Ref ID 90810

# Upper Sacramento River
## *Fall and Late-Fall run Adult Chinook Monitoring Program*

### Program Information

**Mark-Recapture Survey**

*Cost:* $200,000
*Funding Source:* Department of Fish and Game and CALFED Ecosystem Restoration Program. 75% of funds are Sport Fish Restoration Program Federal Grant; 25% of funds are CA match from non-dedicated Fish and Game Preservation and State General Funds.
*Years of Existing Monitoring Program Data:*
*Years of Historic Data:* 1996 – present
*Previous Sampling Methods:* Balls Ferry trap and weir (after completion of Shasta dam), Counts at Red Bluff Diversion Dam
*Data Management:* Microsoft Excel, Access, Word, ArcView
*Annual Report:*

- Escapement estimates submitted to PFMC and Grand Tab
- Annual SFRA report published in September.
- CA Dept. of Fish and Game, Inland Fisheries Division Administrative Reports: Chinook salmon spawner stocks in California's Central Valley; 1953-1999.

*Collaborators:* Staff from the California Department of Fish and Game (CDFG) and the Pacific States Marine Fisheries Commission (PSMFC).

**Redd Survey (For Winter, Spring, Fall and Late-fall-runs)**

*Cost:* $30,000
*Funding Source:* U.S. Bureau of Reclamation
*Years of Existing Monitoring Program Data:* 1969 – present
*Years of Historic Data:* 1969 – present
*Previous Sampling Methods:* None.
*Data Management:* Microsoft Excel
*Annual Report:* Sport Fish and Restoration Annual Report (September)
*Collaborators:* Staff from the California Department of Fish and Game (CDFG), and the Pacific States Marine Fisheries Commission (PSMFC).

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## Mark-Recapture Carcass Survey and Redd Survey

*Study Area* – The mark-recapture carcass survey is completed on the Upper Sacramento River from Keswick dam (RM 302) to the power lines just downstream of the mouth of Clear Creek (RM 288.8). The study area is broken into three sampling reaches: 1) Keswick Dam to ACID, 2) ACID to RM 294, and 3) RM 294 to the Clear Creek Power lines.

The redd survey is completed in the mark-recapture study area and downstream of the study area. The area is broken into 13 reaches: 1) Keswick Dam to Anderson Cottonwood , 2)ACID to the Highway 44 Bridge, 3) Highway 44 Bridge to Airport Rd Bridge, 4) Airport Rd Bridge to Balls Ferry Bridge, 5)Balls Ferry Bridge to Battle Creek, 6) Battle Creek to Jellys Ferry Bridge, 7) Jellys Ferry Bridge to Bend Bridge, 8) Bend Bridge to Red Bluff Diversion Dam (RBDD), 9) RBDD to Tehama Bridge, 10) Tehama Bridge to Woodson Bridge, 11) Woodson Bridge to Hamilton City Bridge, 12) Hamilton City Bridge to Ord Ferry Bridge, and 13) Ord Ferry Bridge to Princeton Ferry.

## Field and Laboratory Methods

*Mark-Recapture Carcass Survey* – The mark-recapture carcass survey is conducted from the September to the beginning of May. The cut-off date for fall-run and late-fall run is mid-December. The date varies each year and is determined using professional judgment and observation of more fresh carcasses. A survey period consists of three days of sampling. Reaches are designed for one full day of work. Reach 3 is sampled on the first day. Reach 2 is sampled on the second day and Reach 1 is sampled on the third day.

Boats are used to conduct the mark-recapture carcass survey. Typically, a boat with two personnel is used to survey the west side of the stream and a second boat with two personnel is used to survey the east side of the stream. During peak carcass collections, up to five boats are used to ensure complete coverage of the stream. Boats move from the downstream end to the upstream end of the survey reach. Areas surveyed are from the shore to the center of the stream. For areas with a high number of carcasses (i.e. Turtle Bay; RM 296.5), boats work side by side to process carcasses. Crews are instructed to search all areas of the visible river bottom to avoid pre-determined search patterns based on prior experience with finding carcasses.

All carcasses are sampled. Carcasses are collected using a 15 ft long wooden pole with a five pronged gig attached to one end. Each carcass is categorized using the following criteria:

1. Adipose fin Present, Absent, or Unknown
2. Large ($\geq$ 61 cm) or Small ($<$ 61 cm)
3. Male or Female
4. Recapture or New Encounter
5. Fresh or Decayed
6. Spawned or Not Spawned (Females only)

7. Location (River mile and GPS waypoint)
8. Fork length (cm), Genetic samples, and Scales taken or not taken.
9. Carcass Tagged or Chopped

Adipose fin clipped carcasses (hatchery fish) are used to evaluate hatchery supplementation programs and are not used in the mark-recapture survey. Carcasses are processed for categories 2-9 listed above. Heads are collected from carcasses with an adipose fin missing, partially absent, or unknown to recover coded-wire tags. The remaining carcass is chopped in half and returned to the stream. The carcass is not used for the mark-recapture survey because the carcass is chopped at first encounter.

Untagged carcasses with an adipose fin (natural fish) are processed for categories 2-9 listed above. Carcasses that are fresh (recently died with one clear eye or red/pink gills) are tagged in the upper jaw. Carcasses that are non-fresh are tagged in the lower jaw. If a non-fresh carcass is not suitable (too decayed) for tagging the carcass is chopped and recorded as a chop. All carcasses are released back into the stream.

Carcasses are tagged for the mark-recapture survey and examination of individual carcass movements. The tags used for the mark-recapture survey are aluminum or copper coated steel hog ring staples with an attached small (1-2 cm) square piece of thin colored plastic sheet. Tags for each sample period are a unique color to identify recaptured carcasses by tagging period. Many of the fresh carcasses are also tagged with a disc tag bearing a unique identification number. Recaptures of disc tagged fish are used to determine individual carcass movements (GPS waypoints and river mile are recorded at marking and recapture of carcass), length of time to recapture, and number of times an individual carcass could be recaptured.

Spawning condition is accessed for female carcasses. Female carcasses are classified as spawned or unspawned. A spawned female has few eggs remaining in the body cavity and the caudal fin is worn from redd construction. An unspawned female has many eggs in the body cavity and an unworn caudal fin indicating that a redd was not constructed.

Fork length, tissue samples, and scales are collected for most fresh and some non-fresh carcasses. Fork length is measured to the nearest centimeter and used to determine age structure of the population. Tissue samples are collected from a sub-sample of carcasses at a pre-determined ratio (i.e. 1:3) established at the beginning of the day. Tissue samples are for genetic analysis. Scales are taken for age estimation.

*Redd Survey* – Weekly aerial redd surveys are conducted by a fixed wing airplane depending on aircraft availability. Fall-run redd surveys are in October and November. Late-fall surveys are in mid-December and February. Redds are counted in the thirteen sampling reaches. Data is used for estimating escapement outside of the mark-recapture carcass survey study area. In addition, the data is used to index spawning distribution.

*Genetic Analysis* – Tissue samples are collected from a sub-sample of most fresh and some non-fresh carcasses at a pre-determined ratio (i.e. 1:3) established at the beginning of the day.

*Age Estimation* – Fork length and scales are collected from most fresh carcasses and some non-fresh carcasses to estimate age from a length frequency distribution or reading scales.

*Coded-Wire Tag Recovery* – Heads are collected from carcasses if the adipose fin is missing, partially absent, or unknown. Heads are frozen for future analysis. The Department's Ocean Salmon Project dissects the heads for Coded-wire tags in the laboratory.

*Biological Data* – Fork length, sex, spawning condition, scales, tissue samples, location, and hatchery/natural status are measured or recorded.

*Physical Data* – Physical data collected during the survey period are 1) flow from Keswick Dam, 2) water temperature, 3) water clarity and 4) weather condition. Flow data is obtained from the California Data Exchange Center. Water temperature is measured using a handheld thermometer (°F) for each survey. Water clarity is measured using a Secchi disc to the nearest tenth of a foot. Water clarity greater than 16 ft is recorded as 16+. Weather conditions are recorded daily for each section surveyed.

## Data Analysis Methods

*Escapement Estimation* – Fall-run and Late-fall run Chinook escapement is estimated using the unclipped adipose fin large (≥ 61 cm) female carcass data with the Jolly-Seber model (Seber 1982; Boydstun 1994) and then expanded using adjustments for unaccounted females and males. Adjustments are: 1) Expansion for adipose fin clipped large females that were recovered for the CWT program, 2) Expansion for large females spawning outside of the carcass study area, 3) Expansion for large males, 4) Expansion for small males and females 5) Expansion for Chinook taken for hatchery programs and 6) Expansion for angler harvest. Data for the runs is separated based on the cut-off date described above.

The unclipped adipose fin large (≥ 61 cm) female carcass (fresh and non-fresh) data is used to estimate natural large female escapement with the Jolly-Seber model (Seber 1982):

$$E = N_1 + \sum_{i=1}^{j} D_i ;$$

where $N_1$ is the number of unclipped large female carcasses in the population during period 1 (first period of spawning and dying) and $D_i$ is the number of carcasses that joined the population between periods $i$ and $i+1$ (accounts for carcasses leaving population) with period $j$ being the last survey period (Table 1).

The natural (unclipped adipose fin) large female escapement estimate is adjusted to account for adipose fin-clipped (hatchery) large female carcasses:

$$E_{Adj_H} = \frac{F_L}{F_{LN}} * E \ ;$$

where $F_L$ is the count of all fresh large female carcasses observed, $F_{LN}$ is the number of fresh large natural female carcasses (unclipped adipose fin), and $E$ is described above.

The adjusted large female escapement estimate is further adjusted to account for large females outside of the study area using the aerial redd counts:

$$E_{Adj_{H_R}} = \frac{R}{r} * \left(E_{Adj_H}\right);$$

where $R$ is the number of total redds observed during the aerial redd surveys, $r$ is the number of redds observed in the study area, and $E_{Adj_H}$ is described above.

Total in-river female escapement is estimated by adjusting the adjusted large female escapement estimate for the number of small female carcasses observed:

$$E_F = \frac{F}{F_L} * E_{Adj_{H_R}} \ ;$$

where $F$ is the total number of fresh female carcasses counted, $F_L$ and $E_{Adj_{H_R}}$ are described above.

Total in-river adult female escapement is estimated as:

$$E_{AF} = E_F * \frac{F_A}{F};$$

where $E_F$ is described above, $F_A$ is the number of fresh adult female carcasses ( FL > 599mm), and $F$ is described above. Length cut-offs for adult female and female grilse is determined using a length frequency distribution from the fresh carcass data.

Total large in-river male escapement for Fall-run is estimated using count data from Red Bluff Diversion Dam (RBDD) and for Late-fall run is estimated using count data at the Coleman National Fish Hatchery (CNFH):

$$E_{LM} = \frac{M_T}{F_T} * E_{Adj_{H_R}} \ ;$$

where $M_T$ is the number of large males counted, $F_T$ is the number of large females counted, and $E_{Adj_{H_R}}$ is described above. An adjustment factor for males spawning outside of study area is not needed because these males are accounted for in the female estimate.

Total male escapement is estimated by adjusting the large in-river escapement estimate for small males:

$$E_M = E_{LM} * \frac{M}{M_L};$$

where $E_{LM}$ is described above, $M$ is the total number of fresh male carcasses observed in the mark-recapture carcass survey, and $M_L$ is the total number of large fresh male carcasses observed.

Total in-river adult male escapement is estimated as:

$$E_{AM} = E_M * \frac{M_A}{M};$$

where $E_M$ and $M$ are described above and $M_A$ is the number of fresh adult male carcasses (FL > 669 mm) observed. Length cut-off for adult male and male grilse was determined using a length frequency distribution from fresh carcass data.

Total fall-run and Late-fall run Chinook salmon escapement is estimated as:

$$E_T = E_F + E_M + H;$$

where $E_F$ and $E_M$ are described above, and $H$ is the total number of fall-run or late-fall run Chinook harvested by anglers. Harvest data from the Department's Angler Survey Program (discontinued in 2003) is used to approximate the number of salmon harvested.

Table 1. Equations, variables, and definitions of variables used for estimating escapement with the Jolly Seber model.

| Equation | Variable | Definition |
|---|---|---|
| $N_1 = E_1 + \frac{(N_2 - T_1 * S_1)}{\sqrt{S_1}}$ | $N_1$ | The number of carcasses in the population at the start of the survey period 1. |
| $D_i = \frac{B_i}{\sqrt{S_i}}$ | $D_i$ | The number of carcasses that join the population between periods $i$ and $i+1$. |
| $S_i = \frac{N_{i+1}}{(b_i - R_i + T_i)}$ | $S_i$ | The survival rate of tagged carcasses from periods $i$ to $i+1$. |
| $N_i = \frac{b_i(E_i + 1)}{(R_i + 1)}$ | $N_i$ | The estimate of the total number of carcasses in the population immediately prior to each survey. |
| $b_i = \frac{(T_i + 1)K_i}{(C_i + 1)} + R_i$ | $b_i$ | The estimate of the number of tags available for recapture in each survey period. |
| $B_i = N_{i+1} - S_i(N_i - E_i + T_i)$ | $B_i$ | The number of carcasses that join the population between periods $i$ and $i+1$. (Does not account for leaving carcasses) |
| | $T_i$ | The number of carcasses tagged in period $i$. |
| | $E_i$ | The total number of carcasses examined in period $i$ including tagged, chopped, and recaptured. |
| | $R_i$ | The sum of all recaptures in a single period $i$ regardless of the period the carcass was tagged. |
| | $C_i$ | The sum of all recaptures over all periods for a survey period $i$. |
| | $K_i$ | Sum of all recaptures made later then $i$ of carcasses tagged before period $i$. |

*Genetic Analysis* – Collected tissues are archived.

*Age Estimation* – Age composition of the Fall-run and Late-fall-run population is determined using length frequency data. Length cut-offs are determined for male and female adults (3+ year-old) and grilse (2 year-old) based on the modes of the length frequency graphs. Percentages of male and female adults and grilse of the population are calculated using the length cut-offs and carcass survey data.

Scales are used to estimate age and compare with length frequency estimates. However, age estimates from scales are not reported and are not used for length frequency comparison before annual reports are published.

*Coded-Wire Tag Recovery* – Percentages are calculated for the number of CWT recoveries of adult and grilse females and males in the population. Percentages are calculated using fresh and non-fresh survey data and compared between fresh and non-fresh carcass survey data.

*Biological Data* – Sex composition is determined for the population by the percentage of fresh carcasses that are male or female that is natural, hatchery, large, small, adult, grilse, and natural and hatchery of adult and grilse.

Spawning success is determined based on the percentage of female carcasses that are spawned and unspawned.

Temporal distribution is determined based on the percentage of carcasses observed in the survey reaches each month of the survey.

Spatial distribution for fresh, non-fresh, and fresh and non-fresh combined is examined by calculating the percentage of carcasses found in the survey reaches and at river miles. In addition, the aerial redd survey data is used to provide an index of spawning distribution within the study area and outside the study area. Percentage of redds in the 10 redd survey reaches are calculated to determined where most fish are spawning.

Survival characteristics of Fall-run and Late-fall-run carcasses are determined using the recaptured disc- tagged carcasses. Survival is the length of time a carcass is available for personnel to encounter them. The survival time for carcasses is calculated between the initial tagging date and first recapture date and last recapture date. Survival time is averaged and range of survival times is described.

The distance carcasses travel and distribute is examined using the GPS data of disc-tagged carcasses. Distance carcasses travel is examined between male and female carcasses.

*Physical Data* – Described is a summary of water temperature, water clarity, stream flow, maximum air temperature, and weather.