BIOLOGICAL AND WATER QUALITY MONITORING IN THE RUSSIAN RIVER ESTUARY, 1998

THIRD ANNUAL REPORT

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I. SUMMARY

This report summarizes the results for the third year of a five-year study to evaluate the impact of sandbar breaching at the mouth of the Russian River. The study included water quality sampling, fish and invertebrate sampling, and observations of pinniped numbers and behavior before, during, and after breaching. As in the 1997 study, fish and water quality surveys were made on three dates for each event: a prebreaching survey made while the beach was closed and the water level high, a draining survey made the day following breaching, and a tidal survey made after the river mouth had been open for a few days.

In the summer of 1998 the Russian River estuary mouth did not close for the first time until 26 August, and the sandbar was breached 8 times between then and early November. This pattern of berm closure and breaching was very different from that in 1997 (when closures first occurred in late March), but was more similar to the 1996 year, when the river mouth did not close until July and was breached seven times by early November. Five breaching events were studied in 1998.

STUDY RESULTS AND CONCLUSIONS

As was the case in the two previous seasons, water quality profiles made at deep channel sites showed stratification (saline water overlain by brackish or fresh water) during the period studied. Near-bottom dissolved oxygen at these sites often was reduced or absent during bar-closed conditions and renewed by tidal action following breaching. The renewal of dissolved oxygen to the saline layers during fall 1998 may also have been influenced by river flows, which after the first week of September were higher than normal summer baseflow conditions. In 1992-1993, a wedge of saline, anoxic water killed mysids and fish as it drained from Willow Creek following a breaching event (Heckel, 1994). During 1998 (unlike 1996 or 1997), fresh water low in dissolved oxygen was recorded in Willow Creek outflows on 3 occasions, and may have been responsible for observed mortalities of juvenile prickly sculpin following a breaching when the water level was over 8 feet at Jenner.

Smolts of wild steelhead use the estuary during the summer and fall, and breaching provides an intermittent avenue to the sea. The steelhead smolts collected in fall 1998 were not larger for their age than fish reared in tributary streams, so the estuary smolts probably did not remain long enough in the food-rich estuary to show accelerated growth. Juvenile steelhead which appeared to be parr (i.e., not smolts)—which may indicate a potentially longer estuary residence—were found in the estuary in only one of the three years studied (1997).

The estuary contains a diverse assemblage of marine, estuarine, and freshwater fish and invertebrate species. The estuary alternates between a tidal estuary (bar-open) and a coastal lagoon (bar-closed). The 1996 and 1997 reports concluded that the bar-open state is, in general, beneficial to the biota. This conclusion is further supported by the 1998 findings. Among the benefits of an open bar are the following:

- Tidal exchange helps keep the saline water layers oxygenated, and re-supplies marine plankton used as food by some of the organisms in the estuary.

- Food-rich mud flats and beaches exposed at low tides are available to wading birds and foraging mammals.

- Migrating salmonids and other fishes can enter or leave the estuary at any time.

- Harbor seals use their preferred haulout sites at the mouth and at the snag area between Willow Creek and Sheephouse Creek. Curious onlookers can have a bigger impact on pinniped behavior than does the breaching operation.

The present management plan of breaching the sandbar when the river rises to 7 to 9 feet at Jenner should be modified to breach before the level exceeds 8 feet. This plan limits bar-closed episodes to 7 to 10 days duration, and avoids flooding of riverside properties.

RECOMMENDATIONS

The three-year study has shown that the breaching activity may have a beneficial impact on fish and seals. The existing breaching and study protocol should be followed in 1999, with minor changes as indicated below.

- Breaching should occur before water level exceeds 8 feet.

- The level gage at the Jenner visitor's center should be modified to provide a continuous, digitally-logged record.

- The potential cause of low dissolved oxygen in Willow Creek should be investigated, including continuous monitoring with a recording datasonde.

- Breaching impacts on seals, as well as public safety, should be minimized by effective patrolling on breaching day before, during and after (while the outflow channel cuts through the berm) breaching, and by the effective use of signs and cordons.

- A bathymetric survey of fish habitat should be made. The survey can be used to decide whether additional beach seine stations should be added to the field surveys to better characterize salmonid use of the estuary.

II. INTRODUCTION

BACKGROUND

The Russian River estuary in Sonoma County is subject to frequent closure by the formation of a barrier beach across its mouth. The barrier beach is artificially breached by personnel from the Sonoma County Department of Roads when the water level behind the beach berm increases to levels which threaten to inundate shoreline properties. The Sonoma County Water Agency has responsibility for management of the breaching program and for biological monitoring of breaching events in the estuary.

A study of the hydrological, biological, and social impacts of artificially breaching the mouth of the Russian River was conducted in 1992-1993 for Sonoma County and the California State Coastal Conservancy under the direction of the Russian River Interagency Task Force. The final report of that study (Heckel, 1994) included selection of a preferred estuary management program which was used as the basis for the Russian River Estuary Management Plan subsequently adopted by the Board of Supervisors. The Management Plan includes biological and water quality monitoring to be conducted during artificial breaching events to support the adopted management approach or provide the basis for modification, as appropriate. The present report is the third of a projected five annual biological monitoring studies required by the Management Plan.

The results of the 1996 and 1997 study programs were presented in previous reports (MSC 1997, 1998). This report presents the results of the 1998 field study and includes discussion of the data collected over the three-year period.

STUDY PROGRAM

The study program conducted during 1998 was similar to the approach used in the 1997 study, in that prebreaching, draining, and tidal surveys were conducted. However, features of the 1998 events (discussed in a later section) precluded following some details of the approach used in 1997. Specifically, the strategy followed in 1997 of conducting pre-breaching surveys after the river mouth had been closed at least seven days, could not be followed. In 1998, the mouth never remained closed longer than 5 days, due to higher river flows. The following elements were included in the 1998 study:

- A “preclosure” tidal survey was made on 19 August since the estuary had remained open all summer.

- “Prebreaching” surveys were conducted after the river mouth closed and the water was at an elevation of 5-7 feet on the Jenner scale.

- "Draining" surveys were conducted on the day following successful breaching, while the system was still in the process of being flushed.

- "Tidal" surveys were conducted four to seven days after breaching, so that the data collected would be representative of typical bar-open, tidal circulation in the estuary.

- Recording temperature/salinity/dissolved oxygen sensors were deployed at three estuary locations throughout the study period.

- Pinniped observations were made on the same schedule as in 1996-7, i.e., before, during, and after breaching events.

The station locations (Figure 2-1) are the same sites used in 1996 and 1997. Stations 2, 3, and 4 are at the same locations as the corresponding stations used for biological and water quality sampling in the previous study (Heckel, 1994).

At Station 1, otter trawls and water quality measurements were taken near the jetty in water 8-11 meters (m) deep, but the beach seining for Station 1 was conducted at the western tip of Penny Island, about 300 m from the pier pilings. Beach seining was, by necessity, conducted at gently sloping beaches located as closely as possible to the designated station locations used for otter trawling and water quality sampling.

At Station 2, beach seining was conducted on 19 August on the north shore opposite the station location shown in Figure 2-1. Seines were not deployed at this station on subsequent dates in 1998 because the beach slope is too steep for seine deployment during prebreaching (high water level) surveys, and post-breaching (low water level) surveys were not possible because of the numerous snags that accumulated there since the 1997 field season. No nearby site suitable for seining was identified. Thus, seining at Station 2 was discontinued after the 19 August survey. Otter trawls and water quality profiles were taken during each survey, in the 6-8 m deep channel adjacent to the south shore.

At Station 3, beach seining was conducted on the beach in front of the Ranger's residence just upstream of the mouth of Willow Creek, whereas, water quality sampling was conducted in the deep (4 m) channel adjacent to the east river bank 200 m downstream from the Willow Creek mouth. Otter trawling was conducted in shallow (2 m) water near the deep channel (the deep channel was filled with submerged trees and large rock outcrops). On each prebreaching survey, and on other surveys whenever the creek was navigable, water quality profiles were also taken inside Willow Creek at a location (Station 3A) about 0.5 km upstream from the bridge where the water was about 2 m deep at high water (Figure 2-1). On survey days when Willow Creek was not navigable, temperature, salinity, and dissolved oxygen were measured in the shallow riffle located downstream of Station 3A. Station 3 plankton trawls were conducted in the shallow (1 m) channel leading southward from the Willow Creek mouth, as well as at a control site located about 300 m upstream of the creek mouth, north of the Ranger's residence.

At Station 4, water quality sampling was conducted in the deep (14 m) channel pool adjacent to the rocky cliff on the northwest bank just below the mouth of Sheephouse

Figure 2-1

Creek. Otter trawling followed a route that included both the deep channel and shallower nearshore waters, and beach seining was done on the southeast bank opposite the mouth of Sheephouse Creek.

Potential effects of artificial breaching on harbor seals' use of their preferred haulout site on sandspits near the river mouth at Jenner were monitored by a program of counting seals, and humans near the seals, before, during, and after breaching events, coupled with intensive observations of seal/human interactions during breaching events, and by analysis of daily, year-round census data for the same seal colony, obtained from a separate study.

METHODS

Water Quality Monitoring

Water quality vertical profiles (observations at 1 m vertical intervals) were conducted at each station each time biological sampling was conducted. Portable YSI salinity and dissolved oxygen meters were used to obtain *in situ* data on temperature, salinity, conductivity, and dissolved oxygen. The profiles were performed in the deepest part of the channel at each station, to determine whether or not salinity stratification was present. Near each water quality monitoring station a monument was established from which the water level at the time of sampling was measured. This enabled the water depths to be expressed relative to zero on the staff gage at the Jenner visitor's center. Water quality profiles for the 1998 data could therefore be plotted relative to this datum.

As in the 1997 study, submerged, continuous-recording meters (Hydrolab Datasonde III) were installed in the deep channels at Stations 1, 3, and 4 on 31 August. These instruments were used to record temperature, salinity, and dissolved oxygen a few cm above the river bottom. The datasondes were typically retrieved on the day of the prebreaching surveys and returned to the laboratory where data files were downloaded and the instruments were cleaned, serviced, and recalibrated. Datasondes were redeployed the following morning. Sondes were deployed continuously throughout the study season at stations 1 and 3. The sonde deployed at station 4 was moved on 22 September to Station 3A in Willow Creek, in order to monitor the creek outflow, which evidently experienced near-anoxia during draining on 15 September (discussed in a later section).

Biological Monitoring: Fish and Macro-Invertebrates

Otter trawls are nets which are dragged along the bottom behind a boat. Otter trawl sampling was conducted in the deep channel at each station to collect slow-moving, benthic fishes and macro-invertebrates (e.g., crabs, shrimp, and mysids). The trawl used in this study is eight feet wide at the mouth, with 1/8 in. (square) mesh throughout. Single tows of four-minute duration were conducted at each station. The trawl was towed at 3-5 mph. behind a 16 ft. aluminum skiff powered by a 25 hp. outboard motor. After each successful trawl was completed, the contents of the net were brought aboard and emptied into a large plastic tray filled with water for sorting, counting, and species identification. Nearly all specimens were released alive and unharmed. A small number of invertebrates and non-salmonid juvenile or larval fish were preserved for closer examination in the laboratory. Fish were identified to the species level, except for a few juvenile rockfish, which were identified only to the genus *Sebastes*. Most invertebrates were identified to species; in a few cases identifications were only to the genus or family level.

Beach seines collect fishes throughout the water column near shore. Beach seine sampling was used to capture more agile fishes (especially salmonids) which cannot be caught by otter trawl, as well as mid-water fishes. The beach seine used in this study is 100 ft. long, 8 ft. deep, with an 8 by 8 by 8 ft. bag in the center, and is composed of 3/8 in. mesh knotless nylon netting. The seine was deployed by using the boat to pull one end offshore, and then around in a half-circle while the other end was held onshore by another person. Both team members then pulled the net ashore by hand. Captured fish and invertebrates were placed in a water-filled tray for sorting, identifying, and counting prior to release. Captured steelhead smolts were also measured and examined closely for general condition and wild vs. hatchery origin prior to release. Scale samples were collected from captured steelhead smolts, in order to determine the age of the fish. Scales were examined by Mr. Shawn Chase, SCWA fishery biologist. Beginning with the survey of 15 September, small finclip samples were collected from captured steelhead smolts by Ms. Jeanne Robertson of Bodega Marine Laboratory as part of an ongoing salmonid genetic research program conducted by Dr. Michael Banks.

Biological Monitoring: Plankton

Plankton trawls were made in conjunction with prebreaching and with draining surveys conducted at Station 3, at the mouth of Willow Creek, and at another site in the river a short distance upstream of the mouth of Willow Creek (Figure 2-1). The net used is a standard egg and larval net (conical, mouth 0.5 m diameter, 505 µm mesh). The plankton net was towed slowly behind the boat, just above the river bottom in shallow (approximately 1 m) water for two minutes. A General Oceanics flowmeter was attached to the mouth of the net to estimate the volume of water sampled.

Biological Monitoring: Pinnipeds

Observations of pinniped (mostly harbor seals) numbers and behavior near the traditional haulout site at the river mouth were made before, during, and after breaching events, following the method used by Hanson's team in the previous study (Heckel, 1994). A pinniped behavior specialist (Joseph Mortenson or Jamie Hall) stationed on the bluffs along Highway One counted harbor seals and people near the seals at half-hourly intervals throughout the day. Activities by humans on the beach which triggered responses in seal behavior (i.e., disturbances) were noted during intensive observation periods, and analyzed using a method previously developed at Jenner (Mortenson, 1996); this method was derived from standard interference measures used in studies at the Point Reyes National Seashore (Allen, 1984; Allen and King, 1992). The method generates an hourly interference rate (i.e., the number of minutes per hour in which disturbance occurs).

The day prior to breaching provided a baseline for considering the effects of breaching per se (i.e., effects not due to breaching activity and/or human spectators it may attract). During the day of breaching seal numbers and behavior were observed before, during and after breaching. Observations made on the day following breaching were used to indicate the extent of recovery toward prebreaching use of the area. Pinniped studies were made in conjuction with breaching events I, III, IV, and VI (see Table 3-1 below). Additional data showing seasonal trends in harbor seal use of the Jenner haulout site were obtained from a separate, ongoing study conducted by Elinor Twohy. In her study, harbor seals are counted once each day throughout the year, from the same vantage point as used in this study.

III. RESULTS

BREACHING EVENTS AND MONITORING EFFORT IN 1998

The bar closed eight times between late August and early November, but never remained closed for more than five days (Table 3-1). This is in contrast to 1997, when all of the surveys were made following closures of at least 7 days. The estuary filled more quickly in 1998 because after the first week of September river flows averaged 320 cfs (8 September through 12 November), which is roughly double the usual summer base flows. River flows at Hacienda Bridge during the study season are presented in Appendix A-37, and their effect on water quality parameters in the estuary are discussed in the following section.

The estuary mouth did not remain open as long (1-9 days) following breachings in 1998 as it did in 1997 (4-44 days), but comparing only September and October of each year, the contrast is less striking. Wind and surf are typically more active at this time of year.

Since the sequence of beach closures and breachings was rapid in 1998, it was more difficult to accomplish the study goal of three surveys (prebreaching, draining, tidal) for each event.

In 1998, the river mouth did not close for the first time until 26 August. Since the estuary had remained tidal continuously all summer--unlike in the previous two summers--it was decided to conduct a preclosure tidal survey in addition to surveys in response to closing/breaching events. This was done on 19 August.

Five breaching events were studied, three in September and two in October (Table 3-2). No prebreaching survey was made in conjunction with the second breaching, and on two occasions (28 September and 8 October), prebreaching surveys were made early on the breaching day. In both of these cases the surveys were completed before the estuary had significantly drained. The tidal survey following the breaching of 27 October could not be made since the estuary closed again the day after it was breached. As a result, the final tidal survey was made on 12 November.

WATER QUALITY MONITORING

In situ *Profiles*

The Water quality profile data collected before the first beach closure (Appendix A-1 and Appendix A-16) typify tidally-influenced conditions. All 4 stations had a stratified water column with a fresh or brackish layer above a saline layer. At stations 1 and 2, the surface layer was brackish (0.5-1.6 ppt) and the near-bottom salinity approached that of seawater (approximately 30 ppt). At stations more distant from the mouth, the surface

Table 3-1 Table 3-2

layer was fresh and the near-bottom salinity was one to a few parts less than seawater (26.6 ppt at Station 4). The vertical distribution of dissolved oxygen under tidal conditions also showed stratification. At the surface, the water was near saturation at all stations. Stations 2, 3, and 4 showed a DO maximum in the pycnocline (layer of maximum change of salinity with depth). Close to the mouth (Stations 1 and 2), near-bottom DO was only slightly less than surface values. Near-bottom DO at Station 3 decreased to 2.5 ppm (roughly one-third the surface value), and at Station 4, which is more distant from the mouth and deeper, DO was reduced to 1 ppm at a depth of 6 m, and was anoxic at the bottom (14 m). The river flow during the period immediately preceding these measurements was fairly typical of dry-weather flows (averaging 164 cfs for the first 19 days of August).

Profiles before, during and after the first breaching episode (Appendix A-2 through A-4, and A-17 through A-20) show that at the time of the prebreaching survey, the fresh water surface layer had thickened and the near-bottom layers had reduced (Station 1) or absent dissolved oxygen (Stations 2, 3, and 4). No renewal of DO in these lower strata occurred following the first breaching.

Following the second breaching (see Appendix A-5 and A-6, and A-21 through A-24), DO was reintroduced near the bottom at Stations 1 (by the time of the draining survey) and Stations 2 and 3 (by the tidal survey), but Station 4 remained anoxic at the time of the tidal survey.

Near-bottom DO before the third breaching (28 September) was not depleted during the bar-closed phase as it had been during the first two events (see Appendix A-7 through A-9, and A-25 through A-27). Indeed, it appears to have been renewed during that phase. DO was evidently reintroduced to the lower strata at the deep station (Station 4) some time between 21 September (when the datasonde—recording zero DO—was removed) and 28 September (Appendix A-28, upper panel). The bar closed on 23 September (Table 3-1). Salinity stratification was not disturbed during this period, so DO must have been introduced by lateral transport (see datasonde results, below).

The fourth breaching had little effect on the near-bottom DO at any of the sampling stations (Appendix A-10 through A-12, and A-21 through A-32); nor did the fifth (Appendix A-13 through A-15, and A-33 through A-36).

Water quality profiles made in Willow Creek (Station 3A) during prebreaching surveys never showed anoxia, but during the draining survey of 15 September, a value of only 1.8 ppm DO was recorded in the creek outflow (Appendix A-5). The breaching during this event was done at an elevation of 8.2 feet (Table 3-1), the highest level that the estuary attained in the 1998 season. During the draining survey several dead juvenile prickly sculpin were found in the creek channel and on the banks around the creek mouth. That the dead fish were found on the banks as well as in the channel bottom would indicate that the lethal agent was active before the creek drained to the level when the draining survey was made. Whether anoxia or near-anoxia killed the fish is not known. There was no apparent effect on plankton collected in tows during the draining survey (see below). This occurrence is somewhat similar to the finding of the 1992-1993 study when saline, anoxic water with dead mysids entered the estuary from Willow Creek following breaching. The outflow from the creek on 15 September was not saline, however. The datasonde unit which had been deployed at estuary Station 4 was moved to the creek station on 22 September, following the downloading/recalibration. Records are discussed in the following section.

Datasonde Records

Datasondes recorded water quality conditions near the bottom at estuary Stations 1, 3, and 4 (Appendix A-37). These records confirm and elucidate water quality changes discussed above in conjunction with profiles made with YSI meters. Appendix A-37 clearly shows that near-bottom DO was not replenished at Stations 3 and 4 following the first breaching event, nor at Station 4 by the time the sonde was removed following the second breaching (21 September). The third breaching event evidently did not result in replenishment of near-bottom DO at Station 3—this did not occur until well after the fourth breaching event. Also depicted in Appendix A-37 are berm closures and the Russian River Flow at Hacienda Bridge for the same period as the datasonde deployments (DWR data). Flows typical of dry weather conditions (<200 cfs) occurred only in early September. Higher flows (200-300 cfs) during most of the study period may have facilitated horizontal transport of DO in the saline layer. This is discussed further below.

Datasonde records for the Willow Creek station (Station 3A--Appendix A-38) began on 22 September and continued through 12 November. Appendix A-38 shows the salinity on a separate scale. There was a diel DO sag in the creek of 2-3 ppm. Lowest DO values often coincided with draining after breaching events: minima were 2.5 and 2.2 ppm following the third and fourth breaching events (breached at 7.8 and 6.5 feet, respectively). The overall lowest DO recorded was 1.5 ppm at 0800 hr on 29 October, just after the brief bar-open period following the breaching of 27 October (breached at 7.4 ft). Whether these DO minima are sufficiently low to cause mortality in prickly sculpins is not known.

BIOLOGICAL MONITORING

Fish and Macro-Invertebrates

A list of all the fish species captured by otter trawl and seine in the 1992-1993 study (Heckel 1994) as well as the 1996, 1997, and 1998 studies is provided in Table 3-3, showing 43 species representing 21 families. Only one species (bonyhead sculpin) caught in 1998 had not been captured in one or more of the earlier years studied. However, considerable variability in species captured from year to year is evident. Studies at nearby estuaries showed similar variability both from year to year and between estuaries (Commins et al., 1990, 1996). The number of species and list of species observed each year is heavily influenced by sporadic invasions of estuaries by marine species. A great number of nearshsore marine species may occasionally venture into the mouths of estuaries, but the number of species routinely captured in the Russian River estuary and other estuaries in the region is quite small (staghorn and prickly sculpin, Pacific herring, steelhead, topsmelt, surfsmelt, shiner surfperch, threespine stickleback, starry flounder, English sole, Pacific sanddab, and bay pipefish are nearly always represented in the yearly catches). In the Russian River estuary, marine species are most often captured nearest the river mouth (Station 1), and species generally considered to be freshwater species are usually caught at the most upriver stations (Stations 3 and 4). In Table 3-3, freshwater species include three common native species (Sacramento sucker, Navarro roach, and Sacramento squawfish,) and two uncommon native species (hardhead and Russian River tuleperch—neither of which was collected in 1998). Of five introduced species in Table 3-3 (mosquitofish, green sunfish, bluegill, smallmouth bass, and carp), none were collected in 1998.

Otter trawls typically sample epibenthic and benthic species, and at most stations trawls were deployed in deep channels with saline near-bottom layers. Trawl catches therefore included marine-estuarine benthic species. Prickly sculpin comprised 77 percent of the entire catch by otter trawl (Table 3-4) and were abundant at each station, as were they in previous years (MSC 1997, 1998). Of the species each representing at least 1 percent of the total catch, all but Navarro roach are common estuarine species in this region. Roach are restricted to freshwater (Moyle, 1976). Trawl catches of Navarro roach only occurred at Station 4, the most upriver station. Trawls conducted at Station 4 always included a depth range that ensured that about half of the trawling time was in a deep, usually saline layer, and half in a shallower layer of fresh water. Presumably, the roach (as well as the squawfish and sucker) were collected in the freshwater portion of the trawls.

Examination of the 1998 trawl data (Appendices B-1 through B-15, graphed in Appendices B-16 through B-27) shows few trends in pre- versus post-breaching species captured, number of species, or number of individuals. High variability is the most obvious feature of the data. The 1998 data alone are limited seasonally (all collections during September and October), but catches from the previous two years made by the same methods can be combined with the 1998 data to provide an examination of pre- versus post-breaching, as well as seasonal and year-to-year trends (see Discussion).

The beach seines used in this study sample the whole water column in shallow (up to about 6 ft. depth) near-shore areas. These areas are typically fresh or brackish, so marine species are not usually caught. Beach seines surround an area, isolating the fish within; they are more effective at catching fast-swimming species (including salmonids) than bottom trawls. In 1998 beach seines, 14 species were captured, with 40 percent of the total catch represented by topsmelt, followed by Sacramento sucker (30 percent), and Sacramento squawfish and prickly sculpin (each 13 percent) (Table 3-5). Topsmelt dominated the catch by beach seine in 1996 and 1997 as well (MSC 1997, 1998). All of the 14 species caught by beach seine in 1998 were also captured by beach seine in either 1996 or 1997.

Beach seine catches in 1998 (Appendices B-28 through B-42, graphed in Appendices B-43 through B-54) show a trend of fewer species and fewer individuals caught during pre-breaching surveys than in draining and tidal surveys. The same trend was noted in 1996 and 1997 (MSC, 1997, 1998), and is most likely a reflection of both the difficulty of retrieving the seine at high water by pulling it through flooded emergent and terrestrial vegetation and debris, and that such habitat is less likely to be used by fish for foraging or resting than would be habitat that is normally submerged. However, not all fish species were less abundant at high water, as an analysis of the combined three-year data set shows (see Discussion).

A total of 37 steelhead were captured by beach seine in 1998 (Table 3-5). Nearly half of the total (17 fish) were caught in one tow at Station 1 during the 2 September draining survey (Appendix B-55). The size-frequency distribution for all the steelhead captured in 1998 is shown in Figure 3-1. One steelhead is represented twice in Figure 3-1; it was a uniquely marked fish captured during the draining survey on 15 September at Station 3, then captured again during the tidal survey on 21 September at the same station. The length of this fish was recorded as 4 mm longer the second time it was captured, but whether the difference was due entirely to growth during the interval is problematic. Fish are measured quickly in order to minimize handling time, and although lengths are recorded to the nearest one mm, they are probably accurate to the nearest 5 mm (for this reason lengths presented in Figure 3-1 have been expressed in 5 mm classes). At least three age/year classes are represented in Figure 3-1; age vs. length relationships will be analyzed in the Discussion. No other salmonids were captured in the estuary in 1998.

Figure 3-2 summarizes the salmonids captured in the last 3 years in the estuary. Here the occurrence of salmonid catches are presented according to the date of capture and the average temperature in the upper 2 m at the time and station of capture. Fewest successful salmonid captures occurred in midsummer (none between 7 July and 5 August). Over one-third of the captures that included one or more salmonids occurred at temperatures over 20^{o} C. The maximum temperature at which salmonids were caught was 23.1^{o} C.

Macro-invertebrates collected in otter trawls are included in the Appendix (Tables B-1 to B-15). The most common invertebrates collected during the 1998 surveys were the bay shrimp *Crangon franciscorum* and the mysid *Neomysis mercedis.* Other shrimp species which occurred in 1997 were rare (*C. nigricauda*) or absent (*C. nigromaculata*) in 1998. Bay shrimp may have been more abundant in 1998 than in 1996 or 1997 (see Discussion). A few small Dungeness crabs, *Cancer magister,* were collected at Station 1, but this species was not as abundant here as in the 1997 collections. Juveniles of other *Cancer* species, *C. productus*, *C. jordani, C. antennarius, and C. gracilis* were occasionally collected. Differences between the 1998 invertebrate catches and those in 1996-1997 reflect both year-to-year variability and the restricted sampling season in 1998.

Plankton

Plankton tows were made above and below the mouth of Willow Creek during prebreaching and draining surveys to determine whether the phenomenon observed in 1992-1993 (anoxic water and dead mysids streaming out of the marsh/creek following breaching) would occur. No such conditions occurred in 1996 through 1998. Appendix

C-1 shows the plankton data collected in 1998. As was the case in 1997 (but not 1996), very little vegetation occurred there, so the list of planktonic/epibenthic invertebrates is shorter, since few plant-inhabiting species (mostly insects) were collected. As in 1997, the only frequently collected invertebrates were the mysid *Neomysis mercedis*, the amphipods *Eogammarus* (=*Anisogammarus*) *confervicola* and *Corophium* sp., and sphaeromatid isopods. *Neomysis* is often collected in larger numbers in the otter trawls, although it is not collected quantitatively. Mysids are more common in the deeper, saline layers than in the shallows up- and downstream of Willow Creek where plankton collections are made. Variations in numbers of isopods and amphipods in the plankton tows may be due to the inclusion of sediments in the net as it skims along near the bottom, since these may be more benthic than epibenthic in habitat.

The plankton collected downstream of the Willow Creek mouth on 15 September 1998 (when dead fish were found) included a few mysids as well as more benthic invertebrates. None appeared dead or moribund.

Pinnipeds and Other Aquatic Mammals

The 1998 daily census of the harbor seal colony at Jenner showed increasing numbers of seals from January through July, then a sharp decrease in August (Figure 3-3, Appendix D-1). A peak in numbers during moult (June-July) is characteristic of central California harbor seals (Allen, 1984), as the seals apparently spend more time resting at haulout sites while moulting (Allen et al. 1987). In the two prior years to the current study, peak numbers were observed in February-March, but a separate peak occurred in July each year, followed by a sharp decline in August (MSC, 1997, 1998).

Seal numbers at the Jenner haulout site fell during closures of the river mouth in 1998 (Figure 3-4), as has been found in earlier studies (Hanson, 1993; Mortenson, 1994; Mortenson and Twohy, 1995; Mortenson, 1996; MSC, 1997, 1998). However, the difference in mean number of seals present when the river mouth was open vs. closed was more extreme than in the 1996 and 1997 studies. In 1998, no seals were seen in the daily counts during bar-closed conditions in August, September or early October (Figure 3-4, Appendix D-4, D-5). Some seals were observed in the daily count before and just after the short-lived beach opening on 27 October (Figure 3-4, Appendix D-5, bottom panel). The more complete abandonment of the closed beach in 1998 could be because closures in the 1998 study did not occur until late summer and fall, when seal numbers are low to begin with, and when seals are more reactive to visitors (Mortenson, 1996). In 1996 and 1997, some of the closures occurred earlier in the year when seal numbers are higher and seals are less reactive to humans. Thus, a greater proportion of the colony remained at the haulout site when the river mouth was closed. The apparent absence of seals during bar closed conditions could also be an artifact of the time of day when the daily count is made, since early-morning observations on prebreaching and breaching days showed a few seals (Figure 3-5).

Breaching day observations typically showed that seals left the beach early in the day, but often returned later after breaching operations were completed. However, seals also left the beach on prebreaching mornings, either in response to people on the beach, traffic

Figure 3-3, Figure 3-4

noise, or for no apparent reason (Figure 3-5). Seals were always much more abundant by the day following breaching(Figure 3-5).

In 1998, as in the previous two years, observations made during pre- and postbreaching water quality and fish sampling cruises showed that a small group of seals (6-8 individuals) were typically seen hauled out on snags at low tide between Stations 3 and 4. During flooded conditions, the snags were submerged, and the seals dispersed; some were occasionally seen swimming throughout the study area during flooded conditions.

Solitary California sea lions (*Zalophus californianus*) were occasionally observed between Station 1 and the visitor's center during bar-open conditions. River otters (*Lutra canadensis*) have been observed occasionally during the last three years in the estuary. During 1998, a group including two adults and five juveniles was seen on several occasions, usually near Station 4 during draining and tidal surveys.

IV. DISCUSSION

WATER QUALITY

Conclusions about water quality behavior before and after breaching events in 1996 and 1997 were based on observations made during dry-weather flows. They can be summarized as follows:

> Prebreaching profiles at the deeper stations showed a stratified water column with fresh (or brackish) water overlaying a pocket of saline water. Dissolved oxygen in the deeper water typically was reduced or absent after a few days of bar-closed conditions. Station 1 profiles during the draining phase usually showed that dissolved oxygen was renewed in the saline bottom layer, although the salinity stratification remained. Near-bottom dissolved oxygen at the other stations was also renewed by tidal action following breaching events, but depending upon the depth and distance from the mouth, reaeration occurred later. For example, at Stations 2 and 3, dissolved oxygen was often not increased near the bottom until the tidal survey. Station 4, being deepest and farthest from the mouth sometimes had near-bottom dissolved oxygen increased by the time of the tidal survey, but more typically, deep-layer anoxia was not relieved until a few days later. Datasonde records show that near-bottom layers at Station 4 sometimes remained anoxic between breaching events.

The increase in near-bottom DO which was observed following breaching events was not associated with vertical mixing, because the salinity stratification was not disrupted (although at Station 4 fresh water sometimes penetrated up to 3-4 m into the salty layer during the postbreaching tidal period—see Appendix A-28). Diffusion of oxygen into the deep layer must take place, but it is unlikely to explain the rapidity of the renewal. Therefore it is assumed that the primary agent in renewal of DO was horizontal movements in the saline layer by tidal action, which would bring oxygenated saline water from adjacent shallower areas to the channel pool stations and provide energy by which they could be mixed into the low-oxygen layers. Shallower areas adjacent to the deep pools where profiles were made probably have higher DO due to photosynthetic production. *Ulva* (sea lettuce) was particularly abundant during the 1998 season, for example, and often loaded the otter trawls. The data collected in 1998 further suggest that increases in river outflow above the normal dry-weather volumes might also play a role in facilitating horizontal movements in the saline layer. During ebb tides the outflowing fresh water layer may accelerate the downstream movement of the salty layer below. Over the last 3 years, most of the instances when near bottom DO was not renewed following breaching occurred in August and September (Appendix A-39).

Another factor which probably determines whether DO is renewed following breaching is the extent of initial flushing, which is determined by the height of the estuary and timing of berm breaching relative to the tide. On some occasions the estuary flushes deeply following the breaching, and on other occasions the water leaks out but does not result in a resonant flushing. Provided that the berm opening is sufficiently wide and deep, the tidal amplitude probably also plays a role in horizontal water movement within the estuary.

The variables that may determine the extent of horizontal exchange of DO into the depths of saline pools during tidal conditions thus include:

- Intensity of initial flushing
- Tidal amplitude (spring/neap cycle)
- Month of year
- Cross-sectional area of berm opening
- River outflow

Provided that DO is available, these deepest pools may provide a cool-water saline refuge for upmigrating salmonids, which may "hold" in the estuary in fall before ascending to spawning sites following rains. However, the majority of the aquatic habitat in the estuary is shallower than the pool stations (such as Station 4) where profiles were recorded. These areas do not experience anoxia, and so provide habitat with an adequate DO supply for resident fishes.

Fish mortalities observed in the outflow from Willow Creek may have been associated with low DO. No anoxia was found, although values as low as 1.5 ppm were recorded. No mortalities were observed in invertebrates, and the observed deaths of prickly sculpin apparently occurred before the lowest water was reached following the postbreach draining (the time when lowest DO was recorded by datasondes). These mortalities were associated with draining following an elevation of 8.2 feet (the 1998 maximum). Heckel (1994) observed an anoxic episode following breaching at an elevation over 9 ft, and concluded that anoxic events in the creek outflow were more likely when breachings were made when the estuary was deepest. The 1998 data support the earlier conclusion that low DO in the creek outflow is most likely when the estuary is deepest before breaching, and suggest that in the future the estuary be breached before it reaches a level of 8 feet. Causes of anoxic water in the creek should also be investigated.

BIOLOGICAL MONITORING

The Estuary as Salmonid Rearing Habitat

A consideration of the function of the estuary as a salmonid rearing habitat is essential to understanding whether the present management program of artificial breaching protects salmonid populations which use the estuary during summer. It is therefore of interest to review the evidence collected so far which bears on the subject of whether steelhead remain in the estuary during summer, or simply pass through on their way to the sea.

If significant numbers of steelhead spend a significant portion of their life cycle rearing in the Russian River estuary, as opposed to quickly passing through on their way to sea, juvenile steelhead captured in the estuary would, on average, be larger in size than steelhead of the same age or year class captured at the same time in Russian River tributaries. This is because a more abundant supply of food (especially mysid shrimp and other crustaceans) is available in the estuary than in upland streams.

Greatly enhanced growth rate was a major advantage of estuary rearing, as opposed to creek rearing, in J. J. Smith's (1990) study of four small estuaries in San Mateo and Santa Cruz counties in central California. However, the estuaries Smith studied differ in several ways from the Russian River estuary. They are much smaller, have little summer inflow, and, while closed, the saline bottom layer gradually seeped out through the sandbar. This resulted in ideal conditions for steelhead rearing. In contrast, the Russian River estuary has a persistent saline bottom layer and summer flow that is relatively large compared to the volume of the estuary.

Ages (based on scale growth rings) are assigned to 34 of the 37 steelhead captured in the Russian River estuary in 1998 (Figure 4-1, data in Appendix E-1), and these are compared to data for steelhead sampled in October 1998 as part of another study (MSC, unpublished data, see Appendix E-2) conducted in four Russian River tributaries (Green Valley Creek, Mark West Creek, Santa Rosa Creek, and Maacama Creek). Age determinations for all the fish shown in Figure 4-1 were done by Shawn Chase (SCWA). The histograms for the tributaries represent pooled samples of fish from several locations within the four tributary watersheds (Appendices E-2 and E-3) and do not represent a random sample with respect to length or age frequency, i.e., the number of fish in each size or age class shown in Figure 4-1 for tributaries do not indicate the proportional representation of that size or age class in the population. Figure 4-1 shows the range of size of fish within each year class. For example, the open bars on the left side of the figure indicate that young-of-the-year fish (age 0+--fish that came from eggs spawned in 1998) in the tributaries ranged from about 60 to 105 mm. in length, while age 1+ fish ranged from 95 to 160 mm. The estuary data (upper half of the figure) represent a nearly random sample, in that scales were sampled from 34 of the 37 steelhead captured in 1998. Figure 4-1 shows that there is no obvious difference in size between same-aged fish from the tributaries and from the estuary. Thus, from the growth standpoint, the available evidence does not support the conclusion that steelhead spend much time rearing in the estuary.

In contrast, another line of evidence supports the idea that some steelhead rearing occurs in the Russian River estuary. Figure 4-2 shows the size distribution of steelhead captured in the estuary during all three years of the current study (only one steelhead was captured in the 1992-1993 study, and it was dead). Most of the fish represented in the figure were judged on their appearance, while being measured, to be smolts, i.e., juveniles on their way to sea, or ready to go to sea. Juveniles that are not going to sea anytime soon retain their parr marks and juvenile coloration. During the process of becoming smolts, the parr marks disappear under a layer of newly formed, shiny, silvery, deciduous scales (the scales easily flake off if handled roughly). In 1997, when the first breaching events occurred much earlier in the summer than in 1996 or 1998, quite small young-of-the-year steelhead (the cluster on the left, from 50 to 100 mm.) were captured in May and June surveys, and these fish had the parr marks and vivid colors typical of juveniles (or "parr") not undergoing smoltification. If they were not smolts, presumably they were juveniles rearing in the estuary. The design of this study does not result in capture of sufficient numbers of steelhead throughout the summer to allow tracking of the growth rate and survivorship of a cohort of steelhead such as those young-of-the-year parr caught in May and June 1997. Another, albeit tenuous bit of evidence that tends to support the estuary-rearing model is the case, mentioned earlier, of the steelhead that was caught twice (six days apart) at Station 3 in 1998, possibly having grown measurably in the meantime. At least that one fish was apparently not making a beeline for the sea, and its apparent increase in size is *de facto* evidence that it was feeding, i.e., rearing, in the estuary, if only for a few days. In fact, most of the smolts captured in the estuary during the three years of study have appeared to be very fit and plump, suggesting that they are gorging on food while in the estuary.

The evidence available so far from the ongoing study is not sufficient to fully evaluate the importance of the estuary as steelhead rearing habitat. Steelhead were found in the estuary each of the three years studied (although they appear to have been more rare in the 1992-1993 study), but their size indicates that most of these do not spend a long time there. If these fish linger for a few days before resuming their migration to the sea—as our recaptured fish seems to have done—they would not be adversely affected by the present breaching program which insures that the estuary does not remain closed for more than about 7 to ten days at a time.

Variability From Year to Year

Variability in the pattern of berm closure and of biological features in the estuary continue to be a striking feature of the data from the third year's study. In 1998 the estuary did not close until late August, but was breached several times in September and October. Continuous tidal conditions through the summer apparently encouraged the growth of *Ulva* in the saline layer, but did not increase the number of marine fish or invertebrates collected (with the possible exception of bay shrimp, discussed below). The smaller number and size of Dungeness crabs found in the estuary in 1998 may be unrelated to environmental conditions in the estuary. The importance of the estuary as a salmonid rearing habitat may vary from year to year as well.

This biological variability is typical of aquatic systems and demonstrates the necessity for doing multi-year studies to support conclusions about how an ecosystem functions. Year-to-year trends in fish catches are discussed in the following section.

An Analysis of the Three-Year Data Set

Three years of trawl and seine data are now available, and analysis of the combined data set for trends that can be related to pre- versus post-breaching, seasonality, and year-to-year patterns is appropriate. Total beach seine catches, as mentioned above, generally were higher in the postbreaching/tidal surveys than in prebreaching surveys (Figure 4-3, top panel). Fish diversity was also higher in the postbreaching surveys (Figure 4-3, bottom panel): Prebreaching surveys never had more than 4 species per day, whereas postbreaching/tidal surveys never had fewer than 4 species per day. Fish diversity did not

Figure 4-3

show seasonal or year-to-year trends.

A similar analysis of individual species catches in beach seines (Appendix B-56 through B-59) shows that while most fish species followed the general trend of lower catches during the prebreaching survey, a few (mainly freshwater or euryhaline) species such as prickly sculpin (Appendix B-57), Sacramento sucker (Appendix B-58), and steelhead (Appendix B-59) were equally likely to be caught at high as at low water. With regard to seasonality, catches of these same three species were about equal in both early (May through July) and later (August through October) periods. A second group, including pacific herring, shiner surfperch, and starry flounder) were more abundant early in the year. Topsmelt, surf smelt, and threespine stickleback were most abundant later in the year. Few species were equally abundant in all three years.

Examination of otter trawl catches for the three-year period (Figure 4-4) shows no clear tendency for either numbers or diversity to be related to pre- versus post-breaching surveys. Most species followed this pattern (Appendix B-60 through B-63). Some species (surf smelt, Sacramento sucker, threespine stickleback) in otter trawl catches, however, tended to be more abundant in prebreaching trawls. Pacific herring may have been more abundant in postbreaching/tidal surveys. Neither prickly sculpin, starry flounder nor threespine stickleback showed much seasonality in otter trawl catch. Species more likely to be caught early in the year included Pacific herring, staghhorn sculpin, English sole, Pacific sanddab, and Sacramento sucker. Shiner surfperch, surf smelt, and bay pipefish were more commonly caught later in the year. Most species were less abundant in 1998 than in one or more of the previous years. A significant exception was bay shrimp (Appendix B-63, all *Crangon* species combined), which appeared to be more abundant in 1998.

Seal Behavior During Closures and Breachings

All pinnipeds haul out of the sea at times and have throughout the 20 million years of their evolution. The major reasons for hauling probably include heat conservation, safety from predators, protection and sheltering of vulnerable young, and molting. Seals may prefer the beach at Jenner since they can haul out there in all but the most extreme weather and over a range of tides. In contrast, rocky haulouts may be sometimes under water, are more exposed to swell and wind waves, and are more accessible to the seals' predators, great white sharks and killer whales. Resting underwater may be less preferred than hauling out on the beach at Jenner because of increased heat loss in water and exposure to predators. Why seals are more abundant on the Jenner beach when the beach berm is open than when the berm is closed is less clear, but there may be more disturbances by humans on the closed beach.

In all three years studied, when the river mouth has closed, often the harbor seals in the Jenner colony abandoned their haulout site on the sandspits inside the mouth. Seals returned soon after the berm was breached, regardless of whether or not the breaching was performed by SCWA crews, unauthorized citizens, or natural events. Thus, it is reasonable to conclude that the mouth-open condition is preferred by the seals, and is

Figure 4-4

presumably beneficial to them. Evidence indicates that, at least in fall, many of the seals that leave the preferred site when the mouth closes move about ¾ mile north along the coast, where they apparently rest at intervals while submerged (Mortenson, in preparation). This scenario (i.e., their nearby presence) accounts for their rapid re-occupation of their preferred haulout site as soon as breaching is accomplished. Indeed, seals are often seen congregating in the breakers just offshore of the breaching operation, apparently waiting for the earliest opportunity to move back to their preferred sites inside the river mouth.

However, even accepting that the mouth-open condition is preferable and beneficial to the seals, there is concern about minimizing unnecessary disturbance of the seals during and following artificial breaching operations, as any disturbance by humans is considered harassment under the Marine Mammal Protection Act. Disturbance can be caused either by the breaching process itself (bulldozers operating and crew members on foot) or by curious beachgoers attracted by the breaching operation. The evidence obtained to date indicates that humans on foot (whether crew members or visitors) are more alarming to the seals than are the bulldozers in operation. In fall, seals abandoned their haulouts on the closed beach in the mornings of prebreaching days as well as on breaching days. In spring and early summer, however, seals tended to remain on the river bar on prebreaching days. Some or all seals left the beach during breaching, largely in response to the sounds and movement of SCWA personnel. However, in two breaches, some seals stayed or rehauled as the bulldozer worked.

The SCWA crew's success at keeping unnecessary visitors away from the breaching area has improved throughout the three years of study, through more effective use of signs and through verbal contact with visitors as they approach the breaching area. The effectiveness of this effort could be further improved in the future by posting guards and keeping signs up after the bulldozer crew has left the site, as the rushing water leaving the estuary and cutting an expanding channel across the beach creates a spectacle that is naturally attractive to any humans in the area. Such curiosity seekers put themselves at risk of drowning and also deter seals from swimming up the channel to return to their preferred haulout site.

V. CONCLUSIONS

The 1998 study confirms most of the conclusions made following the earlier studies (Heckel, 1994; MSC, 1997, 1998). The estuary has a biota that is adapted to survival in an environment that alternates between being a tidal estuary and a coastal lagoon, and, in general, the bar-open state is more beneficial to the local biota. The present management plan of breaching the sandbar when the river rises to 7 to 9 feet should be modified to breach before the river exceeds 8 feet. Additional conclusions derived from the 1998 study program are as follows:

- The biota of the estuary exhibits high variability from one year to the next. Even with this wide variability, the results of the study indicate that the breaching activity is beneficial to biota in the Russian River estuary.

- The renewal of DO in the saline near-bottom layers of deep pools may be facilitated by increases in river flows, in addition to post-breaching flushing and tidal action.

- During fall 1998, near-anoxic water drained from Willow Creek on at least 3 occasions following breaching events, and may have been implicated in the death of several juvenile prickly sculpin. Low DO in water from the creek appears to be related to breaching when the water level is over 8 feet.

- Smolts of wild steelhead use the estuary during the summer and fall, and breaching provides an intermittent avenue to the sea. The steelhead smolts collected in fall 1998 were not larger for their age than fish reared in tributary streams, so the estuary smolts probably did not remain long enough in the food-rich estuary to show accelerated growth. Steelhead parr—which may indicate a potentially longer estuary residence—were found in the estuary in only one of the three years studied.

- When the bar is open, harbor seals use a traditional haulout site on the sandspits just inside the mouth of the estuary. When the bar is closed, most of the seals abandon their preferred haulout site and move to a less preferred one just north of the mouth, returning as soon as breaching occurs. The preferred site inside the mouth is presumably beneficial in some way to the seals.

- In fall seals left the closed beach in the morning whether or not breaching took place.

- Curious people who gather at the breaching site before, during and after the breaching can have more impact on pinniped behavior than does the breaching process itself. This impact can be minimized by posting signs and cordons, and especially by patrolling the area to keep people away.

VI. Recommendations

The three-year study has shown that the present program of artificial breaching of the estuary has a beneficial impact on the aquatic habitat of fish and seals. In view of the high year-to-year variability, it seems advisable to continue the monitoring program. If this is done, we recommended minor changes to the program as follows:

- Breaching should occur before water level exceeds 8 feet. This is to minimize the likelihood of low DO in the outflow of Willow Creek following breaching.

- A continuous record of estuary levels would be useful to evaluate and interpret study results of future estuary surveys. A water-level logging system to obtain a continuous record of estuary heights should be established at the Jenner visitor center. The existing gage is evidently not configured to provide such a record.

- The potential cause of low DO in Willow Creek should be investigated. Willow Creek DO should be continuously monitored with a recording datasonde.

- Age determination by scale analysis of steellhead smolts provides a powerful tool to understand the estuary's role as a salmonid rearing habitat, and should be continued.

- Breaching impacts on seals should be minimized by effective patrolling before, during and after breaching, and the effective use of signs and cordons. This will also increase visitor safety.

- A bathymetric survey should be conducted to characterize the salmonid and other fish habitat in the estuary. Survey results will be used to determine whether the level of beach seining effort should be increased to better characterize salmonid use of the estuary.

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VIII. APPENDIX