the viability of certain prey populations may be important to the well-being of harbor seals in the Bay.

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Mammals

California Sea Lion

Zalophus californianus

David G. Ainley
Robert E. Jones

Life History

California sea lion is the pinniped ("seal") most often seen in zoos and circuses. In coastal waters of Central California, California sea lions prey mostly on schooling species, such as anchovies, Pacific whiting, midshipman and squid, as well as other fishes (Jones 1981). In the Bay, they feed mainly on anchovies, herring, surfperch, leopard sharks and spiny dogfish, and shrimp and crabs (Hanni and Long 1995). During the breeding season, bulls haul out at traditional breeding sites where they establish territories; females haul out to form groups, called harems, which each male tries to force onto his territory. In early summer (June), one pup is born to each adult female. Soon thereafter, the female mates with the harem master, but implantation is delayed for months while the mother nurses the pup. Pups form groups while their respective mothers forage at sea; some pups remain with their mother through the following winter (Jameson and Peeters 1988).

Historical and Modern Distribution

California sea lions occur along the West Coast of North America, from Vancouver to the Gulf of California; an isolated population exists on the Galapagos Islands and, formerly, another existed in Japan. The total population size of this species for the North American West Coast, as of 1990, was about 220,000; the population has been growing at about 10.2% per year since the early 1980s (Lowry et al. 1992). Population growth, following passage of the Marine Mammal Protection Act in 1972, is a recovery from former persecution.

Along the West Coast, the species breeds from Pt. Piedras Blancas, San Luis Obispo County, California,

Figure 5.9 California Sea Lion – Current Locations and Suitable Habitat

Note: Sea lions are likely present in areas identified as "suitable" habitat based on current information regarding habitat types. Sea lions may also be present in other areas.

Mammals

south to the Gulf of California, Baja California, Mexico, although on rare occasions pups have been born at the Farallon Islands, San Francisco County; Ano Nuevo Island, San Mateo County; and the Monterey Breakwater, Monterey County. However, virtually all the animals that occur north of Pt. Piedras Blancas are adult and subadult males, and subadult females.

During the May-June pupping season, few adult California sea lions occur in Central and Northern California. Otherwise the species is present there year round. In Central California, the largest numbers occur during the spring (April), when males that wintered in the north migrate south to breeding colonies; another smaller peak occurs in early autumn during the more leisurely migration north (Huber et al. 1981). During years of warm ocean temperatures (El Niño) much larger numbers of California sea lions visit Central and Northern California, including many more juveniles than usual (Huber et al. 1981).

In San Francisco Bay, California sea lions occur year round, but with a dynamic difference from that of the adjacent outer coast. Greatest numbers are present during the winter herring run (Dec-Feb; Hanni, pers. comm.). Following the winter peak, numbers decline to just a few animals by June and July. Numbers then increase gradually before a sudden increase in December. Known haul-out spots in San Francisco Bay are rare, and include only Pier 39, occasionally at Angel Island, and at Seal Rock just outside the Golden Gate (**Figure 5.9**). The largest number haul out at Pier 39, but the phenomenon is only a recent one (unlike Seal Rock, which has been used by sea lions for at least the last 100 years; Sutro 1901). At first, in winter 1989-90, only a few individuals hauled out at Pier 39, but the next year they reached an average 500 (± 100 SD) per day (February 1991); since then peak numbers during winter declined and now average about 200-300 animals per day (Marine Mammal Center, unpubl. data). The use of wharves at Pier 39 likely is the result of the following factors: 1) the increased size of the species' total population (greater now than chronicled history; Lowry et al. 1992) and concomitant expansion of habitat use, 2) the construction of the wharves in the late 1980s, 3) the increasing temperatures of the California Current (which make Northern California more suitable for this species), and 4) the chance finding of this site by several individuals seeking food during the low food year of 1989-1990 (El Niño). These pioneers thus established a tradition among a group of sea lions.

Suitable Habitat

This animal uses those deep, principally marine waters that occur in the outer Bay, off Marin and San Francisco counties (e.g., Raccoon Straits to San Francisco and out through the Golden Gate). On occasion, isolated individuals, and mostly carcasses, have been found in Milpitas, Alameda, Napa, and as far upstream in the Delta as Sacramento. When salmon were netted en masse in the Delta 100 years ago, California sea lions were attracted in large numbers as far as Sacramento to take advantage of the netting operation (Sutro 1901), much as they do today in the case of herring in the Bay (and their infamous pillaging of steelhead held at the locks in Puget Sound, Washington). If free from disturbance, it is possible that sea lions would haul out on rocky peninsulas at places such as Angel Island and Alcatraz Island.

Conservation and Management

The presence of this species in San Francisco Bay is contingent upon the availability of safe haul-out sites and easily available food. Thus, its occurrence likely is tied to the fate of such fish as herring. The population in the Bay is sensitive to disturbance, to capture in gill nets (used illegally), and to certain diseases, such as leptospirosis, that result from the cattle that are grazing in coastal areas (and streams).

Nancy Black

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Important Data Sets

Marine Mammal Center. Annual census of sea lions at Pier 39, San Francisco. Krista Hanni.

NOAA, Southwest Fisheries Science Center, La Jolla. Annual census of pinnipeds along the California coast. Jay Barlow.

Mammals

Non-Native Predators: Norway Rat and Roof Rat

Rattus norvegicus and *Rattus rattus*

Andrée M. Breaux

Life History

Norway (or brown) rats and roof (or black) rats are similar in appearance, though the roof rat has a longer tail and can vary in color between brown and black. Norway rats have coarse fur, large naked ears, and scaly tails that are shorter than their body length (less than half of total length), pigmented venters, and tuberculate molars. Norway rats are largely nocturnal and are excellent swimmers and climbers. Roof rats have tails that are longer than their body length and pale venters, and they share the tuberculate molars that distinguish both Norway and roof rats from wood rats (Kurta 1995, Jameson and Peeters 1988).

Both the Norway and roof rats are prolific breeders, and the Norway rat tends to have slightly larger litters. Large males dominate female harems and the females actively defend resources and nest sites (Kurta 1995). Sexual maturity for both the Norway and roof rats is reached at about three to four months and breeding can occur continuously throughout the year. Litter sizes for Norway rats are between four and ten young, though litters as large as 22 young have been reported (Kurta 1995). Roof rat litters are generally between five and eight young (Jameson and Peeters 1988).

The Norway rat has been described as "the most unpleasant mammal in the world" (Jameson and Peeters 1988) as a result of its tendency to eat crops in the field as well as in storage, its tendency to eat both live and dead prey, and its ability to spread deadly diseases. It is capable of catching fish and small rodents (Kurta 1995). The Norway rat is an omnivore while the roof rat is a vegetarian.

USFWS

Norway Rat (*Rattus norvegicus*)

Historical and Modern Distribution

Norway rats probably originated from the Old World tropics, but are now found globally. They are believed to have reached North America around 1775 (Kurta 1995) and are generally associated with buildings, sewers, harbors, garbage dumps, and agriculture. They reach elevations of 1,000 meters. Roof rats probably originated from the tropical Orient and can now be found in globally temperate climates. Roof rats are associated with trees, including agricultural groves, as well as with dense thickets and roofs and attics (Jameson and Peeters 1988).

The Norway and roof rats tend to occur in different habitats with the larger and presumably more powerful Norway rat occupying more urban areas, and the smaller roof rat living in more natural areas. Rats which are found in San Francisco Bay marshes are more likely to be roof than Norway rats (Jurek, pers. comm.). Where urbanization abuts natural marshes as it does in many areas of the South Bay, and garbage provides a food supply, Norway rats are likely to find the marsh habitats quite hospitable. In 1927, DeGroot noted that reclaimed land behind dikes along the San Francisco Bay shoreline was responsible for an increase in rats and a decrease in native California clapper rails (*Rallus longirostris obsoletus*): "No sooner is a dyke constructed than Norway rats appear in great numbers. Large gray fellows they are, on a dark night appearing to be as large as small cotton-tail rabbits....The Clapper Rail has no more deadly enemy than this sinister fellow" (DeGroot 1927).

In the Central Bay marshes, rats have been sighted at the Elsie Roemer Bird Sanctuary in Alameda, Crown Beach, the Martin Luther King Regional Shoreline and Arrowhead marsh sites, and on Brooks Island off the Richmond Harbor (DiDonato, pers. comm.).

Rats are not regarded as a serious problem in the North Bay marshes, except in the Corte Madera marsh where there is inadequate buffering of the marsh from urbanization. Elsewhere, the extensive agricultural lands are probably preferred as habitat by the rats over the wetter marshlands (Botti, pers. comm.).

Suitable Habitat

Not addressed for non-native predators.

Control and Management

A 1992 report on the status of wildlife in the San Francisco Bay stated that there existed a "critical need" for research on the population dynamics and distributions of introduced mammalian predators such as the red fox, the Norway rat, and the roof rat (USFWS 1992). The report stated that techniques such as the reintroduction of the coyote to control the red fox in the South Bay, should be investigated. Control of rats has not been

Staffan Vilcans/Mia Bruksman

Roof Rat (*Rattus rattus*)

implemented and continues to be a problem in the South Bay for endangered species, such as clapper rails and, quite possibly, salt marsh harvest mice (*Reithrodontomys raviventris*). Additional threats to other target species selected by this project as representative of wetland species in the San Francisco Bay region (e.g., California voles (*Microtus californicus*), ornate shrews *(Sorex ornatus californicus*), salt marsh wandering shrews *(Sorex vagrans haliocoetes*), and amphibians, reptiles, terrestrial invertebrates in general, and some ground nesting birds) probably occur.

Studies of South Bay marshes have documented predation of not only clapper rail eggs, but also of live chicks. While the primary predators may be raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes regalis*), feral dogs, or feral cats, rats have been seen in the South Bay in relatively large numbers (Foerster et al. 1990; Albertson, pers. comm.; Harding, pers. comm.). Harvey (1988), in a study of clapper rails in three south San Francisco Bay marshes, attributed 24 percent of nest failures to Norway rats. A 1992 U.S. Fish and Wildlife study of hatching success and predation for 54 active clapper rail nests in south San Francisco Bay found rodents to be responsible for 90% of the eggs destroyed and 79% of the predation at monitored nests. Rodents were thought to be the predators because of the characteristic debris left behind after feeding, in this case egg shells, egg contents, and chick body parts. Other characteristics peculiar to rodent predators is the manner of leaving half of the egg shell intact with visible tooth marks, or a U-shaped notch eaten into the side of the shell (USFWS 1992 and 1997).

Negative impacts on native mammalian populations from rats in marshes include direct predation by the omnivorous Norway rat, competition for habitat, and illness or mortality resulting from diseases. While the devastation to humans from rats carrying plague, typhus, hepatitis, and trichina worms has been known for centuries in some cases (Jameson and Peeters 1988), the devastation to native wildlife is not as well-documented.

Clearly there is a need to implement the research suggested in 1992 on the distributions and population dynamics of Norway and roof rats in San Francisco Bay wetlands. While feral cats may help control the young rat populations, cats do not tend to eat the large adult rats (Jurek, pers. comm.), and the feral cats and dogs themselves are likely to prey on the small native mammals, amphibians, reptiles, and terrestrial invertebrates that are indigenous to the wetlands. Control measures are difficult, since there is no poison specific to rats that is safe for endangered mammals, such as the salt marsh harvest mouse. Given the difficulties in any control programs (e.g., public outcry against removing feral cats and the difficulty of trapping or shooting these large rodents) the most effective control measure at this time is to protect marshes with large buffers, and to keep shelter and garbage far from the wetland edge.

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Joe DiDonato, East Bay Regional Park District, Oakland.

Elaine Harding, University of California, Santa Cruz.

Ron Jurek, California Department of Fish and Game, Endangered Species Division, Sacramento.

Non-Native Predator: Red Fox

Vulpes vulpes regalis

Elaine K. Harding

Life History

The red fox is one of the most widely distributed mammals in the world, occupying a range of habitats and elevations. There are actually two red fox subspecies in California, the introduced red fox, *Vulpes vulpes regalis*, and the native, state threatened, red fox, *Vulpes vulpes necator*, which is found only in the Sierra Nevada from 5,000 to 8,400 ft (Jurek 1992). Red fox have a head and body length of about 45.5-90.0 cm and a tail length of 30.0-55.5 cm, with a weight averaging 3-14 kg (Nowak 1991). The pelage coloration is generally pale yellowish red to deep red on the upper parts and white or ashy underneath. It can be distinguished from the gray fox by its black lower legs and white tip on the tail.

Red fox family groups usually consist of a male, a female and offspring, with the territories ranging in size from 2.6 to 20.8 square kilometers (Sargeant 1972). However, urban populations may achieve even greater densities, with home ranges as small as 0.45 sq. km in Great Britain (Trewhella et al. 1988). Den sites in urban areas are often within flood control levees, freeway embankments (Sallee et al. 1992) or salt marsh levees.

Breeding occurs from December through April, with a peak in March, with the number of offspring produced (and surviving to juvenile age) averaging 3.5 (Storm 1976). Multiple dens may be used during this time, with the females often moving the litters to different locations throughout the season. The survival of juveniles to recruitment is estimated at 0.19 in midwestern populations (Storm et al. 1976) to 0.65 in southern California populations (Sallee et al. 1992). Foxes have been reported to breed at 10 months, with yearlings often breeding their first spring. Additionally, the survival of adults in urban California populations is 0.58, higher than the midwest at 0.23 (Storm et al. 1976). Adults may survive up to five years in the wild.

Red fox have extremely broad diets, including birds, small mammals, reptiles, amphibians, insects, vegetation and refuse (Foerster and Takekawa 1991). They are also known to be surplus killers, where food that is taken may be cached (buried in the ground) and never recovered. Because they are such capable predators, they are highly detrimental to native fauna which are not adapted to avoid or escape them. Foxes are known to decimate ground nesting bird populations, through predation of eggs, young and adults.

Joe DiDonato, bioQuest

Historical and Modern Distribution

The red fox subspecies, *V.v. regalis*, is originally from the Great Plains, and was probably brought to the Central Valley for commercial fur farming in the late 1800s (Jurek 1992). The current distribution of fox throughout the state is based upon a study by Sallee, et al. (1992) which found occurrences of red fox in 36 counties. The greatest concentration of sightings were in the urban areas of Los Angeles and San Francisco Bay, with fox also found throughout the Central Valley and Monterey Bay areas. It is difficult to estimate the number of fox in California, but according to records kept by Animal Control in Orange County, there were 102 individuals in the county during the summer of 1991 (Sallee et al. 1992).

The red fox was first seen in South San Francisco Bay in 1986 (Foerster and Takekawa 1991), with subsequent sightings reported from all seven Bay Area counties (Sallee et al. 1992). Populations of red fox have established in or adjacent to tidal marshes, diked baylands, salt ponds, landfills, agricultural lands, golf courses, grasslands and urban areas. In particular, the fragmented wetlands of San Francisco Bay have become a likely source for expanding populations, as many avian and mammalian prey can be found within these habitats.

Suitable Habitat

Not addressed for non-native predators.

Control and Management

In the San Francisco Bay Area, red fox have been implicated in the population declines of the endangered California clapper rail, threatened western snowy plover, endangered California least tern, Caspian tern, and colonial nesting species, such as great blue herons and great egrets (Foerster and Takekawa 1991; Albertson 1995; USFWS, unpubl. data). In response to growing evidence of the impact of red fox on the clapper rail, the U.S. Fish and Wildlife Service began a Predator Management Program in 1991 (Foerster and Takekawa 1991). The subsequent removal of red fox and other targeted predators has resulted in a significant increase in the local populations of California clapper rail (Harding-Smith 1994, Harding et al. 1998). Comparable success has occurred in Southern California where removal of red fox along coastal marshes was correlated with remarkable increases in the populations of light-footed clapper rails (USFWS and U.S. Navy 1990). Additionally, predator management is becoming a common method of endangered species protection, within both government (Parker and Takekawa 1993) and private sectors.

It is imperative that all future restoration and management activities within the wetland ecosystems of San Francisco Bay consider the present and future impacts of red fox on the native wildlife. Clearly, a healthy marsh can no longer be defined by simply the quantity and composition of native vegetation and wildlife, but must include the external impacts of human urbanization which alter an ecosystem's internal functioning through the introduction of contaminants, human disturbance and non-native species. The long-term viability of many avian and small mammal species will be impacted by expanding red fox populations in the bay area, so that no site will soon remain uninhabited nor unaffected by this wily species. Therefore, the quality and quantity of connections between sites, as well as the characteristics and extent of the surrounding matrix, will be of the utmost importance in understanding fox population dynamics and prey abundance within and between sites. Biologists and land managers must continue to study the dispersal patterns, demographics and predation impacts of red fox so that more effective methods of control can be developed.

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