ENTRIX

CHINOOK SALMON FRY OUTMIGRANT PILOT STUDY
MOKELUMNE RIVER, CALIFORNIA
PHASE I
SPRING 2000

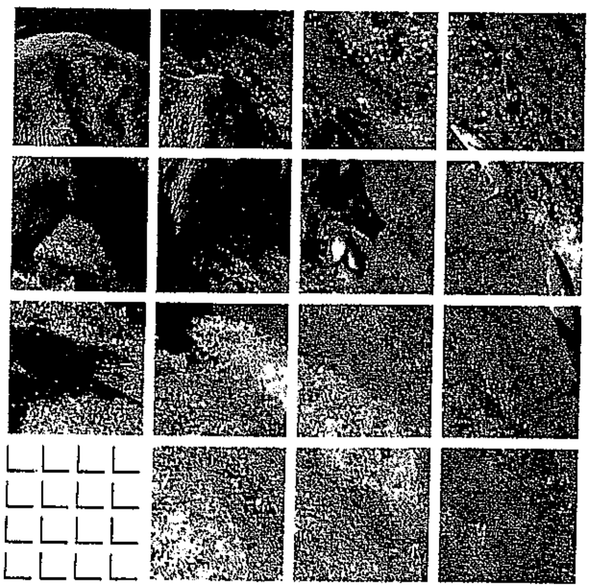
Prepared for:

CALIFORNIA URBAN WATER AGENCIES
Sacramento, CA

Prepared by:

ENTRIX, INC.
2601 Fair Oaks, Suite 200
Sacramento, CA 95684

S.P. Cramer and Associates
P.O. Box 247
Mi Wok Village CA 95346



Project No. 310501

July 2001

CHINOOK SALMON FRY OUTMIGRANT PILOT STUDY
MOKELUMNE RIVER, CALIFORNIA
PHASE I
SPRING, 2000

Prepared for:

CALIFORNIA URBAN WATER AGENCIES
Sacramento, CA

Prepared by:

ENTRIX, INC.
2601 Fair Oaks, Suite 200
Sacramento, CA 95684

S.P. Cramer and Associates
P.O. Box 247
Mi Wok Village CA 95346

Project No. 310501

July 2001

Page

Page

Fall-run chinook salmon of the Central Valley in California exhibit variable juvenile life stage rearing strategies (Allen and Hassler 1986). The growing body of information show two outmigration events, an early outmigration of fry immediately following emergence in January-February and a second outmigration of smolts in May-June (Workman 1999, Snyder and Titus 1995, Snyder and Titus 1998, Demko and Cramer 1996,). Fall-run chinook salmon juveniles use the Sacramento/San Joaquin Delta (Delta) for rearing according to Rich (1920), Kjelson et al. (1981,1982), Brandes and McLain (In Press), and Sommer et al. (2000). Delta habitat may be very important for fry in late winter and early spring when water temperatures are low. Smolts that enter the Delta in May or June encounter water temperatures that are typically higher than optimal levels so they are unlikely to remain in the Delta for extended periods. Additional predation risk exists for smolts when warm water temperatures increase feeding rates by piscine predators on juvenile salmon. Ongoing studies on smolt-sized salmon in the Central Valley rivers and Delta are designed to expand the knowledge base and improve management of this valuable resource. The fate of fry that outmigrate from Central Valley rivers is not well understood. This pilot study was undertaken to begin developing information on this potentially valuable early life history strategy.

Chinook salmon have the most varied and complex life history of the five Pacific salmon species (Healey 1980) except for steelhead. Life history strategies vary greatly in regard to upstream migration timing, timing of spawning and rearing strategies (Myers and Horton 1982). There are four recognized runs, fall, late-fall, winter and spring, each defined by the timing of the adult entry into freshwater. The Sacramento-San Joaquin system is the only system supporting all four runs of chinook salmon (Groot and Margolis 1991). Juvenile chinook can spend as long as a year or more in fresh water (defined as stream-type) or as little as a few months in fresh water before migrating to the ocean (ocean type) (Healey 1982; Allen and Hassler 1986). The Mokelumne River supports a fall run of ocean type chinook salmon. The only other anadromous salmonid it supports is a run of steelhead.

Fry outmigration has been documented in several Central Valley rivers including the American, Sacramento, Stanislaus and Tuolumne (Snyder and Titus 1995, 1998; Demko and Cramer 1996). Some chinook may depend solely on estuaries for nursery habitat, while others may only use it as a migration corridor (Healey 1982, 1980, Kjelson et al. 1981). Kjelson et al., (1981, 1982) noted that salmon rearing in the Sacramento-San Joaquin Delta are resident for approximately two months before migrating seaward. Estuary/delta rearing is seen as an active behavior rather than a passive displacement (Mains and Smith 1964).

In the Lower Mokelumne River (between Camanche and Woodbridge Dams), fry tend to utilize the river edges and remain near the surface (Workman 1999). Other investigators have found that during high flows new habitat may become available during floodplain inundation as demonstrated in the Yolo Bypass (Sommer et al. 2000) and on the Cosumnes River floodplain (Moyle unpublished data).

CUWA recognizes that water management activities combined with restoration actions advanced through the Anadromous Fish Restoration Program (AFRP) of the Central Valley Project Improvement Act (CVPIA) are directed at improving conditions for anadromous salmonids. By far the majority of these activities have been directed at improving habitat conditions or survival of smolt-sized fish. For example, longterm studies conducted in the San Joaquin River have been exclusively focused on assessing smolt survival (USFWS 1997, 2000). Recently, the USFWS has conducted pilot studies to explore the salmon fry habitat and habitat use in the lower Sacramento River and Steamboat slough (McLaine, pers com, 2001).

There is limited information on habitat use by fry. This pilot study was undertaken as Phase 1 of a "Juvenile Chinook Salmon Rearing River and Delta Habitat Study" to determine:

- if salmon fry can be effectively captured in riverine and tidally influenced habitats
- to assess which collection methods work best
- to characterize the habitats available for salmon use in the study area
- to assess habitat use, growth and outmigration timing of salmon fry using habitats in the study area.

See 4-27

The Mokelumne River provides ~~is~~ a suitable system to conduct such a pilot study for several reasons. First it is close to the Delta, minimizing the geographic area to conduct a pilot study in both riverine and tidally influenced habitats. Secondly, there is a basic understanding of fry and smolt use of the Lower Mokelumne River (Workman 1999, Hartwell, 1990-1996). There is a good record of the timing of the fall-run chinook fry and smolt outmigrations from the operation of rotary screw traps (RST) at Woodbridge Dam. Fry and smolt studies continue to be conducted in the lower Mokelumne River as part of a water rights agreement between East Bay Municipal Utilities District (EBMUD) and the State Water Resources Control Board (SWRCB). Additionally, The Nature Conservancy's Cosumnes River Preserve is conducting studies of floodplain use by salmon and other fish species also in the watershed.

A final objective of this study is to share the findings of this pilot effort with resource managers in an effort to refine additional studies and obtain funding to carry such studies forward.

The study area includes the Mokelumne River from Woodbridge Dam to the confluence of the San Joaquin River (Figure 2-1). The study area is located in Northern San Joaquin and Southern Sacramento Counties and is bordered by Highway 12 to the south, Highway 99 to the East, Twin Cities Road to the North and the Sacramento River to the West. The upstream end of the project is located at Woodbridge Dam, in the town of Woodbridge, on the western edge of the town of Lodi. From Woodbridge Dam, the Mokelumne River runs northwest toward the town of Thornton and the confluence with the Cosumnes River, also known as Benson's Ferry. The river then turns west to New Hope Landing where it branches into the North and South Mokelumne Rivers. The river channels turn south toward Highway 12. Just north of Highway 12, the South Mokelumne River turns west to join the North Mokelumne River. After rejoining, the channel turns south to flow into the San Joaquin River (Table 2-1).

The lower 2 miles of the Cosumnes River, Snodgrass Slough (up to Twin Cities Road), and Beaver, Hog, and Sycamore sloughs were included in the study area. Dry Creek, a major tributary to the Mokelumne River was not included because it is leveed from the Mokelumne River and water and fish cannot freely move between the two systems. Potato Slough was also sampled because it is another route for Mokelumne River salmon fry to move out into the Delta, although it was not included as part of the initial study area. Overall, the study area included 49 miles of Mokelumne River channel. River Mile (RM) 0 is located at the confluence with the San Joaquin River and RM 39, as measured along the South Fork, is located at Woodbridge Dam. The North Fork Mokelumne River is about 10 miles in length.

The entire river is a low gradient, sand bed, alluvial river channel. Most of the river from Woodbridge Dam to the confluence with the San Joaquin River is confined by reclamation district levees. The levees are typically located close to the banks of the main channel, allowing only limited flood plain to interact with the river. Rip rap is a found on a few outside bends in reach M2, but overall is a relatively minor component in this Reach. However, it is the dominant bank feature in the remaining reaches of the Mokelumne River. Numerous irrigation diversions are also present in Reach M2, M1 and SM and NM. Reaches M1, SM and NM also receive agricultural drain water. The entire study area is influenced by tides, but the influence is attenuated as distance upstream of New Hope Landing increases.

Tidal influence in the study area is attenuated during high runoff conditions. Tidal influence affected water surface elevations and water velocities, but did not result in flow reversal during the study period in reaches M1 or M2. Reaches SM, NM and M are strongly influenced by tidal action.

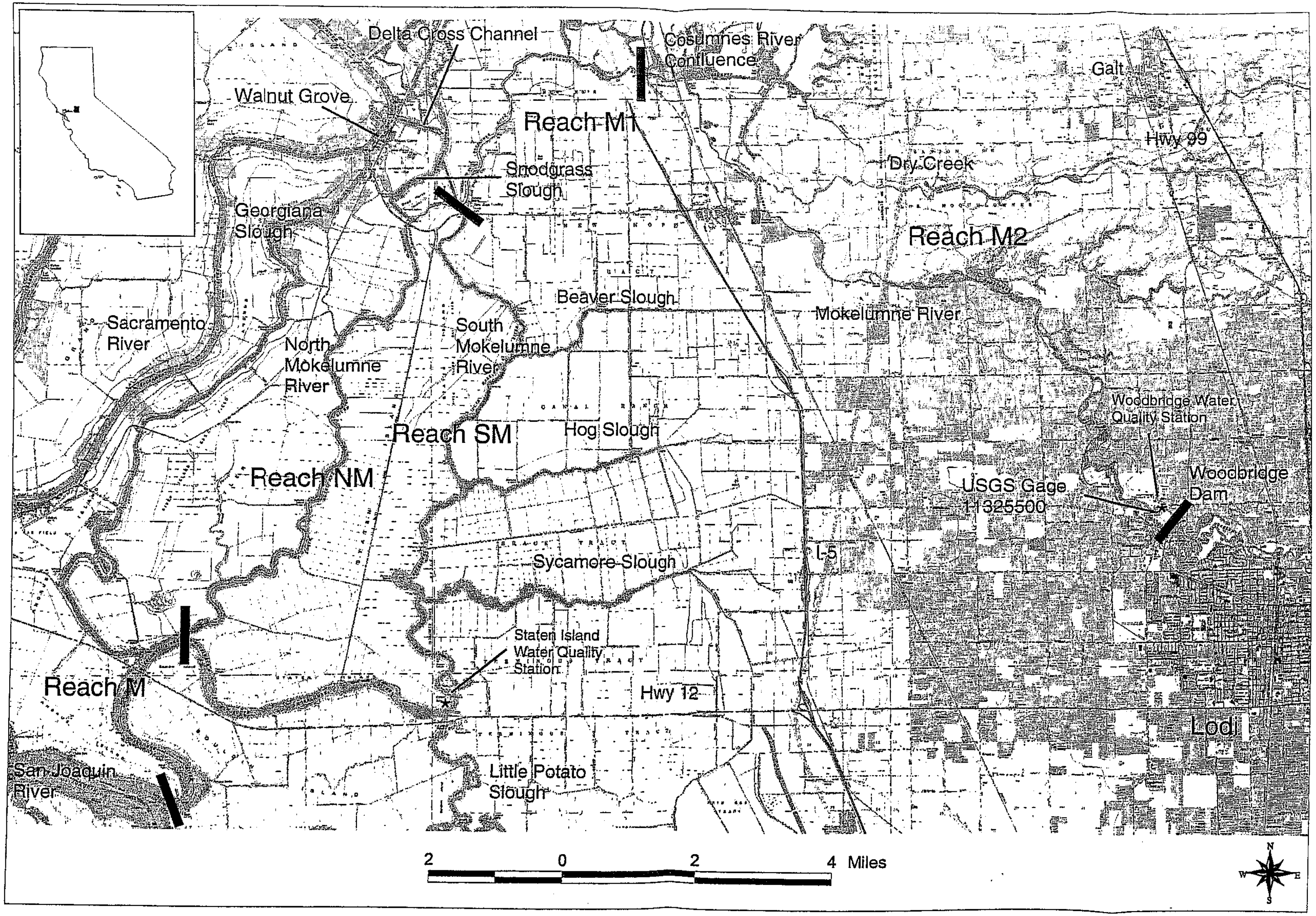
The study area includes the Mokelumne River from Woodbridge Dam to the confluence of the San Joaquin River (Figure 2-1). The study area is located in Northern San Joaquin and Southern Sacramento Counties and is bordered by Highway 12 to the south, Highway 99 to the East, Twin Cities Road to the North and the Sacramento River to the West. The upstream end of the project is located at Woodbridge Dam, in the town of Woodbridge, on the western edge of the town of Lodi. From Woodbridge Dam, the Mokelumne River runs northwest toward the town of Thornton and the confluence with the Cosumnes River, also known as Benson's Ferry. The river then turns west to New Hope Landing where it branches into the North and South Mokelumne Rivers. The river channels turn south toward Highway 12. Just north of Highway 12, the South Mokelumne River turns west to join the North Mokelumne River. After rejoining, the channel turns south to flow into the San Joaquin River (Table 2-1).

The lower 2 miles of the Cosumnes River, Snodgrass Slough (up to Twin Cities Road), and Beaver, Hog, and Sycamore sloughs were included in the study area. Dry Creek, a major tributary to the Mokelumne River was not included because it is leveed from the Mokelumne River and water and fish cannot freely move between the two systems. Potato Slough was also sampled because it is another route for Mokelumne River salmon fry to move out into the Delta, although it was not included as part of the initial study area. Overall, the study area included 49 miles of Mokelumne River channel. River Mile (RM) 0 is located at the confluence with the San Joaquin River and RM 39, as measured along the South Fork, is located at Woodbridge Dam. The North Fork Mokelumne River is about 10 miles in length.

The entire river is a low gradient, sand bed, alluvial river channel. Most of the river from Woodbridge Dam to the confluence with the San Joaquin River is confined by reclamation district levees. The levees are typically located close to the banks of the main channel, allowing only limited flood plain to interact with the river. Rip rap is a found on a few outside bends in reach M2, but overall is a relatively minor component in this Reach. However, it is the dominant bank feature in the remaining reaches of the Mokelumne River. Numerous irrigation diversions are also present in Reach M2, M1 and SM and NM. Reaches M1, SM and NM also receive agricultural drain water. The entire study area is influenced by tides, but the influence is attenuated as distance upstream of New Hope Landing increases.

Tidal influence in the study area is attenuated during high runoff conditions. Tidal influence affected water surface elevations and water velocities, but did not result in flow reversal during the study period in reaches M1 or M2. Reaches SM, NM and M are strongly influenced by tidal action.

Figure 2-1. Mokelumne River Study Area from Woodbridge Dam to the San Joaquin River Showing Major Features and the Study Reaches.



ENTRIX, Inc.

The amount of riparian vegetation and habitat found on the levees or adjacent to the channel varies greatly by reach. Reach M2 contains most of the riparian vegetation within the study area. The Cosumnes River and portions or Snodgrass Slough also contain well developed riparian communities. The riparian community includes Valley Oaks (*Quercus lobata*), Fremont cottonwood (*Populous fremontii* ssp. *fremontii*), White alder (*Alnus rhombifolia*), California sycamore (*Platanus racemosa*), willows (*Salix* spp.), Black walnut (*Juglans californica*), Oregon ash (*Fraxinus latifolia*) and Box elder (*Acer negundo* var. *californicum*). Freshwater marsh and scrub shrub are present in areas where larger woody vegetation does not dominate.

The Mokelumne River within the study area was divided into five reaches. Reach M2, the most upstream reach, is located between Woodbridge Dam and the confluence with the Cosumnes River. Reach M2 is 15.7 miles in length and is riverine aquatic habitat with only minor tidal influence during the period of the study. Flow in this reach is regulated by releases from Camanche Reservoir, located at RM 64, and diversions at Woodbridge Dam. Habitat features in the channel are limited to deep runs alternating with indistinct pools. No riffles are present. The channel is relatively narrow ranging between 40-80 ft in width. Steep banks are prevalent throughout this entire reach, with the exception of the few point bars, where more gradual slopes exist (Table 2-1).

Table 2-1 Descriptions of reaches within the study area.

Channel	Reach Descriptions	River Miles	Reach Designation
Mokelumne	Woodbridge Dam to confluence with the Cosumnes River (Bensons' Ferry)	RM 39 to RM 23.3	M2
	Cosumnes River to New Hope Landing (Wimpy's Marina)	RM 23.3 to RM 19	M1
	North Fork	RM 0 to RM 10	NM
	South Fork	RM 19 to RM 3.9	SM
	Confluence of NF and SF to the San Joaquin River	RM 3.9 to RM 0	M
Cosumnes	Confluence with Mokelumne to 2 miles upstream	RM 0 to RM 2	C
Snodgrass Slough	Spot Sampled	Not stationed	SS
Sycamore Slough	Spot Sampled	Not stationed	SS
Potato Slough	Spot Sampled	Not Stationed	PS

Reach M1 is located between the confluence of the Cosumnes River and New Hope Landing, where the river divides into the North and South Mokelumne Rivers. Reach M1 is 4.3 miles in length and is primarily riverine in nature with some tidal influence during the study period. This reach conveys flows from Reach M2, but also receives unregulated flows from the Cosumnes River. The reach is similar in appearance to reach M2, however, the banks of the entire reach are covered with older rip rap interspersed with mature trees and understory vegetation. This reach is wider than reach M2, ranging from 60 to 120 ft in width. Several mid-channel islands exist in this reach.

Reach SM includes the South Mokelumne River channel from New Hope Landing to the confluence with the North Mokelumne River, a distance of 15.1 miles. This reach was strongly influenced by tidal action during the study period. Woody riparian vegetation is limited to the upper reaches of the South Mokelumne River, principally upstream of Beaver Slough, and to a few restoration sites at more downstream locations. The channel width varies from about 60 to 120 ft in the upper reaches gradually widening in a downstream direction to about 300 to 400 ft. Solitary alders, sycamores, cottonwoods and willows occupy the rip rap covered levees along this reach south of Beaver Slough. Hog and Sycamore sloughs are also tributary to the South Mokelumne River. Little Potato Slough connects with the South Mokelumne River near Highway 12, where the South Mokelumne River bends toward the west before rejoining the North Mokelumne.

Reach NM includes the North Mokelumne River channel from New Hope Landing to the confluence with the South Mokelumne River, a distance of 10 miles. This reach was strongly tidally influenced during the study period. Nearly all of this reach is devoid of large woody vegetation, except for occasional solitary trees. Sparse scrub shrub such as Himalayan blackberry (*Rubus discolor*) a few willows (*Salix* spp.) and emergent vegetation such as bulrushes (*Scirpus* spp.) and cattail (*Typha latifolia*) are the dominant vegetation types found along the channel. Snodgrass Slough is a tributary to this reach. Channel widths in the North Fork are similar to the South Fork also increasing in a downstream direction.

Reach M includes the Mokelumne River channel from the confluence of the North and South Mokelumne rivers to the confluence of the San Joaquin River, a distance of 3.9 miles. This reach is strongly influenced by tidal action. Georgiana Slough, a distributary channel of the Sacramento River joins the Mokelumne River just north of Highway 12. The channel at this location is about 600 to 800 ft wide and is bordered by beds of emergent vegetation inside rip rap covered levees. Woody riparian vegetation exists along the west bank near the confluence of Georgiana Slough and along areas associated with marinas. Several marinas occupy the west shore of this reach between Georgiana Slough and the confluence with the San Joaquin River.

The study area also includes the lower 2 miles of the Cosumnes River (Reach C), Snodgrass Slough (SS) and Sycamore Slough (SC). Potato Slough (PS) was also sampled but was not included in the initial study area.

The banks of Beaver, Hog and Sycamore sloughs are similar in appearance to the banks of the South Mokelumne River, with a dominant cover of rip rap and an occasional tree. Sycamore slough has multiple mid channel beds of emergent vegetation, usually *Scirpus* spp. All three sloughs become progressively narrower toward their upper ends. Hydrologically, they are influenced by agricultural practices and by tidal action to a minor extent.

Snodgrass Slough is a complex set of channels associated water courses draining Laguna Creek and the Stone Lake area south of Sacramento. Lost Slough, a high flow distributary channel originating from the Cosumnes-Mokelumne River confluence, joins the Snodgrass Slough complex in the Delta Meadows area near the town of Locke. The Delta Cross Channel discharges into Snodgrass Slough and water from the Cross Channel is conveyed into the North Mokelumne River through Dead Horse Cut. Snodgrass Slough also connects to the North Mokelumne near Walnut Grove. During non-flood events, or times when the Delta Cross Channel is closed, Snodgrass Slough is influenced by tides and river flow from the Delta Cross channel – Dead Horse Cut south. North of the Delta Cross Channel and Dead Horse Cut, the primary influence is tidal, but this is relatively weak. The banks along the Cross Channel, Dead Horse Cut and between the Cross Channel and North Mokelumne along Snodgrass Slough are covered with rip rap. Most of the remaining banks are more natural in appearance with vegetation of dense willows, cottonwoods, Oregon ash Valley Oaks and sycamores. The slough channels vary in width and depth.

The methods for fish collection, habitat characterization, and data processing are described below. The methods employed in this study are in general consistent with the Pilot Study approach. Deviations from the proposed approach are described.

3.1 FISH SAMPLING

The objectives of the fish sampling program were to determine where chinook fry are located so that abundance or catch information can be linked with habitat information to identify preferential habitat use. Several sampling techniques were employed to determine which methods were most efficient for the habitat and flow conditions that existed during the winter and early spring. Sampling was conducted between February 29 and April 5, 2000 using beach seines, boat and backpack electrofishing, fyke traps and minnow traps. Trawling, cast nets and direct observation were other methods that were proposed but proved infeasible for various reasons.

3.1.1 BOAT ELECTROFISHING

A 14 ft. electrofishing boat manufactured by Smith-Root and equipped with a 50 hp outboard motor was used for sampling between March 1 and March 22 in all reaches of the study area. The boat is equipped with a pulsed current generator that was usually set around 120 pulses and 4-6 amps, and was adjusted in response to changing water quality conditions. Sampling was conducted primarily during daylight hours. Several attempts were made to sample at night to evaluate differences in electrofishing capture rates. Only a few night time surveys were ultimately conducted due to difficulty navigating and sampling at night in the study area.

Different sampling protocols for boat electrofishing were employed in riverine and delta reaches. In M1 and M2 boat electrofishing was conducted at sample sites along shoreline areas of consistent habitat and in mid channel locations for a timed interval ranging from a few minutes up to 30 minute time periods. Sampling began at the downstream end of the site and the boat was maneuvered slowly upstream along the bank. The boat operator kept the boat parallel to or at a slight angle to shore while the netting crew operated the on/off switch intermittently applying current to the water. In the tidally influenced delta reaches NM and SM, the sampling approach was adjusted to account for different wind and tidal conditions. When working with the current, the operator typically keep the boat perpendicular to the shoreline with the bow of the boat, and the anodes sweeping along the edge of the waterway.

The field technicians wore polarized sunglasses, making it easier to locate stunned fish below the water's surface. Stunned fish were removed from the water and placed into a divided holding tank aboard the boat. Larger predatory fish were held separately from smaller fish. The following information was collected for each sampling event:

- Sampling time interval
- Number of chinook caught
- Number and species of other fish caught
- Standard fork length or total length depending on species, and
- Condition relative to smoltification.
- Habitat features including shoreline habitat, bank angle and water quality parameters
- Global Positioning System (GPS) location of the sampled reach (Garmin Model III Plus using WAD 84 datum)

The results were recorded on a standardized data sheet.

After the fish sample processing was completed and the catch data was worked up, habitat information was collected for each site as described in Section 3.2. Boat electrofishing sites are displayed in Figure 3-1.

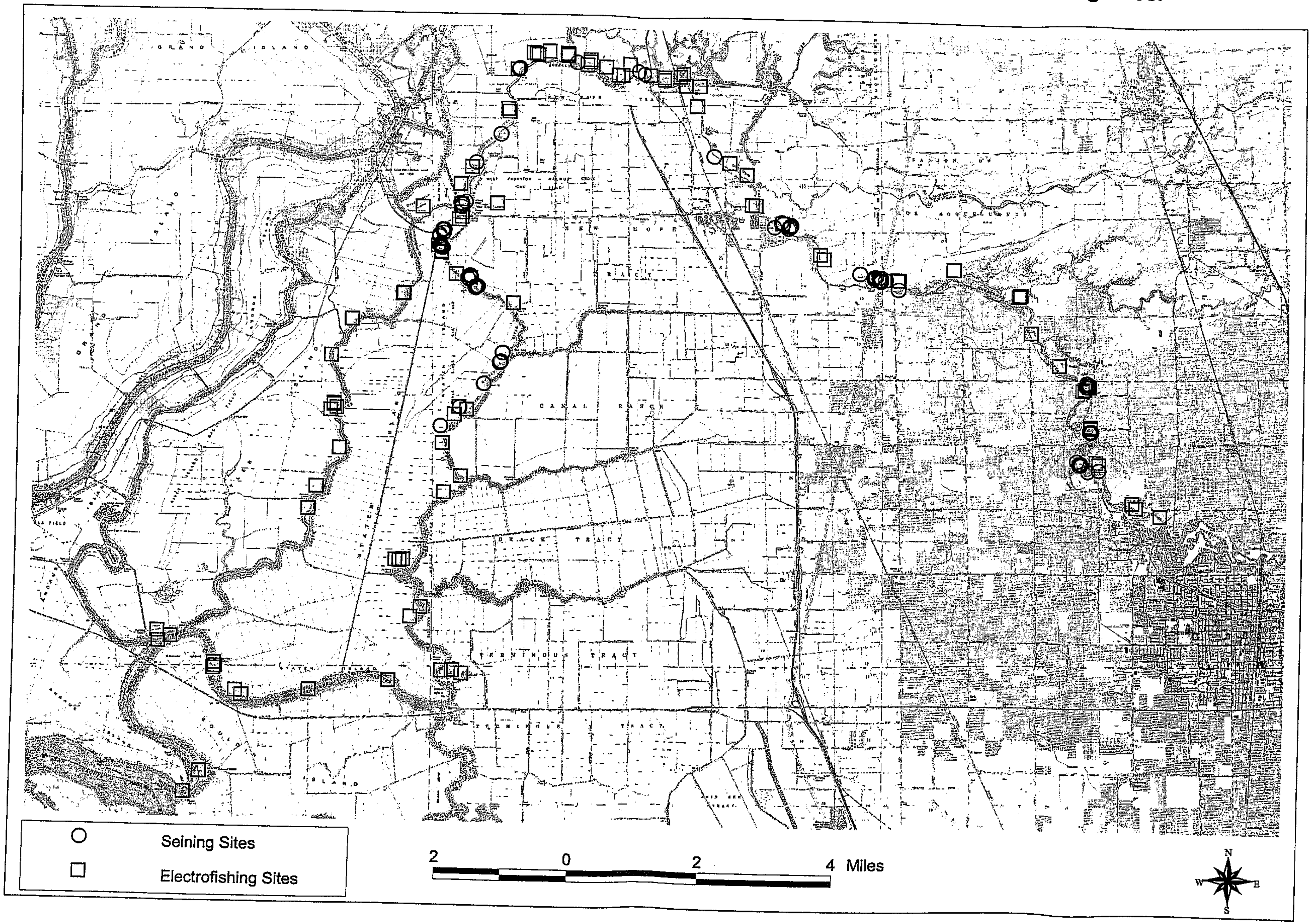
3.1.2 BEACH SEINE

Both 25 and 50 foot beach seines of 3/16" mesh were used in this study. Seines were employed in areas where the bottom was relatively free of obstructions such as woody debris, emergent vegetation, rip rap, or inundated riparian vegetation, and where a debris-free beach is available to land the seine. Because most (92%) of the study area is composed of steep sided channels covered by rip rap, riparian or emergent vegetation, seining sites are strongly biased by habitat type. Sites suitable for seining were at specific sites in the reaches M2 and M1 and in the Delta in reach SM (Figure 3-1).

Seining surveys were conducted between February 29 and March 23, 2000. High flows during a portion of the study period inundated beaches and restricted the use of beach seines during the first week of the fieldwork.

The beach seine surveys were conducted by two technicians. One technician held one end of the net near shore while and the other proceeded into the channel releasing the bunched net as he or she waded into deeper water. Once the maximum distance from shore was reached the crew members dragged the net down current with the outside crew member advancing ahead of the inland crew member and hooking the net back to the beach. At locations with small beaches, the seine sweep was limited to a semicircle determined by the length of the seine. When the net was landed, the catch was emptied into a bucket and processed. After processing the captured fish, habitat information was collected for the site as described in Section 3.3. Because locations suitable for beach seining were limited and many of the seining sites were sampled repeatedly during the study period.

Figure 3-1. Mokelumne River Study Area Showing Locations for Boat Electrofishing and Beach Seining Sites.



3.1.3 BACKPACK ELECTROFISHING

A Smith-Root Type 12 battery powered backpack electrofishing unit was used to sample shallow water (less than 3 ft water depth) habitats that were inaccessible to the electrofishing boat. These habitats included shallow margins in the channels and areas that had dense riparian or aquatic vegetation. In reach M2, floodplain areas that had been inundated by high water then were isolated when the flood peak was over, were sampled using this technique. Backpack electrofishing was used infrequently from March 1 through March 12.

Crew safety was a major concern in using this technique. High current velocity, steep or slick underwater slopes and unstable substrates made this technique treacherous in the main channels. The habitats most successfully sampled included areas that were generally flat and less than waist deep. In each sampling area, one person equipped with the electrofishing unit moved forward sweeping the anode from side to side and operating the on-off switch. A second and third technician followed closely behind with dip nets to capture stunned fish and keep holding buckets. After the catch data was worked up, fish were released and the habitat data was recorded.

3.1.4 FYKE NETS

Fyke nets were used at several locations (Table 3-1). Experimentally designed fyke traps were fished from March 17 through April 5. Each trap consisted of a fyke box flanked by wing panels. The boxes measured 3 ft square and were constructed of steel frames covered by 1/8" plastic mesh. Wing panels were constructed from the same materials and each measured 3ft. by 4 ft. The trap was designed to funnel fish along the panels and through a 2" wide rectangular opening into the box. Water velocity entering the box prevented fish from escaping once they entered.

The fyke nets were generally unsuccessful as capture techniques. In the riverine reaches, the water velocities were too high. In the Delta channels the nets were unsuccessful due to the changing water levels, sediment loads and vandalism.

Table 3-1 Fyke net sampling dates and locations.

Start Date	End Date	River Mile	Notes
March 21	March 22	20.9	Net stolen.
March 24	April 3	28.9	Net damaged
March 17	March 18	19.5	Did not fish well, too shallow at low tide.
March 18	March 19	33.7	Did not fish well, velocity too high.
March 21	April 5	20.5	No catch

3.1.5 MINNOW TRAPS

Baited minnow traps were fished in low velocity habitats of reach M2 above RM 19 (Table 3-2). Three sites were fished by two traps each from March 28 through April 5.

Table 3-2 Minnow trap sampling dates and locations.

Start Date	End Date	River Mile
March 28	April 5	28.8
March 28	April 5	23.1
March 28	April 5	20.4

3.1.6 VISUAL OBSERVATION

Visual observation was proposed in the Pilot Study scope of work to collect information on habitat use or behavior of salmon fry. This technique was not used during the study period because of high and variable turbidity. Reaches M1, SM, NM are typically turbid. Reach M2 is suitable for snorkel observations during certain periods of the year. However, the high flows during the study period resulted in turbidity levels greater than 30 NTU's. Underwater observation becomes very difficult in water with turbidities greater that 3 NTU's, especially in large rivers. Therefore underwater visual methods were impracticable. Field crews never observed fry from the surface except during capture efforts. No surface feeding by fry were observed by the field crews.

3.1.7 OTHER METHODS

Initial fry collections quickly revealed that fry were using areas with current near the shore. The shoreline location made use of a midwater or otter trawl impractical. Boat electrofishing in mid channel was generally unsuccessful in capturing fry, therefore the use of a trawl for capturing fry was abandoned. Cast or throw nets were not employed either since the shoreline areas were not good sites to use cast or throw nets.

3.2 FISH SAMPLE PROCESSING

All fish captured during this study were anesthetized with MS-222 and processed immediately after sampling ceased. A predetermined dose of MS-222 was added to water measured in a calibrated bucket thus ensuring each solution mixed was of equal concentration. Captured fish were identified to species and fork length (fl) or total length (tl) was measured in millimeters (mm) depending on the species. Typically, at least ten specimens per species per sample site were measured for length and the remainder counted (termed plus counts in the data). An effort was made to cover the full size range in the subsample of measured fish.

Salmon fry were examined and rated with respect to their degree of smoltification using a three level condition index. Condition 1 was assigned to fish that showed no signs of smoltification. These fish retained their color, parr marks and had no silvering. Condition 2 fish exhibited fading of the parr marks, some silvering or darkening of the distal margin of the caudal fin. Condition 3 fish exhibited loss of the parr marks, extensive silvering, and a distinct dark margin to the caudal fin and deciduous scales. Salmon fry were also examined for any marks, either dye pigments or adipose clips. Data was recorded on standardized field data sheet (Figure 3-2).

Fish were held in a recovery bucket until they had regained their equilibrium and were actively swimming. They were released at the up current end of the sampled site.

3.3 SAMPLE SITE DATA COLLECTION

For each sampling event time and location, physical habitat parameters and water quality conditions was recorded. The following information was collected at each site:

- Dominant and subdominant habitat type;
- Temperature
- Water quality
- Habitat type length
- Proximity in the channel (left or right bank or midwater)

Each sampling location was marked directly on a field map and GPS coordinates for the downstream end of the site were determined. Water quality parameters measured at each sampling location included temperature (degree centigrade), turbidity (NTUs) and conductivity [micro siemens (µS)]. Temperature was measured with either a hand held thermometer or a Yellow Spring Instruments (YSI) Temperature, Conductivity and Salinity (TCS) meter. Habitat variables were evaluated based on professional judgement and included river channel type, channel feature, substrate slope, substrate type, instream cover and shoreline type and general rating of average water surface velocity for the sampling site.

Location: ________ Site: ________ Recorder: ____________ Date: ________ H2O T. ________ H2O depth: ________ Page: ________ of ________

Weather: ____________ Crew: ____________ GPS: ____________

Conductivity: ________ Turbidity: ________ D.O. ________ Hab. Area ____________ % Hab sampled ________ River mile: ________

Channel Type:	Channel Feature:	Substrate slope:	Subst.	Instream cover:	Shoreline Type:	Gear:	H2O vel:
Main Channel - 1	backwater -1	High (>16 deg)	clay - 1	Rip rap - 1	Beach - 1	Boat E-fish - 1	None - 1
Slough - 2	side channel - 2	Moderate (11-15 deg)	mud - 2	Woody vegetation (rooted and alive) - 2	Vertical Bank - clay peat - 2	Back-pack E-fish - 2	Low - 2
	midchannel island - 3	Low (0-10 deg)	peat - 3	Woody debris (dead and grounded) - 3	Herbaceous (grasses/forbs) - 3	25ft Seine - 3	Med - 3
	bench - 4		sand - 4	Anthropogenic debris - 4	Emergent Vegetation - 4	50ft Seine - 4	High - 4
			rip-rap - 5	Submergent vascular - 5	Shrub/scrub - 5	Panel trap - 5	
			gravel - 6	Emergent vascular - 6	Woody riparian - 6	**Bank Sampled:**	
			cobble - 7	Floating vascular - 7	Riprap - 7	Left - 1	
				Algal - 8		Right - 2	
				Other - 9		Mid-channel - 3	

Electrofish Settings:

Range ________ Time End ________

Pulse ________ Time start ________

Amps ________ Time total ________

Species Code	1	2	3	4	5	6	7	8	9	10	Plus Count	Notes/seine haul#

Comments:

Habitat Map

Figure 3-2 Field Data Sheet

Water velocity was qualitatively evaluated at each site as to whether there was fast, slow or no current. Current at the sampling sites varied according to river flow, tidal stage and location at the site. Point measurements of velocity were not taken because we did not have point locations of the salmon fry. A qualitative assessment of velocity was therefore used. Direction of was not considered, since over half of the study area was tidally influenced.

JUST say "No Velocity measurements" & why ?

GPS end points were used to estimate of the length of shoreline sampled by electrofishing. The size of areas seined was also estimated and recorded.

3.4 HABITAT CLASSIFICATION

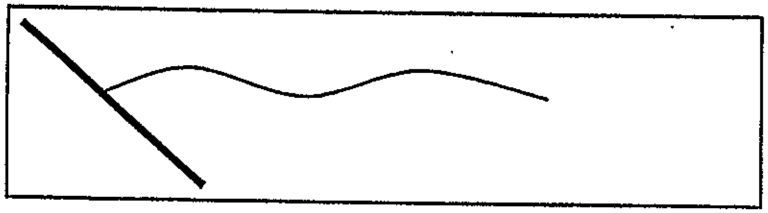
Characterization of the riparian and wetland stream bordering habitats according to Cowardin et al. (1993) was initially proposed. Cowardin provides a hierarchical breakdown of wetland and aquatic habitat types from tidally influenced to riverine aquatic habitats, and it was thought suitable for the study area. While this system works well for expansive wetlands and upland areas adjacent to water bodies, it was found to be poorly suited for relatively narrow margins along the steep shorelines in confined leveed reaches of the study area. One problem with the system is that Cowardin classifies waters less than 2 meters deep as shallow water. The margins of the channel are usually less than 2 meters deep, but much of the open water habitat in mid channel would also fall into the shallow water habitat classification. The Cowardin system is designed to address expansive waterways and wetland areas. It is not detailed enough to classify the edge between these two systems. Since this study was focused on shoreline habitat, it was necessary to develop a system to classify the shoreline habitat that may be important for salmon fry. A classification system was developed that was based upon the slope of the bank and streambed and the dominant and subdominant nearshore and in-water habitat features.

Banks greater than 20 degrees were classified as steep, those less than 20 degrees were classified as low banks. A third category of tidally inundated benches was used to describe areas of very low slope that were inundated during high tide, and typically exposed at low tide. These areas were unique to the North and South Mokelumne Rivers in the Delta. A field guide was developed to assist the field crews in characterizing the habitats (Figure 3-3).

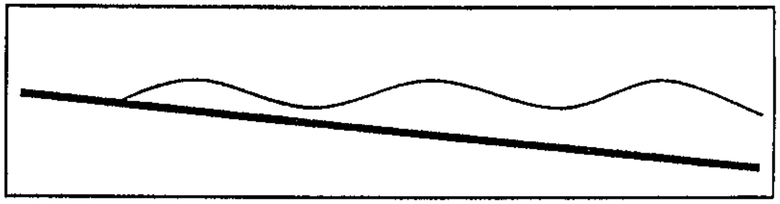
The dominant and subdominant inundated shoreline features were identified. Shoreline features included: herbaceous vegetation (grass and forbs), emergent vegetation (cattails and tules), large woody debris/vegetation (>1" diameter), small woody debris, vegetation thickets (<1" diameter), bare or unvegetated banks, bank revetment (rip rap), beaches or tidally inundated benches, and marinas and boat docks.

The study area was surveyed during low tide cycles to expose as much of the underwater habitat has possible. Habitat classification for the study area was conducted from a boat between April 13 and April 24 along both banks of the 49 miles of river channel along the Mokelumne River.

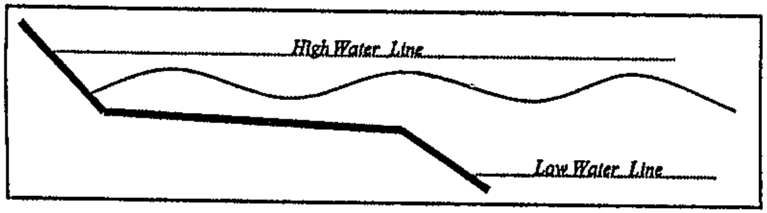
Mokelumne River Habitat Typing Classification



A. **Steep to Moderate Bank (> 20° at or in water)**
   1. Herbaceous (Grass/Forbs)
   2. Emergent (Cattails/Tules)
   3. Large Woody Debris/Vegetation (>1" diameter)
   4. Small Woody Debris/Vegetation Thickets (<1")
   5. Eroding Bank (Non-Vegetated)
   6. Bank Revetment (e.g. Rip-Rap)
   7. Other (e.g. Anthropogenic Debris)

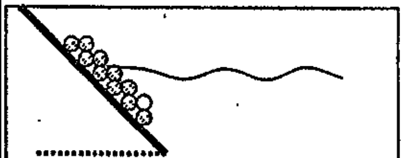


B. **Low Bank (< 20° at or in water)**
   1. Herbaceous (Grass/Forbs)
   2. Emergent (Cattails/Tules)
   3. Large Woody Debris/Vegetation (>1" diameter)
   4. Small Woody Debris/Vegetation Thickets (<1")
   5. Bare (e.g. Beach/Shoal)
   6. Other (e.g. Anthropogenic Debris)



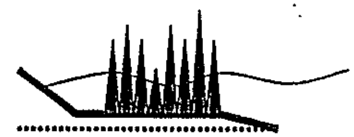
C. **Tidally Inundated Bench**
   1. Herbaceous (Grass/Forbs, usually only shoreline)
   2. Emergent (Cattails/Tules, sparse/dense)
   3. Wood Debris/Vegetation (Small/Large)
   4. Bare
   5. Other (e.g. Anthropogenic Debris)

Typical Examples



A6 - (Bare Rip-Rap Levee)

B1 - (Inundated Herbaceous Vegetation)



C2 -Emergent Vegetation on Bench

ENTRIX, Inc.

Figure 3-3 Field guide for classification of shoreline habitat within the Study Area.

The area of shoreline length of each habitat classification was determined by measuring the length (yards) with laser range finders or by taking beginning and ending coordinates using GPS (Garmin Model III Plus using WGS 84 datum). Field notes were taken of all observations. The GPS data was plotted using Arcview©. The shoreline lengths of the various habitats was then determined using a planimeter. Habitat types were then summarized by slope and dominant feature for each reach and the entire study area.

3.5 DATA MANAGEMENT

Field data sheet entries were checked over at the completion of work at each site by the member of the crew not recording the data. Data records for each day were reviewed by the field crew leader at the end of each day. Data sheets were then ready for data entry.

Field data was entered into an Excel© spreadsheet by Cramer and Associates. The spreadsheet was organized by sampling event reference number. The data for each sampling event was examined for missing or out of range values. Where such issues were identified the field data sheets were examined. If appropriate the data point was corrected. In those cases where a field data point was not available the field was left blank.

Arcview© a geographical information system (GIS) was used to display the sampling locations in the study area. The GIS was also used to plot the habitat information.

3.6 DATA ANALYSIS

Catch efficiency was the metric used to evaluate fish abundance per sampling event. Catch efficiency was calculated for only the boat electrofishing and beach seine data sets. The data set for the backpack electrofishing, fyke net and minnow trap methods was not sufficient for analysis. Catch efficiency for boat electrofishing is reported as fish caught per minute and for beach seining it is reported in fish per foot of seine haul.

Emphasis in the results analysis was placed on the boat electrofishing data because this method is applicable to all reaches and all habitat types. Seining is possible only in areas where a beach or other suitable open shoreline site is present for landing a net. In those instances where a missing data point prevented the calculation of catch efficiency, that sampling event was not included in the final data analysis. electrofishing efficiency (EFE) was calculated as fish per minute (fish/min) and beach seine efficiency was calculated as fish per foot (fish/foot). It should be noted that these two measures of efficiency are not comparable. Even if electrofishing results are presented in catch per foot, the different techniques provide different capture efficiencies and cannot be used interchangeably.

Summary statistics and single factor analysis of variance (ANOVA) were used to evaluate the catch efficiency by reach and dominant habitat type. In several instances the number of sampling events for some reaches were not sufficient to allow statistical analysis. The results of these analyses are presented in Section 4.0.

Field sampling was conducted from February 29 through April 5, 2000 in the Mokelumne River from Woodbridge Dam to the San Joaquin River. Spot sampling was conducted in the channels of the Cosumnes River and in Snodgrass, Sycamore and Potato sloughs. The habitat characterization for the study was conducted on the Mokelumne River during 10 days in April. The distribution of sampling effort and habitat characterization effort. is shown in Table 4-1.

Table 4-1. Field Sampling Summary

Method	Period	Number of Events	Number of Sites
Boat Electrofishing	March 1 to March 22	138	108
Beach Seine	February 29 to March 23	100	115
Backpack Electrofishing	March 1 to March 12	9	9
Fyke Net	March 16 to April 5	29	5
Minnow Trap	March 28 to April 5	24	3
Habitat Characterization	April 13 to April 24	94 miles, both banks	203

Sampling duration varied by reach. In reach M2 sampling occurred for 36 days between March 1 and April 5. In reach M1 sampling occurred between February 29 and April 5, a period of 37 days. In the NM sampling occurred from March 2 to March 22, a period of 21 days. In the SM sampling occurred from March 1 through March 23, a period of 23 days. Summary are presented in this section, the detailed Tables referenced in this section are presented in Appendix A (Table 8-1, Table 8-2, Table 8-3a, Table 8-3b, Table 8-4a, Table 8-4b, Table 8-5, Table 8-6)).

4.1 ENVIRONMENTAL CONDITIONS DURING THE STUDY PERIOD

4.1.1 STREAMFLOW

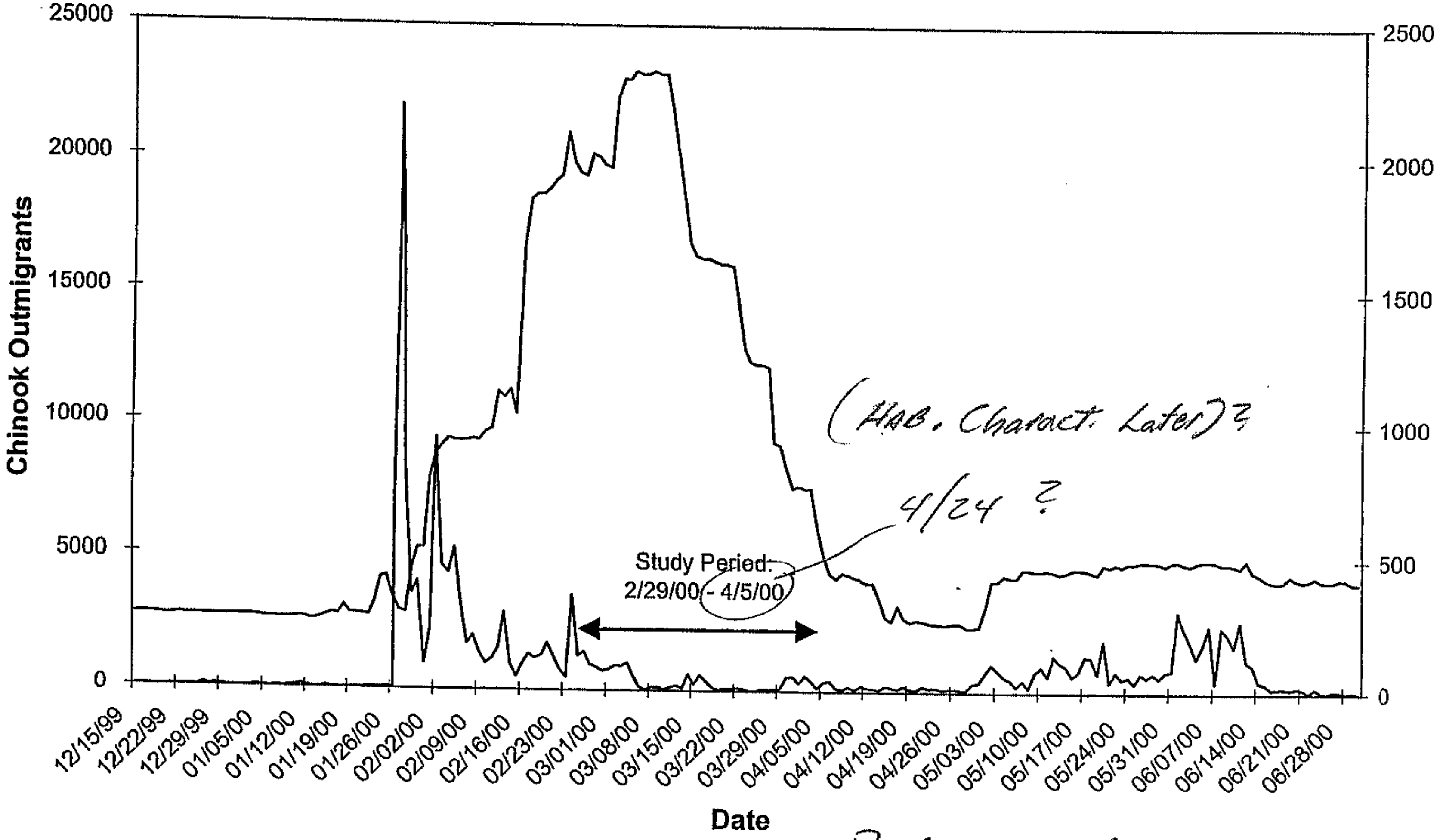
The Mokelumne River is highly regulated and storm flows are managed by releases from Camanche Reservoir located 25 miles upstream of Woodbridge Dam. Figure 4-1 shows the river flows as measured at Woodbridge Dam during the winter and spring of 1999-2000. The study period began shortly before flows were increased from about 1,200 to 1,400 cubic feet per second (cfs). Flows remained at approximately1,400 cfs into the second week of the study period then gradually declined to 400 cfs by early April (Figure 4-1).

2

2

See 4-1

Figure 4-1. Outmigration of Juvenile Fall Chinook Salmon and Woodbridge Dam Outflow 1999 - 2000*



Distinguish Plots clearly

Source: EBMUD Provisional Data 2000

ENTRIX, Inc.

The Cosumnes River is undammed and stormflows are unregulated. Flow patterns in the study area downstream of the confluence (Reaches M1, SM, and NM) were augmented by inflow from the Cosumnes River. Flows from Reach M1 are propagated downstream to where the channel divides into the North and South Mokelumne Rivers. Flows in these channels are influenced by tidal flows and from inflows from Snodgrass Slough which drains the Laguna area of South Sacramento.

4.1.2 Water Temperature

Water temperature was recorded at Camanche Dam, the Woodbridge Gage and at a Department of Water Resources (DWR) monitoring site on the south end of Staten Island in the South Mokelumne River (Figure 2-1). During the study period average daily water temperature was relatively constant at the Woodbridge site ranging between 11 and 12.5 degrees centigrade (°C) (Figure 4-2). Water temperature monitored at Camanche Dam and Staten Island were similar to the temperatures measured at Woodbridge (Figure 4-3). This indicates that water temperature was relatively consistent on a regional basis and that differences between the upstream and downstream ends of the study area were relatively minor during the six week study period.

4.1.3 Turbidity

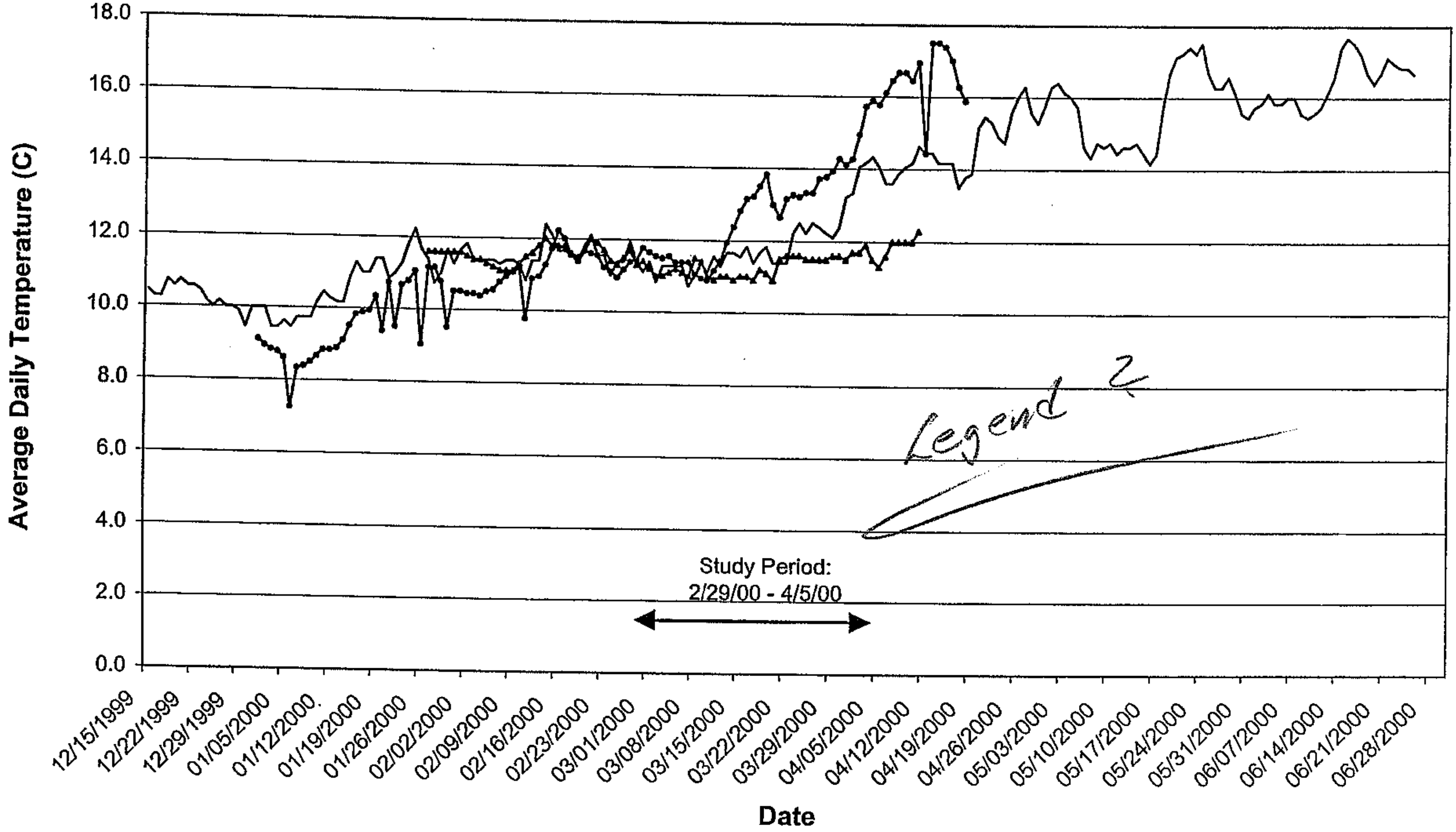
Average daily turbidity was recorded at the Woodbridge Dam monitoring site. During the 1999-2000 winter, turbidity was highly variable ranging from over 1400 NTUs to approximately 30 NTUs. Spikes in turbidity coincide with storm events. Turbidity at the Woodbridge site during the study period did not exceed 199 NTU's (Figure 4-4).

4.2 Fish Sampling Results

This section provides an overview of the salmon fry collection results. A total of 300 sampling events was conducted in the study area between February 29 and April 5, 2000. Of the 300 events, 138 were boat electrofishing, 100 were beach seining, and the remainder of the events were backpack electrofishing (9), fyke netting (29 trap days) and minnow trapping (24 trap days). A total of 794 fall chinook salmon fry were caught with 346 taken by boat electrofishing and 443 taken by seining (Table 8-2). Average weekly fork length of fry captured at the Woodbridge trap is shown in Figure 4-5. Five salmon were captured by backpack electrofishing and none were taken with fyke nets or minnow traps (Table 8-2). No salmon were collected from the five sites sampled in the Cosumnes River nor the five sites sampled in Sycamore Slough. Sites with and without salmon fry are shown for the Mokelumne River sample sites (Figure 4-6). Five salmon were collected from five sites in Snodgrass Slough, six salmon were collected from ten sites in Potato Slough, and 5 salmon were collected from the six sites in reach M of the Mokelumne River (Figure 4-7).

Boat electrofishing captured a total of 330 salmon from the four main reaches of the study area with 200, 32, 43 and 55 salmon collected from reaches M2, M1, SM and NM respectively. Seining captured a total of 443 salmon from three of these reaches with 175, 49 and 209 collected from reaches M2, M1 and SM respectively. Reach M2 received 43.4% of the overall sampling effort (boat electrofishing and seining combined) resulting in 48.5% the salmon captured during the study.

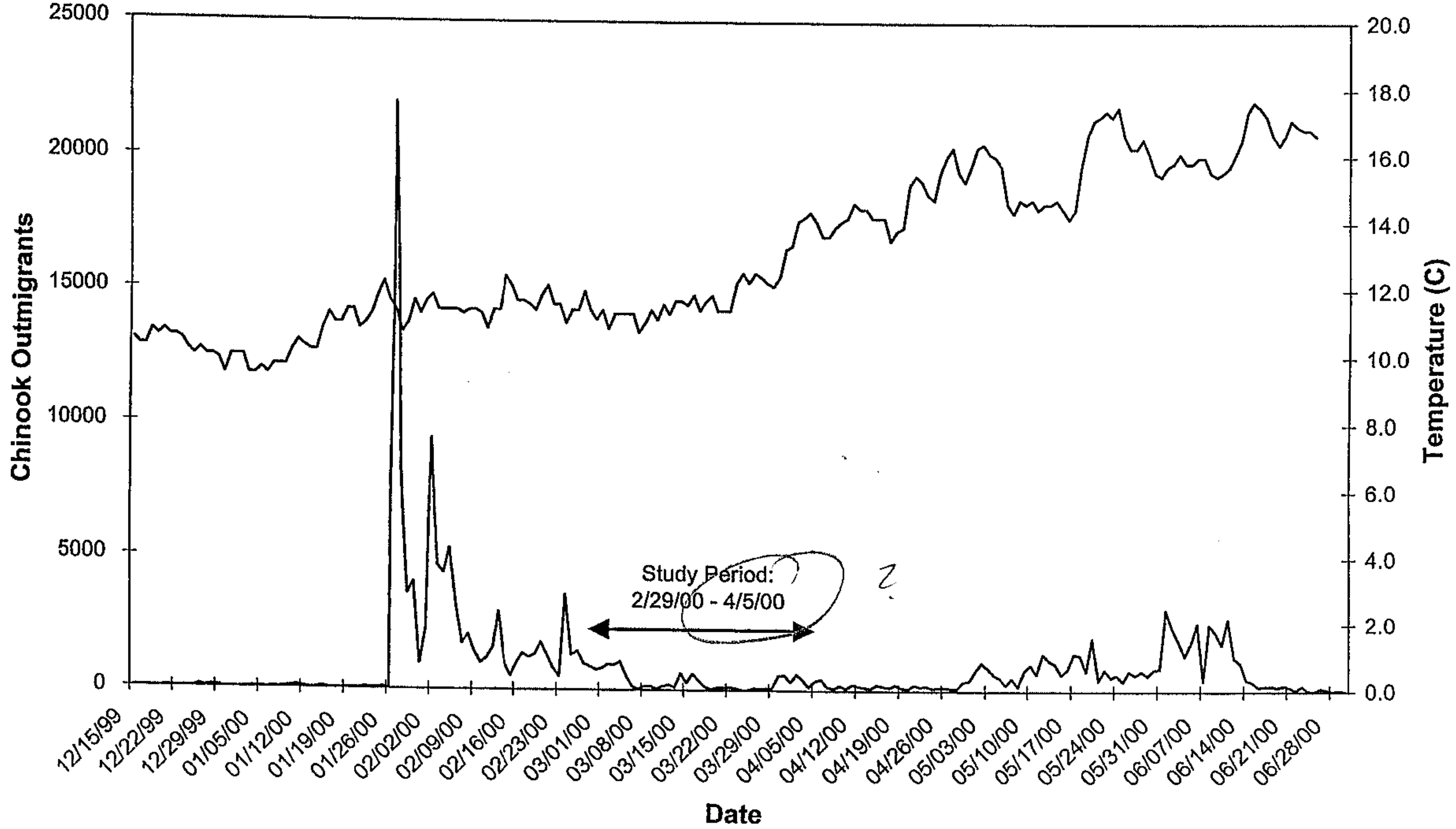
Figure 4-2. Average Daily Water Temperatures at Camanche Dam, Woodbridge Dam, and Staten Island: 1999 - 2000*



Source: EBMUD Provisional Data 2000;
DWR - CDEC

ENTRIX, Inc.

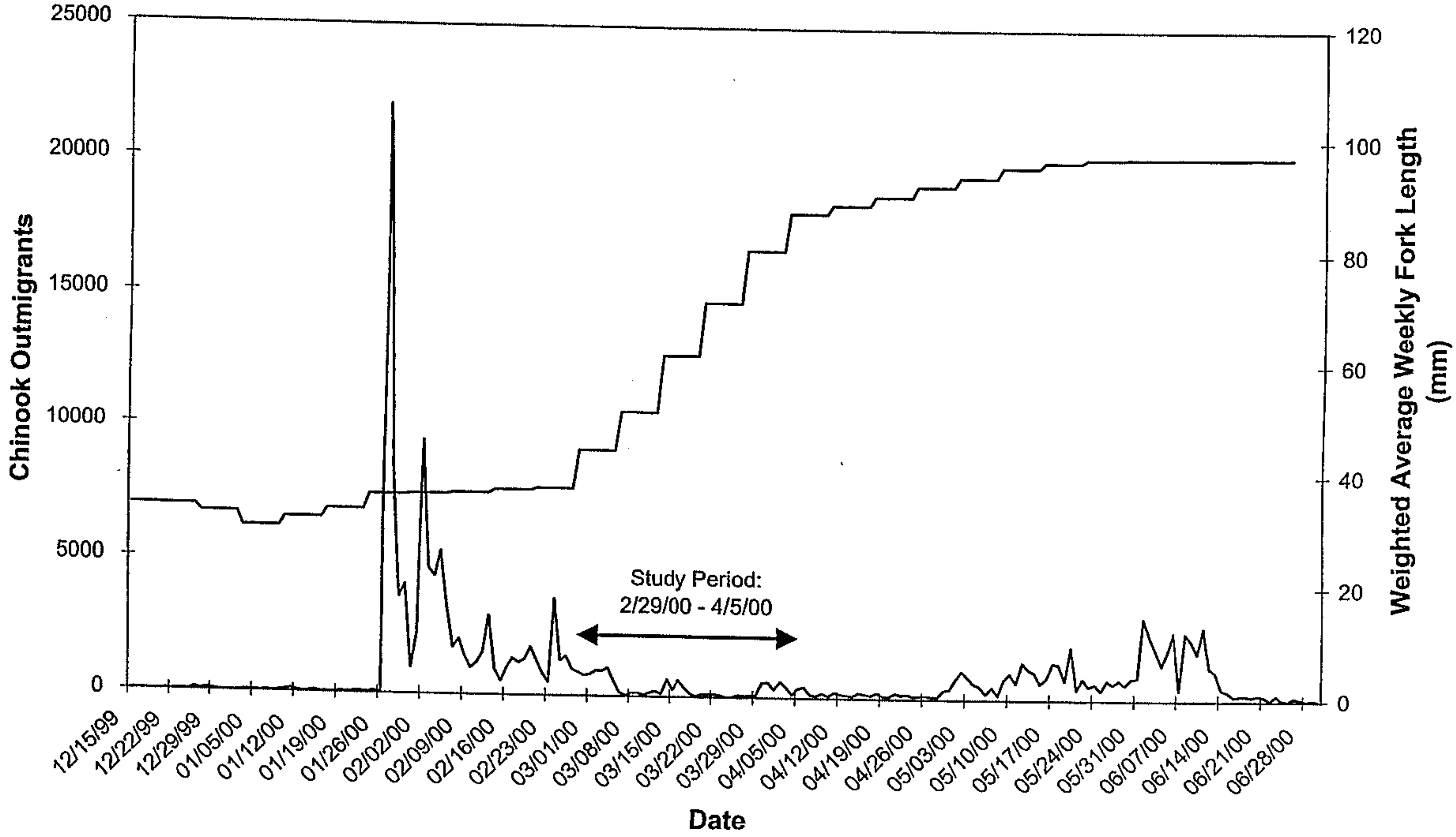
Figure 4-3. Outmigration of Juvenile Fall Chinook Salmon and Average Daily Temperature: 1999 - 2000*



Source: EBMUD Provisional Data 2000

ENTRIX, Inc.

Figure 4-5. Outmigration of Juvenile Fall Chinook Salmon and Weighted Average Weekly Fork Length (mm): 1999 - 2000*



Source: EBMUD Provisional Data 2000

ENTRIX, Inc.

Figure 4-6. Salmon Fry Presence and Absence in the Mokelumne River for Boat Electrofishing and Seining Sites.

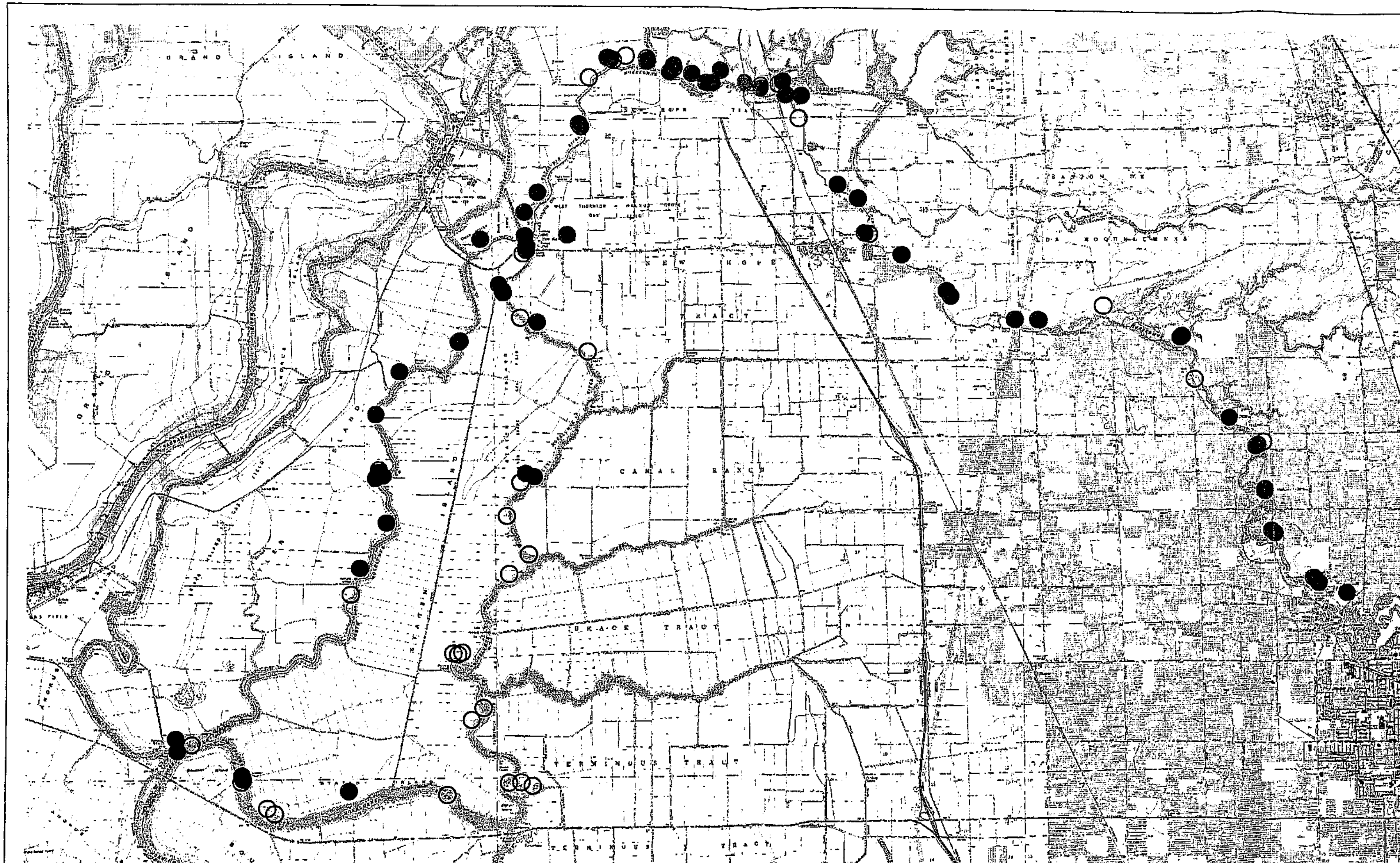


Figure 4-7. Capture Locations for 5 or more Salmon Fry in the Mokelumne River for both Electrofishing and Seining.

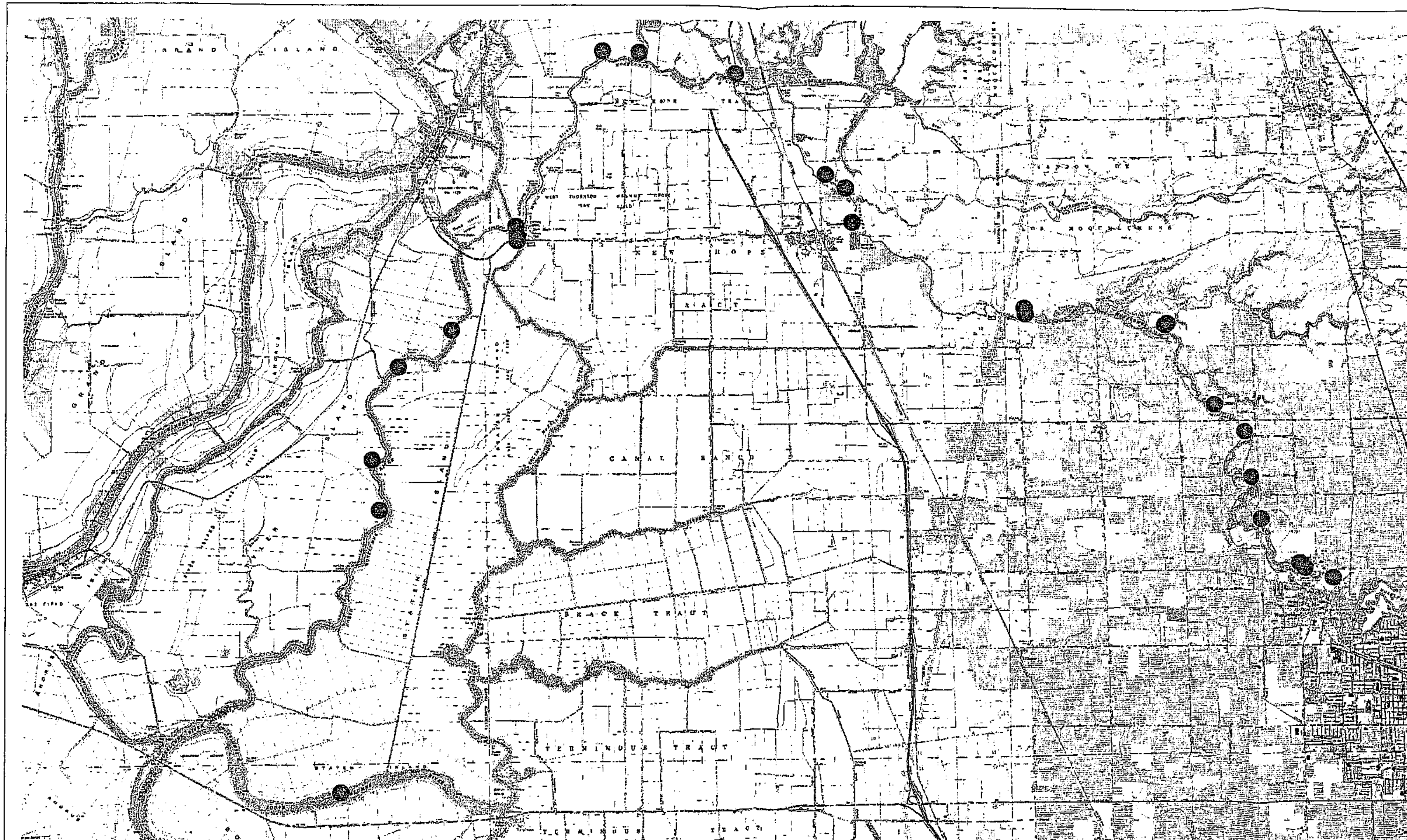
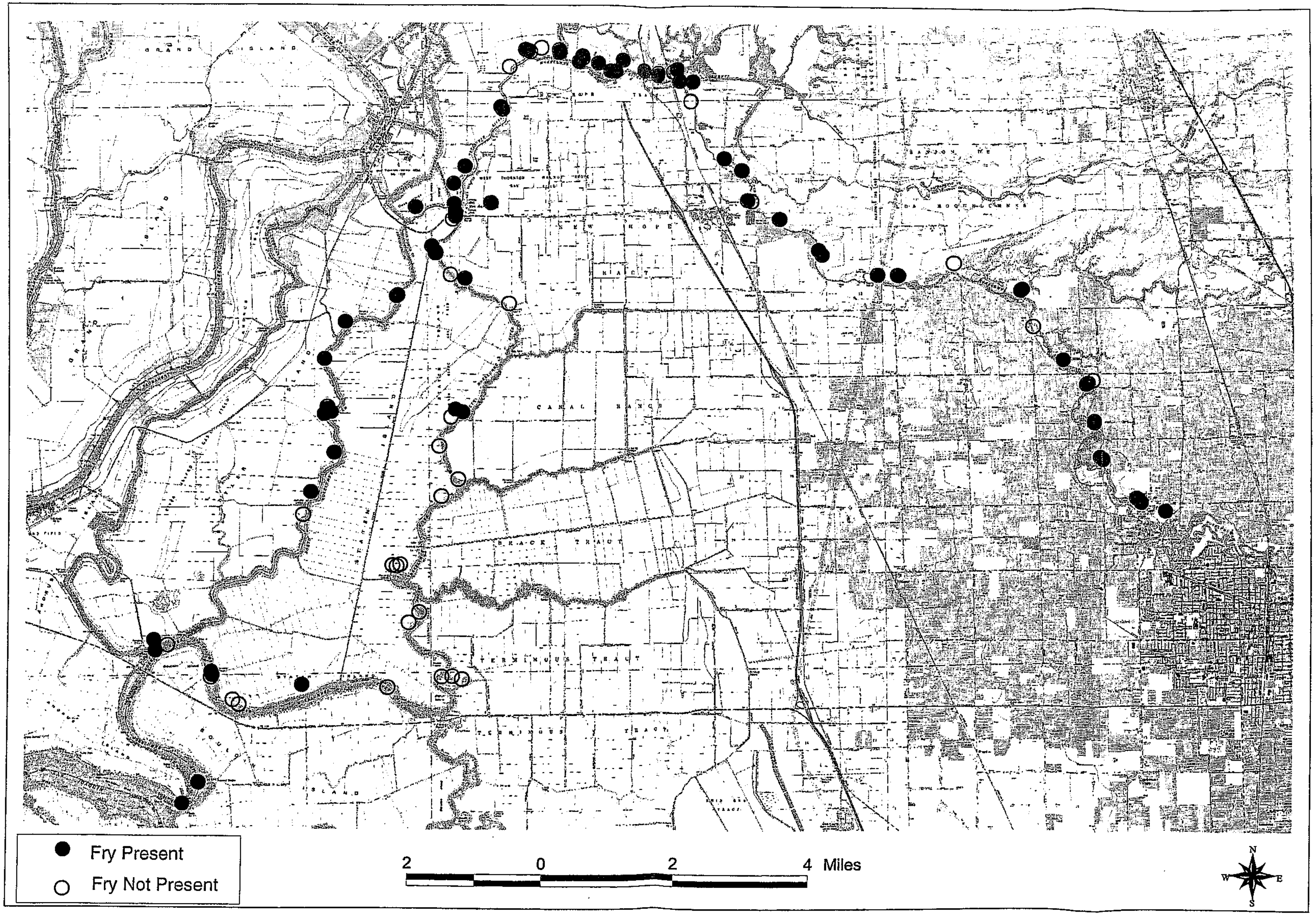
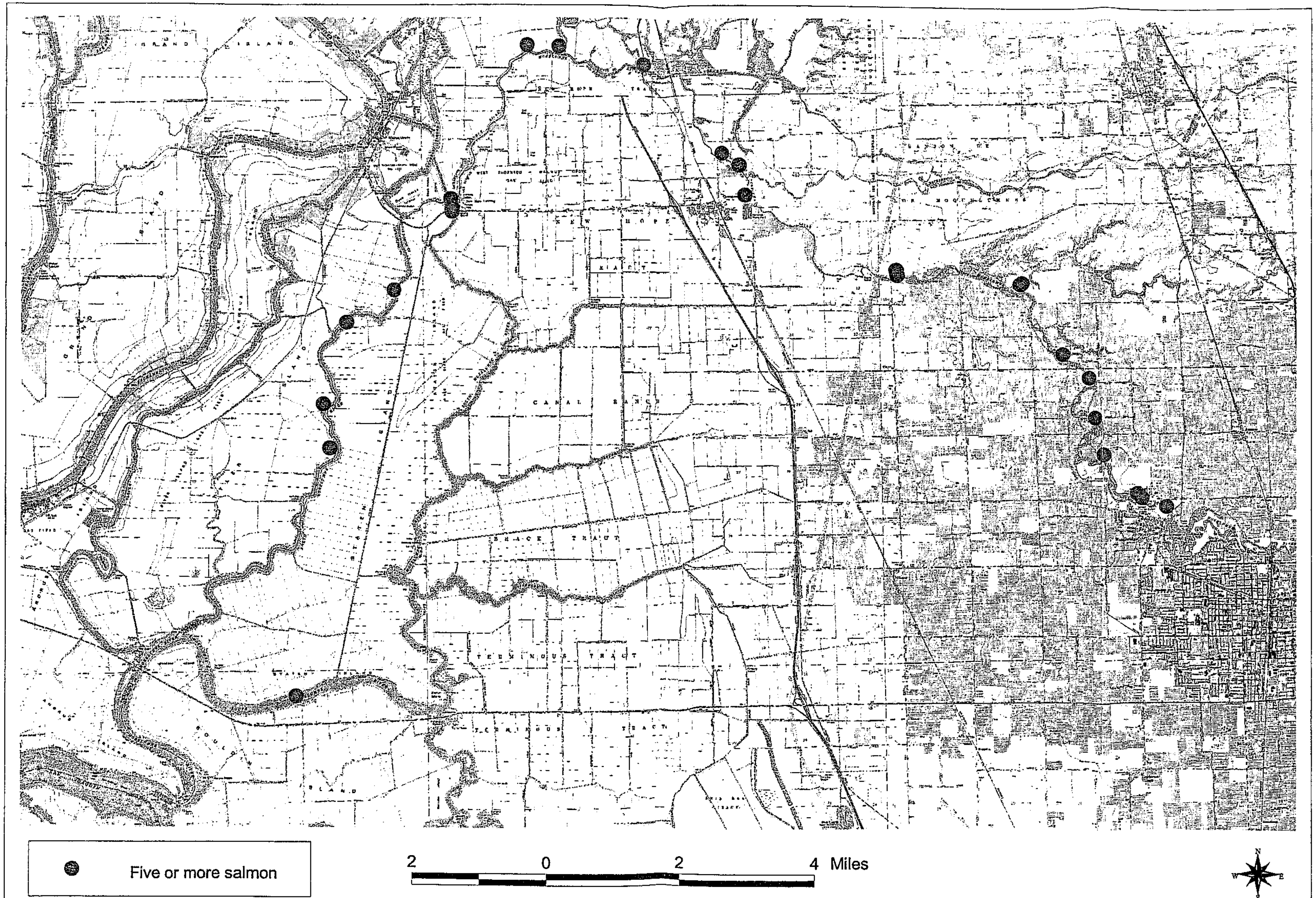


Figure 4-6. Salmon Fry Presence and Absence in the Mokelumne River for Boat Electrofishing and Seining Sites.



ENTRIX, Inc.

Figure 4-7. Capture Locations for 5 or more Salmon Fry in the Mokelumne River for both Electrofishing and Seining.



ENTRIX, Inc.

Reach M1 received 13.7% of the overall effort and yielded 10.5% of the total catch of salmon fry. Reach SM received 35.1% of the effort and resulting in 33.9% on the total catch, and Reach NM received 7.8% of the total effort and produced 7.1% of the total salmon catch. Because 98% of the salmon captured were collected from reaches M2, M1, SM and NM by boat electrofishing and seining, the analysis of habitat use is based on the data for these methods and reaches.

4.2.1 BOAT ELECTROFISHING

A total of 107 boat electrofishing events occurred in reaches M2, M1, SM and NM (Table 4-2). Comparison of catch to effort shows that 60.6% of the salmon fry were collected from Reach M2 where 37.4% of the effort was expended. Reach M1 produced 9.7% of the catch for 16.8% of the effort. Reach SM produced about 13.0% of the catch for 30.8% of the effort. Reach NM produced about 15.2% of the catch for 14.9% of the effort.

Catch rate (Number of chinook/number samples) was highest in reach M2 with an averaged of 5.0 fish per sampling event, Reach M1 averaged 1.78 fish per event, Reach SM averaged 1.3 fish/event and Reach NM averaged 3.44 fish per event (Table 4-2). Figure 3-1 shows the distribution of electrofishing sites in the study area. The majority of the sampling effort took place in reaches M2, M1 and SM. Relatively limited sampling occurred in reaches NM and M. The number of events with 1 to 3 fish per event are nearly equivalent for reaches M2, M1 and SM, but are less for reaches NM and M. Reach SM had the highest incidence of zero catches.

Table 4-2 Boat Electrofishing effort and catch showing the total catch of salmon, number of sites sampled, and capture rate (fish/event) for each reach by week.

	Reach											
Week	M2			M1			SM			NM		
	Catch	No. of Events	Rate	Catch	No. of Events	Rate	Catch	No. of Events	Rate	Catch	No. of Events	Rate
1	NS	NS	NA	NS	NS	NS	5	6	0.83	9	6	1.5
2	18	3	6	2	1	2	13	12	1.08	NS	NS	NA
3	182	37	4.92	12	12	1	7	7	1.0	27	6	4.50
4	NS	NS	NA	18	5	3.6	18	8	2.25	19	4	4.75
Totals	200	40	5.0	32	18	1.7 8	43	33	1.3	55	16	3.44
Percent	60.6	37.4	--	9.7	16.8	--	13.0	30.8	--	15.2	14.9	--

Catch per unit effort (CPUE) was calculated for each reach. Table 4-3 presents the mean CPUE by reach.

Table 4-3 Boat Electrofishing CPUE (fish per minute)

	Reach				
	M2	**M1**	**SM**	**NM**	**M**
Mean	0.67	0.23	0.14	0.83	0.084
Standard Deviation	1.1	0.35	0.24	1.3	0.072
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	5.5	1.3	1.0	4.3	0.20
Count	37	17	30	10	5

CPUE is greatest for Reach NM. However, this result is strongly influenced by the relatively low number of events and a single sample event that captured 13 salmon in 3 minutes. Reach M2 on the other hand had several sampling events with CPUE values greater than 1.0 fish/minute. Reach SM had twenty sampling events that caught no salmon fry. Reach M2 had the highest CPUE.

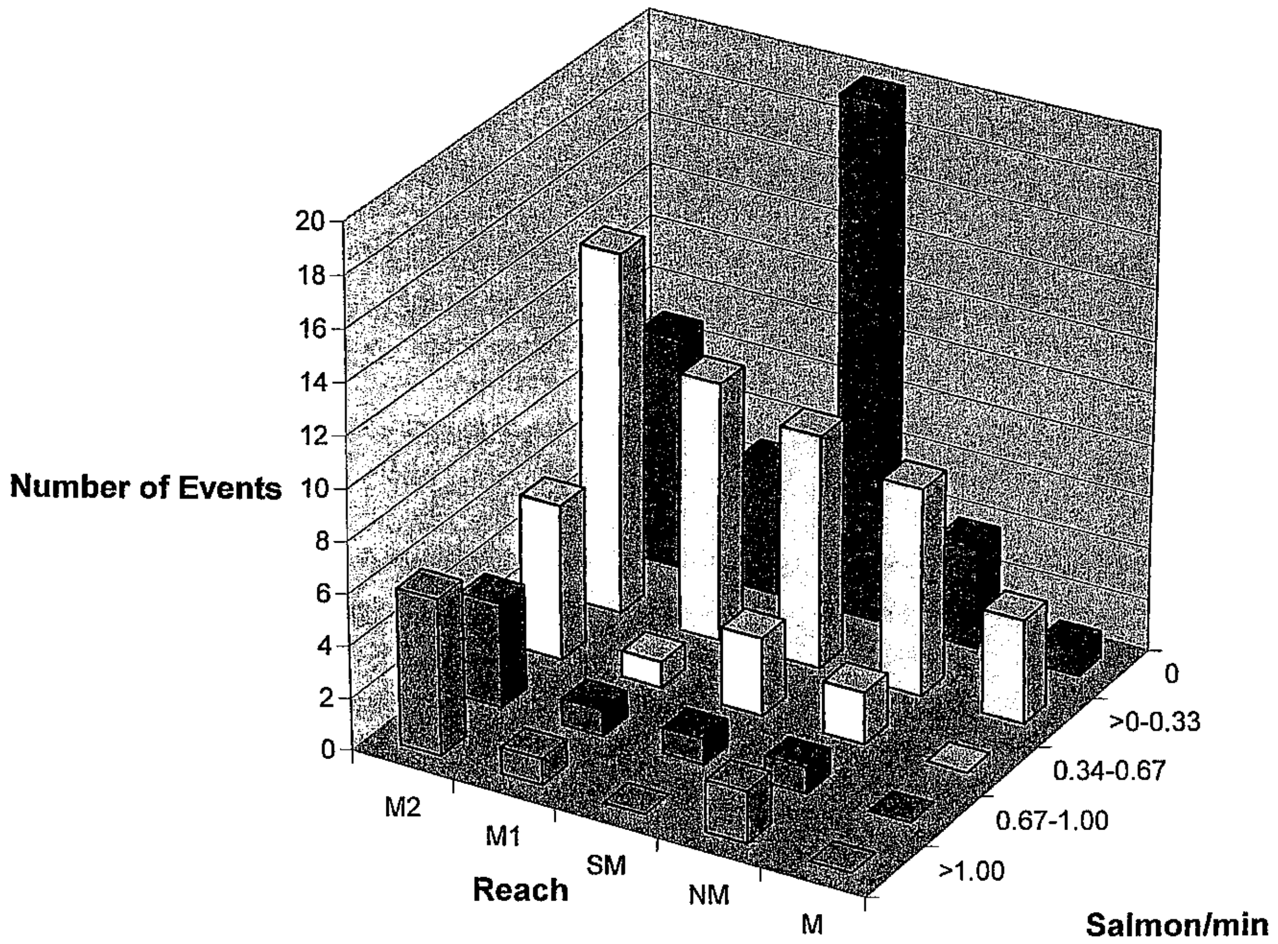
Single factor ANOVA was used to evaluate the potential for significant differences in CPUE between all four reaches M2, M1, SM, and NM (Appendix A.). The sample size for reach M was only five, and its was eliminated from this analysis. When comparing CPUE results across the four main reaches there is a weak but statistically significant difference between at least two of the reaches. The strongest differences are between M1 and M2 and an ANOVA was used test for significant differences. Based on CPUE, M1 and M2 are not significantly different ($p = 0.108$) (Table 8-5).

This analysis indicates that a substantially larger and more evenly allocated sampling effort is necessary to compare abundance and catch per unit effort across all of the reaches. A sample size analysis was performed, based on the existing electrofishing data, for a two-tailed comparison of the differences between two or more means. The estimated sample size necessary to detect a significant differences between two means is 183 samples per reach ($\Delta = 0.1$, $\alpha = 0.05$, $\beta = 0.1$).

Figure 4-8 shows the distribution of CPUE by group. Of interest is the consistent occurrence of zero and low CPUE catches in the four reaches M2, M1, NM and SM. The high incident of zero CPUE in the SM is also evident. Reach M2 also has a more consistent occurrence of the higher CPUE events.

ie Both High and Low

Figure 4-8. Salmon Fry Electrofishing by Reach and CPUE Class



4.2.2 BEACH SEINING

Average catch densities for seining varied between reaches and weeks. A single seine haul was conducted at most sites most of the time, but about a third of the sites had multiple seine hauls. The maximum number of seine hauls at a single site was 5 and that occurred only once. Use of the 50-foot seine was rated equivalent to two 25-foot seine hauls for the purpose of evaluating effort. No seining occurred in Reach NM because of the lack of sites. Capture rate closely tracks effort for all three reaches sampled for beach seining (Table 4-4).

Table 4-4 Seining effort and catch showing the total catch of salmon, number of seine hauls, and capture rate (fish/seine haul) for each reach by week.

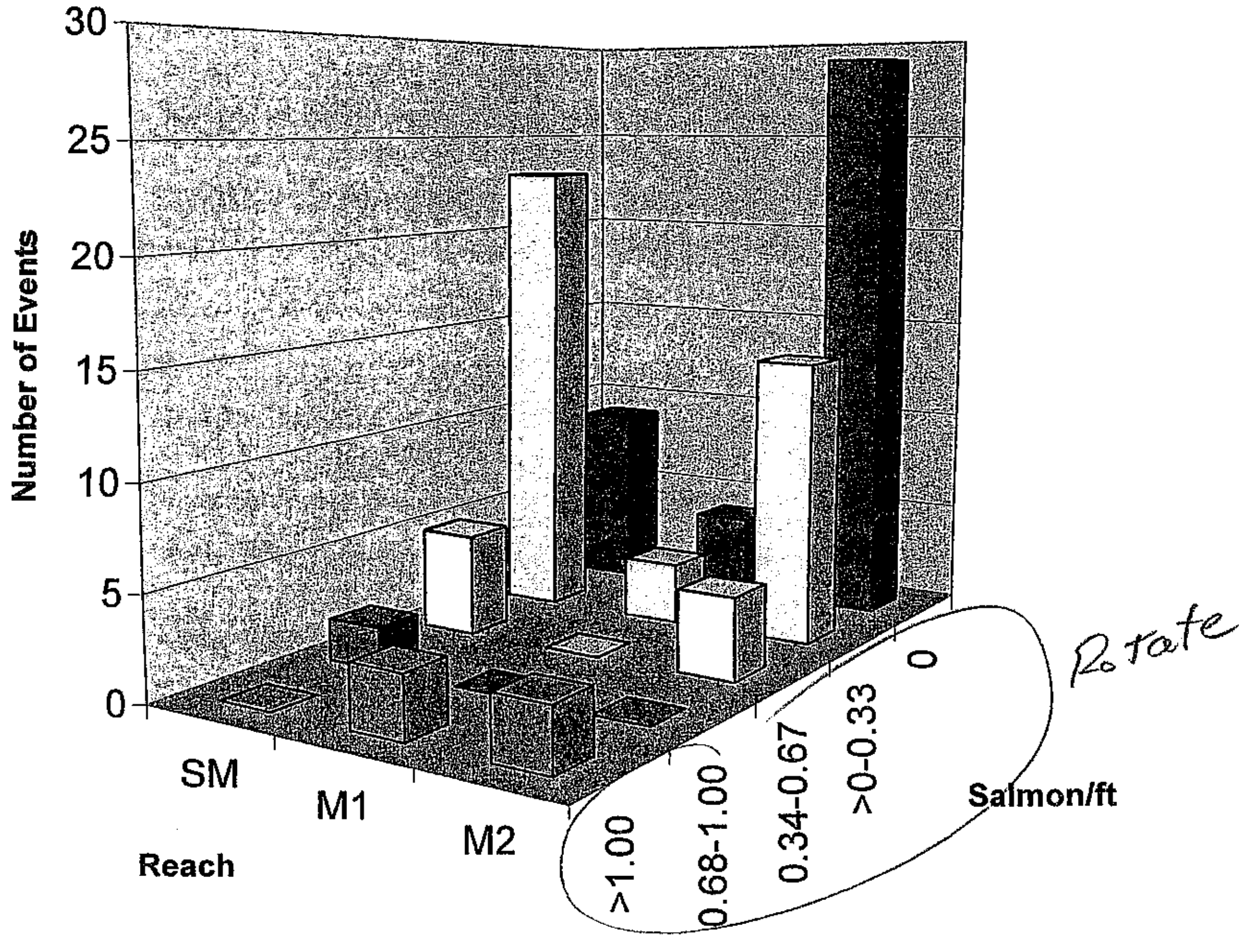
	Reach								
	M2			M1			SM		
Week	Catch	No Hauls	Rate	Catch	No. Hauls	Rate	Catch	No. Hauls	Rate
1	70	10	7.00	12	5	2.4	NS	NS	NA
2	91	27	3.37	2	3	0.67	200	25	8.00
3	3	9	0.33	0	1	0	12	6	2.00
4	11	3	3.67	35	1	35	7	8	0.88
Totals / Mean Rate	175	49	3.57	49	10	4.90	219	39	5.62
Percent of Total for these Reaches	39.5	50.0	--	11.1	10.2	--	49.4	39.8	--

Seining CPUE for the three reaches analyzed is shown in Figure 4-9. Reach M2 has a high incidence of zero catches.

4.2.3 SIZE SELECTIVITY

Average size of juvenile salmon captured showed no significant differences geographically or temporally (Figures 8-1a, 8-1b, 8-2a, and 8-2b Table 8-4a and 8-4b). Fork length increased by approximately 6 to 7 mm during the study period. This increase was not significant. There were only minor differences in size distribution between electrofishing and seining (Figure 8-3). The size range collected by either method is similar. The only notable difference between the two histograms is that seining captured fish in the 38 to 43 mm size range at a higher frequency compared to boat electrofishing.

Figure 4-9. Salmon Fry Seining by Reach and CPUE Class



Why not plot reaches in the same order as 4-8?

4.2.4 FRY OUTMIGRATION

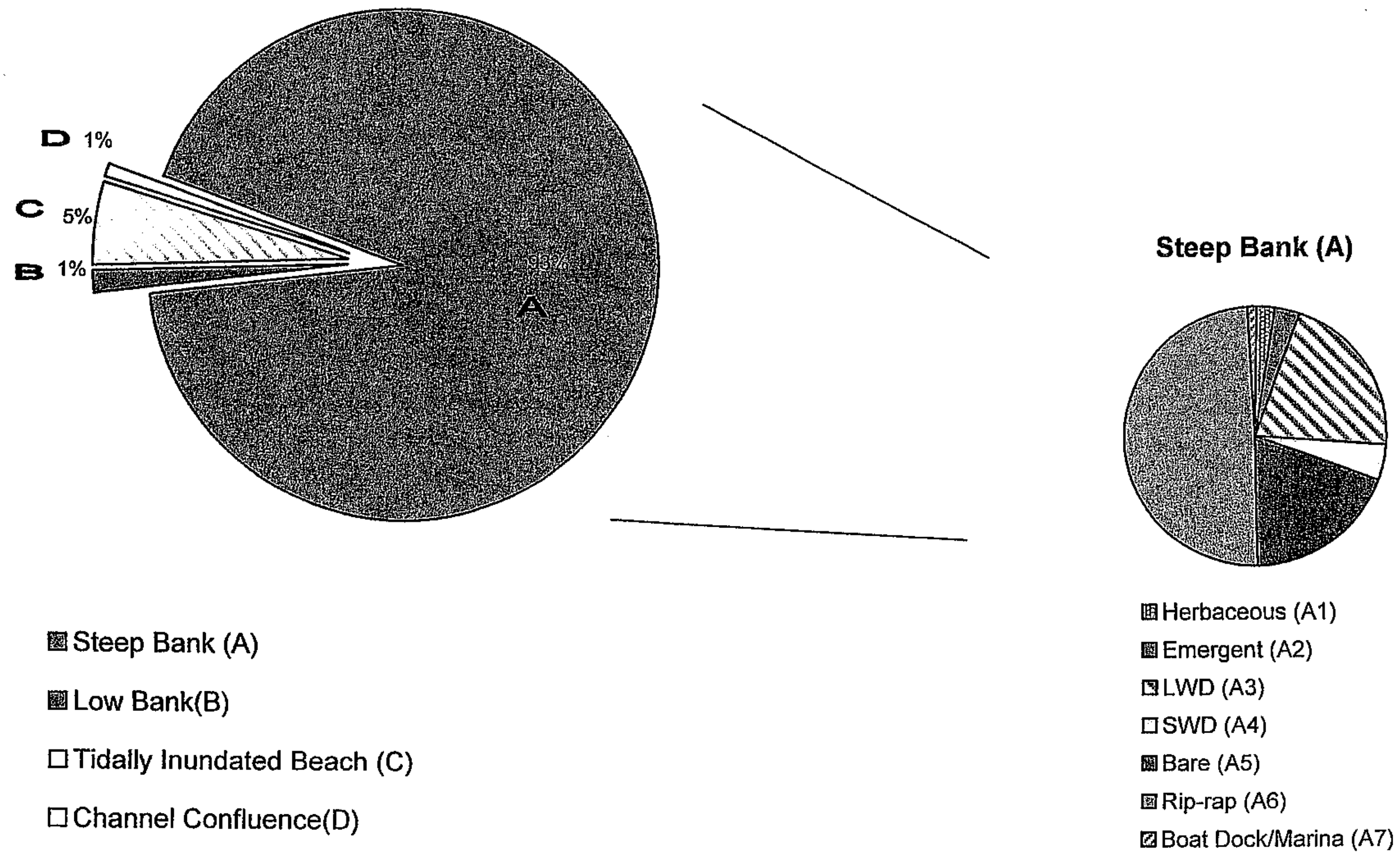
Catch data from the Woodbridge RSTs during the 1999-2000 sampling period clearly show a distinct fry outmigration occurring in late January (Figure 4-1). Two distinct peaks are noted with the highest one occurring on January 27 and a second, smaller one occurring on February 2. Outmigrant counts recorded at the RSTs during the study period were low. Average size of RST captured outmigrants indicate that smolt-sized fish (greater than 80 mm f/l) did not appear at Woodbridge until the end of this study period (Figure 4-5). These two facts indicate that salmon fry collected during this pilot study occurred in the study area as a result of their movement from the Lower Mokelumne River.

4.3 HABITAT CHARACTERIZATION

Overall, 31% of the shoreline habitat occurr in Reach M2, 10% in Reach M1, 22% in Reach NM, 30% in Reach SM and about 7% in the main Mokelumne River (Reach M). Steep rip rap-covered banks comprise 45% of the total study area. The distribution of low bank angle beach habitat is displayed on Figure 4-16, representing about 1% of the study area. Most of the remaining shoreline habitat along the Mokelumne River is steep bank habitat. The habitat characterization results indicate that there is very little low slope beach habitat along the western Mokelumne River.

Shoreline habitats along the study reaches of the Mokelumne River were classified based on the dominant and subdominant categories shown in Table 4-5. The characterization considers the bank angle and the bank covering. The banks of the study area are comprised of 93% steep banks and about 5% tidally inudated benches and beaches. About half of the steep banks are rip rap, a third are bare and a quarter are coverd with small woody debris (Figure 4-10). Reach M2 is 98% steep bank and 2% low bank or beaches. The steep banks are comprised about 60% bare banks, 35% large woody debris and the remainder is split between herbaceous and small woody debris(Figure 4-11). Reach M1 is 100% steep bank. The banks are covered with rip rap which has been in place for many years and has become grown over with shrubs and also supports a number of large trees (Figure 4-12). Reach SM is 89% steep bank, 7% tidally inundated bench and 2% beach. The steep bank is nearly 100% covered with rip rap (Figure 4-13). Reach NM is about 90% rip rap with about 10% tidally inundated bench. The steep banks are nearly 80% rip rap and about 15% small woody debris (Figure 4-14). Reach M is about 82% steep bank and about 12% tidally inundated beach. The steep banks in this reach are comprised of about 35% rip rap and emergent vegetation with the remaining 30% being occupied by marinas (Figure 4-15).

Figure 4-10. Habitat Availability Within the Mokelumne River Channels of the Study Area



ENTRIX, Inc.

Figure 4-11. Habitat Availability Within Reach M2

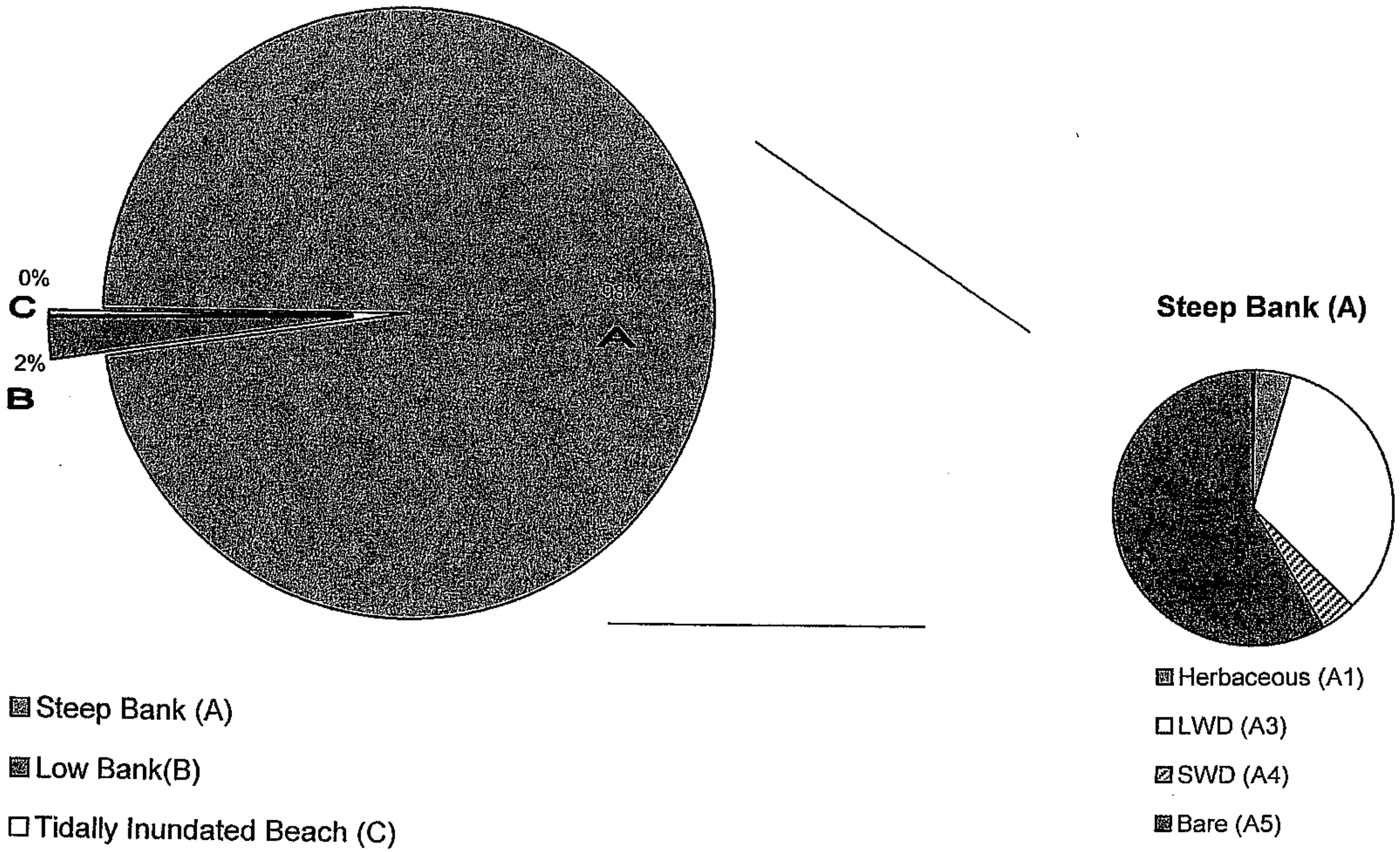
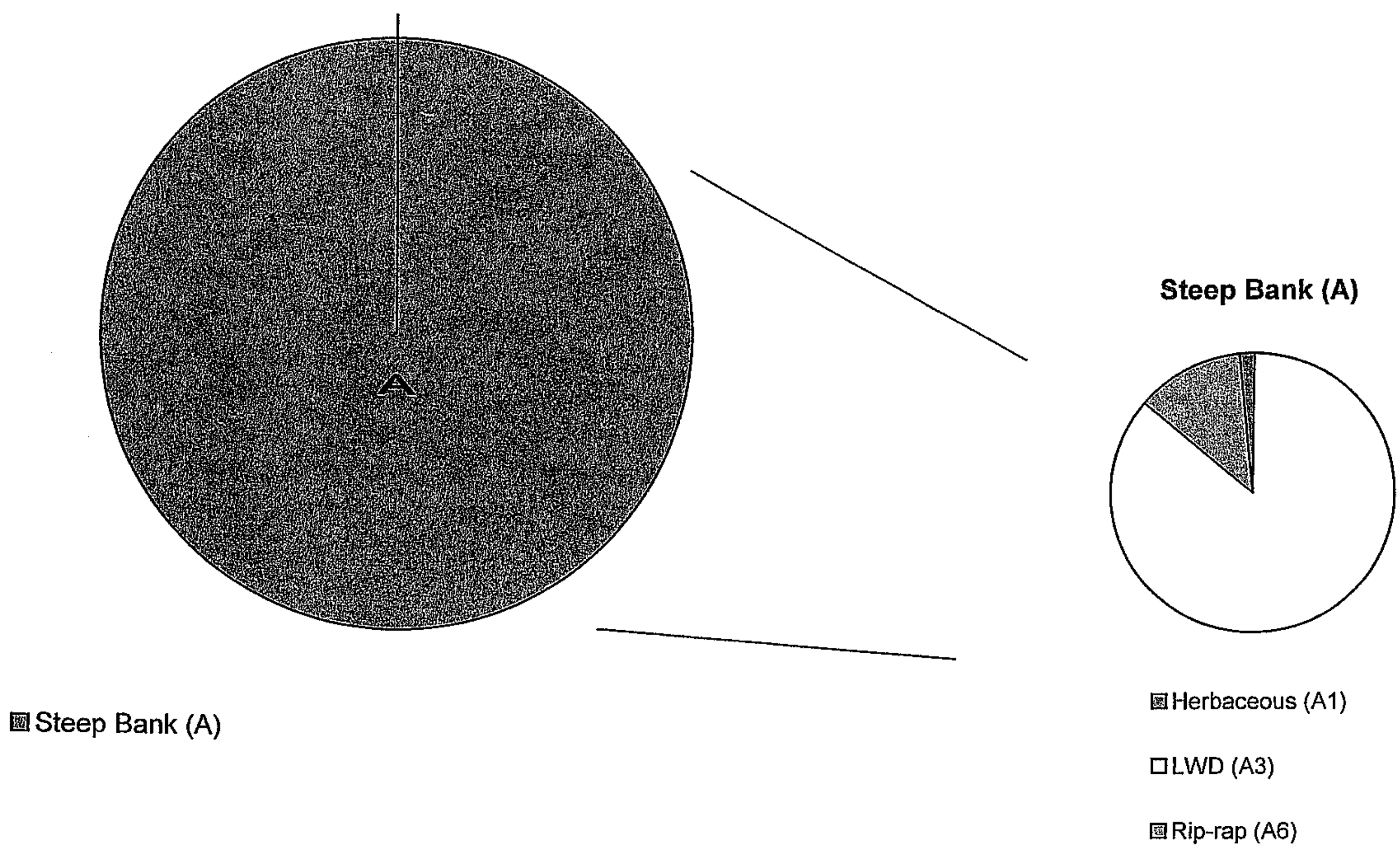
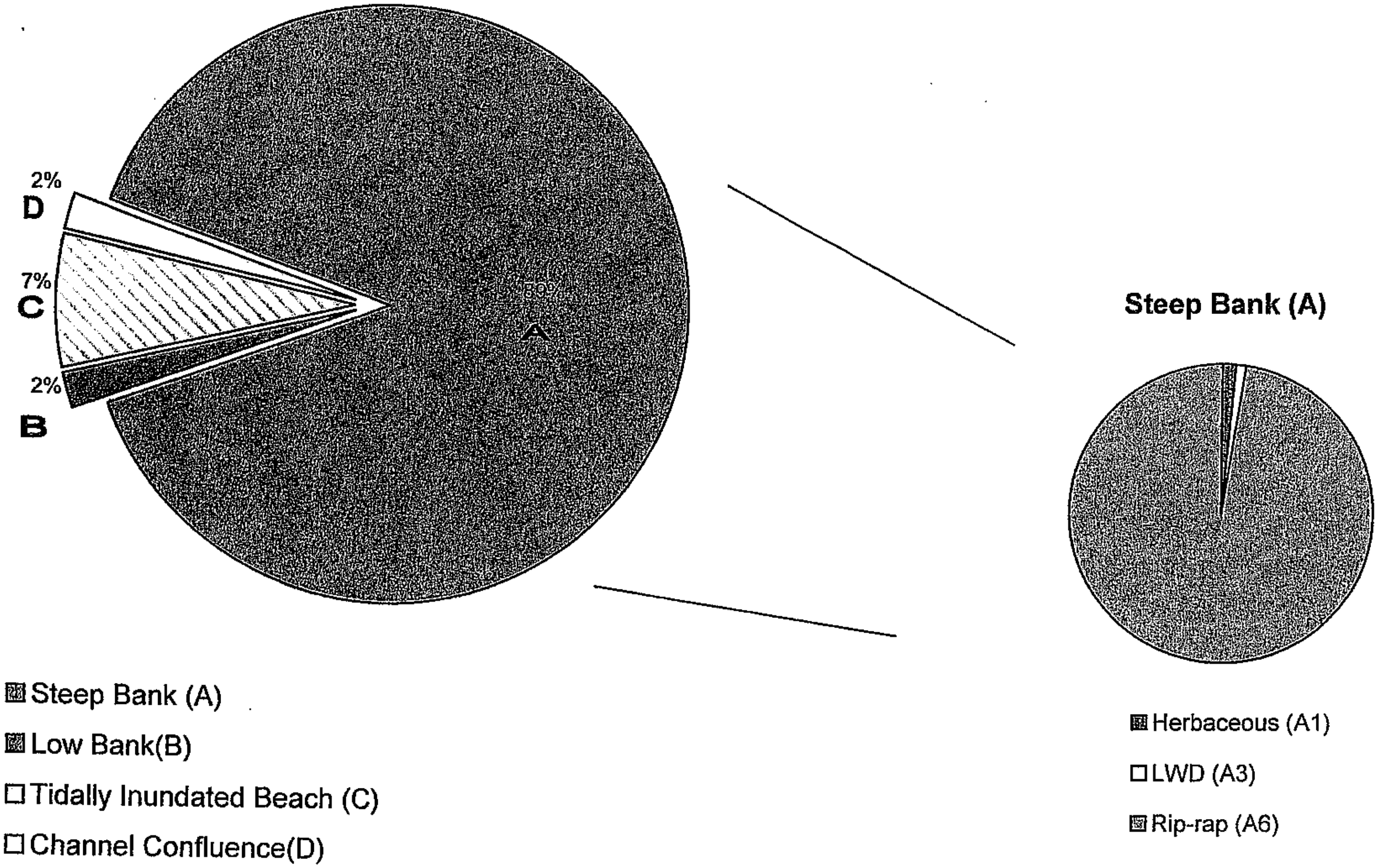


Figure 4-12. Habitat Availability Within Reach M1



ENTRIX, Inc.

Figure 4-13. Habitat Availability Within Reach SM



ENTRIX, Inc.

Figure 4-14. Habitat Availability Within Reach NM

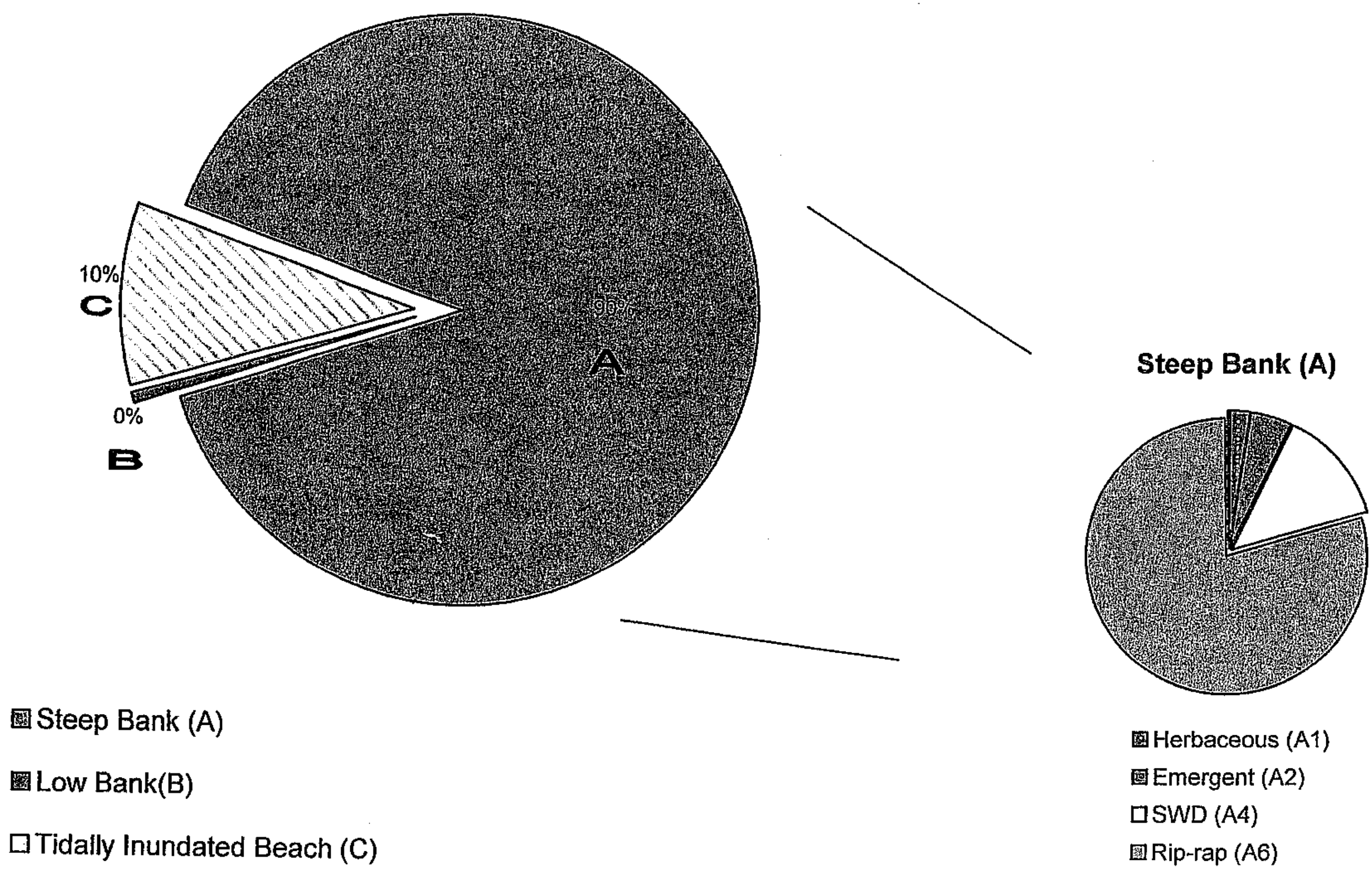
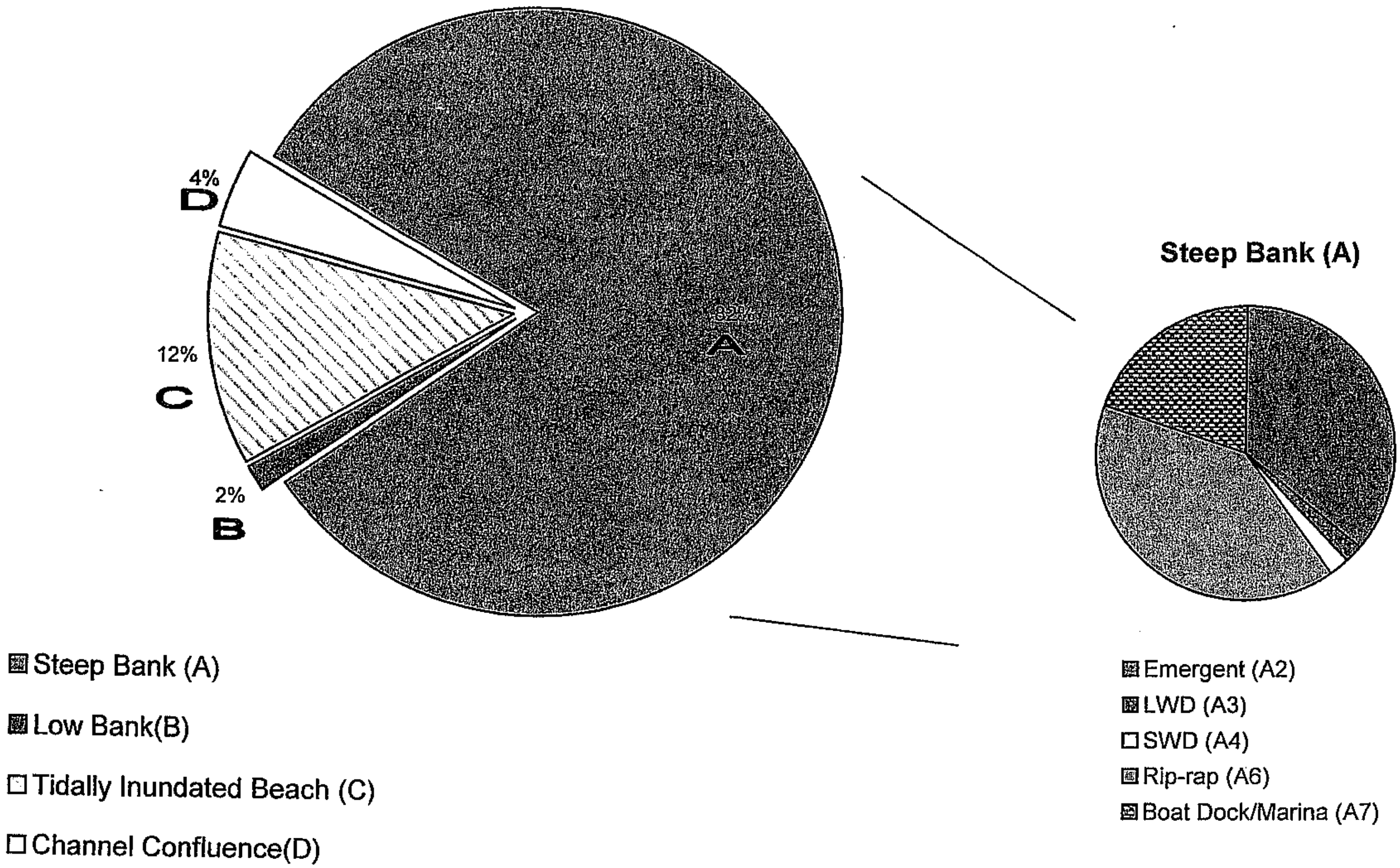
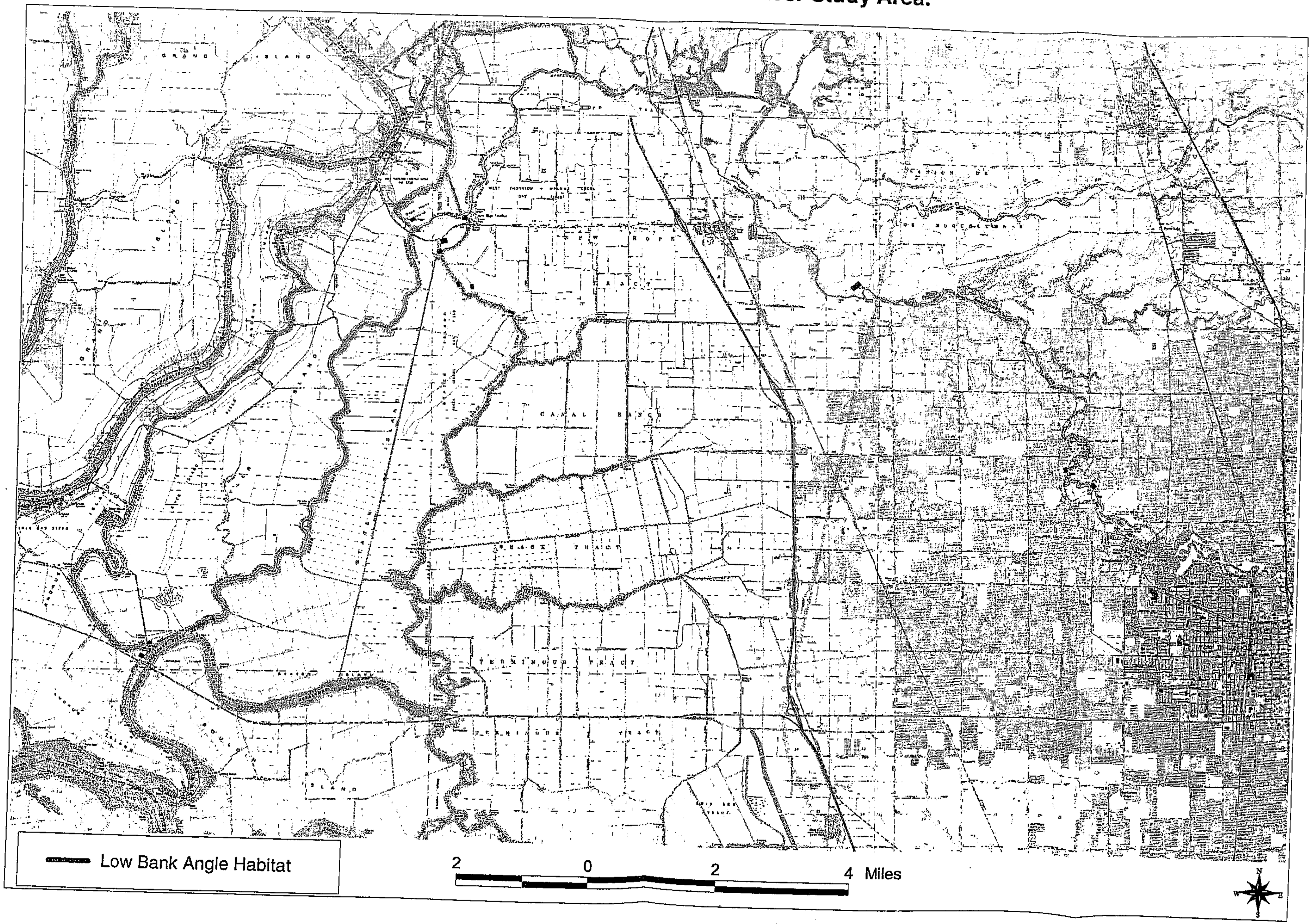


Figure 4-15. Habitat Availability Within Reach M



ENTRIX, Inc.

Figure 4-16. Occurrence of Low Bank Angle Habitat in the Mokelumne River Study Area.



ENTRIX, Inc.

Table 4- 5 Habitat Characterization Codes

Habitat Type	Code
A. Steep to Moderate Bank (>20 degrees at or in water) Default	
1. Herbaceous (Grass/Forbs)	A1
2. Emergent (Cattails/Tules)	A2
3. Large Woody Debris/Vegetation (>1" diameter)	A3
4. Small Woody Debris/Vegetation Thickets (<1")	A4
5. Unvegetated (Bare) Bank	A5
6. Bank Revetment (Rip rap)	A6
7. Other	A7
B. Low Bank (<20 degrees at or in water)	
1. Herbaceous (Grass/Forbs)	B1
2. Emergent (Cattalils/Tules)	B2
3. Large Woody Debris/Vegetation (>1" diameter)	B3
4. Small Woody Debris/Vegetation Thickets (<1")	B4
5. Bare (Beach/Shoal)	B5
6. Other	B6
C. Tidally Inundated Bench	
1. Herbaceous (Grass/Forbs)	C1
2. Emergent (Cattails/Tules)	C2
3. Wood Debris/Vegetation (Small/Large)	C3
4. Bare	C4
5. Bank Revetment (Rip-rap)	C5
6. Other	C6
Mid Channel	Mid

4.4 FISH DISTRIBUTION AND HABITAT PREFERENCE

There is no obvious pattern to salmon distribution or abundance on a geographic scale within the study area (Figure 4-6). There does appear to be a tendancy to encounter more zero catches in the lower portion of the South Mokelumne. Evaluation of habitat preference is based upon the relationship between the effort expended in a specific habitat and the CPUE for that habitat. Electrofishing and seining data were sorted by habitat type and the total electrofishing minutes and total catch was summed. The proportion of effort and catch for each habitat type was computed and compared. If the proportion of total catch is roughly equal to the proportion of effort, then there is no preference inferred by the data. Graphic presentation of this data is simplified by dividing the catch by the effort to develop a ratio of catch to effort. Preference for a specific habitat type is inferred if the ratio is greater than one (e.g. 25% of the effort captured 35% of the catch). Conversely, ratios less than one imply avoidance (Figure 4-17). For this exercise, all habitat data was plotted regardless of the number of sampling events, however the number of samples needs to be considered in the interpretation. For boat electrofishing, habitat types A-1, A-2, A-4, A-7 and B had fewer than 3 events each. Habitat type C-4 had a total of four events. All other habitats had more than 10 events. For the seining method, habitat types A-1 and A-4 had 3 events each. All other habitat types had more than 17 events each.

For boat electrofishing, the capture rate in Habitat Type A-3 (steep bank, small woody debris, n=35) is close to what one would expected if there is no selection for or against the habitat. Habitat Types A-5 (steep bank, unvegetated, n=18) and C (tidally inundated flats, all subdominant types, n=4) shows a higher than expected occurrence of salmon. The remaining habitat types all show indications of avoidance, however the only one with large sample size is A6 (steep bank, rip rap, n=28) (Figure 4-17).

For seining, habitat types A-1 (steep bank, herbaceous, n=3) and B (low bank angle, all types, n=19) are above the ratio of 1 indicating preference. The results for habitat types A-3 (steep banks, LWD, n=23) and A-4 (steep banks, SWD, n=4) indicate avoidance.

Figure 4-19 presents the mean CPUE for M2, M1, SM, NM, and M reaches by habitat type. This Figure shows that the highest values were obtained for habitat types A5, A6, A3 and A4 for reaches M2, M1, SM and NM. Mean CPUE values in fish per minute for the dominant habitat types A3, A5 and A6 are 0.32, 1.1 and 0.25 fish per minute, respectively. A single factor ANOVA based on the CPUE for these three habitat types indicated that mean CPUE values were statistically significantly different between habitat types A3, A5, and A6 ($p = 0.002$)(Table 8-6). This could suggests that chinook fry are found predominantly along bare eroded banks, or that they are easier to capture at these locations. However, examination of the distribution of the location of the habitat types in the study area leads to another conclusion. Most of the steep, bare bank habitat occurs in the upper ten miles of the Mokelumne River. In this reach of the river, fish are more concentrated having had little time to disperse or to be preyed upon. The higher CPUE in Reach M2 is likley also associted with this phenomenon (Figure 4-18).

Velocity

Qualitative velocity measurements were made during field collection. Generally, salmon were found throughout a range of velocities, but tended not be collected where velocities were zero. Salmon fry appeared to be associated with shear zones near the bank. This habitat was more easily distinguished along steep banks.

Water Temperature and Turbidity

Water temperature varied little between sites and throughout the study period, ranging from 10.5 C to 18 C. The water was turbid throughout the study period and turbidity levels were highly variable according to flow, location and the tides.

Figure 4-17. Ratio of Catch to Effort for Electrofishing and Seining by Habitat Type

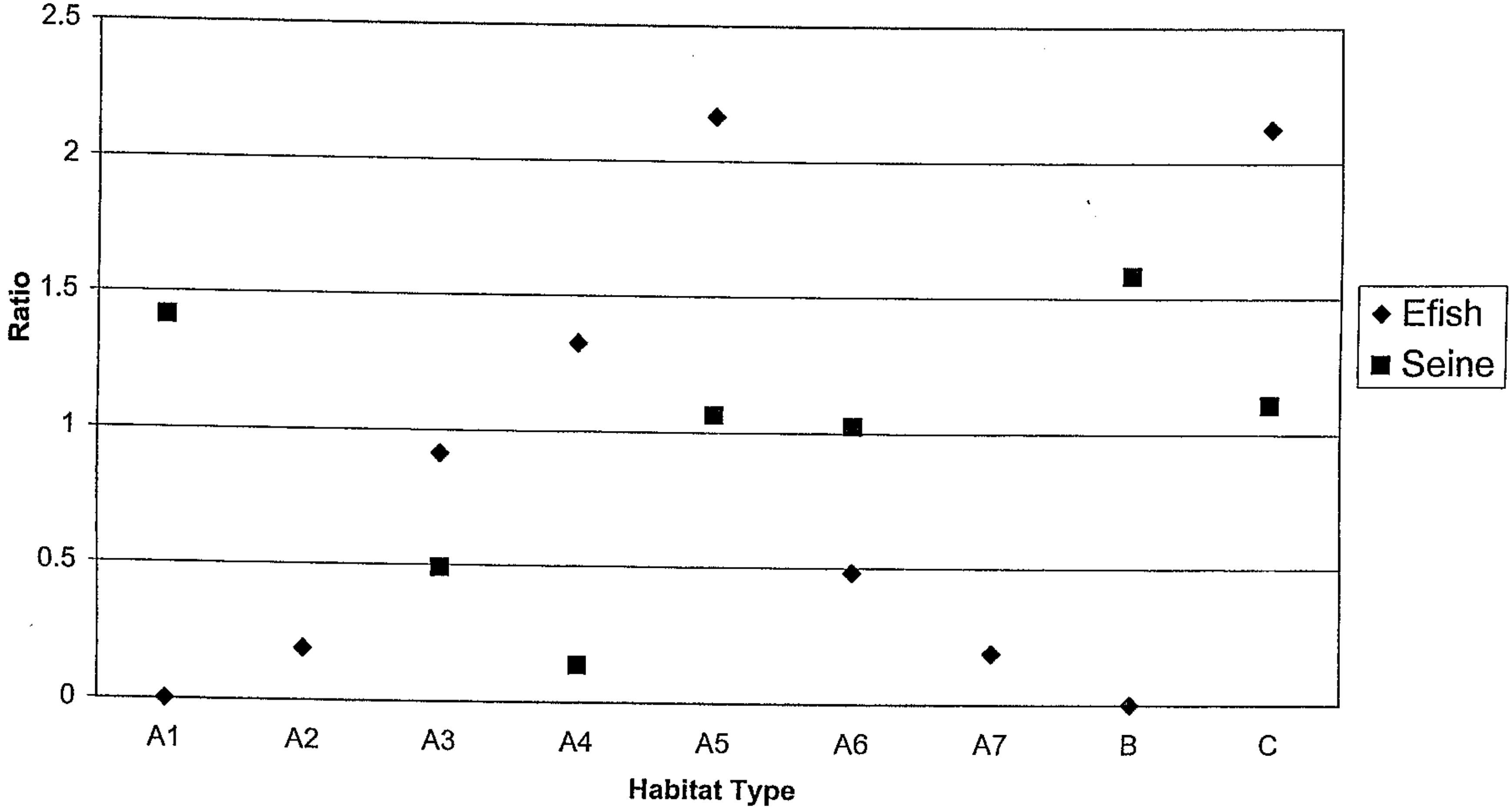
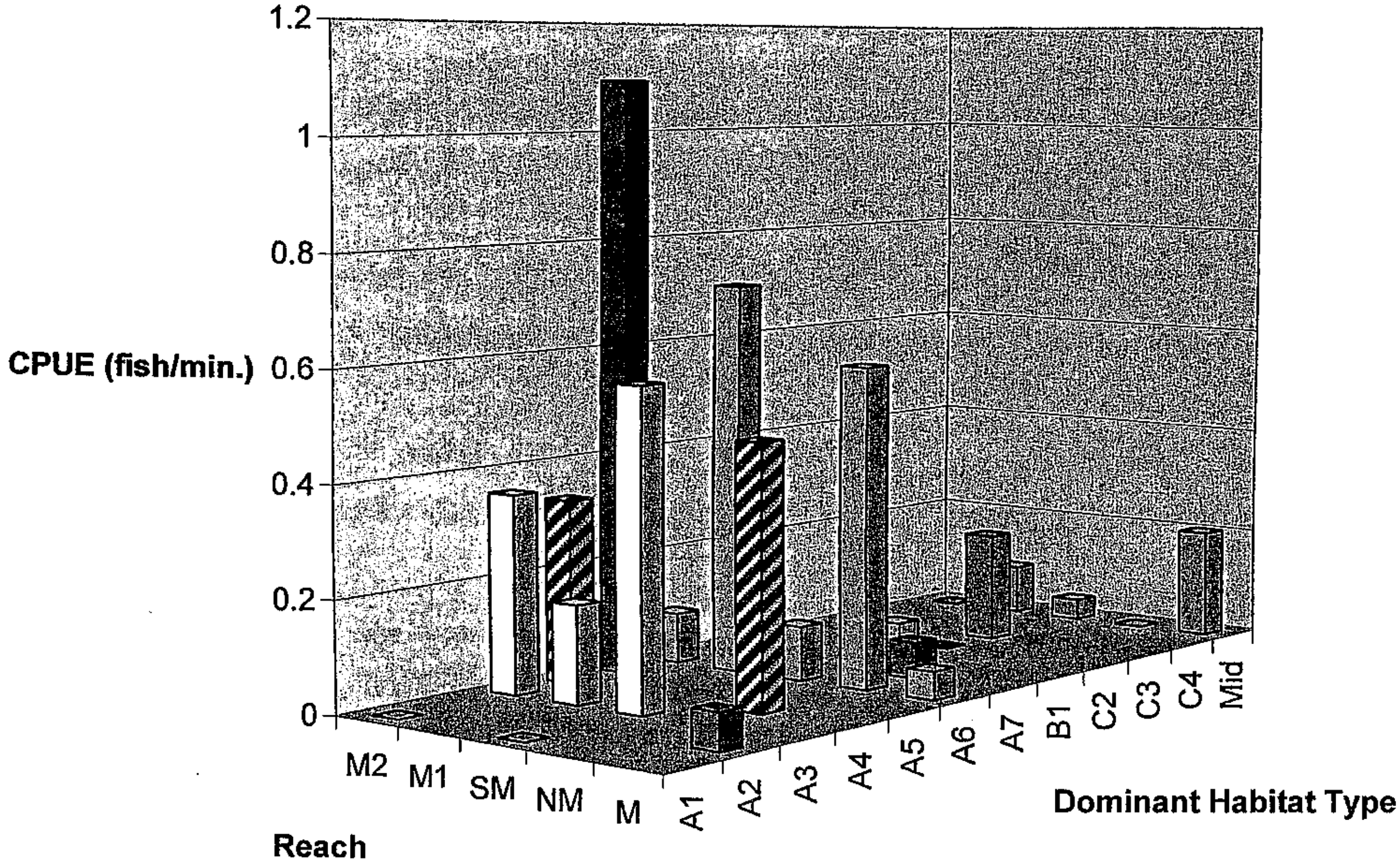


Figure 4-18. Electrofishing Mean CPUE by Reach and Dominant Habitat Type



Substrate Slope

Juvenile chinook appeared to show an affinity for low substrate slope habitats. With all reaches analyzed approximately twice as many chinook were captured per site sampled when substrate slope was low verses when it was either high or moderate. This pattern was observed in the results for all reaches except the NM. This observation is made with some caution because the number of sampling events associated with low slope habitats is very limited and low slope habitats are generally free of obstructions making capture easier.

Substrate Type and Instream Cover

Collections at beaches by seining and by electofishing at inundated tidal benches and along steep, bare banks were loctions where salmon were found in higher abundance. Beaches are relatively unique low bank angle habitats found in reaches M2 and M1 and collections from the tidally inundated benches are restricted to the South Mokelumne River (Figure 4-16).

Chinook Condition

The study period began about two weeks after the major outmigration of fry and extended for a period of six weeks. Due to the early time of year and the relatively short duration of the study it is not surprising that all fry collected were classified as stage 1 or 2. The fry that were collected were small and not yet completely smolted.

4.5 Mark and Release Study

Dye inoculation was done using with the Pow'r-ject system (NewWest Technologies, Santa Rosa) powered by a canister of CO2, or by dental injection gun. The tagging solution was a fluorescent orange, non-toxic microsphere suspension from NewWest Technologies. Only 46 salmon that were captured in reach M2 were tagged during the study. The high incidence of low catch abundance (Figure 4-8 and 4-9) made tagging impractical. The highest catches were around 20 fish, but these were infrequent. Only 26 sites had catches greater than five salmon fry (Figure 4-7). We did not recapture any of these fish in subsequent samples.

A total of 6,069 fry were coded wire tagged (CWT), adipose clipped and released at Woodbridge Dam by EBMUD crews by the end of our field study. We detected none of these tagged fish in our seine or electrofishing catches.

4.6 Summary

The objectives of this pilot study were to:

- Evaluate the distribution of chinook fry in the Mokelumne River;
- Evaluate sampling methods to determine which are most effective at sampling chinook fry from different habitats;

- Characterize the distribution of shoreline habitat types; and
- Determine possible habitat preferences for chinook fry.

The results indicate the following:

- The distribution of chinook fry indicate they are present throughout most channels with flowing water.
- Boat electrofishing is presently one of the methods available for sampling all of the reaches and habitat types in the study area;
- In the study area low slopes with sandy substrates make up about 7% of the shoreline habitat, steep banks with variable substrates comprise about 92% of the shoreline habitat.
- Salmon fry appear to favor shallow areas in the river and in the Delta.

See "Substrate" ¶ on 4-27
& page 5-2
Does Section 5.4 on p 5-3
Put it in best context?

Discussion topics are presented by the objectives of the Pilot study.

5.1 DETERMINE SAMPLING APPROACH AND METHODS

Boat electrofishing and seining were the most successful methods to collect Chinook salmon fry used in the pilot study. Trapping methods are difficult to employ for technical and practical reasons, and would likely not be useful on this system unless they are located on secure property with an around-the-clock observer. The entire Mokelumne River within the study area is navigable and used by anglers and recreational boaters. To be successful at capturing salmon fry, traps would have to employ wings or panels set at or near the surface and these would come into direct conflict with boating activities on the waterways. For this pilot study, boat-based electrofishing and seining provided the best method to address collections over an extensive waterway system. Both methods can employ a crew of 2 field biologists so labor costs are similar, however, boat electrofishing does require the costly, specialized equipment and it may be more difficult to acquire Section 10 permits for boat electrofishing compared to seining. Both methods can be used to collect quantitative data by examining catch per unit effort. This study did not attempt a comparison of catch efficiency between the two sampling methods.

There are limited opportunities to employ other collection methods, especially within the Pilot Study area, because of the limited type of habitats available. There is almost no flood plain habitat within the western Mokelumne River, no extensive freshwater marsh habitat and limited backwater areas. The main habitats are riverine and tidally influenced channels and sloughs and the majority of the shorelines are lined with rip rap. The US Fish and Wildlife Service has been working to develop modified seines that are somewhat successful on rip rap.

The size of chinook fry varied between weeks and reaches. Over the course of the field study there was a slight trend in increasing length, which would be expected, but it was insignificant. The short duration of the study period made it difficult to detect substantial growth. Fish were somewhat smaller in Reach M2 and size increased during the study period. Length frequency histograms suggest the size range of fry captured by boat electrofishing and seining is similar. Seining captured more, smaller fish compared to electrofishing (Figure 8-3, Appendix A).

Backpack electrofishing was useful in Reach M2 to sample over bank flooded areas within the levees after the regulated high flows had passed. But these habitats are extremely rare in the study area. Beach seining is also constrained by the available sites where seines can be employed. Studies on the Cosumnes River Preserve being conducted by UCD and others are employing seining and boat electrofishing on the flood plain. Passive funnel trapping has also be used where flows converge back into the channels, but these sites can only be fished once flood peaks have passed and their success is unproven. Until and unless other collection or detection methods are developed, the most

Good Summary

versatile sampling tool for this study area remains to be an well-operated electrofishing boat.

5.2 DESCRIBE THE TEMPORAL AND GEOGRAPHIC USE OF THE STUDY AREA BY SALMON FRY

There was no strong pattern of use by Chinook salmon fry in the study area. Salmon fry were located throughout the study area in varying densities and there seems to be no pattern to habitat use. This is not surprising giving the different habitat conditions that Chinook salmon fry are exposed to in the study area because habitat conditions in the western Mokelumne River are very different that what is described for the Lower Mokelumne River (Workman 1999). This western Mokelumne River has steep banks and with limited shallow water habitats along the stream margins. There are no distinct pool and glide habitats and riffles are not present. The substrate is fine sands and silts compared to the gravel and cobbles in the Lower Mokelumne River. In general, more consistent catches of salmon fry occurred in Reach M2 compared to all other reaches, The highest incidence of zero catches occurred in the South Mokelumne, particularly in its southern half (Figure 4-6). Reasons for this abundance pattern are more associated with dispersal patterns from the upstream river, than with habitat. As salmon fry move out of the Lower Mokelumne, they would be more concentrated downstream of Woodbridge Dam and then would more gradually disperse into downstream habitat.

High catches of salmon fry (>20) are associated with the upper end of the study area or near New Hope Landing, where the Mokelumne River splits into the North and South Mokelumne River. This is also the location where the riverine system becomes much more strongly influenced by tidal action and perhaps salmon need to hold in these areas and do some staging to adjust to changing conditions. There did not appear to be any shift in habitat use or distribution of fry over the course of the study.

5.3 CHARACTERIZE HABITAT

The initial concept to apply the Cowardin classification system was abandoned when it was realized that the most important habitat to focus on in the study area was the shoreline or edgewater habitat next to the banks. This Cowardin system works well for large geographic areas, but was not designed to classify relatively narrow linear habitat features. The study team developed a classification system to identify features associated with bank angle, substrate and vegetation to describe the shoreline habitats. The study characterized habitats along both banks from the San Joaquin River up to Woodbridge Dam. Over 90% of the study area is characterized as steep bank and nearly half of those steep banks are covered in rip rap. The entire system is also contained within levees set close to the channel. The proximity of the levees does not provide for flood plains to be functional or connected with the channels. Additionally, the regulation of the Mokelumne River provides for only limited flooding duration when storms do occur. These two factors may constrain the ability of the Mokelumne River system to produce food and habitat conditions that would aid in the support of chinook fry. Flood plain function and fish utilization have been the focus of ongoing studies in the Yolo Bypass and the Cosumnes River floodplains (Sommer et. al 2001, Moyle, unpublished data).

5.4 DETERMINE GROWTH AND SURVIVAL

The pilot study proposed to examine growth and survival rates of salmon fry from different habitats. This assumed that salmon would selectively use specific habitats and would remain in these habitats. Neither of these assumptions appear to be correct. Salmon fry within the study area do not appear to be associated with any specific habitat identified in the field sampling. The only habitat that may be important for salmon fry are the tidal benches in the South Mokelumne River. Salmon fry also appear to be continually moving downstream. Slightly larger fry was collected from more downstream reaches (Tables 8-1a and b, Appendix A). Finally, the study covered a relatively brief six week time frame. Given these three factors, any ability to distinguish differences between growth or survival rates would not be possible. Average increase in fish size was about 6-7 mm over the course of the field study.

This pilot study was undertaken as Phase 1 of a two Phased project. The field effort was designed to conduct initial work to assess collection techniques, examine the data and report on recommendations to develop further studies. In concert with the data collection and evaluation is ongoing communication with other researchers conducting salmon fry studies in the lower rivers and Delta. Collaboration with other entities was viewed as a mechanism that would be viewed favorably to stage a second, more comprehensive study designed to address the salmon fry habitat use issue in the Delta. The USFWS conducted pilot salmon fry studies in the northern Delta area of the Sacramento River and Steamboat Slough in the spring of 2001 with similar findings to this pilot study.

If salmon fry are using the Delta for rearing then one of the important questions to ask is how are they using this resource. The two pilot studies conducted to date suggest that they are not using macro habitats such as back water areas, large or small woody debris or other such features salmonids typically use in the upper reaches of rocky alluvial rivers. Fry inhabit turbid channels with sand or mud bottoms that are tidally influenced. Habitat associations are weak, if they are occur at all.

The additional studies that are needed to help identify the functional components of salmon fry Delta habitat should be carried out at a very site-specific level. In reflecting on the Pilot Study results it is apparent that one of the disadvantages of the Pilot Study was the large geographic scope. Not only was this a logistical challenge, but also a study that covered such a large area that it introduced other biases into the data set.

Future sampling efforts should be directed toward understanding why salmon fry are found in the habitats they use. The study should focus on small areas that would be intensively examined. The study period should precede the fry outmigration and continue to operate through the end of the juvenile salmon use period. Due to contract processes the Pilot Study was not able to get a crew into the field until about ten days after the peak outmigration had occurred. It would have been interesting to know if the peak outmigration seen at Woodbridge Dam propagated down stream or was a dispersal mechanism. If established sites consistently collect fry in high abundance, the fry could be marked and released. Nearby collection locations could be used to recapture fry on their path downstream.

Food resources for young salmon are likely a key item for investigation. If salmon fry enter and rear in the Delta, they must be using some food resource. Preliminary studies to identify what salmon fry are eating in the Delta is an important first step. If that can be understood, the next step is to find out what habitat is important for producing that food resource. These studies would require sacrificing large numbers of fry and examining gut contents. It would also require enlisting the knowledge of invertebrate ecologists and perhaps plant ecologists. If food resources are the key to understanding habitat use, then learning more about how the food resource interacts with Delta habitat may be the key to improving conditions for salmon fry survival and growth in the Delta.

Allen, M.A. and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)--chinook salmon. U.S. Fish and Wildlife Service Biological Report 82(11.49). U.S. Army Corps of Engineers. TR EL-82-4. 26 pp.

Brandes, P.L. and J.S. McLain. Juveniles Chinook Salmon, Disturbance, and Survival in the Sacramento-San Joaquin Estuary. Proceedings for USFWS Service Workshop. Fish Bulletin 179. In press.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife document FWS/OBS-79/31.

Demko, D.B., and S.P. Cramer. 1996. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. 1996 Annual Report. Prepared for South San Joaquin Irrigation District and Oakdale Irrigation District.

EBMUD. Unpublished data acquired from Joe Merz. Fisheries Biologist. Lodi, CA.

Healey, M.C. 1980. Utilization of the Nanaimo River Estuary by juvenile chinook salmon (Oncorhynchus tshawytscha). U.S. Natl. Mar. Fish. Serv. Fish. Bull. 77:653-668.

Healey, M.C. 1982. Juvenile Pacific salmon in estuaries: the life support system. Pages 315-341 in V. Kennedy, ed. Estuarine comparisons. Academic Press. New York.

Kjelson, M.A., and P.F. Raquel. 1981. Influences of freshwater inflow on chinook salmon (Oncorhynchus tshawytscha) in the Sacramento-San Joaquin Estuary. Pages88-108 in R.D. Cross and D.C. Williams, eds. Proceedings of the national symposium on freshwater inflow to estuaries, vol. 2. U.S. Fish and Wildlife Service. FWS?OBS-81/04.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile chinook salmon, (Oncorhynchus tshawytscha), in the Sacramento-San Joaquin Estuary, California. Pages 393-411 in V. Kennedy, ed. Estuarine comparisons. Academic Press. New York.

Mains, E.M. and J.M. Smith. 1964. The distribution, size, time, and current preferences of seaward migrant chinook salmon in the Columbia and Snake Rivers. Wash. Dep. Fish. Fish. Res. Pap. 2(3):5-43.

Myers, K.W., and H.F. Horton. 1982. Temporal use of an Oregon estuary by hatchery and wild juvenile salmon. Pages 377-392 in V. Kennedy, ed. Estuarine comparisons. Academic Press. New York.

Rich, W.H. 1920. Early life history and seaward migration of chinook salmon in the Columbia and Sacramento Rivers. Bull. Bur. Fish. (U.S.) 37:74 p.

Soomer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, R. Kurth. 2000. Floodplain rearing may enhance growth and survival of juvenile chinook salmon in the Sacramento River. IEP Newsletter. Summer 2000.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, W.J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Science 58: 325-333.

Snider, B., and R. Titus. 1995. Lower American River Emigration Survey. November 1993 – July 1994. California Dept. Fish and Game. ESD. Streamflow and Habitat Evaluation Program.

Snider, B. and R. Titus. 1998. Evaluation of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing. November 1995 – July 1996. California Dept. Fish and Game. ESD. Streamflow and Habitat Evaluation Program.

USFWS. 1997. Abundance and survival of juvenile chinook salmon in the Sacramento-Sacramento Estuary. 1994 Annual Progress Report.

USFWS. 2000. Abundance and survival of juvenile chinook salmon in the Sacramento-Sacramento Estuary. 1996 Annual Progress Report.

USFWS and USBR. 1999. Comprehensive Assessment and Monitoring Program (CAMP). Annual Report 1998. United States Department of Interior and Central Valley Project Improvement Act. Prepared by CH2MHILL.

Workman, M. 1999. An assessment of the downstream migration of juvenile chinook salmon (Oncorhynchus tshawytscha) in the lower Mokelumne River, California. M.S. Thesis.

APPENDIX A. SUPPORTING TABLES AND FIGURES

Table 8-2 Summary of Sampling by Gear Type

	Sampling Timeframe by Gear Type		No. of Sampling Events by Gear Type	Total No. Salmon Caught by Gear Type
Gear Type	Date	Length (days)		
1	3/1-3/22	22	138	346
2	3/1-3/12	12	9	5
3	2/29-3/23	24	94	432
4	3/12-3/22	11	6	11
5	3/16-4/5	21	29	0
6	3/28-4/5	9	24	0
			Total Count of Salmon Caught	794

Table 8-3a Comparison of Boat Electrofishing Average Catch Density and Standard Deviation

Average Catch Density (fish/min) per Week by Reach for Boat Electrofishing												
	m2	m2	m1	m1	SM	SM	NM	NM	upper	upper	lower	lower
Week[a]	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
3/4/00	na	na	na	Na	0.06	0.10	0.12	0.10	na	na	0.09	0.10
3/11/00	0.66	0.41	0.15	Na	0.11	0.29	na	na	0.41	na	0.11	0.29
3/18/00	0.64	1.11	0.17	0.37	0.13	0.22	1.2	1.9	0.40	0.52	0.67	1.05
3/25/00	na	na	0.36	0.28	0.73	1.29	0.44	0.52	0.36	na	0.59	0.90

Table 8-3b Comparison of Seining Average Catch Density and Standard Deviation.

Average Catch Density (fish/foot) per Week by Reach for Seine												
	m2	m2	m1	m1	SM	SM	NM	NM	upper	upper	lower	lower
Week	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
3/4/00	0.13	0.17	0.05	0.044	na	na	Na	na	0.09	0.11	na	na
3/11/00	0.10	0.20	0.027	0.023	0.21	0.30	Na	na	0.06	0.11	0.21	0.30
3/18/00	0.013	0.028	0.00	Na	0.047	0.027	Na	na	0.01	0.03	0.05	0.03
3/25/00	0.15	0.25	1.4	Na	0.020	0.030	Na	na	0.77	0.25	0.02	0.03

Table 8-4a Comparison of Boat Electro-Fish Average Fork Length and Standard Deviation.

Average Fork Length (mm) per Week by Reach for Boat Electrofishing												
	m2	m2	m1	m1	SM	SM	NM	NM	upper	upper	lower	lower
Week[a]	Average	Std. Dev	Average	Std. Dev	Average	Std. Dev	Average	Std. Dev	Average	Std. Dev.	Average	Std. Dev.
3/4/00	na	na	na	Na	49	3.2	50	6.5	na	na	50	4.8
3/11/00	49	8.7	67	Na	56	6.9	na	na	58	na	56	6.9
3/18/00	54	7.6	57	10	52	7.5	59	9.3	55	1.7	56	8.4
3/25/00	na	na	60	8.2	61	9.4	62	6.7	60	na	61	8.1

Table 8-4b Comparison of Seining Average Fork Length and Standard Deviation.

Average Fork Length (mm) per Week by Reach for Seine												
	m2	m2	m1	m1	SM	SM	NM	NM	upper	upper	lower	lower
Week	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
3/4/00	45	6.5	50	6.4	na	na	na	na	47	6	na	na
3/11/00	50	8.3	39	1.4	56	9.1	na	na	45	5	56	9
3/18/00	43	12	na	Na	57	13	na	na	43	12	57	13
3/25/00	52	5.3	66	9.6	54	11	na	na	59	7	54	11

Table 8-5 ANOVA Table for Boat Electrofishing CPUE

ESE Analysis of Variance

Anova: Single Factor **All Reaches**

SUMMARY

Groups	Count	Sum	Average	Variance
m1	17	3.825461	0.225027	0.122603
m2	37	24.75799	0.669135	1.187186
SM	30	4.058669	0.135289	0.058641
NM	10	8.272222	0.827222	1.818069
m	5	0.421429	0.084286	0.005243

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.595797	4	1.898949	2.843076	0.028329	2.468532
Within Groups	62.78454	94	0.667921			
Total	70.38034	98				

Anova: Single Factor **m1 vs m2**

SUMMARY

Groups	Count	Sum	Average	Variance
m1	17	3.825461	0.225027	0.122603
m2	37	24.75799	0.669135	1.187186

ANOVA

Table 8-5 (cont'd) ANOVA Table for Boat Electrofishing CPUE

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.297384	1	2.297384	2.672551	0.108132	4.026631
Within Groups	44.70035	52	0.859622			
Total	46.99774	53				

Anova: Single Factor **SM vs. NM**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SM	30	4.058669	0.135289	0.058641
NM	10	8.272222	0.827222	1.818069

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.590787	1	3.590787	7.554021	0.00911	4.098169
Within Groups	18.06322	38	0.475348			
Total	21.654	39				

Anova: Single Factor **m1, m2, SM, NM**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
m1	17	3.825461	0.225027	0.122603
m2	37	24.75799	0.669135	1.187186
SM	30	4.058669	0.135289	0.058641
NM	10	8.272222	0.827222	1.818069

ANOVA

Table 8-5 (Cont'd) ANOVA Table for Boat Electrofishing CPUE

	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.010993	3	2.336998	3.351144	0.022467	2.705839
Within Groups	62.76357	90	0.697373			
Total	69.77456	93				

Table 8-6 ANOVA Table for Dominant Habitat Types

Anova: Single Factor **A3, A5, A6 and Mid**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A3	32	10.14757	0.317112	0.153093
A5	17	18.60681	1.094518	2.098979
A6	24	5.893229	0.245551	0.201034
Mid	14	0.771493	0.055107	0.006538

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.65332	3	3.551108	6.848362	0.000353	2.714565
Within Groups	43.03832	83	0.518534			
Total	53.69164	86				

Anova: Single Factor **A3, A5, A6**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A3	32	10.14757	0.317112	0.153093
A5	17	18.60681	1.094518	2.098979
A6	24	5.893229	0.245551	0.201034

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.585883	2	4.292941	6.996103	0.001699	3.127681
Within Groups	42.95332	70	0.613619			
Total	51.53921	72				

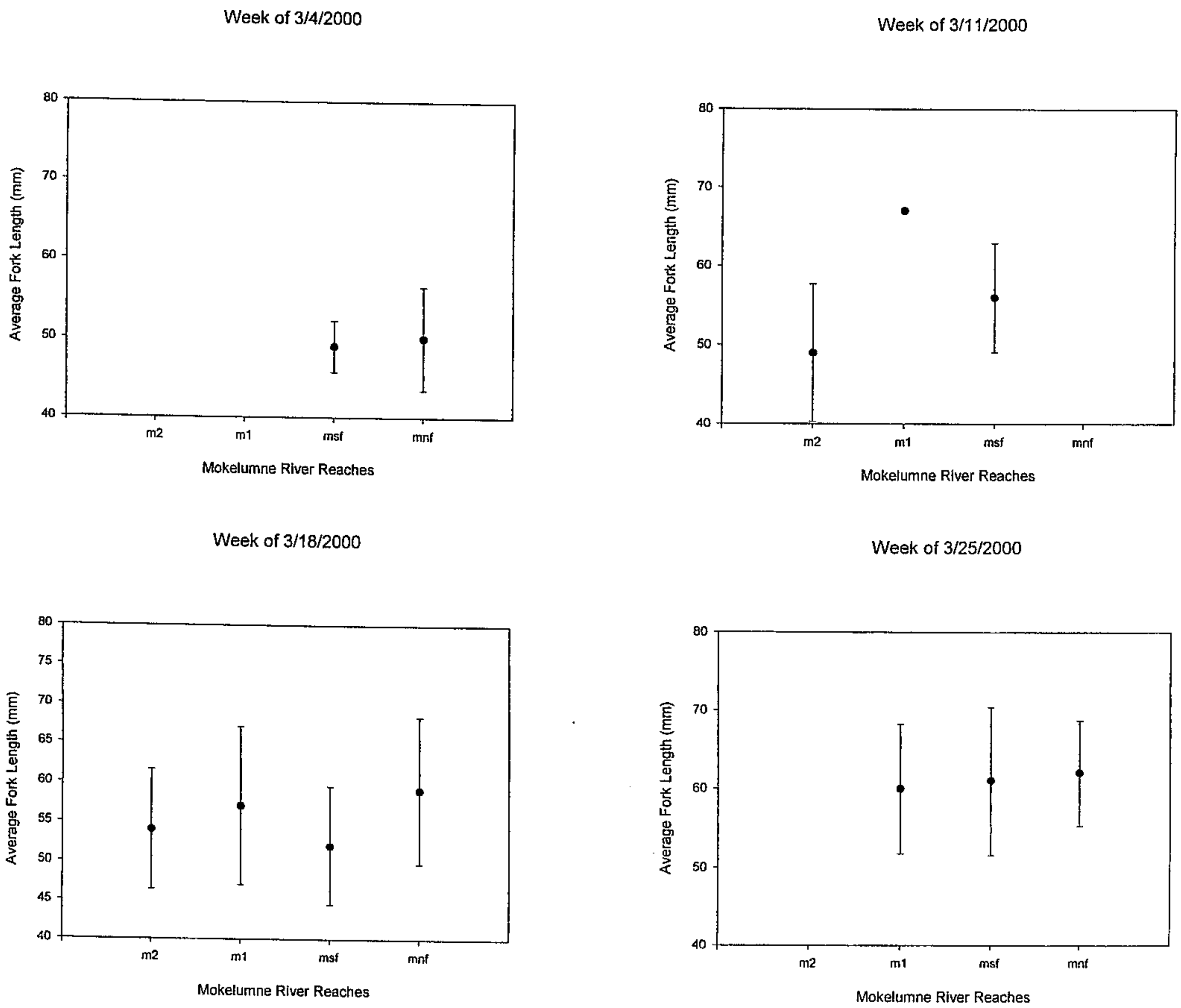


Figure 8-1(a) Average Fork Length +/- one standard deviation of chinook salmon fry outmigrants captured by boat electrofishing in the four reaches of the study area

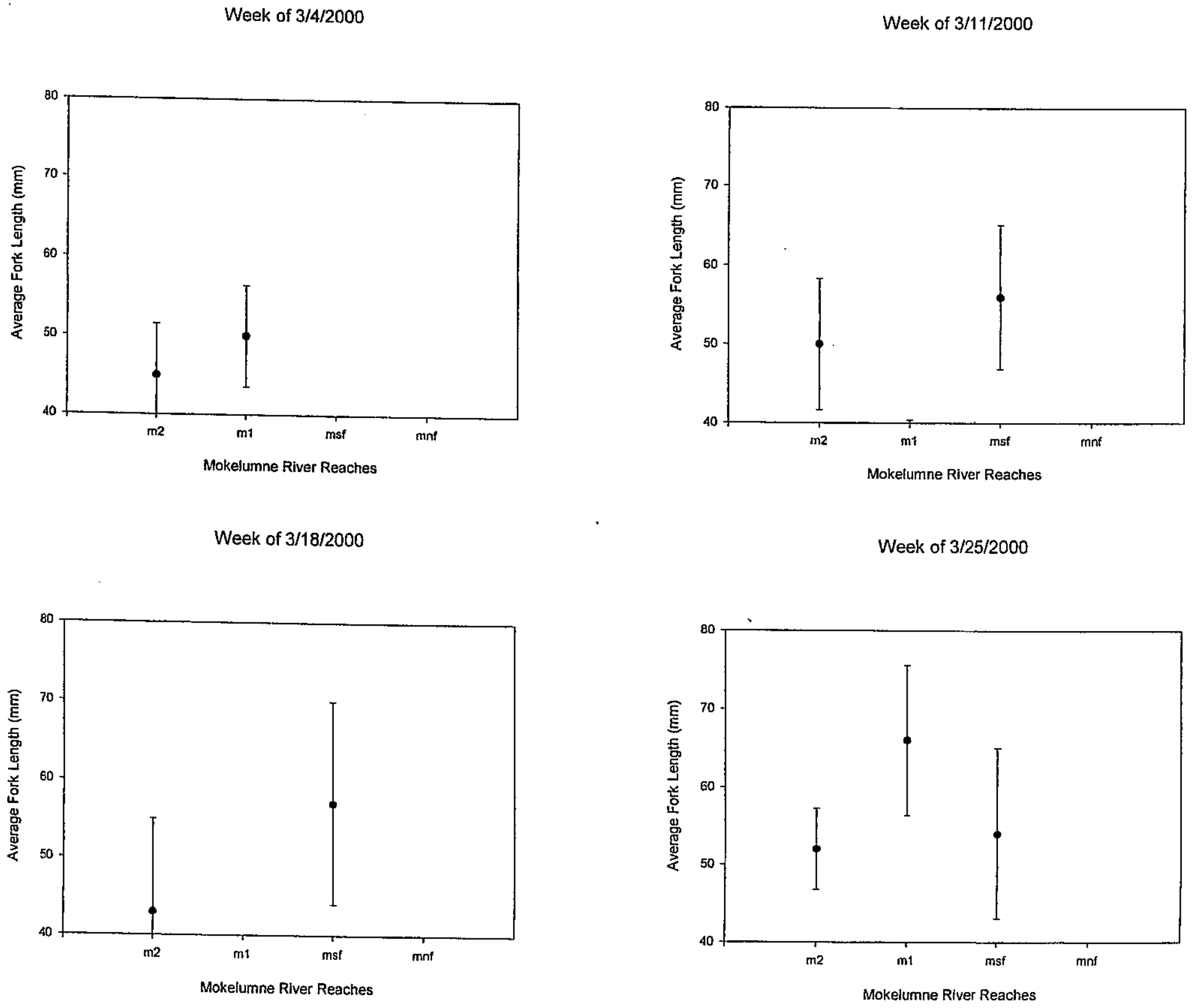


Figure 8-1(b) Average fork length +/- one standard deviation of chinook salmon fry outmigrants captured by seining by week in the four reaches of the study area

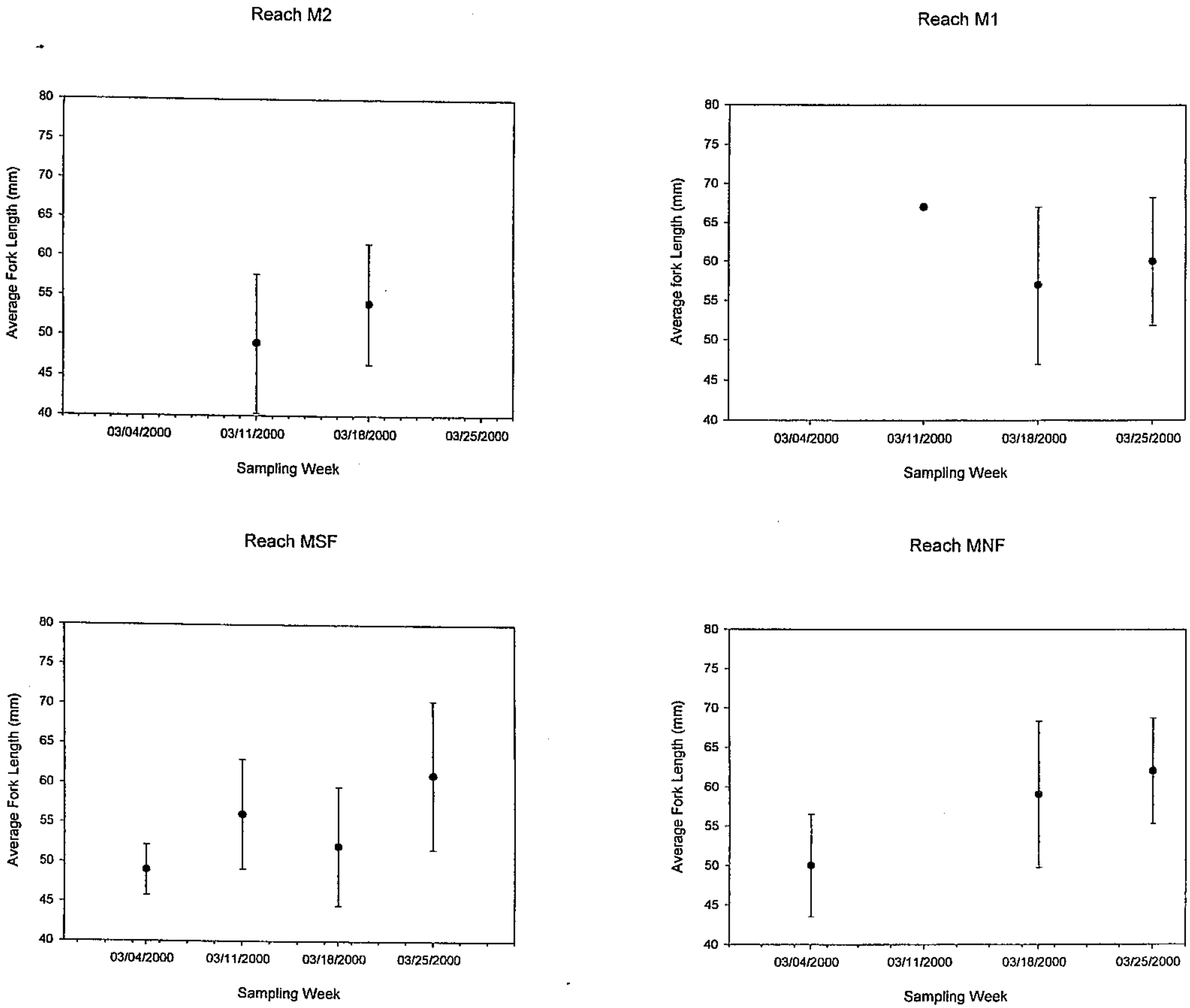


Figure 8-2(a) Average Fork Length +/- one standard deviation of chinook salmon fry outmigrants captured by boat electrofishing by reach during the study period

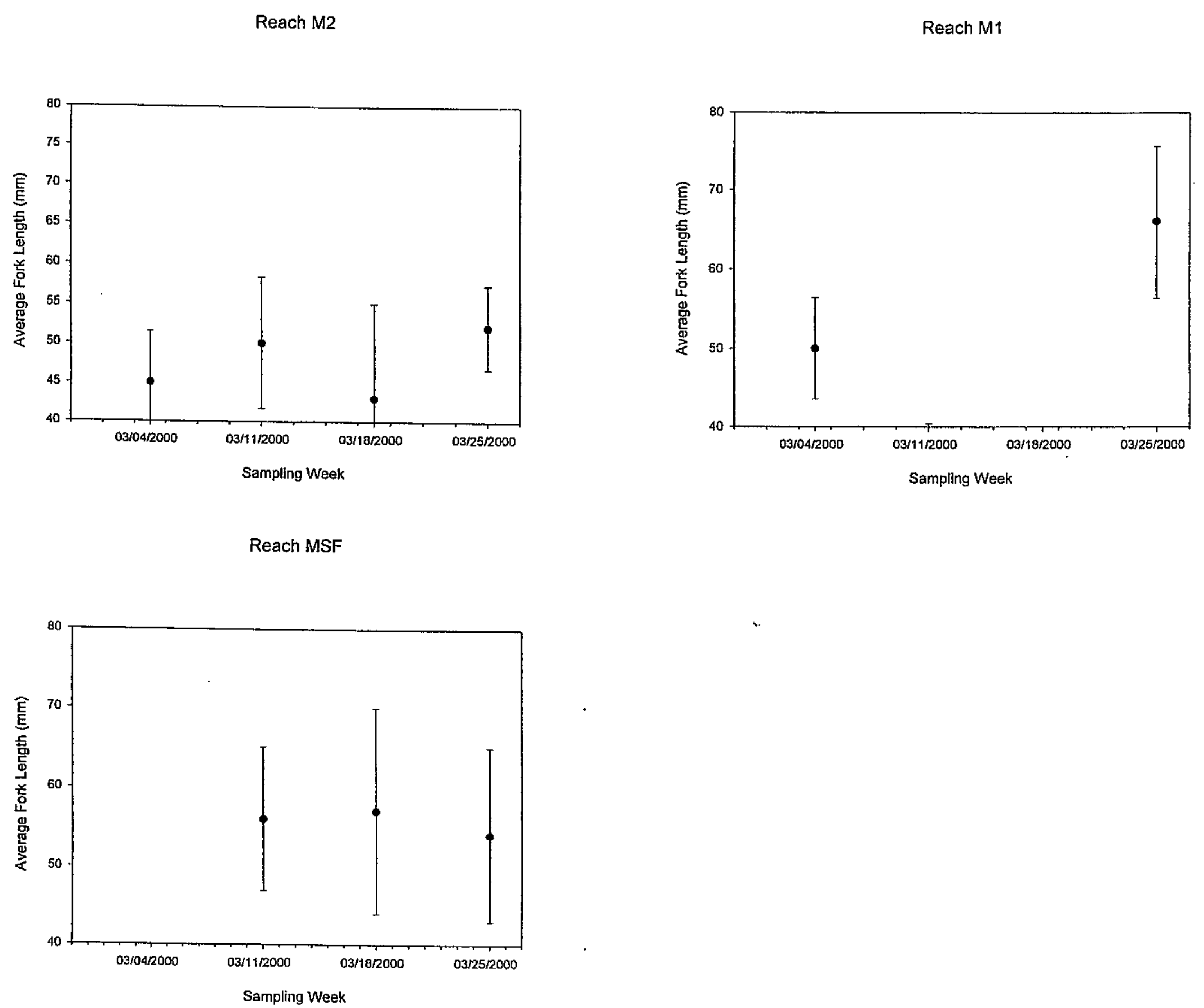
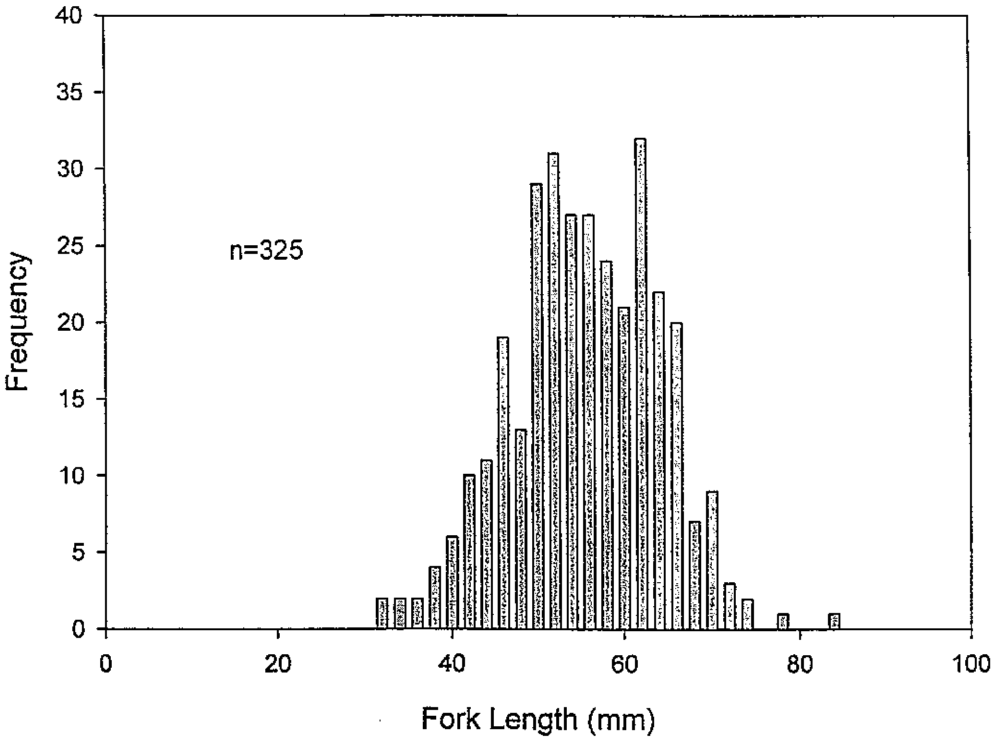


Figure 8-2(b) Average fork length +/- one standard deviation of chinook salmon fry outmigrants captured by seining by reach during the study period

Length Frequency of Fall run chinook salmon fry captured by boat electrofishing



Length-Frequency of Fall run chinook salmon captured by seining

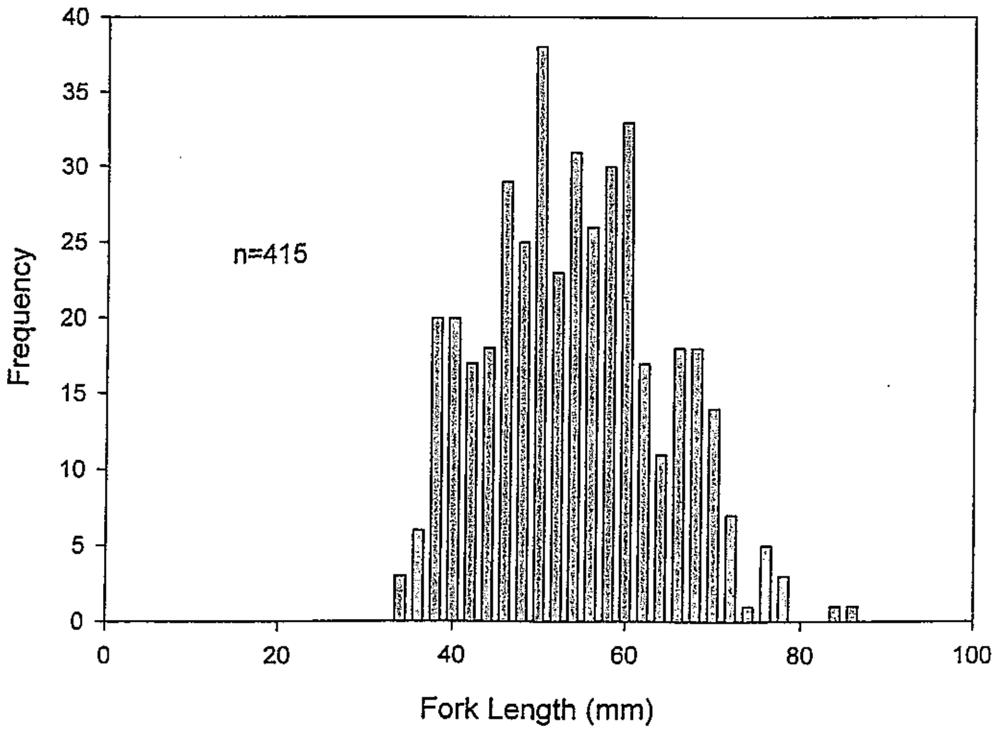


Figure 8-3