7.0 LOWER AMERICAN RIVER SCIENCE-BASED MANAGEMENT FRAMEWORK

Managing an inherently complex ecosystem such as the lower American River, where many processes and relationships interact, means making management decisions with some degree of uncertainty regarding the consequences or outcomes. The FISH Plan proposes a science-based management framework to reduce uncertainty, and to accomplish the FISH Plan goals and objectives. A comprehensive monitoring plan with reliable data output and thorough evaluation will enable managers to make informed choices and decisions regarding the direction of their programs. In addition, the science-based management framework of the FISH Plan will support management learning through implementation and evaluation of alternative management scenarios - a process of directed selection. As described in this chapter, the science framework incorporates the principles of adaptive management to ensure future resource management actions are adapted according to what has been learned.

The difficulties and uncertainties associated with successful ecosystem restoration call for an implementation strategy that is flexible and can accommodate and adapt to new information. Science is a process for learning about nature in which competing ideas about how the world works are measured against observations (Feynman 1965). Since descriptions of the natural world are often incomplete, and scientists' measurements involve uncertainty and inaccuracy, scientists rely upon statistics for formal tools to help them evaluate the confrontations between ideas (i.e., hypotheses) and data (Hilborn and Mangel 1997).

A widely accepted model describes the scientific process as a learning tree of critical experiments (Platt 1964), whose "branches" or steps can be summarized as:

1. Devising alternative hypotheses;
2. Devising crucial and replicable experiments with alternative possible outcomes that will exclude one or more of the competing hypotheses;
3. Performing the experiments and obtaining "clean" (i.e., unambiguous) results; and
4. Recycling the procedure by devising new sets of alternative subordinate or sequential hypotheses to refine understanding of the process or concept under study.

Platt's (1964) learning tree relies heavily on performing crucial and replicable experiments that will produce unambiguous results. In ecology, such experiments are often difficult to perform. The long time periods involved in many ecological processes, the low expectation for replication of ecological experiments, the inability to control all aspects of an ecological experiment, and the intractability of many populations (e.g., endangered or threatened species) to ecological manipulation, often make ecological experimentation difficult or inadequate. Moreover, when ecological experiments are possible, these same factors tend to obfuscate clear or unambiguous results. Therefore, ecologists must rely on observations (as opposed to experiments), inference, good thinking, and models to guide them through the scientific process (Hilborn and Mangel 1997). Under these conditions, a scientific research program serves to guide ecological research by indicating paths to avoid, and paths to pursue. The remainder of this chapter describes the goals and objectives of the science framework, its four key components, structural considerations, and the adaptive management process.

Goal and Objectives of the Proposed Science Framework

The overall goal of the science framework is to reduce, to the extent possible, the uncertainties inherent in the management of lower American River fish and aquatic resources. The framework includes the following five proposed objectives to meet this goal:

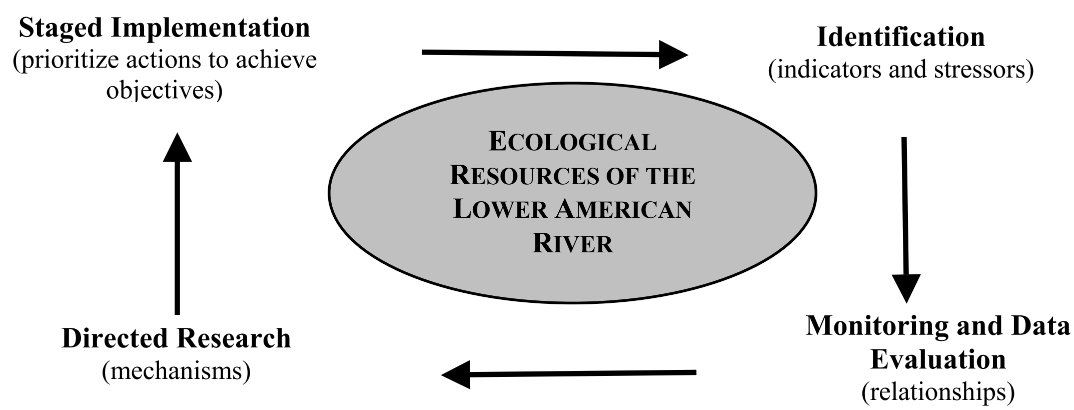
1. **Detect changes** - Serve as an early warning system by detecting project- and ecosystem-induced, short- and long-term changes in the lower American River ecosystem.
2. **Understand system interactions** - Identify causes of change within the lower American River resulting from natural variation, human influences, and their interaction.
3. **Predict trends** - Develop the capacity to predict the status and trends of natural resources for use by resource managers and the public.
4. **Inform interested parties/stakeholders** - Provide information to the public, resource managers, policy makers and others in order to actively manage the ecosystem to meet specified goals and objectives.
5. **Improve resource management** - Develop tools and methods that can help resource managers and regulators improve management of fish and aquatic (riverine) resources and address problems that may arise from human influences (activities).

Three of these objectives - detecting changes, understanding system interactions (identifying causes of change), and predicting trends - rely upon an adaptive management process that includes an effective monitoring plan. The adaptive management and monitoring plan components are described in this chapter.

Science Framework Components

Figure 7-1 identifies four necessary components of a successful science framework. These components include: (1) identifying indicators and stressors; (2) monitoring and evaluating information; (3) conducting directed research efforts; and (4) providing a link to the decision-making process and management actions. These components are the minimum required, and are considered part of the interactive process for understanding and managing ecological resources.

Figure 7-1. Components of understanding and managing the ecological resources of the lower American River.



Information generated from monitoring, evaluation, and research activities provides resource managers with the understanding needed to design actions, to detect responses to their actions, to provide the public with information about the success of these actions, and, above all, to improve resource management.

- **Identification of Ecosystem Attributes/Understand Relationships:** Involves identifying measurable and sampling physical, chemical, and biological indicators to evaluate ecosystem processes, habitats, and species.
- **Monitoring and Data Evaluation:** Involves measuring and evaluating the abundance, distribution, change or status of indicators. For example, examining the correlation between the abundance of a fish species and a physical factor, such as river flow.
- **Directed Research:** Involves analysis or experiments to illustrate mechanisms that explain an observed correlation, such as documenting fish abundance and distribution with varying levels of river flow. Allows for the integration of other research activities in a complementary manner.
- **Staged Implementation (Management Actions):** Calls for a logical prioritization of actions to achieve FISH Plan objectives as effectively as possible. The results of monitoring programs are of value to the extent that they provide information for management decisions (actions), and provide early warnings of ecosystem degradation. The link between monitoring and decision-making begins with the formulation of, and agreement on the monitoring program.

SCIENCE FRAMEWORK MANAGEMENT STRUCTURE

The science framework may be used to link FISH Plan decision-making among the resource management agencies to determine how to evaluate results of monitoring and data review collected through FISH Plan management actions and individual projects and in the RCMP. Following the principles of adaptive management, resource managers will adjust FISH Plan goals as necessary to attain the desired program objectives. The science framework will require a management structure to ensure that:

- Goals and objectives have been identified;
- Sampling design is adequate;
- Funds are available;
- Personnel are available;
- Data are managed; and
- Information is made available to the management agencies.

As of this writing, work has just begun to define the science framework for the lower American River. The FISH Plan's adaptive management process, described below, will be a key component of the envisioned science framework, but it is anticipated that the framework will be on the scale of the RCMP. Ideas are being developed further and preliminary contacts with CDFG, CalFed, the U.S. Geological Survey (USGS), California State University, Sacramento (CSUS), and the University of California at Davis (UCD) have been initiated. One concept is to form science partnerships with these parties, relying on an agreed-upon entity, such as a resource agency (e.g., CDFG, USGS) under contract with RCMP entities to provide oversight of the science-based management element. An alternative concept would be to establish an adaptive management team to oversee and ensure a science-based approach to resource management and implementation of the FISH Plan.

ADAPTIVE MANAGEMENT PROCESS

The adaptive management process is considered an essential component of the lower American River science-based management framework. It is defined as a process that generates, incorporates, evaluates, and responds to new information and conditions in order to achieve the desired objectives. There are several factors that lead to the need for a more clearly articulated, incremental, and science-based approach in the adaptive management process:

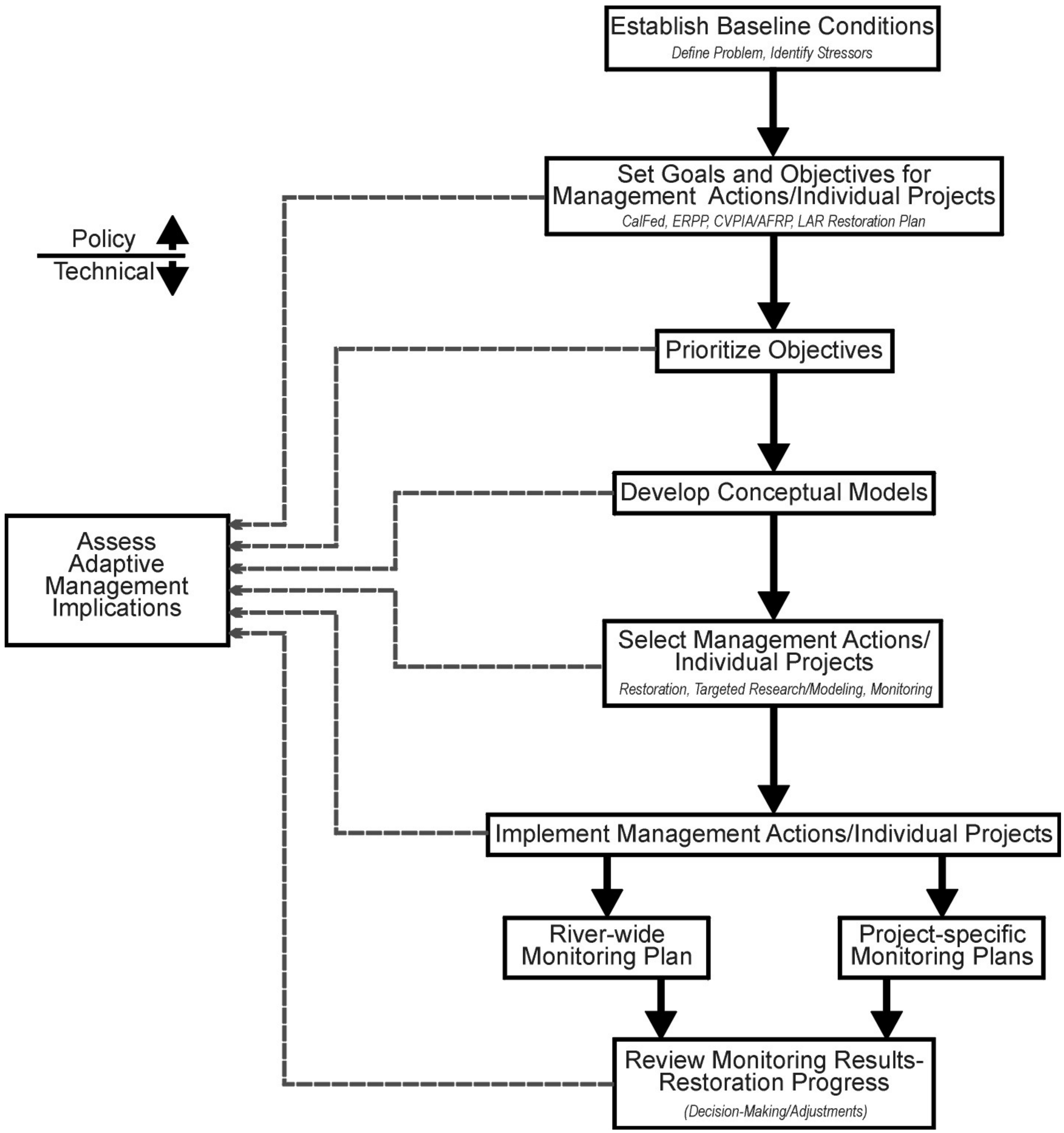
- Multiple competing objectives;
- Complex and uncertain interactions and cause/effect relationships;
- Technical feasibility;
- Limited resources; and
- Multiple individuals and/or organizations responsible and accountable for outcomes.

Adaptive management will be applied to river-wide management actions as well as individual projects within the river corridor. River-wide adaptive management considers the status and trends in fish populations, habitats and processes and more generalized system-wide indicators primarily associated with hydrologic operations and management actions in determining subsequent actions. Project-specific adaptive management focuses on implementing, monitoring and reporting on individual actions within the study area, evaluating the extent to which specific actions meet the objectives of the project and the FISH Plan, and revising subsequent actions accordingly.

The features of a scientifically based, adaptively managed decision-making process, throughout which a high level of disclosure and interaction is critical, are portrayed schematically in **Figure 7-2**. As depicted, the primary steps or actions in the adaptive management process include:

1. Establish quantitative environmental baseline conditions;
2. Set goals and objectives for management actions (or individual projects);
3. Prioritize objectives;
4. Develop conceptual models of ecosystem processes, including natural or created stressors;
5. Evaluate and select potential management actions (or individual projects);
6. Implement the selected management actions (or individual projects);
7. Monitor quantitative variables; and
8. Review and assess the data.

Figure 7-2. Features of the adaptive management process.



Adaptive management relies upon the identification of indicators of ecosystem health, comprehensive monitoring of indicators to measure improvement over time, focused research, and phasing of actions. These principles will be incorporated into the ecological and biological adaptive management process, which includes monitoring and evaluation functions.

The emphasis on the adaptive management process in the FISH Plan reflects the importance of: (1) the scientific basis for a monitoring program; and (2) the feedback of results from the data evaluation into the subsequent round of management decision-making. The model of adaptive management processes has many of the same elements as the CalFed adaptive management process model (CalFed 2001), including establishing goals, specifying conceptual models, initiating actions, and evaluating data. However, the adaptive management process model portrayed in Figure 7-2 has notable differences in that it: (1) acknowledges the distinction between policy roles and responsibilities and technical roles and responsibilities; and (2) places greater emphasis on management and restoration results than scientific predictability.

The Initial FISH Plan was prepared following this sequence of steps. The river-wide monitoring plan serves as the first-level monitoring plan for the entire FISH Plan. Specific management actions taken to implement the FISH Plan also should follow these adaptive management steps. More specifically, individual projects should identify goals and objectives, develop a conceptual model for demonstrating an understanding of project-related ecosystem processes and stressors, describe the anticipated project results, and provide for adaptive management and monitoring components. Project-specific monitoring results will become part of the knowledge base of information on the lower American River, and, as appropriate, the FISH Plan and management actions will be modified (adapted) according to the results.

The major features of the adaptive management process for the lower American River are discussed briefly in the following sections.

7.1.1. ESTABLISH QUANTITATIVE BASELINE CONDITIONS

A quantitative baseline condition must be established to understand the existing conditions and compare and assess changes in those conditions. The *Baseline Report*, described in Chapter 2 of this report, provides the foundation upon which to build a quantitative baseline for adaptive management purposes.

7.1.2. SET GOALS AND OBJECTIVES FOR MANAGEMENT ACTIONS/ INDIVIDUAL PROJECTS

The river-wide management goals and objectives and priorities reflected in this report were developed through the FISH Plan consensus-building process and informed by various technical committee efforts. A standing technical committee will be required to periodically re-prioritize the list of objectives, as necessary, based on feedback from implementation, monitoring, and guidance from other restoration initiatives (i.e., ERPP, CVPIA, AFRP). Goals and objectives for individual projects also should be derived from the FISH Plan goals and objectives for restoring the fish and aquatic habitat resources of the lower American River. However, since project-specific goals and objectives will be focused on meeting the targeted outcome for the individual project in question, they cannot be detailed at this stage in the process.

7.1.3. PRIORITIZE OBJECTIVES

Prioritization of management objectives and actions/individual projects recommended in the Initial FISH Plan has been done as part of a structured process that involved the following elements:

- A technical subcommittee accountable to a broader stakeholder group;
- A facilitated discussion of objectives;
- Consensus building regarding priorities;

- Documented justification of priorities; and
- Provisions to periodically revisit and re-evaluate priorities.

The above sequence of steps reflects a robust and replicable framework for subsequent review of FISH Plan priorities and recommended actions.

7.1.4. SELECT AND IMPLEMENT MANAGEMENT ACTIONS/INDIVIDUAL PROJECTS

Implementation of the river-wide management actions and individual projects should proceed through a structured process for each action or project, involving:

- Scoping;
- Engineering and feasibility evaluations;
- Budgetary analysis;
- Oversight and review; and
- Reporting.

These steps are the responsibility of individual project proponents.

7.1.5. ECOLOGICAL AND BIOLOGICAL MONITORING AND EVALUATION

One result of the AROG, FWG, and TSC meetings has been to discuss potential monitoring programs, pooling the collective knowledge and experiences of veteran resource managers and balancing the interest of diverse resource stewardship interests in the lower American River. Several related water resource management efforts in the lower American River, including the Lower American River Temperature Improvement Study, the Water Forum Successor Effort, CDFG Stream Evaluation Program, and others, have and will continue to inform and give direction to development of the river-wide and individual project monitoring plans.

These monitoring efforts will gauge and evaluate the response of the lower American River fish and aquatic habitat resources to management actions in a manner that will measure progress toward FISH Plan and individual project goals and objectives. Subsequent re-evaluation and determination of potential new or refined monitoring programs will be accomplished through periodic (annual) review and assessment by a standing technical committee based on data and knowledge produced by the monitoring plan. This information will be shared with resource managers and the general public. The method for distributing this information to members of the general public remains under consideration (i.e., annual report sent to interested parties, web page posting, annual conferences). Identification of potential management actions and changes in monitoring plans should be part of a structured process involving the same elements as listed earlier for prioritizing objectives (Section 7.4.3).

RIVER-WIDE ECOLOGICAL AND BIOLOGICAL MONITORING AND EVALUATION PLAN

The River-wide Ecological and Biological Monitoring and Evaluation Plan (River-wide Monitoring Plan) is an essential part of the lower American River science-based management element and adaptive management process. It will provide the assessment of key physical, chemical, ecological and biological variables required for the testing of present alternative hypotheses concerning the system indicators and stressors, and measure responses to particular specific management actions. Moreover, it will enhance the available baseline information on the lower American River which will lead to a better understanding of the system dynamics, allow the development of new hypotheses and support appropriate management actions. The River-wide Monitoring Plan will describe the monitoring and evaluation components necessary for adaptive management of lower American River fish and aquatic habitat.

The purpose of the River-wide Monitoring Plan is to provide a detailed framework to support efficient and cost-effective long-term investigations that will provide the basis for the adaptive management of lower American River fish and aquatic habitat. By using the information and lessons learned from prior monitoring efforts and improving on the existing methodologies, where appropriate, the River-wide Monitoring Plan will enable water resource and fisheries resource managers to adaptively manage competing resource demands. The River-wide Monitoring Plan will provide a detailed and comprehensive "roadmap" for the monitoring, evaluation, and reporting of identified river-wide monitoring components (see River-wide Monitoring Plan Annotated Outline in Section 7.5). It is anticipated that the River-wide Monitoring Plan will be implemented in conjunction with the updated flow management plan for the lower American River (under development).

PROJECT-SPECIFIC MONITORING PLAN

The purpose of clarifying monitoring and evaluation plan requirements on an individual project basis is to help individual investigators collectively generate a comprehensive database, using comparable metrics, to facilitate input into the adaptive management decision-making process and to enhance reporting to resource managers regarding project effectiveness. The list of variables that project proponents are encouraged to address in their project-specific monitoring plans should speak to the following questions:

- What did you expect to happen?
- What actually happened?
- What are the adaptive management implications of the actual results?

The level of detail will depend on the nature and status of an individual project, but all projects should provide the information outlined below.

- Overview/summary of project objectives and associated monitoring objectives
  - Primary biological/ecological objectives
  - Questions to be answered
  - Hypotheses and assumptions
  - Conceptual framework/models
- Monitoring approach and design methodology
  - Parameters
  - Duration
  - Frequency
  - Type of equipment
  - Constituents
  - Location, integration with other projects
  - Reference or copies of protocols
- Data sampling procedures

- Number and type of samples
- Sample handling

- Analysis and reporting
  - Report frequency
  - Content and format
  - Evaluation approach
- Peer review
- Data management and format
- Financial assurances (e.g., how monitoring will be funded)

The monitoring plan methodology needs to be developed prior to any data collection, including pre-project field work. The plan may be tentative in the early stages, dependent on early field surveys and evaluations. A feasibility study would present more general statements on methodology. As final project designs are developed, so, too should the project refine final details of the data collection methodology. Project-specific budgets need to include monitoring for mitigation projects, as well as funding for adaptive management efforts that will need to be undertaken if the mitigation projects do not achieve intended goals. Monitoring plans should identify the timeframe over which monitoring will take place.

As discussed in Chapter 5, project monitoring and evaluation plans cannot be specified until projects are proposed and defined. Ultimately, the adaptive management process should be implemented for each project - complete with hypotheses, monitoring plans, and experimental design. Individual fisheries and aquatic habitat enhancement projects, as well as associated statutory and regulatory compliance requirements, will remain the responsibility of individual project proponents.

The relationships between goals, objectives, project selection, implementation, monitoring and assessment for project-specific actions are very similar to those discussed for the river-wide adaptive management process.

7.1.6. DATA REVIEW AND EVALUATION

Data review and evaluation will be part of a structured process involving the same elements as listed earlier for prioritizing objectives (Section 7.4.3). As part of the evaluation process, monitoring results (data) should be reviewed to determine whether the management actions or individual projects are meeting the stated goals of the project and FISH Plan. Based on these results, in instances where stated goals are not being met, management actions or project activities may be adjusted or modified to more closely obtain the desired outcome and meet goals.

7.1.7. PERFORMANCE EVALUATION/FEEDBACK

A crucial element of the adaptive management process is the phase of activity that evaluates the various monitoring data and then translates those results into revised management actions or project activities. Ideally, project-specific conceptual models and hypotheses will guide the modified or newly defined action. If the relationships were clearly understood, then prescriptions for revisions to the actions could be developed in advance. For some projects, development of these types of protocols may be possible. However, the nature of adaptive management for the lower American River fish and aquatic habitat restoration program is such that it is unlikely that originally intended outcomes will be obtained precisely. Thus, there will be a need to bring together the appropriate technical resources to re-appraise selected management actions given the new knowledge generated by monitoring and data evaluation.

For the lower American River, those resources include the representatives of the agencies and stakeholder community as well as ad hoc input from outside specialists. The effort can be expected to include re-appraising and modifying the conceptual models and the assumptions relative to causal relationships and limiting factors. The group would identify new and/or modified recommended management actions and projects, as well as supportive modeling and/or monitoring approaches. Open exchange and dialogue between the reviewers is critical to ensure technical and restoration progress, and documentation is important to provide future review and feedback. Special meetings of the technical committee will be facilitated to ensure effective exchange and focus within this phase. The focus of meetings may address individual projects, but the discussion must also integrate the findings related to the individual management actions with other watershed and/or regional actions.

ANNOTATED OUTLINE FOR THE RIVER-WIDE ECOLOGICAL AND BIOLOGICAL MONITORING PLAN

The FISH Plan's River-wide Monitoring Plan focuses on five fish species of priority management concern including fall-run chinook salmon, steelhead, splittail, American shad, and striped bass. Special emphasis has been placed upon the first three species to facilitate compliance with ESA and CESA, and to be consistent with state and federal restoration plans, as discussed in Chapter 1. Improvement of habitat conditions for fall-run chinook salmon, steelhead and splittail likely will enhance conditions for American shad and striped bass, as well as for native resident aquatic species.

The River-wide Monitoring Plan includes components developed to answer current hypotheses on the relationships between various stressors, and biological and ecological indicators, primarily as they relate to fall-run chinook salmon and steelhead. The monitoring components outlined in this section use established techniques and observations. Each component has been selected for incorporation into the initial FISH Plan because it meets one or more of the following: (1) encompasses the lower American River study area (i.e., are river-wide); (2) provides opportunity for evaluation of long-term population trends for priority fish species; (3) provides results that relate to the state of the river; or (4) allows for determination of river-wide trends.

The River-wide Monitoring Plan components will be adapted as resource management needs change and in response to the successes or failures of the study. They may, in some form, continue in perpetuity. With this in mind, it is noted that the objectives and actions of individual components may not be the sole responsibility of the LAR Task Force. As the River-wide Monitoring Plan components become more fully developed, entities responsible for funding, implementation, or other aspects of the plan will be identified. The River-wide Monitoring Plan components include:

- Water Temperature Monitoring

- River Hydrology Monitoring
- Adult Chinook Salmon Population Monitoring
- Spawning Gravel Condition Monitoring
- Chinook Salmon Spawning Monitoring (redd surveys)
- Juvenile Chinook Salmon Emigration Monitoring
- Adult Steelhead Spawning Monitoring (creel census and redd surveys, where possible)
- Juvenile Chinook Salmon and Steelhead Rearing Monitoring
- Hatchery Production Monitoring

Each of the monitoring components listed above will be fully developed in the River-wide Monitoring Plan to address the following topics:

- Objectives
- Actions
- Rationale
- Alternative hypotheses
- Experimental design
  - Evaluation approach
  - Survey location
  - Survey period
  - Sampling frequency
  - Survey procedure
  - Sampling controls
  - Data quality control, reporting, and storage
  - Analytical method
  - Equipment
  - Reporting procedure
- Personnel

The following sections provide an annotated outline of the River-wide Monitoring Plan and some detail regarding the objectives and actions associated with each component. The Adult Chinook Salmon Population Monitoring component (see Section 7.5.3) addresses all of the topics identified above to provide an indication of the degree of detail that ultimately can be expected for each of the River-wide Monitoring Plan components.

7.1.8. WATER TEMPERATURE MONITORING

The *Baseline Report* identified water temperature as an essential factor that has influenced and continues to influence lower American River fish species, in particular salmonids, at various stages of their lifecycles. Water temperature has been identified as a main stressor to chinook salmon and steelhead (anadromous salmonids) (see Chapter 4).

Water temperature has been recorded for a ten-year period (1990 to 2000) at eight different locations between RM 0.2 and RM 22.9 along the lower American River. However, although these historic water temperature records are extensive, there are data gaps in the time series of the eight locations. Such discontinuity in water temperature records, if allowed to persist, may hamper the adequate testing of current hypotheses relating water temperature and various biological indicators. It may obstruct a consistent and precise evaluation of responses to management actions and preclude the development of new hypotheses.

OBJECTIVES

Objectives for the Water Temperature Monitoring component are to:

- Make real-time adaptive management decisions to benefit fish resources (particularly species of concern) based on existing conditions including: season, water year type, Folsom Reservoir coldwater pool storage, Folsom Dam shutter configuration, and water demand.
- Develop long-range forecasts of water temperature needs and availability based on existing conditions including: season, water year type, Folsom Reservoir coldwater pool storage, Folsom Dam shutter configuration, and water demand.
- Continue recording lower American River water temperature in a consistent manner.
- Allow for the building of a continuous time series of daily water temperature records at (at least) three locations that are meaningful for the fish resources of the lower American River.
- Provide basic water temperature-related statistics (e.g., daily and monthly averages, variances, maxima and minima) that will serve as explanatory variables in hypothesis testing.
- Develop water temperature profiles for Folsom Reservoir and Lake Natoma.

ACTIONS

The actions listed below have been developed to implement the objectives of the Water Temperature Monitoring component.

- Collect water temperature measurements at a frequency, accuracy, and duration necessary to represent water temperature conditions experienced by fish and other aquatic life throughout the lower American River.
- Collect water temperature profile information from representative locations in Folsom Reservoir and Lake Natoma.
- Model temperature conditions along the lower American River under various combinations of potential conditions represented by different seasons, flow rates, and Folsom Dam shutter configurations.

7.1.9. RIVER HYDROLOGY MONITORING

Flow rates and fluctuations may affect chinook salmon and steelhead populations in various ways, including the timing of spawning and juvenile emigration. Additionally, sudden rapid changes in flow are known to affect egg survival and alevins by exposing redds, and affect the survival of juveniles that become stranded in pools and side channels with inadequate food sources and high competition and predation.

Adequate monitoring of flow rates along the lower American River will provide the basic data to test the influence of flow on spawning and juvenile emigration, as well as on redd dewatering and juvenile stranding.

OBJECTIVES

Objectives for the River Hydrology Monitoring component are to:

- Develop a continuous and accurate record of representative hourly and daily flow rates at USGS gauges (Folsom Dam, Goethe Park, and the north and south forks of the American River).
- Utilize various flow metrics in developing and evaluating biological and ecological functional relationships of the lower American River.

ACTIONS

The actions listed below have been developed to implement the objectives of the River Hydrology Monitoring component.

- Collect accurate and consistent flow rate measurements of necessary frequency, accuracy, and duration at specified locations to represent flow conditions experienced by fish throughout the lower American River.
- Report hourly, daily, weekly, and monthly flow rates for the identified USGS gauges.
- Collect and report flow-stage levels in the lower American River at sufficient sites to further develop and evaluate functional relationships and guide resource management actions.

7.1.10. ADULT CHINOOK SALMON POPULATION MONITORING

Adult abundance, which is referred to as "escapement" for chinook salmon populations, is usually estimated by carcass surveys. The primary purpose of this monitoring is to assess the overall effectiveness of management activities and restoration programs. To accomplish this, accurate escapement estimates are required and the age distribution of the adult fish must be known so that adult abundance can be segregated into broods (i.e., year classes) that correspond to a particular in-river residence period. Current adult monitoring efforts do not entirely meet these requirements.

The accuracy of carcass surveys is of concern as the surveys may not be conducted in a consistent manner and, for safety reasons, cannot be conducted during high flows. Additionally, although samples of fresh carcasses have been collected, often weekly, since 1992, there is concern regarding the extent to which these samples permit a rigorous assessment of the age distribution of spawning adults, sex ratio, rate of successful spawning and pre-spawning mortality.

Although scale samples and often otoliths are collected during carcass surveys, there has not been any up-to-date determination of age distribution of chinook salmon spawning in the lower American River. Instead, either a standard length (e.g., 65 cm) is used to distinguish Age 2 and Age 3+ salmon, or length frequency analyses are used to determine the age of the fish. The standard length method is not consistently accurate and there is uncertainty regarding length-frequency analyses without verification with scales or otoliths. Additionally, males and females of the same age may be different lengths.

Although sex ratio and female spawning rate are currently assessed from samples of fresh carcasses collected during the carcass surveys, there is uncertainty regarding whether these estimates correctly reflect the entirety of the spawning period. For example, weekly carcass samples may not cover the entire spawning period. Moreover, weekly samples occasionally are too small or not proportional to the number of observed fresh carcasses. There also is an unknown degree of imprecision in the visual classification of female carcasses into egg retention classes [“not spawned” (e.g., nearly full ovaries), “partially spawned” (e.g., more than 50 percent egg retention) and “fully spawned” (e.g., few eggs remaining)]. Finally, there is uncertainty regarding the degree to which the ratio of the number of un-spawned females to the number of female carcasses sampled during the survey accurately depicts pre-spawning mortality. In particular, female carcasses have been scarcely sampled during October to early November, when most pre-spawning mortality may occur.

The Adult Chinook Salmon Population Monitoring component would continue carcass surveys in the lower American River through the Spawning Escapement Survey and Carcass Biological Sampling efforts, described in the following sections.

SPAWNING ESCAPEMENT (CARCASS) MONITORING

Knowledge of the dynamics of fish populations is essential for developing appropriate management, restoration and monitoring plans or programs. In the present context of fish management, population dynamics include estimation of the changes in population numbers, composition or biomass. Population size can be estimated by numerous methods. Spawning surveys represent one means of establishing annual spawning run size. Estimating the total annual fall-run chinook salmon population in the lower American River is based on various factors including: (1) extent of spawning below Watt Avenue; (2) extent of spawning above the Nimbus Hatchery training weir; (3) extent of fish passage into the Nimbus Hatchery; (4) amount of angler catch; (5) impingement on the Nimbus Hatchery training weir; and (6) unknown causes of fish disappearance.

Numerous estimation procedures and protocols have been used since 1944 (i.e., expansion of direct counting, Peterson method, Schaefer method, and Jolly-Seber method). Since 1976, CDFG has used fresh carcasses and a modified Schaefer method to estimate annual chinook salmon population size. However, carcasses surveys have not always been implemented with consistency for a representative period, thus a significant degree of uncertainty is associated with the Schaefer estimates of fall-run chinook salmon spawning population and the hypotheses associated with these abundance estimates.

Objectives

Objectives for the Spawning Escapement (Carcass) Monitoring of the Adult Chinook Salmon Population Monitoring component are to:

- Accurately assess the population status of fall-run chinook salmon naturally spawning in the lower American River.
- Provide continuity in the analysis of population trend abundance. In the lower American River, chinook salmon carcasses have been monitored since 1944, and since 1974 the Schaefer method has been utilized to assess escapement.

- Provide potential response variables to assess the impact of various stressors (e.g., lower American River water temperatures and flows) and management actions.
- Assess contribution of hatchery-reared chinook salmon and chinook salmon from other rivers to the population of fall-run chinook salmon naturally spawning in the lower American River.
- Assess the effect of water turbidity on carcass counts and Schaefer escapement estimates.
- Contrast escapement estimates based upon total and fresh carcasses with Schaefer method estimates.
- Evaluate spawning timing and relationship to water temperature.

Actions

The actions listed below have been developed to implement the objectives of the Adult Chinook Salmon Population - Spawning Escapement (Carcass) Monitoring component.

- Estimate total escapement of adults and grilse, by reach, using the Schaefer method.
- Count, record and report all observed fresh and decayed carcasses by date, week, reach and survey.
- Record and report water turbidity by date and sampling site.
- Count carcasses with other marks/tags and record type of mark/tag.
- Remove snout from adipose-clipped carcasses observed and retain in individually labeled plastic bags for later detection, removal and decoding of coded-wire tags.

Rationale

Annual Schaefer estimates of adults and grilse chinook salmon will allow the time series of Schaefer abundance estimates started in 1974 to continue, and avoid the variability that the introduction of a new abundance estimation method might introduce in the analysis of the lower American River fall-run chinook salmon population trend. The counting and recording of all observed fresh and decayed carcasses will provide additional ways to estimate relative abundance and check trends or relationships with stressors detected using only Schaefer abundance estimates. If carcass surveys are performed every year from October 1 to January 31, the cumulative fresh and total carcass counts may provide a consistent way to assess spawning timing. Moreover, weekly estimates of water turbidity at the survey sites will provide a way to quantify effects on tag recovery rate and carcass observations that may influence the accuracy of Schaefer abundance estimates and carcass counts. Recording of all carcasses with foreign marks or tags will aid in assessing hatchery-reared and stray salmon in the fall-run chinook salmon spawning population.

Alternative Hypotheses

Eight alternative hypotheses have been identified for the Spawning Escapement Abundance Monitoring.

Hypothesis A.1: The population of fall-run chinook salmon naturally spawning in the lower American River can be determined.

Hypothesis A.2: Total carcass counts (both fresh and decayed) show the same temporal trend as Schaefer escapement estimates.

Hypothesis A.3: The accuracy of carcass counts and/or Schaefer escapement estimates decreases with water turbidity.

Hypothesis A.4: The accuracy of carcass counts and/or Schaefer escapement estimates decreases with variable water flow rates.

Hypothesis A.5: Weekly carcass counts and/or Schaefer escapement estimates can accurately depict run timing.

Hypothesis A.6: High water temperatures from September through October delay spawning.

Hypothesis A.7: Adult chinook salmon time their upstream spawning migration into the American River in response to high flows rather than in response to major storm events (e.g., declining barometric pressure and air and water temperatures).

Hypothesis A.8: Hatchery-reared salmon as well as strays constitute a significant component of the population of fall-run chinook salmon spawning naturally in the lower American River.

Experimental Design

Survey Location

The lower American River from Sailor Bar (RM 22) to Watt Avenue (RM 9), divided into three reaches:

Reach 1 - Sailor Bar (RM 22) to Rossmoor (RM 18);
Reach 2 - Rossmoor to Goethe Park Footbridge (RM 14.5); and
Reach 3 - Goethe Park Footbridge to Watt Avenue (RM 9).

Survey Period

Every year carcass surveys would start on October 1 and end on January 31. A delayed start or early end of the survey (e.g., hazardous conditions due to high flows, unavoidable logistic problems) would be documented. The lack of observed carcasses in early October does not constitute a cause for delaying the start of the survey because counts of zero observed carcasses are extremely important when assessing spawning timing.

Sampling Frequency

Weekly carcass counting and tag recovery would be performed in each river reach during the entire survey period (18 weeks). Fresh carcass tagging would be performed during the first 16 weeks of the survey period. No tagging would be performed during the last two weeks of the survey period to ensure recovery of all tagged carcasses.

Survey Procedure

The survey procedure would include the following activities:

- Count and tag all fresh carcasses with color-coded hog ring in lower jaw. Fresh carcasses have either one clear eye or pink gills. Carcasses that do not satisfy these conditions are non-fresh or decayed. Tag color-coding may allow identification of tagging week and site (i.e., reach). If, on a particular sampling date, no fresh carcasses are found, the sampling date and site and a count of "zero" would be recorded.
- Return fresh carcasses to flowing water just upstream from where they were collected, and record numbers tags, color code of tag, release date and site (i.e., reach).
- Count and record expected age class (e.g., grilse, adult) of non-fresh carcasses, record observation date and site (i.e., reach) and cut through backbone with machete to remove from future surveys. If on a particular sampling date no decayed carcasses are found, the sampling date and site, and a count of "zero" would be recorded.
- Record water turbidity using a Secchi disc. There would be two measurements per tagging/recovery date and sampling reach. Measurements would be taken at the start and end of the sampling event. Record date, time, site and Secchi-disc depth.
- Record recovered tagged carcasses, age class (grilse or adult), date and site of recovery and color code of tag; cut recovered carcasses through backbone to remove from future surveys.
- Count carcasses with other marks/tags and record numbers recovered, date, site and type of mark/tag.
- Remove snout from adipose-clipped carcasses and retain in individually labeled plastic bags for later detection, removal and decoding of coded-wire tags. Plastic-bag labels should indicate date, site (i.e., reach) of recovery and fork length of carcass.

Data Quality Control, Reporting and Storage

After each sampling week, field and data-entry personnel would check field-recorded data for errors. Survey data would be stored in individual electronic files. Files would contain all raw information and will be in ASCII, comma-separated variable format. The following information would be identified:

- Sampling date;
- Number of adult decayed carcasses counted and chopped by reach (entry of "zero" if no decayed carcass was observed);
- Number of grilse decayed carcasses counted and chopped by reach (entry of "zero" if no decayed carcass was observed);
- Number of fresh carcasses tagged and released by reach (entry of "zero" if no fresh carcass was released);
- Color of tag(s) on released fish;
- Number of fresh carcasses recovered and chopped by reach and color-coding tag;
- Number of carcasses with foreign tags/marks by reach and foreign tag/mark type;
- Number, reach and fork length of recovered, adipose-clipped carcasses whose snouts have been collected;
- Time and value of first Secchi-disc measurement, by reach; and

- Time and value of second Secchi-disc measurement, by reach.

Files would be checked for errors a final time before making them available for analysis. Files would be available no later than three months after the end of the survey (i.e., April 30 if the survey ended on January 31).

Analytical Method

The Schaefer mark-recovery method (Schaefer 1951[1]) as modified by Taylor (1974[2]) would be applied to the tagged and recovered fresh carcasses and total number of carcasses counted (both fresh and decayed) to produce escapement estimates. Escapement would be estimated for the entire survey and for each reach and recovery week.

Equipment

Equipment necessary to perform the surveys includes the following items: drift boat, gaffs, hog rings, pliers, colored surveying tape, machetes, data-recording slates, tape measures, knives, plastic bags, recovery labels for adipose-clipped fish, and Secchi disc.

Reporting Procedure

Every year, CDFG would prepare a final report presenting the results of the annual carcass survey. The report would be prepared no later than six months after the end of the survey (i.e., July 31 if the survey ended on January 31). The report would include the results of the spawning escapement monitoring and the carcass biological sampling.

Report contents corresponding to spawning escapement abundance monitoring would include:

- Brief introduction.
- Description of sampled reaches (including date on which each reach was sampled). Any specific modification made to the sampling protocol would be clearly stated and justified in the report.
- A data table indicating the total number of observed decayed carcasses, tagged fresh carcasses and recovered fresh carcasses by week (date), reach and age class (grilse or adult). If not all observed fresh carcasses were tagged, the observed number would be reported and an explanation of tagging procedure provided.
- Schaefer escapement estimates for the survey and for each reach.
- Periods for which estimates could not be obtained or were generated by means other than Schaefer estimation procedure (e.g., average recovery rates for weeks with no recovery).
- A summary table containing Schaefer model capture-recapture data matrix (e.g., Table 9a in Snider and Reavis 1996[3]).

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1 Schaefer, M. B. 1951. Estimation of size of animal populations by marking experiments. U.S. Fish and Wildlife, *Fishery Bulletin* 52 (69): 189-203.
2 Taylor, S. N. (ed.) 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. California Department of Fish and Game, Rep. No 74-12, 32 pp.
3 Snider, B. and B. Reavis, 1996. Lower American River Chinook Salmon Escapement Survey, October 1995 – January 1996. . California Department of Fish and Game, 17 pp. and 12 figures.

- Table(s) containing fall-run chinook salmon population estimates using Schaefer estimation method (e.g., Table 9b in Snider and Reavis 1996).
- Table(s) containing average flows, water temperatures and water visibility (i.e., average Secchi depths) per survey week. Daily flow discharges (cfs) would be obtained from the USGS gaging station at Fair Oaks (USGS# 11446500) and daily temperatures would be obtained from USGS stations at Hazel Avenue and Watt Avenue bridges.
- Table(s) containing the number of recovered adults and grilse with other marks/tags by survey week.
- Table(s) containing coded-wire tag data from recovered salmon, including coded-wire tag number(s), number of adults/grilse recovered, brood year, number of juveniles planted, release date, release site and hatchery of origin.

Personnel

CDFG would continue to conduct the carcass surveys, data reporting and storage, result reporting and distribution. CDFG also would train field crew on the survey and safety protocols. The field crew would be able to perform survey tasks in a consistent and efficient manner and would be able to differentiate fresh carcasses from decayed ones with the minimum possible error. CDFG also would provide personnel for data-entry and result reporting.

CARCASS BIOLOGICAL SAMPLING

Since 1992, CDFG has conducted biological sampling of fresh carcasses during the carcass surveys that provide Schaeffer escapement estimates. These biological samples have provided initial insight into the distribution of length, gender composition, and females spawning success of fall-run chinook salmon populations in the lower American River. The continuation of this sampling in a consistent manner would facilitate a better understanding of the composition and dynamics of the spawning population and test many of the related hypotheses. The goal would be to intensify the biological sampling of fresh carcasses performed in conjunction with the lower American River carcass surveys.

Objectives

Objectives for the Carcass Biological Sampling of the Adult Chinook Salmon Population Monitoring component are to:

- Assess the annual and weekly sex ratio of the population of fall-run chinook salmon naturally spawning in the lower American River.
- Assess the annual and weekly ratio of successfully spawned females in the population of fall-run chinook salmon naturally spawning in the lower American River.
- Evaluate annual and weekly pre-spawning mortality.
- Assess the length composition of the population of fall-run chinook salmon naturally spawning in the lower American River.
- Assess the age composition of the population of fall-run chinook salmon naturally spawning in the lower American River.
- Estimate adult escapement segregated into broods (i.e., year classes) that correspond to particular periods of in-river residence.

Actions

The actions listed below have been developed to implement the objectives of the Adult Chinook Salmon Population – Carcass Biological Sampling Monitoring component.

- Measure length, determine sex, and record representative samples of the fresh carcasses of fall-run chinook salmon observed during each week of the annual carcass surveys.
- Determine and record the egg-retention status of representative samples of fall-run chinook salmon fresh carcasses observed during each week of the annual carcass surveys.
- Collect representative samples of scales from the fresh carcasses of fall-run chinook salmon observed during each week of the annual carcass surveys.
- Analyze collected scales to determine age.
- Analyze the relationship between the age and length of the fresh carcasses of fall-run chinook salmon spawning in the lower American River.

Rationale

Although sex ratio and female rate of successful spawning have been assessed during past carcass surveys (1992-2000), there is uncertainty regarding whether the samples of fresh carcasses, on which these ratios are based, are representative enough to reflect annual and weekly changes in the ratios as the spawning season progress. It is expected that intensification in the weekly sampling effort will reduce this uncertainty and provide better annual and weekly estimates of sex ratio, as well as rate of successful spawning and pre-spawning mortality, which will allow a more rigorous testing of hypotheses A.1 through A.9 (stated below).

Although scale samples, and often otoliths, have been collected during past carcass surveys, there has not been any up-to-date determination of age distribution of chinook salmon spawning in the lower American River. Thus, any possibility of segregating adult abundance estimates into broods (i.e., year classes) that correspond to particular in-river residence periods has been hindered. The collection of representative scale and otolith samples during annual carcass surveying and an intensification in the age-determination effort is expected to allow the assessment of the age distribution of the population of fall-run chinook salmon spawning in the lower American River. In turn, the assessment of the age distribution of spawning adults will allow testing of hypotheses A.7 to A.10 (listed below), as well as provide key information regarding lower American River fall-run chinook salmon population dynamics.

Alternative Hypotheses

Alternative hypotheses identified for the Carcass Biological Sampling element are listed below.

Hypothesis A.1:	Annual pre-spawning mortality from thermal stress can be substantial.
Hypothesis A.2:	Annual pre-spawning mortality increases as the duration of elevated water temperature continues or increases.
Hypothesis A.3:	Pre-spawning mortality increases as water temperature increases during adult holding, through early November.
Hypothesis A.4:	As the spawning season progresses and water temperature decreases, pre-spawning mortality decreases (new fish enter the river population).
Hypothesis A.5:	Annual female spawning success ratio is dependent upon the water temperatures encountered from November though January.

Hypothesis A.6: There is no significant change in the annual sex ratio of fall-run chinook salmon naturally spawning in the lower American River.

Hypothesis A.7: As the spawning season progresses, there are significant changes in the weekly sex ratio of fall-run chinook salmon naturally spawning in the lower American River.

Hypothesis A.8: There are no significant changes in the annual contribution of Age 2, Age 3 and Age 4+ to the lower American River fall-run chinook salmon spawning population.

Hypothesis A.9: There is a significant long-term decline in the annual proportion of Age 3 and Age 4+ fall-run chinook salmon that spawn in the lower American River.

Hypothesis A.10: Adult escapement estimates by year-class show a significant relationship to the water temperature and flow conditions experienced by fall-run chinook salmon juveniles during their rearing and outmigration period.

Hypothesis A.11: The variation in adult escapement estimates by year-class responds only to biotic and environmental conditions, and the harvest experienced by the brood outside the lower American River, as opposed to in-river conditions.

Experimental Design

Sampling Location

The lower American River from Sailor Bar (RM 22) to Watt Avenue (RM 9), divided into three reaches:

Reach 1 - Sailor Bar (RM 22) to Rossmoor (RM 18);
Reach 2 - Rossmoor to Goethe Park Footbridge (RM 14.5); and
Reach 3 - Goethe Park Footbridge to Watt Avenue (RM 9).

Sampling Period

The sampling period will extend for 18 weeks, October 1 through January 31.

Sampling Frequency

Fresh carcass samples will be taken weekly from each reach over the course of the entire survey period (18 weeks).

Survey Procedure

The sampling procedure would include the activities described below.

- Measure fork length (to the nearest cm), determine sex, and record all fresh carcasses tagged weekly for the Schaefer mark-recapture method. If the number of fresh carcasses is so large that it would obstruct the Schaefer tagging process, take a random sample of no less than 500 fresh carcasses per week and reach.

- Classify and record all fresh female carcasses into egg-retention classes tagged weekly for the Schaefer mark-recapture method. If the number of fresh carcasses is so large that it would obstruct the Schaefer tagging process, take a random sample of no less than 500 fresh female carcasses per week and reach. Female egg-retention classes include: "not-spawned" (e.g., nearly full ovaries); "partially spawned" (e.g., more than 50 percent egg retention); and "fully spawned" (e.g., few eggs remaining).
- Collect scales from all fresh carcasses tagged weekly for the Schaefer mark-recapture method in individually labeled envelopes. Only if the number of fresh carcasses is as large as to obstruct the Schaefer tagging process, take a random sample of no less than 500 fresh carcasses per week and reach. The labels of the scale-envelopes should indicate date, collection site (i.e., reach), fork length and sex of carcass.
- Collect a random sample of at least 100 ovaries from all female carcasses recovered during the annual Schaefer mark-recapture survey. Keep ovaries in individually perforated labeled bags for later determination of degree of egg retention. Bags will be kept submerged in a plastic container with a mix of ethanol-formaldehyde. Bag labels should indicate date, collection site (i.e., reach), fork length, and egg-retention class assigned in the field to the female carcass.

Data Quality Control, Reporting and Storage

After each sampling week, field and data-entry personnel will check field-recorded data for errors. In particular, the labels of all bags and envelopes will be checked to ensure that all collected ovaries and scales are correctly identified. Data will be stored in individual electronic files. Files will contain all raw information and will be in ASCII, comma-separated variable format. Each row will correspond to a sampled carcass. Columns will identify:

- Sampling date;
- Reach;
- Fork length in cm (cells with missing values will be left blank);
- Sex code (Male = 1, Female = 2, Uncertain = 3, Missing gonads = 4, Not determined = blank);
- Field egg-retention code (Not spawned=0, Partially Spawned=1, Fully Spawned=2, Uncertain=3, Missing gonads=4, Not determined=blank);
- Ovary collected (Yes=1, No=0);
- Laboratory egg-retention percentage (indicate actual percentage of egg retention, if determined, or leave blank);
- Scale collected (Yes=1, No=0);
- First scale age reading (indicate age reading by first reader, otherwise leave blank);
- Second scale age reading (indicate age reading, otherwise leave blank); and
- Confirmed age (indicate age reading, if confirmed, otherwise leave blank).

Files will be checked for errors a final time before making them available for analyses. Age readings must be added at this time. Files will be available no later than six months after the end of the survey (e.g., January 31 if the survey ended on July 31).

Analytical Method

Collected ovaries will be examined in the laboratory using microscopy and commonly used histological procedures to determine the actual percentage of eggs retained in the ovaries.

At least 10 scales per length-class will be selected randomly from the pool of scales collected during the survey for age determination. Two readers will independently count the scale annuli and assess and report the age of each scale. After both readers have read all the selected scales, they will read them together and assign and record an age to each scale. The three readings will be entered in the survey files.

Equipment

Field Work Equipment List: Drift boat, gaffs, hog rings and pliers, colored surveying tape, machetes, data recording slates, tape measures, knife, plastic bags and envelopes for collected ovaries, scales and otoliths, labels for bags and envelopes and plastic container with a mix of ethanol-formaldehyde.

Laboratory Equipment List: Histological microscope and a scale-magnification device.

Reporting Procedure

Every year, CDFG will prepare a final report comprised of the results of the annual carcass survey. The report will be released no later than six months after the end of the survey (i.e., July 31 if the survey ended on January 31). The report will include both the results of the spawning escapement abundance monitoring, as well as the results of the carcass biological sampling.

Report contents corresponding to carcass biological sampling will include:

- Brief introduction.
- Description of sampled reaches detailing the dates on which each reach was sampled during the weekly surveys. Any specific modification to the sampling protocol must be clearly stated and justified. In particular, the sampling description would indicate during which weeks of the survey tagged fresh carcasses were not all sampled, indicating the number(s) sampled instead.
- A table showing the length frequency distribution of sampled fresh carcasses by 1-cm length-class, sex and river reach.
- Average fork length and standard deviation of sampled fresh carcasses per sex and river reach.
- Estimates of sex ratio and pre-spawning mortality for the entire survey.
- A report of any significant temporal trend detected in the weekly data (sex and pre-spawning mortality ratios).
- A table displaying the length frequency distribution of female “not-spawned,” “partially-spawned,” and “fully spawned” sampled females by 1-cm length-class. The table will be based on the classification made in the field. In addition, the table will indicate the number of sampled females that were not classified.

- A table summarizing the percentages of egg retention for the 100 collected ovaries analyzed in the histology laboratory.
- An estimate of the error of the field classification into the three egg-retention categories based on the comparison of the laboratory- and field-assigned egg-retention categories for the 100 collected ovaries.
- Three tables summarizing the length-age matrices based on the three scale-readings.
- Estimates of the total numbers and percentages of ages 2, 3, and 4 for the entire survey based on the length frequency distribution of sampled fresh carcasses and the three length-age matrices.

Personnel

CDFG will continue to conduct the carcass biological sampling, data reporting and storage, result reporting and distribution. CDFG also will train field crew on the survey and safety protocols. The field crew will be able to perform survey tasks in a consistent and efficient manner. They will be trained and able to differentiate fresh carcasses from decayed ones as well as determine female egg-retention categories with the minimum possible error. CDFG also will provide personnel for data entry, histological analysis of chinook female gonads, scale reading (i.e., age determination) and result reporting.

7.1.11. SPAWNING GRAVEL CONDITION MONITORING

Sediment supply is an important watershed attribute that contributes to stream channel meander and maintenance of riparian ecosystems and fish spawning areas. Gravel is an essential element of spawning and rearing habitats for fall-run chinook salmon, steelhead and other native fishes. Lack of sediment recruitment from upstream watersheds, ranging from fine sands to cobbles, may adversely influence the structural characteristics of the stream channel and impair spawning habitat (CalFed 2000).

Folsom and Nimbus dams block gravel recruitment on the lower American River. Although gravel supplies are not thought to currently limit salmonid production in the lower American River, they may become limiting in the near future. The long-term adverse effects of impaired upstream gravel recruitment have not been adequately investigated (CalFed 2000).

Objectives

Objectives for the Spawning Gravel Condition Monitoring component include:

- Develop spawning site preference/suitability criteria.
- Identify the rate at which suitable spawning gravels are depleted.
- Identify the rate at which suitable spawning gravels are replenished.
- Identify flow rates required to transport suitable spawning gravel.

Actions

The actions listed below have been developed to implement the objectives of the Spawning Gravel Condition Monitoring component.

- Conduct chinook salmon spawning activity observations (photograph redds at selected flows with on-the-ground verification).
- Analyze gravel composition and site characteristics of used spawning sites to develop site preference/suitability criteria.
- Identify unsuitable spawning gravels in known spawning areas and physically modify these gravels to mimic suitable spawning gravels.
- Assess spawning gravel storage in banks and monitor erosion rates and erosion composition.
- Survey spawning gravel bed mobility and transport rate.

7.1.12. CHINOOK SALMON SPAWNING MONITORING (REDD SURVEYS)

CDFG has conducted annual redd surveys based on aerial photography and ground reconnaissance surveys during the fall-run chinook salmon spawning period (October-January) since 1991. Aerial surveys were conducted regularly from 1991 to 1996. Survey activity was limited in 1997 and 1998, and was fully resumed in 1999. CDFG redd surveys help to hypothesize lower American River relationships between the temporal and spatial distribution of fall-run chinook salmon spawning activity and water temperature and flow.

Objectives

Objectives for the Chinook Salmon Spawning Monitoring component are to:

- Provide continuity to the analysis of the magnitude of spawning and the temporal and spatial distribution of fall-run chinook salmon spawning in the lower American River.
- Assess inter- and intra-annual trends in the temporal and geographic distribution of fall-run chinook salmon spawning in the lower American River.
- Assess inter- and intra-annual trends in the temporal and geographic distribution of redd superimposition in the lower American River.
- Provide validation to assessments of spawning magnitude and timing based on carcass abundance surveys.
- Test current hypotheses on the relationships between the temporal and spatial distribution of fall-run chinook salmon spawning activity, and water temperature and flow.
- Develop baseline information on the distribution of redds at various tested flows to ascertain redd-dewatering, linked to changes in flow.

Actions

The actions listed below have been developed to implement the objectives of the Chinook Salmon Spawning Monitoring component.

- Conduct weekly aerial photography surveys and ground reconnaissance surveys coinciding with ongoing chinook salmon carcass abundance surveys.
- Enumerate fall-run chinook salmon redds in the lower American River by geographic location, habitat type and river flow.

- Assess redd superimposition weekly and annually.

7.1.13. JUVENILE CHINOOK SALMON EMIGRATION MONITORING

Since 1992, CDFG has conducted juvenile fall-run chinook salmon emigration surveys by rotary screw trapping. The 1992 and 1993 studies dealt primarily with overcoming logistic problems inherent to rotary screw trap surveys. From 1994 to 1997, traps were fished during the chinook salmon emigration period, January through July. Starting in 1998, traps have been fished year-round. For most of these surveys, weekly mark-recapture studies have been conducted during peak emigration periods.

Since 1994, the annual rotary screw trap catch and capture efficiency estimates from the mark-recapture studies have provided the only relative abundance estimate of the fall-run chinook salmon emigration from the lower American River. Therefore, there is a need to continue, and possibly intensify, this monitoring effort.

Objectives

Objectives for the Juvenile Chinook Salmon Emigration Monitoring component are to:

- Continue analysis of fall-run chinook salmon emigration from the American River.
- Provide precise estimates of the annual abundance and timing of emigrating juveniles.
- Assess the size and age composition of the population of emigrating juveniles.
- Assess inter- and intra-annual trends in abundance, size and age composition of emigrating juveniles.
- Assess relationships between the abundance and timing of the emigrating juveniles and lower American River flow rates and water temperatures.
- Assess relationships between the abundance of the emigrating juveniles and the abundance of returning adults for the corresponding broods or year-classes.

Actions

The actions listed below have been developed to implement the objectives of the Juvenile Chinook Salmon Emigration Monitoring component.

- Continue rotary screw trap surveying at least during the fall-run chinook salmon emigration period.
- Conduct consistent daily mark-recapture studies during the fall-run chinook salmon emigration period to allow accurate estimates of rotary screw trap efficiency.
- Evaluate the relationship between rotary screw trap efficiency and daily flow rates.

7.1.14. ADULT STEELHEAD SPAWNING MONITORING (CREEL CENSUS AND REDD SURVEYS)

CDFG conducted steelhead redd counts only in 1991/92 (Snider and McEwan 1993), when flow and water conditions were favorable for visual observations. In that survey, it was reported that steelhead redds were too small to be consistently recognized in aerial photographs, leaving less efficient ground surveys to provide most steelhead redd data. There is a need to develop an efficient survey design for the evaluation of steelhead redds.

Creel census surveys have been conducted in past years to estimate steelhead in-river harvest rates as well as to assess the temporal and geographical distribution of wild and hatchery adult steelhead. Staley (1976) conducted intensive creel census surveys during the 1971-1972 and 1973-1974 steelhead sport fishing seasons, while Meyer (1981-1986) conducted censuses during the 1982-86 sport fishing seasons. Since April 1998, CDFG has continued creel census efforts on the American River. In addition to providing estimates of in-river harvest rates, recent creel census surveys have shown a predominance of steelhead without clipped adipose fins (presumably wild fish) through September. Steelhead with clipped adipose fins, on the other hand, appear to predominate from October through December. Establishing the cause for this observed distribution pattern will require the continuation and intensification of steelhead creel census surveys.

Objectives

Objectives for the Adult Steelhead Spawning Monitoring component are to:

- Develop an efficient survey for the assessment of steelhead redds.
- Initiate and continue full-scale analysis of the magnitude of spawning, and the temporal and spatial distribution of steelhead spawning in the lower American River.
- Assess inter- and intra-annual trends in the temporal and geographic distribution of steelhead spawning in the lower American River.
- Assess inter- and intra-annual trends in the temporal and geographic distribution of redd superimposition in the lower American River.
- Develop and test hypotheses on the relationships between the temporal and spatial distribution of steelhead spawning activity, and water temperature and flow, in the lower American River.
- Develop baseline information on the distribution of redds at various tested flows to ascertain redd-dewatering linked to changes in flow.
- Develop survey method for creek census.
- Assess inter- and intra-annual trends in abundance (creel census survey).

Actions

The actions listed below have been developed to implement the objectives of the Adult Steelhead Spawning Monitoring component.

- Design, conduct and compare weekly aerial photography surveys and ground reconnaissance surveys.
- Develop a method to integrate aerial and terrestrial redd counts in more precise estimates of redd counts.
- Enumerate steelhead redds in the lower American River by geographic location and habitat type.
- Assess redd superimposition weekly and annually.
- Design and implement a comprehensive creel census survey to determine catch per unit effort (CPUE) and develop metric of relative abundance based on these results.

7.1.15. JUVENILE CHINOOK SALMON AND STEELHEAD REARING MONITORING

CDFG has been conducting seining surveys and rotary screw trapping surveys to define the temporal and spatial distribution of salmonids and other fish in the lower American River from 1992 through 1999. CDFG has produced fish community survey reports through 1995. In addition, steelhead captured by seining are reported for 1998/97 in Snider and Titus (2000). Comparison of the catches taken by rotary screw traps and seining efforts suggest that both fishing devices are adequate to broadly represent the temporal distribution of juvenile steelhead.

Unfortunately, rotary screw traps do not appear to provide adequate estimates of juvenile steelhead abundance (Snider et al. 1997b). Results from a seining survey conducted concurrent with the 1994/95 screw trap survey demonstrated the screw trap's inability to capture the majority of steelhead juveniles. Substantially more young-of-the-year steelhead were captured by seining than were caught by the screw traps (1,231 vs. 27 fish), suggesting that few steelhead, if any, actively emigrate as YOY or that the traps did not catch them.

A continuous and simultaneous juvenile chinook salmon and steelhead monitoring effort using rotary screw trapping and other methods (i.e., seining, electrofishing, snorkeling and direct counting) would be required. This effort would enhance current knowledge of the geographical and temporal distribution of juvenile chinook salmon and steelhead rearing timing and the effects of environmental variables (i.e., flow, visibility) on the fishing efficiency of the devices used.

Objectives

Objectives for the Juvenile Chinook Salmon and Steelhead Rearing Monitoring component are to:

- Enhance the knowledge of the geographical and temporal distribution of chinook salmon and steelhead juveniles during rearing periods.
- Assess the relative capture/detection efficiency of various surveying methods (e.g., seining, electrofishing, snorkeling and direct counting, rotary screw trapping).
- Provide the best estimates of the annual abundance and timing of rearing juveniles.
- Assess the size composition and maturity of the population of rearing juveniles.
- Assess inter- and intra-annual trends in abundance, size and age composition of rearing juveniles.
- Assess relationships between the abundance, size and age composition, and timing of the rearing juveniles, and lower American River flow rates and water temperatures.

Actions

The actions listed below have been developed to implement the objectives of the Juvenile Chinook Salmon and Steelhead Rearing Monitoring component.

- Continue rotary screw trap surveying year-round.
- Conduct surveys using methods other than rotary screw trapping (e.g., seining, electrofishing, snorkeling and direct counting)
- Conduct consistent daily mark-recapture studies during the juvenile chinook salmon and steelhead rearing period to estimate relative detection/capture efficiencies for the methods identified in the objectives.
- Evaluate the relationship between relative detection/capture efficiencies and river conditions.

7.1.16. HATCHERY PRODUCTION MONITORING

An accurate determination of the hatchery-reared and released fish contribution to the total lower American River chinook salmon and steelhead spawning population and straying rates is not possible due to the lack of a constant fractional marking program for Central Valley hatcheries. The last constant marking programs implemented in Central Valley hatcheries ended in 1984 (program ran from 1978 to 1984). The absence of an estimate of hatchery-reared and released fish to the total lower American River chinook salmon and steelhead spawning population(s) precludes testing restoration success linked to hatchery releases in the Central Valley.

Objectives

Objectives for the Hatchery Production Monitoring component are to:

- Assess contribution of hatchery-reared and released chinook salmon and steelhead to the naturally spawning adult population.
- Assess survival rates of chinook salmon and steelhead fry relative to the naturally spawning adult population.
- Assess the age composition of the returning population of Nimbus Hatchery-released chinook salmon and steelhead.
- Assess straying rates of Nimbus Hatchery-released chinook salmon and steelhead.

Actions

The actions listed below have been developed to implement the objectives of the Hatchery Production Monitoring component.

- Tag/mark chinook salmon and steelhead reared and released from the Nimbus Hatchery.
- Tag/mark chinook salmon and steelhead reared and released from other hatcheries in the Central Valley.
- Collect, prepare and read scales from Nimbus Hatchery-reared and released chinook salmon and steelhead returning to Nimbus Hatchery.
-