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Department of Fish and Game

THE STATUS OF BANK SWALLOW POPULATIONS ON THE SACRAMENTO RIVER, 1986.

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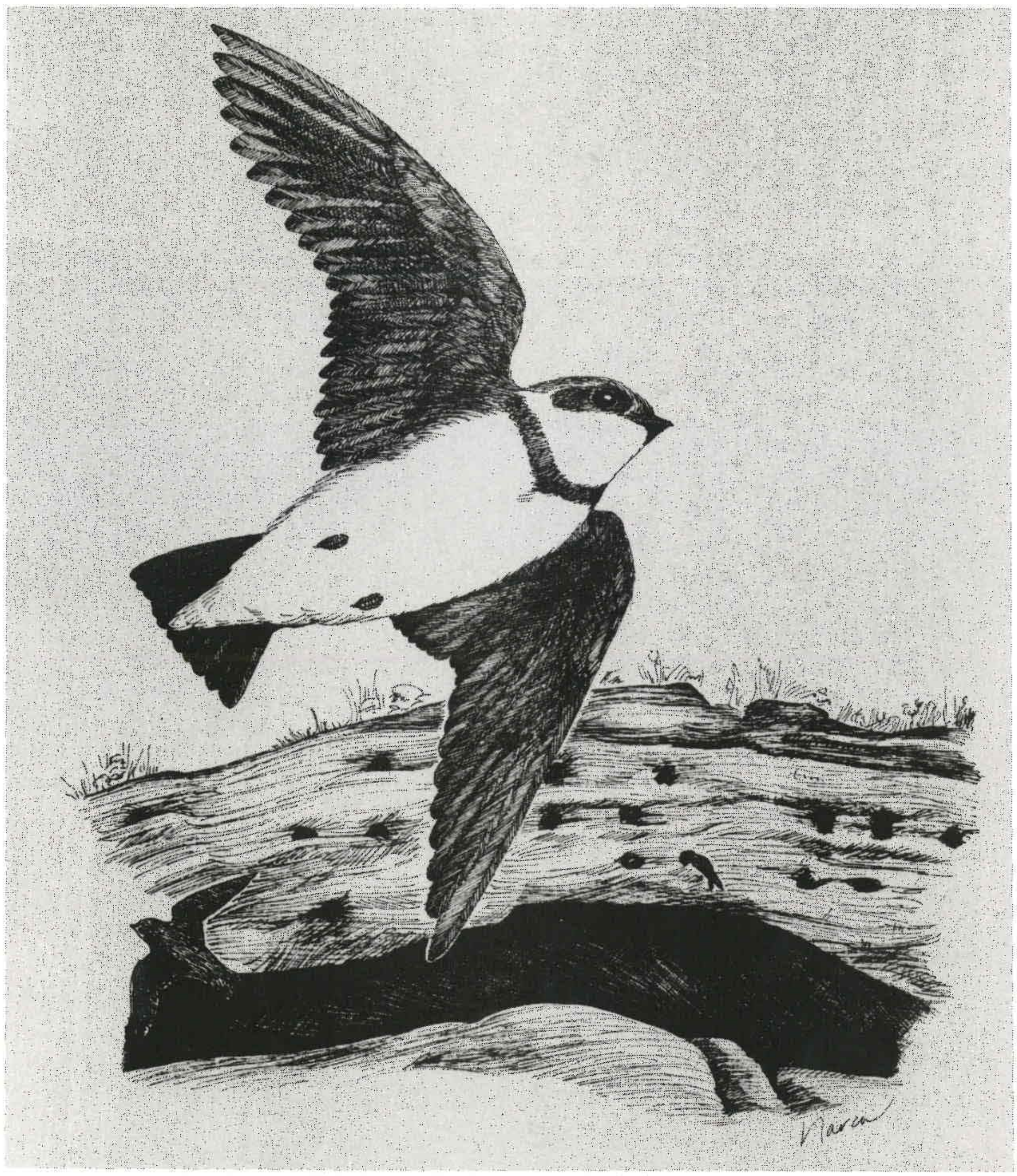
Joan M. Humphrey and Barrett A. Garrison



Wildlife Management Division
Administrative Report 87-13

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Joan M. Humphrey[2/] and Barrett A. Garrison[3/]

ABSTRACT

A study to determine the population size and distribution, nesting ecology and impacts of land use practices on Bank Swallow breeding colonies on the Sacramento River, California, and its major tributaries was conducted from May to August, 1986. At randomly selected sites nesting data were collected and habitat parameters were measured. Birds were banded to determine nest site fidelity and movements.

We located approximately 16,149 breeding pairs of Bank Swallows occupying 60 colonies on the Sacramento River. This may represent about 80% of the known State population. Two colonies were found on the major tributaries examined from their confluence to 8 km (5 mi) upstream. Colonies were located on nearly vertical river banks. Bank Swallows occupied about 56% of the burrows present in a particular colony. Burrows were found primarily in silty loam to sandy loam soils.

Nesting habitat destruction represents the greatest threat to the Sacramento River Bank Swallow population. Federal and State sponsored riprapping and bank stabilization projects, if completed as currently proposed, would destroy the nesting habitat of 8935 breeding pairs (55%) in the next 5 to 10 years. An additional 1064 pairs (7%) may be adversely affected by nearby construction activities.

Management recommendations include listing the Bank Swallow as a Threatened Species in California, protection of Bank Swallow populations and their riverine bank habitat, and conducting further research to determine the statewide distribution and status of the Bank Swallow. Alternatives to current bank stabilization methods must be developed if viable populations of Bank Swallows are to be maintained.

1/ Wildlife Management Division Contract Final Report.
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2/ Joan M. Humphrey, 733 M Street, Davis, CA 95616.

3/ Barrett A. Garrison, 2562 Walnut Blvd. #96, Walnut Creek, CA 94596.

RECOMMENDATIONS

1. List the Bank Swallow (<u>Riparia</u> <u>riparia</u>) as a Threatened Species in the State of California.

2. Protect existing Bank Swallow nesting habitat from destruction and colonies from human harassment.

3. Determine the statewide distribution, abundance and status of the Bank Swallow.

4. Institute long-term monitoring of Bank Swallows on the Sacramento River.

5. Monitor bank stabilization activities on the Sacramento River during the Bank Swallow breeding season to ensure protection of active colonies.

6. Determine the existence and characteristics of double brooding in the Bank Swallow.

7. Conduct further research on habitat requirements of the Bank Swallow.

8. Assess detrimental impacts to nesting colonies of high river flows during the summer.

9. Evaluate the effects of the experimental bank stabilization project at Woodson Bridge State Recreation Area on the affected Bank Swallow colony.

10. Propose a State Park featuring a natural riparian ecosystem functioning at Sacramento River Mile (RM) 140 to RM 240.

11. Determine the methods and feasibility of mitigating for loss of Bank Swallow habitats due to bank stabilization and riprapping projects.

INTRODUCTION

The Bank Swallow (Riparia riparia) is the smallest of the North American swallows and is a colonial bird of lowland rivers and coastal bluffs. The species creates nesting habitat by burrowing into sandy loam soils. It is distinguished from other swallows by its distinct brown breast band contrasting against clean white underparts and brown upperparts. The Bank Swallow was once locally common throughout lowland California (Grinnell and Miller 1944). Today the species is reduced in, or eliminated from, much of its former breeding range in the State (especially southern California) and is designated as a Bird Species of Special Concern in California (Remsen 1978).

There is little published information on the Bank Swallow in California. Hence, we have few details on its historic abundance, distribution or ecology in the State. Most records are short nesting or sighting notes of very limited scope, such as Talmadge (1947). The biology of the Bank Swallow has been well studied in the eastern United States and in Europe, where it is referred to as the Sand Martin. The species breeds widely throughout the Northern Hemisphere and winters in the Southern Hemisphere.

Hickling (1959) described three types of Bank Swallow nesting habitat: seacliffs of hard consolidated sand, river banks of sand and sandy earth, and active sand and gravel pits. On the Sacramento River, Bank Swallows nest in steep river banks that are subject to frequent erosion. These cut banks are a natural component in a cross section of the riparian zone (Strahan 1984).

Human land-use activities involving bank stabilization and riprapping projects are certain to conflict with the Bank Swallows' need for freshly eroded riverbank for nest sites. These proposed projects threaten a substantial portion of existing Bank Swallow nesting habitat along the Sacramento River, and certainly have eliminated many historical colonies.

Most published Bank Swallow research involves birds nesting in the artificial environment of sand quarries (Spencer 1963, Freer 1977, 1979). Our research is unique because it concerns study of a population along a large, freely flowing river. The objectives of this initial phase of our study were: to ascertain the species population and distribution along the Sacramento River and its major tributaries; to examine the nesting ecology and to determine reproductive success and colony occupancy; to describe the habitat of nesting colonies; and to identify and assess detrimental impacts to Bank Swallow populations and nesting habitat. Research is planned for 1987 in the remainder of California to determine the statewide status of the species and the relative importance of various breeding locales to the viability of the California population of Bank Swallows.

STUDY AREA

The Sacramento River study area extended from the Shasta Dam in the north to the Sacramento/San Joaquin Delta in the south, a distance of 491 km (305 River Miles (RM)). We concentrated our research efforts along a 256 km (160 mi) stretch of the river from Red Bluff to the confluence of the Feather River (Figure 1). Major tributaries, including the Feather River, were surveyed to at least 8 km (5 mi) upstream from their confluence with the Sacramento River.

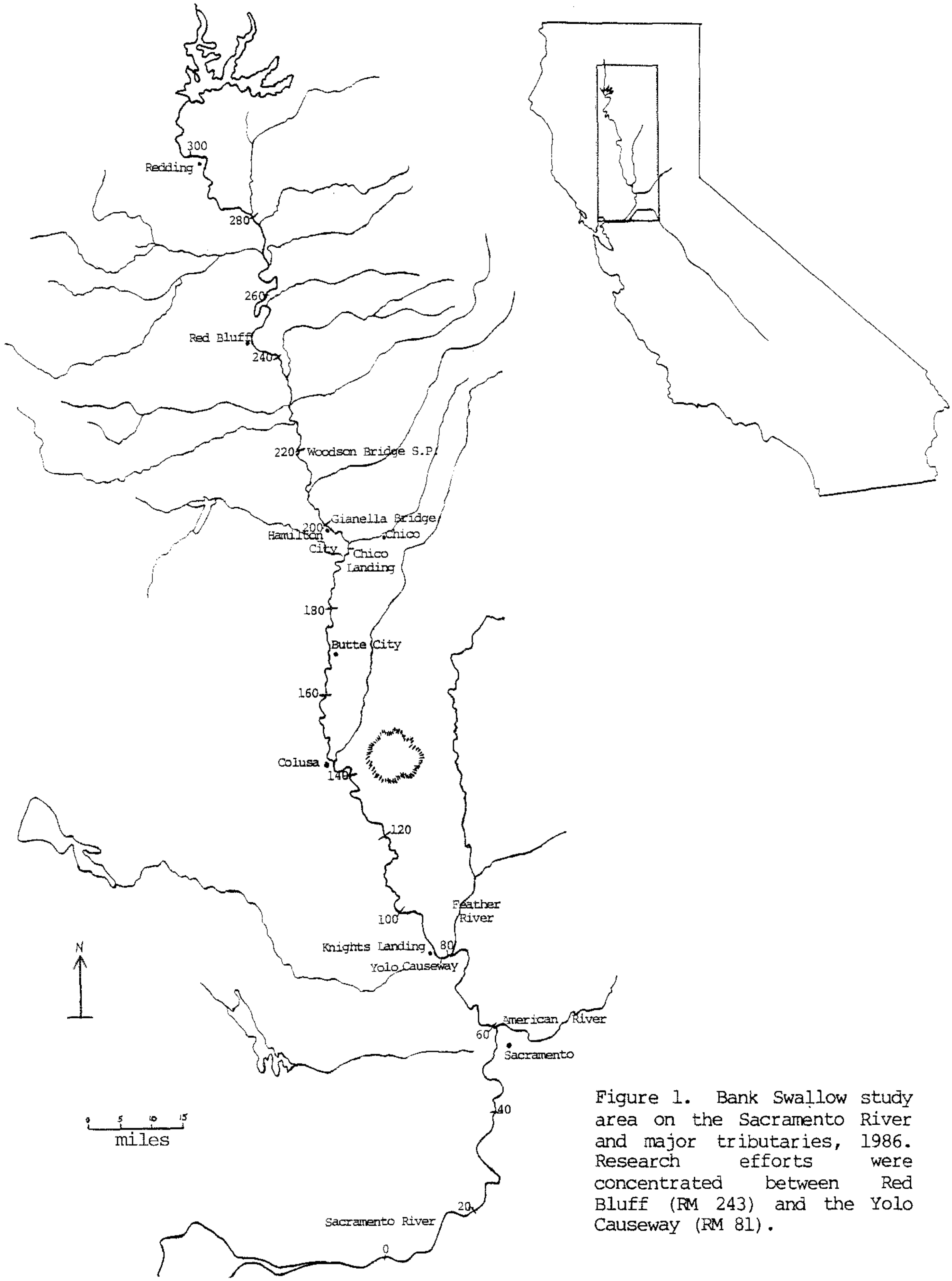

Figure 1. Bank Swallow study area on the Sacramento River and major tributaries, 1986. Research efforts were concentrated between Red Bluff (RM 243) and the Yolo Causeway (RM 81).

The Sacramento River is a example of the changing nature of a river transport system (Zumberge and Nelson 1972), and our study area includes its three sections. The mountainous headwaters of the Sacramento River, from elevation 1830 m (6000 feet) at RM 400, deliver water and sediments to the floodplain area starting above the town of Red Bluff (RM 243) at an elevation of 75 m (245 feet). The main trunk system meanders throughout the upper ends of the flood plain now best represented by the area from Red Bluff (RM 243) to the town of Colusa (RM 143). The section south of Colusa is now a modified delta, created by this massive transport system through the deposition of sedimentary materials.

Brice (1977) noted that the river enters the Central Valley near RM 255 and travels southward in winding curves with the most circular meander loops between Chico Landing (RM 194) and the town of Butte City (RM 170). He further noted that natural levees increase in height and width between Butte City and Colusa. South of Colusa, river meanders decrease and are restrained by the continuous natural levees until a point below the Feather River confluence where streampower is too low relative to bank resistance for meanders to develop.

METHODS

We started this study 1 May with a search of library references published since 1864. In addition we researched major museum records and made personal inquiries throughout the state for historical and recent Bank Swallow information and records. This information was used to estimate the percentage of the statewide population of Bank Swallows breeding on the Sacramento River. Egg collection data, in particular, was sought to document historic breeding locations.

Survey and census work to locate and estimate the Bank Swallow population along the Sacramento River was conducted by motorboat and automobile from 13 May to 9 July 1986. Following examination of aerial photographs for suitable habitat (vertical banks, meandering river channels, etc.), survey work along tributaries was conducted by airplane and bicycle (Appendix A). We estimated the number of burrows at each colony. Population estimates, colony locations, former locations, and potential Bank Swallow habitat were plotted on aerial photographs. Initial burrow estimates were adjusted using an accuracy factor of 0.94 (field estimate/complete count) derived from counts at 34 colonies. For example, at Colony 86-5 we estimated 145 burrows on our initial survey but counted 156 burrows when we returned for intensive study. From this, 145/156 = 0.94, so the underestimated initial estimate would be divided by the accuracy factor to obtain an adjusted burrow total. This burrow adjustment was necessary as excavation of burrows continued after the initial survey, some field estimates at larger colonies were slightly inaccurate, and a few burrows were lost due to continued bank erosion during the nesting season. Photographs (35mm color slides) were taken to further document nesting localities.

After the initial survey of colonies was completed, a sample was taken for intensive study. Colonies were categorized as "small" (1-130 burrows, N = 21), "medium" (131-375 burrows, N = 20), and "large" (over 375 burrows, N = 19). A sample of 32 colonies (11 small, 11 medium, and 10 large) were randomly selected for detailed study (Table 1). A colony was defined as a group, or several subgroups, of breeding swallows with burrows separated more than 1 km (0.6 mi) from another group of breeding swallows.

Table 1. Bank Swallow colony location, size and number of breeding pairs of birds located on the Sacramento River, 1986.

	Colony Size		Colony Location	
Colony Number	Burrows[1]	Breeding Pairs[2]	River Mile	County
86-1	37	20	81.8R[3]	Yolo
86-2	122	68	87.5L[4]	Sutter
86-3[5]	127	71	97.1L	Sutter
86-4	271	151	100.4L	Sutter
86-5[5]	155	87	111.3L	Sutter
86-6[5]	26	15	119.4R	Colusa
86-7	106	59	121.7L	Sutter
86-8	213	119	126.1R	Colusa
86-9[5]	342	193	127.9RL	Colusa/Sutter
86-10	1159	648	130.5RL	Colusa/Sutter
86-11	532	297	144.3L	Colusa
86-12[5]	261	146	147.5R	Colusa
86-13[5]	351	196	150.5RL	Colusa
86-14	75	42	155.1L	Colusa
86-15	1553	868	156.2RL	Colusa
86-16[5]	106	59	158.7R	Colusa
86-17	362	202	159.3L	Colusa
86-18[5]	686	383	161.7L	Colusa
86-19[5]	346	193	162.1R	Glenn
86-20	957	535	165.4L	Glenn
86-21[5]	1149	642	166.5R	Glenn
86-22[5]	69	39	168.7R	Glenn
86-23[5]	127	71	171.6R	Glenn
86-24	1117	624	173.4R	Glenn
86-25	1064	595	173.9R	Glenn
86-26[5]	458	256	178.1L	Butte
86-27[5]	21	12	179.4R	Glenn
86-28[5]	170	95	181.4R	Glenn
86-29[5]	1617	904	182.8L	Butte
86-30[5]	372	208	184.5L	Butte
86-31[5]	404	226	185.5R	Glenn
86-32[5]	54	30	187.9R	Glenn
86-33[5]	64	36	188.9L	Butte
86-34[5]	1490	833	190.5L	Butte
86-35[5]	155	87	192.6L	Butte
86-36[5]	458	256	195.1RL	Glenn/Butte
86-37	37	21	201.4R	Glenn
86-38[5]	3192	1784	202.4R	Glenn
86-39	138	77	206.6L	Butte
86-40[5]	85	48	209.8R	Tehama
86-41	181	101	211.3R	Tehama
86-42	86	45	213.5L	Tehama
86-43[5]	3192	1784	218.6L	Tehama
86-44	176	98	221.1RL	Tehama
86-45[5]	96	54	221.9L	Tehama
86-46	1063	594	222.5L	Tehama
86-47[5]	64	36	224.1R	Tehama
86-48	64	36	226.1L	Tehama
86-49[5]	1383	773	231.7RL	Tehama
86-50	106	59	232.5R	Tehama
86-51[5]	138	77	234.3RL	Tehama
86-52[5]	218	122	237.0R	Tehama
86-53[5]	186	104	239.8L	Tehama
86-54	160	89	241.8L	Tehama
86-55	117	65	263.8R	Tehama
86-56	553	309	271.6L	Tehama
86-57	226	149	273.4R	Tehama
86-58	250	140	275.7L	Shasta
86-59	468	262	279.9L	Shasta
86-60	101	56	291.8L	Shasta
	28,894	16,149		

1/ Based on 0.94% accuracy.
2/ Based at 55.9% occupancy.
3/ Colonies located on the right side of river facing downstream (normally west)
4/ Colonies located on the left side of river facing downstream (normally east)
5/ Colonies randomly selected for intensive study.

Habitat parameters were measured at randomly selected colonies (Appendix B, C & D). Data collected included: colony length, bank height, burrow column height, colony height, distance from vertical bank to water, aspect, and bank slope. Distances greater than 100 m (110 yds) were estimated from aerial photographs. Vertical transects were established at three equally spaced locations across a colony (Figure 2), and the means of the transect measurements were calculated. Characterizations of the habitat above the colony were recorded at the transect locations. Additional habitat parameters were measured or noted and observed swallow behavior was recorded. We used the mean, plus and minus the standard error, and range to describe the data expressed in this paper. Descriptive habitat parameters were compared statistically (Zar 1974). Relationships between habitat variables were assessed with the Pearson correlation coefficient (r). The Kruskal-Wallis nonparametric test for analysis of variance was used to test for differences (ANOVA). The test statistic for this statistical analysis is H. The t-test was used to test for differences between means of habitat variables. Significance was set at P 0.05, and all analyses were done using CRISP software (Stegner and Bostrom 1984).

Soils were sampled within the strata containing swallow burrows. The weathered soil surface was scraped flat and a standard seamless soil tin was pushed into the substrate to obtain samples of equal volume. In moist soils it was easy to extract soil samples, but in dry soils a sharp knife was needed for boring and extracting the sample tin. Electrical tape was used to secure the sample and lids of tins until processing. Bulk density and percentage soil moisture were calculated for each sample. We determined soil type from bulk density measurements (Hausenbuiller 1978). We attempted to determine the series names of the soils. This was difficult in the field and was complicated because not all the counties (i.e., Butte, Sutter, Colusa) had soil surveys available.

We estimated burrow occupancy and swallow reproductive success from a random sample of 10-100 burrows per colony at 26 colonies. A flashlight was used to illuminate the burrow to determine burrow status. We considered burrows occupied if young, eggs, or a nest were found. Bank Swallow young were aged according to size, feather development and color, gape flange development, and mobility, and were categorized into five age groups. We estimated dates of egg laying by back dating. No measurements were taken at collapsed burrows or burrows of unknown status. We followed a technique similar to that of MacBriar and Stevenson (1976) for estimating the number of breeding pairs at each colony by multiplying burrow estimates by the average occupancy rate.

We banded Bank Swallows for future study of the species relocation abilities at three sites, two of which are scheduled for bank stabilization work which will destroy the colony. Birds were captured (Figure 3) in mist nets placed in front of the burrows. We attempted unsuccessfully to obtain food samples from mouths of adults captured in the mist nets when returning to feed their young.

At Colony 86-30 where bank sloughing had exposed at least 25 nest chambers and caused abandonment of the clutches, 15 non-viable eggs were collected for pesticide analysis. At other colony sites individual abandoned eggs were taken from burrows. Three eggs were analyzed for pesticide residue levels at the Department of Fish and Game's Pesticide Lab in Rancho Cordova, California.

We assessed potential detrimental impacts to swallow populations and habitats by reviewing proposed Federal and State sponsored bank stabilization projects

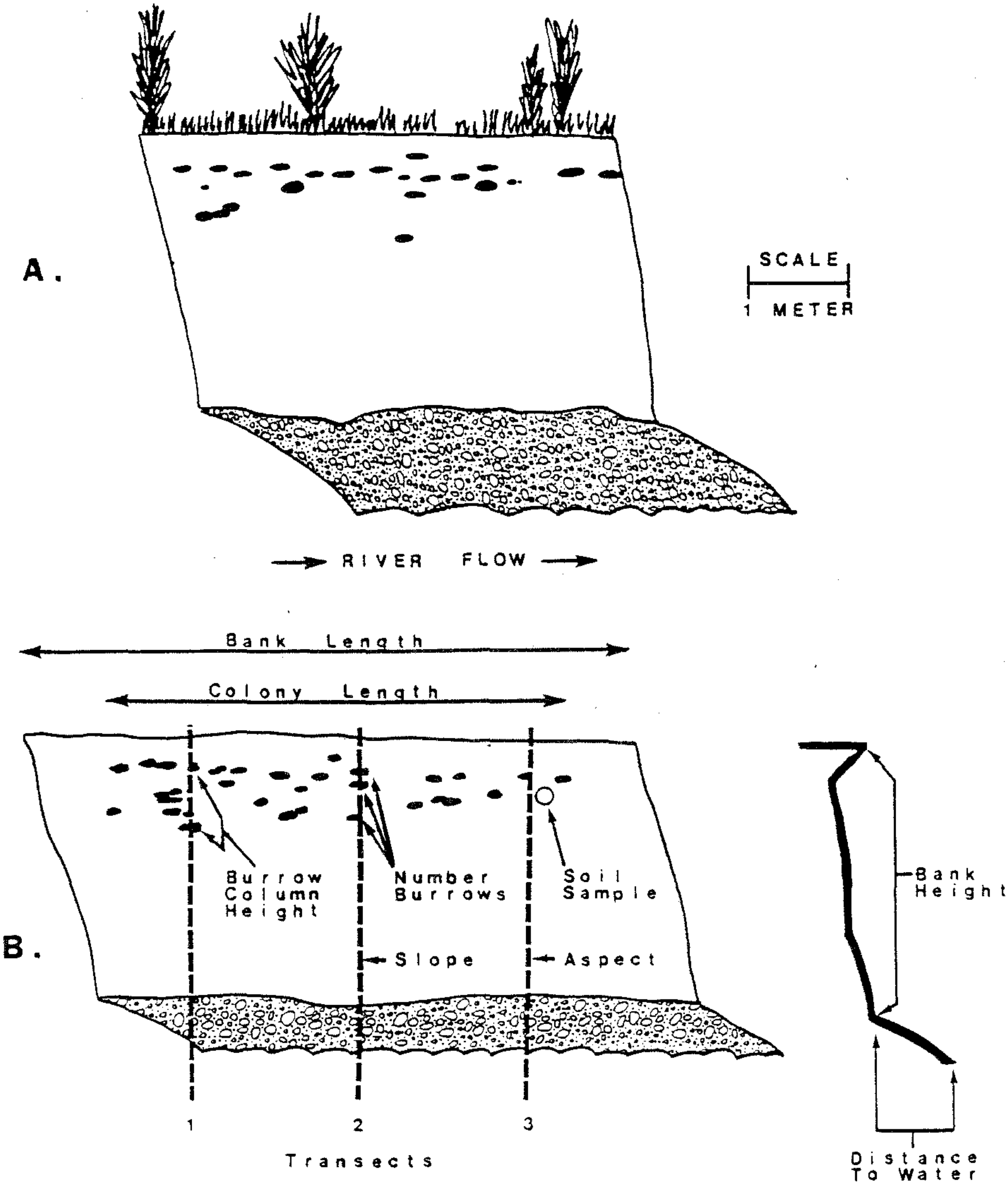

Figure 2. A) Front view diagram of bank section of a typical Bank Swallow colony on the Sacramento River, 1986, illustrating a Swiss cheese appearance. B) Front and side view diagrams of Bank Swallow colony illustrating habitat sampling design.

Photo by Barrett A. Garrison

Figure 3. Adult (shown; note diagnostic field mark, the band of dark feathers on the upper chest area) and juvenile Bank Swallows were captured and banded in an attempt to follow their movements and migratory habits.

(U.S. Army Corps of Engineers 1983, The State Reclamation Board 1986, U.S. Army Corps of Engineers unpubl. report). We defined colonies as threatened if the colony location was within the actual area of the proposed bank stabilization project, or if levee or riprap maintenance activities could destroy the exact location of the colony. Colonies within 0.5 km (0.3 mi) of a proposed riprap location were defined as affected. Unaffected colonies were those not yet examined for threats or not currently threatened or affected. Land-use activities around swallow colonies were recorded to determine the effects of agricultural practices on the habitat.

RESULTS

Population Distribution and Size

We located 60 colonies along the Sacramento River between Redding (RM 292) and the Yolo Causeway (RM 81) (Table 1). Only two colonies were located along the tributaries of the Sacramento River within the 8 km (5 mi) study limits, and we observed no suitable habitat for nesting Bank Swallows along the smaller tributaries. Evidence of colonies prior to 1986 was difficult to identify due to the continual erosion of the riverbanks. Major flooding occurred in March 1986 and probably eroded away many of the colony locations used in 1985.

Six colonies (10.0%) were located north of RM 243, an area characterized by rocky river banks and bluffs, steep canyons, and dams. Forty-four colonies (73.0%) were located between Red Bluff (RM 243) and Colusa (RM 143), where the river meanders and has not been extensively channelized. Ten colonies (16.7%) were located south of RM 143 where the river is channelized by levee systems, but contains widely dispersed, relatively small areas of bank or levee erosion. The distribution of colonies was markedly clumped toward portions of the river that have expansive areas of bank erosion (Figure 4).

We estimated the Sacramento River Bank Swallow breeding population to be 16,149 pairs (95% confidence interval = 14,597-17,700), and to represent 80% of the known statewide total (Table 1). We found a mean of 269 $\pm$ 48 pairs per colony. Colonies varied in size from 12 to 1,784 pairs. The population was not evenly distributed throughout the study area, and was even more clumped than colony location towards portions of the river with expansive bank erosion (Figure 5). Of the population, 85.1% (13,737 pairs) were located along the meandering river between RM 243 and RM 143, with an average of 312 pairs per colony. The population density was lowest at the north and south reaches of the river. The largest population concentration was located between Woodson Bridge State Recreation Area (RM 220) in Tehama County and Gianella Bridge (RM 200) in Butte County, where colonies averaged 537 breeding pairs.

We found more small colonies than large ones (Figure 6). Thirty-five colonies (58.3%) had fewer than 150 pairs, 13 colonies (21.7%) held between 151 and 450 pairs, and 12 colonies (20.0%) held over 525 pairs. Two colonies (86-38 & 86-43) were estimated to contain 1784 pairs each (Table 1).

Colonies were located only on the Sacramento River, Feather River, American River, and Cow Creek. We did not observe suitable Bank Swallow habitat in other areas. Nine colonies were located on tributaries of the Sacramento River. One small colony (75 burrows) was located on the American River, Sacramento County, in a vertical bank created by levee erosion. This colony was approximately 6-8 km (4-5 miles) upstream from the confluence of the American and Sacramento Rivers. There were two reports (P. Deitrich, C. Calza,

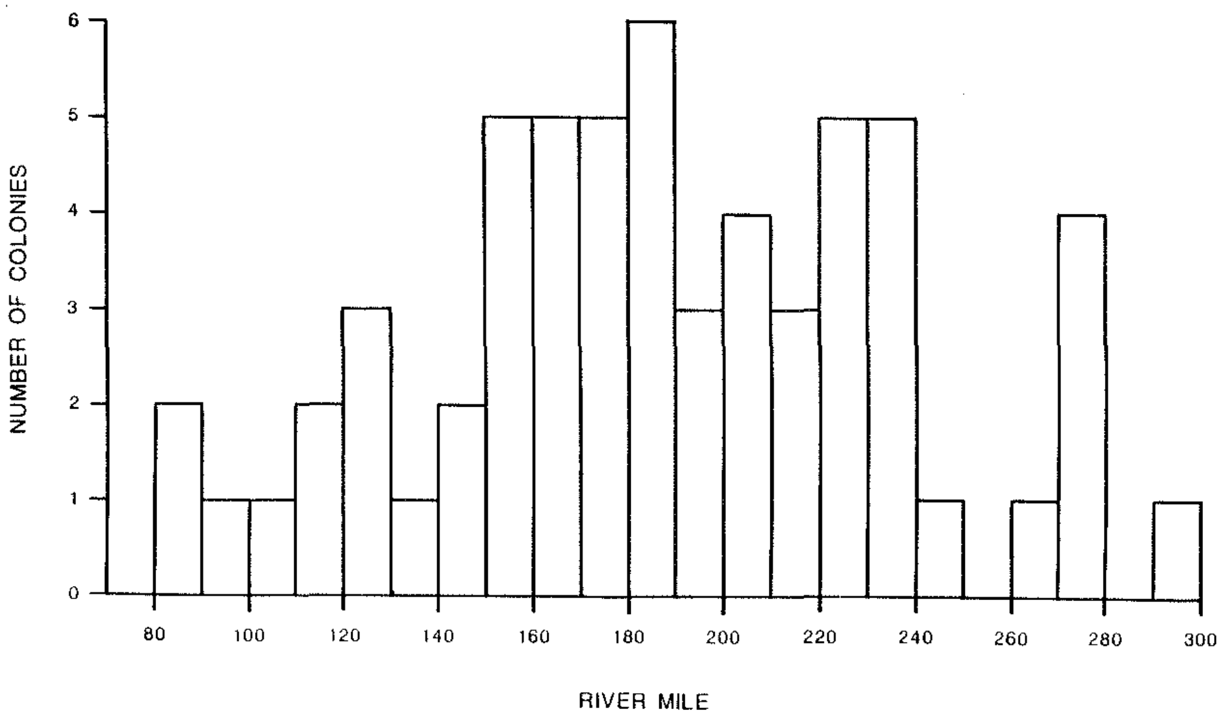

Figure 4. Geographic distribution of 60 Bank Swallow colonies by 10-river mile sections located on the Sacramento River, 1986.

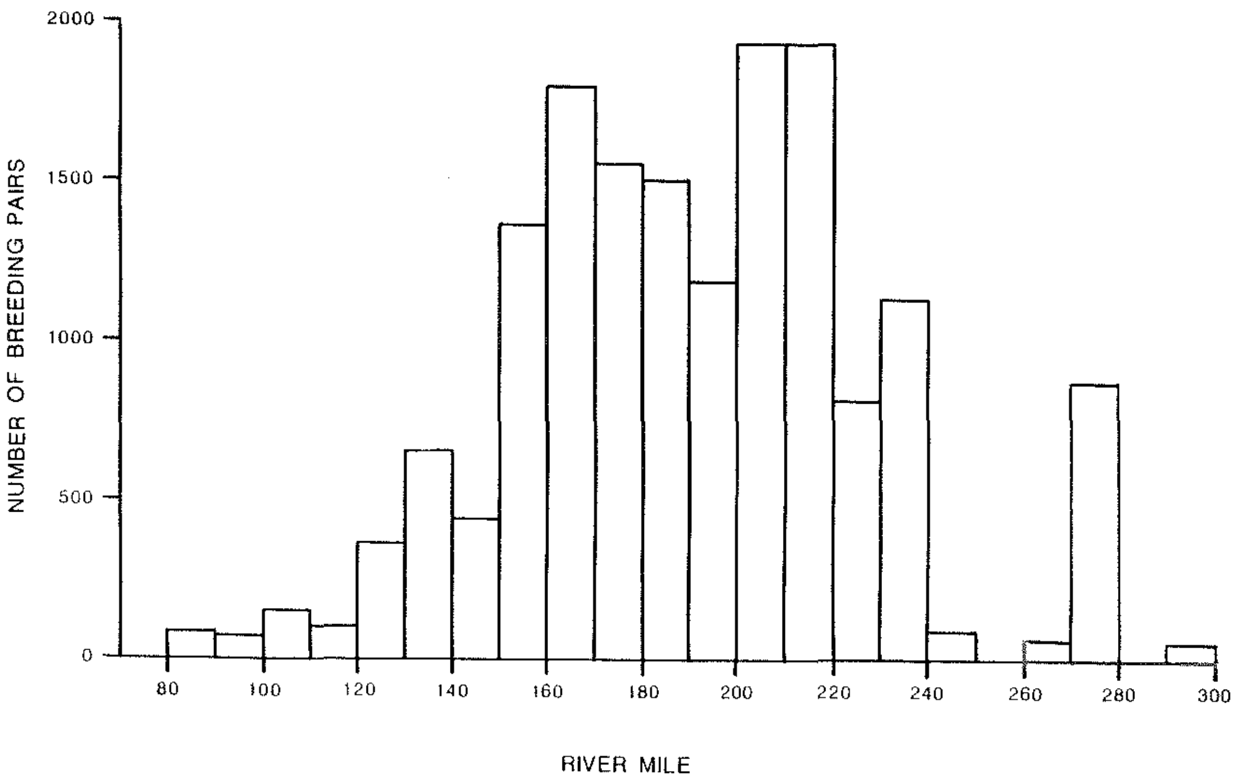

Figure 5. Geographic Distribution of Bank Swallow population (estimated 16,150 pair) by 10-river mile sections on the Sacramento River, California, 1986.

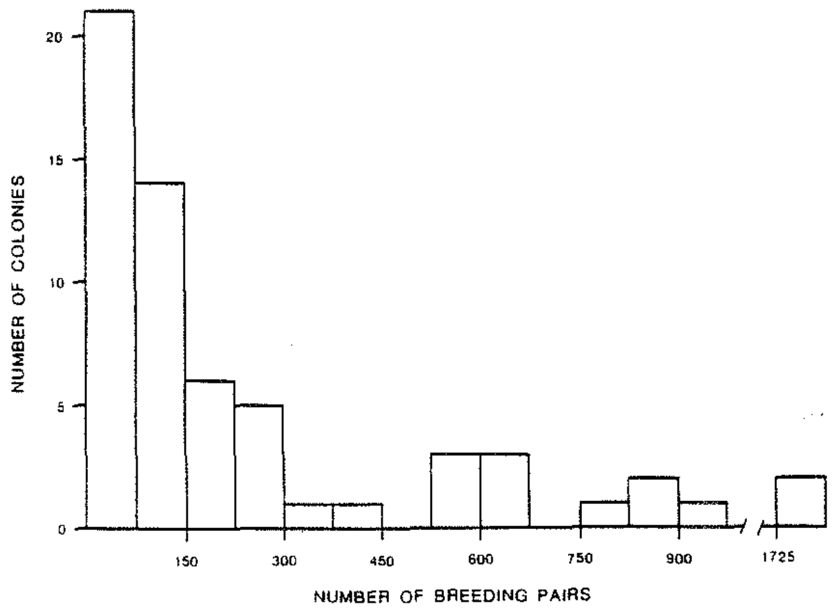

Figure 6. Relationship of Bank Swallow colony size to number of breeding pairs located on the Sacramento River, 1986.

pers. commun. 1986) of one colony of approximately 100 burrows along Cow Creek, Shasta County, in sandstone bluffs similar to the bluffs in which colony 86-59 was located. We located seven colonies on the Feather River ranging from an estimated 140-2000 burrows. None of the Feather River colonies were within the 8 km (5 mi) zone upstream from the confluence with the Sacramento River. Five Feather River colonies were concentrated upstream from Live Oak, Sutter County, and downstream from Oroville, Butte County, and the remaining two colonies were located in Sutter County approximately 11 km (7 mi) upstream from the river's mouth.

It appeared that the swallows were occupying virtually all of the available habitat within the study area. We located several sections of river bank which might have been suitable for Bank Swallow colonies. As no measurements were taken at these sites, it is difficult to fully assess their potential as nesting substrate. Based on qualitative field observations, these sites seemed suitable by virtue of their tall vertical banks, close proximity to water, and nearby open habitats.

Nesting Ecology

The burrow occupancy rate was 55.9% $\pm$ 2.7% (1330 burrows checked at 26 colonies). The mean number of young per nest was 2.84 $\pm$ 0.07 (211 nests checked at 14 colonies). We were unable to measure clutch size because the study began too late in the breeding cycle. The three eggs tested for pesticide contamination contained pesticide residue levels below those considered detrimental (Department of Fish and Game Pesticide Lab files).

We observed breeding activities throughout the period from early May to early July (Table 2). Colonies contained young of various ages at any one time,

Table 2. Chronological data from 199 Bank Swallow nests with young of known age on the Sacramento River in 1986. Note the peak of fledgling sized young in early June and the resurgence of breeding activity in middle July that may correspond to double brooding.

Date	Colony Number	Total burrows checked	Number of nests with eggs	Number of nests with young	Number of young (age in days)				
					0-5	6-10	11-15	16-20	20+
5-31	86-35	17	1	5	5	8			8
6-2	86-36	50		30	5				104
6-4	86-34	77	2	16	9	7	4		25
6-6	86-29	78	1	26	2+	19	11		43+
7-8	86-31	40		16	11	3	8	11	18
7-8	86-51	79	3						
7-9	86-38	99		17	6	11+	18	2+	6
7-10	86-28	50		14	17+	20+		3	
7-10	86-30	43		7	8+	7	1		1
7-10	86-32	46		21	9+	31+	6	10	9
7-11	86-26	54	2	2	1+				
7-15	86-21	130	4	5		8	3		
7-15	86-19	70	1						
7-15	86-23	57	1	9	3	13	3		
7-16	86-12	100	2	14	1+	10+	10	9	

+ = minimum number

although small groups of burrows or subcolonies appeared to have young at the same stage of development. This clustering of young of the same age was also noted by Petersen (1955). Fledgling young were already present at burrow entrances on 13 May when field work began, indicating that egg laying occurred as early as 10 April. Very young broods and eggs were present on 16 July. Turner and Bryant (1979) noted the rapid leg development of young Bank Swallows. We frequently observed these not fully feathered nestlings running deeper into the burrows.

By mid-July most of the earliest used colony sites were abandoned and overgrown with vegetation. Scattered nesting continued in subcolony areas where evidence of fresher excavation was noted. Burrows were often devoid of droppings even after the young fledged indicating well developed nest sanitation when young were present. Beyer (1938) and Petersen (1955) made similar observations in their Bank Swallow research.

By 7 June, increasing numbers of adults and juvenile Bank Swallows were seen near the colonies, perching on branches on sand bars, wires, and trees. Petersen (1955) described these as post-nesting loafing sites. We witnessed a display of post-nesting burrowing activity on 10 July as about 20 juvenile and adult Bank Swallows gathered on a uneven textured slope and engaged in burrow digging motions. Stoner (1936) and Petersen (1955) observed similar behavior. The majority of Bank Swallows had departed from their breeding areas by 31 July.

Banding Observations

We banded 350 birds (320 adults and 30 juveniles) from 1 June to 6 June at colonies 86-29, 86-34, and 86-35. Our objective was to band adults only, so we attempted capture before the young fledged. Mist nets were placed within 10 cm (4 inches) of the ground and 20 cm (8 inches) of the burrows since birds approached nests and attempted to fly under and behind the nets to reach their burrows.

Over 170 of the birds banded were adult females based on presence of a brood patch. Less than 5% of the females displayed an edamatous brood patch which indicates an incubating or brooding bird. The remaining females showed the recovery stage brood patches indicative of a bird with older young (Petersen 1955). This corresponds with the high number of near-fledging-age young observed at the banding locations (Table 2). The young birds banded were estimated to be from 18 to 28 days of age. Bank Swallows generally fledge by day 22 but can fledge as early as day 18 (Turner and Bryant 1979).

On five adult birds we observed worn toenails and dirty bills caused by burrow excavation. Gaunt (1965) described the use of the bill in the excavation of the burrow. External parasites (mites or fly larvae) were observed on about 25 nestlings.

Associations with other species

The same earthen river banks used by Bank Swallows are nesting sites for other species as well. Of 35 Bank Swallow colony locations, 25 (71.4%) accommodated other species at the same site. Northern Rough-winged Swallow (*Stelgidopteryx serripennis*) burrows occurred in 18 (51.4%) of the banks, and Belted Kingfisher (*Ceryle alcyon*) burrows were found in 11 (31.4%) of the banks. Bank Swallows, Rough-winged Swallows, and Belted Kingfishers were found together at 6 (17%) of the sites. One record each (2.8%) occurred for Black Phoebe (*Sayornis nigricans*) and Cliff Swallows (*Hirundo pyrrhonata*) nesting on the bank. Studies of Bank Swallow colonies in British sand quarries have reported 16 avian species that have occupied relict or modified burrows, or have dug their own burrows (Mead and Pepler 1975).

Breeding Rough-winged Swallows and Belted Kingfishers were consistently found in the same reaches of the river as Bank Swallows. We rarely observed these other species in areas devoid of Bank Swallow habitat indicating they also appear to be limited by available bank habitat.

The only other vertebrate that used colony burrows was the gopher snake (*Pituophis melanoleucus*). Gopher snakes, besides foraging on swallow eggs and young, used burrows for thermoregulation and as a secure refuge for skin-shedding.

Predators

We observed several instances of predation by gopher snakes on Bank Swallows. Gopher snakes, or indirect evidence of their presence (shed skins, feces), were found in 20 (1.5%) of the 1330 burrows examined. We found partially digested swallow carcasses and avian remains in snake excrement. On 31 May, five snakes were found at colony 86-35 where the nestlings were 5 to 10 days old, and predation appeared to be high.

On 8 July during peak fledging, a juvenile Peregrine Falcon (Falco peregrinus) was observed preying on Bank Swallows at two colonies. Raccoon (Procyon lotor) tracks under a colony indicated the animal was interested in the burrows 1.8 m (6 ft) above. Dawson (1923) noted that if the nature of the bank permits access "weasels and their ilk sometimes find entrance to the nesting burrows, and they are an easy prey to underbred small boys as well". There are recent reports of some fishermen using nestling Bank Swallows as bait for their hooks.

Habitat of Nesting Colonies

Orientation and Associated Habitats

Except for a sandstone bluff at RM 280, all Sacramento River Bank Swallow colonies were found in recently eroded vertical riverbanks. Bank Swallows showed a preference for the outer curves of the river bank where erosion is heaviest (Hamblin 1975). We found 44 (73.3%) of the 60 colonies on outer bends, 9 (15.0%) were on straight reaches of the river, and 7 (11.6%) were on inner bends. Of the breeding pairs, 14,266 (88.3%) were found on outer bends, 1220 pairs (7.6%) were on inner bends, and 663 pair (4.1%) were on straight reaches of the river. This tendancy toward outer bank selection was most obvious within the meandering area between RM 243-143, where 35 (81.8%) of the 44 colonies and 12,695 (92.4%) of the 13,737 breeding pairs nested on outer bends (Figure 7).

The colonies we located often had open terrain immediately above and behind them (Table 3). The habitat above the colonies ranged from sand bars to riparian forest, and grassy fields to oak woodlands, but usually retained a patchy openness compared with surrounding areas. In orchards these were areas of small or removed trees. Oak woodland and riparian forests were often interspersed with patches of grassy fields.

Table 3. Results of 99 habitat type characterizations above 32 Bank Swallow colonies on the Sacramento River 1986. Colonies are generally associated with open habitats.

Open habitats (sandy or grassy fields)	53
Walnut or almond orchards	16
Riparian forests	15
Agricultural fields (fallow or row crops)	11
Oak woodlands	4

Most (82%) of the 99 transects sampled at Bank Swallows colonies faced directions other than South or Southwest (Figure 8). Further study is needed to determine the cause for this preference. Soil moisture and bank availibility may play roles in colony orientation.

Colony Characteristics

Bank Swallow colonies we located on the Sacramento River were relatively similar in appearance (Table 4, Figures 7 & 9). The 3-4 m (10-13 ft) tall, vertically eroded riverbanks were usually devoid of green vegetation and at water's edge. We estimated roots present in 33.7% of the colonies. The typical colony had burrows occupying only 15% of the bank's vertical face, with 20% of the bank above and 65% of the bank below the colony. The average

Photo by Barrett A. Garrison

Figure 7. Example of a typical medium sized (131-375 burrows) Bank Swallow colony on an outer bend of the Sacramento River with a forested area immediately above and behind the site.

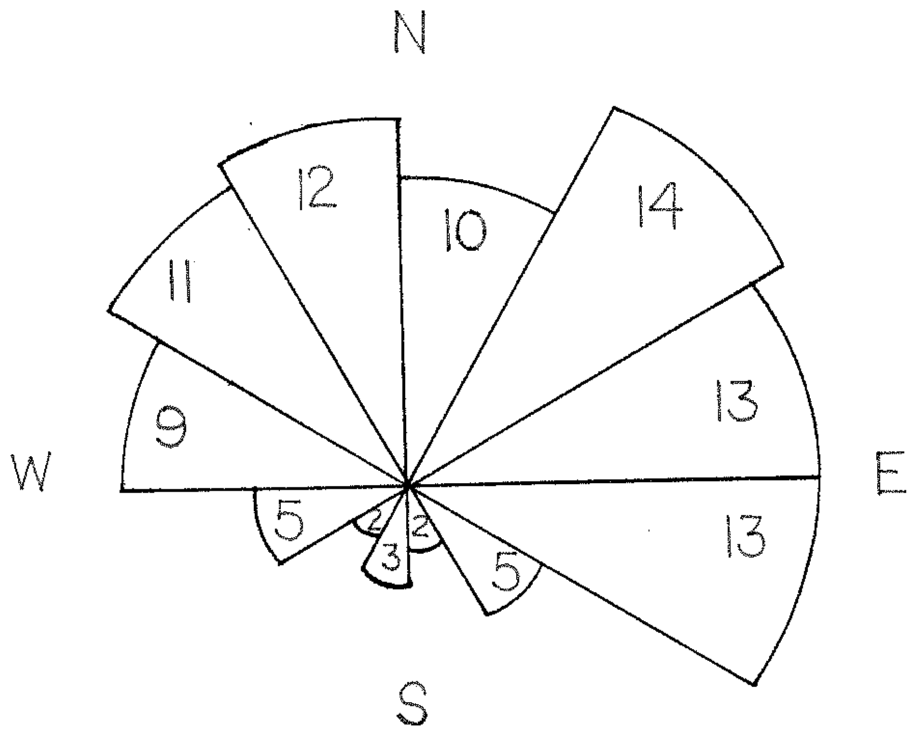

Figure 8. Orientation (compass direction faced) of burrow entrances from 99 transects taken at 32 Bank Swallow colonies on the Sacramento River, 1986.

distance from the lowest burrow to the base of the vertical slope or to the water was 2.1 m (6.9 ft), and the distance above the highest burrow to the bank top was 0.7 m (2.3 ft). Colony length averaged 14.5% of the cut bank length with an average slope of 83.3° $\pm$ 0.9° (68.3°-96.7°). We found that burrow density was positively correlated with bank slope (Table 5).

Table 4. Descriptive habitat statistics of 32 Bank Swallow colonies between RM 240 and RM 97 of the Sacramento River, 1986

	METERS			FEET		
Habitat Variable	Mean	SE	Range	Mean	SE	Range
Bank Height	3.3	0.3	1.3-7.3	10.8	1.0	4.3-24.0
Distance to Water	4.1	0.8	0.0-21.8	13.5	2.6	0.0-71.5
Colony Length	66	12	2.0-336	218	41	7-1201
Bank Length	455	78	13-1,900	1492	256	43-6234
Top Burrow to Bank Top	0.7	0.1	0-1.4	2.3	0.3	0-4.6
Bottom Burrow to Bank Top	1.2	0.1	0-3.2	1.2	0.3	0-10.5
Burrow Column Height	0.5	0.1	0.0-1.7	1.6	0.3	0.0-5.6
Burrow Density (burrows/unit)	0.8	0.1	0.0-1.9	0.2	0.0	0.0-0.6
	CENTIMETERS			INCHES		
Burrow Width	7.2	0.2	5-14	2.8	0.1	2-5.5
Burrow Height	5.5	0.1	3-11	2.2	0.0	1.2-4.3
Burrow Depth	61.5	0.3	10-105	24.2	0.1	3.9-41.3
Distance between Burrows	13.2	0.2	1-59	5.2	0.1	0.4-23.2

Photo by Barrett A. Garrison

Figure 9. Example of a typical Bank Swallow colony showing marked stratification of burrow locations and open habitat immediately above and behind the site.

Table 5. Correlation matrix for habitat variables measured at 32 Bank Swallow colonies on the Sacramento River, California, 1986. All correlations have 30 degrees of freedom. Top number is r-value and bottom number is P-value for each correlation.

	RIVER MILE	BREEDING PAIRS	ASPECT	SLOPE	BANK HEIGHT	BURROW DENSITY	NUMBER OF BURROWS	HIGHEST BURROW TO BANK TOP	LOWEST BURROW TO BANK TOP	BURROW COLUMN HEIGHT
BREEDING PAIRS	0.2330 0.1993									
ASPECT	0.0542 0.7684	0.0075 0.9675								
SLOPE	0.0515 0.7796	-0.0368 0.8414	0.0123 0.9469							
BANK HEIGHT	-0.4407 0.0116	0.2560 0.1574	0.1507 0.4103	-0.1467 0.4229						
BURROW DENSITY	0.2964 0.0996	0.1572 0.3902	-0.0720 0.6952	0.4272 0.0147	-0.4106 0.0196					
NUMBER OF BURROWS	0.0266 0.8850	0.5720 0.0006	-0.0971 0.5971	0.2049 0.2607	0.2774 0.1243	0.6450 0.0001				
HIGHEST BURROW TO BANK TOP	0.0193 0.9165	0.2916 0.1054	0.0723 0.6943	0.0755 0.6812	0.5380 0.0015	-0.0682 0.7109	0.3329 0.0627			
LOWEST BURROW TO BANK TOP	0.1473 0.4212	0.6993 0.0000	0.1417 0.4391	-0.0256 0.8895	0.5964 0.0003	0.0860 0.6397	0.6441 0.0001	0.7504 0.0000		
BURROW COLUMN HEIGHT	0.1698 0.3528	0.8204 0.0000	0.1029 0.5751	-0.0365 0.8427	0.4830 0.0051	0.2102 0.2481	0.7280 0.0000	0.4313 0.0137	0.9040 0.0000	
DISTANCE TO WATER	0.0066 0.9713	0.1060 0.5636	-0.0123 0.9468	0.0420 0.8194	-0.3308 0.0644	0.0986 0.5912	-0.1400 0.4448	-0.2247 0.2163	-0.1961 0.2819	-0.1503 0.4116

The typical Bank Swallow burrow was wider than high (Table 4, Figures 10 & 11). In shape, burrows were mostly ellipsoid (80%), but were also circular (14%), square (4%), or triangular (2%). Active burrows were significantly deeper than inactive burrows (P 0.01, N = 187). Incompletely dug burrows accounted for the shallower depth measurements. Burrows were primarily level (70%), but also angled upwards (19%), or downwards (11%).

Bank height was negatively correlated to river mile, so bank height at Bank Swallow colonies is closely related to the river's downstream development between RM 240 and RM 97 (Table 5). Bank height was positively correlated with burrow column height, distance of top burrow to bank top, and distance of bottom burrow to bank top (Table 5). The number of burrows per colony, distance from the bottom burrow to the top of the bank, and burrow column height were positively correlated with the number of breeding pairs. Burrow density was positively correlated with bank slope and number of burrows. However, burrow density was negatively correlated with bank height. These correlations indicate a relatively strong positive relationship between actual colony size (number of breeding pairs) and physical indicators of colony size (i.e., measurements of burrows). This relationship may be misleading because the number of breeding pairs within a colony was estimated from the number of burrows.

Most (73.8%) of the 88 Bank Swallow burrows analyzed were located in evenly textured silty loam to sandy loam soils (Table 6). The mean bulk density of soils samples (N = 88) was 1.23 $\pm$ 1.2 grams/cc, a loam soil (Hausenbuiller 1978). Bank Swallows were not found burrowing in coarser soils or soils mixed with small rocks or pebbles. The typical colony had burrows in narrow layers of softer silty or sandy soil sandwiched between layers of other soils (Figure 9).

Table 6. Soil texture classes of 88 samples taken at 32 Bank Swallow colonies on the Sacramento River, 1986.

Textural Class	Bulk Density(g/cc)	Number	Percent
Sand	1.55	3	3.4
Sandy Loam	1.40	6	6.8
Fine Sandy Loam	1.30	19	21.6
Loam	1.20	34	38.6
Silt Loam	1.15	6	6.8
Clay Loam	1.10	4	4.5
Clay	1.05	10	11.4
Aggregated Clay	1.00	6	6.8

Most of the soils where burrows were located are crumbly when moist and very hard when dry. These layered soils are saturated annually by winter flood waters. We found that Bank Swallows often dug their burrows in high moisture soil layers immediately above less permeable strata (Figure 8). It appeared that the moisture content of soils was related to ease of burrowing and also facilitated soil sampling. Because of the late starting date of our field work, we did not obtain soil moisture levels while the birds were burrowing. Our samples do reflect a drying out of the bank face soils throughout the season. In early June, soil moisture was 7.8 $\pm$ 0.6% (0-23%, N = 22), and in mid-July, soil moisture was 3.8 $\pm$ 0.3% (0.1-34.1%, N = 65).

Eighteen of the colonies were located in the Columbia soil series, which consists of stratified fine sandy loam to silt loam soils. Streambank erosion is considered a serious problem in areas of these soils which

Photo by Joan M. Humphrey

Figure 10. Typical view of a portion of a Bank Swallow nesting colony showing soil stratification and size and distance relationships of individual burrows.

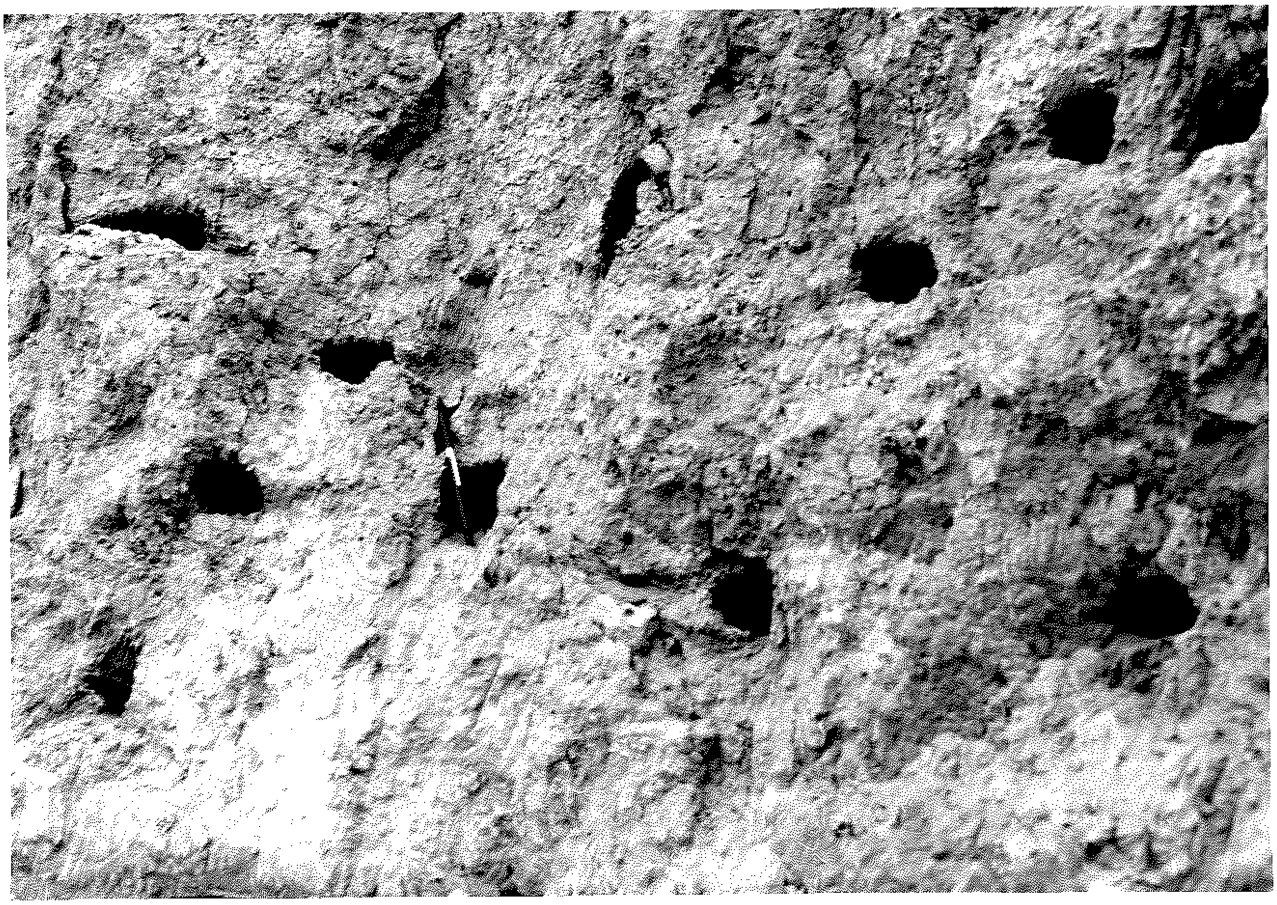

Photo by Barrett A. Garrison

Figure 11. Example of relative size of Bank Swallow burrows (see pen) and spacing pattern and distance between burrows.

directly border the river (U.S. Soil Conservation Survey 1968). Seven of the colonies were in the Columbia silt loam, which is typical of soils used by Bank Swallows on the Sacramento River. This soil type occupies areas of various sizes on both sides of the Sacramento River from Colusa County to Tehama County. The upper 0.3-1.5 m (1-6 ft) of soil is described as slightly hard silt loam and very fine sandy loam which contain stratified thin layers of loamy fine sand and sand that are friable when moist (U.S. Soil Conservation Survey 1968).

Threats to the Population

We recorded instances of both direct and indirect human disturbance of colonies. We observed three instances of bank sloughing in May and June with some destruction of colonies. This sloughing was due to under-cutting the easily eroded banks because of high water releases from Shasta Lake. This was the greatest cause of observed mortality. The most southerly colony completely vanished between visits to the site on 21 May and 21 June. This area is a popular speed boat and water skiing location and the bank became terraced due to wave action. The lost colony was also adjacent to a popular fishing access. A few colonies which were easily accessible had burrows disturbed by humans as evidenced by rocks or other materials stuffed into the entrances.

Riverbank erosion is the natural process that creates Bank Swallow habitat. Proposed riprapping projects represent the largest single threat to Bank Swallow populations and habitat on the Sacramento River (Figure 12). According to planning documents we have reviewed, many existing colony locations will be destroyed, and new habitat will not become available (U.S. Army Corps of Engineers 1983). Construction activity on adjacent sites may also have an adverse impact on Bank Swallow nesting and foraging behavior. Construction activities with the greatest potential impact are planned between RM 143 and RM 243 (Tables 7 & 8, Figures 13 & 14). This is the region of greatest number of colonies and greatest Bank Swallow population abundance (Table 1, Figures 4 & 5).

A minimum of 31 colonies (51.6%) are threatened by proposed Federal and State bank stabilization projects, and an additional five colonies (8.3%) may be affected by these activities (Figure 13, Tables 7 & 8). These are minimum figures since once completed, the projects may disrupt the local hydrology, and maintenence activities allowed without formal review processes may destroy Bank Swallow colonies. In addition, we understand that the U.S. Army Corps of Engineers is developing bank stabilization plans that will impact additional Bank Swallow colonies south of RM 143.

A minimum of 8,935 breeding pairs (55.3%) are threatened with loss of nesting habitat, and an additional 1,064 pairs (7.7%) also may be affected by proposed activities near colonies (Figure 14, Tables 7 & 8). If all proposed projects (Army Corps of Engineers 1983) are completed, Bank Swallow population declines will occur within the next 5 to 10 years beginning as early as 1987.

Table 7. Effects of proposed Federal and State sponsored bank stabilization projects (RM 243-143) on the Bank Swallow population (estimated 16,150 pairs in 60 colonies) on the Sacramento River.

	RM 143-243	Percentage of Reach RM 143-243	Percentage of Total Study Area
Pairs threatened	8,935	65.0	55.3
Pairs affected	1,064	7.7	6.6
Pairs unaffected	3,738	27.2	23.1
TOTAL	13,737	99.9	85.1
Colonies threatened	31	70.4	51.7
Colonies affected	5	11.4	8.3
Colonies unaffected	8	18.1	23.1
TOTAL	44	99.9	73.3

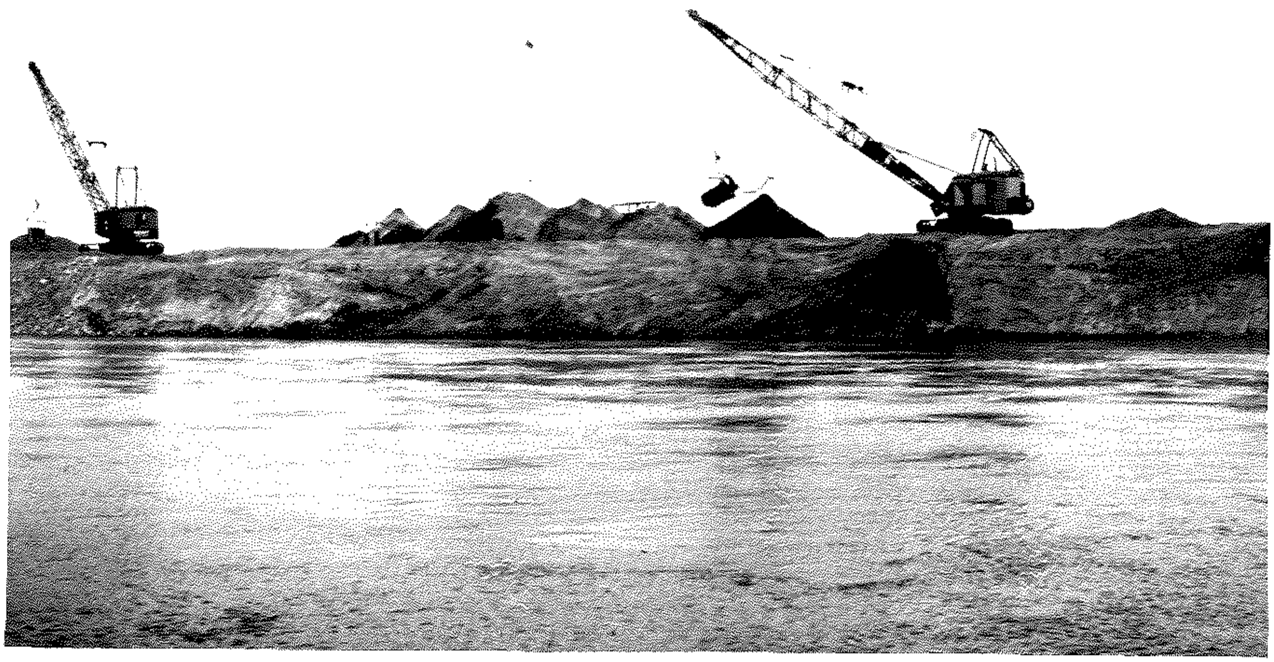

Photo by Ronald W. Schlorff

Figure 12. Bank stabilization activities of State and Federal agencies, such as those depicted here, have the potential to eliminate much of the remaining Bank Swallow habitat on the Sacramento River.

Table 8. 1986 Bank Swallow colonies that are threatened (lost), affected or unaffected by proposed Federal and State sponsored bank stabilization projects on the Sacramento River (RM 143 to RM 243).

Colony Number	Breeding Pairs Lost	Breeding Pairs Affected	Breeding Pairs Unaffected	River Mile
86-11			297	144.3L
86-12 2/,4/	146			147.5R
86-13	65		131	150.5RL
86-14 2/	42			155.1L
86-15 2/	868			156.2RL
86-16 2/	59			158.7R
86-17 2/,4/		202		159.3L
86-18 2/		383		161.7L
86-19 2/	193			162.1R
86-20 2/	535			165.4L
86-21 2/	642			166.5R
86-22 2/	39			168.7R
86-23 2/	71			171.6R
86-24 2/	624			173.4R
86-25 2/	595			173.9R
86-26 2/		256		178.1L
86-27 2/,4/	12			179.4R
86-28 2/	95			181.4R
86-29			904	182.8L
86-30			208	184.5L
86-31 2/	226			185.5R
86-32 2/	30			187.9R
86-33 2/	36			188.9L
86-34 2/,3/	833			190.5L
86-35 2/,3/	87			192.6L
86-36			256	195.1RL
86-37 1/,2/	21			201.4R
86-38			1784	202.4R
86-39			77	206.6L
86-40 2/	48			209.8R
86-41 2/		101		211.3R
86-42			45	213.5L
86-43 1/,2/	1784			218.6L
86-44 1/	98			221.1RL
86-45 2/	54			221.9L
86-46 1/,2/	594			222.5L
86-47 1/,2/	36			224.1R
86-48			36	226.1L
86-49 1/,2/	773			231.7RL
86-50 1/,2/	59			232.5R
86-51 1/	77			234.3RL
86-52 2/		122		237.0R
86-53 2/	104			239.8L
86-54 1/	89			241.8L
	8935	1064	3738	

Data from U.S. Army Corps of Engineers, Sacramento District Office files:
1/ Comprehensive Channel Stabilization Plan
2/ Erosion Control Investigation (RM 143-243)
3/ Contract 40
4/ Contract 40A

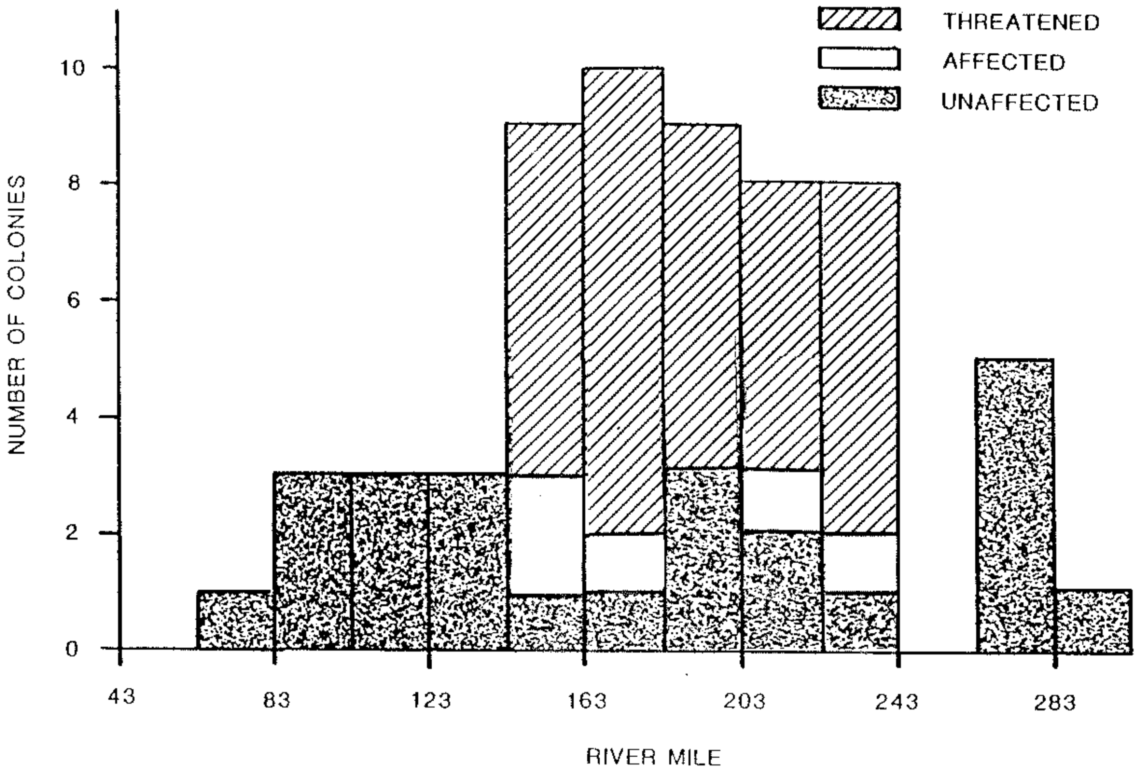

Figure 13. Geographic distribution of 60 Bank Swallow Colonies located on the Sacramento River, 1986, denoting colonies threatened, affected, or unaffected by proposed State and Federal bank stabilization projects from RM 143-243.

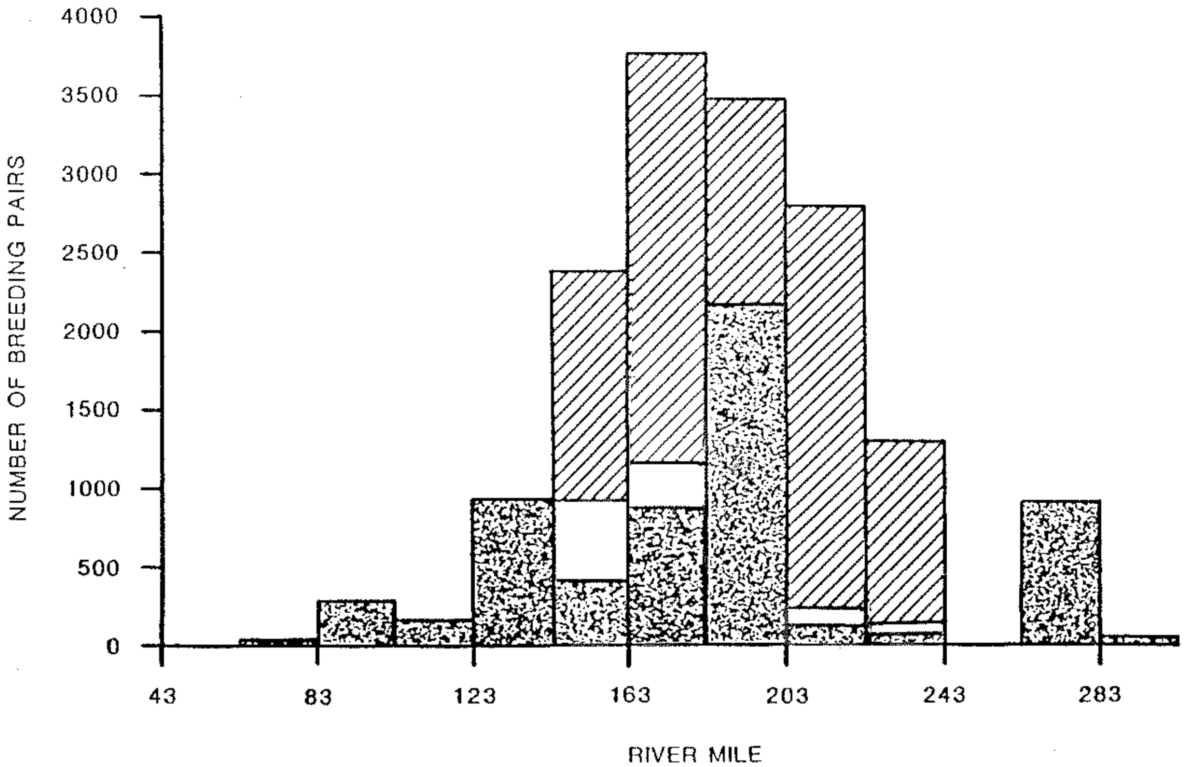

Figure 14. Geographic distribution of Bank Swallow population (estimated 16,150 pairs) on the Sacramento River, 1986, denoting breeding pairs threatened, affected or unaffected by proposed State and Federal bank stabilization projects from RM 143 to RM 243.

1/ Based on currently available proposed project data from the U.S. Army Corps of Engineers, Sacramento.

DISCUSSION

Population Size and Distribution

The Sacramento River system includes a vast flood plain extending southward from Redding (RM 293) to Colusa (RM 143). Most of California's current population of Bank Swallows are concentrated on this alluvial plain where the river still meanders in a mostly natural state. In this upper alluvial plain, the river system has provided both the erosion and soil types needed for prime nesting habitat. Upstream from Red Bluff (RM 243), suitable habitat appears marginal, and is absent north of Redding (RM 293). South of Colusa, the colonies are small and scattered primarily in pockets of levee erosion and riprap washouts. Suitable habitat is absent south of RM 81, where the river is almost entirely riprapped.

The paucity of colonies along many tributaries is evidence of the lack of appropriate habitat. This results from the coarser soils and the lack of deep water below the colony throughout the summer. The Feather River is the tributary most like the Sacramento River and could be expected to produce the most additional colonies. The finer particles which continue downstream in both the Sacramento and Feather Rivers have provided the sediment that built the naturally high river levees during times of flood. Both the height of the erosional banks and the proper soil types have been created by the natural system (Scott and Marquiss 1984). Bank Swallows and natural river systems are closely interconnected.

The remaining riparian portion of the Sacramento River, from RM 243 to RM 143, is the only major area in California with the proper combination of suitable soils and erosion which provide appropriate habitat for Bank Swallows. Most of the southern California streams and rivers have been channelized and Bank Swallows are no longer found breeding there (Remsen 1978). While natural lowland rivers were once common throughout the State, much of the riparian areas in California have been eliminated by various human activities, including flood control and bank protection. The population of Bank Swallows along the Sacramento River is unique and is, based on preliminary research, estimated to be 80% of the total State population. Further study is scheduled for 1987 to obtain statewide population and distribution figures.

Nesting Ecology

We observed a burrow occupancy rate of 55.9%. Hickling (1959) observed that about half the holes were unused for nesting. MacBriar and Stevenson (1976) reported an 80% occupancy rate in Wisconsin. Our observed occupancy rate may be low as we were not always able to observe the top burrows due to their inaccessability. The upper burrows represent the most favored locations for breeding and have a higher occupancy rate than lower burrows (Petersen 1955).

In Britain, Morgan (1979) reported an average clutch size of 4.8 eggs and an average brood size of 3.5 young. This is higher than our observations of 2.8 young per nest. Freer (1977) found clutch size in New York to be 4.38 ± 0.08 (N = 170 nests). A reduction of clutch size by approximately one egg as the season progressed was observed in Wisconsin and New York (Stoner 1936, Petersen 1955). In Iowa, Stoner also noted that clutches of 5 or 6 eggs on average produced broods of 4 or 5 young. Our study began late in the breeding cycle, and this brood size reduction may account for our lower observations.

The nesting data suggests that, but does not answer the question of whether, Bank Swallows double brood (Table 2). This is important to the population dynamics, but very difficult to assess. The Bank Swallow in Britain is considered to double or possibly triple brood (Cowley 1979). There are two peaks of egg laying, in late-May or early-June and mid-July (Mead 1979a). In California the breeding season starts earlier than it does in Britain, and observed peaks of egg laying indicate multiple broods may occur here. Further study is recommended to verify this observation.

Our study area had young in various stages of development from at least 10 April to past 16 July. The breeding birds generally arrive near the beginning of April, but have been observed in the Sacramento Valley as early as 14 March (ABF). First-time breeding Bank Swallows arrive at the breeding colony two to three weeks later than the older adults. This creates considerable nesting overlap between the late arrivals and second broods attempts, and suggests that the older birds get the optimal nesting locations (Freer 1979, Mead and Harrison 1979).

Site tenacity in Bank Swallows is lower than in Barn Swallows (Hirundo rustica) or Cliff Swallows which have more stable nesting sites (Freer 1979). Even so, 90% of the juveniles settle within 10 km (6 mi) of the natal colony (Sargent 1962). Prior reproductive success is an important factor in site tenacity. Unsuccessful nesting and deterioration of the bank prompt relocation in succeeding seasons, and specific sites are abandoned if predation or mortality is high (Freer 1977, 1979). British banding studies further show a geographic fidelity to the nesting area as 90% of the banded birds returned within 10 km (6 mi) of banding (Cowley 1979). The median subsequent settlement distance was 6 km (3.5 mi) for juveniles and 3 km (1.5 mi) for adults in the study reported by Mead (1979a).

The Bank Swallow is a short-lived species with an average life span just under three years, but exceptional birds may reach age seven (Stoner 1936, 1942). From banding returns in New York, Freer (1977) found an annual survival rate of 54%. British studies have estimated the post-fledging mortality at 80% and mean annual adult mortality at 65%. These studies have found that most mortality (traffic, wires, migration, unknown causes) occurs in the nine months of the year they are outside the breeding area although sandfalls and predation are important causes of mortality during the three months the birds are at the colony site (Harwood and Harrison 1977, Mead 1979b, Cowley 1979).

Avian predators like the American Kestrel (Falco sparverius) are the most commonly reported predators at Bank Swallow colonies (Freer 1973, Mead and Pepler 1975). On 8 July we observed a Peregrine Falcon preying on Bank Swallows at two colonies. Black rat snake (Elaphe obsoleta) predation has been shown by Blem (1979) to increase in marginal habitat. The colony at which we observed five gopher snakes on 31 May appeared to have had areas of lesser slope facilitating ground predator access. In Britain, Mead and Pepler (1975) reported on 21 avian and mammalian Bank Swallows predators, including mankind (Homo sapiens) as also noted by Hickling (1959) and Dawson (1920).

The preference by Bank Swallows for the riparian cutbanks was also noted by Bergstrom (1951:58) who stated "Bank Swallows require a special sort of disturbance community in which to nest, an abrupt bank with a minimum of vegetation. The best sites along streams are on curves where annual erosion takes place."

Brice (1977) commented on the tendancy of meanders and river loops to be perpendicular to the overall direction of the river. The Sacramento River flows North to South, and would seem to meander in a generally east-west direction. This pattern does not satisfactorily explain the disproportionate amount of northerly facing burrows and absence of southerly ones in our study. Spencer (1963) found in his study of Vermont and Pennsylvania Bank Swallows at 25 quarry locations that 17 had a southern or eastern exposure, and none faced north.

The habitat types above the colonies appear representative of the study area and compare with results of a study done by the U.S. Army Corps of Engineers (1973) assessing vegetative cover percentage for both left and right banks of the Sacramento River from RM 61 to RM 243. Their findings averaged 9% agriculture, 36% trees, 40% shrubs or grasses, and 14% barren areas compared with our findings (RM 97 - 240) of 11% agriculture, 35% trees and 53% open or grassy areas.

Colony Characteristics

Our habitat findings are similar to those reported in other studies (Bergstrom 1951, Petersen 1955, Spencer 1963). Average occupied burrow depths of 66 cm (25.8 in) and 71 cm (28 in) were found by Hickling (1959) and Stonor (1936). Our value of 62 cm (25.6 in) reflects measurements of burrows unoccupied or incompletely dug as well as occupied. Spencer (1963) found burrow depths of 25.4-102.6 cm (10 to 40 in) with an average of 58.9 cm (23.2 in), and with burrow depth generally greater in finer soils. A positive relationship between length of burrow and percentage of sand in the soil was found by Petersen (1955). He also found average distance between neighboring burrows to be 18.5 cm (7.3 in) compared to our 13.2 cm (5.2 in).

We found the number of burrows was positively correlated with the slope, so that more nearly vertical surfaces had more burrows. Spencer (1963) found the number of burrows to vary inversely with the percentage of coarse sand and gravel, and to be in direct proportion to the amount of exposed surface of a uniformly fine texture. Thus, the size and location of the colony is dependent on soil type, the quantity of suitable soil, and its steepness.

We observed increases in bank height along the Sacramento River from RM 240 to RM 97. Brice (1977) noted increase in bank width and height particularly between RM 170 to RM 140. He also noted that predominantly silt soils were layered with fine sands from RM 188 to RM 165. In this context, we found that the higher banks had larger burrow columns and greater occupancy rates.

Availability of suitable soils for nesting appears very important to Bank Swallows and may be a limiting factor in colony location. In our study and Petersen's (1955) research, apparent preference was shown for the more sandy strata while the gravelly layers were avoided. We found 74% of the colonies (N = 32) in sandy loam to silt loam soils. In Wisconsin, Petersen found 60% of the colonies (N = 10) to be in these soils. In a study of Bank Swallows in Vermont and Pennsylvania, 72% of the colonies (N = 25) studied indicated a definite preference for well drained and loosely packed, loamy sand or sandy loam soils (Spencer 1963).

Generally, the Sacramento-San Joaquin Delta area is composed of very fine sands, largely silts, and more clays than the midriver area which is frequently composed of medium to fine sands, sandy silts and minor clays. The upper river region soils are composed of increasingly larger size coarse sands and gravels. In addition, the deposition of natural levees is related to the size grain of its soils. The silty delta levees have broadened widely and are lower than the taller sandy midcourse levees. These middle river areas contain soils more suitable for Bank Swallow habitat.

Threats to the Population

Streambank erosion is necessary to maintain typical Bank Swallow habitat. Erosion will be reduced when additional regulatory and storage facilities are constructed on the river and its tributaries (U.S. Soil Conservation Survey 1968). Flood control operations along the Sacramento River, such as the Shasta Dam, have modified the flow of the river, resulting in substantially higher than natural flows in late spring. The natural levees and surrounding soils are extremely porous and because of the high flows, the streambanks never dry out and are more susceptable to erosion (Scott and Marquiss 1984). The tendency of swallows to nest in banks of soils that erode easily when moist puts them in a precarious situation. Bank faces which eroded in May and June from high waters caused the collapse of colonies or portions of colonies. This unnaturally timed bank undercutting and erosion caused considerable mortality.

Bergstrom (1951:58) noted that "while dependent on annual erosion, a major limitation on the [Bank Swallow] population is high water in nesting season. In a short-lived species a year's failure or severe reduction is a very severe strain." He further reported on the Connecticut River rising unseasonally twice in the six years of his study. This high water caused considerable loss to the portions of the colony involved. In 1946 one section was reduced from 55 burrows to 1, another from 185 burrows to 101. In 1947, sections with 785 burrows on 25 May were reduced to 608 burrows on 13 June. At individual colonies along the Sacramento River, we observed losses of a similar magnitude although we do not have exact counts on the number of colonies affected. The loss of one colony to erosion caused by speedboat activity further attests to the fragile nature of these banks when moist, and the threat to the colony location and the breeding birds. The level of mortality caused by bank sloughing is unknown, but we believe it is significant and needs further study.

Bank Swallow colonies have been lost to erosion control projects for many years. This loss on the Sacramento River was never quantified and remains unknown. At a study of a colony in Connecticut it was noted that "the only other colony comparable was eliminated 30 years ago when the bank was riprapped to protect the channel" (Bergstrom 1951:61). Our understanding of the potential threats to the Sacramento River Bank Swallow population is based on plans outlined in the Erosion Control Investigation for RM 143 - RM 243 (U.S. Army Corps of Engineers unpubl. report). These plans generally recommend bank protection at the outside of each riverbend not presently considered adequately protected, by reshaping the bank and covering it with rock riprap.

With almost 90% of the breeding pairs we located utilizing outside riverbends to establish their colonies, any riprap of these areas is a significant threat to the population. Any plan which eliminates erosion of the outside riverbends will eliminate species such as the Bank Swallow that are dependent on erosion for maintenance of nesting sites. Preliminary examination of their distribution in California indicates that there is no other suitable habitat of this magnitude for these birds. This is an extremely serious problem and one for which no practical mitigation currently exists.

Although Bank Swallows have been documented using active sand and gravel quarries in which the vertical face is renewed annually by mining processes (Spencer 1963, Hoogland and Sherman 1976, Mead 1979, Freer 1979), this use of artificial environments is rare in California. A reduction of at minimum 55% of the population is unhealthful for any species, and may result in catastrophic population declines in colonial species such as the Bank Swallow.

We have examined bank stabilization and riprapping plans only for the area of greatest Bank Swallow concentration (RM 143-243). The threat to the other colonies on the Sacramento River is unknown, but we believe that they are faced with similar problems since their preferred habitat is threatened by the very nature of modern day bank stabilization practices. Any colony adjacent to existing riprap is threatened by maintenance as are colonies located in areas of levee washouts. No erodable place along the river appears safe for Bank Swallows in the forseeable future. Similarly colonies outside the study area, in places such as the Feather River, may also be threatened if the standard riprapping is proposed there.

The colony at Woodson Bridge State Recreation Area (RM 218.6) was one of the two largest colonies, representing 11% of the total Sacramento River population. An experimental bank protection method, known as palisading, was employed there in August, 1986 after the breeding season was concluded (Figure 15). The integrity of the bank face remains, and the colony site was not destroyed. The full impact of this method of bank stabilization on the nesting habits of the swallows can not be fully evaluated for several years.

It may be that the pilings and webbings of the palisading now perpendicular to the bank may change the immediate colony environment by allowing easier access by predators (by creating new perches) and interfering with the normal flocking patterns of birds at the nesting colony. In addition, if bank erosion at Woodson Bridge is curtailed, the suitability of the bank will decline through time as the bank face becomes less vertical. Blem (1979) has demonstrated that when this happens, predation increases and Bank Swallow colonies decline, and these sites are eventually abandoned.

Experimental techniques such as palisading may be effective in controlling erosion, may be more visually pleasing and may provide habitat for some later successional stage riparian species. However, these techniques do not take into account the needs of the flora and fauna, especially bank nesting species and those dependent on early stages of riparian habitat, for a free flowing river.

The Bank Swallow is remarkably adapted to life in the ever flowing and changing riparian environment. Bank Swallows quickly colonize newly created habitat and move elsewhere when it is no longer suitable. It is a primary colonizer, and its habitat needs to be renewed on a regular basis. Stream stabilization projects are simply not compatible with Bank Swallows, since the habitat creating forces of erosion cease to exist.

Photo by Joan M. Humphrey

Figure 15. An alternative bank stabilization method called palisading was constructed at Woodson Bridge State Recreation Area in August, 1986 after the Bank Swallow breeding season. The impact of construction on this Bank Swallow nesting colony is currently unknown (note person on bank for scale).

We believe the Bank Swallow should be listed as a Threatened Species in California. Annual monitoring should continue to follow population trends. If threats continue and populations decline from the baseline established in this study, the species may then require Endangered status. Proposed erosion control projects threaten a minimum of 55% of the Bank Swallow population along the Sacramento River and currently no suitable mitigation techniques exist. Efforts should be made to protect existing colonies and to develop bank stabilization techniques which have minimal impact on bank-nesting avifauna. Above all, Federal and State resource management agencies must recognize that a river free of erosion is not compatible with the maintenance of viable populations of bank-nesting species.

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APPENDIX A

Locale, date and method of Bank Swallow populations surveys conducted on the Sacramento River and tributaries[1/], 1986.

Area	Date	Method
Sacramento River RM 243 to RM 199	5/13/86	Motorboat
Sacramento River RM 199 to RM 168	5/14/86	Motorboat
Sacramento River RM 168 to RM 119	5/20/86	Motorboat
Sacramento River RM 119 to RM 69	5/21/86	Motorboat
Sacramento River Shasta Dam to RM 281	5/23/86	Automobile
Sacramento River RM 69 to RM 46	5/27/86	Automobile
Sacramento River RM 281 to RM 258	5/30/86	Motorboat
Sacramento River RM 258 to RM 243	6/1/86	Motorboat
American River Nimbus Dam to Ancil Hoffman Park	6/22/86	Bicycle
Feather River, Butte, Cottonwood, Battle, Thomes, Stony Creeks	6/27/86	Fixed-wing Aircraft
Sacramento River RM 46 to Delta	7/9/86	Motorboat

1/ Tributaries excluded from surveys because of apparent lack of suitable habitat include Big Chico, Pine, Mill, Antelope, Payne's, Battle, Bear, Cow, and Elder Creeks.

APPENDIX B

BANK SWALLOW COLONY DATA

Date______________ Time______________ Observers________________________

River System and River Mile (nearest tenth)__________________________________

Location___________________ County______________ Ownership______________

General Colony Data

Bank type___________________ Habitat above colony_________________________

No. of burrows__________ No. of birds__________ Colony position in river (% or straight)______________ Bank protection presence, type, and distance (m) to colony____

Breeding information____

____

Other species breeding in bank____

Specific Colony Data

Bank length (m)_______ Bank height at tallest point (m)________ Aspect at center_________ Slope at center_________ Soil series at center__________

Distance (m) to nearest agricultural practice and type________________________

Distance (m) to nearest riparian zone and width of zone at widest point_______

____

Colony length (m)_______ Colony height at tallest point (m)________________

Colony location vertically on bank (%)__________ Colony location horizontally on bank (%)__________ Distance to water from lowest burrow (m)______________

Distance from center of colony to nearest active colony (m)__________________

Comments:____

____

____

____

APPENDIX C

BANK TRANSECT SAMPLE

Date__________ Time__________ Observers________________

River System and River Mile____________________________

Location________ Swallow Absence/Presence_____ Colony No.________

Transect Sample No._______

HABITAT PARAMETERS ALONG TRANSECT

1. Aspect________
2. Slope_______
3. Bank height (m) from top of bank to base of vertical slope or water_____
4. No. of burrows along transect________
5. Distance (m) from top burrow _______ and bottom burrow _______ to bank top
6. Height (m) of burrow column________
7. Distance (m) to water from base of bank________
8. Type of bank________________
9. Soil series________________
10. Root absence/presence________
11. Habitat type above bank________________

Comments:____

APPENDIX D

BANK SWALLOW BURROW MEASUREMENTS

Date __________ Time __________ Observers __________

River system and river mile (nearest tenth) __________

Location __________ Colony no. __________

Depth (cm)																		
Height (cm)																		
Width (cm)																		
Distance to nearest burrow (cm)																		
Shape																		
Angle																		
Soil profile layer																		
Aspect																		
Activity																		

Shape: 1=circular, 2=ellissoid, 3=square, 4=triangular, 5=

Activity: 1=active, 2=inactive