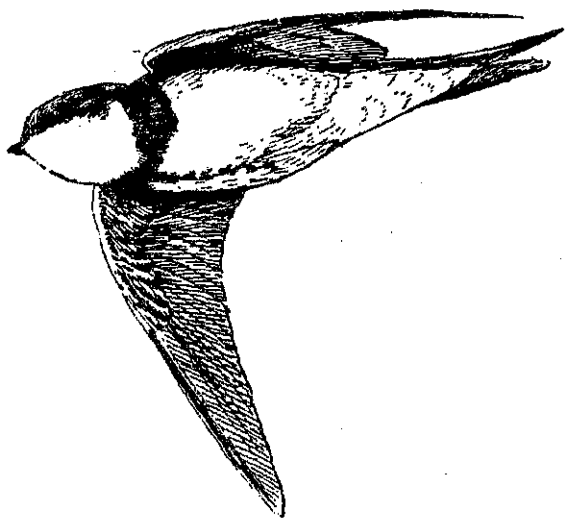
FINAL REPORT

EVALUATION OF EXPERIMENTAL NESTING HABITAT AND SELECTED ASPECTS OF BANK SWALLOW BIOLOGY ON THE SACRAMENTO RIVER, CALIFORNIA 1988 TO 1990



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FINAL REPORT

EVALUATION OF EXPERIMENTAL NESTING HABITAT AND SELECTED ASPECTS OF BANK SWALLOW BIOLOGY ON THE SACRAMENTO RIVER, CALIFORNIA, 1988 TO 1990

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INTRODUCTION

This final report presents the results of a three-year monitoring study of experimental nesting habitat for bank swallows (<u>Riparia riparia</u>) on the Sacramento River, California. Experimental nesting habitat was constructed at eight locations on the Sacramento River. The purpose was to evaluate the effectiveness and feasibility of constructing replacement habitat to compensate for bank swallow nesting habitat losses caused by ongoing bank protection projects of the U.S. Army Corps of Engineers (Corps) and California Reclamation Board (Board). The Sacramento Field Office, Fish and Wildlife Enhancement, U.S. Fish and Wildlife Service (Service) conducted the monitoring study with cooperation and assistance from the California Department of Fish and Game (Department) from 1988 to 1990.

Interim U.S. Fish and Wildlife Service reports were written in 1988 (Garrison 1989a) and 1989 (Garrison 1989b) summarizing the first and second years of the monitoring effort, respectively. This final report summarizes data collected from 1988, 1989, and 1990 from bank swallow colonies at the experimental sites as well as natural sites along the Sacramento River. Conclusions regarding the effectiveness of the experimental nesting habitat and additional mitigation recommendations are presented in this report. In addition, selected aspects of the species biology are included to provide some background on bank swallow natural history.

Impacts to bank swallows from riprap installation were identified as early as 1985. The Service, in its evaluation of the Sacramento River Bank Protection Project, under the authority of the Fish and Wildlife Coordination Act (Public Law 85-624), began developing mitigation recommendations in 1987. In 1986, the Service and Department conducted the first comprehensive study of bank swallows on the Sacramento River. This study documented the distribution, abundance, and nesting ecology of the bank swallow on the Sacramento River (Garrison and Humphrey 1987, Humphrey and Garrison 1987). One of the significant findings of the study was that proposed and authorized bank protection installation represented the greatest threat to existing and potential bank swallow colony sites on the Sacramento River. This conclusion was made after reviewing aerial photographs of future bank protection sites provided by the Corps and comparing bank swallow colony locations to protection sites. Shortly thereafter, the Service, in consultation with the Department, developed detailed mitigation recommendations which were provided to the Corps (letter dated October 19, 1987). In 1988, the Service provided the Corps with additional mitigation recommendations for bank swallow nesting habitat destroyed due to bank protection construction (letter dated February 17, 1988). In these letters, the Service specified its mitigation planning goal for bank swallow nesting habitat as no net loss of in-kind habitat value. The mitigation goal was based on the high value of suitable nesting habitat to the species and the scarcity of the habitat. This mitigation goal assumes that in-kind habitat values can be fully replaced. Bank swallows are locally uncommon birds in California, and approximately half of the State's population is found on the Sacramento River in a 200-mile reach of river from Sacramento to Redding. In 1987, mitigation efforts consisted of delaying construction until August 1 when swallows abandon nesting colonies. In 1988, mitigation efforts consisted of (1) delaying construction until August 1, and (2) experimental efforts to maintain the abundance and distribution of suitable nesting sites. The first attempts at compensating losses with experimental habitat mitigation were implemented in September 1987 and March 1988 when six sites were constructed. Two more experimental sites were constructed in September 1988 and March 1989. A cooperative three-year monitoring study was initiated in March 1988 involving the Service, Department, Corps, and Board.

PROJECT DESCRIPTION

The Sacramento River Bank Protection Project was originally authorized by the Flood Control Act of 1960. It included bank protection work designed to protect levees and flood control facilities of the Sacramento River Flood Control Project. The Sacramento River Flood Control Project was authorized by the Flood Control Act of 1917, and it consists of approximately 980 miles of levees, weirs, and overflow areas from Collinsville (River Mile [RM] 0) at the confluence of the Sacramento and San Joaquin Rivers, to RM 176.0 on the east bank and RM 184.5 on the west bank of the Sacramento River near Ord Ferry. The flood control structures provide protection to communities and agricultural lands in the Sacramento Valley and Sacramento-San Joaquin Delta. In 1983, Public Law 97-377 extended the authorized work area of the Bank Protection Project upstream to RM 194.0 at Chico Landing (Figure 1). As of February 1987, 704,060 linear feet had been installed and 124,170 linear feet was proposed for installation from the total authorization of 835,000 linear feet (Jones and Stokes Associates 1988).

STUDY AREA

The monitoring study was conducted on the Sacramento River between Chico Landing (RM 194.0), Butte County, downstream to the Colusa-Sacramento River State Recreation Area (RM 145.0), Colusa County, California (Figure 1). This river reach is lined by riparian forests typical of the Central Valley of California and by agricultural lands. Dominant riparian trees are Fremont cottonwood (_Populus fremontii_), red willow (_Salix laevigata_), black willow (_S. lasiandra_), box elder (_Acer negundo_), valley oak (_Quercus lobata_), and California sycamore (_Platanus racemosa_). Agricultural lands include orchards and row crops. The Sacramento River was at one time an alluvial river with natural levees and a meandering channel. Man, however, has greatly altered the natural fluvial processes of the river by building levees, installing bank protection, constructing dams, and diverting water (Scott and Marquiss 1984). The eight experimental bank swallow nesting habitat sites were at different locations within the study area (Figure 1, Table 1).

METHODS

Experimental Sites

A total of eight experimental sites were constructed between 1987 and 1989 to evaluate their effectiveness in compensating losses of nesting habitat (Figure 1, Table 1). Five of the eight sites were constructed on natural riverbanks that had little or no history of bank swallow use in 1986 and/or 1987 (Table 1). These five locations were known as "enhanced" sites and were generally unsuitable for swallow use due to lack of a vertical face, presence of

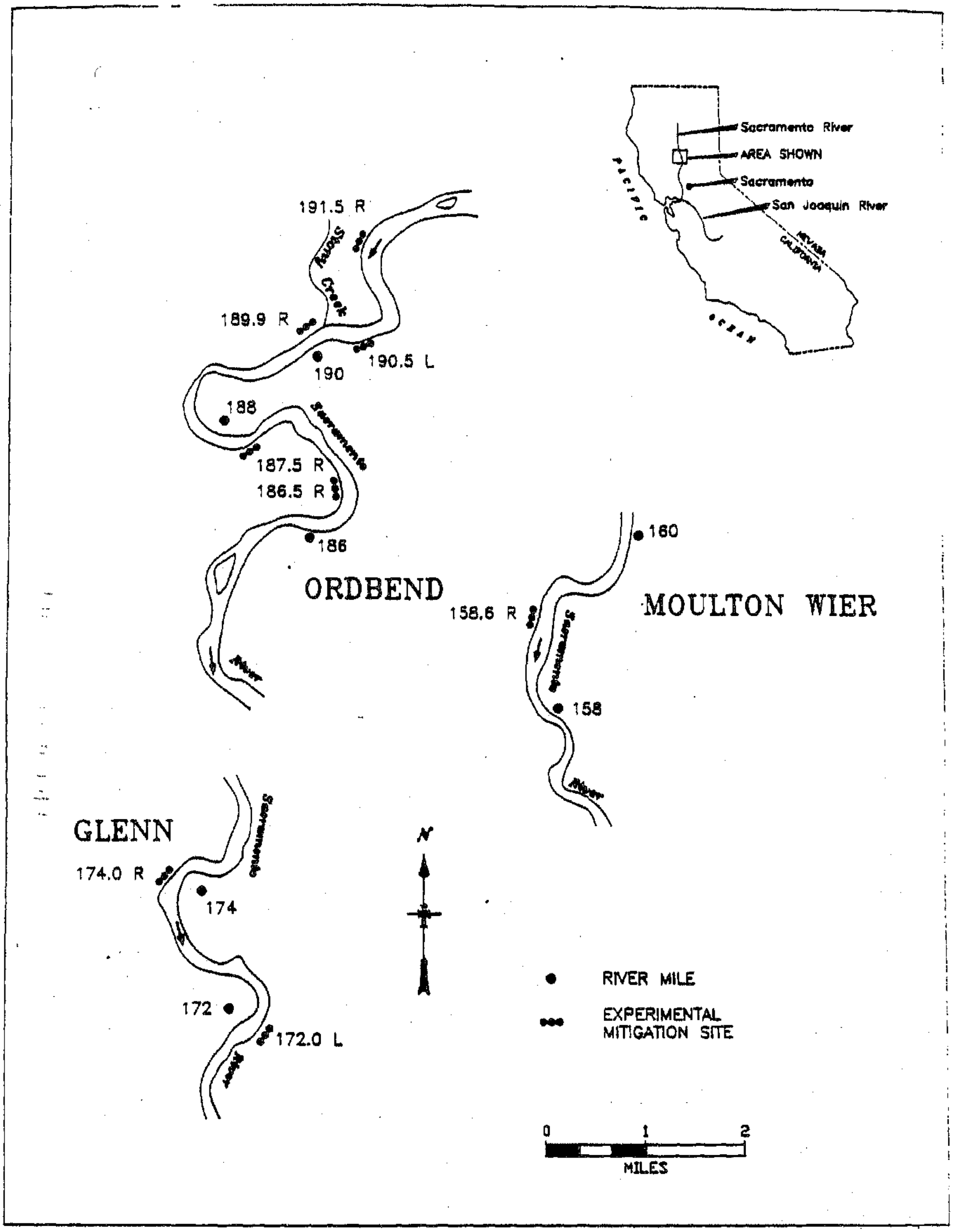


Figure 1. Location of eight experimental bank swallow nesting habitat sites on the Sacramento River, California.

Table 1. Location and description of experimental bank swallow (*Riparia riparia*) nesting habitat sites along the Sacramento River, California.

Location	Site Description	Construction Action
RM 158.6R[1]	natural bank occupied by bank swallows in 1986 and unoccupied in 1987	reshape natural bank in 1988
RM 172.0 L	natural bank unoccupied by bank swallows in 1986 and 1987	reshape natural bank in 1988
RM 174.0 R	natural bank destroyed by riprap in 1987; natural bank occupied by bank swallows in 1986 and 1987	man-made bank in 1988
RM 186.5 R	natural bank unoccupied by bank swallows in 1986 and 1987	reshape natural bank in 1988
RM 187.5 R	natural bank unoccupied by bank swallows in 1986 and 1987	reshape natural bank in 1988
RM 190.0 R	natural bank unoccupied by bank swallows in 1986 and 1987	reshape natural bank in 1988
RM 190.5 L	natural bank destroyed by riprap in 1988; natural bank occupied by bank swallows in 1986, 1987, and 1988	man-made bank in 1989
RM 191.5 R	natural bank destroyed by riprap in 1988; natural bank unoccupied by bank swallows in 1986, 1987, and 1988	man-made bank in 1989

[1]Side of river heading downstream; R - right; L - left.

vegetation on the bank, or weathered and hardened soil (see Garrison 1988 for photographs). The enhanced sites were selected during field surveys in January and February 1988. The selection was based on the potential to improve or enhance their suitability as bank swallow nesting habitat. In March 1988, habitat suitability of the five sites was enhanced using crews from the California Conservation Corps. Vertical faces were cut, vegetation was removed, and fresh soils were exposed at the sites. Additional maintenance activities were conducted in March 1989 and 1990.

The remaining three sites were known as "artificial" sites. They were constructed of soil mounds built landward of the riprap at the top of the bank. One site (RM 174.0 R) was constructed between September 1987 and March 1988. Two additional sites (RM 190.5 L, RM 191.5 R) were constructed between September 1988 and March 1989. All three artificial sites were constructed using similar techniques. Each of the sites was constructed on a riprapped bank, and soil from the bank was deposited in one or two mounds paralleling the bank. The mound(s) were set approximately 20-30 feet back from the top of the riprap and in view of the water. Select soil material consisting of silty, loamy soil from the natural bank was used to construct the front and center of the bank. The remainder of the artificial bank was constructed from spoil soils from the site. The front of the bank was shaped to a 1:1 slope, and the bank's face and top were covered with tarp after construction to protect it from winter rains and floods. In March, the tarp was removed and a vertical face was cut with heavy machinery. Maintenance activities, consisting of scraping the face and removing vegetation, were conducted as necessary in March 1989 and 1990.

<u>Monitoring</u>

Monitoring of the sites was conducted by boat from March to June 1988-1991. All experimental sites were visited at approximately 7-14 day intervals from March to June. However, some sites, such as RM 158.6 R, were checked less frequently as the season progressed. Biologists from the Service, Department, Corps, and Board participated in the field surveys. Natural colony sites from RM 199.0 to RM 144.0 were randomly selected and monitored at the same time for a comparison between the experimental mitigation sites and natural sites.

At experimental and natural colony sites, the number of burrows was counted with a hand-held tally counter. Burrows counted had dark entrances (> 1 inch deep) when viewed from a distance of 15-50 feet. All burrows in active sections of the bank were counted, and old burrows in inactive sections of the bank were not counted. Bank swallows flying into and out of burrows defined active sections of the colony. However, in some cases, colonies were relatively small and confined to discrete areas of the bank, and old, inactive burrows were among active burrows. In these cases, the old, inactive burrows were counted along with the active burrows because bank swallows could occupy old burrows at any time during the breeding season. Observations during the breeding season of individual colonies were continued to determine which sections of the bank were inactive, and inactive burrows in these sections were excluded from the burrow totals.

Inactive burrows were excluded from the burrow totals for several reasons. The proportion of inactive burrows in a colony differed among colonies. Including inactive burrows in the totals for a colony would result in a great deal of inconsistency in the totals. Burrow counts were used as an index for the number of breeding adults in a colony. In fact, population estimates were derived using burrow counts multiplied by burrow occupancy rates. Inactive burrows remaining from previous nesting seasons do not represent breeding pairs from the current season. Also, including inactive burrows in the burrow totals would artificially reduce the occupancy rates.

Burrow counts were rounded to the nearest 10 burrows to adjust for minor errors in counting. Burrow number will change throughout the breeding season. The number of burrows increased early in the breeding season as birds arrived from the wintering grounds and colonies grew larger in size. After the colonies achieved maximum size and no new birds moved into the colonies, burrow numbers fluctuated as sections of the bank collapsed and burrows were destroyed and/or additional burrows were dug. Maximum burrow counts, regardless of date, were used to estimate colony size and bank swallow populations in the study area.

At colonies in the experimental sites and randomly selected natural sites, a random sample of burrows (n = 33-13b) was checked using a mini-flashlight. These burrows were checked to estimate burrow occupancy and productivity. An angled dental mirror attached to an extendable automobile radio antenna was used earlier in the season to check for eggs and small nestlings. The mirror was not used later in the season as the nestlings grew larger and were visible using the flashlight. Burrow samples were checked at sections of the colony that were accessible. This may have resulted in some bias in the occupancy and productivity estimates because it has been demonstrated that productivity is greatest in burrows higher up on the bank (Peterson 1955, Sieber 1980). However, the bias equally affected all colonies.

Burrows with eggs, young, a nest, or an adult in an incubating or brooding posture were considered occupied. Burrows of unknown status were excluded from calculations. Occupancy was determined by dividing the number of occupied burrows by the total number of burrows in the colony. The number of young in a nest was counted, and the average number of young/nest with young was calculated as a measure of colony productivity. The Mann-Whitney two-sample test was used to determine differences in percent occupancy and average number of young between natural and experimental sites for each year. Statistical significance was set at $P < 0.05$. The Kruskal-Wallis test was used to assess differences over the three-year study period.

RESULTS AND DISCUSSION

Selected Aspects of Bank Swallow Biology

Breeding Ecology. The following section presents aspects of bank swallow biology that appear to be of most interest to resource agencies and of most value in management of the species.

Beginning in 1986, several studies have been conducted on the ecology, population distribution and abundance of the bank swallow in California (Garrison and Humphrey 1987, Humphrey and Garrison 1987, Laymon et al. 1988, Garrison et al. 1987, Garrison et al. 1990). These studies determined that over 70 percent of the State's population occurs on the Sacramento River and its tributaries including the Feather River (Laymon et al. 1988). Bank swallow populations in southern California and other locations in the State have been extirpated, and the most likely causes are channelization of streams and rivers, development along coastal areas, and water diversions (Laymon et al. 1988).

Throughout California, present-day bank swallow colonies are located along rivers, streams, lakes and coastal areas that have soils with significant amounts of sand. Clay and silt are also present, but in lesser amounts. Garrison (1989c) reported that soils from bank swallow colonies on the Sacramento River contained an average of 64.9 percent sand, 24.6 percent clay, and 10.6 percent silt. Most of the colonies were on sandy loam soils (50%), loamy sand (19%), or loam (13%). Alluvial valleys with rivers and streams and coastal areas with bluffs that are subject to wind and wave erosion are areas in California having bank swallow colonies.

Bank swallows occur in California during the breeding season, and they winter in South America. Bank swallows begin arriving at their breeding sites in California in mid-March, and continue to arrive throughout March, April, and May. The number of colonies increases throughout this period, achieving maximum size by mid-May to early June. Table 2 presents data on colony size throughout the 1988 breeding season. Similar trends were evident with data collected in 1989 and 1990. However, there were fewer survey dates in 1989 and 1990 and these data are not presented.

Burrow counts vary throughout the breeding season due to several factors. Colonies increase in size as swallows arrive at the breeding grounds and occupy sites. Also, once the number of birds at a colony has stabilized, burrow number may increase as nesting and non-nesting burrows are dug. In addition, burrow number may change because bank sections collapse. Swallows may re-nest and dig new burrows if the collapse occurs early in the season. However, if the collapse occurs late in the season, swallows may not re-nest. In addition, errors can occur in counting; this is especially true with large colonies.

Annual surveys of bank swallow populations should be conducted during the period when all the colonies are occupied and at their maximum size. Based on these data, annual surveys should be conducted the last week of May or the first week of June.

During the breeding season, the nesting colony is the center of bank swallow activity. Upon arrival at a colony site, bank swallows form nesting pairs and begin nesting activities. Older birds return to the nest sites before first-year birds and select nest sites higher on the face of the bank (Sieber 1980). Birds often return to the same colony site as the previous year, especially if they bred successfully, while yearlings return to the natal colony or other nearby areas (Freer 1979). Bank swallows are not as site-tenacious as other

Table 2. Number of burrows in bank swallow colonies by survey date in 1988 on the Sacramento River, California. Maximum counts are underlined, and dates without counts, after a date with a count, were not surveyed. On dates without an NS or burrow count prior to the earliest burrow count, the colony sites were not occupied.

Colony Location	3/25	3/31	4/7	4/15	4/26	5/5	5/13	5/26	5/27	6/8	6/9
158.6 R[1]	NS[2]	NS	190		250	200			210		
170.8 L	NS	20	20	30	60	150	140		150		130
171.3 R	NS						60		60		60
171.7 R	NS	160		250	260	260	310		300		
172.0 L	NS		10	20	200	210	220		210		320
173.1 L	NS				10	30	30		30		60
173.4 R	NS			NC[3]	20	30	30		30		170
173.5 L	NS			40	30	40	40		40		30
174.0 R	NS			50	100	100	100		100		90
174.5 L	NS								60		200
175.5 L	NS	NS	240	510	620	490	600		600		600
183.9 R							20	170		150	
184.5 L					20	50	70	70		60	
185.4 R					170	210	220	260		200	
185.8 R	10	120	360	590	580	510	470	630		500	
186.5 L								70		70	
187.8 R			330	840	1,050	1,180	1,180	1,180		1,540	
190.0 R			310	380	410	290	310	340			340
190.5 L	250	720	1,100	1,960	2,540	1,960	2,510	2,730			2,330
192.4 L			50	500	590	430	450	490			500
194.6 L	NS	NS						290			280
195.0 R	NS	NS	130	190	580	910	280	620			570

[1]Side of river moving downstream; R - right; L - left.
[2]NS - colony site not surveyed.
[3]NC - burrows not counted at occupied colony.

swallows such as cliff swallows (*Hirundo pyrrhonota*) and barn swallows (*Hirundo rustica*), which nest in more stable sites (Freer 1979, Loske 1983).

Bank swallows will dig new burrows or renovate and occupy burrows remaining from previous nesting seasons. Within a colony, there may be subcolonies scattered along the bank face. Breeding may be synchronized among nesting pairs in subgroups, but subgroups may be asynchronized (Turner and Rose 1989). Upon arrival at the colony, the male claims an area and begins digging a burrow. When the burrow is approximately 12 inches deep, the male performs a display to attract females. This advertising display is performed from the burrow and includes singing, ruffling of head and throat feathers, and vibration of closed wings. Upon approach of the female, he flies out, still singing (Kuhnen 1985). He also makes circling flights around the burrow, returning to the nest hole, calling and landing or hovering by the entrance to lure the female into the burrow. Once a pair bond is established, the male and female complete the burrow excavation. Males form a pair bond with one female but they will attempt to mate with other females (extra-pair copulation). Once a pair is formed, the male defends the female from other males attempting extra-pair copulations. Most of the breeding takes place in the burrow (Turner and Rose 1989).

Humphrey and Garrison (1987) present detailed information on the nesting ecology of the bank swallow on the Sacramento River including information on breeding period, clutch size, and colony occupancy. Within a colony, not all burrows are used for breeding. On the Sacramento River in the reach from Colusa to Chico Landing, average colony occupancy has ranged from 46 percent in 1986, 44 percent in 1988, 47 percent in 1989, and 39 percent in 1990. Data from 1988 to 1990 include natural and experimental nesting sites. Humphrey and Garrison (1987) reported an average occupancy of 56 percent for the Sacramento River from Redding to Verona.

Throughout their Holarctic breeding range, bank swallow colonies occur primarily in man-made sites such as sand and gravel pits, road and railroad cuttings, sawdust mounds, and even in rubbish heaps and faces of cut peat (Turner and Rose 1989). However, in California, the vast majority of colonies are in natural sites such as banks and bluffs of rivers, streams, lakes, and coasts. In fact, Laymon et al. (1988) found only 8 of 111 colonies (7%) in man-made sites. Colonies on bluffs around reservoirs were not considered to occur in man-made sites.

Eggs are laid in the early morning at daily intervals, and clutches range from 3 to 6 eggs with an average of 5 eggs (Turner and Rose 1989). Both sexes incubate, although the male does only a third of the incubation (Turner 1980). Incubation starts with the next to the last egg. The incubation period averages 14 days, but varies from 12 to 16 days. The nestling period is about 22 days, and both parents brood and feed the nestlings. When nestlings are 10 to 12 days old, they run forward to the entrance of the burrow to meet the parents returning with food. Feeding trips to the nest by parents average 5.2 minutes (Bryant and Turner 1982). Fledglings return to the burrow for 4 to 5 days after their first flight. Parents recognize their chicks' calls and vice versa, and siblings recognize each other (Beecher et al. 1981a and 1981b, Beecher and Beecher 1983).

Bank swallows vacate breeding colonies on the Sacramento River from late June to early August. After abandoning colonies, birds are found in flocks feeding and roosting on the river throughout July and August in intraspecific flocks or mixed-species flocks with other species of swallows including tree swallows (_Tachycineta bicolor_), northern rough-winged swallows (_Stelgidopteryx serripennis_), and cliff swallows.

Creation of Natural Bank Swallow Nesting Habitat on the Sacramento River. It is necessary to understand the erosional processes that create and maintain river cutbacks to understand the ecology of the bank swallows. Bank swallow nesting habitat on the Sacramento River naturally consists of eroding banks in close proximity to the river. The following section on bank erosion on the Sacramento River is based on the discussion in Water Engineering and Technology (1987).

River banks erode by fluvial entrainment and mass wasting. Fluvial entrainment erodes banks in two ways. First, sediments may be removed directly from the bank and transported downstream. Second, water flow may scour the base of the bank causing gravitational failure of the remaining intact bank. Gravitational failure is of greatest importance for banks on the outer bends of the river where the scouring forces are greater. Bank failure results when scouring causes the bank height to increase beyond a critical height and bank angle becomes vertical.

Mass failure is caused by processes that reduce the strength and stability of the bank; these processes are directly associated with soil moisture conditions. The effective strength of banks of poorly-drained soils such as clays depends upon climatic conditions and bank characteristics. Heavy rainfall or rapid drawdown of the river following a high flow will reduce the stability of the bank. The bank fails because the saturated soils have reduced strength and increased weight. Saturated banks are often held in place by high water levels, and the banks collapse when water levels drop and the weight of the water which held the bank in place is removed. Wetting and drying cycles cause cracks and breaks to form in the bank because of shrinkage and swelling of the soil. Bank erosion can also occur when the river overflows its banks in very high water conditions. Water returning to the river channel can erode banks by creating gullies.

Banks will eventually stabilize themselves without erosion. Sediment can build up at the base of the bank when water flow is unable to remove it. Stability increases when sediment builds up, thereby reducing bank angle and loading the toe of the slope.

The composition, height, and angle of the bank are responsible for the type of bank failure. Therefore, the bank failure mechanisms found along the Sacramento River are complex. According to Water Engineering and Technology (1987), 22 percent of the total bank length along the Butte Basin reach (RM 174.0 to RM 193.0) is eroding. Within the Butte Basin reach, bank erosion is due primarily to shear failure whereby an exposed portion of the bank collapses under its own weight when it is undercut. Plane slip failures are the most common mechanism of erosion in the Butte Basin reach. Plane slip failures are typical of vertical banks with relatively low heights where a crack passes through to the base of the bank.

Bank swallows appear to utilize eroding banks with vertical faces of appropriate height and soil type regardless of the erosional process. The larger colonies, such as those at RM 188.0 R, RM 190.5 L, and RM 195.0 R, are located in banks that are eroded by both fluvial entrainment and mass wasting with plane slip failures. Some of the smaller colonies are found in banks that have been eroded by small plane slip failures.

Wintering Ecology. There is little information on the wintering ecology of bank swallows from California. Almost 2,000 bank swallows have been banded on the Sacramento River from 1986 to 1990, and there have been no recoveries outside of the Sacramento River. Therefore, the specific wintering grounds and migration routes of California bank swallows remain unknown at this time. However, Rappole et al. (1983) present information of the wintering ecology of North American bank swallows. The wintering grounds are known to be northern and central South America primarily east of the Andes Mountains including Columbia, Venezuela, eastern Guyana, northern Peru, western and central Brazil, eastern Bolivia, eastern Ecuador, Paraguay, and northern Argentina. Bank swallow wintering habitats include grasslands, savannahs, and freshwater and brackish marshes, and they feed on terrestrial, arboreal, and aerial invertebrates. Bank swallows migrate throughout the southern states, Central America, the West Indies and northern South America (Turner and Rose 1989).

Bank Swallow Population Trends on the Sacramento River, 1986 to 1990

Information on bank swallow populations on the Sacramento River has been gathered since 1986, and these data are summarized in Table 3. Complete surveys were conducted in 1986, 1987 and 1990, and information is available for the reach from Butte City (RM 169.0) to Chico Landing (RM 199.0) for all five years (Table 3). The five reaches used in Table 3 represent relatively distinct geographic zones along the river, and these reaches could function as natural zones for ongoing population monitoring and management actions.

Over the period 1986 to 1990 and using 1986 as the baseline, there has been a 24 percent decline in the number of colonies and a 25 percent decline in the total number of burrows over the entire river (Table 3). Average number of burrows/colony has remained the same over the same period.

For the Butte City to Chico Landing reach over the five-year period, the number of colonies and total number of burrows were greatest in 1988 and 1989. This increase may have resulted to some extent from the construction of five experimental sites in 1988 and two additional sites in 1989. With 1986 as a baseline, the number of colonies declined 18 percent and the total number of burrows declined 41 percent from 1986 to 1990. The large decline in the total number of burrows is due, in large part, to the reduction in colony size.

In addition, a notable decline has occurred in the reach from the mouth of the Feather River to Colusa (RM 81.0-RM 143.0) (Table 3). Since 1986, there has been a 54 percent decline in the number of colonies and a 61 percent decline in the total number of burrows. Coincidentally, this reach is the southern extreme of the bank swallow's distribution on the Sacramento River. Also, this reach has the greatest amount of bank protection and a limited amount of bank swallow habitat (Keck 1990).

Determining the cause(s) of the population decline is difficult given the limited nature of the data. Bank protection projects certainly are responsible for the loss of colony sites. Loss of colony sites can manifest itself in population declines if replacement habitat does not exist. The colony at RM 190.5 L was one of the largest natural colonies on the river. In 1988, the colony had a maximum of 2,730 burrows and accounted for 31 percent

Table 3. Bank swallow population information by river reach on the Sacramento River, California, 1986 to 1990.

River Reach	1986	1987	Year 1988	1989	1990
Verona to Colusa RM 81.0-RM 143.0					
No. colonies	13	12		6	6
Total burrows	2,480	3,720		750	980
Avg. burrows/colony	190	310		130	200
Colusa to Butte City RM 144.0-RM 168.0					
No. colonies	14	13	18		16
Total burrows	6,170	6,980	7,790		7,450
Avg. burrows/colony	440	540	430		470
Butte City to Chico Landing RM 169.0-RM 199.0					
No. colonies	17	17	25	22	14
Total burrows	7,610	5,110	8,920	7,090	4,490
Avg. burrows/colony	450	300	360	320	320
Chico Landing to Red Bluff RM 200.0-RM 243.0					
No. colonies	20	19			15
Total burrows	9,520	8,540			6,880
Avg. burrows/colony	480	450			460
Red Bluff to Redding RM 243.0-RM 292.0					
No. colonies	6	5			3
Total burrows	1,660	1,400			820
Avg. burrows/colony	280	280			270
Total RM 81.0-RM 292.0					
No. colonies	70	66			53
Total burrows	27,440	25,750			20,620
Avg. burrows/colony	390	390			390

of the burrows in the reach from Butte City to Chico Landing. The site was riprapped in the fall of 1988, and an artificial site was built in 1988 and 1989. In 1989, swallows nested in the artificial site and the colony had a maximum of 1,740 burrows representing 25 percent of total burrows in the reach. However, in 1990, the colony declined to 470 burrows, representing 11 percent of the reach population. Therefore, the total burrow count of the colony at RM 190.5 L declined 83 percent from 1988 to 1990. In addition, paralleling the decline at RM 190.5 L was a 50 percent decline in the swallow population from Butte City to Chico Landing.

Natural colonies in the Butte City to Chico Landing reach represented a smaller proportion of the population, but their populations were somewhat variable. In comparison, the natural colonies at RM 192.3 L and RM 195.0 R represented 6 percent each in 1988, 3 percent and 6 percent in 1989, and 12 percent and 5 percent in 1990, respectively, of the total number of burrows in the reach.

There have been other causes postulated by staff of the Corps and Board for declines in bank swallow populations. These include: (1) loss of wintering habitat; (2) increased predation and parasitism rates; (3) decrease in prey populations; and (4) ongoing drought conditions in California. Data do not exist to substantiate or refute the first three postulates. However, declines have been noted for all river reaches over the period 1986 to 1990. These consistent declines could possibly indicate that the factor(s) causing declines are affecting all segments of the population on the Sacramento River to some extent.

The ongoing drought probably is having an effect on the bank swallow population on the Sacramento River. Garrison et al. (1990) reported that bank swallow populations from Colusa to Chico Landing exhibited an increase in the number of colonies and a reduction in colony size from 1986 to 1988. However, these changes were not statistically significant ($\underline{P} = 0.333$). They attributed these changes to the reduction and fragmentation of suitable nesting sites due to reduction in river bank erosion. This appears to be the case with the Butte City to Chico Landing reach (Table 3). The reduction in the number of colonies may be indicative of the ongoing effect of the drought. Habitat suitability of colony site has declined because of a reduction or lack of erosion, and colonies in sites with low suitability may be smaller and produce fewer young. Also, bank swallows eventually abandon colony sites with declining habitat suitability. As noted by Garrison et al. (1990), the increase in number of colonies with a reduction in colony size indicates that colonies were established in smaller patches of suitable habitat. These smaller patches are the result of localized sloughing of banks, not widespread erosion.

Use of Experimental Sites and Natural Sites

Six experimental sites were available for use in 1988, and two additional sites were built in 1989 and 1990 (Table 1). Data on percent occupancy, number of young, and number of burrows were collected at all experimental sites and randomly selected natural colony sites. In addition, burrow counts were conducted at all natural colonies in the study area.

There were no significant differences in the various measures of bank swallow use of experimental and natural colony sites. For each year, average percent occupancy was not significantly different between the experimental and natural colony sites (Table 4, Mann-Whitney Test, $P \leq 0.08$) although 1989 approached statistical significance. However, occupancy was lowest at the experimental sites all three years of the study. Also, there were no significant differences between the experimental and natural sites in the average number of young per nest with young (Table 4, Mann-Whitney Test, $P \leq 0.27$). In addition, the average number of burrows in a colony was not significantly different for each year between experimental sites and natural sites (Table 4, Mann-Whitney Test, $P \leq 0.12$). However, despite a lack of statistical significance, average burrow count was substantially greater in experimental sites than natural sites in 1989; this difference was due to the large colony at RM 190.5 L (Table 4).

Table 4. Bank swallow use of artificial nesting sites on the Sacramento River, California, 1988 to 1990. See text for a description of artificial and enhanced sites. No data indicates that the site was not yet built, "0" indicates the site was not occupied, and "-" indicates that no data were collected.

Location	Type	Percent Occupancy 1988	1989	1990	Avg. No. Young/Nest 1988	1989	1990	Total Burrows 1988	1989	1990
158.6 R[1]	Enh.[2]	40	33	0	3.9	-	0	210	200	0
172.0 L	Enh.	63	35	11	3.2	-	-	210	250	140
174.0 R	Art.	58	0	0	3.2	0	0	100	0	0
186.5 R	Enh.	31	0	0	-	0	0	70	0	0
187.5 R	Enh.	32	28	0	2.8	4.0	0	270	290	0
189.9 R	Enh.	30	27	45	2.5	-	3.7	340	50	440
190.5 L	Art.		67	43		4.3	4.1		1,740	470
191.5 R	Art.		0	0		0	0		0	0
Average Art. and Enh. Sites		42	38	33	3.1	4.2	3.9	200	510	350
Average Natural Sites		44	56	42	3.2	3.8	4.2	290	260	280

[1]Side of river moving downstream; R - right; L - left.
[2]Type of artificial site; Enh. - enhanced; Art. - artificial.

A separate analysis was conducted by assessing differences in the data for experimental and natural sites over the three-year study period. From 1988 to 1990, percent occupancy did not differ significantly for experimental sites (Kruskal-Wallis test, $H = 0.30$, $P < 0.86$) or natural sites (Kruskal-Wallis test, $H = 2.69$, $P < 0.26$). However, percent occupancy of experimental sites did decline over the three-year study period (Table 4).

Average number of young was not significantly different for experimental sites (Kruskal-Wallis test, $H = 5.16$, $P < 0.08$), but the average number of young in natural colony sites increased from 1988 to 1990 (Kruskal-Wallis test, $H = 7.63$, $P < 0.02$). The number of burrows in a colony remained the same over the study period for experimental sites (Kruskal-Wallis test, $H = 1.28$, $P < 0.53$) and natural sites (Kruskal-Wallis test, $H = 1.27$, $P < 0.53$).

Another measure of use by bank swallows is the percentage use of a colony site for the three-year study period. Data for both experimental and natural sites on the Sacramento River are presented in Table 5. No statistical tests were conducted because of the large disparity in sample size.

Over the study period, the average percent use was greater by 6 percent for experimental sites than natural colony sites (Table 5). In addition, for 1988 and 1989, use was greater for the experimental sites than natural sites. However, in 1990, natural colony sites had greater use than experimental sites (Table 5). Over the three-year study period, use of the three artificial and five enhanced sites averaged 44 and 73 percent, respectively.

The experimental sites received greater use than natural sites for several reasons. Some of the experimental sites were maintained annually, while natural sites depended on river flows and erosion to maintain habitat. In addition, the larger number of natural sites resulted in greater variability in use. Also, many of the natural sites with the lowest use levels were the smallest colonies ($\leq$ 100 burrows), and there were proportionally more small natural colonies than experimental colonies. Experimental sites with lowest use were not annually maintained throughout the study period (e.g., RM 187.5 R, RM 186.5 R).

Experimental Sites Compared to Natural Sites

Based on the data presented above, bank swallow colonies at experimental sites were similar to those at natural sites. Parameters included colony size, occupancy, productivity, and use. These similarities were also evident in 1989 (Garrison 1989a and 1989b). The variability in the data and the small number of experimental sites may have been responsible, to an extent, for the lack of differences in the data.

There are few reasons to expect that the physical characteristics of experimental sites, especially enhanced sites, should differ from natural sites, and there are few reasons to expect that swallow use should differ. Bank swallows are known to use man-made sites for nesting, and the experimental sites were designed to include the same characteristics of natural sites. The artificial banks were, however, most dissimilar from natural sites, and their relatively low level of use reflects the dissimilarity. For example, the site at RM 191.5 R was not used at all, the site at RM 174.0 R was used one of three years, and the colony at RM 190.5 L declined substantially in size in only two years. These reductions occurred despite annual maintenance, while many natural sites had suitability decline

Table 5. Burrow counts and percentage of use of artificial and natural bank swallow colonies on the Sacramento River, 1988 to 1990. Counts are maximum number of burrows over the breeding season, and blanks indicate no use.

Location	Type	1988	1989	1990	Pct. Use
144.3 L	Nat.	550	60	230	100
158.6 R	Enh.	210	200		67
169.3 L	Nat.		70		33
169.6 R	Nat.			60	33
169.9 R	Nat.		70		33
170.7 L	Nat.	130	510		67
171.0 L	Nat.		80		33
171.3 R	Nat.		30		33
171.5 R	Nat.	60	80		67
172.0 L	Enh.	210	250	140	100
173.0 L	Nat.	60			33
173.3 R	Nat.	170	270		67
173.6 L	Nat.	30		50	67
173.8 R	Nat.			100	33
174.0 R	Art.	100			33
174.5 L	Nat.	200	100		67
175.5 L	Nat.	600	880	440	100
178.1 L	Nat.	250	280		67
181.5 R	Nat.	30			33
182.6 R	Nat.	10			33
182.8 L	Nat.	310			33
183.0 L	Nat.	40			33
183.9 R	Nat.	150			33
184.8 L	Nat.	60	230	250	100
185.0 R	Nat.	80			33
185.2 L	Nat.		140	360	67
185.5 R	Nat.	700	540		67
186.5 R	Enh.	70			33
187.5 R	Enh.	270	290		67
187.7 R	Nat.	1,270		540	67
188.0 R	Nat.		400	400	67
190.0 R	Enh.	340	50	440	100
190.5 L	Nat./Art.	2,730	1,740	470	100
191.0 R	Art.	Not built			0
192.3 L	Nat.	500	200	550	100
194.5 L	Nat.	280		210	67
195.0 R	Nat.	570	410	210	100
Average Percent Use Enhanced and Artificial Sites		100	63	38	63
Average Percent Use Natural Sites		72	59	41	58

[1]Side of river moving downstream; R - right; L - left.
[2]Type of artificial site; Nat. - natural; Enh. - enhanced; Art. - artificial.

due to lack of erosion. The only maintenance natural sites received was from the river. Yet, many natural sites were occupied at levels equal to the experimental sites.

Enhanced sites were most similar to natural sites in physical characteristics and swallow use. However, use of enhanced sites was significantly affected by maintenance activities. Maintenance was conducted annually in 1989 and 1990 only at RM 190.0 R. Maintenance was conducted in 1989 at RM 158.6 R and RM 187.5 R, and no maintenance was conducted after initial construction in 1988 at RM 186.5 R and RM 172.0 L. Enhanced sites at RM 190.0 R and RM 172.0 L were the only enhanced sites used by swallows all three years of the study, and sites at RM 187.5 R and RM 158.6 R were used the first two years.

Over the course of the study, observations were made of predation and parasitism at natural and experimental sites. In 1990, high levels of parasitism of nestlings by swallow bugs were observed at the experimental (RM 190.0 R) and natural sites (RM 192.4 L and RM 165.3 L). It was difficult to determine whether levels were different between experimental and natural sites. Parasitism of nestlings has been reported to be a disadvantage of bank swallow coloniality (Hoogland and Sherman 1976) and reduces bank swallow productivity (Stoner 1926 and 1936).

In 1989 and 1990, great blue herons (Ardea herodias) and great egrets (Casmerodius albus) were observed hunting at the artificial site at RM 190.5 L. These birds were observed hunting repeatedly throughout the breeding season at the swallow burrows taking nestlings from burrow entrances. The habit of nestlings sitting at the burrow entrances, awaiting the return of their parents with food, facilitates heron and egret predation. This type and level of predation by herons and egrets was not observed at natural colonies along the Sacramento River. In addition, herons or egrets were not observed hunting at the artificial site at RM 174.0 R, possibly because of the small colony size. The design of the artificial sites facilitated heron and egret predation. Bank swallow burrows were concentrated in an area 3-5 feet above the ground because of the height of the bank; this height is optimal for herons and egret hunting. The wide, flat berm between the bank and the top of the riprap allowed the birds to walk along the base of the bank. Heron and egret predation was, in 1990, frequently observed at RM 190.5 L despite a dense growth of star thistle (Centaruea sp.) which made walking difficult. Avian predators at natural sites include American kestrels (Falco sparverius) and peregrine falcons (F. perregrinus) which take swallows in the air.

Two of the three artificial sites were used by bank swallows. These two sites (RM 190.5 L and RM 174.0 R) had bank swallow colonies prior to riprap construction. Therefore, it is highly likely that some of the swallows nesting in the artificial sites were from the previous natural colony. Bank swallows did not nest at the artificial site (RM 191.5 R), and it did not have a natural colony site. Bank swallows will return to nesting colony sites in successive years (Freer 1979, Mead 1979, Petersen and Mueller 1979). However, the rate of return depends on several factors including age, sex, reproductive success, and parasitism levels.

Three soil samples were collected at each of the three artificial sites. The samples were analyzed using a different technique than that used to determine the soil types of natural colonies; therefore, the results are not directly comparable. Seven of the nine samples (77.8%) were classified as either a lean clay with sand or lean clay. All three samples from RM 191.5 R were classified either a lean clay with sand or lean clay. The remaining two samples (22.2%) were classified sandy silt. Samples at natural colonies were classified using the U.S.D.A. soil texture classification system, and only one of 62 samples (1.6%) was classified as a clay soil (clay loam). If the two classification systems are comparable, then the artificial sites were constructed of predominantly clay soils which are rarely used for nesting by bank swallows.

Implementation of Past Mitigation Recommendations

Garrison (1989a, 1989b) provided a detailed discussion of the implementation of mitigation recommendations made to the Corps by the Service and Department. In 1988 and 1989, five of twenty sites (25%) recommended for enhancement were enhanced, while the remaining 15 sites (75%) were rejected. Lack of landowner approval, safety/access concerns, and adequate habitat suitability were primary reasons for rejection of recommended sites. In addition, bank swallows occupied four of the 15 rejected sites (26.7%) indicating that enhancement may not be necessary at some recommended sites. Three of the six sites (50%) recommended for artificial sites in 1988 and 1989 had a site constructed, and high cost was the reason for rejection of the other three sites. The Board entered into one year right-of-entry agreements with landowners of enhanced sites in 1988, and attempted to enter into agreements for an additional two years in 1989. Landowners at four of the five enhanced sites (80%) signed the two-year agreements, with the landowner at RM 172.0 L declining. Therefore, no maintenance could be conducted in 1989 and 1990 at RM 172.0 L.

Annual maintenance of artificial and enhanced sites was recommended in order to maintain habitat suitability of the experimental sites. In dry years without significant erosion of river banks, maintenance of experimental mitigation sites is absolutely essential if swallows are to use the sites. Annual maintenance was conducted in 1989 and 1990 at one of the five sites (RM 190.0 R) and the site was occupied by swallows. The higher use rates of experimental compared to natural colony sites is probably due in large part to the maintenance. Maintenance was conducted at RM 187.5 R in 1989; however, maintenance could not be completed because of heavy storms and high river flows in March. In addition, maintenance was not done in 1989 at RM 186.5 R despite right-of-entry because high river levels precluded access. In addition, maintenance was not conducted in 1990 at RM 186.5 R. Maintenance was conducted at RM 158.6 R in 1989 and not in 1990; this site was not occupied in 1990. All artificial sites received some annual maintenance each year; however, colony size declined despite annual maintenance.

Other Mitigation Efforts

The Service follows the sequence of steps advocated by the Council of Environmental Quality for their mitigation recommendations. These steps in order of preference are: (1) avoiding impacts; (2) minimizing impacts; (3) rectifying impacts; (4) reducing impacts over time; and (5) compensating for impacts. Rectifying impacts and reducing impacts over time appear to be somewhat infeasible for impacts to bank swallows due to the nature of the project and the types of impacts to bank swallows. Therefore, avoidance, minimization, and compensation are the three steps most relevant to bank swallow impacts. To date, all three steps have been employed to address impacts to bank swallows, although the desired sequence has not always been followed.

Experimental nesting habitat can only be considered compensation for impacts. Garrison (1989a) demonstrated that experimental habitat has only compensated for a fraction of the habitat losses due to recent bank protection work. Even with the addition of artificial sites at RM 190.5 L and RM 191.5 R in 1989, and the acceptance of the experimental habitat as mitigation, habitat losses far exceed compensation needs. In order to achieve compensation in terms of habitat area (ft^2) of vertical banks, construction of enhanced and artificial sites must be increased substantially. In addition, long-term easements or outright land purchases would be necessary to insure maintenance, monitoring, and mitigation credits. Although securing the land does not guarantee continued bank swallow use, it is essential if artificial and enhanced sites are to compensate for impacts.

Avoidance has consisted of delaying construction and recommending against construction. For colony sites where bank protection was installed, construction was delayed until August 1 to allow birds to complete nesting and vacate the colony. However, this type of avoidance simply delays the ultimate impact which is the loss of the nesting site. The impacts can be completely avoided by not constructing the project, and no construction has been recommended for two projects to date. The Department issued a California Endangered Species Act Biological Opinion on June 21, 1990 on the proposed rock groins for RM 192.4 L, which found that the proposed project would adversely affect the bank swallow and jeopardize the swallow's existence. The Opinion avoided the impact by halting construction. The Service, in cooperation with the Department, recommended that bank protection not be constructed at many of the bank protection sites proposed under Contract 44. In addition, the Corps reduced the length of a bank protection site at RM 126.3 R, thereby minimizing the impact to the colony site. The Department has yet to issue a Biological Opinion regarding Contract 44.

On the Sacramento River, no habitat has been purchased or conservation easement secured specifically to provide mitigation values for bank swallows. In addition, other experimental methods have not been implemented to compensate for unavoidable impacts to bank swallow nesting habitat.

Additional Mitigation Recommendations

Mitigation recommendations should follow the desired sequence of mitigation planning. Avoidance of impacts should be the first priority. New alternatives to traditional bank protection methods such as riprap and rock groins should be pursued. Any bank protection method designed to halt erosion at a river bank, whether over a long or short time, will cause a loss of bank swallow nesting habitat. Deferring work, off-set levees and a meander belt which allows the river to meander within a specified area will ultimately avoid and minimize impacts to bank swallow nesting habitat. Allowing the river to erode to a levee or a geologic feature which resists erosion, such as a hard clay plug, will avoid bank swallow impacts because the birds would abandon the site naturally due to its unsuitability.

Minimizing impacts can be accomplished at sites where bank protection is necessary by simply reducing the length and height of bank protection. In the reach of the Sacramento River below Colusa, erosion is often confined to small, discrete locations on the bank. Bank protection plans often are designed to riprap the entire bank to tie into existing riprap. It seems possible that riprap could be placed only in erosion pockets. In addition, there is often a berm between the river and the levee. Bank protection could be delayed until the berm erodes to the levee.

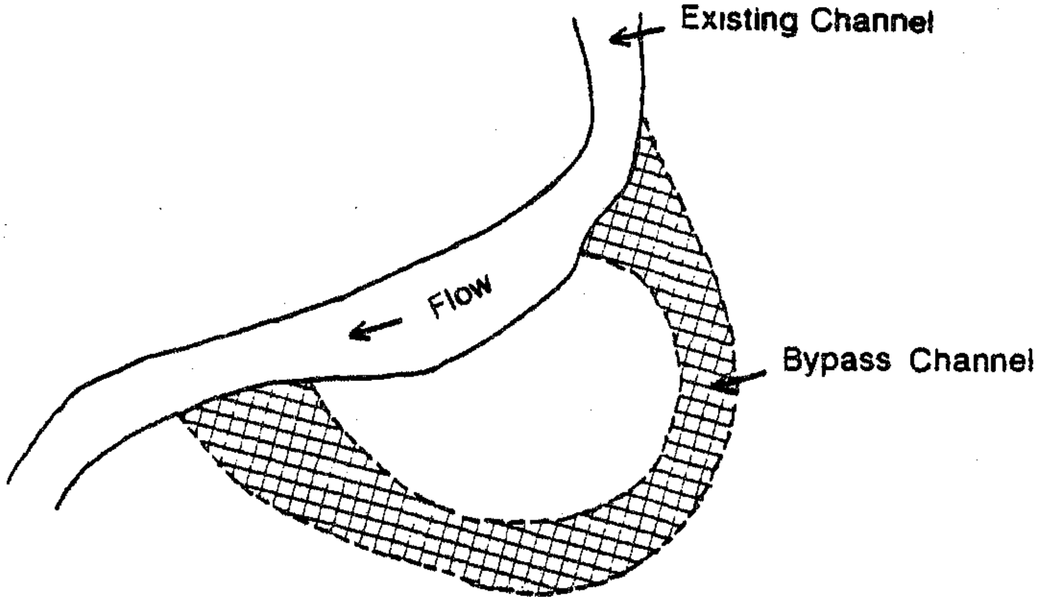
Mitigation for unavoidable impacts using the experimental techniques analyzed in this report is not adequate. Therefore, it appears full mitigation for unavoidable impacts cannot be accomplished using the available techniques. We believe that an additional technique should be pursued on an experimental basis to evaluate its feasibility. Engineering analyses are necessary in addition to a biological evaluation to determine its feasibility.

This new method simply involves the creation of an erosive force against a bank with suitable soils similar to the erosion actions already creating and maintaining bank swallow habitat on rivers and streams. A preliminary design is presented in Figure 2.

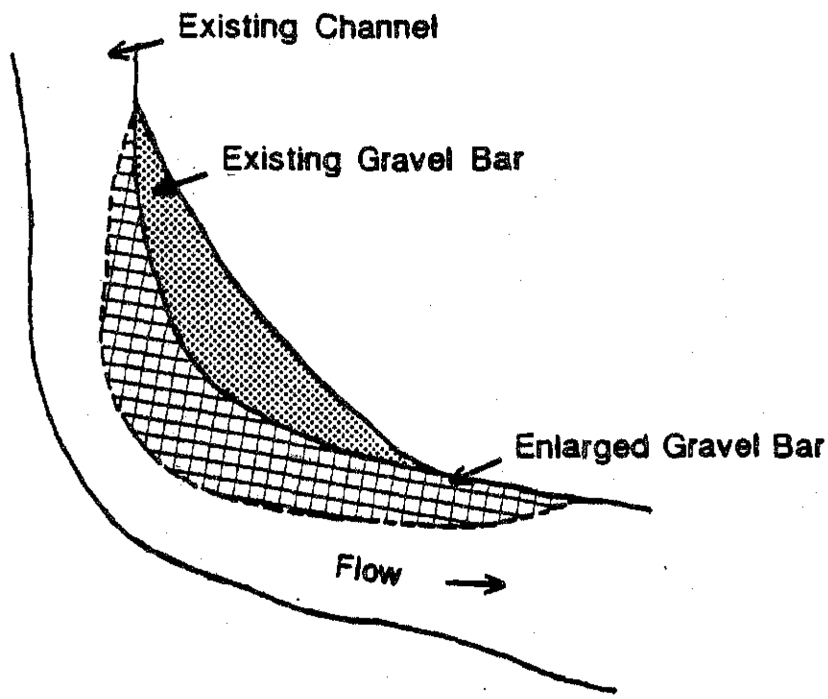
Erosion of banks on rivers and streams is caused by the force of water either digging at the base of the bank or rising up to reach the bank. The bank erodes or sloughs off when the water level drops and the face shears off due to the increased weight of the soil or undercutting of the bank. Often these forces work together to erode banks. The pattern of gravel bars and eroding banks is prevalent on the Sacramento River with the gravel bar forcing the water into the outer bank. The bank will erode if it is composed of soils prone to erosion such as sands and silts.

With this technique, a gravel bar/outer bank system is created in one of two ways. First, a bypass channel is constructed off the main stem of the river through soils suitable for use by bank swallows. The channel is designed and dug to create a meander loop of a river or stream. A gravel bar is created of proper size to create an erosive force of sufficient magnitude to erode the opposite outer bank. The channel must be deep and long enough to create a bank of proper height and length, and it must be shallow and narrow enough to create the proper flow. The second method involves the construction or enlargement of a gravel bar on the main stem of the river which either creates or increases the erosive force of water against the outer bank.

Acquisition of fee title or conservation easement is necessary for lands used with the gravel bar/outer bank system because it is unlikely landowners will grant permission to increase erosion. This method has several benefits over



A. Bypass channel alternative.



B. Enlarged gravel bar alternative.

Figure 2. Preliminary schematic diagram of gravel bar/outer bank system designed as an experimental technique to compensate for bank swallow nesting habitat losses on the Sacramento River, California. See text for description of alternatives.

the other experimental methods. The river is responsible for maintaining the site. Human intervention after construction may not be necessary if the site is selected and engineered to function under normal flows. In addition, this method is identical to the natural processes on the river which create and maintain bank swallow nesting habitat. However, the island created between the bypass channel and main stem of the river will likely be temporary because the erosional processes in the main channel may eventually eliminate the island. Yet, this system may function for many years, especially if done on the main stem of the river.

CONCLUSIONS

Artificial and Enhanced Sites

There were no significant differences between colonies in experimental sites and natural sites in several measures of bank swallow use. Therefore, the experimental sites functioned as natural colony sites to a large extent. This similarity was greatest for the enhanced sites which also received the greatest use over the study period. Despite similarities, there were several factors which collectively functioned to reduce the effectiveness of the experimental sites:

1. Predation by herons and egrets was repeatedly observed at the artificial site at RM 190.5 R; this was not observed at natural or enhanced sites.

2. Compared to natural and enhanced sites, artificial sites received the least amount of use.

3. Bank swallow colony size and use declined over the study period at the artificial sites; these declines exceeded natural and enhanced sites.

4. Maintenance was not conducted at several of the enhanced sites. The lack of maintenance was an important reason why bank swallows did not use enhanced sites.

5. Artificial and enhanced sites require annual maintenance in order to maintain habitat suitability.

6. The amount of enhanced and artificial habitat constructed to date is significantly less than the amount required to compensate for losses of bank swallow habitat.

7. Artificial sites do not have the natural characteristics of bank swallow nesting colonies. It is the natural characteristics that are important in the continued use of a colony site by bank swallows.

8. The majority of sites initially recommended for either enhanced or artificial sites were rejected for various reasons. A

significantly greater acceptance rate would be necessary to more fully attempt to compensate for habitat losses.

Therefore, based primarily on logistic and practical constraints, the experimental sites will not function adequately as a compensation technique to offset unavoidable losses of bank swallow nesting habitat on the Sacramento River. At this time, the Service and Department consider losses of bank swallow nesting habitat to be unmitigable with the two techniques evaluated in this study.

The enhancement technique has considerable promise as a management tool used on an intermittent basis to improve nesting habitat conditions on the Sacramento River. Enhancement of suitable sites can be conducted during years when conditions at known and potential bank swallow nesting sites are unsuitable for nesting. These conditions are likely to occur during drought years, like 1989 and 1990, when many nesting sites were either abandoned or colony size was substantially reduced due to lack of erosion and reduced suitability. Annual surveys could be done during early March to identify sites for enhancement. Landowner approval is necessary; therefore, it is likely that many of the sites will not be enhanced. However, any enhancements, if occupied by bank swallows, could provide additional nesting sites at times when the abundance and distribution of nesting habitat may be limited. This appeared to be the case in 1988 and 1989 when swallow populations increased in the reach from Butte City to Chico Landing.

Several of the problems identified with the artificial sites could have been lessened with the following improvements. Heron and egret predation could have been minimized by increasing the height of the artificial bank from 6 feet to greater than 10 feet. Also, a pile of soil at the base of the bank that had a 45° slope and a slope length of 3-4 feet would have reduced heron and egret access to nest burrows. The width of the berm should have been increased two to three times, and the width and height of the soils appropriate for swallow nesting should have been increased a comparable amount. A weed control effort should have been conducted on top and in front of the bank. Weeds should have been manually removed prior to swallow nesting and after they departed the colony. Artificial sites should have only been constructed where swallow colonies previously existed. Lastly, annual maintenance should have cut the bank face back enough to remove most of the old burrows, leaving only the nest chambers.

RECOMMENDATIONS

The following recommendations are provided to mitigate the loss of bank swallow habitat due to ongoing bank protection projects. We recommend that:

1. An experimental program be initiated to evaluate the gravel bar/outer bank technique as another compensation method. The program should continue for five years at a minimum of five sites on the Sacramento River beginning in 1991.

2. Additional artificial nesting sites not be constructed to compensate bank swallow nesting habitat losses.

3. Existing artificial sites at RM 174.0 R and RM 190.5 L be maintained for the next five years to allow for bank swallow use. Abandon the site if swallows do not use an artificial site for three consecutive years.

4. The enhancement technique be utilized only when necessary to improve bank swallow habitat conditions on the Sacramento River. Surveys should be conducted each year to quantify the abundance and distribution of nesting habitat and identify enhancement sites.

5. The sequential mitigation process be followed as previously described, starting with avoidance. Impacts can be minimized by reducing the amount of bank protection. Developing alternative methods of bank protection will help avoid or minimize impacts to bank swallow nesting habitat.

6. Bank protection at bank swallow nesting sites be constructed only at sites where erosion is occurring. Impacts can be minimized by reducing the amount of bank protection.

7. Purchasing fee title or conservation easements at known and potential bank swallow nesting sites.

The Service considers bank swallow nesting habitat to be unmitigable using the two experimental compensation techniques evaluated in this report. Since the bank swallow is listed as a threatened species under the California Endangered Species Act, bank protection and flood control projects that may adversely affect the species will receive detailed scrutiny by the Department. Its' listing was prompted by a population decline due in large part to the loss of nesting habitat. Therefore, if bank swallow populations are to remain stable on the Sacramento River and its' tributaries, man-caused losses of nesting habitat must be kept to the absolute minimum. Hence, future mitigation for bank protection projects should focus on avoidance and minimization of impacts, not compensation. The two experimental methods evaluated herein were not successful enough to warrant their application and implementation as compensation for losses of bank swallow nesting habitat.

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