CALIFORNIA DEPARTMENT OF FISH AND GAME
ENVIRONMENTAL SERVICES DIVISION
Stream Flow and Habitat Evaluation Program

# CENTRAL VALLEY ANADROMOUS FISH-HABITAT EVALUATIONS
## Sacramento and American river investigations
## October 1995 through September 1996

Annual Progress Report
Prepared for
U.S. Fish and Wildlife Service
Central Valley Anadromous Fish Restoration Program

Stream Evaluation Program
Technical Report No. 97-1
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2/ Stream Evaluation Program Technical Report No. 97-1.


(PL. 102-575).

# INTRODUCTION

In July 1995, the California Department of Fish and Game(DFG) entered into an agreement with the U.S. Fish and Wildlife Service (FWS) to evaluate anadromous salmonid habitat requirements in Central Valley streams. Various studies have been developed and are being implemented by the Stream Flow and Habitat Evaluation Program to provide the FWS Central Valley Anadromous Fish Restoration Program with reliable scientific information. The information is to be used by DFG and FWS to develop flow recommendations to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The basic approach to the evaluations is outlined in "*Proposal to define instream flow and habitat requirements for anadromous resources in Central Valley Streams, September 1994*. The approach includes developing a better understanding of the life history of chinook salmon and steelhead trout emphasizing the relationships between life stage requirements and manageable habitat attributes (e.g., flow, water temperature, channel conditions, etc.). Initially, the evaluations are to be conducted in the Sacramento and American rivers and will include individual investigations of spawning, rearing and migration.

One of the requirements of the agreement is to provide the FWS with annual progress reports (based upon the federal fiscal year, October 1 - September 30). During the first 3 months of the agreement, the DFG prepared for the first complete year of investigation that began in October 1995. This report covers the investigations conducted in both the Sacramento and American rivers during the period October 1995 through the last week of September 1996. During that period, DFG conducted six general investigations in the Sacramento River and three general investigations in the American River (Table 1).

Table 1. Investigations conducted by the Department of Fish and Game to determine anadromous salmonid habitat requirements in Central Valley streams - October 1995 through the last week of September 1996.

| Investigation | Sacramento River | American River |
|---|---|---|
| Habitat mapping | X | Completed |
| Fall-run chinook salmon spawning | X | X |
| Late fall-run chinook salmon spawning | X | not applicable |
| Winter-run chinook salmon spawning | X | not applicable |
| Juvenile salmonid rearing | X | X |
| Juvenile salmonid emigration | X | X |

The results of three investigations conducted during the reporting period are presented as Appendices B, C, D, E and F. These reports cover fall-run chinook salmon spawning evaluations conducted in both the Sacramento and American rivers and winter-run chinook salmon spawning in the Sacramento River. Habitat mapping on the Sacramento River and rearing and emigration investigations on both streams are summarized below.

The purpose of this first annual progress report is to generally describe ongoing investigations and to summarize data being collected to evaluate anadromous fish habitat needs in California's Central Valley. No attempt is made herein to analyze data that generally represents less than a complete year's investigation.

## SACRAMENTO RIVER HABITAT MAPPING

The Sacramento River study reach extends 25.5 miles, from near Battle Creek (river mile (RM) 271.5) to Keswick Dam (RM 302), the upper extent of anadromous fish access in the Sacramento River (Figure 1). Habitat types were mapped in fall 1995. Mapping was based upon channel morphology using a stratified classification system similar to that used on the American River (Snider *et al.* 1991). Habitat types (e.g., pool, riffle, run and glide) were stratified by habitat zone (flatwater, bar complex, side-channel and off-channel). Mapping was conducted using aerial photographs and ground surveys. A total of 143 distinct habitat units were defined comprising 12 different habitats (Table 2). Habitat distribution is summarized in Table 3.

Table 2. Summary of habitat mapping units identified in the Sacramento River study reach, Battle Creek to Keswick Dam

| Habitat | | |
|---|---|---|
| Habitat zone | Habitat type | Number |
| Bar complex | Pool | 5 |
| Bar complex | Riffle | 31 |
| Bar complex | Run | 17 |
| Bar complex | Glide | 8 |
| Flatwater | Pool | 6 |
| Flatwater | Riffle | 7 |
| Flatwater | Run | 19 |
| Flatwater | Glide | 22 |
| Side channel | Pool | 2 |
| Side channel | Riffle | 9 |
| Side channel | Run | 3 |
| Off channel | | 14 |

Table 3. Habitat distribution identified in the Sacramento River study reach, near Battle Creek (RM 271) to Keswick Dam (RM 302).

| Habitat ID # | Habitat type | Landmark | River mile |
|---|---|---|---|
| 1 | BC run | | 271 |
| 2 | BC run | | |
| 3 | BC riffle | | |
| 4 | BC riffle | | |
| 5 | BC pool | Barge Hole/Battle Creek | |
| 6 | BC riffle | | |
| 7 | BC glide | | |
| 8 | FW glide | | 272 |
| 9 | BC run | | 273 |
| 10 | BC riffle | Cottonwood Creek | |
| 11 | FW glide | Redding Island | 274 |
| 12 | FW run | | 275 |
| 13 | FW riffle | | 276 |
| 14 | FW glide | Balls Ferry Bridge Crossing | |
| 15 | FW pool | | 277 |
| 16 | FW run | Ash Creek | |
| 17 | FW riffle | | |
| 18 | FW glide | Bear Creek | |
| 19 | FW run | | 278 |
| 20 | BC run | | |
| 21 | BC riffle | | |
| 22 | BC run | | |
| 23 | BC riffle | | |
| 24 | FW glide | | |
| 25 | FW run | | |
| 26 | FW riffle | Power Line riffle | 279 |
| 27 | FW glide | | |
| 28 | BC pool | Haas Hole | |
| 29 | BC run | Cow Creek | 280 |
| 30 | BC riffle | | |
| 31 | BC run | | |
| 32 | BC riffle | | |

Table 3 (continued)

| Habitat ID # | Habitat type | Landmark | River mile |
|---|---|---|---|
| 33 | FW glide | | |
| 34 | BC run | Deschutes Rd Xing/Stillwater Creek | 281 |
| 35 | OC area | | |
| 36 | BC riffle | Hawes riffle | |
| 37 | OC area | | |
| 38 | BC glide | | 282 |
| 39 | FW glide | | |
| 40 | FW run | | |
| 41 | BC riffle | | |
| 42 | FW pool | | |
| 43 | FW glide | | |
| 44 | FW pool | | 283 |
| 45 | FW glide | North Street Bridge /Churn Creek | 284 |
| 46 | FW run | Hwy 5 Crossing | 285 |
| 47 | FW pool | | |
| 48 | FW glide | | |
| 49 | FW run | | |
| 50 | FW riffle | Lower Plywood riffle | |
| 51 | FW glide | | 286 |
| 52 | FW run | | |
| 53 | BC riffle | Upper Plywood Riffle | |
| 54 | FW run | | |
| 55 | FW riffle | | |
| 56 | FW glide | | 287 |
| 57 | FW glide | | |
| 58 | FW run | | |
| 59 | BC riffle | | |
| 60 | BC riffle | | |
| 61 | SC riffle | | |
| 62 | BC run | | |
| 63 | BC run | | |
| 64 | BC riffle | Joe Deering riffle | |
| 65 | OC area | | |

Table 3 (continued)

| Habitat ID # | Habitat type | Landmark | River mile |
|---|---|---|---|
| 66 | BC riffle | | |
| 67 | FW glide | | |
| 68 | BC riffle | | |
| 69 | BC riffle | | |
| 70 | BC glide | | |
| 71 | OC area | | 289 |
| 72 | OC area | | |
| 73 | BC run | | |
| 74 | OC area | | |
| 75 | BC riffle | | |
| 76 | SC riffle | | |
| 77 | SC pool | | |
| 78 | SC riffle | | |
| 79 | OC area | | |
| 80 | SC pool | Olney Creek | |
| 81 | BC glide | | 290 |
| 82 | SC run | | |
| 83 | SC riffle | | |
| 84 | SC riffle | | |
| 85 | BC run | | |
| 86 | BC riffle | | |
| 87 | BC glide | | |
| 88 | BC riffle | | |
| 89 | OC area | | |
| 90 | FW glide | | 291 |
| 91 | FW run | | |
| 92 | SC riffle | | |
| 93 | SC run | | |
| 94 | SC riffle | | |
| 95 | OC area | | |
| 96 | SC run | | |
| 97 | SC riffle | Tobiasson riffle | |
| 98 | BC riffle | | |

Table 3 (continued)

| Habitat ID # | Habitat type | Landmark | River mile |
|---|---|---|---|
| 99 | FW glide | | 292 |
| 100 | FW run | South Bonny View Road Crossing | |
| 101 | BC pool | | |
| 102 | BC riffle | | |
| 103 | BC riffle | Golf Course riffle | |
| 104 | BC run | | 293 |
| 105 | FW run | | |
| 106 | BC run | | |
| 107 | OC area | | |
| 108 | BC riffle | Wyndom riffle | |
| 109 | FW glide | | 294 |
| 110 | BC glide | | |
| 111 | BC run | | |
| 112 | BC riffle | Cypress Avenue Bridge Crossing | 295 |
| 113 | BC glide | | |
| 114 | OC area | | |
| 115 | BC run | | |
| 116 | OC area | Kutras Lake | |
| 117 | BC riffle | | |
| 118 | BC pool | | |
| 119 | BC riffle | | |
| 120 | FW glide | | |
| 121 | FW run | Kutras Island | |
| 122 | FW run | | |
| 123 | BC riffle | East Island | |
| 124 | BC riffle | Turtle Bay East | |
| 125 | BC riffle | West Island | |
| 126 | OC area | | |
| 127 | OC area | | |
| 128 | SC riffle | | |
| 129 | BC glide | Hwy 299- 44 /Turtle, Bay West | |
| 130 | BC pool | | |
| 131 | BC run | | |

Table 3 (continued)

| Habitat ID # | Habitat type | Landmark | River mile |
|---|---|---|---|
| 132 | BC riffle | Redding riffle | |
| 133 | FW glide | Pumping Plant | |
| 134 | FW run | | |
| 135 | FW riffle | | |
| 136 | FW glide | | 298 |
| 137 | FW run | | |
| 138 | FW riffle | DWR Gravel Restoration Site | |
| 139 | FW pool | ACID Dam/"Lake Redding" | |
| 140 | FW glide | | |
| 141 | run | 'boulder run' | 300 |
| 142 | pool | | |
| 143 | run | | 301 |

# UPPER SACRAMENTO RIVER REARING HABITAT EVALUATION

Rearing habitat investigations are intended to determine temporal and spatial distributions of the various juvenile life stages of anadromous salmonids as they occur in the upper Sacramento River.  These investigations compliment juvenile emigration evaluations, discussed below, and should be conducted year around to fully describe behavior of juvenile salmonids relative to habitat conditions in the upper Sacramento River.  Some of the information to be gained from both the trapping and rearing evaluations include relative significance of upper river habitat  to the various life stages under varying conditions of habitat, temporal and physical significance of various habitat conditions in the upper river, significance of stream conditions downstream of the study area - basically an overall understanding of the relationship between fish and habitat in the upper river as it is influenced by potentially manageable biotic and abiotic, habitat attributes.  The results of the evaluation reported here represent only two months of sampling and are primarily provided to illustrate the type of data potentially available for further analysis as the evaluations are continued then replicated over the course of the 5-year study.

Evaluation of anadromous salmonid rearing habitat was initiated in August 1996. Rearing was evaluated from RM 276, upstream to Keswick Dam (RM 302).  This reach is upstream of the direct influence of hatchery management.  The traps being used to evaluate emigration from natal habitat are located at RM 276.  Three replicates of 11 habitats were randomly selected and sampled, if possible, twice per month. (For this report, all the data from the two similar habitats distinguished by zone (i.e., flatwater pool and bar complex pool) were combined to represent five, instead of 11 habitats: riffle, pool, glide, run and off-channel).  Each habitat unit was sampled by direct observation.  Two swimmers would survey a 150 ft long section randomly selected along each bank of the habitat unit.  Data acquired included species, size (in 25 mm size classes), and general habitat attributes (mean depth, mean velocity, cover, etc.). When possible, a site within the habitat unit was also sampled with a 50 ft x 4 ft beach seine. Up to two seine hauls were made per unit.  Data acquired included number of salmonids (by species), size of up to 50 salmon and trout, per haul, (i.e., fork length (FL) to the nearest 0.5 mm, and weight, to the nearest 0.1 g), and general habitat attributes of the seined area.

A total of 137 sites were sampled beginning week 32 (04-10 August) through the first week of October (week 40) (Table 4).  Sample sites included 47 riffles, 26 pools, 34 glides and 30 runs.  No off-channel habitats were sampled during this period.

Snorkel surveys were conducted at all 137 sites.  Seining was conducted in 61 of the 137 sites (Table 5).

Table 4. Weekly distribution of habitat types sampled during the upper Sacramento River rearing habitat evaluation, August - October 1996.

| Week | Riffle | Pool | Glide | Run | Off-channel |
|---|---|---|---|---|---|
| 32 | 6 | 5 | 5 | 4 | 0 |
| 33 | 5 | 0 | 2 | 2 | 0 |
| 34 | 3 | 3 | 4 | 7 | 0 |
| 35 | 5 | 4 | 2 | 1 | 0 |
| 36 | 1 | 1 | 2 | 1 | 0 |
| 37 | 8 | 4 | 3 | 4 | 0 |
| 38 | 10 | 4 | 4 | 3 | 0 |
| 39 | 4 | 3 | 6 | 5 | 0 |
| 40 | 4 | 3 | 5 | 3 | 0 |
| Total | 46 | 27 | 33 | 30 | 0 |

Table 5. Distribution of habitat units (identification numbers per Table 3) sampled by both seine and snorkel and those only snorkeled during the upper Sacramento River rearing habitat evaluation, August - October 1996.

| Week | Seine & snorkel | Snorkel only |
|---|---|---|
| 32 | - | 4, 7, 9, 17, 24, 28, 44, 47, 49, 55, 61, 67, 77, 87, 96, 106, 108, 109, 118, 135 |
| 33 | 6, 10, 18, 21, 30, 31, 38, 63, 75 | - |
| 34 | 81, 82, 91, 104, 110, 123, 130 | 85, 93, 96, 111, 118, 124, 128, 129, 136, 139 |
| 35 | 6, 10, 18 | 9, 28, 33, 44, 50, 66, 77, 78 |
| 36 | 91, 104, 110, 123, 130 | - |
| 37 | 21, 30, 38, 40, 63, 75, 82 | 3, 5, 8, 17, 22, 26, 42, 44, 46, 62, 66, 70, 73 |
| 38 | 6, 10, 21, 23, 30 | 75, 76, 78, 80, 87, 90, 91, 92, 93, 101, 105, 109, 111, 130, 135, 141 |
| 39 | 31, 38, 63, 77, 81, 82, 91, 104, 110, 123, 130 | 2, 15, 23, 24, 28, 30, 45 |
| 40 | 110, 130 | 57, 63, 64, 67, 70, 73, 108, 118, 121, 123, 139, 140 |

## Snorkel Survey Results

### Chinook Salmon

A total 7,568 chinook salmon were counted during the snorkel survey (Table 6). The mean weekly number of salmon counted per sample site ranged from 22 (Week 36) to 147 (Week 34).

The majority of salmon counted were in the 25-50 mm size range (34%) (Figure 2). Twenty-eight percent of the salmon counted were in the 50-75 mm range, 28%were in the 75-100 mm range, and 10% were >100 mm. Small, recently emerged salmon (25-50 mm) dominated the counts during the latter portion of the survey, beginning in week 36 (Figures 3-5). Prior to Week 36, salmon in the 25-50 mm range comprised from <1% to 19.5% of the count; from Week 36 through Week 40, salmon in this size group comprised from 62 to 84% of the count. Prior to week 36, composition of salmon >75 mm ranged from 11% in week 33 to 92% in week 35.

Salmon distribution by habitat type varied both between habitat types and within habitat types over time (Table 7, Figures 6-8). The mean weekly salmon count (*n*/meter) was greatest for runs ((1.74 fish/m) closely followed by pools (1.67 fish/m). Riffle counts averaged 0.82 fish/m; glide counts averaged 0.58 fish/m. During Week 34, when counts were highest and the composition of large salmon (>75 mm) was also high, the majority of salmon were counted in riffles (5.3 fish/m). However, when the composition of large salmon was highest (Week 35), counts were highest in pools (1.9 fish/m) and lowest in riffles (0.035 fish/m). When small, recently emerged salmon dominated the counts (Weeks 36-40), the highest counts were made in pools (range: 0.06 to 4.09 fish/m).

### Rainbow trout

A total of 6,718 rainbow trout were counted during the snorkel survey (Table 8). The mean weekly number of trout counted per sample site ranged from 11.3 (Week 35) to 104.8 (Week 33).

The majority of trout counted were in the 50-75 mm range (47%); 38% were <50 mm (Figure 9). Trout <25 mm were abundant during Weeks 32 (775 fish) and 33 (403 fish), but were scarce during every other week. The nest highest count occurred during Week 36 (16 fish). Trout between 25 and 50 mm were absent during Week 32 but were fairly well represented in weeks 34-40 (Figures 10-12) (counts in week 35 for all sizes of rainbow trout and salmon were low, possibly due to the sites sampled during that week). Trout between 50 and 75 mm were well represented during each week's counts, the highest count occurred during Week 32. Trout >75 mm were counted each week. The highest count of trout in this size range occurred during Week 34; this size group dominated the catch during Week 35, the period with the lowest overall count.

Table 6. Summary of chinook salmon data collected by snorkel survey in the upper Sacramento River rearing habitat evaluation, August - October 1996.

| Week (beginning date) | Number of sites | Total count | *n*/site | Size composition (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | < 25 mm | 25-50 mm | 50-75 mm | 75-100 mm | >100 mm |
| 32 (04 Aug) | 20 | 1,646 | 82.3 | 0 | 7.5 | 37 | 42 | 13 |
| 33 (11 Aug) | 9 | 158 | 17.56 | 0 | 19.5 | 69.5 | 11 | 0 |
| 34 (18 Aug) | 17 | 2,497 | 146.9 | 0 | 14 | 33 | 41 | 12 |
| 35 (25 Aug) | 12 | 388 | 32.33 | 0 | <1 | 7 | 53 | 39 |
| 36 (01 Sep) | 5 | 112 | 22.4 | <1 | 68 | 31 | 0 | 0 |
| 37 (08 Sep) | 20 | 413 | 20.65 | <1 | 62 | 25 | 10 | 3 |
| 38 (15 Sep) | 21 | 343 | 16.33 | 0 | 79 | 18 | <1 | 2 |
| 39 (22 Sep) | 18 | 1,236 | 68.67 | 0 | 70 | 21 | 9 | <1 |
| 40 (29 Sep) | 15 | 770 | 51.33 | <1 | 84 | 12 | 4 | 0 |
| Total | 137 | 7,568 | 55.24 | <1 | 34 | 28 | 28 | 9 |

Table 7. Summary of total counts and count per meter, by habitat type, of chinook salmon counted by snorkeling during the upper Sacramento River rearing habitat evaluation, (August - October 1996).

| Week | Riffle | | | Pool | | | Glide | | | Run | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Count | *n*/meter | Sites | Count | *n*/meter | Sites | Count | *n*/meter | Sites | Count | *n*/meter |
| 32 | 6 | 281 | 1.02413 | 5 | 96 | 0.41986 | 5 | 346 | 1.51323 | 4 | 918 | 5.02 |
| 33 | 5 | 29 | 0.12683 | 0 | | | 2 | 45 | 0.49202 | 2 | 84 | 0.92 |
| 34 | 3 | 733 | 5.34296 | 3 | 401 | 2.92295 | 4 | 142 | 0.7763 | 7 | 883 | 2.76 |
| 35 | 5 | 8 | 0.035 | 4 | 351 | 1.91887 | 2 | 8 | 0.0875 | 1 | 21 | 0.46 |
| 36 | 1 | 20 | 0.43735 | 1 | 50 | 1.09337 | 2 | 14 | 0.15307 | 1 | 27 | 0.59 |
| 37 | 8 | 93 | 0.25421 | 4 | 135 | 0.73803 | 4 | 91 | 0.49749 | 4 | 93 | 0.51 |
| 38 | 11 | 272 | 0.54072 | 4 | 11 | 0.0601 | 4 | 49 | 0.26788 | 3 | 11 | 0.08 |
| 39 | 4 | 203 | 1.10977 | 3 | 561 | 4.08922 | 6 | 186 | 0.67789 | 5 | 177 | 0.77 |
| 40 | 4 | 123 | 0.67243 | 3 | 459 | 3.34572 | 5 | 22 | 0.0962 | 3 | 168 | 1.22 |
| Total | 47 | 1,762 | 0.8198 | 27 | 2,064 | 1.67165 | 34 | 903 | 0.58077 | 30 | 2,382 | 1.74 |

Table 8. Summary of rainbow trout data collected by snorkel during the upper Sacramento River rearing habitat evaluation, August - October 1996.

| Week (beginning date) | Number of sites | Total count | *n*/site | Size composition (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | <25 mm | 25-50 mm | 50-75 mm | 75-100 mm | >100 mm |
| 32 (04 Aug) | 20 | 2,038 | 101.9 | 38 | 0 | 60 | 0 | 2 |
| 33 (11 Aug) | 9 | 943 | 104.8 | 43 | 2 | 47 | 4 | 4 |
| 34 (18 Aug) | 17 | 1,605 | 94.4 | <1 | 32 | 43 | 18 | 6 |
| 35 (25 Aug) | 12 | 135 | 11.3 | <1 | 7 | 49 | 39 | 4 |
| 36 (01 Sep) | 5 | 275 | 55.0 | 6 | 80 | 7 | 2 | 5 |
| 37 (08 Sep) | 20 | 829 | 41.5 | <1 | 44 | 44 | 9 | 3 |
| 38 (15 Sep) | 21 | 368 | 17.5 | 1 | 26 | 40 | 10 | 23 |
| 39 (22 Sep) | 18 | 247 | 13.7 | <1 | 43 | 32 | 4 | 21 |
| 40 (29 Sep) | 15 | 278 | 18.5 | 0 | 17 | 52 | 15 | 16 |
| Total | 137 | 6,718 | 49.0 | 18 | 20 | 47 | 8 | 6 |

The variability in counts by habitat type were not as great as that observed for salmon (Table 9, Figures 13-15). Mean counts ranged from 0.69 fish/m in pools to 1.75 fish/m in runs.

## Seine Survey Results

### Chinook salmon

A total of 389 salmon were collected from 61 sites by seine (Table 10). The weekly mean size of all collected fish ranged from 41.5 mm FL (Week 39) to 63.0 m FL (Week 34). Recently emergent-sized fish (<45 mm FL) were collected each week. Larger, smolt-sized fish (≥70 mm FL) were also collected each week.

Habitat types were not equally represented in the overall seine sample. Seven pools yielded a mean catch of 10.1 fish/site, 14 glides yielded 6.7 fish/site, 20 riffles yielded 8.4 fish/site and 20 runs yielded 2.8 fish/site.

The size distributions of seine caught fish are presented in Figures 16 and 17. The size distributions of seine caught fish was noticeably different from those obtained from the snorkel surveys. The seine data typically contained more small salmon (<50 mm FL) than that represented in the snorkel data; the occurrence of larger salmon (>75 mm FL) was substantially less in the seine data. These differences could be related to the differences in the conditions being sampled, gear selectivity, or both.

### Rainbow trout

Only 278 trout were collected by seine (Table 11). The weekly mean size of all collected fish ranged from 46.7 mm FL (Week 39) to 55.3 mm FL (Week 35). Recently emergent-sized fish (<35 mm FL) were collected in weeks 33, 34, 36 and 39. Larger, smolt-sized fish (typical ≥100 mm FL) were not collected.

Catch per habitat type were very similar, averaging 4.6 fish/site. Seven pools yielded a mean catch of 4.0 fish/site, 14 glides yielded 4.5 fish/site, 20 riffles yielded 5.4 fish/site and 20 runs yielded 3.95 fish/site.

The size distributions of seine caught fish are presented in Figures 18 and 19. Similar to the salmon seine data, the size distributions of seine caught trout was noticeably different from those obtained from the snorkel surveys. The seine data typically contained more trout in the 25-50 mm FL size range than that represented in the snorkel data; the occurrence of larger trout (>50 mm FL) was substantially less in the seine data. Again, these differences could be related to sample conditions, gear selectivity, or both.

Table 9. Summary of total counts and count per meter, by habitat type, of rainbow trout counted by snorkeling during the upper Sacramento River rearing habitat survey, August - October 1996.

| | Riffle | | | Pool | | | Glide | | | Run | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Sites | Count | *n*/meter | Sites | Count | *n*/meter | Sites | Count | *n*/meter | Sites | Count | *n*/meter |
| 32 | 6 | 555 | 2.02 | 5 | 278 | 1.22 | 5 | 327 | 1.43 | 4 | 882 | 4.82 |
| 33 | 5 | 366 | 1.60 | 0 | 0 | | 2 | 290 | 3.17 | 2 | 287 | 3.14 |
| 34 | 3 | 228 | 1.66 | 3 | 152 | 1.11 | 4 | 511 | 2.79 | 7 | 711 | 2.22 |
| 35 | 5 | 39 | 0.17 | 4 | 29 | 0.16 | 2 | 11 | 0.12 | 1 | 14 | 0.31 |
| 36 | 1 | 4 | 0.09 | 1 | 0 | 0.00 | 2 | 31 | 0.34 | 1 | 240 | 5.25 |
| 37 | 8 | 307 | 0.84 | 4 | 297 | 1.62 | 4 | 127 | 0.69 | 4 | 98 | 0.54 |
| 38 | 11 | 264 | 0.52 | 4 | 29 | 0.16 | 4 | 26 | 0.14 | 3 | 49 | 0.36 |
| 39 | 4 | 51 | 0.28 | 3 | 19 | 0.14 | 6 | 92 | 0.34 | 5 | 85 | 0.37 |
| 40 | 4 | 90 | 0.49 | 3 | 42 | 0.31 | 5 | 108 | 0.47 | 3 | 37 | 0.27 |
| Total | 47 | 1,904 | 0.89 | 27 | 846 | 0.69 | 34 | 1,523 | 0.98 | 30 | 2,403 | 1.75 |

Table 10. Weekly catch statistics by habitat type for chinook salmon caught by seine in the upper Sacramento River, August - October 1996.

| | Riffle | | | Pool | | | Glide | | | Run | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week (beginning date) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) |
| 33 (11 Aug) | 5 | 15 | 61.1 (37-95) | 0 | 0 | - | 2 | 1 | 49.0 (49) | 2 | 8 | 43.8 (34-54) | 9 | 24 | 55.3 (34-95) |
| 34 (18 Aug) | 1 | 3 | 68.0 (51-83) | 1 | 0 | - | 2 | 24 | 62.9 (45-90) | 3 | 1 | 78.0 (78) | 7 | 28 | 63.0 (45-90) |
| 35 (25 Aug) | 2 | 33 | 46.5 (33-93) | 0 | 0 | - | 1 | 0 | - | 0 | 0 | - | 3 | 33 | 45.0 (33-71) |
| 36 (01 Sep) | 1 | 1 | 36.0 (36) | 1 | 0 | - | 1 | 2 | 51.5 (43-60) | 2 | 9 | 59.4 (47-78) | 5 | 12 | 56.2 (36-78) |
| 37 (08 Sep) | 3 | 9 | 65.9 (33-85) | 0 | 0 | - | 1 | 2 | 35.5 (34-37) | 3 | 6 | 36.7 (33-41) | 7 | 17 | 52.0 (33-85) |
| 38 (15 Sep) | 6 | 107 | 44.8 (33-104) | 0 | 0 | - | 0 | 0 | - | 0 | 0 | - | 6 | 107 | 44.8 (33-104) |
| 39 (22 Sep) | 2 | 0 | - | 4 | 52 | 44.4 (36-65) | 6 | 47 | 40.3 (33-67) | 10 | 32 | 43.9 (35-60) | 22 | 131 | 41.5 (33-67) |
| 40 (29 Sep) | 0 | 0 | - | 1 | 19 | 38.4 (34-54) | 1 | 18 | 47.4 (31-75) | 0 | 0 | - | 2 | 37 | 43.5 (31-75) |
| Total | 20 | 168 | 48.1 (33-104) | 7 | 71 | 42.8 (35-65) | 14 | 94 | 47.7 (31-90) | 20 | 56 | 46.2 (33-78) | 61 | 389 | 46.8 (31-104) |

Table 11. Weekly catch statistics by habitat type for rainbow trout caught by seine in the upper Sacramento River, August - October 1996.

| Week (beginning date) | Riffle | | | Pool | | | Glide | | | Run | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) | No. Sites | Count | FL mean (range) |
| 33 (11 Aug) | 5 | 22 | 27.0 (27) | 0 | 0 | - | 2 | 0 | - | 2 | 0 | - | 9 | 22 | 27.0 (27) |
| 34 (18 Aug) | 1 | 0 | - | 1 | 0 | - | 2 | 5 | 51.0 (27-64) | 3 | 1 | - | 7 | 6 | 51.0 (27-64) |
| 35 (25 Aug) | 2 | 17 | 55.3 (43-71) | 0 | 0 | - | 1 | 0 | - | 0 | 0 | - | 3 | 17 | 55.3 (43-71) |
| 36 (01 Sep) | 1 | 0 | - | 1 | 0 | - | 1 | 12 | 39.4 (26-48) | 2 | 66 | 56.1 (40-74) | 5 | 78 | 53.5 (26-74) |
| 37 (08 Sep) | 3 | 61 | 49.5 (49-50) | 0 | 0 | - | 1 | 0 | - | 3 | 11 | - | 7 | 72 | 49.5 (49-50) |
| 38 (15 Sep) | 6 | 8 | - | 0 | 0 | - | 0 | 0 | - | 0 | 0 | - | 6 | 8 | - |
| 39 (22 Sep) | 2 | 0 | - | 4 | 25 | 44.6 (26-63) | 6 | 19 | 50.0 (33-74) | 10 | 1 | 41.0 (41) | 22 | 45 | 46.7 (26-74) |
| 40 (29 Sep) | 0 | 0 | - | 1 | 3 | 48.7 (46-51) | 1 | 27 | 52.3 (39-65) | 0 | 0 | - | 2 | 30 | 52.0 (39-65) |
| Total | 20 | 108 | 52.7 (27-71) | 7 | 28 | 45.0 (26-63) | 14 | 63 | 49.0 (26-74) | 20 | 79 | 56.1 (40-74) | 61 | 278 | 51.4 (27-74) |

# UPPER SACRAMENTO RIVER EMIGRATION SURVEY

Emigrating juvenile salmonids are being monitored at Balls Ferry (RM 276) to determine the timing and relative abundance of salmon and rainbow trout (potentially steelhead) emigration relative to precedent conditions of spawning and rearing in the upper natal stream. Sampling is being conducted using two rotary screw traps that were deployed on 22 March 1996 and constantly fished through the reporting period (except during Week 23 when the algae problems discussed below interrupted sampling for the entire week). Initially, the traps were fished 24 h per day, 7 days per week. Beginning in May, however, large amounts of algae were collected in the traps requiring constant cleaning while the traps were fished. As such, when this condition existed, we stratified our sampling to represent a 24 h/day, 7 day/week effort. It was necessary to stratify sampling in Weeks 19-21, Weeks 24-29 and Week 37. During these weeks the traps were fished in 10 hour shifts; either 0130 to 1130 h (dawn shift) or 1400 to 2400 h (dusk shift). Each shift was randomly selected to occur 4 days per week. During each shift, the traps were, by necessity, checked and cleaned each hour. When algae build-up subsided, we went back to fishing the traps 24 h/day 7 days/week and checking them twice per day.

Data acquired from each screw trap per check included effort, number of juvenile salmonids collected by species. Race for chinook salmon was determined using the length-at-time criteria developed by Fisher. All salmon identified as winter run, spring run or late fall run were measured (FL in mm and weight in g). All juvenile rainbow trout were counted and measured. Up to 300 fall-run sized salmon were randomly selected and measured per trap, up to twice daily.

Trap efficiency was evaluated by marking up to 100% of the salmon taken from the trap and releasing them approximately 2,500 ft upstream. Salmon were marked beginning in Week 13 (26 March) They were marked using Alcian blue dye and a specific pattern to indicate the week of marking. During the efficiency test, each fish we measured was also checked for marks. When all fish were not checked, the number of recovered fish was expanded based on the proportion of fish checked to the total number captured. Beginning in Week 13, we marked fish using a Bismark brown bath.

## Emigration Results

### Chinook Salmon

Juvenile salmon were collected every week sampled (Table 12, Figure 20). Mean weekly size ranged from 38.5 mm FL (Week 38) to 80.6 mm FL (Week 25). Recently emerged-sized fish were collected during every week sampled. Smolt-sized fish were also collected during every week sampled (Appendix A, Figures A1-A9).

Table 12. Summary of chinook salmon catch statistics, upper Sacramento River emigration survey using rotary screw traps, 22 March - 5 October 1996.

| Week | Start Date | Weekly catch | Catch/h | Size statistics (FL in mm) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Minimum | Maximum | SD |
| 12 | 17 Mar | 956 | 13.765 | 39.5 | 31 | 142 | 11.48 |
| 13 | 24 Mar | 3,380 | 10.429 | 41.4 | 30 | 150 | 12.59 |
| 14 | 31 Mar | 2,278 | 7.553 | 41.0 | 31 | 117 | 10.71 |
| 15 | 7 Apr | 1,539 | 4.543 | 42.5 | 29 | 139 | 13.78 |
| 16 | 14 Apr | 1,506 | 4.471 | 53.2 | 32 | 143 | 19.17 |
| 17 | 21 Apr | 1,096 | 3.299 | 57.2 | 30 | 160 | 20.61 |
| 18 | 28 Apr | 1,384 | 5.155 | 58.7 | 31 | 155 | 19.58 |
| 19 | 5 May | 345 | 1.076 | 65.1 | 34 | 103 | 17.33 |
| 20 | 12 May | 9 | 0.350 | 68.7 | 51 | 95 | 15.87 |
| 21 | 19 May | 139 | 0.862 | 65.5 | 23 | 100 | 18.88 |
| 22 | 26 May | 83 | 0.396 | 70.5 | 35 | 113 | 17.51 |
| 23 | 2 June | 0 | - | - | - | - | - |
| 24 | 9 June | 32 | 1.422 | 72.4 | 34 | 107 | 19.20 |
| 25 | 16 June | 65 | 0.747 | 80.6 | 27 | 115 | 19.26 |
| 26 | 23 June | 85 | 1.000 | No measurements | | | |
| 27 | 30 June | 182 | 2.747 | 71.8 | 27 | 116 | 20.51 |
| 28 | 7 July | 160 | 1.855 | 59.7 | 35 | 106 | 23.20 |
| 29 | 14 July | 135 | 1.378 | 72.9 | 25 | 105 | 21.85 |
| 30 | 21 July | 127 | 0.661 | 69.5 | 30 | 119 | 23.17 |
| 31 | 28 July | 184 | 0.723 | 63.4 | 33 | 107 | 22.91 |
| 32 | 4 Aug | 181 | 0.591 | 63.4 | 31 | 110 | 23.05 |
| 33 | 11 Aug | 156 | 0.584 | 52.5 | 30 | 115 | 23.94 |
| 34 | 18 Aug | 311 | 0.925 | 45.4 | 30 | 112 | 20.76 |
| 35 | 25 Aug | 661 | 1.980 | 45.8 | 31 | 122 | 20.19 |
| 36 | 1 Sep | 214 | 1.451 | 46.9 | 30 | 108 | 22.51 |
| 37 | 8 Sep | 4 | 0.034 | 48.3 | 33 | 72 | 16.07 |
| 38 | 15 Sep | 108 | 1.177 | 38.5 | 28 | 101 | 14.39 |
| 39 | 22 Sep | 105 | 1.221 | 43.1 | 22 | 118 | 22.19 |
| 40 | 29 Sep | 349 | 3.966 | 38.3 | 22 | 118 | 16.30 |
| Total | | 15,774 | 2.946 | 49.3 | 22 | 160 | 19.78 |

Catch rates (fish/h) ranged from 0.03 fish/h (Week 37) to 13.8 fish/h (Week 12) (Figure 21). (Effort was not measured during Week 26 due to problems associated with debris build up, as described above). Catch rate appeared to be related to the occurrence of the excessive algae build-up repeatedly experienced throughout the sample (Figure 21). The apparent relationship might have been due to changes in migration behavior associated with the algae, or it may have been the result of changes in the effectiveness of the traps, or due to the stratified, thus reduced, sampling effort. Unfortunately, we did not mark fish to determine trap efficiency during the periods of excessive algae due to the time involved in keeping the traps fishing.

A total of 15,774 chinook salmon were counted. Fall-run sized chinook salmon dominated the catch (11,829 salmon), followed by late fall-run-sized salmon (1,744 salmon) winter-run-sized salmon (1,730) and spring-run-sized salmon (471). Spring-run sized salmon were collected from Week 12 through Week 22 (except during Week 21) (Figure 22, appendix figures A1 - A9). Fall-run chinook salmon were collected during each week sampled, except weeks 26, 37 and 38. Late-fall run sized salmon were first collected during Week 14 then were collected during every subsequent week sampled except Weeks 20 and 26. Winter-run sized salmon from the 1995 brood year were collected from Week 12 through Week 18. Winter-run from the 1996 brood year were collected beginning in Week 27 through Week 40.

Spring-run chinook salmon size ranged from 69 to 115 mm FL (Figure 23). Fall-run chinook salmon ranged in size from 30 to 140 mm FL, late fall-run from 23 to 110 mm FL, and winter-run from 22 to 160 mm FL. Sampling was started too late to capture spring-run sized emergents. Smolt-sized spring-run were represented in every week that spring-run were caught. Emergent-sized fall-run were caught through Week 19; smolt-sized fall-run were present each week fall-run were caught. Emergent-sized late fall-run were collected Weeks 14 through 31 (when late fall-run were present in the catch). Smolt-sized late fall-run were collected Weeks 30 through 40. All the winter-run collected from brood year 1995 (Weeks 12 - 19) were smolt-sized. Emergent-sized winter-run were collected Weeks 27 through 40.

### Rainbow Trout

Rainbow trout (potentially steelhead) were collected in every week sampled (except Week 20 when total effort was only 25 h (Table 13). Catch rate ranged from 0.028 fish/h during Week 37 to 0.908 fish/h during Week 29 (Figure 24). Total catch ranged from 2 fish during Week 24 to 109 fish in Week 35 (Figure 25). Recently emerged fish were collected in every week except weeks 36, 38 and 40. Yearling trout were collected in Weeks 13, 16, 17 and 18 (Figure 25).

Table 13. Summary of rainbow trout catch statistics, upper Sacramento River emigration survey using rotary screw traps, 22 March - 5 October 1996.

| Week | Start Date | Weekly Catch | Catch/h | Size statistics (FL in mm) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Minimum | Maximum | SD |
| 12 | 17 Mar | 9 | 0.130 | 54.0 | 23 | 98 | 34.14 |
| 13 | 24 Mar | 17 | 0.052 | 94.0 | 27 | 229 | 36.20 |
| 14 | 31 Mar | 9 | 0.030 | 52.9 | 33 | 63 | 10.62 |
| 15 | 7 Apr | 28 | 0.083 | 61.5 | 26 | 120 | 21.98 |
| 16 | 14 Apr | 72 | 0.214 | 59.3 | 21 | 235 | 26.90 |
| 17 | 21 Apr | 59 | 0.178 | 65.2 | 38 | 225 | 24.30 |
| 18 | 28 Apr | 80 | 0.298 | 66.0 | 34 | 263 | 24.30 |
| 19 | 5 May | 19 | 0.059 | 63.5 | 38 | 82 | 11.32 |
| 20 | 12 May | 0 | 0.000 | - | - | - | - |
| 21 | 19 May | 13 | 0.081 | 61.6 | 25 | 83 | 18.35 |
| 22 | 26 May | 10 | 0.048 | 45.7 | 22 | 69 | 17.57 |
| 23 | 2 June | - | - | - | - | - | - |
| 24 | 9 June | 2 | 0.089 | 41.5 | 23 | 60 | 18.50 |
| 25 | 16 June | 7 | 0.080 | 24.0 | 19 | 29 | 4.34 |
| 26 | 23 June | 10 | 0.118 | 47.7 | 27 | 77 | 19.59 |
| 27 | 30 June | 6 | 0.091 | 35.0 | 22 | 86 | 22.96 |
| 28 | 7 July | 75 | 0.870 | 28.3 | 20 | 78 | 9.65 |
| 29 | 14 July | 81 | 0.827 | 32.9 | 22 | 100 | 14.55 |
| 30 | 21 July | 58 | 0.302 | 31.8 | 22 | 95 | 14.42 |
| 31 | 28 July | 43 | 0.169 | 47.7 | 23 | 185 | 31.34 |
| 32 | 4 Aug | 58 | 0.189 | 43.9 | 21 | 120 | 24.50 |
| 33 | 11 Aug | 31 | 0.116 | 40.4 | 22 | 104 | 19.65 |
| 34 | 18 Aug | 39 | 0.11 6 | 45.1 | 22 | 80 | 16.95 |
| 35 | 25 Aug | 106 | 0.318 | 57.4 | 23 | 96 | 16.86 |
| 36 | 1 Sep | 48 | 0.325 | 72.0 | 72 | 72 | 0 |
| 37 | 8 Sep | 3 | 0.026 | 51.7 | 30 | 63 | 15.33 |
| 38 | 15 Sep | 11 | 0.120 | 69.3 | 57 | 97 | 12.37 |
| 39 | 22 Sep | 22 | 0.256 | 63.4 | 34 | 77 | 10.25 |
| 40 | 29 Sep | 37 | 0.420 | 71.1 | 48 | 110 | 13.46 |
| Total | | 953 | 0.178 | 51.5 | 19 | 263 | 27.43 |

### Trap Efficiency

Trap efficiency, measured as the percent of marked fish recaptured, was evaluated during 18 of the 30 weeks (Table 14). A total 3,249 salmon were marked and 50 were recaptured for an overall trap efficiency of 1.54%. Weekly efficiency ranged from 0.00 (4 weeks) to 7.6% during Week 32.

## LOWER AMERICAN RIVER EMIGRATION SURVEY

Emigration from the lower American River was monitored using a single rotary screw trap (8 ft diameter) located just downstream of the Watt Avenue Bridge (RM ). The trap was fished continuously from October 1995 (Week 40) through September (Week 39). Data were acquired as described above for the upper Sacramento River emigration survey.

### Emigration Results

### Chinook Salmon

The first juvenile chinook salmon was collected during Week 48 (beginning 29 November 1995) (Table 15, Figure 25). Salmon were then caught in every week from Week 50 through Week 25 (ending 23 June 1996). One salmon was caught in Week 27 and two were caught in Week 29.

Salmon capture rates were 0 for Weeks 49, 26 and 28. Catch rates exceeded 100 fish/h during Weeks 4 through 7), and they exceeded 50 fish/h seven weeks out of 10 between 1 January and 1 March 1996.

Total catch ranged up to 28,423 salmon during Week 4 and 25,484 salmon during Week 5 (Figure 26). Recently emerged-sized salmon (FL <45 mm FL) dominated the catches from Week 51 through Week 16. Smolt-sized salmon, from the 1996 brood year, first appeared in the catch in Week 13; the last emergent-sized salmon appeared during Week 17.

### Steelhead Trout

The first juvenile steelhead caught were three yearling-sized trout caught during Week 3 (Table 16, Figure 27). Young-of-the-year (YOY) steelhead were first caught during Week 11 (Table 16). A total 125 YOY and 19 “older” (up to 457 mm FL) steelhead were caught through September (Week 40).

Table 14. Results of rotary screw trap efficiency evaluations conducted with marked chinook salmon during the upper Sacramento River emigration survey, 22 March - 5 October 1996.

| Week | Number marked | Number recaptured | Efficiency |
|---|---|---|---|
| 12 | 0 | - | - |
| 13 | 415 | 7 | 1.69 |
| 14 | 496 | 0 | 0 |
| 15 | 157 | 2 | 1.27 |
| 16 | 67 | 1 | 1.49 |
| 17 | 62 | 0 | 0 |
| 18 | 226 | 2 | 0.88 |
| 19 | Algae problems - no fish marked | | |
| 20 | Algae problems - no fish marked | | |
| 21 | Algae problems - no fish marked | | |
| 22 | 32 | 1 | 3.13 |
| 23 | Algae problems - no fish marked | | |
| 24 | Algae problems - no fish marked | | |
| 25 | Algae problems - no fish marked | | |
| 26 | Algae problems - no fish marked | | |
| 27 | Algae problems - no fish marked | | |
| 28 | Algae problems - no fish marked | | |
| 29 | Algae problems - no fish marked | | |
| 30 | 44 | 0 | 0 |
| 31 | 102 | 4 | 3.92 |
| 32 | 144 | 11 | 7.64 |
| 33 | 129 | 3 | 2.33 |
| 34 | 237 | 2 | 0.84 |
| 35 | 558 | 9 | 1.61 |
| 36 | 155 | 5 | 3.23 |
| 37 | Algae problems - no fish marked | | |
| 38 | 21 | 0 | 0 |
| 39 | 93 | 0 | 0 |
| 40 | 311 | 3 | 0.96 |
| Total | 3,249 | 50 | 1.54 |

Table 15. Summary of catch data and size statistics for chinook salmon collected by rotary screw trap in the lower American River, October 1995 through September 1996.

| Week | Number caught | Catch/h | Size (FL in mm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | Minimum | Maximum | SD |
| 48 | 1 | 0.009 | 29.0 | - | - | - |
| 49 | 0 | 0.000 | | | | |
| 50 | 10 | 0.060 | 43.5 | 25.0 | 92.0 | 23.50 |
| 51 | 135 | 1.087 | 35.0 | 28.0 | 77.0 | 9.65 |
| 52 | 155 | 1.370 | 33.8 | 29.0 | 37.0 | 1.27 |
| 1 | 510 | 4.140 | 34.2 | 28.0 | 40.0 | 1.91 |
| 2 | 1,765 | 10.568 | 35.1 | 28.0 | 43.0 | 1.91 |
| 3 | 9,508 | 57.105 | 35.8 | 31.0 | 62.0 | 1.57 |
| 4 | 28,423 | 163.821 | 35.9 | 30.0 | 54.0 | 1.62 |
| 5 | 25,484 | 153.703 | 36.7 | 30.0 | 46.0 | 1.84 |
| 6 | 19,291 | 114.691 | 36.5 | 29.0 | 49.0 | 1.77 |
| 7 | 16,152 | 112.323 | 36.6 | 31.0 | 47.0 | 1.92 |
| 8 | 10,497 | 63.618 | 36.3 | 30.0 | 51.0 | 1.81 |
| 9 | 4,597 | 27.527 | 36.9 | 30.0 | 54.0 | 2.39 |
| 10 | 7,757 | 65.295 | 37.1 | 30.0 | 52.0 | 2.56 |
| 11 | 5,280 | 31.150 | 37.9 | 28.0 | 56.0 | 3.35 |
| 12 | 1,125 | 6.757 | 37.6 | 31.0 | 65.0 | 4.10 |
| 13 | 247 | 2.815 | 40.8 | 33.0 | 74.0 | 6.80 |
| 14 | 529 | 3.574 | 40.6 | 32.0 | 80.0 | 7.99 |
| 15 | 81 | 0.477 | 52.8 | 35.0 | 70.0 | 11.34 |
| 16 | 62 | 0.330 | 49.8 | 34.0 | 83.0 | 9.54 |
| 17 | 15 | 0.103 | 57.9 | 45.0 | 85.0 | 10.84 |
| 18 | 53 | 0.317 | 63.5 | 47.0 | 98.0 | 9.96 |
| 19 | 159 | 0.603 | 66.8 | 48.0 | 87.0 | 8.71 |
| 20 | 43 | 0.691 | na | | | |
| 21 | 25 | 0.143 | 76.2 | 66.0 | 89.0 | 5.39 |
| 22 | 78 | 0.667 | 76.0 | 60.5 | 91.0 | 5.65 |
| 23 | 33 | 0.191 | 81.3 | 66.0 | 89.5 | 5.19 |
| 24 | 17 | 0.124 | 80.6 | 64.0 | 93.5 | 6.26 |
| 25 | 4 | 0.022 | 85.6 | 79.0 | 95.0 | 6.55 |
| 26 | 0 | 0.000 | | | | |
| 27 | 1 | 0.006 | 88.0 | - | - | - |
| 28 | 0 | 0.000 | | | | |
| 29 | 2 | 0.014 | 88.3 | 81.0 | 95.0 | 7.25 |
| Total | 132,039 | 20.173 | 37.3 | 25.00 | 98.0 | 5.93 |

Table 16. Summary of catch data for steelhead trout collected by rotary screw trap in the lower American River, October 1995 - September 1996.

| Week | Number caught | Size (FL in mm) | | | |
|---|---|---|---|---|---|
| | | Mean | Minimum | Maximum | SD |
| 3 | 3 | 299.3 | 196.9 | 457.2 | 113.30 |
| 4 | 4 | 282.1 | 210.8 | 384.0 | 66.40 |
| 5 | 0 | | | | |
| 6 | 0 | | | | |
| 7 | 0 | | | | |
| 8 | 0 | | | | |
| 9 | 0 | | | | |
| 10 | 0 | | | | |
| 11 | 4 | 54.2 | 26.0 | 131.0 | 44.40 |
| 12 | 9 | 57.4 | 26.0 | 280.0 | 76.70 |
| 13 | 3 | 29.3 | 26.0 | 35.0 | 4.05 |
| 14 | 9 | 30.9 | 25.0 | 42.0 | 6.50 |
| 15 | 0 | | | | |
| 16 | 12 | 38.8 | 26.0 | 52.0 | 8.92 |
| 17 | 13 | 36.3 | 26.0 | 49.0 | 7.89 |
| 18 | 5 | 35.4 | 28.0 | 46.0 | 8.26 |
| 19 | 5 | 56.8 | 49.0 | 67.0 | 6.21 |
| 20 | 15 | 54.3 | 41.0 | 69.0 | 8.13 |
| 21 | 10 | 46.2 | 22.0 | 61.0 | 10.16 |
| 22 | 19 | 51.1 | 31.5 | 76.0 | 8.59 |
| 23 | 7 | 61.1 | 56.0 | 74.0 | 6.03 |
| 24 | 1 | 63.0 | | | |
| 25 | 1 | 77.5 | | | |
| 26 | 0 | | | | |
| 27 | 0 | | | | |
| 28 | 5 | 132.7 | 68.0 | 341.0 | 104.97 |
| 29 | 8 | 88.9 | 69.0 | 115.0 | 16.24 |
| 30 | 8 | 104.6 | 85.0 | 128.0 | 15.36 |
| 31 | 3 | 94.2 | 89.8 | 100.5 | 4.64 |
| 32 | 2 | 214.0 | 106.0 | 322.0 | 108.00 |
| 33 | 1 | 342.0 | | | |
| 34 | 1 | 123.0 | | | |
| 35 | 0 | | | | |
| 36 | 0 | | | | |
| 37 | 1 | 162.0 | | | |
| 38 | 0 | | | | |
| 39 | 0 | | | | |
| 40 | 0 | | | | |
| Total | 149 | | 22.00 | 457.0 | |

## LOWER AMERICAN RIVER REARING HABITAT EVALUATION

Rearing habitat was evaluated monthly in the lower American River during March, April, May and June. Sites were selected to represent habitats present in the rearing reach of the river, typically upstream of RM 9. Sampling was conducted using the methods described for the seining component of the upper Sacramento River rearing evaluation.

Sampling did not begin until late in March (Week 14), well after the majority of salmon had emigrated from the lower American River, as described above. A total 886 salmon were collected, 524 (60%) during March (Table 17). The catch rate was nearly 3-times greater in March than in April (the month with the second highest catch). Recently emerged-sized salmon were collected during March and April. Smolt-sized salmon were collected during each month.

Table 17. Catch summary for chinook salmon collected by seine during the lower American River rearing habitat evaluation, March - June 1996.

| | | Catch data | | Size statistics (FL in mm) | |
|---|---|---|---|---|---|
| Month | # of hauls | Total n | n/haul | Mean | Range |
| March | 19 | 956 | 50.3 | 42.4 | 31-93 |
| April | 27 | 552 | 20.4 | 55.8 | 38-105 |
| May | 18 | 101 | 5.6 | 72.1 | 59-86 |
| June | 42 | 1 | <0.1 | 110 | - |
| Total | 106 | 1610 | 15.2 | | 31-110 |

# FIGURES

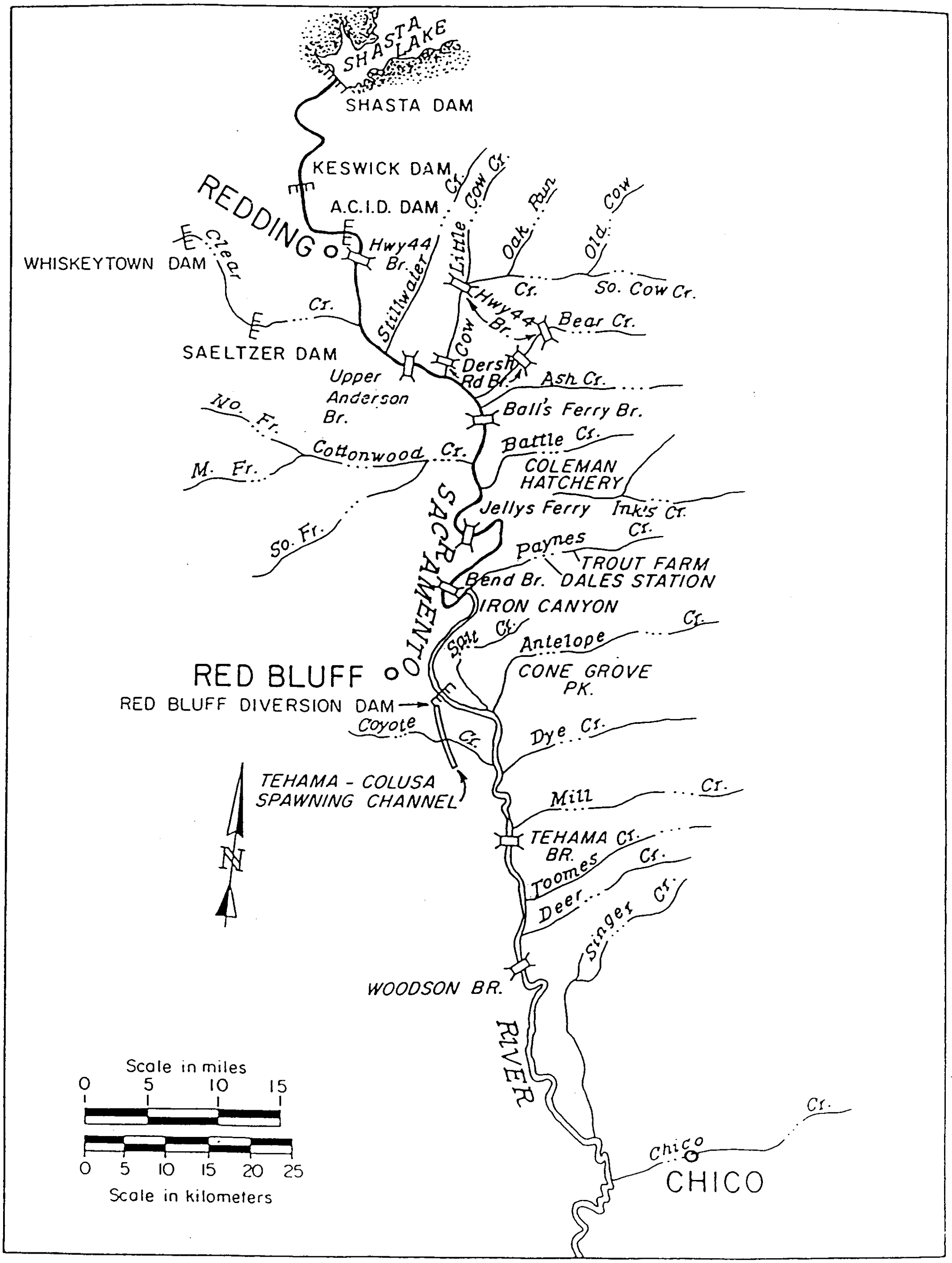


Figure 1. Upper Sacramento River.

# Chinook salmon size composition - upper Sacramento River snorkel survey, August - October 1996.

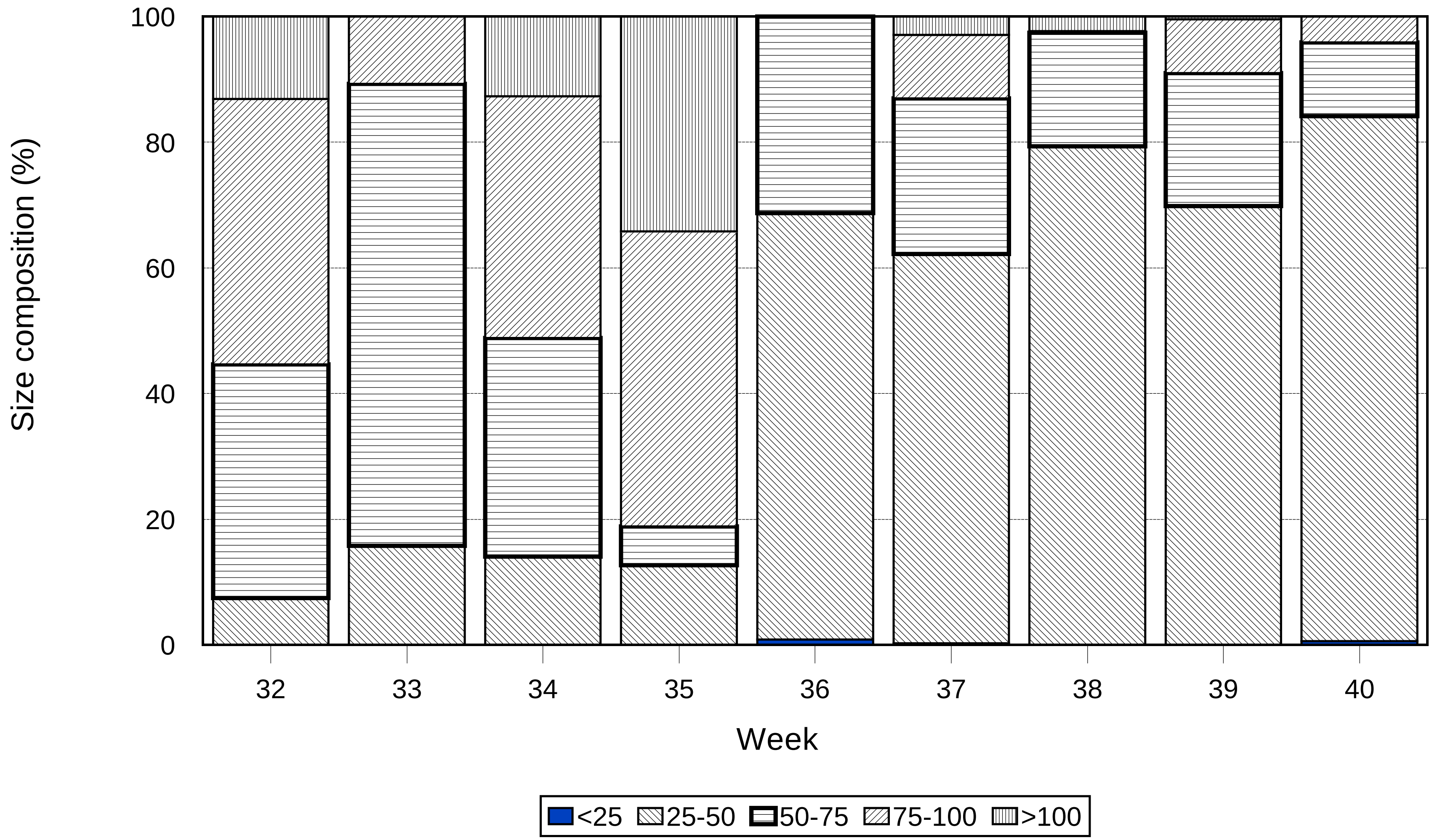


Figure 2. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey - August - October 1996.

# Chinoook salmon size composition - upper Sacramento River snorkel survey, August 1996

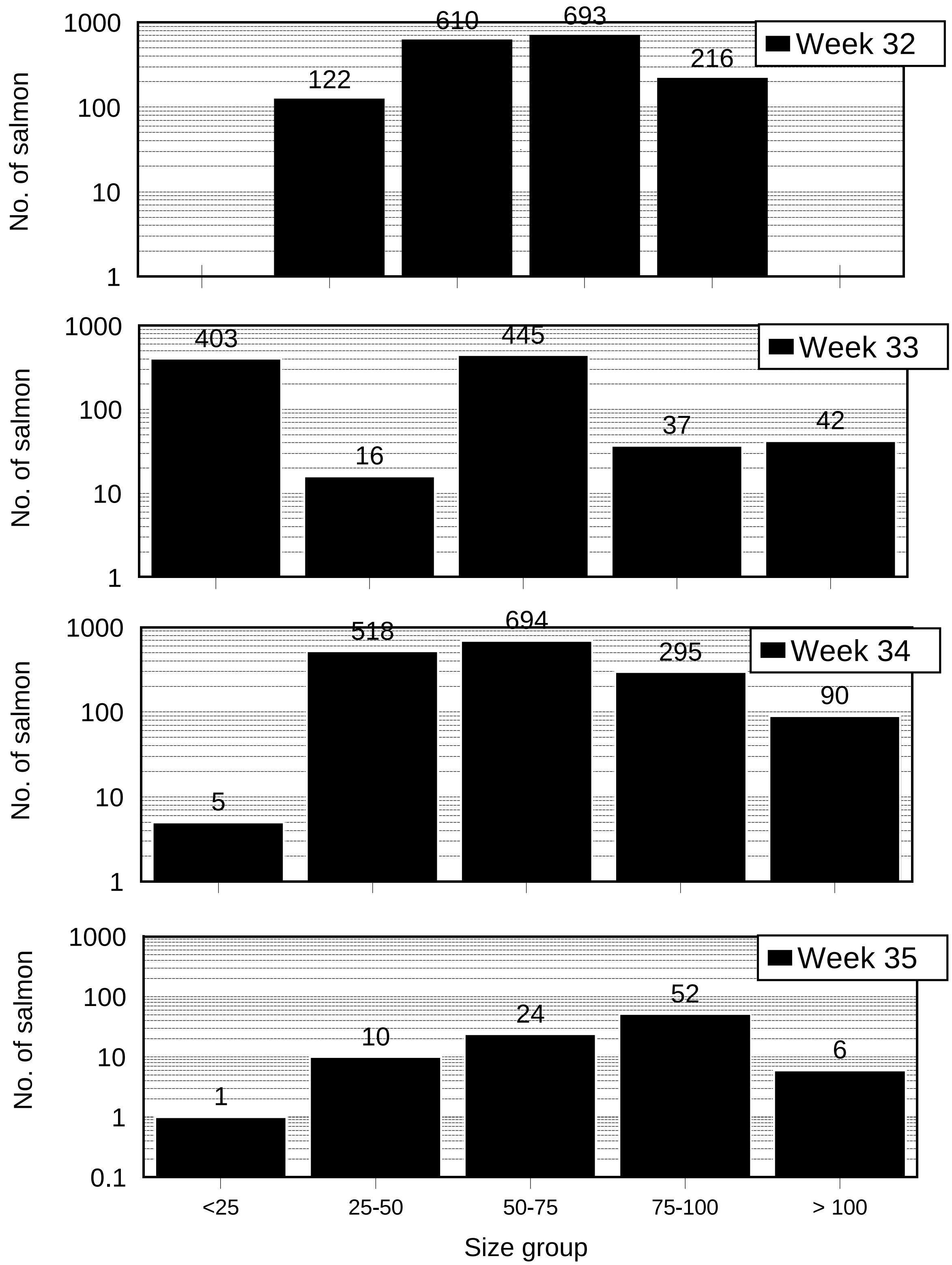


Figure 3. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, August 1996.

# Chinook salmon size composition - upper Sacramento River snorkel survey, September 1996

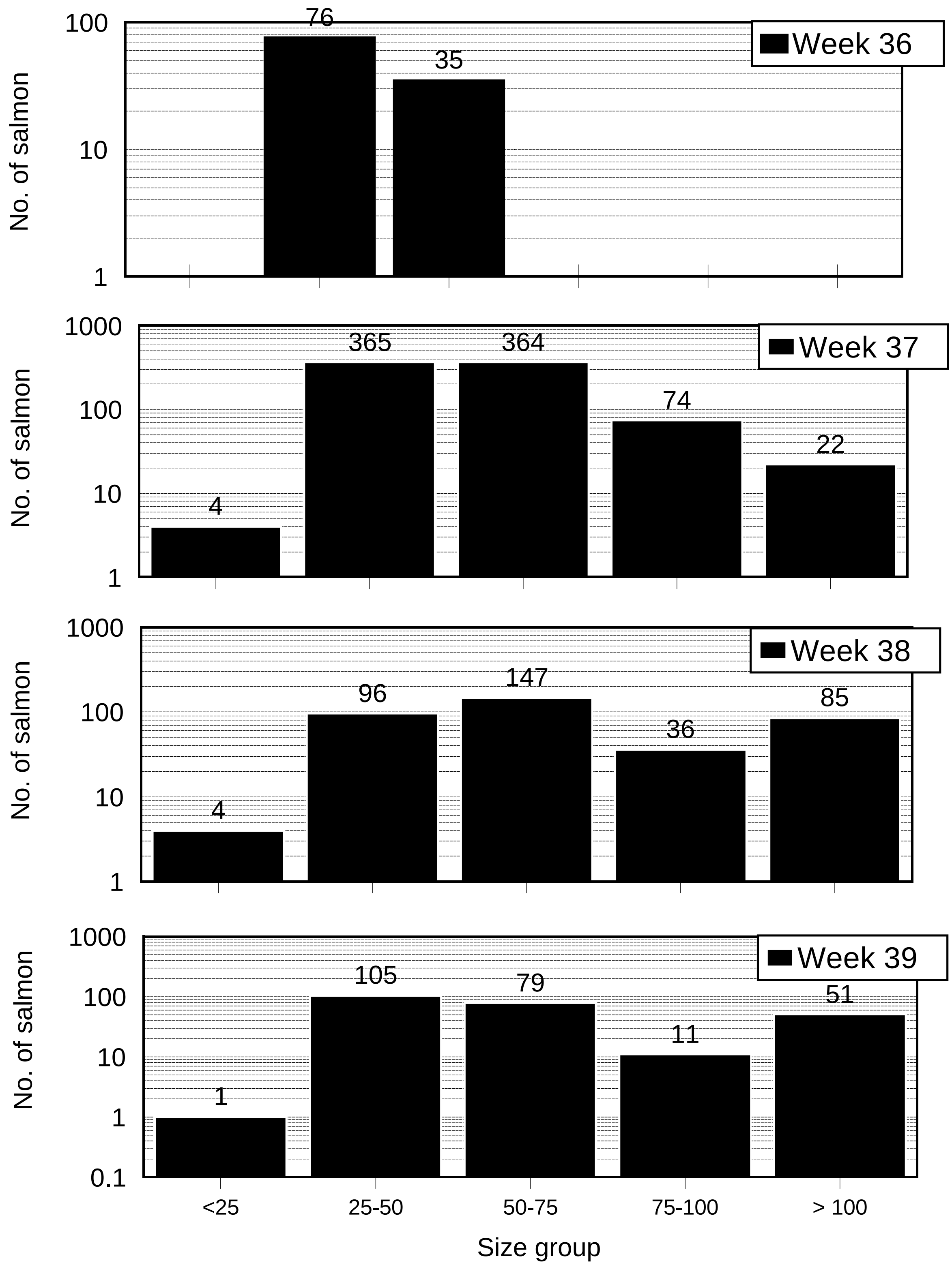


Figure 4. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, September 1996.

# Chinook salmon size composition - upper Sacramento River snorkel survey, October 1996

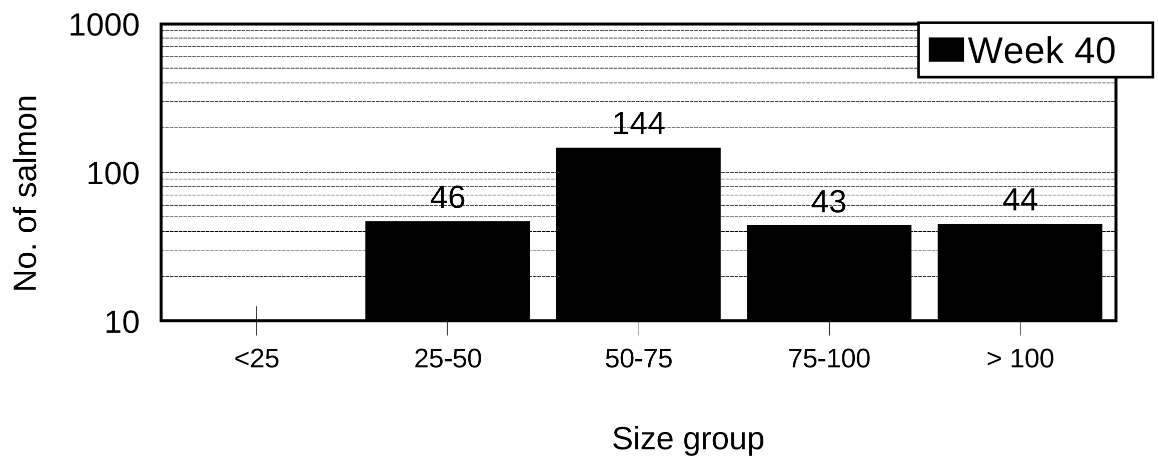


Figure 5. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, October 1996.

# Chinook salmon habitat use distribution - upper Sacramento River snorkel survey, August 1996

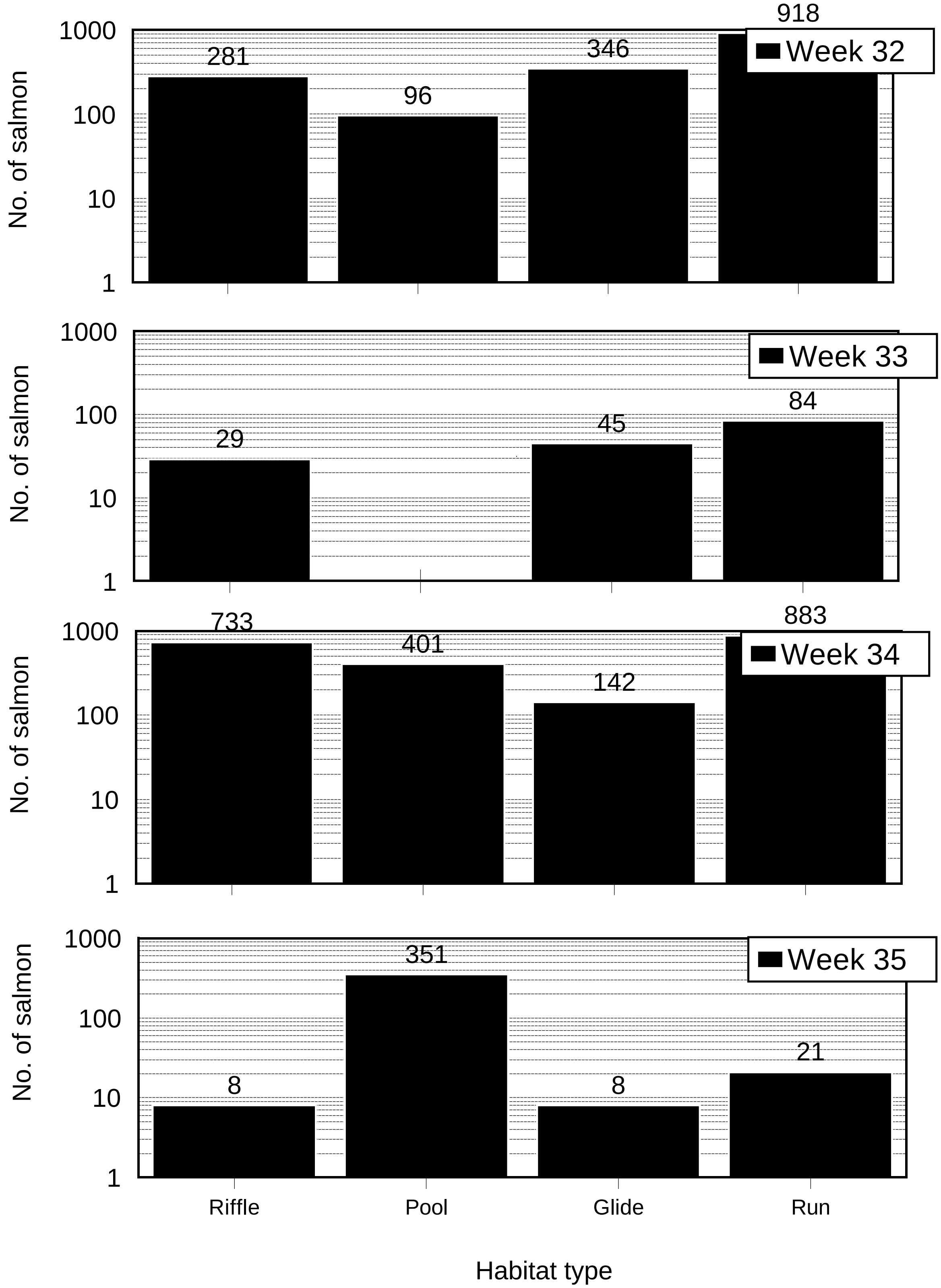


Figure 6.  Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, August 1996.

# Chinook salmon habitat use distribution - upper Sacramento River snorkel survey, September 1996

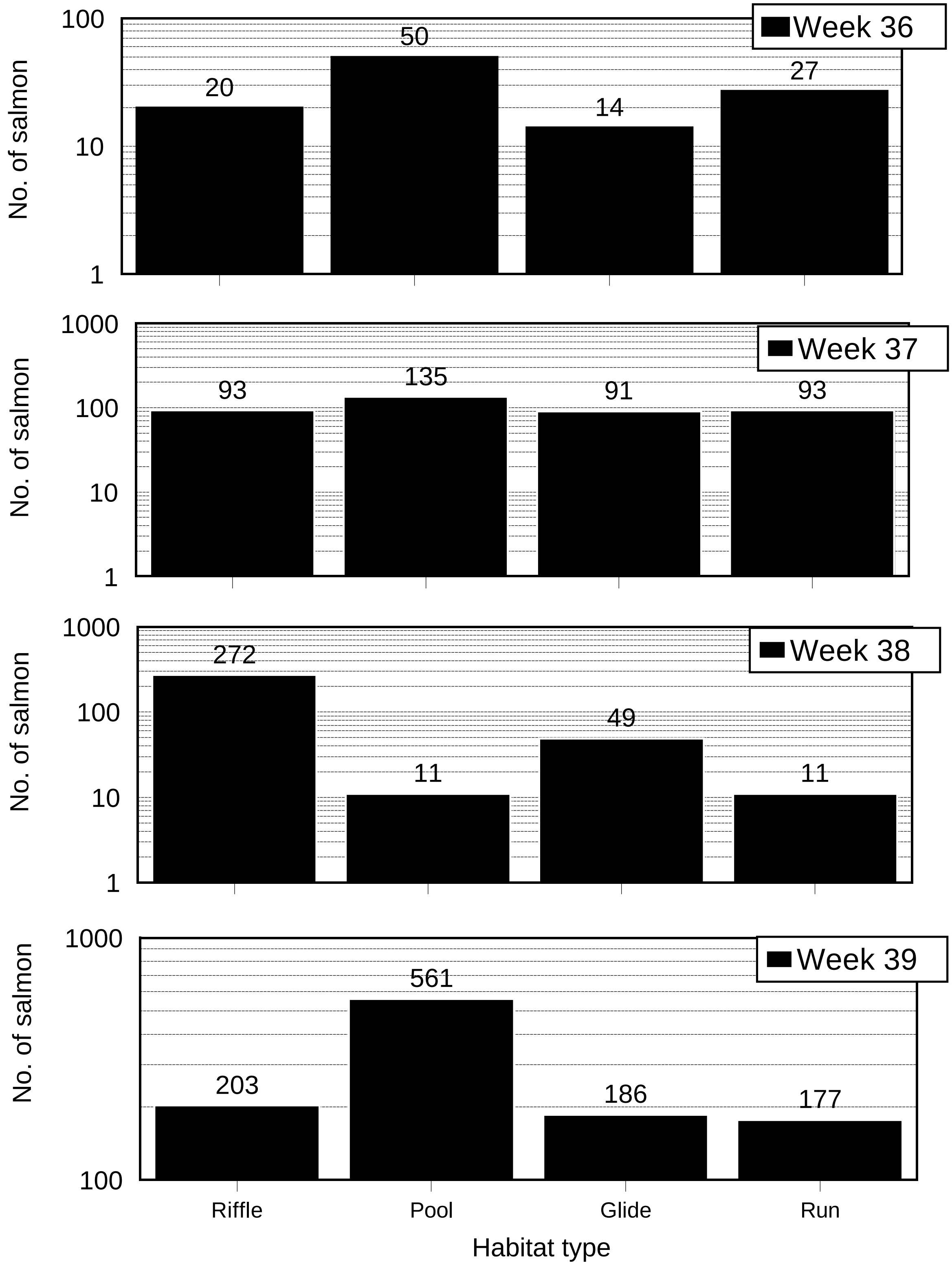


Figure 7. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, September 1996.

# Chinook salmon habitat use distribution - upper Sacramento River snorkel survey, October 1996

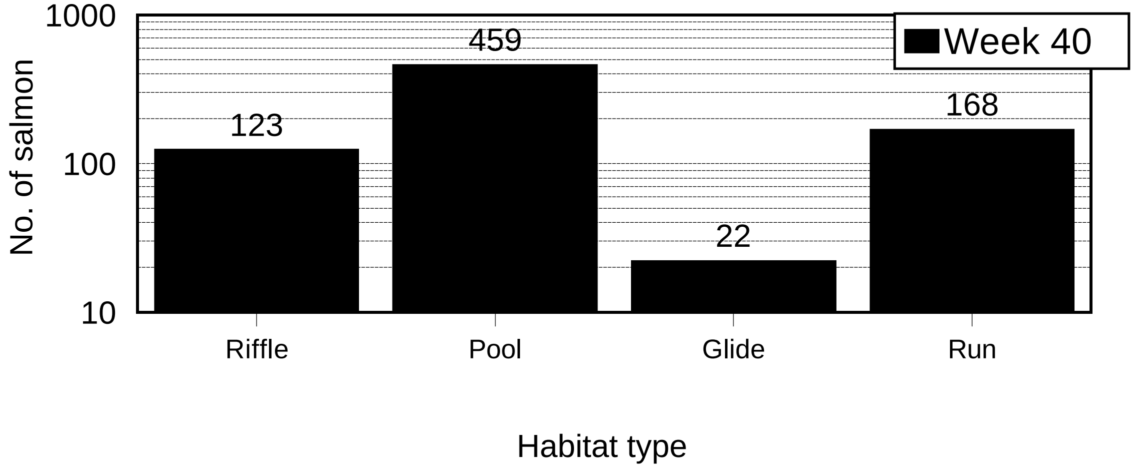


Figure 8. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, October 1996.

# Rainbow trout size composition - upper Sacramento River snorkel survey, August - October 1996.

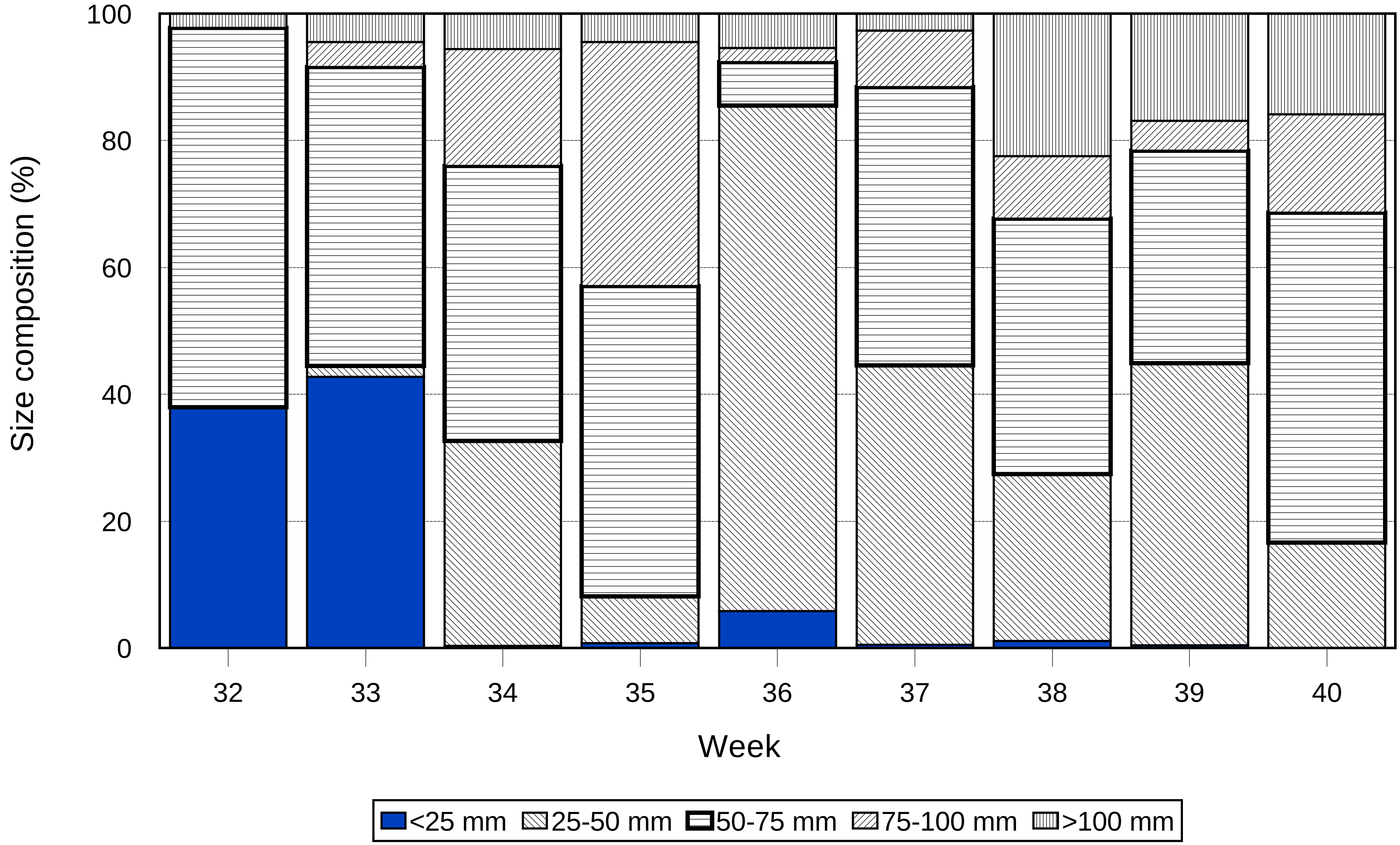


Figure 9. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey - August - October 1996.

Rainbow trout size distribution - upper Sacramento River snorkel survey, August 1996

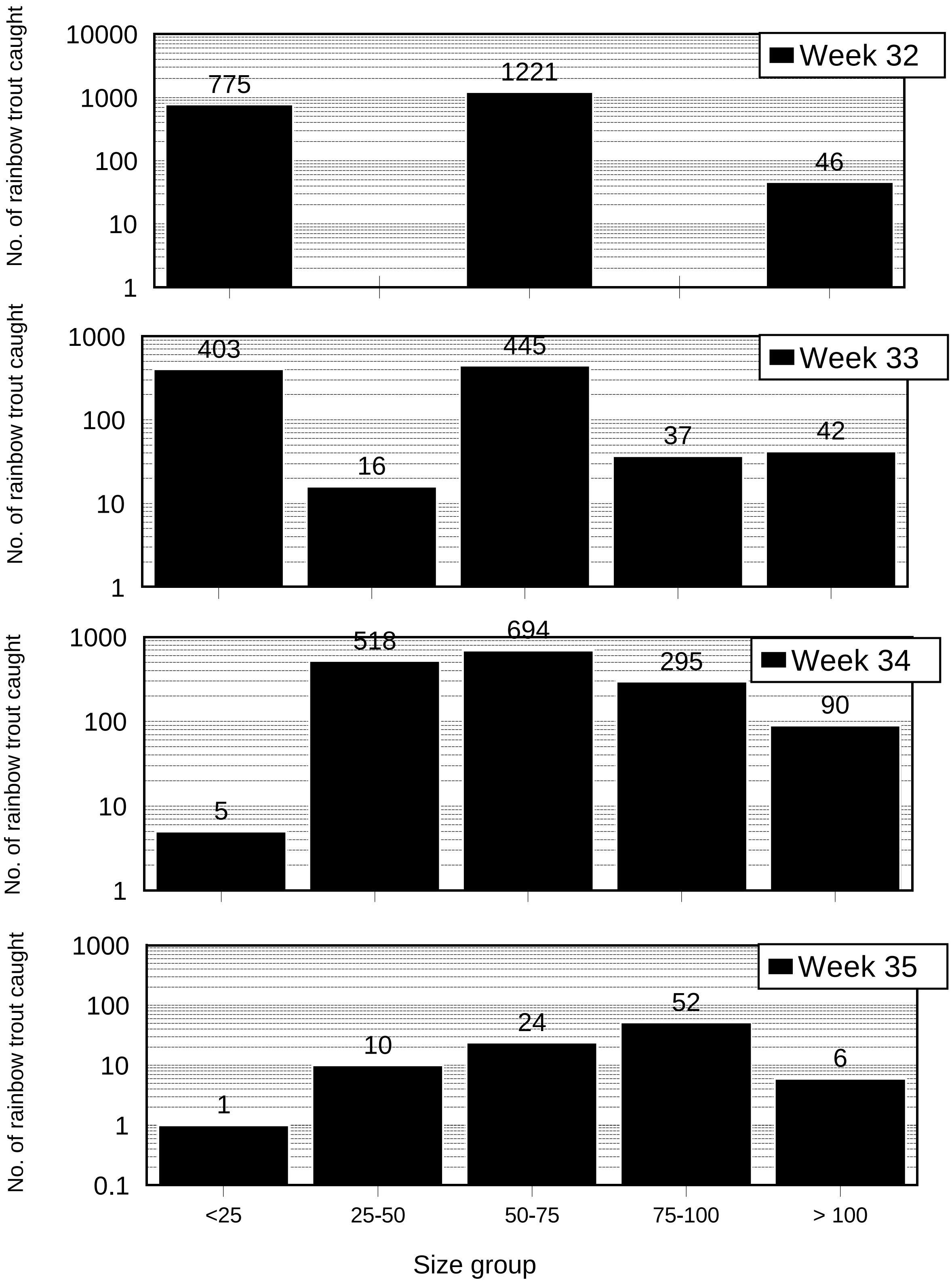


Figure 10. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, August 1996.

# Rainbow trout size distribution - upper Sacramento River snorkel survey, September 1996

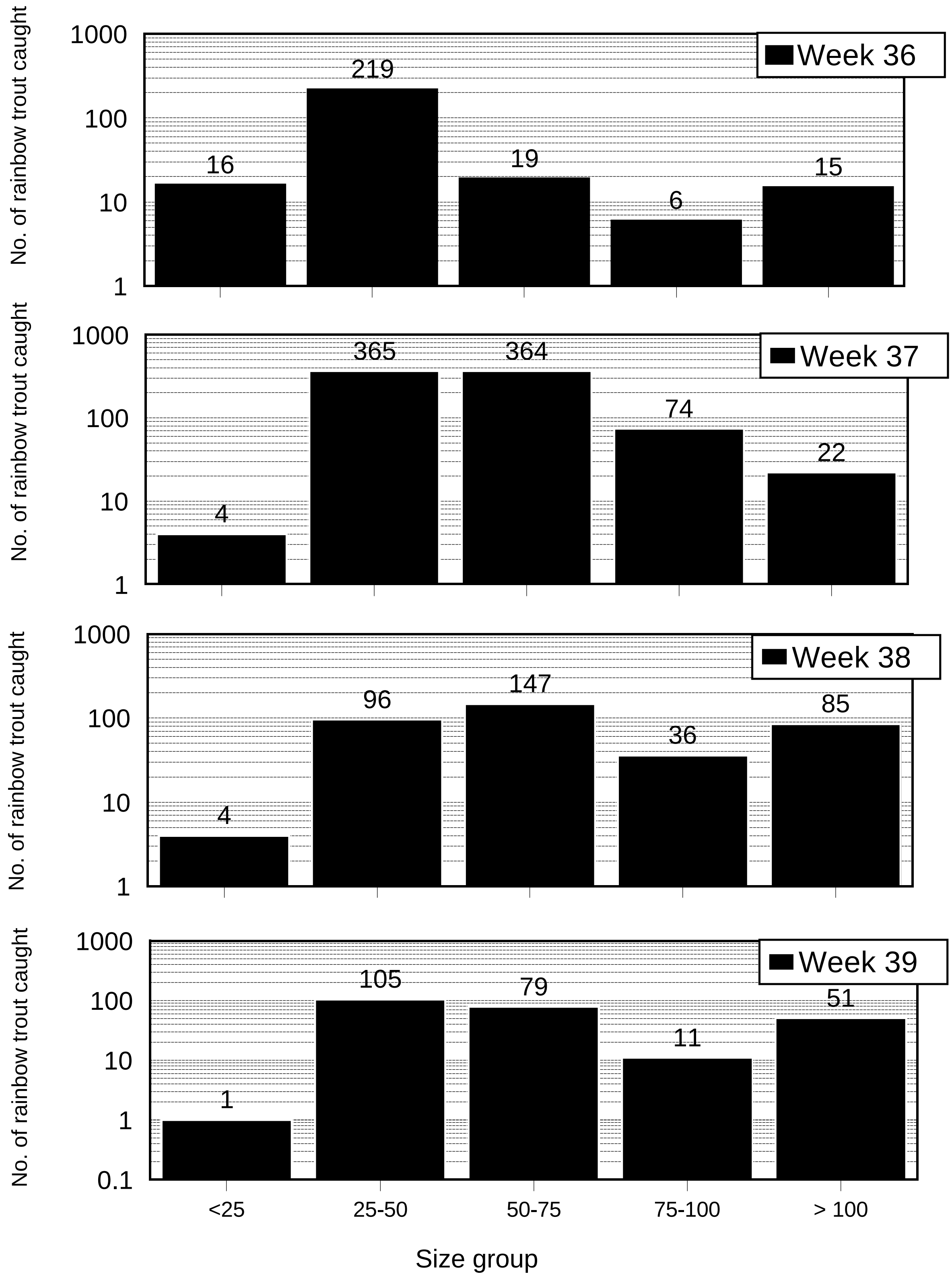


Figure 11. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, September 1996.

# Rainbow trout size distribution - upper Sacramento River snorkel survey, October 1996

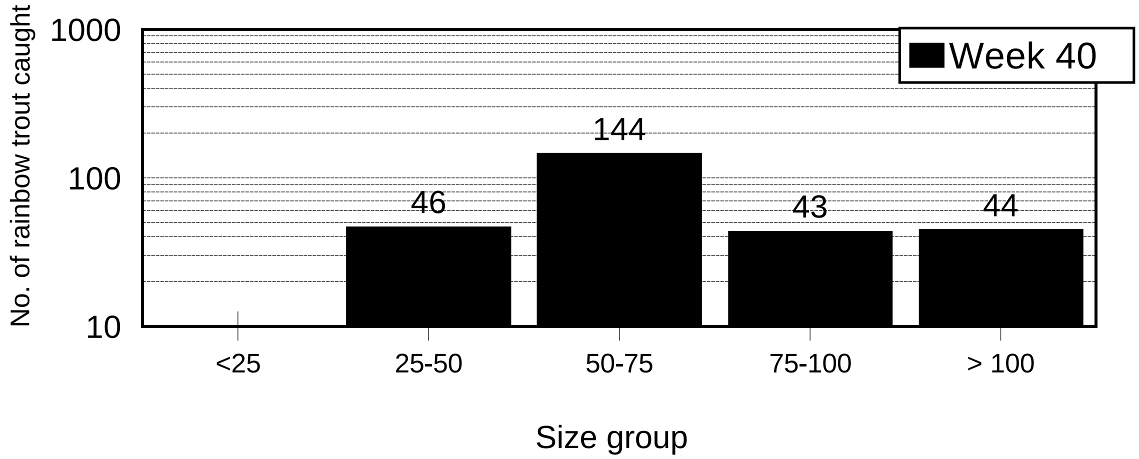


Figure 12. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, October 1996.

# Rainbow trout habitat use distribution - upper Sacramento River snorkel survey, August 1996

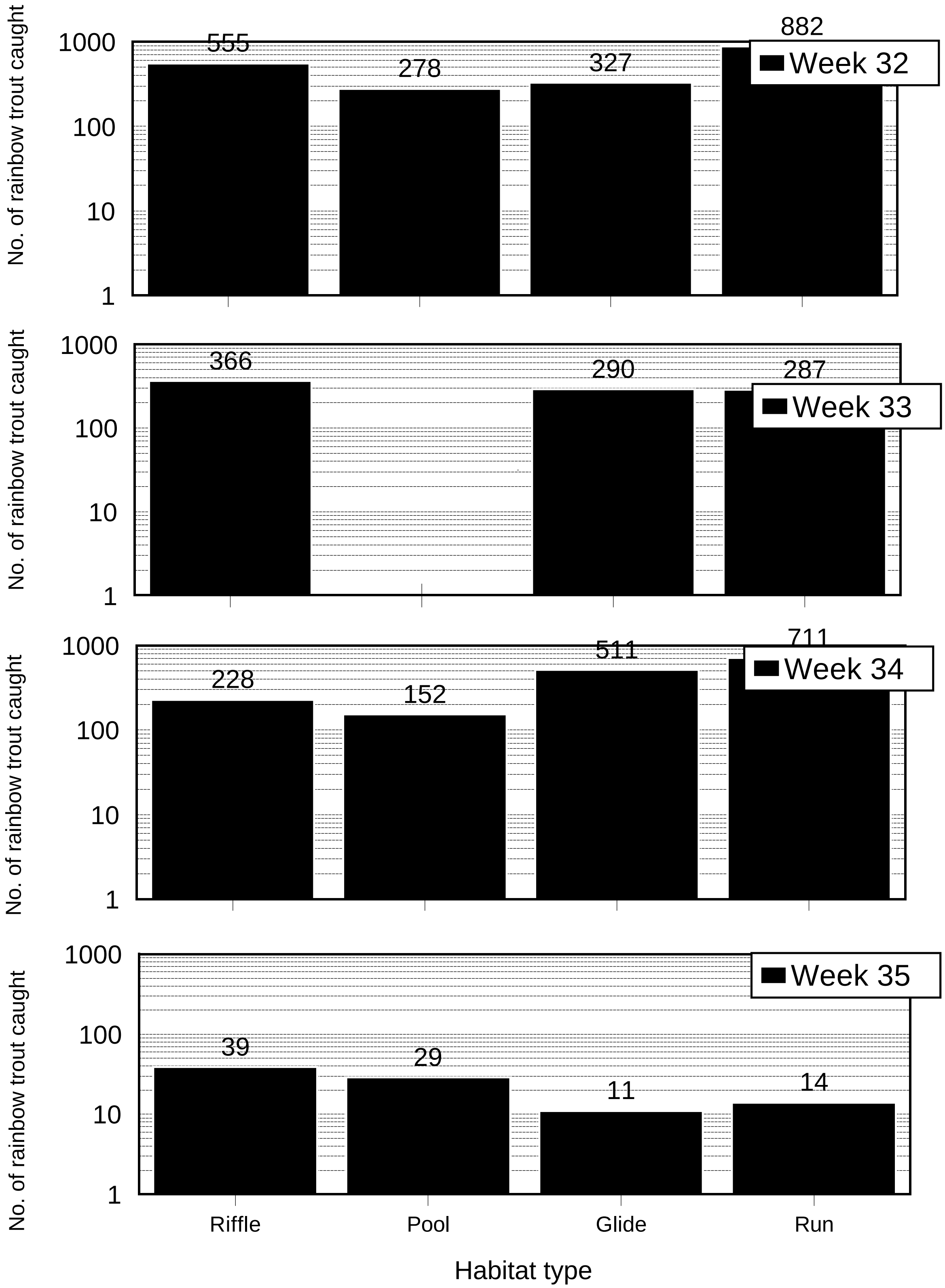


Figure 13. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, August 1996.

# Rainbow trout habitat use distribution - upper Sacramento River snorkel survey, September 1996

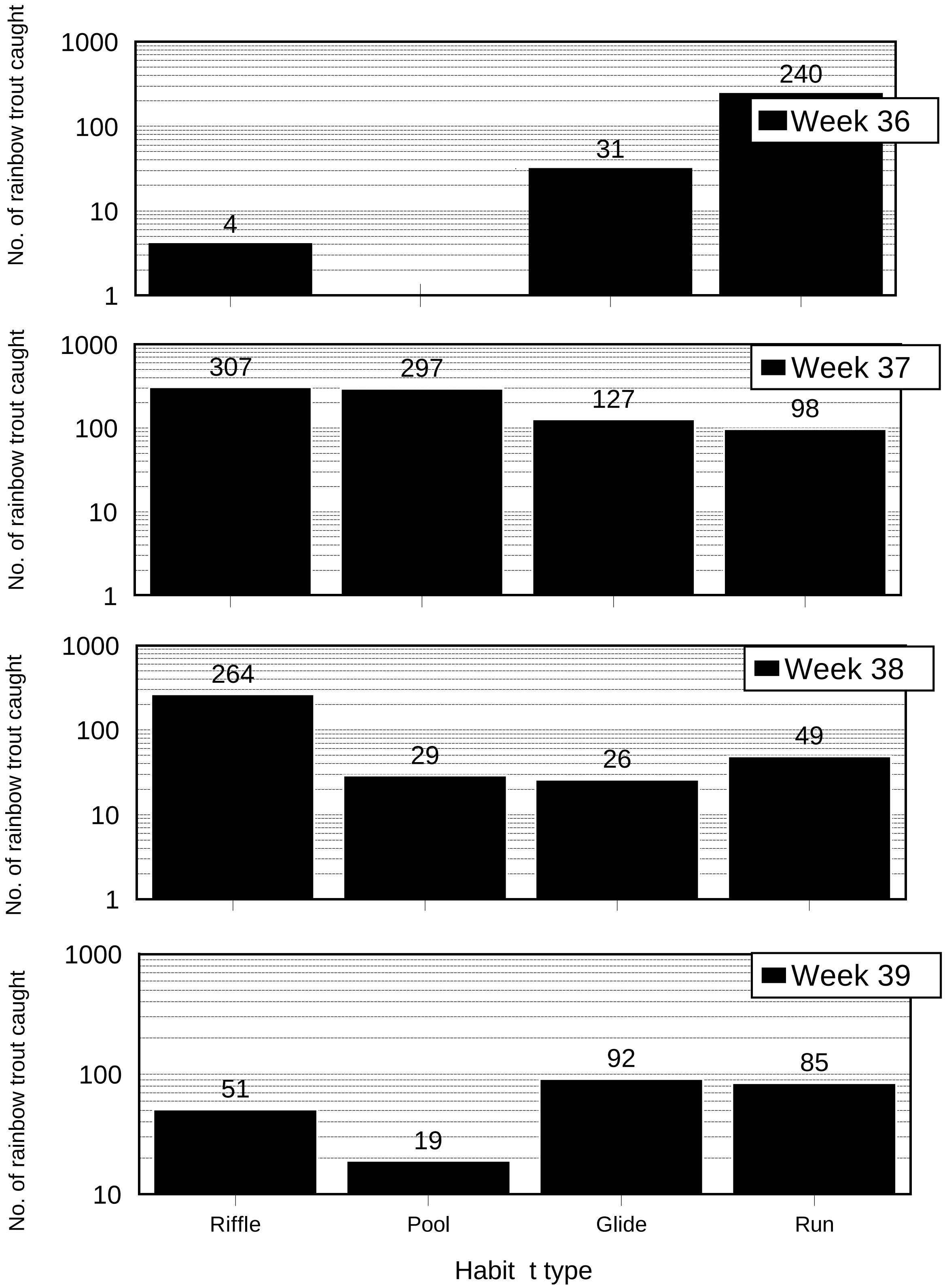


Figure 14. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, September 1996.

Rainbow trout habitat use distribution - upper Sacramento River snorkel survey, October 1996

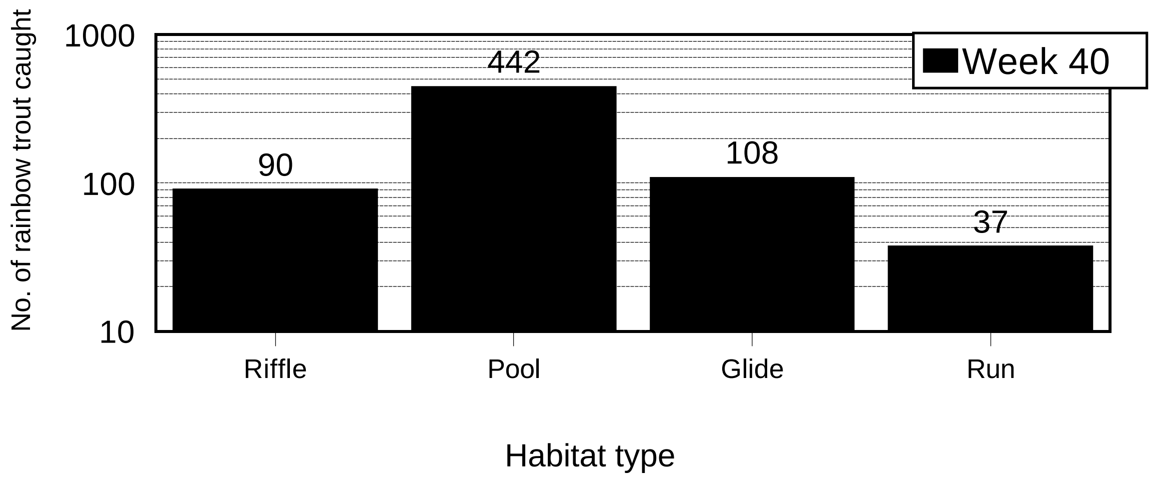


Figure 15. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, October 1996.

Weekly size distribution of chinook salmon collected by seine from the upper Sacramento River, 1996.

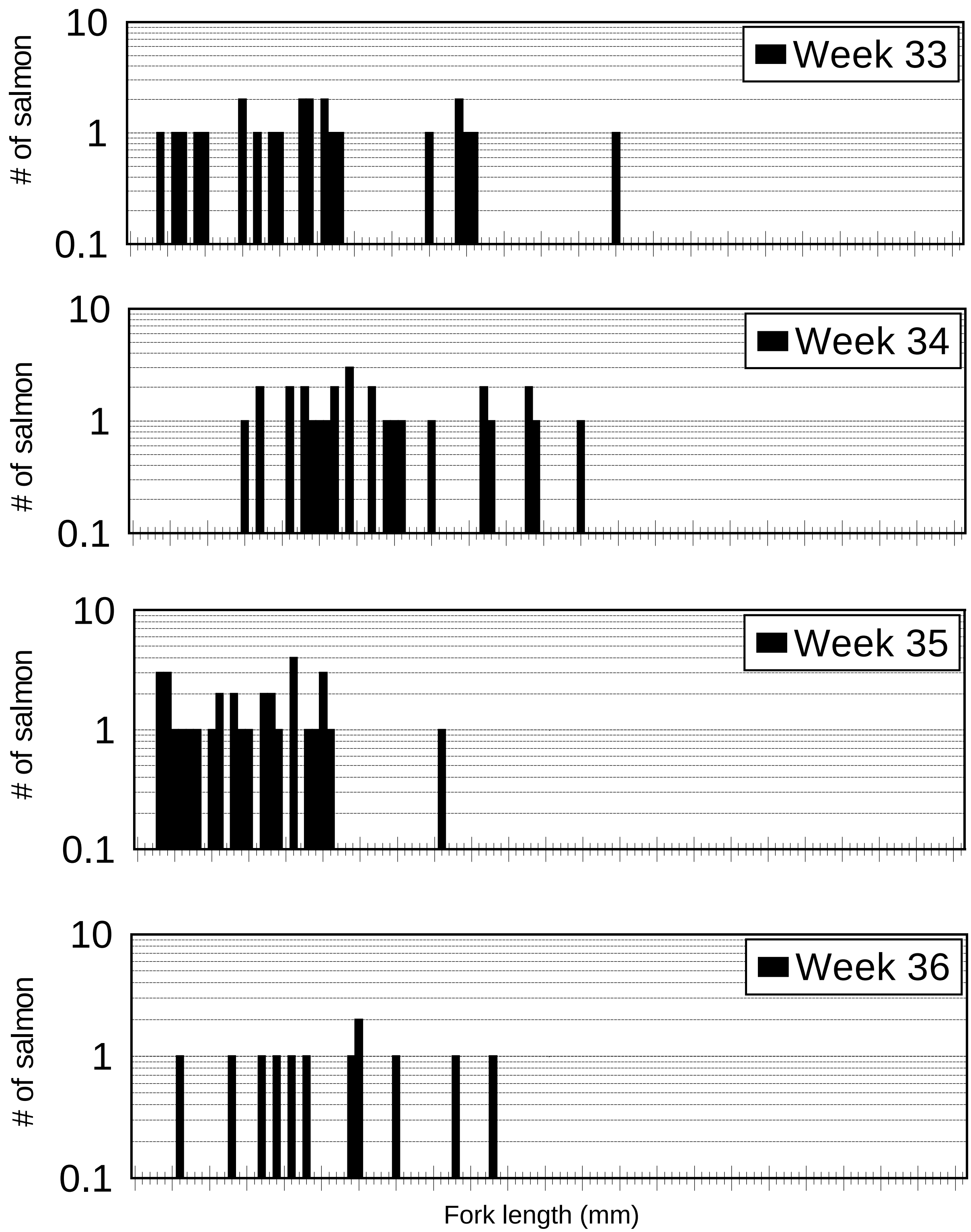


Figure 16. Size distribution of chinook salmon collected by seine in the upper Sacramento River, 11 August - 7 September 1996.

## Weekly size distribution of chinook salmon collected by seine from the upper Sacramento River, 1996.

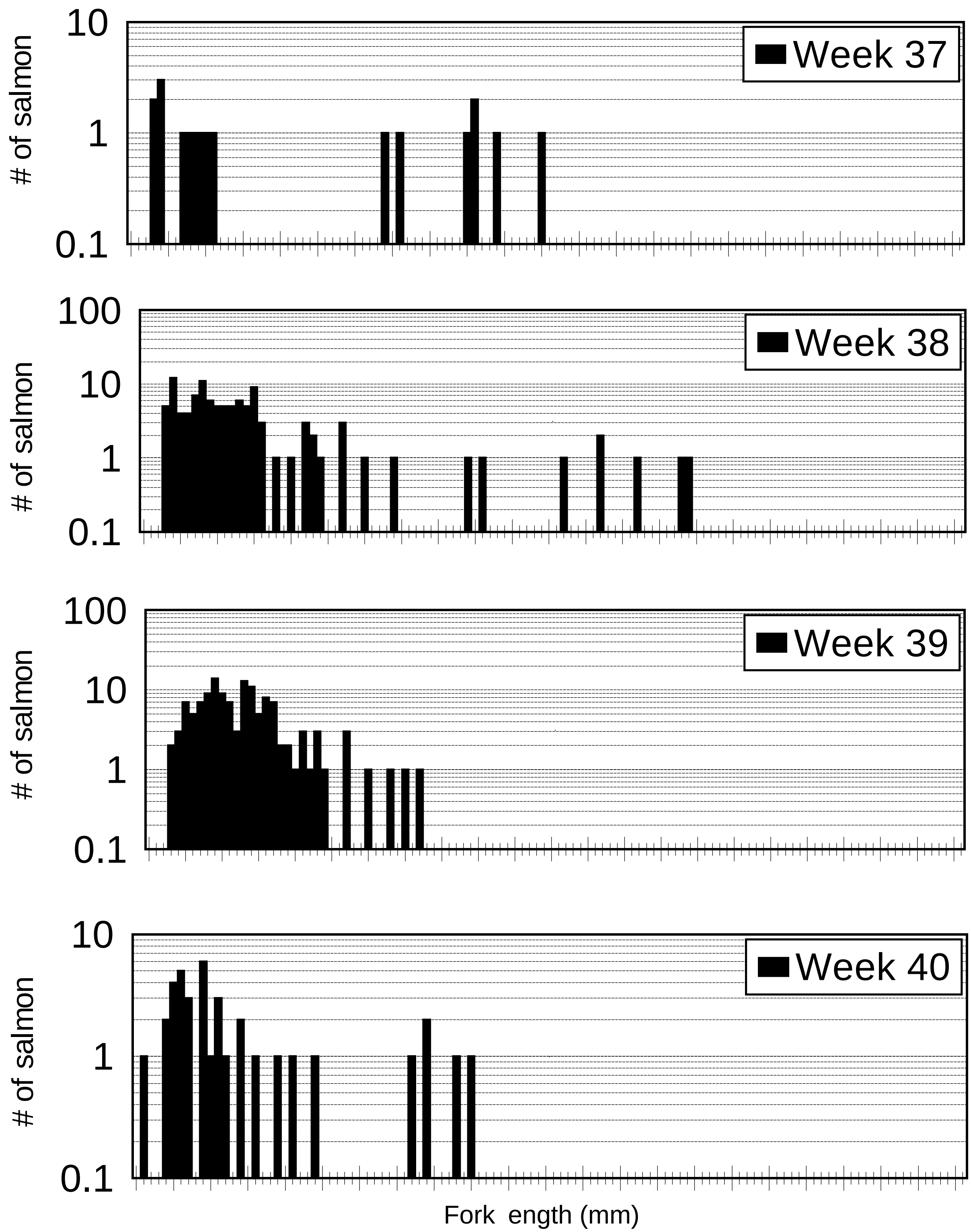


Figure 17. Size distribution of chinook salmon collected by seine in the upper Sacramento River, 8 September - 4 October 1996.

Weekly size distribution of rainbow trout collected by seine from the upper Sacramento River, 1996.

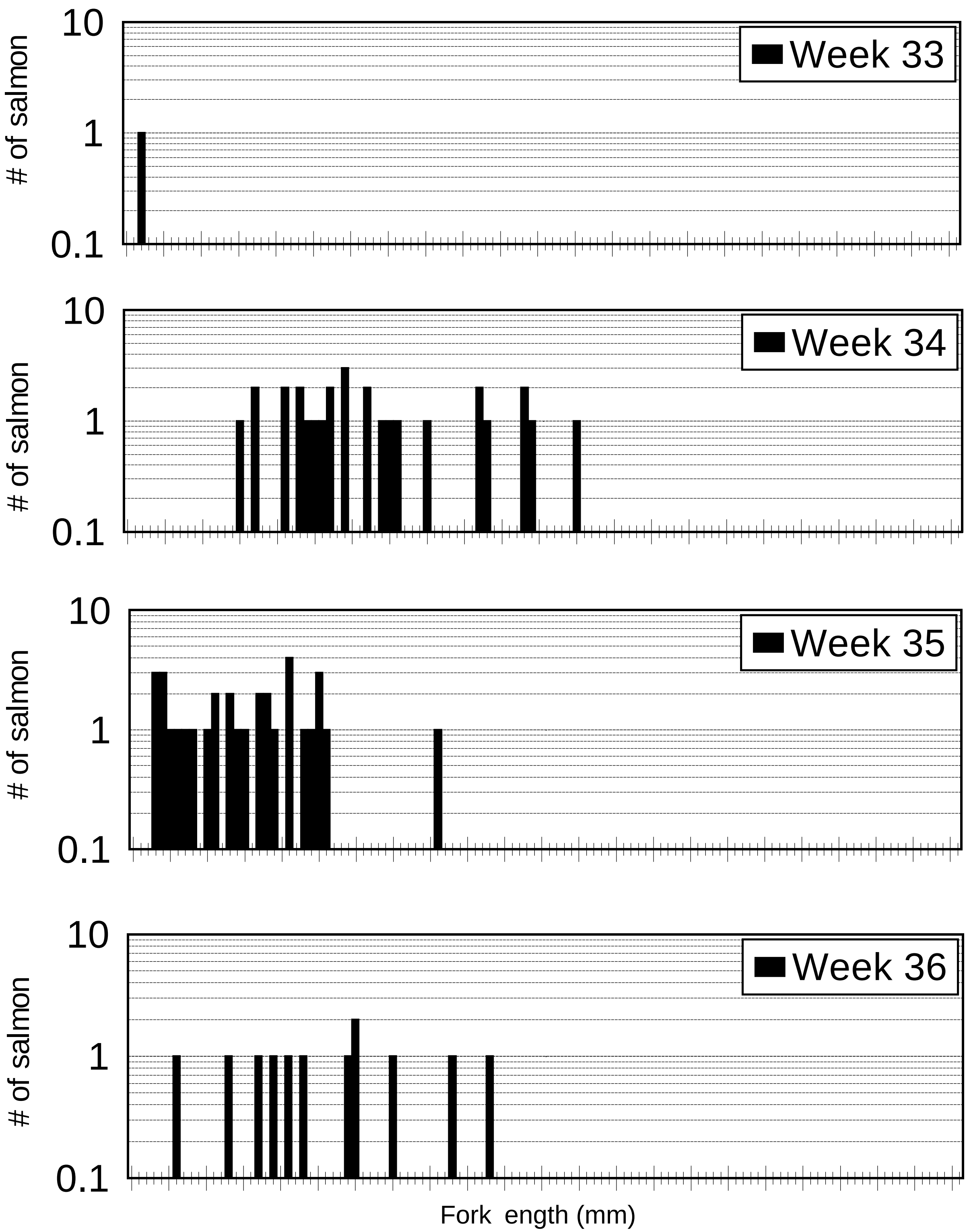


Figure 18.  Size distribution of rainbow trout collected by seine in the upper Sacramento River, 11 August - 8 September 1996.

Weekly size distribution of rainbow trout collected by seine from the upper Sacramento River, 1996.

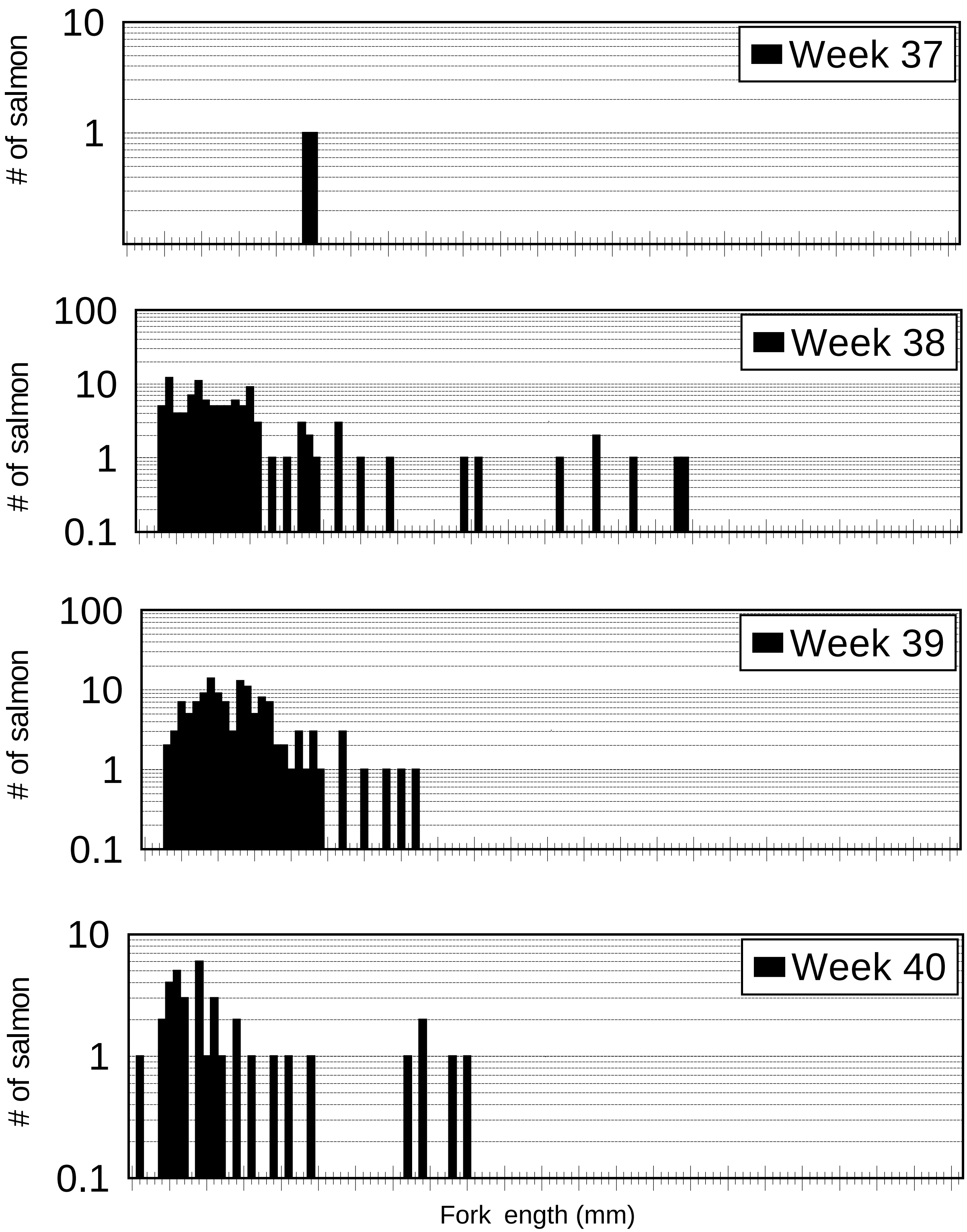


Figure 19. Size distribution of rainbow trout collected by seine in the upper Sacramento River, 8 September - 4 October 1996.

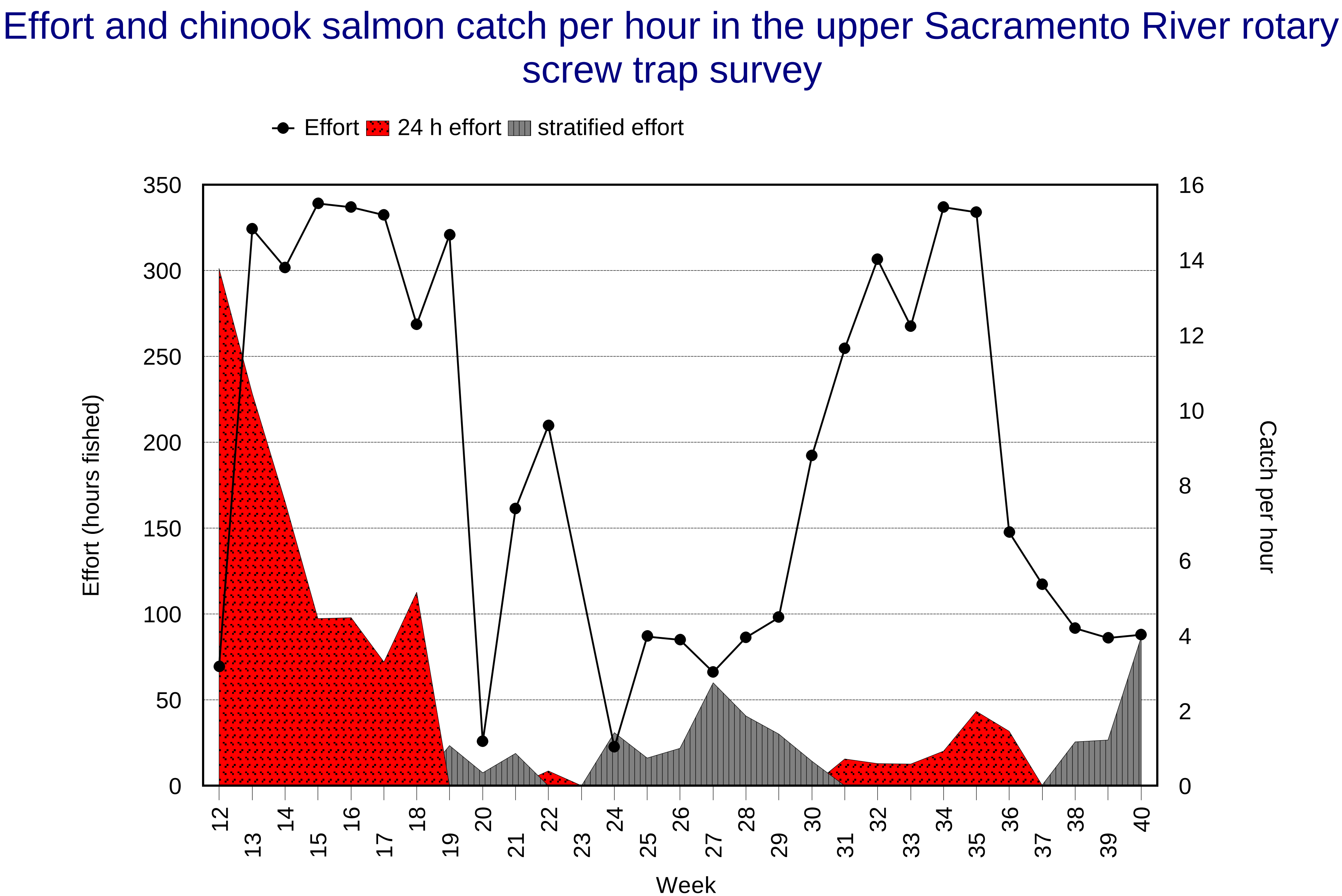


Figure 20. Weekly catch per hour and hours fished by rotary screw trap showing periods of stratified sample effort due to algae build-up in traps in the upper Sacramento River - 22 March - 4 October 1996.

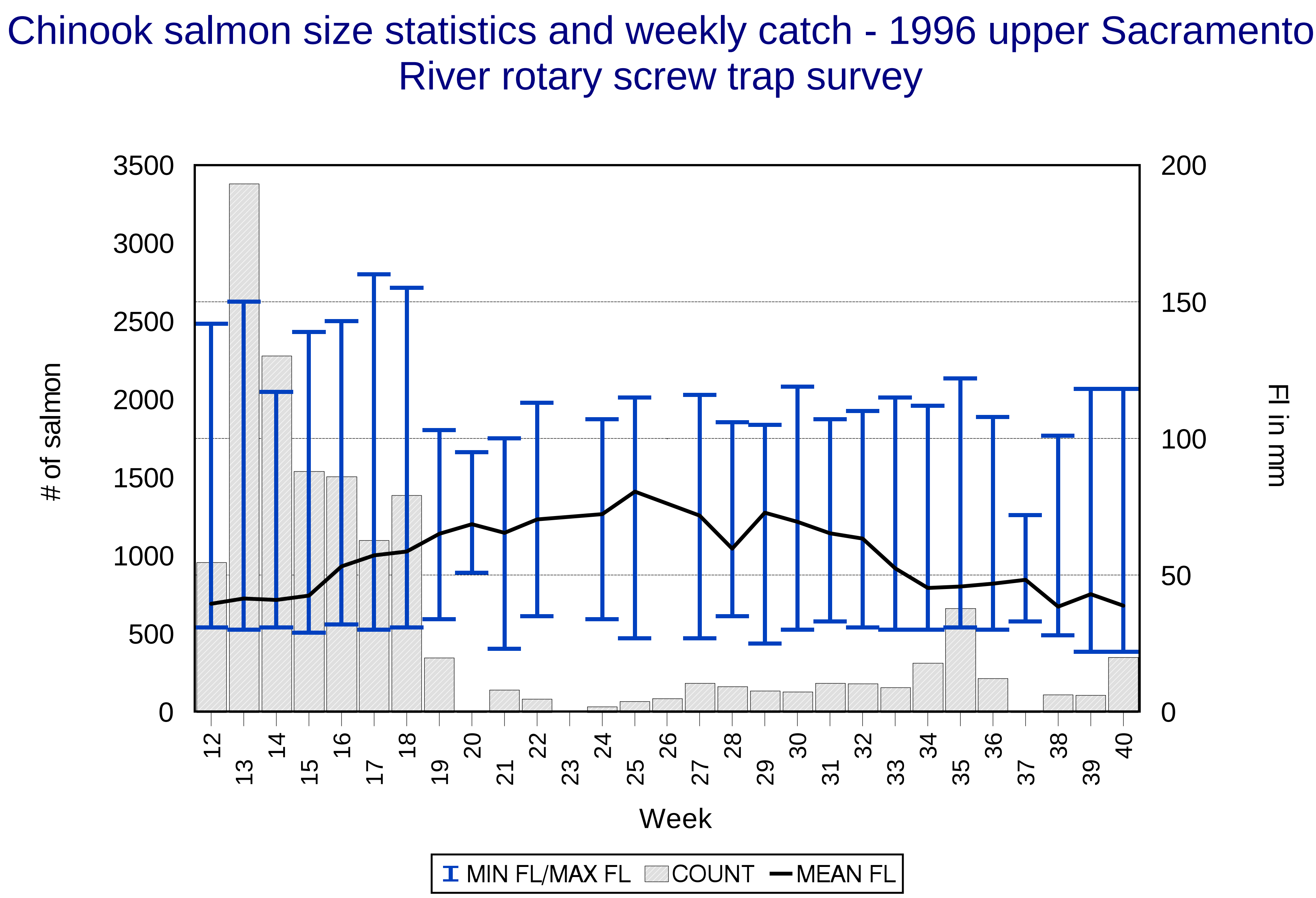


Figure 21. Weekly catch and size statistics for chinook salmon collected by rotary screw trap in the upper Sacramento River, 23 March - 4 October 1996.

# Catch distribution of chinook salmon races collected by rotary screw trap, upper Sacramento River, 22 March - 4 October 1996

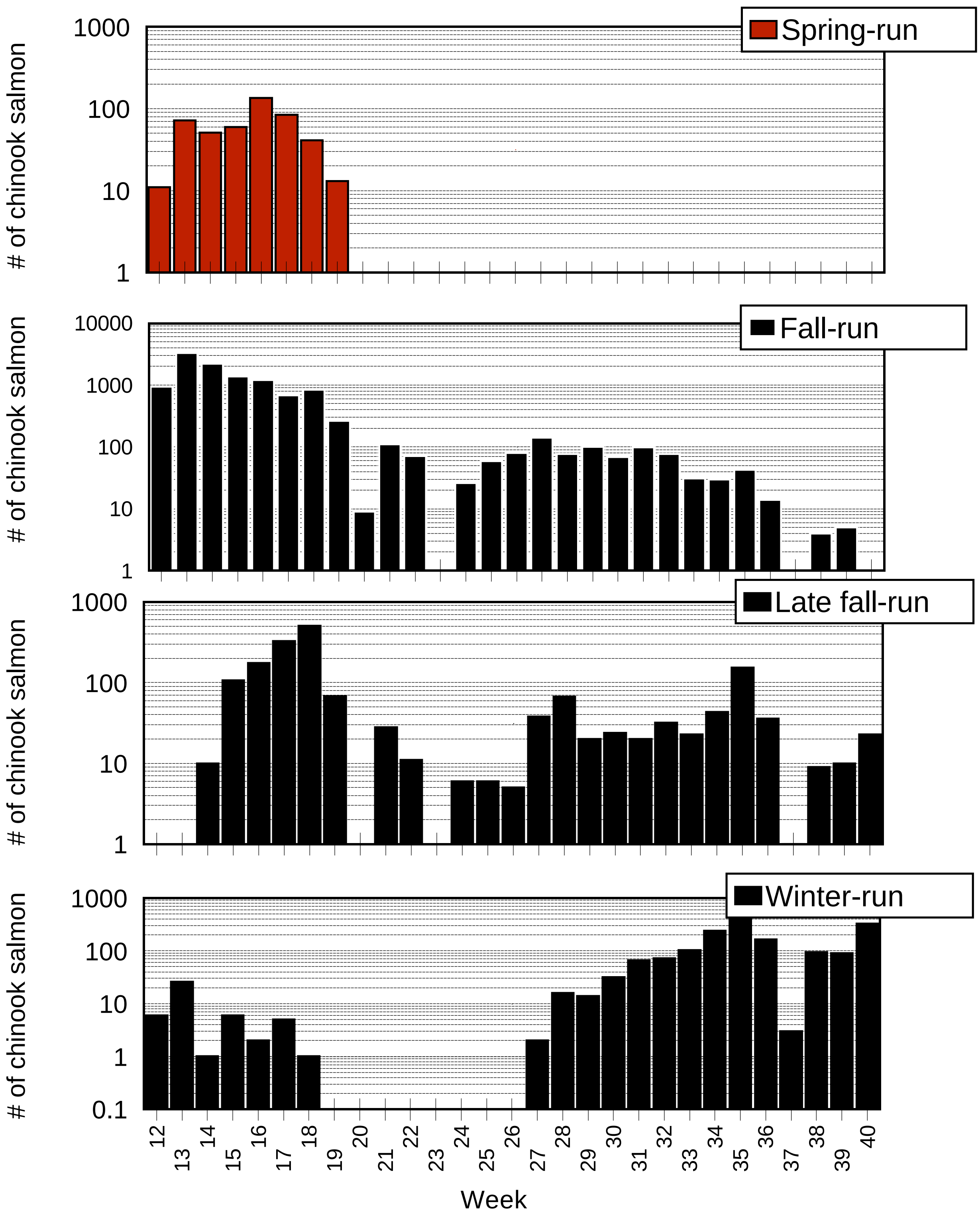


Figure 22. Catch distribution of chinook salmon races collected by rotary screw trap in the upper Sacramento River, 22 March - 4 October 1996.

# Catch and size statistics for chinook salmon by race

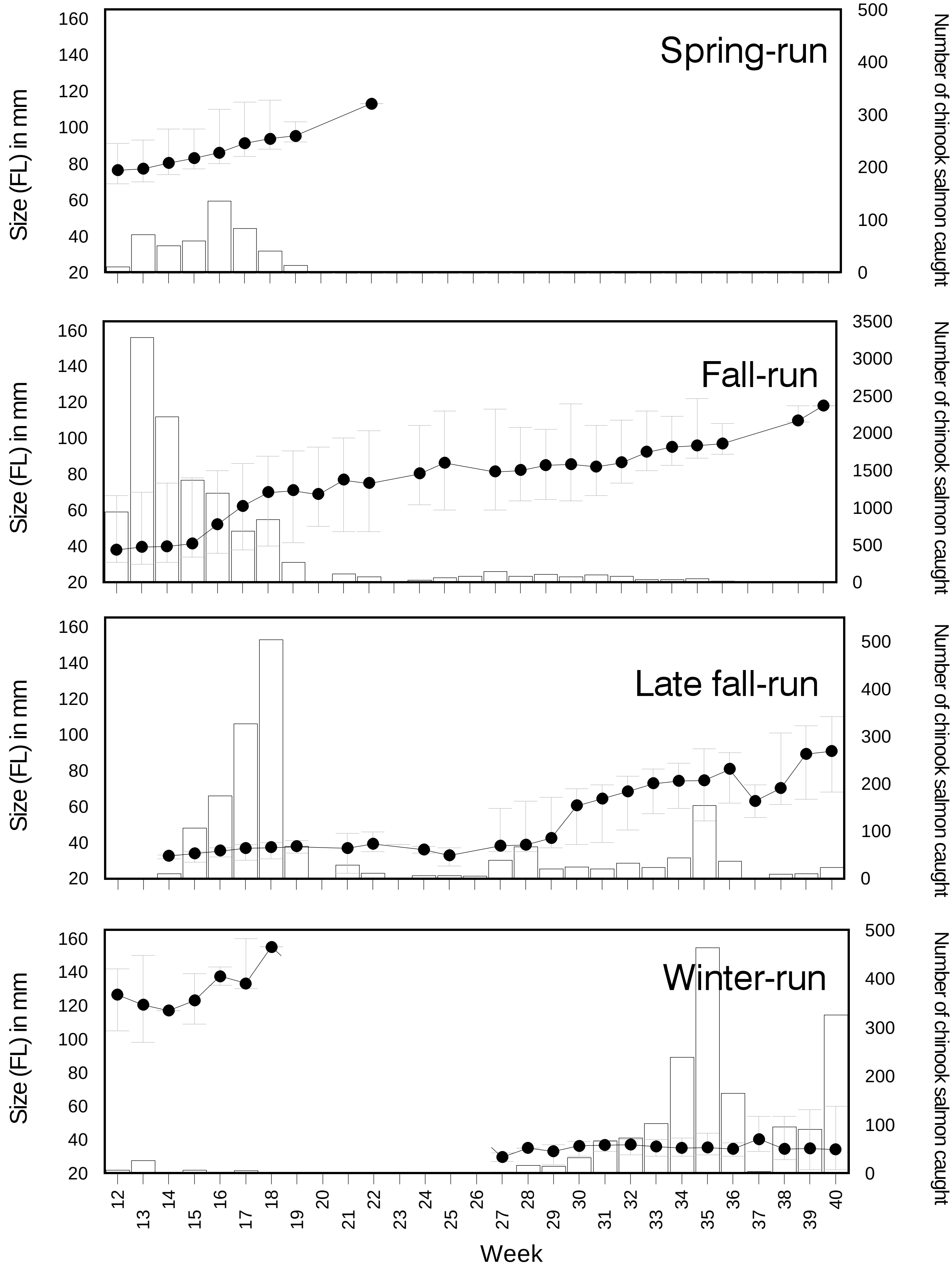


Figure 23. Weekly catch and size statistics for the four races of chinook salmon collected by rotary screw trap in the upper Sacramento River, 22 March - 4 October 1996

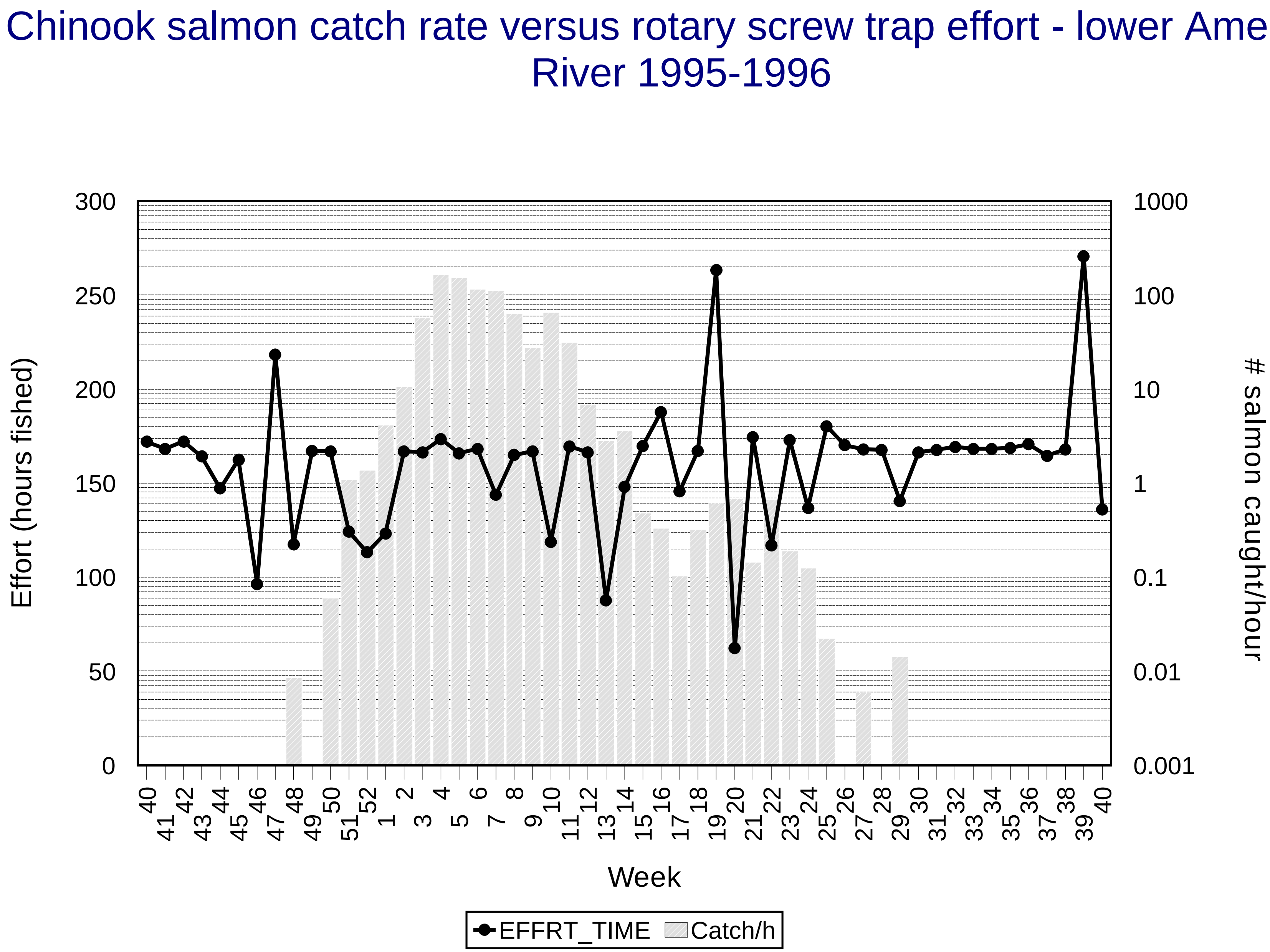


Figure 25. Weekly chinook salmon catch rate versus hours fished by rotary screw trap in the lower American River - October 1995 through September 1996.

# Chinook salmon size statistics and weekly catch during the 1995 - 1996 lower American River emigration survey

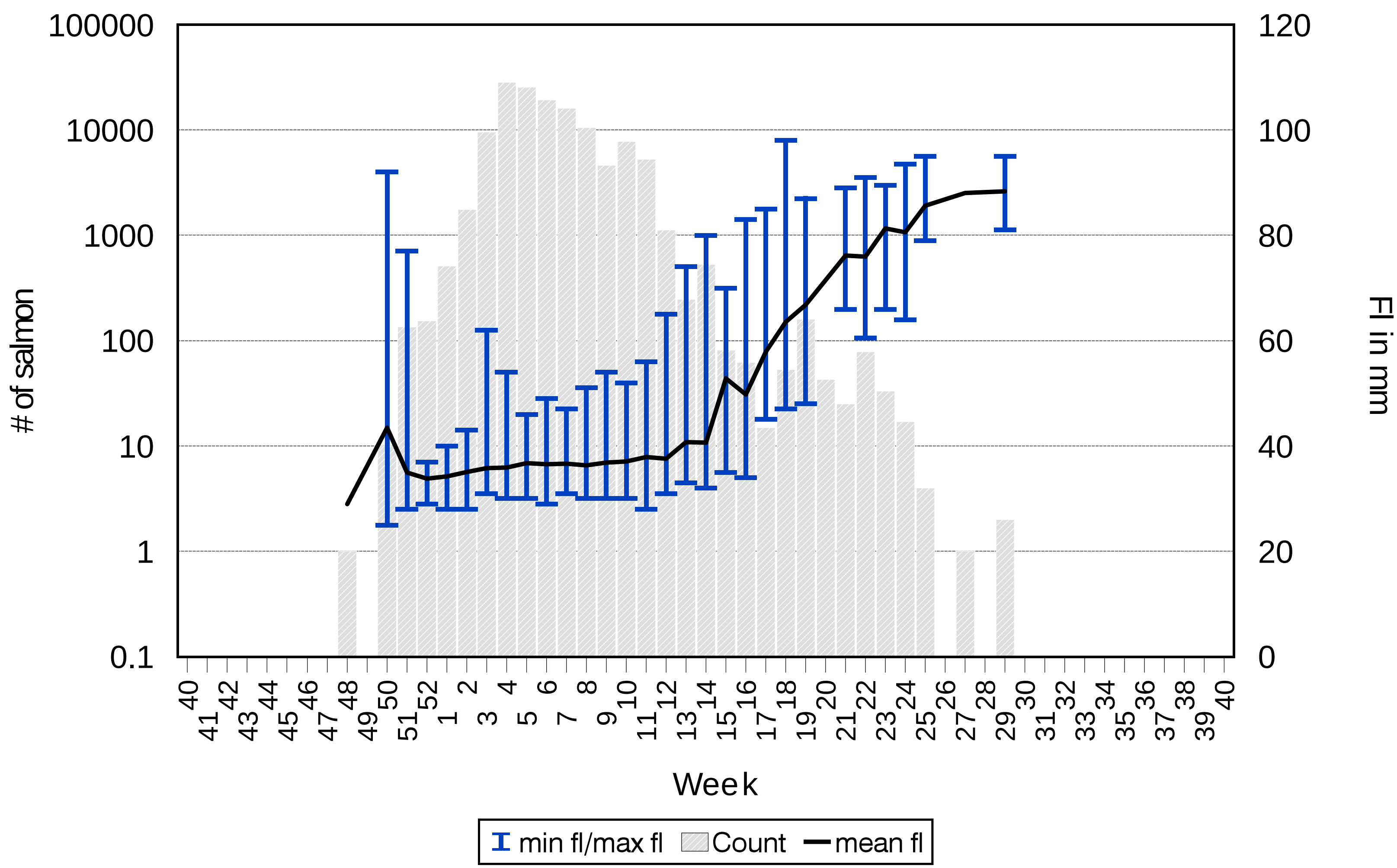


Figure 26. Weekly catch and size statistics for chinook salmon collected by rotary screw trap in the lower American River, October 1995 through September 1996.

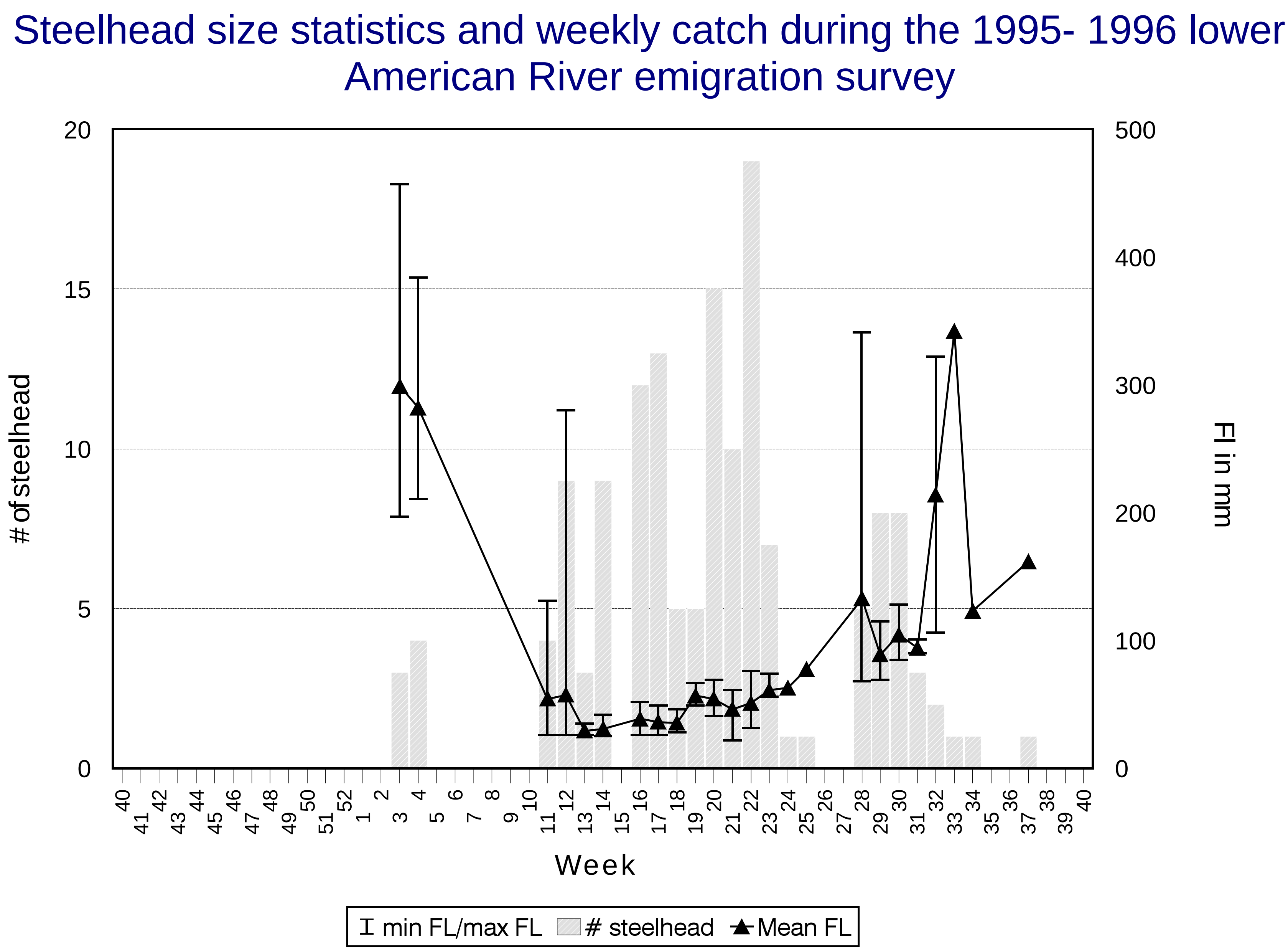


Figure 27. Mean fork length and size range of steelhead caught by rotary screw trap during the lower American River emigration survey, October 1995 through September 1996.

# APPENDIX A

## Upper Sacramento River Emigration Survey
## Salmon Weekly Size Distribution

# APPENDIX B

**Upper Sacramento River Fall-run Chinook Salmon Redd Survey**
**Fall 1995**

**DEPARTMENT OF FISH AND GAME**
Environmental Services Division
Stream Flow and Habitat Evaluation Program

# Chinook Salmon Redd Survey Sacramento River, Battle Creek to Keswick Dam

# Fall 1995

Prepared by the staff of
The Stream Flow and Habitat Evaluation Program

August 1996

# PREFACE

This study was developed and implemented by the Stream Flow and Habitat Evaluation Program of the California Department of Fish and Game (DFG) as part of the investigations undertaken to provide the Central Valley Anadromous Fish Restoration Program of the U. S. Fish and Wildlife Service (USFWS) with reliable scientific information to develop the instream flow needs for Central Valley Project (CVP) controlled streams and rivers.

This report is a provision of the agreement between the USFWS and the DFG that the DFG assist the USFWS in implementing the Central Valley Project Improvement Act (CVPIA). Title 34, Section 3406(b)(1)(B) of the CVPIA requires the Secretary of the Department of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers, based on recommendations of the USFWS after consultation with the DFG.

# SUMMARY

During fall 1995 the first of a two-part study was undertaken to assess whether aerial photography could be used on the Sacramento River to identify the magnitude of spawning, the temporal and spatial distribution of spawning, and the occurrence of redd superimposition. Photographs of the river from Battle Creek upstream to Keswick Dam were taken at the beginning of October and end of November to cover the time period and river segment that the majority of fall-run chinook salmon spawning occurs.

As a check of the potential variation between direct and photographic documentation of redds, each aerial photo flight was scheduled to coincide with a weekly redd count using direct observation.

The aerial photo surveys are conducted from a fixed wing aircraft flying at an elevation of 6,000 feet using a camera with a 9" x 18" negative format. The weekly redd counts are made by direct observation from a fixed wing aircraft flying at 700 feet.

Limitations encountered in the use of aerial photographs to document the presence of fall-run redds included: sun angle and related shadows along river edges obscuring longitudinal bars known to be heavily used by spawning salmon; high background turbidity combined with spawning in water deep enough to impair visibility; and the presence of remnant redds from past spawning years and other spawning runs (winter- and spring-run) that confounded identification of new fall-run redds. Additionally, the high flight elevation required for the camera lens focal length limited visibility.

In comparative reaches observed during the same time periods, the redd count by photo documentation versus direct observation identified 42% more redds the week of October 4, and 40% less redds the week of November 19, 1995.

High use spawning areas were identifiable, but photographic resolution was not high enough to determine whether superimposition had occurred or whether redds were simply constructed so closely together that individual redds could no longer be discerned.

Ground reconnaissance surveys planned to coincide with each aerial redd survey to calibrate the aerial redd counts were not done. Rapidly changing fall 1995 weather conditions and the associated short-notice difficulties of coordinating flight and ground crews prevented the coincident surveys from being completed.

## CONCLUSIONS

1. The Sacramento River's typically high background turbidity combined with the deeper water where many salmon spawn limits visibility and, therefore, the likelihood that redds will be accounted for with the photo-documentation equipment and methods used for the fall 1995 photographic survey. In order to deal with variables outside our control, a higher resolution mapping camera with a longer focal length should be used on the Sacramento River.

2. Sacramento River fall-run chinook salmon have a tendancy to spawn extremely close to, although not necessarily superimpose, adjacent redds. The occurrence and degree of superimposition cannot be determined with the photographic method and documentation time interval used in the fall 1995 survey. In order to overcome the natural limits on visibility that make it difficult to discern the difference between superimposed versus closely constructed redds, a shorter photo documentation interval will be required.

## RECOMMENDATIONS

1. For the 1996 fall-run chinook salmon aerial survey photographic documentation equipment and methods should be changed to include a high resolution mapping camera with a 9" x 9" negative, a longer lens focal length of 81/4 ", and a lower flight elevation of 1,700 feet.

2. In order to assess whether the difference between superimposed versus closely constructed redds can be discerned by photo documentation, the fall 1996 aerial photo survey interval of three flights, one at the beginning of each month should be changed to four flights at two week intervals in October and November. Since 90 percent of the fall-run spawning is typically complete by the end of November, the December flight should be eliminated.

3. As during the fall 1995 survey, each monthly aerial photo survey should coincide with a weekly direct observation count as a check on improvements in documentation methods and the potential variation between direct observation and photographic documentation of redd numbers.

# INTRODUCTION

The first of two planned aerial photographic surveys to document the presence of fall-run chinook salmon redds on the Sacramento River was conducted during fall 1995. The aerial photo surveys are intended to document temporal and spatial spawning distribution and to compliment weekly direct observation aerial redd counts.

The aerial photo surveys are made from a fixed wing aircraft flying at an elevation of 6,000 feet and using a camera with a 9" x 18" negative format.

Every year, weekly aerial redd counts are made by direct observation from a fixed wing aircraft at an elevation of 700 feet above the river. The aerial redd count data is used in combination with fish count data collected at Red Bluff Diversion Dam (RBDD) to estimate the spawning population size (Mills and Fisher 1994).

As a check of the potential variation between direct observation and photographic documentation of redds, each monthly aerial photo survey was planned to coincide with a weekly direct observation count.

The weekly aerial redd counts cover a 140-mile segment of the river between the town of Princeton upstream to Keswick Dam. Because the potential technical and logistical limitations on the use of aerial photography to document the occurrence of redds on the Sacramento River were not well known, the scope of the initial survey was limited to the 31-mile segment of the river from the confluence of Battle Creek upstream to Keswick Dam, where 90% of the spawning typically occurs.

Anticipated limitations to the use of aerial photography on the Sacramento River to effectively document the presence of redds included: sun angle and related shadows on a predominantly north-south flowing river; relatively high background turbidity; high episodic turbidity contributed from tributary streams after storm events; impaired visibility caused by spawning in water typically deeper than 5 feet, and the tendency of Sacramento River fall-run salmon to spawn so closely together that individual redds cannot be identified (Fry and Petrovich 1970). Another limitation, the magnitude of which was unappreciated until we began mapping redds on the aerial photos, is the presence of remnant redds from past spawning years and spawning runs (winter- and spring runs). In many parts of the river, the aerial photography documented redd pots from past spawning activity with greater clarity than newly constructed redds.

Additionally, the high flight elevation required for the short camera lens focal length seemingly exacerbated the physical and biological limitations on visibility. For example: no redds were visible in Reach 3 with photo documentation flown at 6,000 feet while many hundreds of redds were visible in the same reach at the same time during direct observations flown at 700 feet.

The first week of October 42% more redds were identified using aerial photography (36 redds) than were identified by direct observation (14 redds). Conversely, during the week of 19 November, 40% more redds were identified using direct observation (861 redds) than were identified using aerial photography (341 redds).

## OBJECTIVES

1. Determine whether it is logistically possible to create a photographic record to enumerate fall-run chinook salmon redds in the upper Sacramento River by geographic location and habitat type.

2. Develop a photographic record of spawning activity in the upper Sacramento River in order to:

    - describe and evaluate trends in temporal and geographic distribution of spawning,

    - describe and evaluate trends in temporal and geographic distribution of redd superimposition

    - describe and evaluate trends in temporal and geographic distribution of spawning compared with temporal and geographical differences in flow.

# METHODS

The study area encompassed 31-mile section of the Sacramento River from just downstream of the mouth of Battle Creek at river mile (RM) 271 upstream to the base of Keswick Dam at RM 302 (Figure 1[1/]). Redd locations were determined using aerial photography.

Aerial photographic surveys were planned for the first week of each month of the spawning period (October, November, December). The first fight occurred as scheduled on October 4, 1995. The second flight was delayed by weather until November 20, 1995. A planned third flight was canceled because 90 percent of the fall-run spawning activity had occurred by the time weather conditions had improved enough to photographically survey the river.

Water clarity was not methodically measured during the survey period, but was visually estimated to be greater than 8 feet. U. S. Bureau of Reclamation release records at Keswick Dam and temperature data collected by Department of Fish and Game (DFG) thermographs were used to describe river conditions during the aerial survey (Table 1).

## Aerial Survey

The aerial survey photographs were taken at a scale of approximately 1 inch to 200 feet (1:2400). The negatives from each flight were reviewed before printing. Only those negatives of locations appearing to contain redds were printed and enlarged to a scale of approximately 1 inch to 50 feet (1:600). Individual redds were located on the enlarged photographs and traced onto mylar overlays. Only discrete, newly constructed redds were counted for each flight.

Redds were counted by river mile, river reach, and habitat type (Tables 2 and 3, Figure 2). Habitat type was determined from a habitat characterization study conducted by the DFG. Habitat types were stratified by habitat zone, (bar complex, flatwater, secondary channels, and off-channel areas) and were defined as glide, riffle, run and pool.

## Redd Superimposition

Redd superimposition is determined by comparing mylar overlay tracings from the latest flight with tracings from the previous flight. Superimposition was considered to have occurred if the tracings overlapped by at least 50 percent. The number and location (river mile, reach, habitat type) of superimposed redds can then be identified for each flight.

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1/ Table 1 and Figure 1 and all subsequent Tables and Figures follow the Literature Citations

# RESULTS and DISCUSSION

## Redd Counts

A total of 377 redds were counted by photo documentation versus 875 redd counted by direct observation. As mapped from the aerial photographs, 36% (135) of the redds were counted in Reach 1, the majority of spawning activity was observed upstream of river mile 280, in Reach 2 where 64% (242) of the redds were counted, and no redds were observed in Reach 3 (Table 4)

Redd counts made by direct observation of the same reaches for the same time periods identified 31% of the redds in Reach 1 (270 redds), 58% of the redds in Reach 2 (495 redds), and 11% of the redds in Reach 3 (96 redds) (Table 4).

## Temporal Distribution

Spawning began in the first week of October and was more than 90% complete by the beginning of November, consistent with years past (Mills and Fisher 1994).

A comparison of fall-run chinook salmon redd counts made by photo documentation and direct observation, and escapement survey carcass counts is included in Table 5....

## Geographic Distribution

The majority of the spawning activity occurred in Reach 2, with 64% of the spawning activity observable by aerial photography concentrated between river miles 280 and 285 (Table 3). This is comparable to the 58% concentration in Reach 2 noted by direct observation in fall 1995 (F. Fisher, personal communication 1996), but differs from the longer-term 1967-1991 average (Mills and Fisher 1994). Based on the longer-term average the geographic distribution of spawning activity is evenly concentrated in Reach 1 and Reach 2 (43% and 44%, respectively).

## Habitat Use

Based on the photo documentation, 44 habitat sites were used for spawning. Of the 377 redds counted, 81% of all redds were counted in 4 of the 11 available habitat types: 33% were in bar complex riffles (123 redds), 19% in flatwater glides (73 redds), and 15% in secondary channel riffles (56 redds) (Table 6). Bar-complex runs, pools and glides, flatwater riffles and glides, secondary channel runs, and off-channel areas were also used for spawning, although to a much lesser extent.

The 8 most heavily used sites (sites with 20 or more observed redds) accounted for 76% of the observed redds (Table 7, Appendices I and II). Four (4) habitat sites were used for spawning during both survey periods (Table 8).

Because redds counted by direct observations are not mapped by habitat type, a comparison cannot be made between the photo survey and direct observation habitat use.

**Redd Superimposition**

The locations (river mile, river reach, habitat type) affected by high spawning use were identifiable, but the number of unique redds, whether superimposition had occurred, and to what degree, could not be determined. During direct observation counts, the number of redds in areas of high spawning use are estimated by the observer based on an estimate of the area disturbed by spawning activity divided by a mean redd size (F. Fisher personal communication). We made no attempt to similarly estimate redd numbers because although areas of high spawning use were generally identifiable they were too poorly defined on the photographs to provide a confident aerial measurement.

The affects of high spawning use or potential redd superimposition were not observed until Flight 2 when 18 of the 44 habitat units used for spawning were observed to be affected (Table 9, Appendix II). Thirteen (72%) of the habitat types affected by high spawning use or some degree of superimposition were in Reach 2.

High spawning use and potential superimposition occurred in 8 of the 11 habitat types available, but was most often observed in bar complex riffle and flatwater glide habitat. The effects of high spawning use or potential superimposition were not observed in off-channel areas or in bar complex and flatwater pools.

# ACKNOWLEDGMENTS

The Sacramento River habitat was characterized by Kris Vyverberg, DFG Stream Flow and Habitat Evaluation Program geomorphologist. Data on chinook salmon redd measurements and spawning depths were provided by Charlie Brown (DFG). Aerial redd survey data collected by direct observation from a fixed wing airplane were provided by Frank Fisher and Karl Wahler, Region 1 DFG. Field data were collected by Larry Hanson and Jon Ferguson (DFG), and Mark Gard, Sean Gallagher, and Paul Zedonis of the USFWS. Photographic mapping of chinook salmon redds was done by Doug Post and Kris Vyverberg (DFG) in consultation with Frank Fisher. The DFG thanks these individuals for their efforts.

Funding for this study was provided by the U. S. Fish and Wildlife Service and the California Department of Fish and Game.

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U. S. Fish and Wildlife Service. 1995. *Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California. Annual Progress Report Fiscal Year 1995.* Ecological Services, Instream Flow Assessments Branch, Sacramento Field Office. 57 pp.

# TABLES

**Table 1.** General information for the fall-run chinook salmon aerial redd survey, upper Sacramento River, fall 1995.

| FLIGHT | DATE | FLOW[1/] (cfs) | CLARITY[2/] | REDDS COUNTED | TEMPERATURE[3/] | |
|---|---|---|---|---|---|---|
| | | | | | EF | EC |
| 1 | 10/4/95 | 5,000 | 8+ | 36 | 55 | 12.8 |
| 2 | 11/20/95 | 5,000 | 8+ | 341 | 56 | 13.3 |

1/ Mean flow between 1 October and 29 November
2/ Water clarity visually estimated
3/ Temperature range between survey periods

**Table 2.** Location of study reaches for the fall-run chinook salmon aerial redd survey, upper Sacramento River (USFWS 1995).

| REACH | LOCATION | RIVER MILE |
|---|---|---|
| 1 | ACID Dam to Keswick Dam | 298.5 to 302.0 |
| 2 | Cow Creek to ACID Dam | 280.2 to 298.5 |
| 3 | Battle Creek to Cow Creek | 271.0 to 280.2 |

**Table 3.** General information for map site location of fall-run chinook salmon redds (see Figure 2), upper Sacramento River River, fall 1995.

| Map Site # | Habitat Site ID # | River Mile | # of Survey Periods Used | Total # of Redds |
|---|---|---|---|---|
| 1 | 136 | 298 | 1 | 1 |
| 2 | 129 | 297 | 2 | 18 |
| | 125 | 296 | 1 | 1 |
| | 124 | 296 | 1 | 2 |
| | 122 | 296 | 1 | 21 |
| 3 | 114 | 295 | 1 | 5 |
| 4 | 110 | 294 | 1 | 3 |
| | 109 | 294 | 1 | 16 |
| 5 | 103 | 293 | 1 | 3 |
| 6 | 99 | 292 | 1 | 2 |
| | 94 | 291 | 1 | 2 |
| | 92 | 291 | 1 | 2 |
| | 89 | 291 | 1 | 3 |
| 7 | 84 | 291 | 1 | 5 |
| | 83 | 291 | 2 | 20 |
| | 82 | 291 | 1 | 5 |
| | 78 | 291 | 2 | 24 |
| | 76 | 291 | 1 | 2 |
| | 75 | 290 | 1 | 14 |
| 8 | 66 | 289 | 1 | 8 |
| | 63 | 288 | 1 | 3 |
| | 62 | 288 | 1 | 2 |
| | 59 | 287 | 1 | 1 |
| 9 | 45 | 284 | 1 | 21 |
| 10 | 43 | 284 | 1 | 14 |
| | 42 | 283 | 1 | 3 |
| | 41 | 282 | 1 | 10 |
| 11 | 38 | 282 | 1 | 13 |
| | 36 | 282 | 1 | 10 |
| 12 | 32 | 281 | 1 | 2 |
| | 31 | 280 | 1 | 6 |
| 13 | 27 | 279 | 1 | 10 |
| | 26 | 279 | 1 | 10 |
| | 23 | 279 | 1 | 10 |
| 14 | 21 | 279 | 1 | 4 |
| | 18 | 278 | 1 | 9 |
| 15 | 13 | 276 | 1 | 35 |
| | 12 | 275 | 1 | 7 |
| 16 | 10 | 274 | 1 | 3 |
| 17 | 6 | 274 | 1 | 30 |
| | 5 | 274 | 1 | 3 |
| | 4 | 273 | 1 | 1 |
| | 3 | 272 | 2 | 7 |
| | 2 | 271 | 1 | 6 |

**Table 4.** Comparison of aerial photographic survey and direct observation counts of fall-run chinook salmon redds by river reach by flight, upper Sacramento River, fall 1995.

| WEEK FLIGHT DATE | REACH 1 | | REACH 2 | | REACH 3 | |
|---|---|---|---|---|---|---|
| | Photo Count | Direct Count | Photo Count | Direct Count | Photo Count | Direct Count |
| October 4 | 5 | 3 | 31 | 11 | 0 | 0 |
| November 20 | 130 | 270 | 211 | 495 | 0 | 96 |
| **TOTAL** | **135** | **273** | **242** | **506** | **0** | **875** |
| **PERCENT** | **35.8%** | **31%** | **64.2%** | **58%** | **0.0%** | **11%** |

**Table 5.** Comparison of fall-run chinook salmon escapement survey carcass counts, redds counted during the aerial photo redd survey, and direct observation redd counts, Sacramento River, fall 1995 (Snider, Hanson, and Reavis 1996).

| SURVEY PERIOD | ESCAPEMENT CARCASS COUNT | | FLIGHT | AERIAL PHOTO COUNT | | DIRECT OBSERVATION REDD COUNT | |
|---|---|---|---|---|---|---|---|
| Week | Number | % Total | | Number | % Total | Number | % Total |
| Oct 1-7 | 55 | 5.2 | 1 | 36 | 9.6 | 14 | 1.6% |
| Nov 19-25 | 993 | 94.8 | 2 | 341 | 90.4 | 861 | 98.4% |

**Table 6**. Summary of fall-run chinook salmon redd counts by habitat type per flight and by percent total of all habitat types used for spawning, upper Sacramento River, fall 1995.

| Habitat Zone | Habitat Type | FLIGHT NUMBER | | Total Count | Percentage of all Habitat Used |
|---|---|---|---|---|---|
| | | 1 | 2 | | |
| Bar Complex | riffle | 6 | 117 | **123** | 32.6 |
| | run | 2 | 8 | **10** | 2.7 |
| | pool | 0 | 3 | **3** | 0.8 |
| | glide | 6 | 25 | **31** | 8.2 |
| Flatwater | riffle | 0 | 7 | **7** | 1.9 |
| | run | 0 | 56 | **56** | 14.9 |
| | pool | 0 | 3 | **3** | 0.8 |
| | glide | 1 | 72 | **73** | 19.4 |
| Secondary Channel | riffle | 21 | 24 | **55** | 14.6 |
| | run | 0 | 8 | **8** | 2.1 |
| Off-Channel | | 0 | 8 | **8** | 2.1 |

**Table 7.** Habitat sites with 20 or more fall-run chinook salmon redds, Sacramento River, fall 1995.

| SITE ID # | REACH | HABITAT ZONE | HABITAT TYPE | # of REDDS |
|---|---|---|---|---|
| 6 | 3 | Bar Complex | Riffle | 30 |
| 13 | 3 | Flatwater | Riffle | 35 |
| 45 | 2 | Flatwater | Glide | 21 |
| 78 | 2 | Secondary Channel | Riffle | 24 |
| 83 | 2 | Secondary Channel | Riffle | 20 |
| 122 | 2 | Flatwater | Run | 21 |

**Table 8.** Habitat sites where fall-run chinook salmon redds were observed during both survey periods, upper Sacramento River, fall 1995.

| SITE ID # | REACH | HABITAT ZONE | HABITAT TYPE | NUMBER OF REDDS |
|---|---|---|---|---|
| 3 | 1 | Bar Complex | Riffle | 7 |
| 78 | 2 | Secondary Channel | Riffle | 24 |
| 83 | 2 | Secondary Channel | Riffle | 20 |
| 129 | 2 | Bar Complex | Glide | 18 |

**Table 9.** Habitat sites where the affects of high spawning use and potential superimposition were observed, Sacramento River, fall 1995.

| SITE ID # | REACH | HABITAT ZONE | HABITAT TYPE | REDDS DISCERNABLE |
|---|---|---|---|---|
| 6 | 1 | Bar Complex | Riffle | 30 |
| 12 | 1 | Flatwater | Run | 24 |
| 18 | 1 | Flatwater | Glide | 20 |
| 26 | 1 | Flatwater | Riffle | 10 |
| 27 | 1 | Flatwater | Glide | 10 |
| 31 | 2 | Bar Complex | Run | 2 |
| 32 | 2 | Bar Complex | Riffle | 6 |
| 36 | 2 | Bar Complex | Riffle | 13 |
| 38 | 2 | Bar Complex | Glide | 10 |
| 43 | 2 | Flatwater | Glide | 14 |
| 63 | 2 | Secondary Channel | Run | 3 |
| 66 | 2 | Bar Complex | Riffle | 8 |
| 82 | 2 | Secondary Channel | Run | 5 |
| 83 | 2 | Secondary Channel | Riffle | 14 |
| 84 | 2 | Secondary Channel | Riffle | 5 |
| 99 | 2 | Flatwater | Glide | 2 |
| 122 | 2 | Flatwater | Run | 21 |
| 129 | 2 | Bar Complex | Glide | 12 |

# APPENDIX C

## Upper Sacramento River Fall-run Chinook Salmon
## Spawner Escapement Survey
## Fall 1995

DEPARTMENT OF FISH AND GAME
ENVIRONMENTAL SERVICES DIVISION
Stream Flow and Habitat Evaluation Program

# FALL-RUN CHINOOK SALMON SPAWNER ESCAPEMENT SURVEY
# MAINSTEM SACRAMENTO RIVER
# October - December 1995[1/,2/]

Prepared by

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October 1996

1/ This work was supported by funds provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program, as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report 96-6.

# INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Flow and Habitat Evaluation Program (SF&HEP) conducted an intensive fall-run chinook salmon escapement survey on the mainstem Sacramento River during the fall-winter of 1995 to estimate fall-run chinook salmon spawner abundance and distribution. This survey was carried out to accommodate the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, that requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with DFG. In response to this Act, the FWS and the DFG entered a "Cooperative Agreement" to determine flow needs of anadromous salmonids in the mainstem Sacramento River.

The primary mission of the SF&HEP - to improve understanding of the relationships between salmon and habitat in the mainstem Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, and Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys should allow this distinction. An intensive spawner escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

# HISTORICAL BACKGROUND

Salmon spawner surveys were first conducted in the mainstem Sacramento River in 1937 to evaluate the potential effect of Shasta Dam on chinook salmon. From 1937 through 1942, salmon were counted as they passed through a fish ladder at Anderson-Cottonwood Irrigation District's (ACID) dam (river mile ), near Redding (Fry 1961) (Needham et. al.1943). The counts were made to determine the number of fish that would be blocked by Shasta Dam. The counts were made by the Division of Fish and Game (became the Department of Fish and Game in 1952) in 1937, the U. S. Bureau of Reclamation from 1938 through 1941, and the FWS in 1942. ACID Dam is a low, flash board dam that is typically installed in April and is maintained until October or early November. During both installation and dismantling, fish could jump over the flash boards and avoid being counted. Excessively high spring flows sometimes delayed installation of the flash boards and prevented counts.

From 1943 through 1945, salmon spawner counts on the mainstem were made at Balls Ferry (river mile 276). A rack was built for counting and trapping salmon. It was also intended to force part of the population to spawn downstream to reduce spawning density between Balls Ferry and the recently constructed Keswick Dam (river mile 302). Many fish passed this rack uncounted during periods of high flows and by moving through holes underneath the rack.

Fry (1961) concluded that the 1940's spawner escapement estimates for the mainstem were probably much lower than the actual population. This was due to both the tendency to overrate the ability to observe, thus count fish moving through the weir, even when visibility seemed excellent, and to underestimate how many salmon went through small holes in the counting weir. From 1946 through 1952 a variety of methods were used by both the DFG and FWS to estimate salmon spawning escapement to the mainstem. Both ground and aerial surveys were made to count carcasses and redds. The estimates were substantially based upon these data and "professional judgement" using the experience of individuals associated with the program. These estimates were never tested against other methods or counts.

DFG also used a tag-and-recovery method from the 1950 through 1955 to estimate populations in the mainstem Sacramento River (Fry 1961). Live fish were captured in fyke traps located downstream of the spawning grounds, at Fremont Weir (river mile 84), then tagged and released. The tags were later recovered from the carcasses during spawning area surveys, upstream of river mile 200. This method was satisfactory on the American and Stanislaus rivers, but proved much less satisfactory on the mainstem Sacramento River (Fry 1961). He gave the following reasons for this method being unsatisfactory: (I) the difficulty of recovering adequate numbers of spawned-out carcasses; (ii) the trapping site was too far below the spawning area; and (iii) the trap selected for smaller fish.

From 1956 through 1968, spawner estimates were made by experienced DFG biologists using carcass counts(no tag-recapture estimates were made), aerial redd counts, and comparisons with previous years' observations (Dick Hallock, pers. comm). Turbidity, flow, and number of survey trips were integrated into the estimate. Using the estimate and the carcass counts, carcass "recovery" was estimated to range from 0.7 to 4.0%.

Beginning in 1969, estimates were based on fish counts made at the fish ladders on Red Bluff Diversion Dam (RBDD) at river mile 243 (Menchen 1970). The counts were adjusted for periods when no counts were made, including when the dam was open due to normal operation or during floods, and during night hours when no counts were made. The estimated number of fish caught by anglers was subtracted from the number passing over RBDD to calculate spawner escapement. Aerial redd counts were used to determine the distribution of spawning upstream and downstream of RBDD. These results were used to expand RBDD counts and calculate a total estimate for the entire mainstem.

Since 1986, the gates at RBDD have been raised in the fall and lowered during the following spring to improve fish passage. Since 1994, the gates are normally open between September 15th and May 15th. Direct (fishway) counts cannot be made when the gates are raised. Salmon spawner estimates are now computed by dividing the number of fish counted in the fishway by the estimated portion of the total run represented in the counting period. The estimated portion was based on historical data when counts were made year around.

The 1995 escapement survey represents the first attempt since 1968 to estimate salmon spawner escapement in the mainstem Sacramento River based on the ground surveys. It also represents the first attempt ever in the mainstem to use carcasses and a tag-recapture model to estimate spawner escapement.

When monitoring stocks over a long period, such as the Central Valley salmon escapement surveys, the sampling design should assure the data be collected in a consistent manner and represent the population as a whole (Ney 1993). Inconsistencies in methods before 1968 were primarily due to changes in funding that often reduced or eliminated sampling effort, thus the data used to make estimates. Also, population estimates were often based on counts made upstream of where varying portions of the salmon population would spawn - ACID Dam, Balls Ferry Racks, and RBDD. This limited the ability to consistently estimate the entire spawning population unless spawning distribution was also measured. Another limitation was the unknown number of fish that could migrate uncounted above the counting sites. This prompted Fry and Petrovich (1970) to conclude: “Until we can determine the magnitude of salmon movement through the gates at the Red Bluff Dam the counts there cannot be regarded as more than an index.”

## OBJECTIVES

- To estimate the 1995, in-river, fall-run chinook salmon spawning population for the mainstem Sacramento River.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements, and the status of chinook salmon in the mainstem Sacramento River.

## METHODS

A carcass tag-and-recapture study was conducted in the mainstem Sacramento River during fall-winter 1995 to estimate fall-run chinook salmon spawner escapement. The study section extended 25.5 miles from ACID Dam downstream (river mile 298.5) to Cottonwood Creek (river mile 273) (Figure 1). Carcasses were tagged and released into running water for later recapture, unlike the earlier tag-and-recovery study when live fish were tagged and released at Fremont weir. Carcass tag-and-recapture studies along with use of the Schaefer or Jolly-Seber models have been regularly used to estimate escapements in other Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). This protocol was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974).

Three models have been used by the DFG to estimate escapement from carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1992). It has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to estimate escapement to smaller tributary streams (e.g. Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in “larger” Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$ 10% (Boydstun 1992 and Law 1992). Still, there is considerable disagreement among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.). Law (1992) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

The escapement survey began on October 1, immediately following initiation of spawning activity, and continued through December 23, 1995. The study reach from Acid Dam to Cottonwood Creek was surveyed weekly (Figure 1). This reach was further divided into four reaches and each reach was surveyed one day per week (Table 1).

The carcass tag-recapture study was conducted to provide estimates using both the Schaefer and Jolly-Seber models. Complete carcasses (i.e., with the head in tact) were normally tagged. Carcasses that were chopped (not tagged) included: I) those on shore in a “leathery condition”; ii) those in Reach 4 (the most downstream reach) that would likely wash out of the survey area and never be recovered; and iii) carcasses in excess of the number crews could tag during a day. “Fresh” and “decayed” carcasses were combined to calculate estimates for both the Schaefer and Jolly-Seber models. Data acquired weekly for estimating population size included number tagged, number chopped, and number recovered (by week of tagging). Unfortunately, only the number recovered data were collected during the last two survey weeks. This error resulted in a slight underestimate of the population for those two weeks. Since the error occurred during the end of spawning, when the population was relatively very low, it only slightly affected the overall spawner population estimate.

Data collected from a subsample of the fresh carcasses included sex, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, partially spent if more than 50% of the eggs remained, and unspent if the ovaries were nearly full of eggs.

Table 1. Location of survey reaches for the mainstem Sacramento River fall-run chinook salmon escapement survey, October 1995 - December 1995.

| Reach | Location | River mile |
|---|---|---|
| 1 | ACID Dam to Cypress St. Bridge | 298.5 - 295.0 |
| 2 | Cypress St. Bridge to Bonnyview Bridge | 295.0 - 292.0 |
| 3 | Bonnyview Bridge to North St. Bridge | 292.0 - 284.0 |
| 4 | North St. Bridge to Cottonwood Cr. | 284.0 - 273.0 |

# RESULTS

A total of 8,653 carcasses (adults and grilse) was observed (Table 2). Temperature ranged from 53 $^{o}$F during week 12 to 57 $^{o}$F during week 7. Flows were 6,500 cfs during the first week; 5,400 cfs during the second survey week; and 4,800 cfs during the remainder of the survey (Figure 2).

## Temporal Distribution

The number of carcasses observed steadily increased from the first week, peaked in the sixth week (November 5-10), and then declined each week afterwards (Table 3 and Figure 3).

Table 2. General survey information for the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October 1995 - December 1995.

| Week | Dates | Flows (cfs)[1/] | Water temperature (°F)[2/] | Carcass count[3/] |
|---|---|---|---|---|
| 1 | Oct 1 - 7 | 6,500 | 55 | 55 |
| 2 | Oct 8 - 14 | 5,400 | 55 | 240 |
| 3 | Oct 15 - 21 | 4,800 | 55 | 602 |
| 4 | Oct 22 - 28 | 4,800 | 54 | 969 |
| 5 | Oct 29 - Nov 4 | 4,800 | 56 | 1,492 |
| 6 | Nov 5 - 11 | 4,800 | 56 | 1,619 |
| 7 | Nov 12 - 18 | 4,800 | 57 | 1,523 |
| 8 | Nov 19 - 25 | 4,800 | 56 | 993 |
| 9 | Nov 26 - Dec 2 | 4,800 | 55 | 753 |
| 10 | Dec 3 - 9 | 4,800 | 56 | 500 |
| 11 | Dec 10 - 16 | 4,800 | 54 | 7[4/, 5/] |
| 12 | Dec 17 - 23 | 4,800 | 53 | 5/ |
| | | | Total | 8,753 |

1/ Measured discharge at Keswick Dam, US Bureau of Reclamation.
2/ Weekly average of measurements recorded at Balls Ferry for days sampled.
3/ Includes both adults and grilse
4/ These were fresh carcasses measured and examined for ripeness but not included in the tag-and-recapture study.
5/ Only tag recaptures were recorded during weeks 11 and 12.

## Spatial Distribution

The greatest portion (40%) of carcasses was observed in Reach 1 (Table 3 and Figure 4). Twenty-one percent were observed in Reach 2, 23% in Reach 3, and 16% in Reach 4.

Table 3. Summary of carcass distribution (adults and grilse) during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

| Week | Reach 1 | | Reach 2 | | Reach 3 | | Reach 4 | |
|---|---|---|---|---|---|---|---|---|
| | M[1/] | C[2/] | M | C | M | C | M | C |
| 1 | 25 | 0 | 24 | 0 | 6 | 0 | 0 | 0 |
| 2 | 100 | 2 | 46 | 0 | 60 | 5 | 26 | 1 |
| 3 | 209 | 29 | 120 | 11 | 115 | 10 | 101 | 7 |
| 4 | 311 | 36 | 187 | 12 | 216 | 20 | 165 | 22 |
| 5 | 457 | 52 | 282 | 46 | 320 | 49 | 249 | 37 |
| 6 | 556 | 49 | 247 | 37 | 349 | 50 | 271 | 60 |
| 7 | 445 | 76 | 265 | 85 | 286 | 76 | 210 | 80 |
| 8 | 418 | 116 | 168 | 60 | 188 | 43 | 3/ | 3/ |
| 9 | 220 | 113 | 69 | 62 | 86 | 49 | 99 | 55 |
| 10 | 205 | 78 | 69 | 36 | 70 | 42 | 3/ | 3/ |
| 11 | 4/ | 7[4/,5/] | 4/ | 4/ | 4/ | 4/ | 4/ | 4/ |
| 12 | 4/ | 4/ | 4/ | 4/ | 4/ | 4/ | 4/ | 4/ |
| Total | 2,946 | 551 | 1,477 | 349 | 1,696 | 344 | 1,121 | 262 |

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.
3/ No surveys were conducted.
4/ Only tag recaptures were recorded during weeks 11 and 12.
5/ Not included in the tag-and-recapture study.

## Size Distribution

We measured 481 fresh carcasses (Table 4). The sample mean size was 81.1 cm FL. Size ranged from 47 to 111 cm FL. Male salmon averaged 84.0 cm FL (range: 47 - 111 cm FL). Female salmon averaged 79.9 cm FL (range: 54 - 104 cm FL).

Length frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adult (>2-year-old salmon) for both sexes (Figures 5 and 6). Male (n=36) and female grilse (n=7) were defined as salmon ≤ 64 cm FL (Table 5). Male grilse averaged 57.9 cm FL (range: 47 - 64 cm FL, SD=4.6); male adults (n=147) averaged 87.3 cm FL (range: 65 - 111 cm FL, SD=9.1). Female grilse averaged 59.0 cm FL (range: 54 - 64 cm FL, SD=3.5); female adults (n=291) averaged 79.4 FL (range: 65 - 104 cm FL, SD=5.9).

The mean weekly size for females ranged from 77.7 to 87.4 cm FL (Table 4 and Figure 7). Mean weekly size for males ranged from 77.9 to 93.0 cm FL (Figure 8).

Grilse comprised 9% (43) of the 481 measured carcasses (Table 6). The greatest number of grilse (15) was observed in the forth week (October 22-28) (Figure 9). Most grilse were observed during the early weeks with very few seen after week 8.

## Sex Composition

Males comprised 38% (183) of the fresh carcasses examined; 147 (80%) were adults and 36 (20%) were grilse (Table 7). Females comprised 62% (298) of the fresh carcasses examined, 291 (98%) were adults, and 7 (2%) were grilse. Male grilse comprised 84% (36) of the grilse observed and female grilse comprised 16% (7).

The ratio of female to male adult spawners was nearly 2:1 (291:147) (Table 7 and Figure 10). Most of the adult population consisted of females during the period sex composition was observed (weeks 4 though 11), while the grilse population was mostly males (Figure 11).

## Spawning Success

We examined 231 females for egg retention (Table 8). Ninety four percent (217) had completely spawned, 3% (7) had not spawned, and 3% (7) had only partially spawned. Completely spawned females comprised more than 90% of the total females observed during weeks 4 through 10.

Table 4. Size and sex for fall-run chinook salmon carcasses measured during the mainstem Sacramento River chinook salmon spawner escapement survey, October - December 1995.

| Week[1/] | All salmon | | | Male salmon | | | Female salmon | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number measured | Length (FL in cm) | | Number measured | Length (FL in cm) | | Number measured | Length (FL in cm) | |
| | | Mean | Range | | Mean | Range | | Mean | Range |
| 4 | 112 | 78.9 | 47-109 | 45 | 77.9 | 47-109 | 67 | 79.6 | 56-104 |
| 5 | 66 | 80.5 | 60-103 | 12 | 90.2 | 84-103 | 54 | 78.3 | 60-96 |
| 6 | 100 | 80.3 | 55-108 | 44 | 81.9 | 55-85 | 56 | 79.0 | 57-90 |
| 7 | 82 | 79.2 | 54-98 | 30 | 81.8 | 55-102 | 52 | 77.7 | 54-88 |
| 8 | 47 | 79.0 | 49-99 | 23 | 79.9 | 49-99 | 24 | 78.1 | 68-85 |
| 9 | 36 | 80.8 | 55-99 | 14 | 82.8 | 55-99 | 22 | 79.6 | 71-91 |
| 10 | 31 | 81.3 | 50-98 | 13 | 84.4 | 50-98 | 18 | 79.1 | 65-88 |
| 11 | 7 | 89.0 | 75-111 | 2 | 93.0 | 75-111 | 5 | 87.4 | 83-90 |
| Total(mean) | 481 | 81.1 | 47-111 | 183 | 84.0 | 47-111 | 298 | 79.9 | 54-104 |

1/ Fork length data were not obtained for weeks 1 - 3.

Table 5. Summary of adult and grilse size and numbers by sex for carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

| | Female | | Male | |
|---|---|---|---|---|
| | Grilse | Adult | Grilse | Adult |
| Number | 7 | 291 | 36 | 147 |
| Mean FL (cm) | 59.0 | 79.4 | 57.9 | 87.3 |
| Range FL (cm) | 54-64 | 65-104 | 47-64 | 65-111 |
| Standard deviation | 3.5 | 5.9 | 4.6 | 9.1 |

Table 6. Age composition (grilse and adult) of carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

| Week | Adults | | Grilse | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| 4 | 97 | 87 | 15 | 13 |
| 5 | 63 | 95 | 3 | 5 |
| 6 | 88 | 88 | 12 | 12 |
| 7 | 76 | 93 | 6 | 7 |
| 8 | 42 | 89 | 5 | 11 |
| 9 | 35 | 97 | 1 | 3 |
| 10 | 30 | 97 | 1 | 3 |
| 11 | 7 | 100 | 0 | 0 |
| Total(mean) | 438 | (91) | 43 | (9) |

Table 7. Sex composition of fall-run chinook salmon grilse and adult carcasses measured during the mainstem Sacramento River chinook salmon spawner escapement survey, October - December 1995.

| Week[1/] | Grilse[2/] | | | | Adult | | | |
|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | |
| | Number | % | Number | % | Number | % | Number | % |
| 4 | 13 | 11 | 2 | 2 | 32 | 29 | 65 | 58 |
| 5 | 0 | 0 | 3 | 5 | 12 | 18 | 51 | 77 |
| 6 | 11 | 11 | 1 | 1 | 33 | 33 | 55 | 55 |
| 7 | 5 | 6 | 1 | 2 | 25 | 30 | 51 | 62 |
| 8 | 5 | 11 | 0 | 0 | 18 | 38 | 24 | 51 |
| 9 | 1 | 3 | 0 | 0 | 13 | 36 | 22 | 61 |
| 10 | 1 | 3 | 0 | 0 | 12 | 39 | 18 | 58 |
| 11 | 0 | 0 | 0 | 0 | 2 | 29 | 5 | 71 |
| Total(mean) | 36 | (7) | 7 | (1) | 147 | (31) | 291 | (61) |

1/ No lengths were takes during weeks 1 - 3.
2/ Grilse are defined as $\leq$ 64 cm FL .

Table 8. Spawning completion (egg retention) summary for female carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

| Week | # females checked for egg retention | Spawned Number (%) | Partially spawned Number (%) | Unspawned Number (%) |
|---|---|---|---|---|
| 5 | 54 | 49 (91) | 3 (6) | 2 (3) |
| 6 | 56 | 55 (98) | 0 (0) | 1 (2) |
| 7 | 52 | 49 (94) | 2 (4) | 1 (2) |
| 8 | 24 | 22 (92) | 1 (4) | 1 (4) |
| 9 | 22 | 21 (95) | 0 (0) | 1 (5) |
| 10 | 18 | 17 (94) | 1 (6) | 0 (0) |
| 11 | 5 | 4 (80) | 0 (0) | 1 (20) |
| Total(mean) | 231 | 217 (94) | 7 (3) | 7 (3) |

### Population Estimates

A total of 6,978 adult carcasses was tagged from Week 1 through Week 10. Thirty-three percent (2,287) were subsequently recaptured. The same carcass tag-and-recapture data (fresh and decayed carcasses) were used in the Schaefer and Jolly-Seber models to calculate an adult escapement estimate in the mainstem Sacramento River between ACID Dam and Cottonwood Creek (Table 9).

An estimate of 24,159 adult spawners was calculated using the Schaefer model (Table 10). Adults made up 91% of the total escapement based on carcasses measured (Table 6). A total escapement estimate of 26,546 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.91. An adult escapement estimate of 17,237 was calculated using the Jolly-Seber model. This estimate also was expanded by dividing by 0.91 resulting in a total escapement estimate of 18,942 spawners.

The population estimates for salmon spawning in the mainstem Sacramento River from ACID Dam to Cottonwood Creek are as follows:

| | Schaefer model | Jolly-Seber model |
|---|---|---|
| Total estimate | 26,548 | 18,942 |
| Adult estimate | 24,159 | 17,237 |
| Grilse estimate | 2,389 | 1,705 |

The 1995 escapement of 26,548 is considerable less than the 1956-1994 average of 69,823 for the section of stream from Keswick Dam to RBDD (Table 11 and Figure 12). Based upon aerial redd surveys, most mainstem salmon spawning above RBDD occurs in the section between ACID Dam and Cottonwood Creek (Fisher pers. comm.)

## DISCUSSION

Several of the procedures used during the 1995 fall-run survey should be changed to increase accuracy of the population estimates. The combining of the fresh and decayed carcass recoveries as was done in 1995 tends to inflate the population estimate calculated from the Schaefer model (Law 1992).

The stream reach from ACID Dam upstream to Keswick Dam was not surveyed in 1995. Normally less than 8% of the fall-run salmon that spawn in the mainstem above RBDD, do so in this reach (based on distribution from aerial redd counts). Up to 20% may have spawned there in 1985. Many of the carcasses of fish that spawn above ACID Dam likely wash downstream of the dam and would have been observed during our survey.

Based on Law's analysis (Law 1992), the Schaefer model will over estimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those observed on the mainstem Sacramento River during 1995. Similarly, based on Law's (1992) analysis, the Jolly-Seber model will slightly under estimate the mainstem Sacramento River escapement.

We recommend that the following changes be included in future survey efforts to improve population estimates:

1. Categorize all tagged carcasses as fresh or decayed. When the tagged carcasses are later recovered, note how they were originally categorized.

2. Note all carcasses (tagged and untagged) observed during last 2 weeks of the survey.

3. Survey reach of stream from Keswick Dam downstream to ACID Dam.

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Table 9. Summary of tagging and recapture of adult carcasses by week, during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

| Week of tagging | Number tagged | Number recaptured | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Week of recapture | | | | | | | | | | | Total recaptured |
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| 1 | 47 | 9 | 0 | 4 | 2 | | | | | | | | 15 |
| 2 | 219 | | 84 | 13 | 10 | 1 | | | | | | | 108 |
| 3 | 524 | | | 145 | 46 | 10 | 3 | | | | | | 204 |
| 4 | 779 | | | | 231 | 77 | 16 | | | | | | 324 |
| 5 | 1,284 | | | | | 367 | 80 | 12 | | | | | 459 |
| 6 | 1,382 | | | | | | 374 | 79 | 14 | 1 | | | 468 |
| 7 | 1,180 | | | | | | | 253 | 70 | 10 | | | 333 |
| 8 | 763 | | | | | | | | 184 | 43 | 2 | 1 | 230` |
| 9 | 464 | | | | | | | | | 94 | 8 | 2 | 104 |
| 10 | 336 | | | | | | | | | | 34 | 8 | 42 |
| Total | 6,978 | 9 | 84 | 162 | 289 | 455 | 473 | 344 | 268 | 148 | 44 | 11 | 2,287 |

Table 10. Adult population estimate matrix using the Schaefer Method during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October 1995 - December 1995.

| Week of recovery | Weekly adult population estimates 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | 739 | | | | | | | | | | 739 |
| 3 | 0 | 1,348 | | | | | | | | | 1,348 |
| 4 | 80 | 168 | 2,370 | | | | | | | | 2,618 |
| 5 | 38 | 123 | 718 | 3,377 | | | | | | | 4,256 |
| 6 | | 9 | 115 | 827 | 4,587 | | | | | | 5,538 |
| 7 | | | 32 | 160 | 932 | 4,600 | | | | | 5,724 |
| 8 | | | | | 129 | 899 | 3,456 | | | | 4,484 |
| 9 | | | | | | 156 | 936 | 2,303 | | | 3,394 |
| 10 | | | | | | 13 | 153 | 617 | 1,814 | | 2,596 |
| 11 | | | | | | | | 7 | 36 | 272 | 314 |
| 12 | | | | | | | | 3 | 9 | 64 | 76 |
| Subtotal | 857 | 1,649 | 3,236 | 4,364 | 5,649 | 5,668 | 4,545 | 2,929 | 1,858 | 336 | 31,090 |
| Tagged | | -219 | -524 | -779 | -1,284 | -1,382 | -1,180 | -763 | -464 | -336 | -6,931 |
| | | | | | | Population estimate | | | | | 24,159 |

Table 11. Fall-run chinook salmon escapement estimates (adults and grilse), mainstem Sacramento River from Keswick Dam to Red Bluff Diversion Dam, 1956 - 1994. (Data provided by Frank Fisher, Department of Fish and Game, Red Bluff)

| Year | Total | Year | Total |
|---|---|---|---|
| 1956 | 84,716 | 1976 | 43,612 |
| 1957 | 47,300 | 1977 | 15,784 |
| 1958 | 99,300 | 1978 | 32,235 |
| 1959 | 249,600 | 1979 | 47,758 |
| 1960 | 210,000 | 1980 | 21,961 |
| 1961 | 134,700 | 1981 | 26,261 |
| 1962 | 115,500 | 1982 | 17,731 |
| 1963 | 135,200 | 1983 | 26,226 |
| 1964 | 140,500 | 1984 | 36,898 |
| 1965 | 98,900 | 1985 | 51,647 |
| 1966 | 107,900 | 1986 | 67,958 |
| 1967 | 78,100 | 1987 | 76,039 |
| 1968 | 95,600 | 1988 | 65,204 |
| 1969 | 114,600 | 1989 | 48,512 |
| 1970 | 65,950 | 1990 | 32,225 |
| 1971 | 52,247 | 1991 | 19,272 |
| 1972 | 33,559 | 1992 | 26,912 |
| 1973 | 40,424 | 1993 | 33,923 |
| 1974 | 45,590 | 1994 | 31,017 |
| 1975 | 52,248 | | |

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# FIGURES

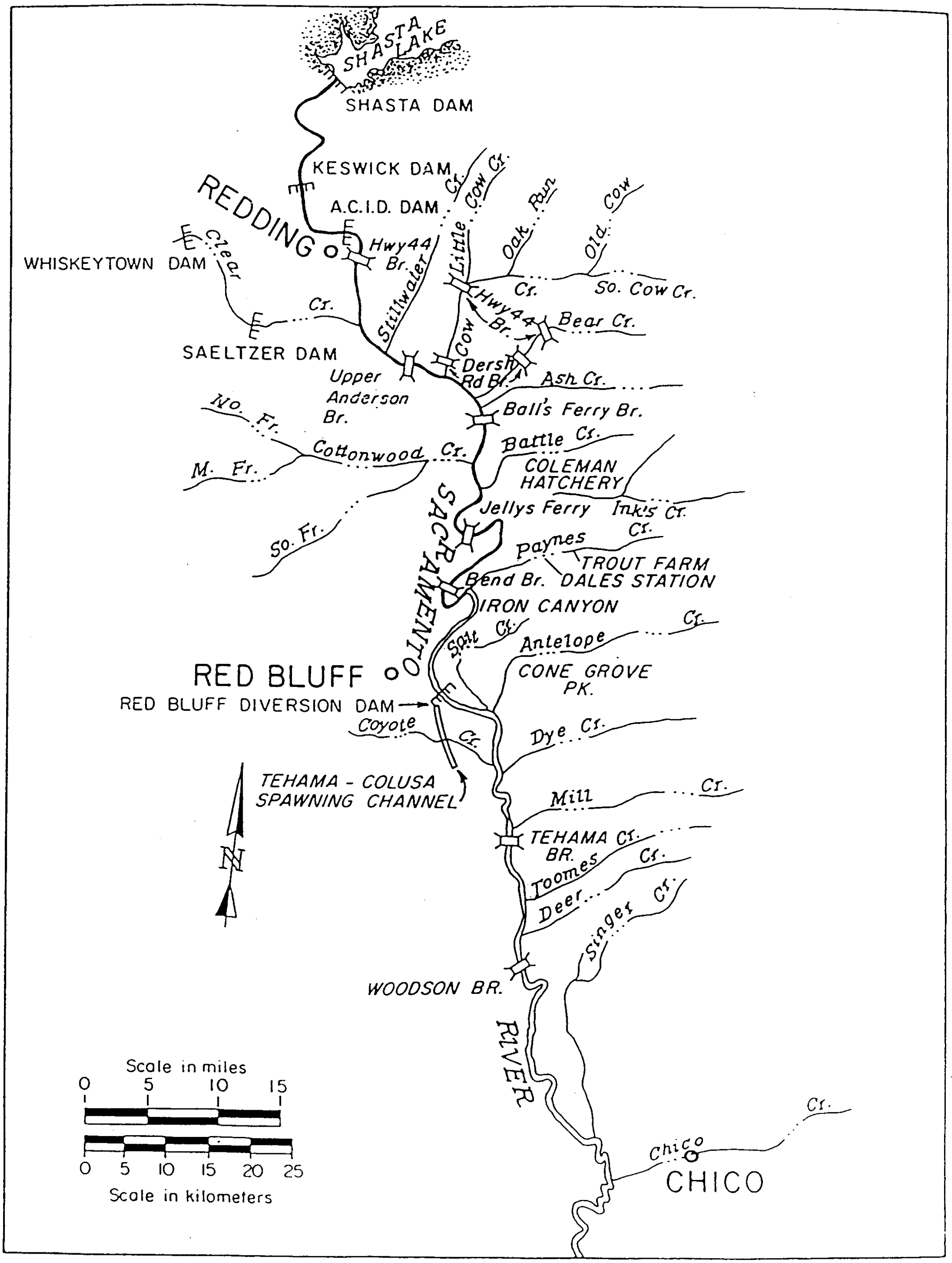


Figure 1. Upper Sacramento River.

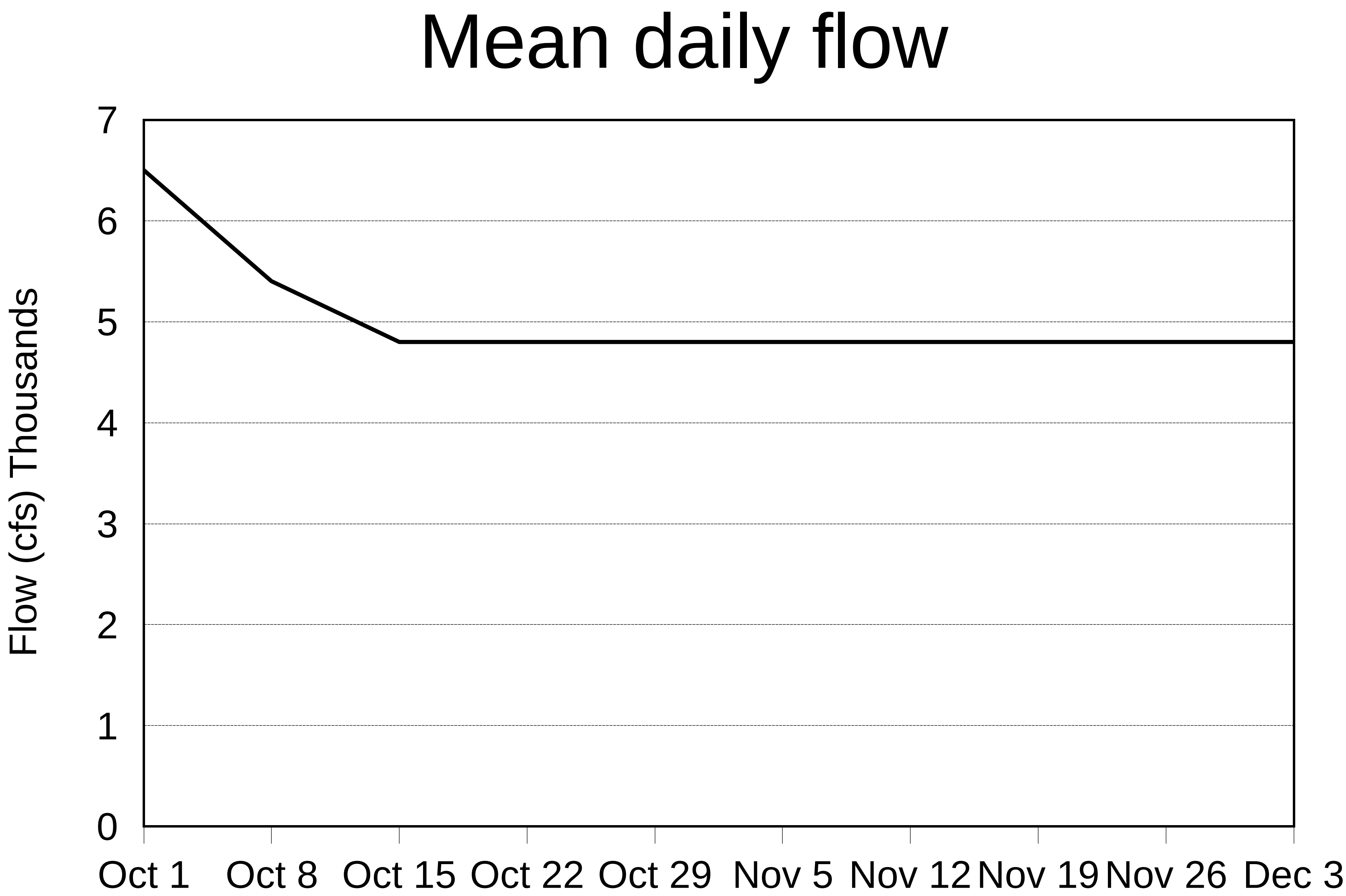


Figure 2. Mean daily flow measured at Keswick Dam during the 1995 upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

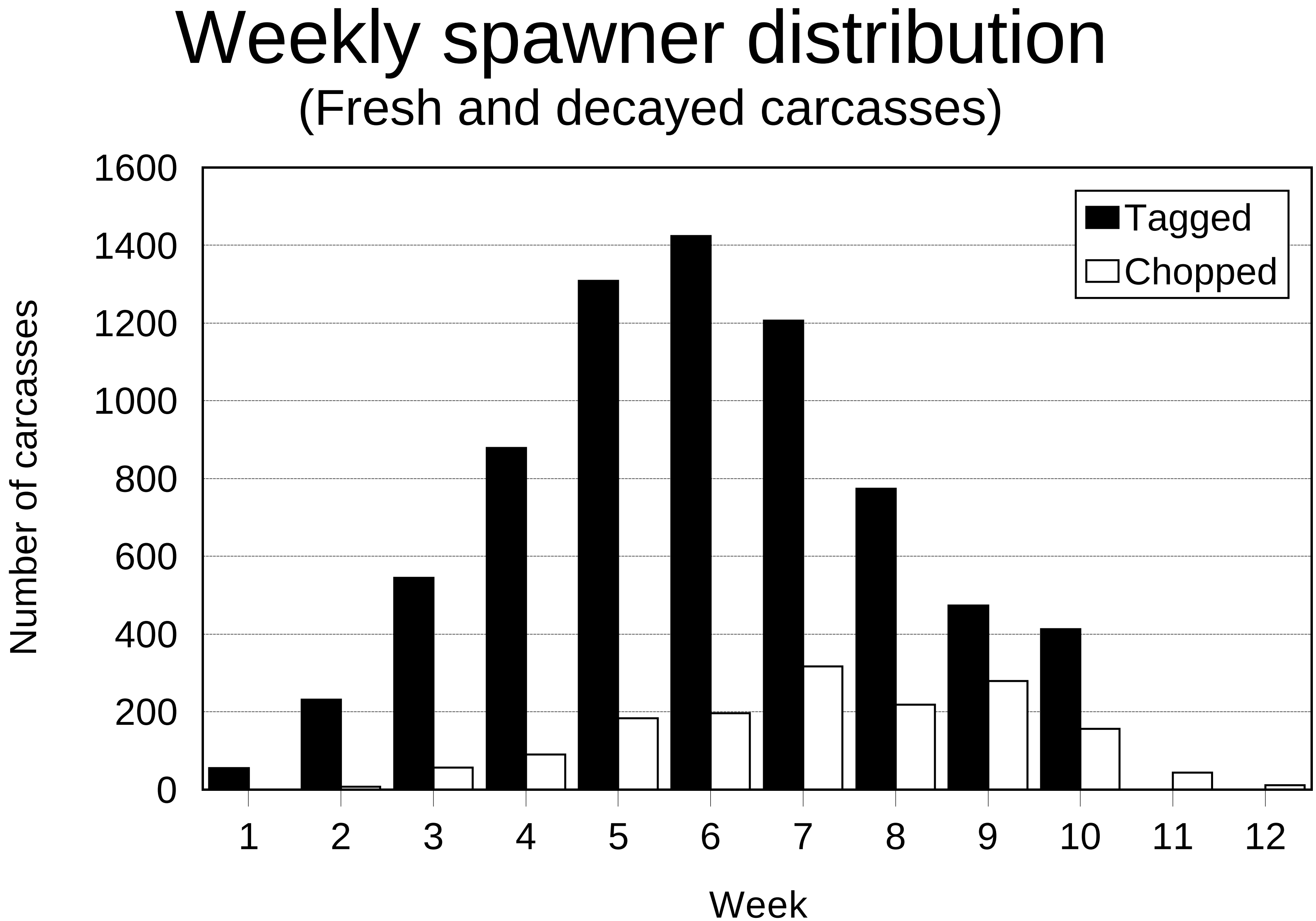


Figure 3. Weekly carcass distribution observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

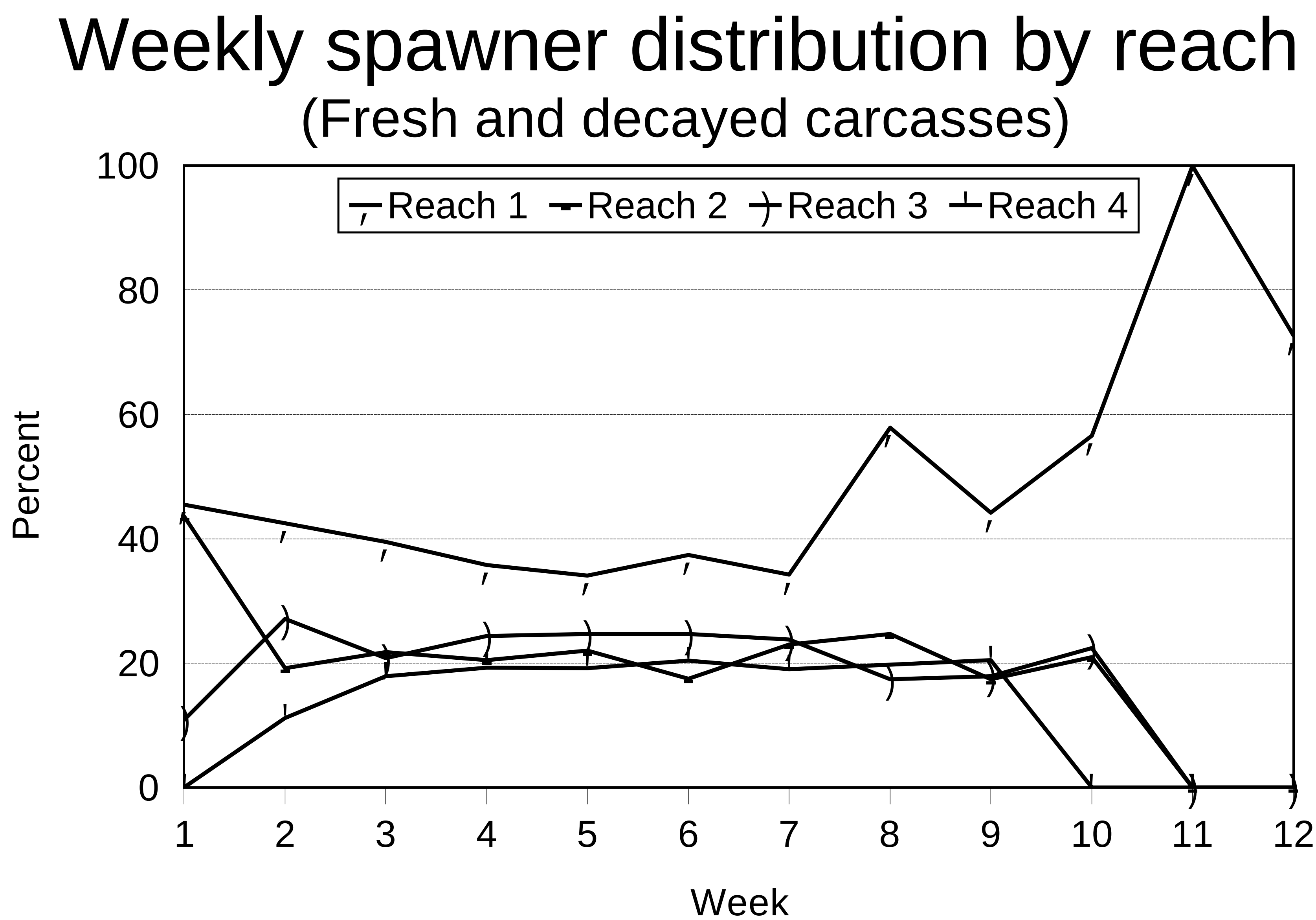


Figure 4. Weekly carcass distribution (percent by reach) observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995 (No observations made during weeks 8 and 10 in Reach 4).

# Female chinook salmon length frequency

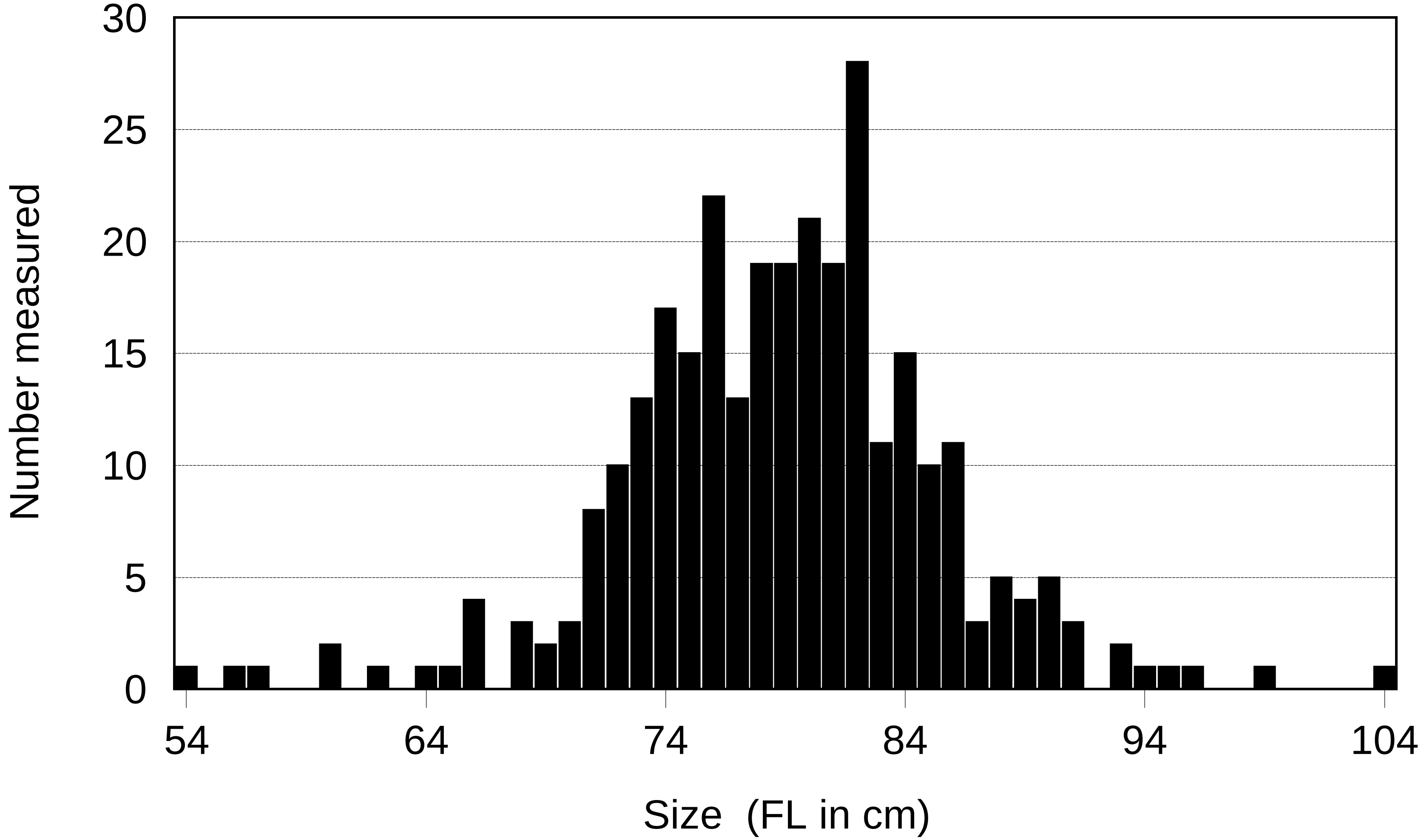


Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, October - December 1995.

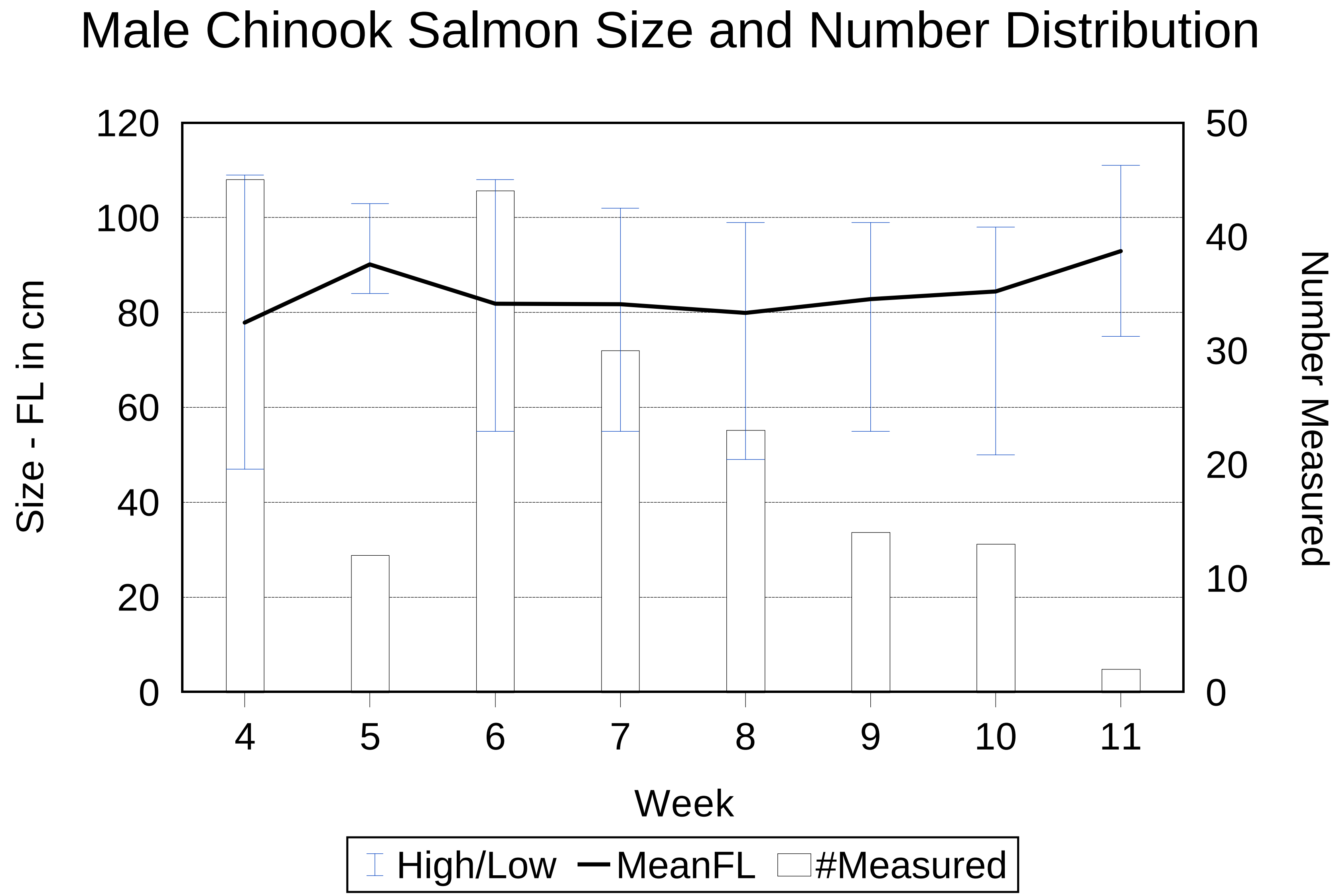


Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the 1995 upper Sacramento River spawner escapement survey, October - December 1995

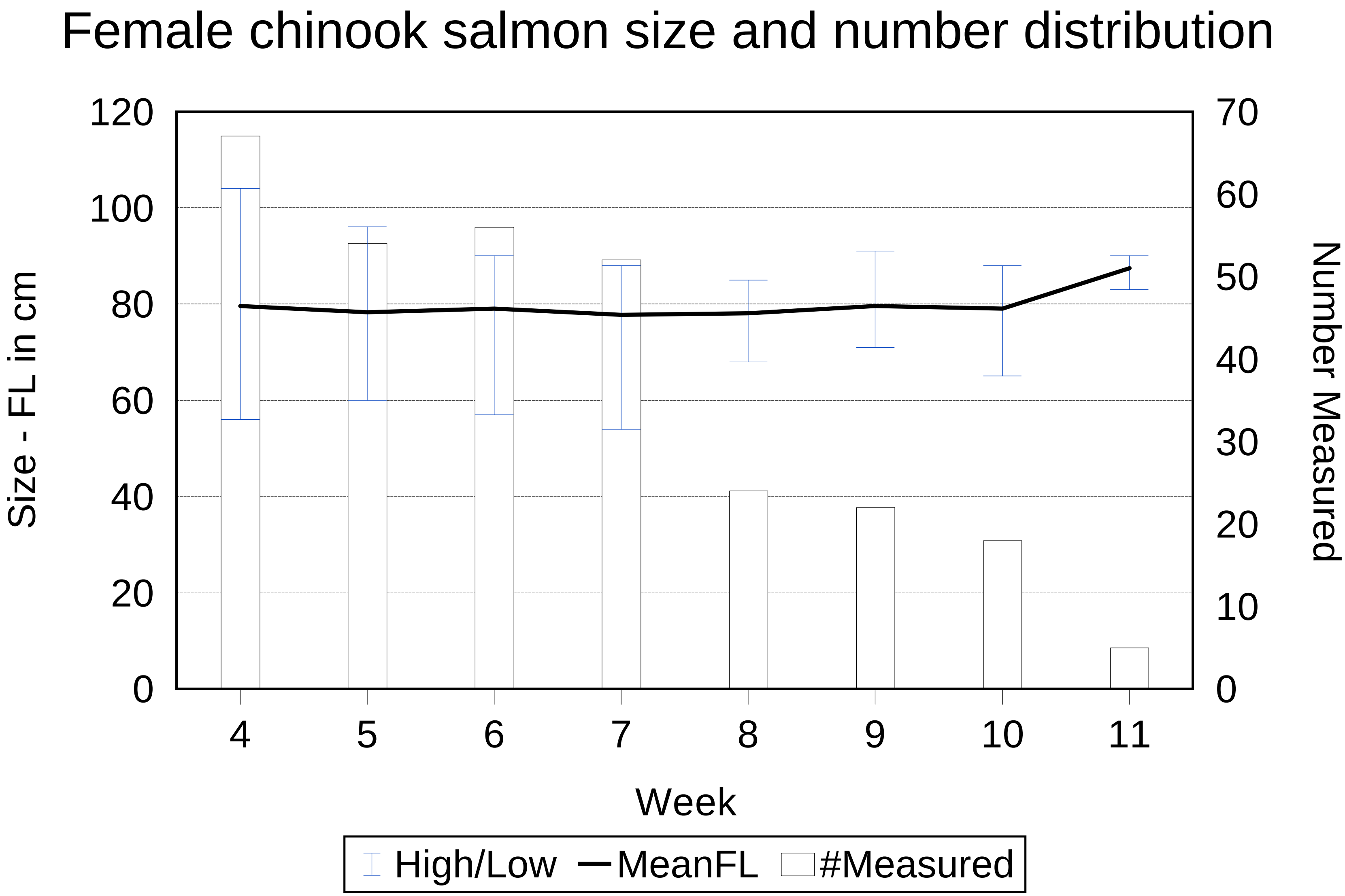


Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the 1995 upper Sacramento River spawner escapement survey, October - December 1995

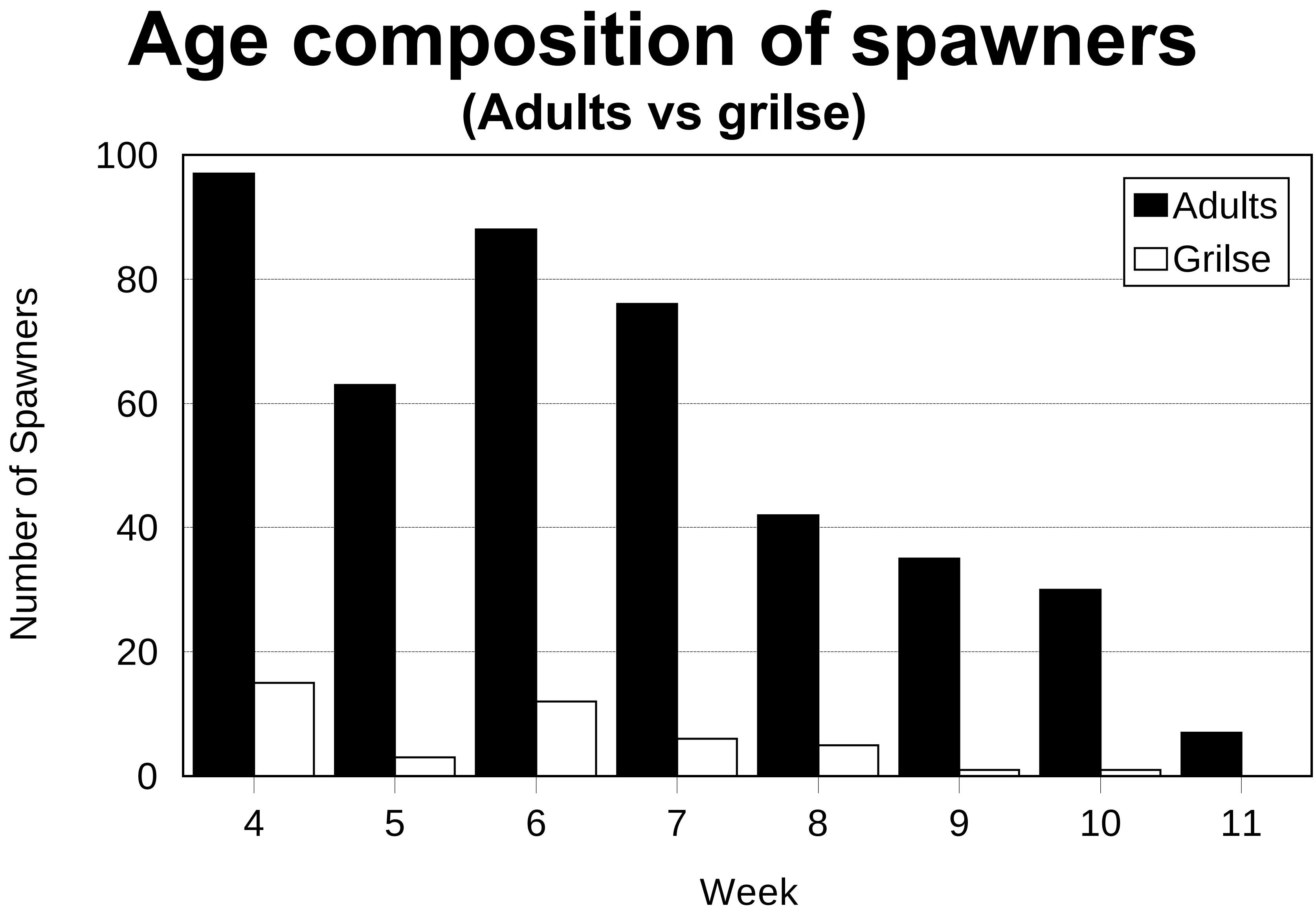


Figure 9. Age composition of fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

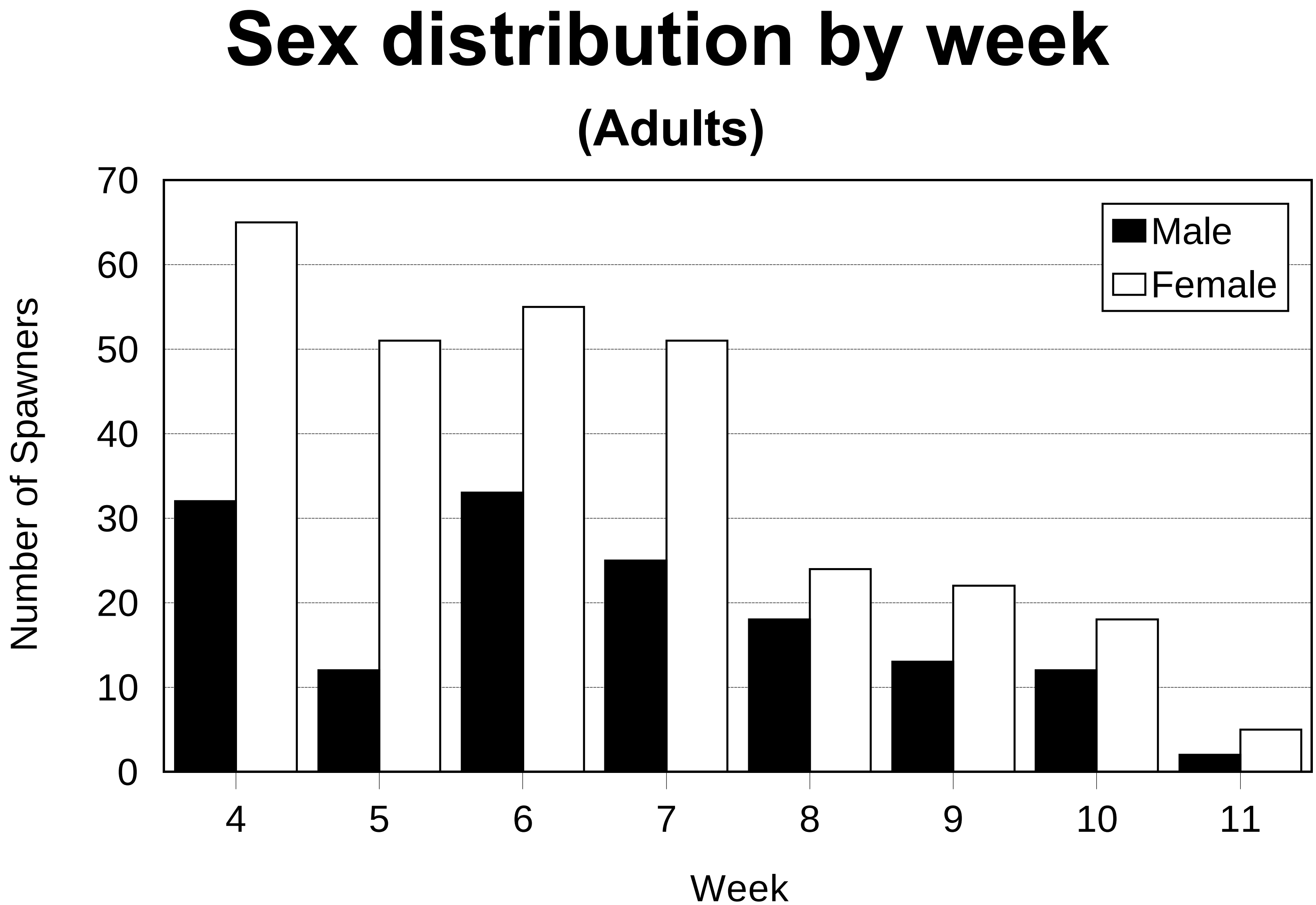


Figure 10. Weekly distribution of the sex of adult-sized fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

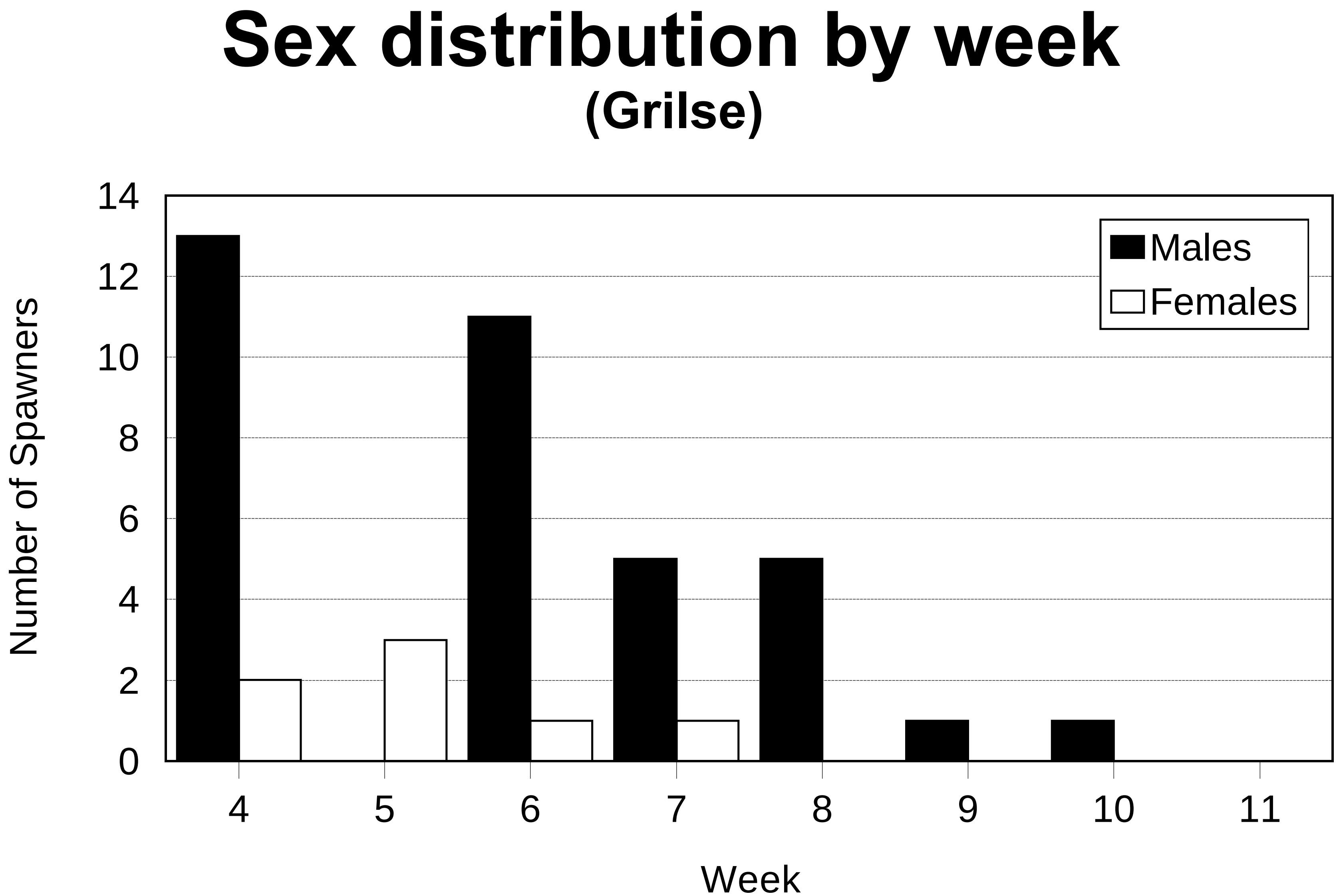


Figure 11. Weekly distribution of the sex of grilse-sized fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

# Escapement estimates

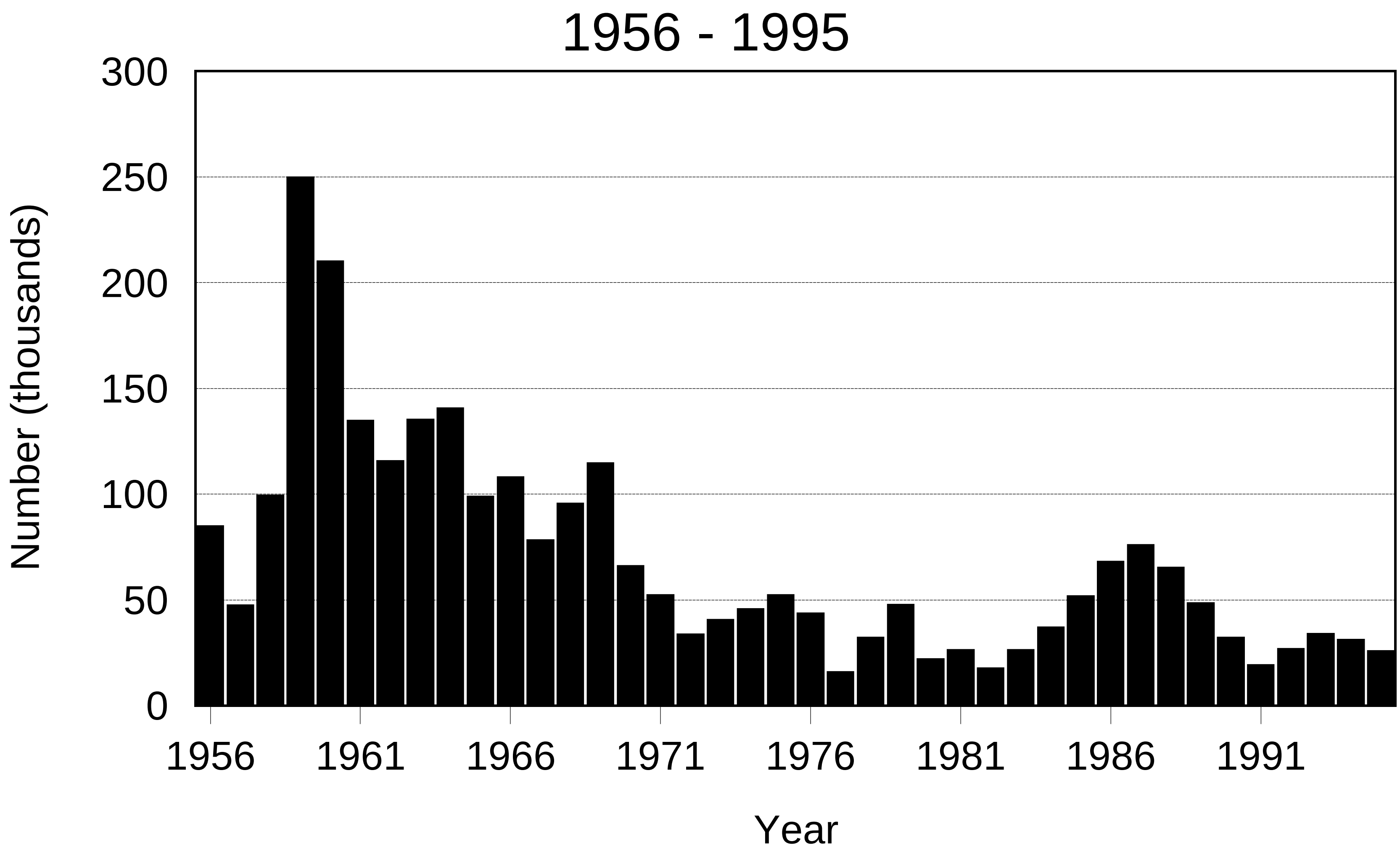


Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1994).

# APPENDIX D

## Upper Sacramento River Late Fall-run Chinook Salmon
## Spawner Escapement Survey
## Winter 1996

# SUMMARY REPORT: 1996 Upper Sacramento River Late-fall-run Chinook Salmon Spawner Escapement Survey

Late-fall-run chinook salmon is one of the four chinook salmon races that spawn in upper Sacramento River. Relatively little is known about temporal and spatial distribution and the relative abundance of late-fall-run chinook salmon spawner populations in the Sacramento River. Late-fall salmon migrate when agriculture diversions (e.g., ACID and RBDD) have been seasonally discontinued and associated fishway counts that provide similar information for the other races of chinook in the upper river, are absent. Furthermore, these fish spawn in the winter and early spring when flows are typically high and conditions for studying their spawning activity are poor. Late-fall usually begin to arrive in the upper river, near Red Bluff, beginning in November. Spawning usually occurs from January through early April.

The primary objective of 1996 spawner survey was to evaluate the feasibility of using carcass surveys to estimate late-fall-run escapement. The success of the fall-run chinook carcass survey (Snider, Hanson and Reavis 1996) and the possibility of low flows and good sampling conditions prompted evaluation of this method in spite of the high possibility of failure due to the typically, incompatible flow conditions. Eventually, the information gained from this evaluation would be used to estimate the 1996 late-fall salmon spawner populations and identify temporal and spatial distributions of spawning relative to flow and other habitat conditions, and to pursue reliable methods for evaluating late-fall salmon spawning activity for future use. Such data would be used to identify relationships between late-fall salmon spawning, including spawning habitat availability, and various, manageable habitat attributes.

## General Approach

The survey area was divided into the following four reaches: 1- RM 295 to RM 298, 2 - RM 292 to RM 295, 3 - RM 283 to RM 292, and 4 - RM 276 to RM 283. This study was initiated on January 16 and ended on March 12, 1996 due to high water that had plagued survey efforts for several weeks (Table 1). Weekly flow averages ranged from 4,800 to 50,800 cfs during the survey. Weekly average water temperatures ranged from 47$^o$ to 50$^o$ F.

The methods used to conduct the tag-recovery study and estimate late-fall-run escapement was similar to those used to estimate the 1995 fall-run escapement (Snider, Hanson, and Reavis 1996). Carcasses with the head intact were tagged in the jaw with a colored plastic ribbon and released into running water near the location where they were first observed (Table 2). The tagged carcasses were then available for recovery in subsequent weeks.

**Table 1.** General survey information for the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, January to March 1996.

| Week | Dates | Flows (cfs) | Water temperature ($^{0}$F) |
|---|---|---|---|
| 1 | Jan 16 - 19 | 4,800 | 47 |
| 2 | Jan 22 - 24 | 4,800 | 47 |
| 3 | Jan 29 - Feb 1 | 12,700 | 49 |
| 4 | Feb 5 - 7 | 9,000 | 49 |
| 5 | Feb 13 - 15 | 33,900 | 49 |
| 6 | Feb 20 - 21 | 42,300 | 49 |
| 7 | Feb 26 - 28 | 50,800 | 49 |
| 8 | Mar 4 - 6 | 30,100 | 50 |
| 9 | Mar 11 - 12 | 19,400 | 50 |

**Table 2.** Tag-and-recovery data for the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, January to March 1996.

| Week | Number tagged | Tag color | Number chopped | Number recovered | Total fish recovered |
|---|---|---|---|---|---|
| 1 | 12 | Blue | 1 | 0 | 13 |
| 2 | 122 | Green | 20 | 4 - Blue | 146 |
| 3 | 59 | Pink/black | 15 | 12 - Green | 86 |
| 4 | 46 | Red | 18 | 15 - Pnk/blk<br>11 - Green<br>1 - Blue | 91 |
| 5 | 0 | Blue | 0 | 0 | 0 |
| 6 | 0 | Yellow | 0 | 0 | 0 |
| 7 | 0 | White | 0 | 0 | 0 |
| 8 | 0 | Orange | 0 | 0 | 0 |
| 9 | 0 | Pink | 0 | 0 | 0 |

## Results

No escapement estimate was made from the tag-and-recovery data obtained during the 1996 late-fall-run escapement survey.  Carcass recovery was affected by high flows starting in Week 3.  No carcasses were observed after the fourth week (February 5 - 7). Since late-fall run spawn from December through April, only a fraction of the 1996 run was surveyed.  The fraction of the total run that spawned before Week 5 is unknown.

The spatial distribution of spawners is as follows:

| Reach | Number (chopped and tagged) | Percent |
|---|---|---|
| 1 and 2 | 275 | 94 |
| 3 | 18 | 6 |
| 4 | 0 | 0 |

The numbers of carcasses tagged or chopped by week are as follows: Week 1 - 13, Week 2 - 142, Week 3 - 74, Week 4 - 64.  No carcasses were observed after Week 5. Increased flows starting in Week 5 affected carcass recovery rates.

Seven carcasses were measured and identified as to gender.  Three males were measured (96, 110, and 110 cm FL), and four females were measured (94, 92, 85, and 87 cm FL).  These salmon were  measured on 5 February 1996.

## General Conclusions

The high flow conditions that occurred during the 1996 survey are typical of what will occur during normal and wet years. Under such conditions, there will not be sufficient data collected to base an escapement estimate.

Although high flows may prevent sufficient data to estimate spawning escapement, information could still be collected on pre-spawning mortality, age and sex composition, and spatial and temporal distribution.  Late-fall-run surveys should be evaluated at a lower level of effort.  Escapement surveys should be confined to river miles 283 to 298; no carcasses were observed below this section  in 1996. This section of the upper Sacramento River could normally be surveyed in 2 days with 4 people and 2 boats.

# APPENDIX E

**Upper Sacramento River Winter-run Chinook Salmon**
**Spawner Escapement Survey**
**Spring 1996**

# APPENDIX F

## Lower American River Fall-run Chinook Salmon Spawner Escapement Survey Fall 1995

DEPARTMENT OF FISH AND GAME
Environmental Services Division
Stream Flow and Habitat Evaluation Program

# Lower American River Chinook Salmon Escapement Survey October 1995 - January 1996[1/,2/]

Prepared by

Bill Snider
and
Bob Reavis

July 1996

1/ This work was supported by funding provided by U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report No. 96-4

# INTRODUCTION

An intensive fall-run chinook salmon escapement survey was conducted on the lower American River during the fall-winter of 1995 to estimate spawner abundance and distribution. This was the forth consecutive year that the Technical Advisory Committee (TAC) established by the Alameda County Superior Court was intimately involved with the escapement survey (Snider *et al*. 1993, Snider *et al*. 1995, and Snider and Bandner 1996). The primary charge of the TAC - to improve understanding of the relationships between salmon and habitat in the lower American River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on the temporal and longitudinal spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, and Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrent with redd surveys should allow this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Since the early 1970's, tag-and-recapture data have been collected during the spawner surveys to estimate escapements to several Central Valley tributary streams, including the American River. Three models have been used by the Department of Fish and Game to estimate escapement: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the most simple but least accurate (Law 1992). It has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller tributary streams (e.g. Cosumnes, Merced, Stanislaus, and Tuolumne rivers), and was used to calculate the 1984 American River estimate. A modification of the Schaefer model has been used in “larger” Central Valley tributary streams since 1973 (Taylor 1974). This model has been used to estimate the lower American River escapement starting in 1976. Based on Law’s analysis (Law 1992), the Schaefer model will over estimate escapement when carcass “survival” (carry-over from week-to-week) and recovery rates are equivalent to those typically observed on the American River. Similarly, based on Law’s (1992) analysis, the Jolly-Seber model will slightly under estimate the lower American River escapement. The Jolly-Seber model is more accurate when model assumptions are meet and recovery rates are $\geq$ 10% (Boydstun 1992 and Law 1992). Still, there is considerable disagreement among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by this model are too low (Fisher and Meyer, pers. comm.). Law (1992) states the both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

# OBJECTIVES

- To estimate the 1995, in-river, fall-run chinook salmon spawning population for the lower American River.

- To continue to examine the Jolly-Seber and Schaefer population models and recommend future escapement estimation procedures.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements and the status of chinook salmon in the lower American River.

# METHODS

Lower American River carcass surveys annually begin once spawning activity is observed. In 1995, surveys were conducted from October 23, 1995 through January 5, 1996. The 14-mile-long stream segment from Sailor Bar (river mile 22) downstream to Watt Avenue (river mile 9) was surveyed weekly (**Figure 1**). This stream segment was further divided into three reaches (**Table 1**). Surveys were made on Monday, Tuesday, and Wednesday with Thursday surveys if needed. A subsample of "fresh" carcasses was measured and the females were examined to determine the degree of spawning (egg retention).

Since 1988, tag-recapture methods were conducted to provide estimates using both the Schaefer and Jolly-Seber models; separate records were kept for the tag and recapture of fresh and decayed carcasses. The standard Schaefer model protocol was to tag only fresh carcasses. When the Jolly-Seber model was initiated in 1988, the standard protocol was to tag both fresh and decayed carcasses. Fresh carcass data were used to calculate an estimate using the Schaefer model. The combined fresh and decayed carcass data were used to calculate an estimate using the Jolly-Seber model. Estimates derived from the Schaefer model are more directly comparable to previous year's estimates, and therefore provide a consistent indication of population trends. Law's analysis showed that the Schaefer model was most accurate when using fresh carcass data. The Jolly-Seber model was most accurate when using combined fresh and decayed carcass data.

To determine freshness, all carcasses were examined for eye clarity and gill color. A carcass was considered "fresh" if either one eye was clear or the gills were pink, otherwise it was considered "decayed". Fresh and decayed carcasses were distinctly marked: fresh carcasses were tagged in the upper jaw and decayed carcasses in the lower jaw. Tagged carcasses were recorded as adult or grilse and fresh or decayed, then returned to flowing water near the location where they were collected. Untagged carcasses were recorded in the same manner, then chopped through the backbone to remove them from future surveys.

Table 1. Location of survey reaches in the lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

| Reach | Location | River mile |
|---|---|---|
| 1 | Sailor Bar to Rossmoor | 22.0 to 18.0 |
| 2 | Rossmoor to Goethe Park Footbridge | 18.0 to 14.5 |
| 3 | Goethe Park Footbridge to Watt Avenue | 14.5 to 9.0 |

Data collected from a subsample of the fresh carcasses included fork length (FL) in centimeters, reach of stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining; as partially spent if more than 50% of the eggs remained; and unspent if they were unspawned.

# RESULTS AND DISCUSSION

A total of 1,980 fresh carcasses and 19,264 decayed carcasses (adults and grilse) was observed (**Table 2**). Water clarity ranged from 12.7 feet in late October to 2.5 feet in late December. Flow was a 2,500 cfs throughout the survey period. Temperature ranged from 64°F during the first survey week to 51°F during the last week.

## TEMPORAL DISTRIBUTION

The number of observed carcasses steadily increased from the first week, peaked in the sixth week (November 27-30), and then declined each week afterwards (**Table 3** and **Figure 2**). Few carcasses were observed during the first two weeks or the last week of the survey. Fresh carcasses were observed during every week of the survey.

## SPATIAL DISTRIBUTION

Most carcasses were observed in Reach 1 (61% of all carcasses and 75% of the fresh carcasses) (**Table 3** and **Figure 3**). At least 69% of fresh carcasses were observed in Reach 1 during all weeks except for the last week of the survey when only one fresh carcass (observed in Reach 2) was seen (**Figure 4**). Estimates of spawning distribution were affected by the following factors: i) no surveys were conducted in Reach 3 during weeks 4 and 5 which slightly inflated the estimates of the portion of the population spawning in the upper two reaches, and ii) an unknown portion of the carcasses observed in the lower reaches likely drifted downstream after spawning in an upstream reach deflating the estimate for Reach 1.

Table 2. General survey information for the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

| Week | Dates | Flow (cfs) | Secchi depth (ft)[1/] | Water temperature (°F)[1/] | Carcass count[2/] | |
|---|---|---|---|---|---|---|
| | | | | | Fresh | Decayed |
| 1 | Oct 23-25, 1995 | 2,500 | 12.7 | 64 | 16 | 60 |
| 2 | Oct 30-Nov 1, 1995 | 2,500 | 10.0 | 63 | 73 | 152 |
| 3 | Nov 6-8, 1995 | 2,500 | 9.0 | 61 | 175 | 526 |
| 4 | Nov 13-15, 1995 | 2,500 | 8.5 | 59 | 410 | 2,119 |
| 5 | Nov 20-22, 1995 | 2,500 | 9.3 | 60 | 439 | 4,344 |
| 6 | Nov 27-30, 1995 | 2,500 | 9.3 | 59 | 457 | 5,610 |
| 7 | Dec 4-7, 1995 | 2,500 | 8.4 | 59 | 270 | 3,733 |
| 8 | Dec 11-15, 1995 | 2,500 | 7.0 | 57 | 89 | 1,665 |
| 9 | Dec 18-20, 1995 | 2,500 | 2.5 | 54 | 41 | 748 |
| 10 | Dec 27-29, 1995 | 2,500 | 4.0 | 52 | 9 | 224 |
| 11 | Jan 3-5, 1996 | 2,500 | 4.7 | 51 | 1 | 83 |
| | | | | Totals | 1,980 | 19,264 |

1/ Average of measurements made from days surveys were made.
2/ Includes grilse and adults.

Table 3. Summary of fall-run chinook salmon carcass distribution during the 1995 lower American River spawner escapement survey (includes adults and grilse but not tag recoveries), October 1995 - January 1996.

| | Reach 1 | | | | Reach 2 | | | | Reach 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | | Decayed | | Fresh | | Decayed | | Fresh | | Decayed | |
| Week | M[1/] | C[2/] | M[1/] | C[2/] | M[1/] | C[2/] | M[1/] | C[2/] | M[1/] | C[2/] | M[1/] | C[2/] |
| 1 | 13 | 0 | 28 | 17 | 1 | 2 | 8 | 0 | 0 | 0 | 3 | 4 |
| 2 | 53 | 0 | 64 | 20 | 15 | 0 | 47 | 9 | 5 | 0 | 7 | 5 |
| 3 | 129 | 0 | 225 | 116 | 41 | 0 | 102 | 43 | 5 | 0 | 10 | 30 |
| 4 | 274 | 0 | 172 | 1,077 | 115 | 21 | 103 | 767 | 3/ | 3/ | 3/ | 3/ |
| 5 | 334 | 0 | 448 | 2,303 | 105 | 0 | 241 | 1,352 | 3/ | 3/ | 3/ | 3/ |
| 6 | 334 | 0 | 452 | 2,577 | 114 | 0 | 251 | 1,618 | 9 | 0 | 21 | 691 |
| 7 | 217 | 0 | 346 | 2,017 | 41 | 0 | 163 | 752 | 12 | 0 | 34 | 421 |
| 8 | 79 | 0 | 243 | 642 | 9 | 0 | 92 | 447 | 1 | 0 | 20 | 221 |
| 9 | 35 | 0 | 92 | 387 | 6 | 0 | 29 | 106 | 0 | 0 | 17 | 117 |
| 10 | 0 | 9 | 0 | 123 | 0 | 0 | 0 | 58 | 0 | 0 | 0 | 43 |
| 11 | 0 | 0 | 0 | 56 | 0 | 1 | 0 | 15 | 0 | 0 | 0 | 12 |
| Totals | 1,468 | 9 | 2,070 | 9,335 | 447 | 24 | 1,036 | 5,167 | 32[4/] | 0[4/] | 112[4/] | 1,544[4/] |

1/ Number of carcasses tagged
2/ Number of untagged carcasses chopped
3/ No data collected

## SIZE DISTRIBUTION

A total of 1,104 carcasses was measured (**Table 4**). The sample mean FL was 81.0 cm. Size ranged from 48 to 112 cm FL. Male salmon averaged 82.7 cm FL (range: 48 - 112 cm FL). Female salmon averaged 78.4 cm FL (range: 55 - 99 cm FL).

Length frequency distributions were used to define a general size criterion distinguishing grilse (2-year old salmon) and adult (>2-year old salmon) for both sexes (**Figures 5 and 6**). Male grilse (n=97) were defined as salmon ≤ 70 cm FL; female grilse (n=16) were ≤ 65 cm FL (**Table 5**). Male grilse averaged 60.9 cm FL (range: 48 - 70 cm FL, SD=5.5); male adults (n=506) averaged 86.8 cm FL (range: 71 - 112 cm FL, SD=7.0). Female grilse averaged 60.8 cm FL (range: 55 - 65 cm FL, SD=3.0) ; female adults (n=485) averaged 79.0 FL (range: 66 - 99 cm FL, SD=5.6).

Mean weekly size for females ranged from 70.1 to 79.9 cm FL (**Table 4** and **Figure 7**). The mean weekly size for males ranged from 70.0 to 102.0 cm FL, but it only ranged from 75.1 to 86.9 cm FL for the first 9 weeks when over 99% of the males carcasses were measured (**Figure 8**).

Grilse comprised 10% (113) of the 1,104 measured carcasses (**Table 6**). The greatest number of grilse (25) was observed in the third week (November 6-8) (**Figure 9**). Both male and female grilse were observed throughout most of the survey.

Table 4 Size and sex statistics for fresh fall-run chinook salmon carcasses measured during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

| | All salmon | | | Male salmon | | | Female salmon | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Length (FL in cm) | | | Length (FL in cm) | | | Length (FL in cm) | |
| Week | Number measured | Mean | Range | Number measured | Mean | Range | Number measured | Mean | Range |
| 1 | 13 | 74.1 | 50-90 | 10 | 75.1 | 50-91 | 3 | 70.1 | 62-85 |
| 2 | 80 | 78.9 | 50-95 | 52 | 79.1 | 50-95 | 28 | 77.4 | 70-88 |
| 3 | 162 | 80.0 | 48-101 | 101 | 80.6 | 48-101 | 61 | 79.0 | 62-89 |
| 4 | 130 | 80.5 | 56-109 | 76 | 82.6 | 58-109 | 54 | 77.5 | 56-99 |
| 5 | 191 | 81.0 | 53-112 | 105 | 83.3 | 53-112 | 86 | 78.3 | 55-91 |
| 6 | 248 | 81.1 | 55-108 | 124 | 84.3 | 55-108 | 124 | 77.9 | 60-96 |
| 7 | 156 | 82.8 | 48-110 | 75 | 86.9 | 48-110 | 81 | 79.8 | 66-96 |
| 8 | 74 | 80.2 | 55-102 | 37 | 82.9 | 55-102 | 37 | 77.4 | 58-89 |
| 9 | 40 | 79.5 | 55-108 | 19 | 79.1 | 56-108 | 21 | 79.9 | 55-99 |
| 10 | 9 | 74.6 | 56-87 | 3 | 70.0 | 56-87 | 6 | 76.8 | 63-86 |
| 11 | 1 | 102.0 | - | 1 | 102.0 | - | 0 | - | - |
| Totals | 1,104 | 81.0 | 48-112 | 603 | 82.7 | 48-112 | 501 | 78.4 | 55-99 |

Table 5. Summary of adult and grilse size and numbers by sex for fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

| | Female | | Male | |
|---|---|---|---|---|
| | Grilse | Adults | Grilse | Adults |
| Total measured | 16 | 485 | 97 | 506 |
| Mean FL (cm) | 60.8 | 79.0 | 60.9 | 86.8 |
| Range FL (cm) | 55-65 | 66-99 | 48-70 | 71-112 |
| Standard Deviation | 3.0 | 5.6 | 5.5 | 7.0 |

## SEX COMPOSITION

Males comprised 55% (603) of the fresh carcasses examined (**Table 7**); 506 (84%) were adults and 97 (16%) were grilse. Females comprised 45% (501) of the fresh carcasses examined; 485 (97%) were adults and 16 (3%) were grilse. Male grilse comprised 86% (97) of the grilse observed; female grilse comprised 14% (16).

The ratio of male to female adult spawners was nearly 1:1 (506:485) (**Table 7** and **Figure 10**). Males were more numerous in the early season through the fifth week (November 20-22) and females were more numerous afterwards. The final week was the exception when the only fresh carcass observed was an adult male in Reach 2. Grilse sex composition ranged from 67% male in Week 10 to 100% male in weeks 2 and 7 (**Figure 11**).

## SPAWNING SUCCESS

There were 478 females examined for egg retention (**Table 8**). Of these, 327 (68%) had completely spawned, 89 (19%) had not spawned, and 62 (13%) had partially spawned. Unspawned females were seen throughout most of the survey season. Substantial portions ($\geq$ 20%) of the females observed in weeks 1,2,3,4,6, and 9 were unspawned.

Table 6. Age composition (grilse and adult) of fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

| Week | Adults | | Grilse [1/] | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| 1 | 8 | 62 | 5 | 38 |
| 2 | 70 | 88 | 10 | 12 |
| 3 | 137 | 85 | 25 | 15 |
| 4 | 112 | 86 | 18 | 14 |
| 5 | 175 | 92 | 16 | 8 |
| 6 | 230 | 93 | 18 | 7 |
| 7 | 148 | 95 | 8 | 5 |
| 8 | 70 | 95 | 4 | 5 |
| 9 | 34 | 85 | 6 | 15 |
| 10 | 6 | 67 | 3 | 33 |
| 11 | 1 | 100 | 0 | 0 |
| Totals (average) | 991 | (90) | 113 | (10) |

1/ Grilse were defined as males $\leq$ 70 cm FL and females $\leq$ 65 cm FL based upon length frequency distribution (figures 5 and 6).

Table 7. Sex composition of fall-run chinook salmon grilse and adults carcasses measured during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

| | Adults | | | | Grilse [1/] | | | |
|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | |
| Week | Number | % | Number | % | Number | % | Number | % |
| 1 | 6 | 75 | 2 | 25 | 4 | 80 | 1 | 20 |
| 2 | 42 | 60 | 28 | 40 | 10 | 100 | 0 | 0 |
| 3 | 78 | 57 | 59 | 43 | 23 | 92 | 2 | 8 |
| 4 | 63 | 56 | 49 | 44 | 13 | 72 | 5 | 28 |
| 5 | 92 | 53 | 83 | 47 | 13 | 81 | 3 | 19 |
| 6 | 108 | 47 | 122 | 53 | 16 | 89 | 2 | 11 |
| 7 | 67 | 45 | 81 | 55 | 8 | 100 | 0 | 0 |
| 8 | 34 | 49 | 36 | 51 | 3 | 75 | 1 | 25 |
| 9 | 14 | 41 | 20 | 59 | 5 | 83 | 1 | 17 |
| 10 | 1 | 17 | 5 | 83 | 2 | 67 | 1 | 33 |
| 11 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals (mean) | 506 | (51) | 485 | (49) | 97 | (86) | 16 | (14) |

1/ Grilse were defined as males $\leq$ 70 cm FL and females $\leq$ 65 cm FL base upon length frequency distribution (figures 5 and 6).

Table 8. Spawning completion (egg retention) summary for female fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

| Week | # females measured | # females checked for egg retention | Number (%) spawned | Number (%) unspawned | Number (%) partially spawned |
|---|---|---|---|---|---|
| 1 | 3 | 2 | 0 (0) | 2 (100) | 0 (0) |
| 2 | 28 | 18 | 10 (55) | 5 (28) | 3 (17) |
| 3 | 61 | 61 | 34 (56) | 21 (34) | 6 (10) |
| 4 | 54 | 49 | 37 (76) | 10 (20) | 2 (4) |
| 5 | 86 | 84 | 60 (72) | 12 (14) | 12 (14) |
| 6 | 124 | 121 | 83 (68) | 24 (20) | 14 (12) |
| 7 | 81 | 80 | 55 (69) | 8 (10) | 17 (21) |
| 8 | 37 | 36 | 30 (83) | 0 (0) | 6 (17) |
| 9 | 21 | 21 | 13 (62) | 7 (33) | 1 (5) |
| 10 | 6 | 6 | 5 (83) | 0 (0) | 1 (7) |
| 11 | 0 | 0 | 0 | 0 | 0 |
| Totals (means) | 501 | 478 | 327 (68) | 89 (19) | 62 (13) |

## POPULATION ESTIMATES

A total of 1,794 fresh adult carcasses were tagged from Week 2 through Week 10 (**Table 9a**). There were 7 fresh adult carcasses tagged during Week 1 that were never recovered; these carcasses along with the decayed carcasses observed during weeks 1 and 2 were added to the $C_j$ of the Week 3 recovery period. A total of 569 (32%) of the fresh carcasses tagged from Week 2 through the remainder of the season were subsequently recovered. The fresh carcass data were used in the Schaefer model to estimate an adult spawner escapement of 63,086 adults (**Table 9b**). Since adults made up 90% of the escapement, a total escapement (adults and grilse) of 70,096 was calculated by dividing the adult estimate by 0.90.

A total of 3,038 decayed adult carcasses was also tagged from Week 1 through Week 10; 1,006 (33%) were subsequently recovered. The tag-recover data from the decayed and fresh carcasses were combined in the Jolly-Seber model yielding an adult escapement of 38,676 (**Table 10**). This estimate was expanded, as above, resulting in a total escapement estimate of 42,973.

The population estimates for salmon spawning in the American River below the Nimbus Racks are as follows:

| | Schaefer model | Jolly-Seber model |
|---|---|---|
| Total estimate | 70,096 | 42,973 |
| Adult estimate | 63,086 | 38,676 |
| Grilse estimate | 7,010 | 5,297 |

In addition to the 70,096 salmon that spawned in the lower American River downstream from Nimbus Hatchery, there were 6,498 fall-run salmon that entered Nimbus Hatchery.
The Schaefer adult escapement estimate was more than double the previous 28 years' (1967 - 1994) mean of 28,621 fish (**Table 11** and **Figure 12**).

# ACKNOWLEDGMENTS

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Table 9a. Summary of tagging and recapture of fresh adult fall-run chinook salmon carcasses by week during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

Schaefer model capture-recapture data matrix

| Week of Recovery$_{(j)}$ | $R_{(ij)}$ by Week of Tagging $_{(i)}$ 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Tags recovered $R_{(j)}$ | Carcasses counted $C_{(j)}$ | Ratio $C_{(j)}/R_{(j)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 13 | | | | | | | | 13 | 895 | 68.85 |
| 4 | 3 | 43 | | | | | | | 46 | 2,338 | 50.83 |
| 5 | | 5 | 110 | | | | | | 115 | 4,641 | 40.36 |
| 6 | | | 5 | 120 | | | | | 125 | 5,907 | 47.26 |
| 7 | | | 3 | 8 | 151 | | | | 162 | 3,952 | 24.40 |
| 8 | | | 1 | 1 | 7 | 56 | | | 65 | 1,702 | 26.18 |
| 9 | | | | | 1 | 1 | 27 | | 29 | 737 | 25.41 |
| 10 | | | | | 2 | 1 | 5 | 2 | 10 | 214 | 21.40 |
| 11 | | | | | | 2 | | 2 | 4 | 78 | 19.50 |
| Recovery $R_{(i)}$ | 16 | 48 | 119 | 129 | 161 | 60 | 32 | 4 | | | |
| Tagged $M_{(i)}$ | 62 | 152 | 350 | 416 | 433 | 262 | 83 | 36 | | | |
| $M_{(i)}/R_{(i)}$ | 3.88 | 3.17 | 2.94 | 3.22 | 2.69 | 4.37 | 2.59 | 9.00 | | | |

Table 9b. Lower American River adult chinook salmon population estimate using the Schaefer Model by tagging fresh carcasses only with all captured untagged carcasses removed, October 1995 - January 1996.

Population estimation (i)

| Week of recovery (j) | Week of tagging | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| 3 | 3,468 | | | | | | | | 3,468 |
| 4 | 591 | 6,921 | | | | | | | 7,512 |
| 5 | | 639 | 13,057 | | | | | | 13,696 |
| 6 | | | 695 | 18,287 | | | | | 18,982 |
| 7 | | | 215 | 629 | 9,907 | | | | 10,752 |
| 8 | | | 77 | 84 | 493 | 6,403 | | | 7,057 |
| 9 | | | | | 68 | 111 | 1,780 | | 1,959 |
| 10 | | | | | 115 | 93 | 278 | 385 | 871 |
| 11 | | | | | | 170 | | 351 | 521 |
| Subtotals | 4,059 | 7,560 | 14,044 | 19,001 | 10,583 | 6,778 | 2,057 | 736 | 64,818 |
| Tagged | | -152 | -350 | -416 | -433 | -262 | -83 | -36 | -1,732 |
| | | | | Estimated population of natural spawning adults | | | | | 63,086 |

Table 10. Summary of tagging and recapture of adult fall-run chinook salmon carcasses (fresh and decayed) by week during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

Jolly-Seber capture-recapture data matrix

| Week of recovery (j) | Week of tagging (i) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Tagged fish recovered R(j) | Total fish recovered C(j) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | 0 | 66 |
| 2 | 19 | | | | | | | | | 19 | 212 |
| 3 | 1 | 39 | | | | | | | | 40 | 663 |
| 4 | | 5 | 117 | | | | | | | 122 | 2,433 |
| 5 | | 1 | 10 | 177 | | | | | | 188 | 4,714 |
| 6 | | | 2 | 10 | 323 | | | | | 335 | 6,117 |
| 7 | | | 1 | 6 | 27 | 386 | | | | 420 | 4,210 |
| 8 | | | | 1 | 5 | 20 | 162 | | | 188 | 1,825 |
| 9 | | | | | | 9 | 12 | 152 | | 173 | 881 |
| 10 | | | | | | 5 | 7 | 21 | 42 | 75 | 279 |
| 11 | | | | | | | 2 | 2 | 11 | 15 | 89 |
| R (i) | 20 | 45 | 130 | 194 | 355 | 420 | 183 | 175 | 53 | <-Tagged fish recovered | |
| M (i) | 45 | 162 | 451 | 603 | 1,076 | 1,128 | 788 | 419 | 160 | <-Total fish tagged | |

Table 11. Fall-run chinook salmon escapement estimates, lower American River, 1967 - 1995.

| Year | Grilse | Adults | Total |
|---|---|---|---|
| 1967 1/ | 3,132 | 14,868 | 18,000 |
| 1968 1/ | 2,777 | 23,423 | 16,200 |
| 1969 1/ | 8,208 | 35,452 | 43,660 |
| 1970 1/ | 2,753 | 25,927 | 28,680 |
| 1971 1/ | 5,210 | 36,470 | 41,680 |
| 1972 1/ | 3,352 | 14,107 | 17,459 |
| 1973 1/ | 4,688 | 77,554 | 82,242 |
| 1974 2/ | 1,769 | 51,827 | 53,596 |
| 1975 1/ | 2,699 | 29,433 | 32,132 |
| 1976 2/ | 1,181 | 21,978 | 23,159 |
| 1977 2/ | 4,701 | 36,904 | 41,605 |
| 1978 2/ | 595 | 12,334 | 12,929 |
| 1979 2/ | 896 | 36,419 | 37,315 |
| 1980 2/ | 8,805 | 25,454 | 34,259 |
| 1981 2/ | 2,521 | 40,941 | 43,462 |
| 1982 1/ | 4,323 | 28,677 | 33,000 |
| 1983 1/ | 7,313 | 19,087 | 26,400 |
| 1984 3/ | 2,196 | 25,251 | 27,447 |
| 1985 2/ | 11,392 | 44,728 | 56,120 |
| 1986 2/ | 4,443 | 44,929 | 49,372 |
| 1987 2/ | 2,960 | 18,185 | 21,145 |
| 1988 4/ | 1,905 | 13,974 | 15,879 |
| 1989 2/ | 2,459 | 14,619 | 17,078 |
| 1990 2/ | 1,167 | 5,541 | 6,708 |
| 1991 2/ | 1,506 | 16,639 | 18,145 |
| 1992 2/ | 1,297 | 3,175 | 4,472 |
| 1993 2/ | 6,162 | 20,624 | 26,786 |
| 1994 2/ | 2,927 | 28,405 | 31,333 |
| 1995 2/ | 7,010 | 63,086 | 70,096 |
| Average | 3,805 | 28,621 | 32,426 |

1/ Expanded direct count
2/ Schaefer method
3/ Petersen method
4/ Jolly-Seber method

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# Figures

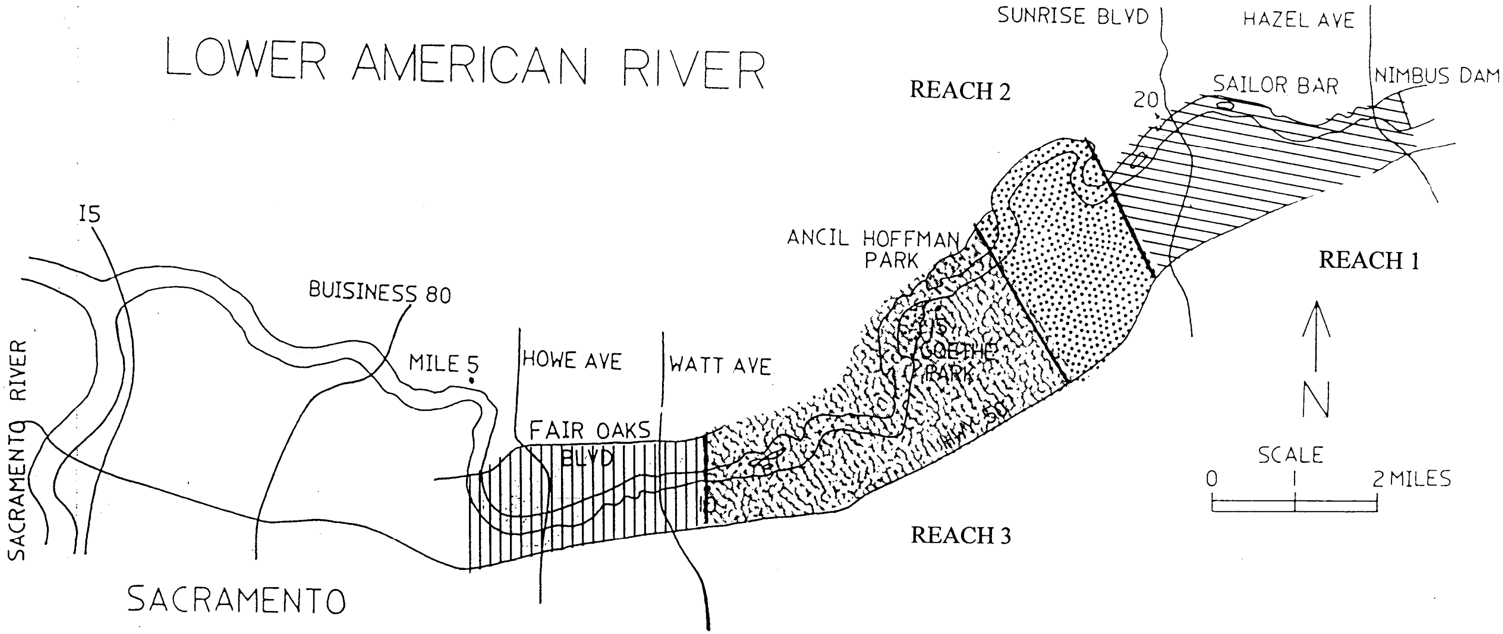


Figure 1. Location of lower American River spawner escapement survey reaches.

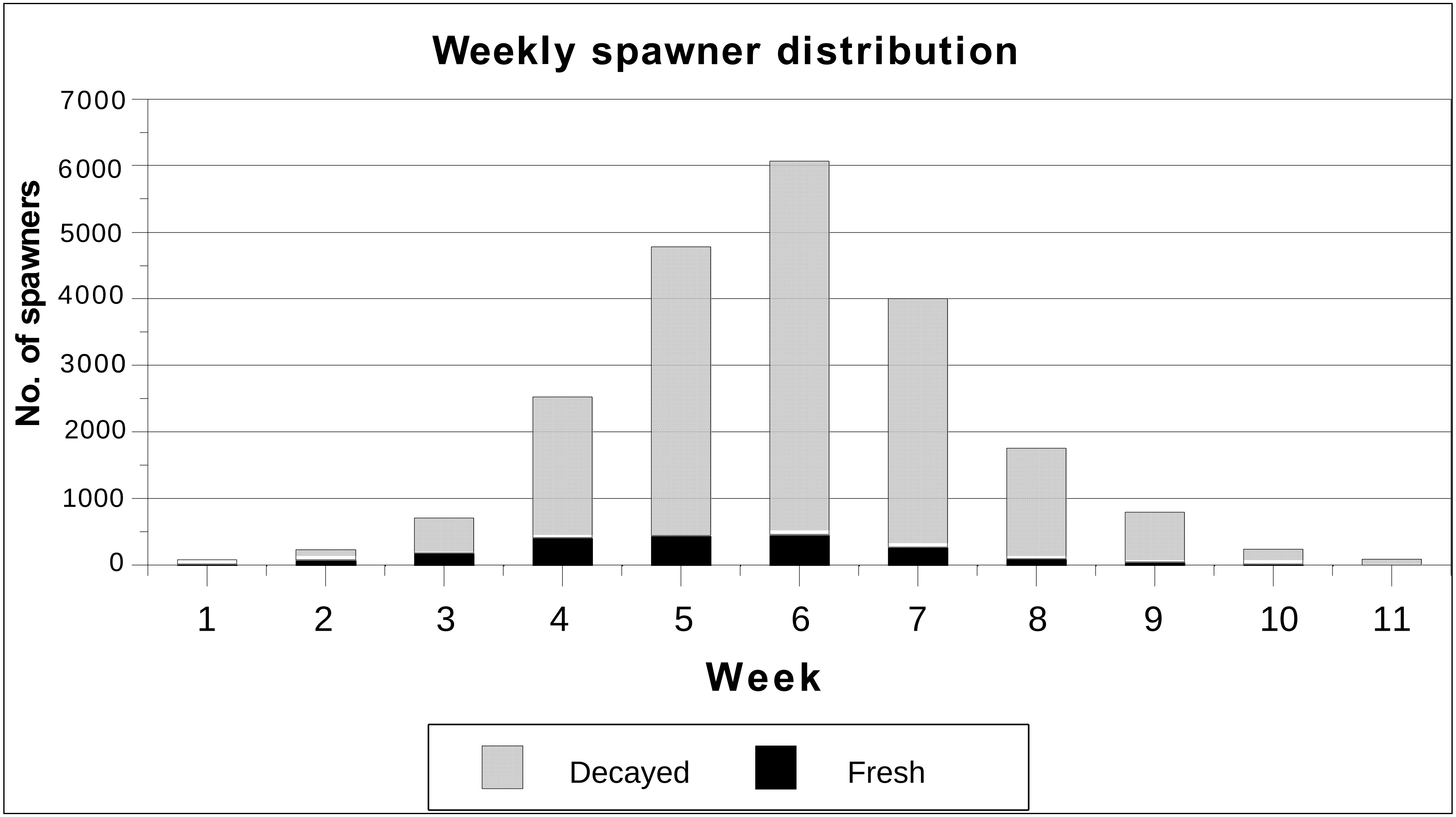


Figure 2. Weekly spawner carcass distribution observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

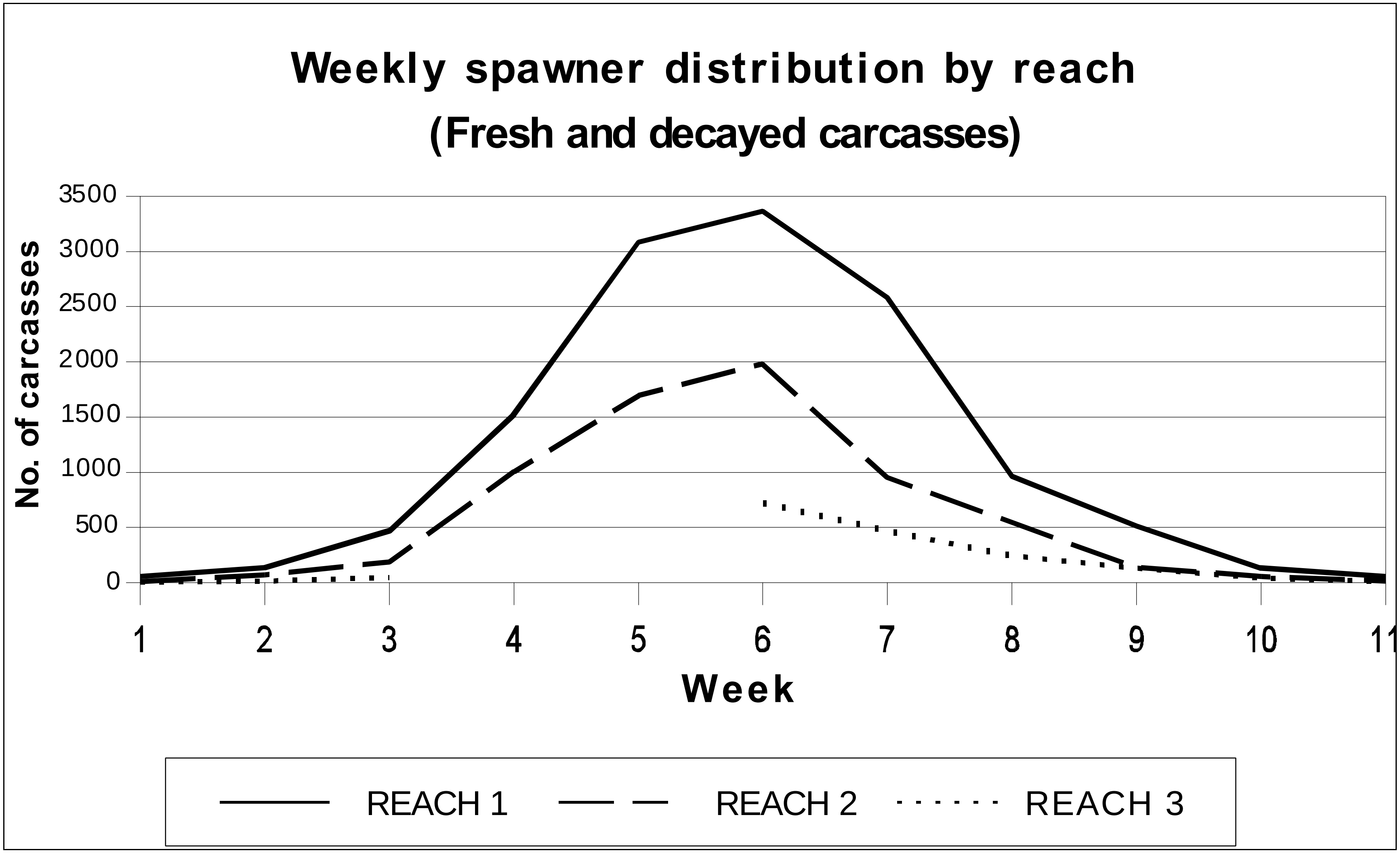


Figure 3. Weekly carcass distribution (totals by reach) observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

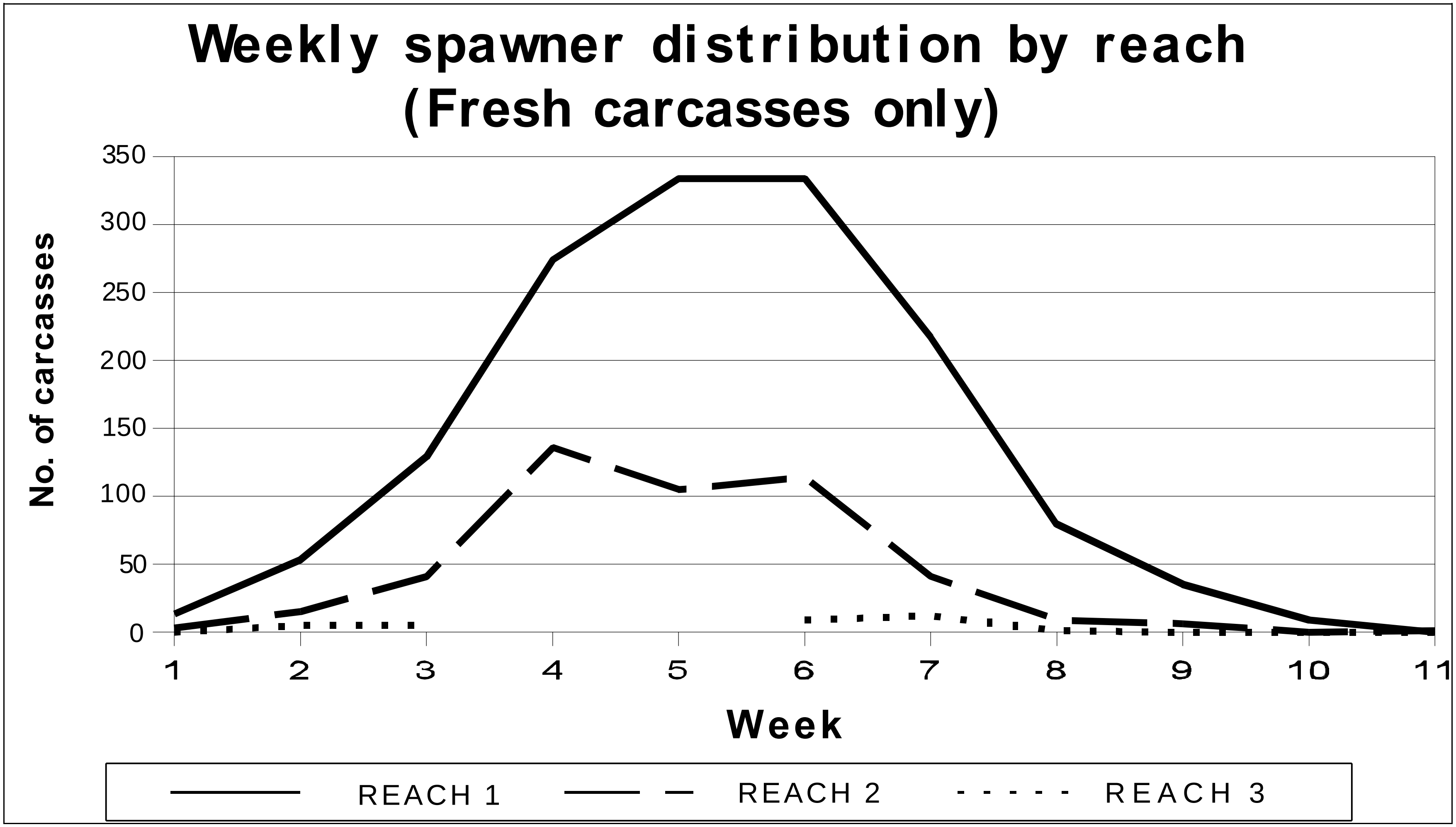


Figure 4. Weekly spawner carcass distribution (totals by reach) for fresh carcasses observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

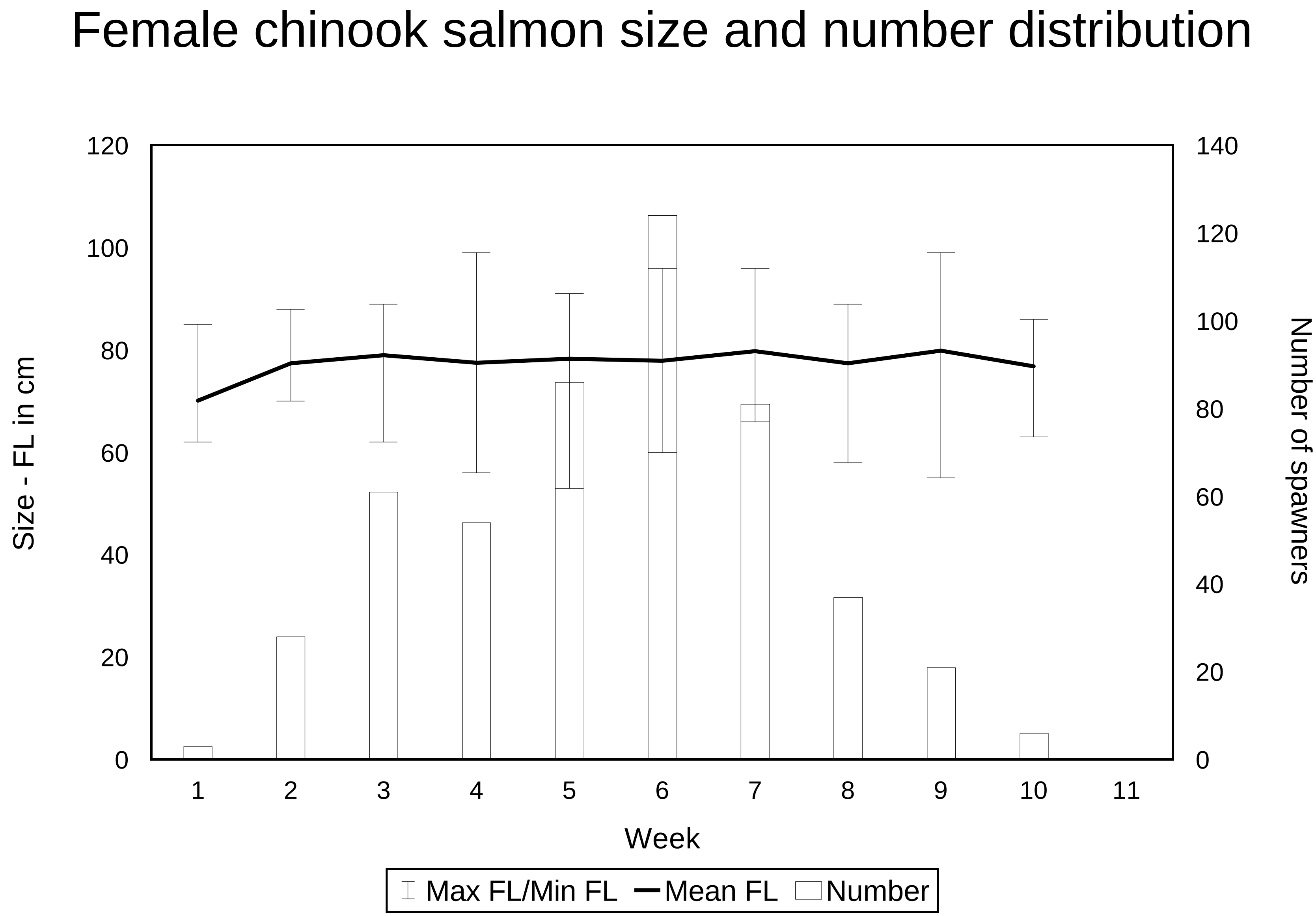


Figure 7. Mean size, size range and number of female chinook measured weekly during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

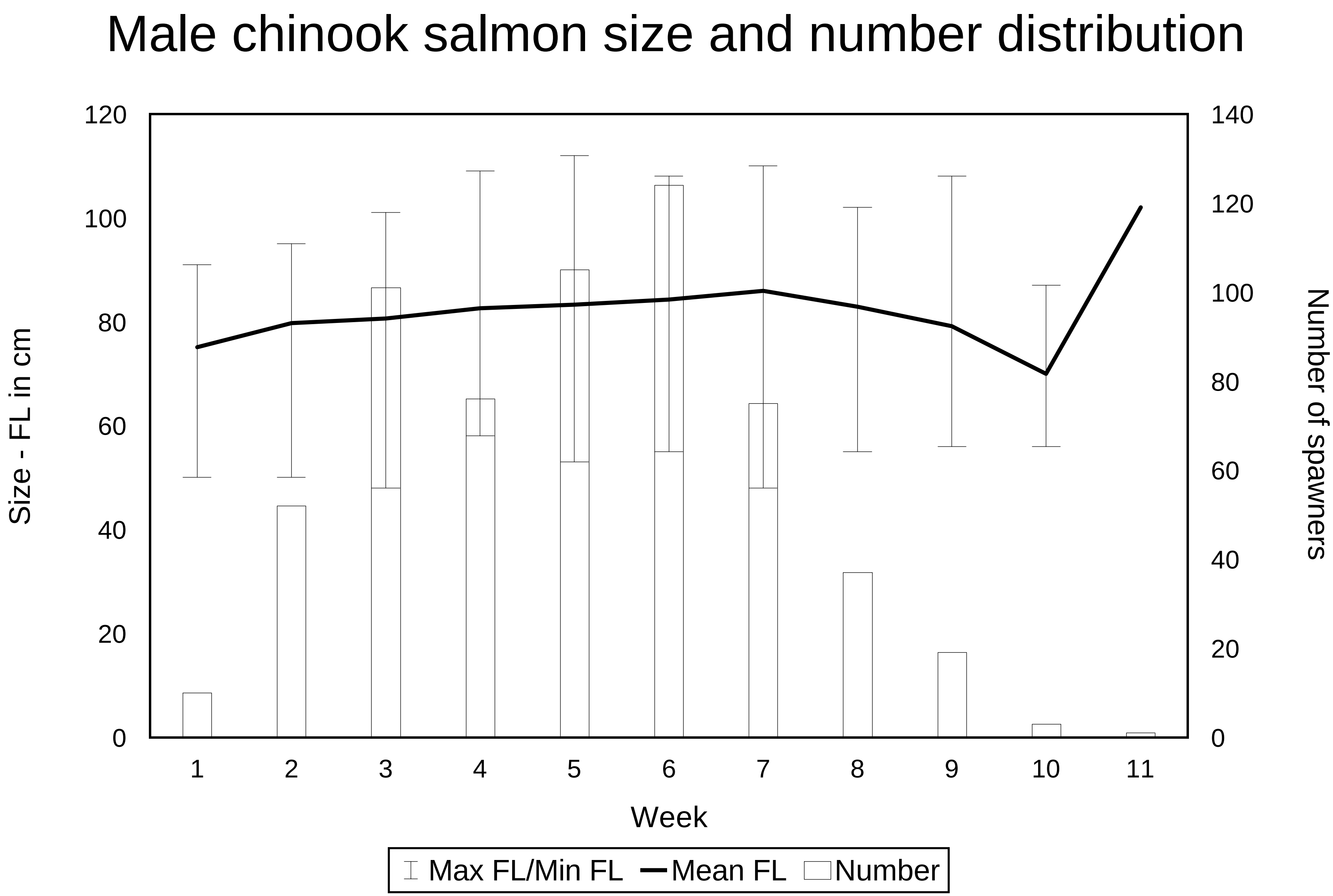


Figure 8. Mean size, size range and number of male chinook salmon measured weekly during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

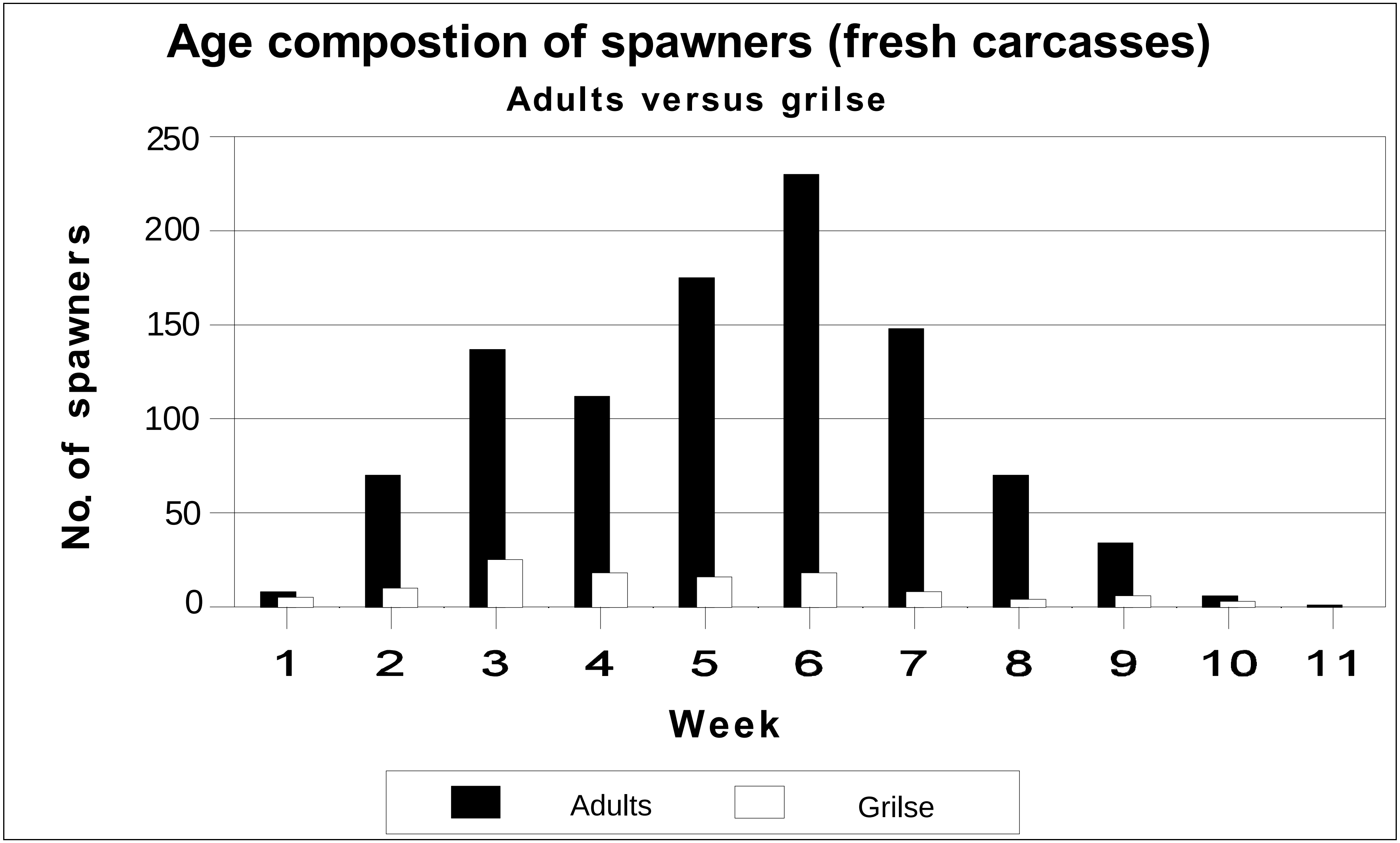


Figure 9. Age composition of chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

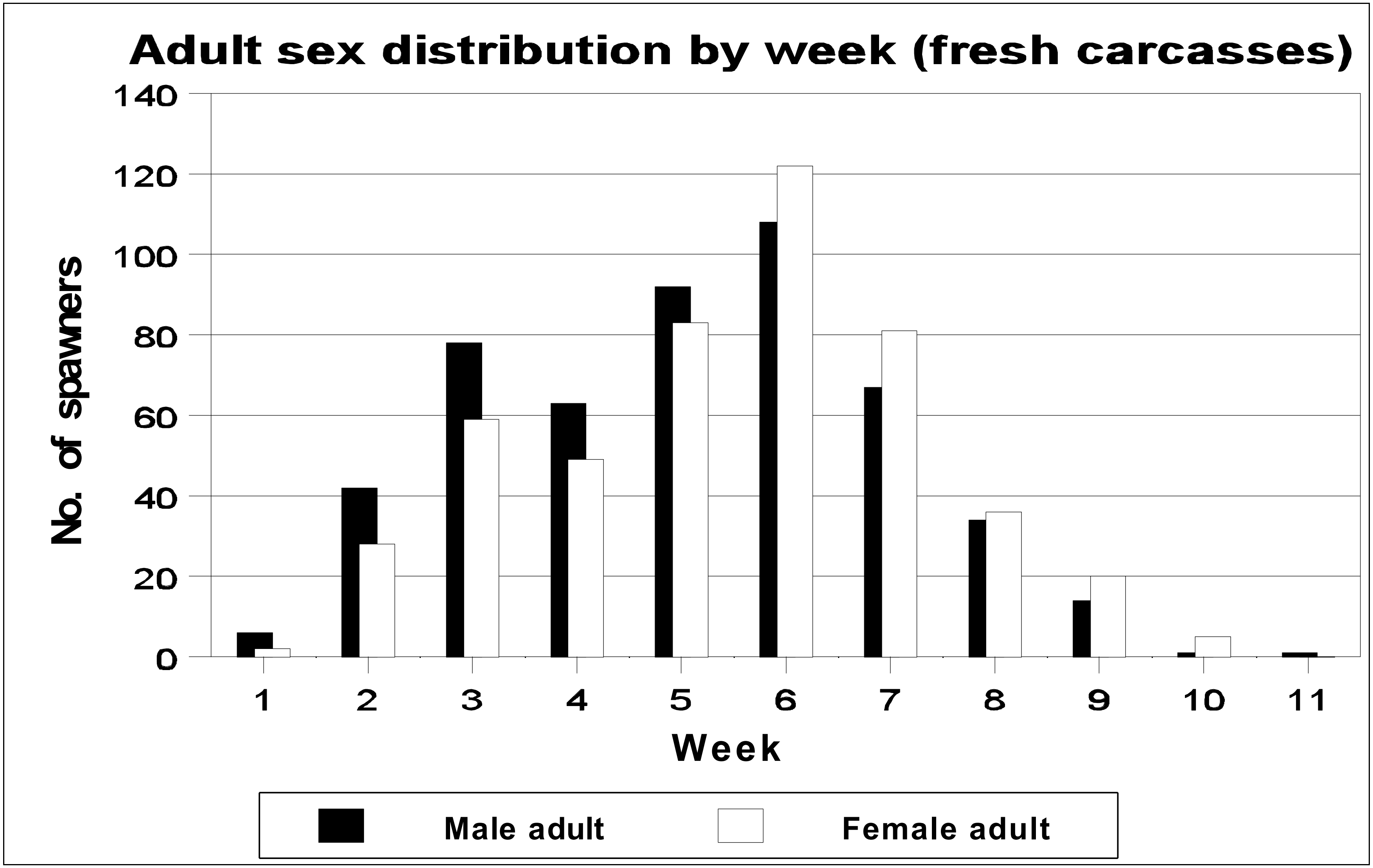


Figure 10  Weekly distribution of the sex of adult-sized chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

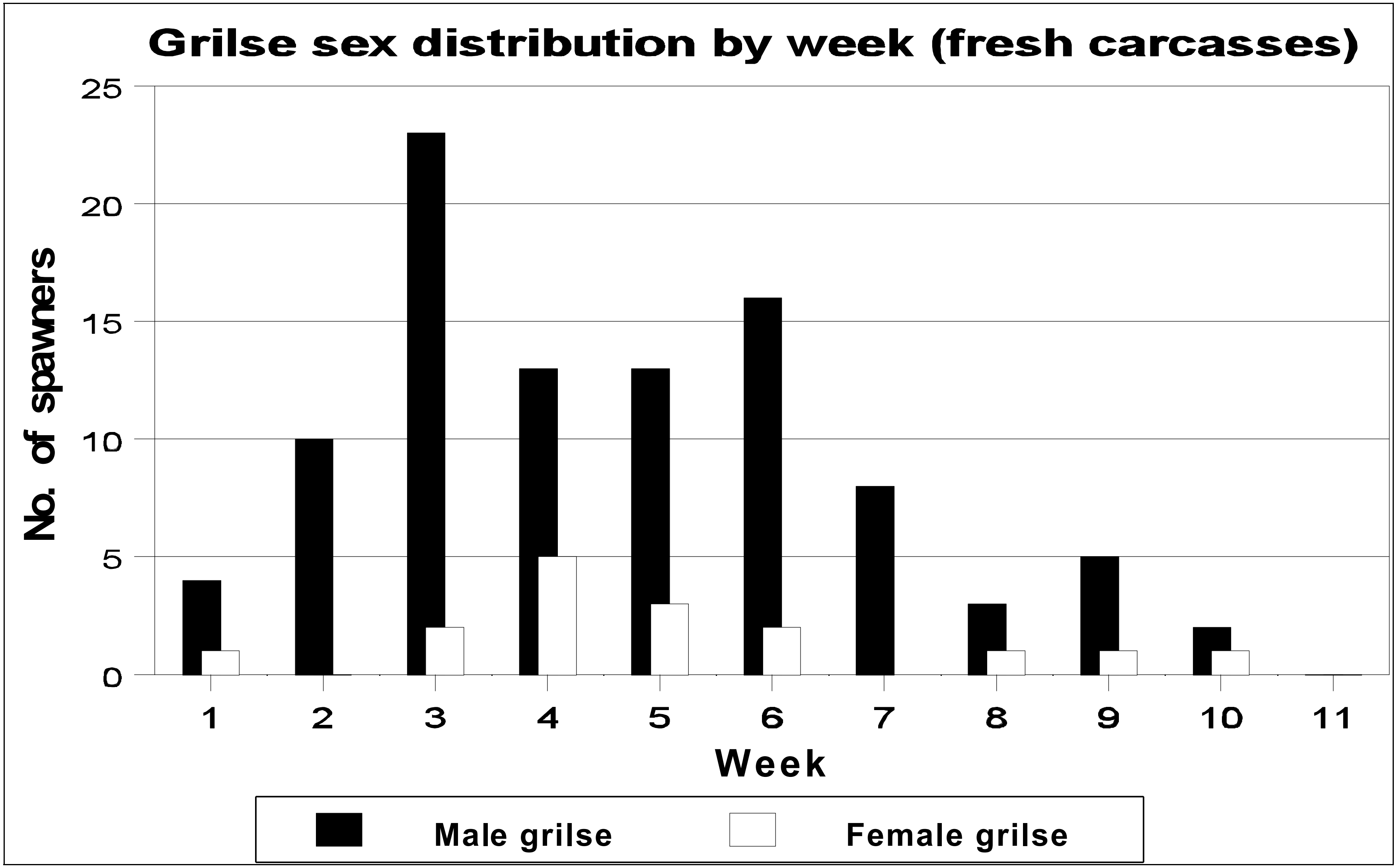


Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

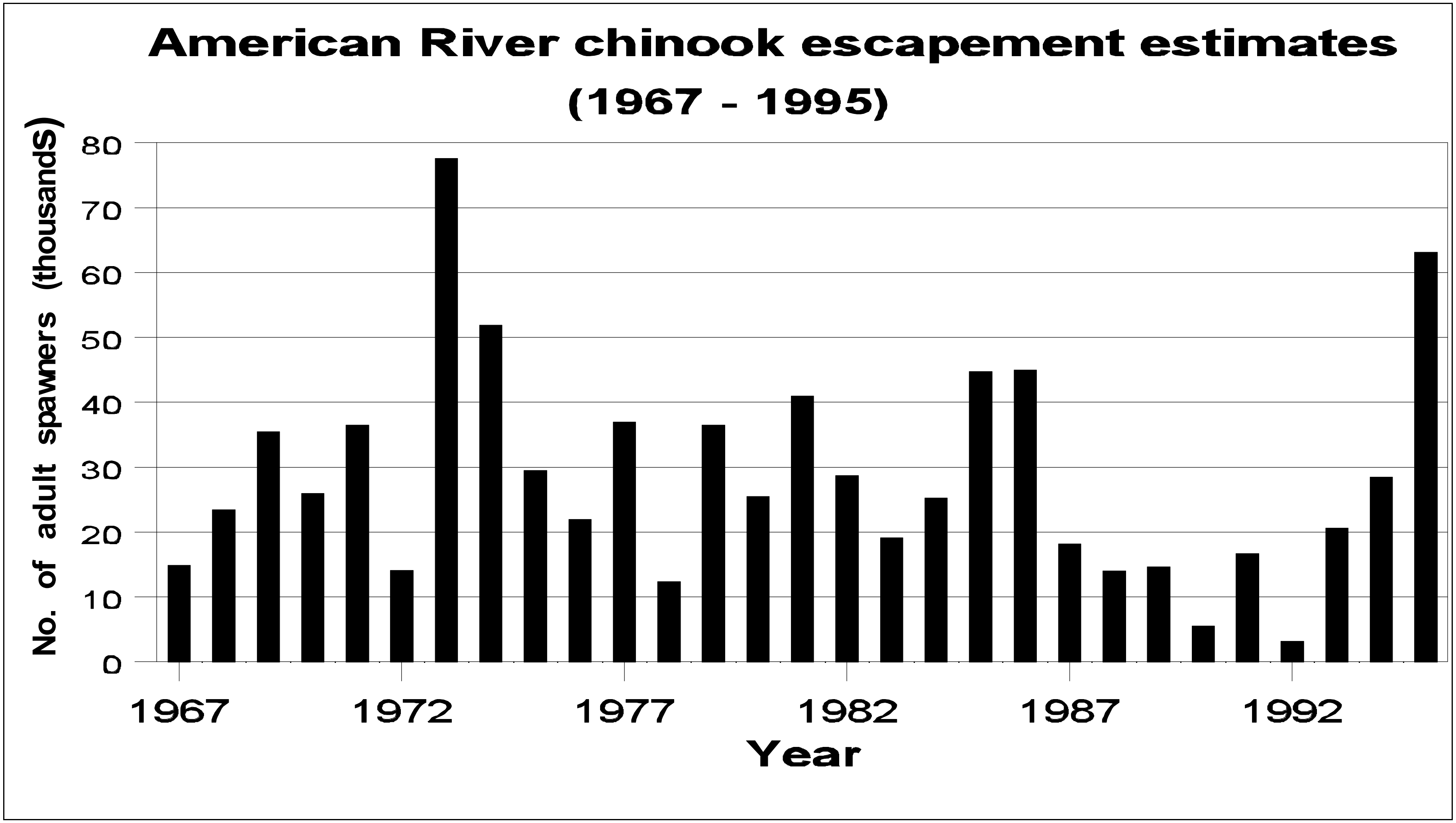


Figure 12. Summary of adult escapement estimates for fall-run chinook salmon in the lower American River, 1967 - 1995.