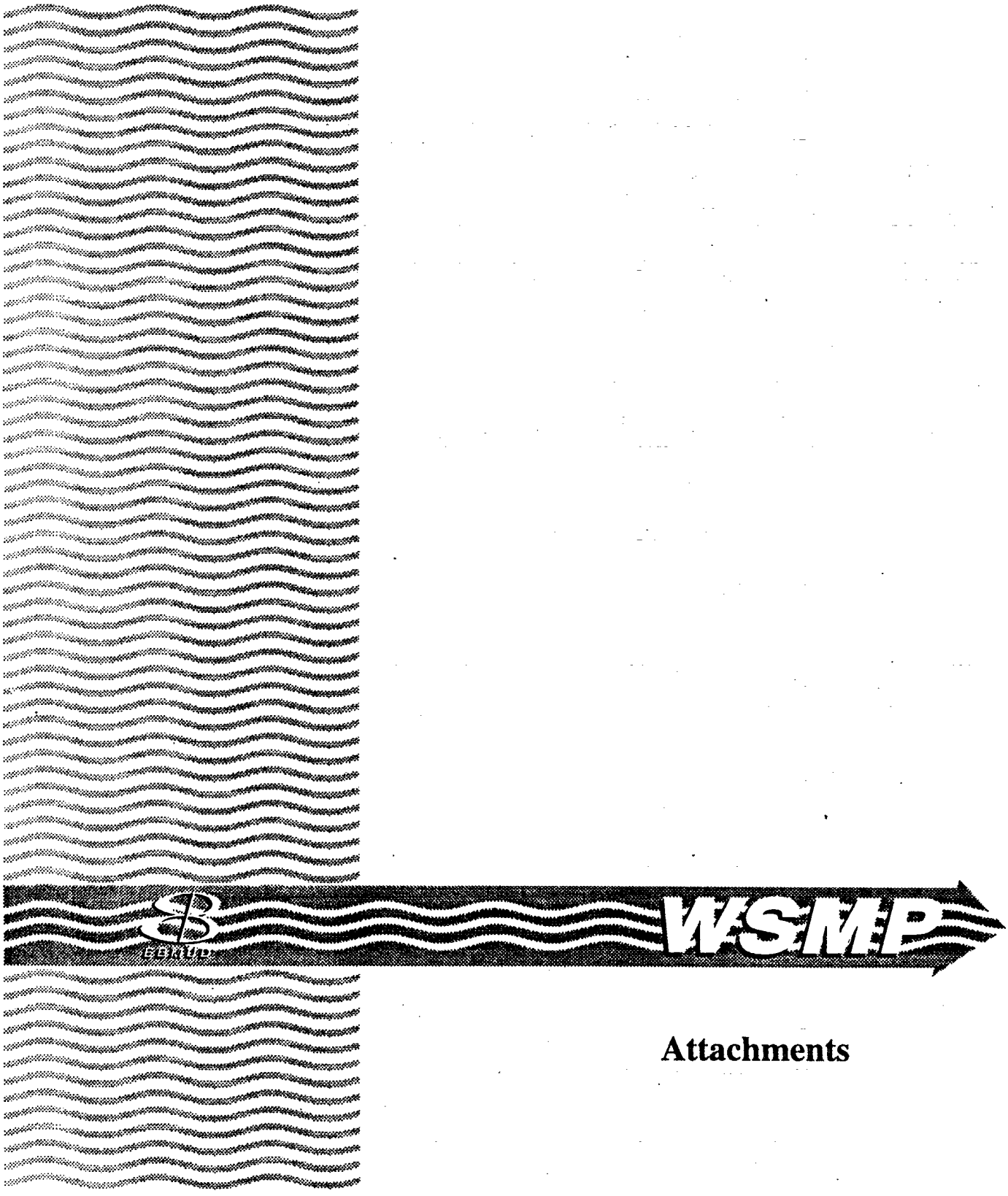

Attachments

C-100980

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PROJECT MANAGER

Edward W. Bianchi, Ph.D.

PRINCIPAL INVESTIGATORS

Edward W. Bianchi, Ph.D.
William Walsh, Ph.D.

FISHERIES BIOLOGISTS
Jeff Hagar
Frank Hein
Lisa Holsinger
Wayne Kicklighter
Carol Marzuola
Gary Miller

MODELER
Jung Ho Yoon

STATISTICIANS
AiLing Chai, Ph.D.
Anne Flannery

FIELD TECHNICIANS
Michael Cashman
Sarah Chamberlain
Michael Cross
Jim Crowley
Joseph Drennan
Larry Freilich
Jacqueline Garcia
Warren Hankinson
Mark Heene
Larry Laughlin
James McConnell
Elizabeth Mizuno
Craig Watts
Thomas Williams

LABORATORY TECHNICIANS
Susan Glendening
Anne Huber
Larry Travanti

DATA MANAGEMENT
Carol Marzuola
John Scott

DATA ENTRY/VERIFICATION
Revik Delfin
Clarissa Richardson
John Scott
Laura Swezey

GRAPHICS
Bryan Adams
Tom Grignon
Betty Gai

EDITORS
Victoria Van Meter
Jane Christmas

REPORT PRODUCTION
Bryan Adams
Shirley Brim

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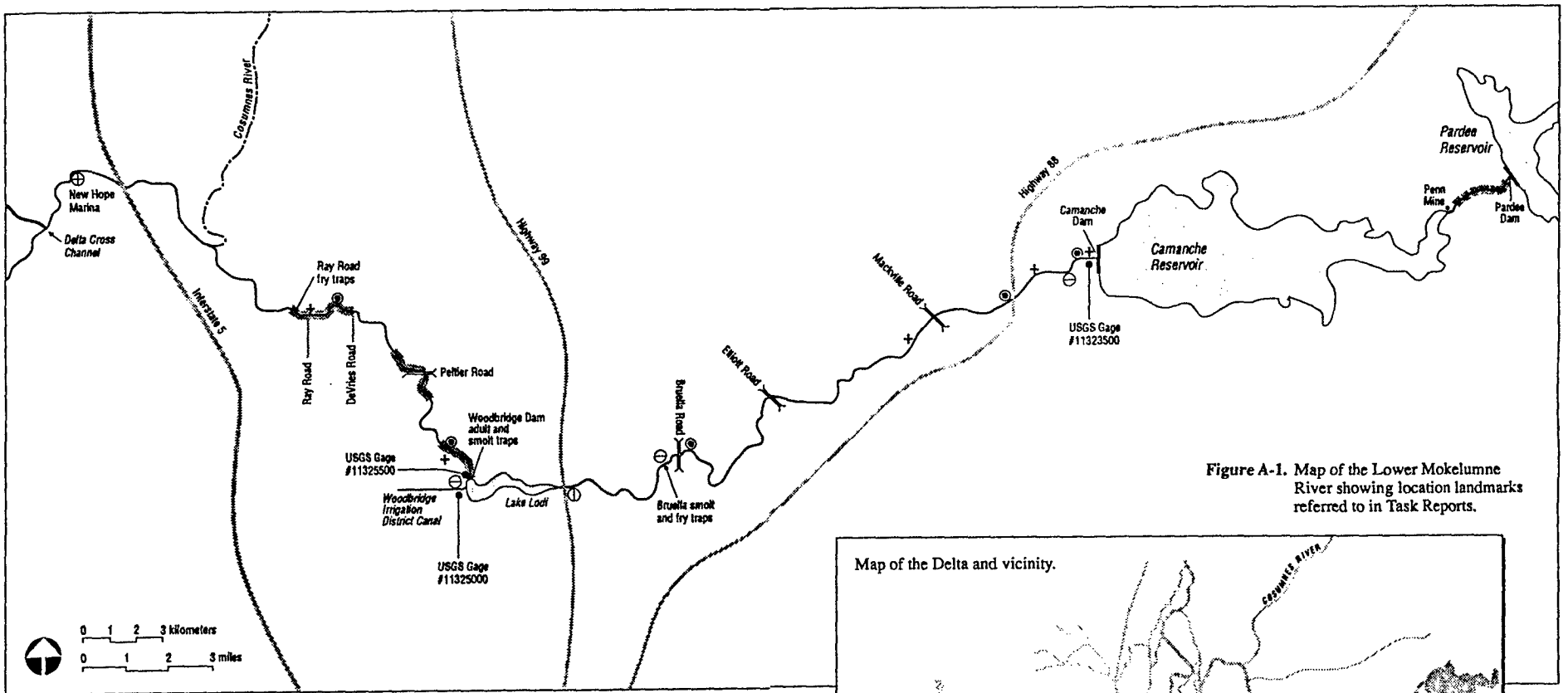
APPENDIX A - EXECUTIVE SUMMARY

BioSystems was contracted by EBMUD to conduct aquatic studies in the Mokelumne River downstream of Pardee Dam in 1990-1992 to provide a scientific technical foundation for developing and evaluating alternative management actions for the maintenance of the fisheries resource (Figure A-1, A-2).

The major objectives of the aquatic studies were:

- To develop an in-stream water temperature model to predict the effect of flow on temperature conditions in the river between Camanche Dam and the Cosumnes River (Tasks 1, 2 and 3);
- To determine the distribution of potential rearing and spawning habitat of chinook salmon and steelhead trout, based on habitat conditions and prey and predator abundances (Tasks 4, 5, 6 and 8);
- To determine the suitability of the Lower Mokelumne River from Woodbridge Dam to the extent of tidal influence for native warmwater fish and important introduced species (i.e., striped bass and American shad) (Task 7);
- To identify the environmental factors that influence in-migration (Task 9), spawning habitat selection and redd placement (Tasks 10 and 11), emergence patterns and spawning success (Task 12), and fry and smolt out-migration (Tasks 13 and 14);
- To document the mortality of out-migrating chinook salmon smolts in the Mokelumne River between Camanche Dam and Lake Lodi, in Lake Lodi, and in the Delta (Task 15);
- To examine the effects of temperature and timing of spawning and out-migration on overall smolt production (Tasks 16 and 17);
- And to document aquatic habitat and fish abundance between Pardee and Camanche reservoirs (Task 18).

Three separate SNTEMP models (Modules 1, 2 and 3) were developed for the Mokelumne River between Camanche Dam and the confluence of the Cosumnes River (Task 1). Three different SNTEMP models were needed because during the summer months a segment of the Mokelumne River is impounded to form Lake Lodi. Because of temperature stratification in the impoundment, a separate model was needed to predict temperature conditions downstream. Water temperature leaving Lake Lodi from April through mid-October was predicted using the Water Quality for River-Reservoir System (WQRRS) model (Task 2). Output from the WQRRS model was used as input for the SNTEMP model for the reach downstream of Lake Lodi.



Legend

- + Location of datapods
- ◉ Invertebrate sampling site
- ⊖ 1990 Pilot study release site
- ⊖ 1991 Mortality study release site
- ⊕ CWT release site – study fish
- ⊗ CWT release site – wild fish
- Electrofishing sites

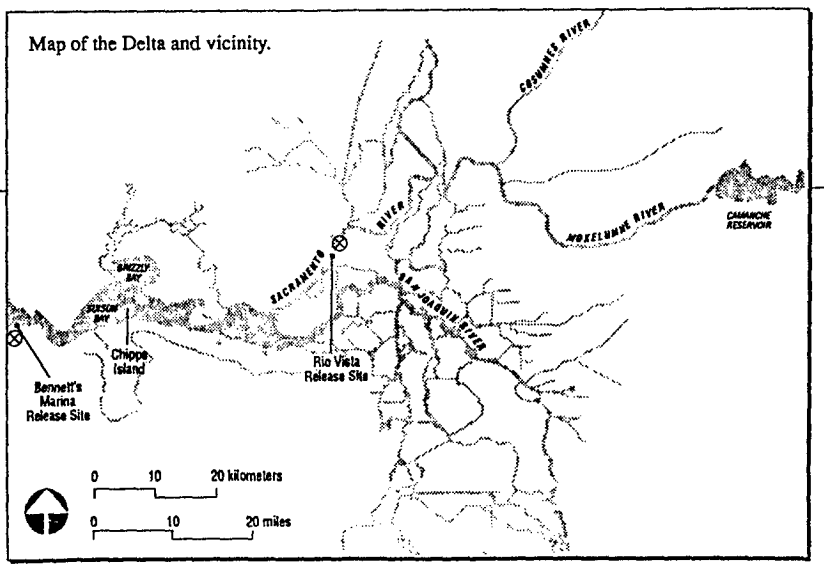


Figure A-1. Map of the Lower Mokelumne River showing location landmarks referred to in Task Reports.

Module 1 of the SNTEMP model was calibrated for the entire reach of the Mokelumne River during the winter months (mid-October through March) when Lake Lodi is not present. Module 2 was calibrated for the Mokelumne River reach from Camanche Dam to the beginning of Lake Lodi from April through mid-October. Module 3 was calibrated for the reach of the Mokelumne River from Woodbridge Dam to the confluence of the Cosumnes River from April through mid-October. Eight years of temperature, flow, and meteorological data were used to develop the SNTEMP models for the Mokelumne River. Part of the water temperature data set used to develop the model was collected in the river by BioSystems from April - October 1990 using Omnidata datapod digital recorders (Task 3).

After calibration of Module 1 (SNTEMP model), the total mean difference between the observed and predicted water temperatures was 0.05°C and the maximum error was 1.5°C. For Module 2, the total mean difference between the observed and predicted water temperatures was 0.11°C and the maximum error was 0.91°C. Similarly, the total mean difference between the observed and predicted water temperatures for Module 3 was 0.03°C and the maximum error was 0.54°C.

The WQRRS model requires topographical, hydrological, meteorological, and water temperature data from Lake Lodi. The Lake Lodi WQRRS model was calibrated using 1990 data, since this was the most complete temperature data set available. Fifteen sets of water temperature profile data were available for the summer months in 1990. A comparison of observed and predicted water temperature profiles in front of Woodbridge Dam for the fifteen data sets showed a mean differences of -0.43°C and a maximum single deviation of 2.43°C.

The distribution of potential rearing and spawning habitat of chinook salmon and steelhead rainbow trout was evaluated based on habitat conditions (Tasks 4 and 5) and prey and predator abundances (Tasks 6 and 8).

Electrofishing and habitat surveys were conducted in the Lower Mokelumne River between Woodbridge Dam and Ray Road (tidal influence) to assess the suitability of the chinook salmon rearing habitat (Task 8). Surveys were conducted in late April and late June - early July 1990 during the out-migration of chinook salmon to assess predator populations and habitat conditions. During the April survey the stomach contents of large predators (mainly squawfish) were examined to investigate predation of chinook salmon smolts. The stomachs of potential predators were not examined in the latter surveys since all smolts were being trapped and trucked to the Delta at that time. During the electrofishing surveys the length, average width, depth, relative substrate composition, and water temperature was recorded at each of the sampling sites to assess habitat conditions.

A total of 1,097 fish representing 23 species were collected in the electrofishing surveys. Potential salmonid predators residing in the river included smallmouth bass, largemouth bass, spotted bass, and Sacramento squawfish. During the surveys, most of the large

predators (i.e., squawfish) were collected just downstream of Lake Lodi at the Woodbridge Golf Course site. The stomach contents of the larger predators, (squawfish, largemouth bass, and smallmouth bass) were examined during these surveys; however, no smolts or fish parts were found.

The length of river habitat surveyed below Woodbridge Dam was 4,324 m. Approximately 30 percent of the river between Woodbridge Dam and Ray Road was surveyed (electrofished and habitat mapped). River habitat in this reach consisted mainly of run/pool complexes with silt (43%) and sand substrates (45.5%). The proportion of habitat types found in the survey was 67 percent runs and 32 percent pools. Riffle habitat was minimal and accounted for <1 percent of the habitat identified.

Aquatic habitat on the Mokelumne River between Camanche Dam and Lake Lodi was mapped to characterize habitat conditions in the river and to identify the distribution and abundance of chinook salmon rearing and spawning habitat (Task 4). The dominant aquatic habitat in the Camanche reach was runs (83%), while riffles, pools, and backwaters accounted for nearly equal proportions of the remaining area. Almost all of the spawning habitat (96% of total area) was found between Camanche Dam and 3.5 km below Mackville Road.

Two temperature surveys were conducted in 1990 to determine if coldwater refugia were present in the Mokelumne River between Camanche Dam and Lake Lodi (Camanche reach) and below Woodbridge Dam to DeVries Road (Woodbridge reach) (Task 5). Coldwater refugia were defined as pockets of water in the river or in backwaters that exhibit temperatures 2° C cooler than the average temperature found in the main channel. These pockets may serve as rearing habitat for juvenile chinook salmon and steelhead rainbow trout. Because temperature differences (due to stratification or springs) are likely to be observed during warm months, our surveys were conducted during the summer. Temperature profiles were taken along transects placed in runs, pools, and backwaters.

No coldwater refugia were found in the main river of Camanche reach. Three refugia were identified in backwaters located off the main river in the upper portion of Camanche reach. These refugia exhibited temperatures 2.2° to 2.4° C cooler than those found in the main river. No refugia were identified in the main river or backwaters of Woodbridge reach.

Qualitative invertebrate surveys (drift and benthic samples) were conducted in three areas of the Mokelumne River downstream of Camanche Dam in the fall of 1990 and spring of 1991 (Task 6). The three areas surveyed included an upper site between Camanche Dam and Highway 88, a middle site near Bruella Road, and a lower site downstream of Woodbridge Dam between the Woodbridge Golf Course and Ray Road. The purpose of these surveys was to evaluate special and temporal differences in prey availability for juvenile life stages of steelhead rainbow trout and chinook salmon.

During the fall sampling, the benthic invertebrate fauna differed between the sampling areas. Trichoptera larvae (52.1%) and diptera larvae (27.8%) were abundant at the upper site. Oligochaeta (54.5%) and trichoptera larvae (22.3%) were numerous at the middle site. At the lower site, oligochaeta (53.2%) and freshwater clams (24.1%) were numerically the most abundant. Fall invertebrate abundance at the upper site was 3,692.1/m^2 and 4,259.6/m^2 at the lower site. Only 1,075.6/m^2 were collected at the middle site.

Similarly, the invertebrate fauna in the benthic samples differed during the spring surveys. Diptera larvae (54.5%) and ephemeroptera nymphs (21.4%) comprised most of the benthic invertebrates at the upper site. Diptera larvae (54.3%) and freshwater clams (29.0%) were numerous at the middle site, while oligochaetes (53.8%) and freshwater clams (29.7%) were abundant at the lower sites. In the spring, more benthic invertebrates were at the upper site (7,255.6/m^2) than at the middle (3,066.7/m^2) or lower sites (1,011.1/m^2).

During the fall, both the upper and lower drift fauna were comprised mainly of diptera and trichoptera larvae. Emphemeroptera and diptera larvae were most abundant in the drift at the middle site. During the spring sampling, cladocerans dominated the drift at the upper site (90.6% of total). Ephemeropterans and oligochaetes were numerous in the drift at the middle site. Drift at the lower site was comprised mainly of diptera, cladocerans, ephemeroptera nymphs, and clams. Drifting invertebrates were more numerous at the upper site during both sampling periods.

Use of the Lower Mokelumne River from Woodbridge Dam to the extent of tidal influence by native warmwater fish and important introduced species (i.e, American shad and striped bass) was documented (Task 7). The fish assemblages of the Lower Mokelumne River were determined from field surveys by EBMUD and BioSystems. The results of these surveys indicate that there are 8 native species and 18 introduced species in the Lower Mokelumne River. None of these findings indicate that American shad or striped bass were in the lower river during the dry years from 1990 to 1992.

Most aspects of chinook salmon life history in the Mokelumne River were examined during the three year study. Adult escapement patterns (Task 9), redd construction (Task 10), fry emergence patterns (Task 12), rearing fry distribution (Task 13), and fry and smolt out-migration (Task 14) were documented.

Chinook salmon escapement into the Mokelumne River was documented during October-December in 1990 and 1991 using a video monitoring system and a fish trap in the Woodbridge Dam fish ladders (Task 9). In 1990, our in-migration study documented 497 chinook salmon migrating past Woodbridge Dam between 1 October and 15 December. Thirty-one percent of the salmon migrating past the dam were grilse (fish <61 cm TL); the remaining 69 percent were adults. No clear division of the length frequencies of adult and grilse salmon was apparent. Male salmon comprised 62 percent

of migrating fish, female salmon made up 35 percent; the remaining 3 percent of the fish were not identified to sex.

In 1991, it was estimated that 410 chinook salmon migrated past Woodbridge Dam between 1 October and 29 December. Of these fish, 85 percent were adults and 15 percent were grilse. Females comprised a higher proportion of fish in 1991 than in 1990, accounting for 47 percent of the total fish. Males comprised 46 percent, while 7 percent were not identified to sex.

The influence of precipitation on the overall size of the runs in 1990 and 1991 does not appear to be significant. During the 1990 migration season, 38 percent of all salmon passed the dam during precipitation events while 62 percent migrated during periods with no precipitation. In 1991, 30 percent of all salmon passed the dam during precipitation events, while 70 percent migrated during periods with no rainfall. In-migration in both years was preceded by attraction flows provided by EBMUD.

During the spawning seasons of 1990-1991 and 1991-1992, EBMUD conducted surveys on the river to document the spatial and temporal distribution and size of chinook salmon redds (Task 10). During the 1990-1991 spawning season, a total of 115 potential redds were identified; of these, 28 redds were categorized as abandoned or incomplete and 14 redds represented multiple redds superimposed upon each other. Over half of the redds (57%) were between Camanche Dam and Mackville Road. The peak in redd construction was during the third week of November. Mean redd size was 10.6 m^2 (range 0.5-33.1 m^2).

During the 1991-1992 spawning season, a total of 127 redds were identified, of which 27 were incomplete or abandoned and five were categorized as superimposed. Redds were equally distributed above and below the Mackville Road. Two peaks of redd activity were observed, one during the fourth week of November and one during the third week of December. Mean redd size was 5.5 m^2 (range 0.5 - 33.5 m^2). Of the completed solitary redds, many (55%) were located at the top of the habitat; almost all (86%) were on berms (gravel ridges). Most of these berms were oriented perpendicular to streamflow.

Using information on chinook salmon habitat preference and aquatic habitat quality and quantity, the maximum number of female spawners that can be supported in the Camanche reach of the Mokelumne River was estimated (Task 11). Three types of spawning habitat (potential, weighted usable area [WUA], and preferred) were considered in this analysis. Potential habitat encompasses all spawning habitat identified and measured during mapping surveys on the Mokelumne River (Task 4). Chinook salmon spawning WUA was determined from the 1987 IFIM studies (Envirosphere 1988). Preferred habitat is based on spawning habitat selection, as described in the scientific literature and actually observed during redd surveys (Task 10). The total area of spawning habitat was divided by the mean redd area (5.5 m^2) observed during the 1991-1992 spawning season (Task 10) to estimate the carrying capacity for chinook

salmon spawners. Using the estimates of preferred and WUA habitat, it's estimated that from 2,282 to 5,212 spawning females can construct redds without superimposition in the Mokelumne River. Using BioSystem's estimate of potential habitat, the predicted number of female spawners is 15,888. The estimates of all three types of spawning habitat are probably too high, especially since the classification of spawning habitat was qualitative and does not take into account microhabitat features such as embeddedness or armoring that would further lessen spawning quality.

Fry emergence was monitored from 28 chinook salmon redds in 1991 to assess the effect of water temperature and substrate conditions on spawning success (Task 12). Based on results from the 1991 study, the study design was modified in 1992 to include the use of incubation capsules in controlled laboratory and field experiments to quantify the effect of water temperature on spawning success. Twelve wild salmon redds were trapped in 1992 to further evaluate the effect of substrate conditions on spawning success and to quantify any effects emergent trapping may have on egg survival and subsequent production estimates.

In 1991, 19 (68%) of the 28 monitored redds produced fry. The mean number of fry emerging per redd was 128.2 and ranged from 0 to 1,519. The mean length of emerging fry was 35.9 mm TL. In 1992, 8 (68%) of the 12 monitored redds produced fry. The number of fry produced per redd averaged 312.9 and ranged from 0 to 1,768. The mean length of emerging fry in 1992 (38.2 mm TL) was significantly larger than fry emerging in 1991. During these studies, it was found that the location and size of the emergent trap did not appear to have an affect on fry production estimates. In addition, it was concluded that the emergent traps are not smothering eggs and do not appear to differentially effect egg survival in selected redds.

The size distribution of substrate collected from salmon redds in 1991 and 1992 were similar. Overall, gravel-size particles (6.3-7.5 mm) dominated the substrate in wild salmon redds in both years. In 1991, 72 percent of the redds sampled contained fines at levels known to reduce egg survival (i.e., 10-15% of 6-12 mm fines; Chapman 1988). In 1992, 75 percent of the redds sampled contained high amounts of fines. In 1991 it was found that fry emergence from wild redds was inversely related to the percentage of fines; however, no similar correlation was found in 1992 wild redds, an indication that other factors are influencing fry emergence.

During the 1992 experimental studies, results from the hatchery ambient location and Mackville and Van Assen Park sites were consistent with the hypothesis that warm temperatures in the river early in the incubation period reduce egg survival. The data suggest that many factors unrelated to habitat quality may influence the number of fry collected in emergent raps; therefore, emergent trapping results require very careful interpretation.

Following the emergence period, annual seining surveys were conducted by EBMUD to determine the relative abundance, distribution and condition of rearing chinook salmon

and steelhead rainbow trout in the Mokelumne River between Camanche Dam and Lake Lodi from 1990 to 1992 (Task 13). The effects of in-river conditions on these variables were also evaluated between years.

Chinook salmon fry were most abundant at seining sites located from Camanche Dam to downstream of Mackville Road from late February to late April; based on these results, the vast majority of salmon rearing occurs upstream of Elliott Road, particularly in the vicinity of Mackville Road. Steelhead rainbow trout fry were more abundant in 1991 (79 fish) and 1992 (81 fish) than in 1990 when only five fry were captured. Four sites sampled in all three years were used to test differences in CPUE between sampling periods and years. A higher catch per unit effort (CPUE) was observed in 1992 than in 1991; however, the CPUE in 1990 was not significantly different than that observed in 1991 or 1992. The high CPUE in 1992 corresponds with relatively greater numbers of smolts captured in downstream traps (Task 14).

Fry out-migration was monitored during winter and early spring in 1991 and 1992 with fry traps installed immediately downstream of the Bruella Road Bridge (Task 14). In 1991, most fry captured in the traps were suckers (n=82); only two salmon fry were caught. More salmon fry (n=1,122) were caught in the Bruella fry traps between February and March in 1992. Because mark-recapture studies conducted that year indicated a 17 percent recapture rate, the actual total number of salmon fry migrating past Bruella Road was estimated at 6,759 fish (range 4,266-16,261). The greatest fry out-migration peak was observed in early March.

The out-migration of chinook salmon smolts in the Mokelumne River at Woodbridge Dam was monitored during the late spring and early summer of 1990, 1991, and 1992 (Task 14). Both the lower and upper fish ladders at the dam were monitored. Smolts were injected with coded wire tags (CWT) and transported to the Sacramento River downstream of the Delta (Bennett's Marina) because of high water temperatures in the river downstream of the dam and in the Delta.

In all years, chinook salmon was the most abundant species trapped. The number of out-migrating chinook salmon smolts was 78,179 in 1990, 31,025 in 1991, and 69,993 in 1992. In 1990, peak out-migration occurred during 8-21 June when over 40 percent of the salmon were caught. In 1991 and 1992, peak out-migration occurred in May when over 60 percent of the total smolts were caught during both years. In 1990 and 1991, most salmon smolts (89 percent and 76 percent, respectively) were caught in the lower trap at Woodbridge Dam; however, in 1992, most salmon smolts (64%) were captured in the upper trap. Statistical analyses indicate that flow and temperature had little effect on the number of smolts out-migrating past Woodbridge Dam in all three years.

In all three years, we observed a bimodal distribution of lengths of out-migrating salmon represented by both young-of-year (YOY) and one-year-old fish. YOY fish accounted for over 95 percent of the salmon caught at Woodbridge Dam. The overall mean total length of out-migrating YOY salmon was 109.3 mm in 1990, 108.1 mm in 1991, and 106.9

C-100989

in 1992. Although the mean length per year differed less than 3 mm between years, there was a significant decrease in length from 1990 to 1992. The condition factor of YOY salmon in 1991 was significantly higher than YOY sampled in 1990 or 1992.

During diel migration studies conducted in 1990, 1991 and 1992, the peak catch of out-migrating smolts occurred between 0400 and 1000 hrs (1990 = 66 %, 1991 = 72%, and 1992 = 79%). Only about 2 percent of the smolts were caught during darkness in each year.

The total number of out-migrating steelhead trapped at Woodbridge Dam was 4,196 in 1990, 4,026 in 1991, and 174 in 1992. These trout were reared in the MRFH and stocked as catchable trout in the upper river.

Mark and recapture studies were conducted in the Mokelumne River in 1990 to document the mortality of out-migrating chinook salmon in Lake Lodi (Task 15). Two pilot studies were conducted on 24 May and 12 June 1990 to assess smolt mortality in Lake Lodi. Approximately 2,000 hatchery chinook salmon smolts were dye marked using a Panjet and released into the upper region of the lake. Fish were recaptured in fish traps located in the upper and lower fish ladders at Woodbridge Dam. In the first pilot study, only 10.1 percent of the released smolts were recaptured. However, we suspect that the survival rate of marked smolts was underestimated because water spilled over the dam allowing fish to move through the lake undetected. In the second pilot study, no water flowed over the dam and 29.1 percent of marked smolts were recaptured.

Due to the high mortality (70.9%) observed in Lake Lodi in the second pilot study in 1990, more detailed mark and recapture studies were conducted in the Mokelumne River in 1991 to document the mortality of out-migrating chinook salmon in the river between Camanche Dam and Lake Lodi, through Lake Lodi, and at the fish screen at the entrance to the WID Canal (Task 15). Marked smolts were released in the river at Camanche Dam, near the confluence of the river and Lake Lodi at Bruella Road, and in Lake Lodi near the fish screens. Marked fish were released at all these locations at three different times (11-12 May, 23-24 May, and 5-7 June). At each time period, approximately 5,000 marked smolts were released at each of the river sites and 500 fish were released in front of the fish screens. Recapture rates for the three combined release dates were 20.9 percent of those released at Camanche Dam, 22.8 percent of those released at Bruella Road, and 23.5 percent of those released at the diversion screens. The majority of marked smolts (>70%) from each of the release sites were recaptured within 5 days.

Recapture rates of fish released at all the sites dropped substantially from early May to early June. Survival rates during the early May release in 1991 were 36.6 percent for the Camanche release, 35.0 percent for the Bruella Road release, and 40.4 percent at the fish screens. During early June, only 5.3 percent of marked smolts were recaptured from the Camanche release, 10.0 percent from the Bruella Road release, and 14.6 percent

C-100990

from the fish screen release. Water temperatures in Lake Lodi and diversion flows in the WID Canal increased considerably during the mark and recapture study.

To document the mortality of out-migrating chinook salmon smolts in the Delta, two groups of approximately 100,000 hatchery fish were injected with CWTs at the MRFH in both 1991 and 1992 (Task 15). In 1991, an estimated 80,041 and 101,980 tagged fish were released at the confluence of Delta water and the Lower Mokelumne River (New Hope Marina) on 23 April and 6 May, respectively. Fish were recaptured at Chipps Island during trawling studies by M. Kjelson of the USFWS. The survival index was 1.63 for the first CWT group and 0.45 for the second CWT group. In 1992, BioSystems released approximately 100,508 and 99,740 tagged smolts on 23 April and 6 May, respectively. The survival index was 0.13 for the first group and 0.06 for the second group.

Using results from the field studies we evaluated the effects of temperature on the timing of out-migration (Task 16) and the survival estimates of Mokelumne River chinook salmon (Task 17). Our analyses indicate that chinook salmon are stimulated to out-migrate from the Mokelumne River once they have accumulated a certain number of daily temperature units, rather than being stimulated by changes in flow, temperature or other environmental factors during the rearing period (Task 16). For the 1990-1991 year class, the number of degree days (DD) required for fry to develop into out-migrating smolts averaged 1,948 (range 1,851-2,015). For the 1991-1992 year class, the number of DD averaged 1,928 (range 1,887-1,971). These means were statistically similar.

The overall survival rates (from incubation through out-migration) of salmon which migrate into the Mokelumne River under different temperature conditions were compared (Task 17). The in-migrating salmon were separated into two groups based on their temperature exposure: the warmwater group included fish that spawned at temperatures greater than 15.5°C, while the cold water group included fish that spawned when temperatures were less than 15.5°C. The survival rates for egg-to-smolt out-migration in the river were less than 0.10 for the warmwater population, but ranged from 0.24 to 0.39 for the cold water population. The survival rate of smolts in Lake Lodi decreased exponentially over time. The overall survival rate of the salmon population averaged 0.011 (range 0.006 and 0.015) in warm water and averaged 0.014 (range 0.010-0.019) in cold water.

Aquatic habitat conditions and fish abundance in the Mokelumne River between Pardee and Camanche reservoirs were documented during winter 1990 (Task 18). Pools (86%) were the most abundant habitat by area in this reach of the river, followed by runs (8%). Overall, fines (50%) were the predominant substrate in the river followed by cobble (22%) and boulder (18%). The amount of spawning habitat for rainbow trout was minimal throughout this reach.

Sculpins (84%) and rainbow trout (14%) were the most abundant fish collected in riffles and runs during electrofishing survey. Rainbow trout (44%) and Sacramento suckers (44%) were the most abundant fish capture in pools during gill net surveys.

C-100992