2.1 Draft Analytical Approach

2.1.1 Introduction

This section describes the analytical approach used by NMFS to evaluate the effects of the proposed action on listed species under NMFS jurisdiction. The approach is intended to ensure that NMFS comports with the requirements of statute and regulations when conducting and presenting the analysis. This includes using the best available scientific and commercial information relating to the status of the species and critical habitat as well as the effects of the proposed action.

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of “to jeopardize the continued existence of a listed species,” which is “to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species” (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification", which “means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features” (81 FR 7214; February 11, 2016). We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action.
- Describe the environmental baseline in the action area.
- Analyze the effects of the proposed action on both species and their habitat using an “exposure-response-risk” approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors (1) reviewing the status of the species and critical habitat, (2) adding the effects of the action to the environmental baseline and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.
- Reach a conclusion about whether species are jeopardized or critical habitat is destroyed or adversely modified.
- If necessary, define a reasonable and prudent alternative to the proposed action.

The sub-sections of this chapter outline the specific conceptual framework and key steps and assumptions NMFS used to assess listed species jeopardy risk. NMFS also used them to assess critical habitat destruction or adverse modification risk. Wherever possible, these sections apply to all five listed species and associated designated critical habitats occurring in the action area. They include:

- Endangered Sacramento River winter-run Chinook salmon evolutionarily significant uint (ESU) (*Oncorhynchus tshawytscha*);
- Threatened Central Valley spring-run Chinook salmon ESU (*O. tshawytscha*);
- Threatened California Central Valley steelhead Distinct Population Segment (DPS) (*O. mykiss*);
- Threatened Southern DPS of North American green sturgeon (*Acipenser medirostris*);
- Endangered Southern Resident killer whale DPS (*Orcinus orca*);
- Designated critical habitats for listed salmonids;
- Designated critical habitat for Southern DPS of green sturgeon;
- Designated critical habitat for Southern Resident killer whale DPS.

The sub-sections of the analytical approach are:

- Section 2.1.2 describes the legal and policy framework provided by the ESA, implementing regulations, case law, and policy guidance related to section 7 consultations.
- Section 2.1.3 gives a general overview of how NMFS conducts its section 7 analysis. It includes various conceptual models of the overall approach and specific features of the approach. It also includes information on tools that we used in the analysis specific to this consultation. The section first describes our listed species analysis as it pertains to individual fish species and the physical, chemical, and biotic changes to the ecosystem caused by the proposed action. It then describes our critical habitat analysis.
- Section 2.1.4 discusses the evidence available for the analysis and related uncertainties. We describe the assumptions we made to bridge data gaps and allow analysis.
- Section 2.1.5 diagrams the overall conceptual approach in the assessment to address integration of all available information and decision frameworks to support our assessment of the effects of the proposed action.
- Section 2.1.6 discusses the presentation of all analyses within this opinion as a guide to locating results of specific analytical steps.

2.1.2 Legal and Policy Framework

Consultations designed to allow Federal agencies to fulfill the requirements of section 7 of the ESA conclude with issuing a biological opinion or a concurrence letter. For biological opinions, section 7 of the ESA, implementing regulations (50 CFR 402.14), and associated guidance documents (e.g., U.S. Fish and Wildlife Service and National Marine Fisheries Service (1998)) require opinions to present:

- a description of the proposed Federal action;
- a summary of the status of the affected species and its critical habitat;
- a summary of the environmental baseline within the action area;
- a detailed analysis of the effects of the proposed action on the affected species and critical habitat;
- a description of cumulative effects; and

- a conclusion as to whether it is reasonable to expect the proposed action is not likely to appreciably reduce the species' likelihood of both surviving and recovering in the wild by reducing its reproduction, numbers, or distribution or result in the destruction or adverse modification of the species' designated critical habitat.

The purpose of the jeopardy analysis is to determine whether appreciable reductions of both the survival and recovery of the species in the wild are reasonably expected, but not to precisely quantify the amount of those reductions. As a result, our assessment often focuses on whether an appreciable reduction is expected or not, but not on detailed analyses designed to quantify the absolute amount of reduction or the resulting population characteristics (absolute abundance, for example) that could occur as a result of proposed action implementation.

For this analysis, NMFS equates a listed species' probability (or risk) of extinction with the likelihood of both the survival and recovery of the species in the wild to conduct jeopardy analyses under section 7(a)(2) of the ESA. In the case of listed salmonids, we use the Viable Salmonid Population (VSP) framework (McElhany *et al.* 2000) as a bridge to the jeopardy standard. A designation of "a high risk of extinction" or "low likelihood of becoming viable" indicates that the species faces significant risks from internal and external processes that can drive it to extinction. The status assessment considers and diagnoses both internal and external processes affecting a species' extinction risk.

For salmonids, the four VSP parameters are important to consider because they are predictors of extinction risk. The parameters reflect general biological and ecological processes that are critical to the survival and recovery of the listed salmonid species (McElhany *et al.* 2000). The VSP parameters of productivity, abundance, and population spatial structure are consistent with the "reproduction, numbers, or distribution" criteria found within the regulatory definition of jeopardy (50 CFR 402.02) and are used as surrogates for "reproduction, numbers, or distribution." The VSP parameter of diversity relates to all three jeopardy criteria. For example, reproduction, numbers, and distribution are all affected when genetic or life history variability is lost or constrained, resulting in reduced population resilience to environmental variation at local or landscape levels.

NMFS notes the inclusion of recovery in the regulations implementing ESA section 7(a)(2) (50 CFR 402.02) (i.e., to "jeopardize the continued existence of" includes "engag[ing] in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listes species in the wild."_In 2014, NMFS finalized a recovery plan for the listed Central Valley salmon and steelhead species (National Marine Fisheries Service 2014); information from this plan is an example of best scientific and commercial data available and will therefore be incorporated into this consultation. A technical recovery team (TRT) that assisted in the recovery planning effort produced a "Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin" (Lindley *et al.* 2007). Along with assessing the current viability of the listed Central Valley salmon and steelhead species, Lindley *et al.* (2007) make recommendations for recovering those species. The framework was used to establish the current status of the listed Central Valley salmon and steelhead species, and both Lindley *et al.* (2007) and the recovery plan were used to evaluate whether the proposed action reasonably would be expected to "reduce appreciably the likelihood of both the survival and recovery of a listed species…."

Additional requirements for the analysis of the effects of an action are described in regulation (50 CFR 402). Our conclusions related to "jeopardize the continued existence of" and "destruction or adverse modification" generally require an expansive evaluation of direct and indirect consequences of the proposed action, related actions, and the overall context of the impacts to the species and habitat from past, present, and future actions as well as the condition of the affected species and critical habitat. (For example, see the definitions of "cumulative effects" and "effects of the action" in 50 CFR 402.02 and the requirements of 50 CFR 402.14(g)).

Recent court cases have reinforced the requirements provided in section 7 regulations that NMFS must evaluate the effects of a proposed action within the context of the current condition of the species and critical habitat, including other factors affecting the survival and recovery of the species and the functions and value of critical habitat. In addition, the courts have directed that our risk assessments consider the effects of climate change on the species and critical habitat and our prediction of the future impacts of a proposed action. NMFS acknowledges that the effects of climate change could have notable impacts on listed species while also recognizing the challenge in quantifying the effects. Conservation of protected resources becomes more difficult when considering a changing climate, especially when accounting for the relative uncertainty of the rate and magnitude of climate-related changes and the response of organisms to those changes. Accordingly, NMFS recently issued general policy guidance for treatment of climate change in ESA decisions (Sobeck 2016). This guidance aligns with case law noting the need to consider climate change in determinations and decisions despite the challenges of climate change uncertainty, and it provides policy considerations related to climate change that NMFS should use in ESA decision-making, including ESA section 7 consultations.

2.1.3 General Overview of the Approach and Models Used

NMFS uses a series of sequential activities and analyses to assess the effects of Federal actions on endangered and threatened species and designated critical habitat. These sequential activities and analyses are illustrated in Figure 2-1 for listed species and Figure 2-2 for critical habitat. The first analysis uses the identified action components and interrelated and interdependent actions that result from the action deconstruction to identify environmental stressors -- the physical, chemical, or biotic aspects of the proposed action that are likely to have individual, interactive or cumulative direct and indirect effects on the environment. As part of this step, we identify the spatial extent of both the action components and any potential stressors, recognizing that the spatial extent of the stressors may change with time. We note that the spatial extent of potential stressors may extend beyond the geographic area included in the project description (i.e., a project description of in-Delta operations may have effects that extend upstream; the spatial extent of those effects is traced as part of this analysis).

The next step in our series of analyses starts by identifying the threatened or endangered species or designated critical habitat that are likely to occur in the same space and at the same time as the potential stressors and their spatial extent. Then we estimate the nature of that co-occurrence to represent the individual exposure assessment. In this step, we identify the number and age (or life stage) of the individuals who are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent or the specific areas and physical and biological features (PBFs) or primary constituent elements (PCEs) of critical habitat that are likely to be exposed.

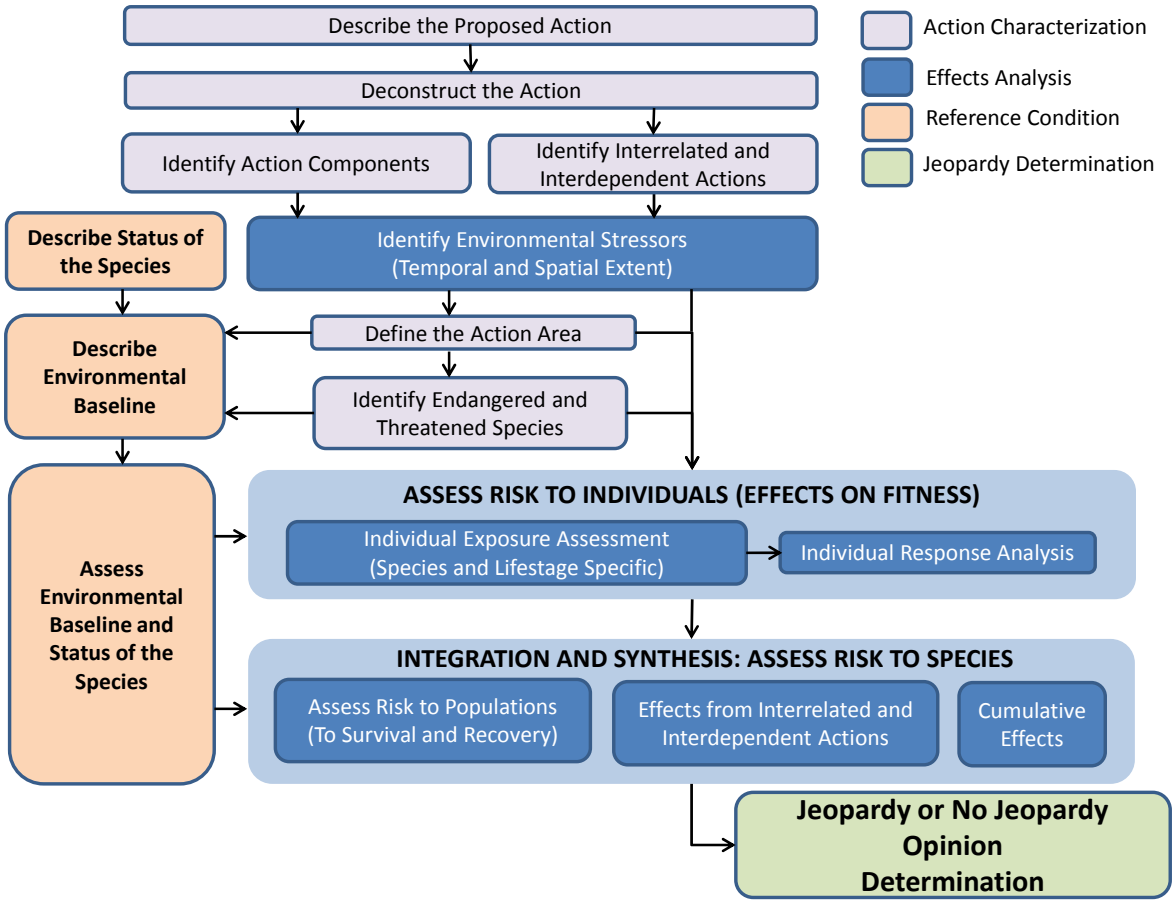

Figure 2- 1. General conceptual model for conducting section 7 analyses as applied to listed species.

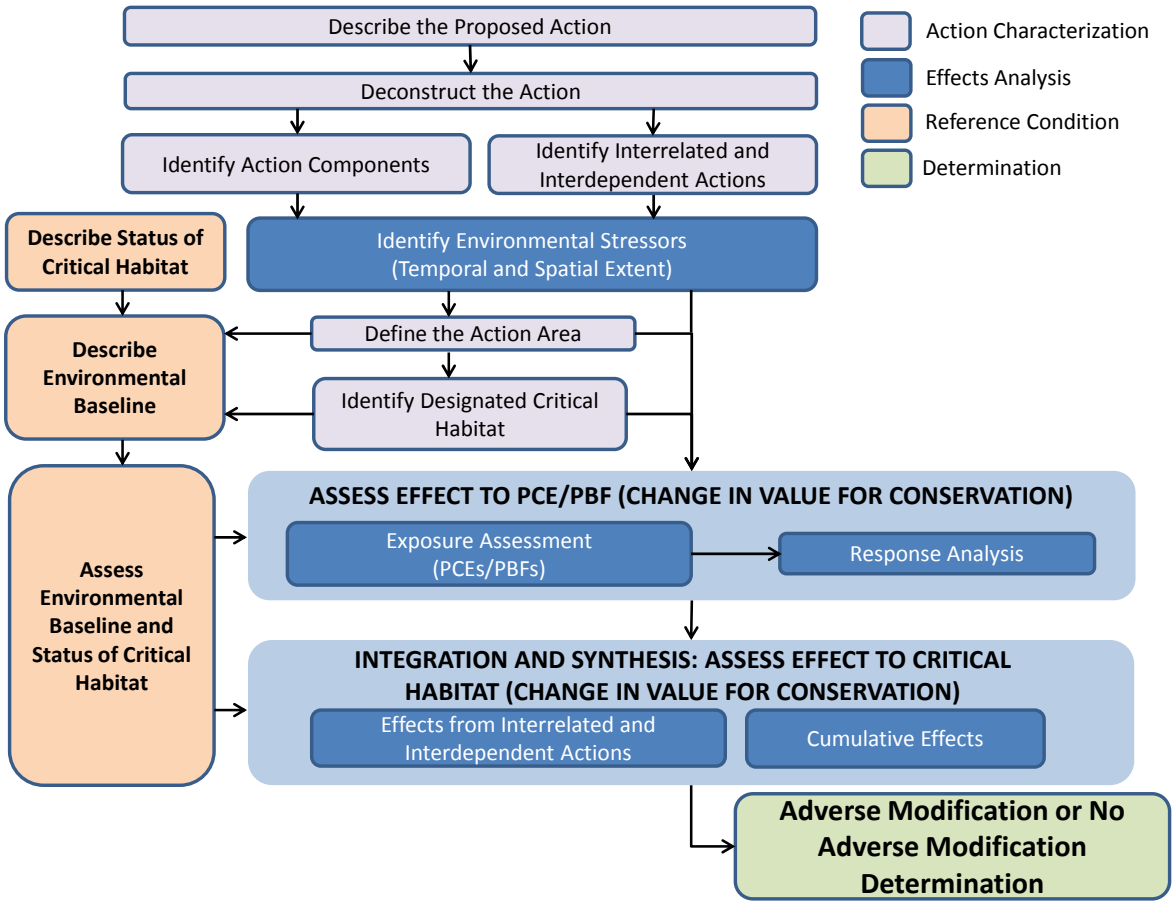

Figure 2- 2. General conceptual model for conducting section 7 analyses as applied to critical habitat.

Once we identify which listed resources (i.e., endangered and threatened species and designated critical habitat) are likely to be exposed to potential stressors associated with an action and the nature of the exposure, we examine the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure. This represents the individual response analysis. The final steps of our series of analyses establish the risks those responses pose to listed resources. These steps represent our risk analysis. They are different for listed species and designated critical habitat and are discussed in the following sections.

2.1.3.1 Application of the Approach to Listed Species Analyses

Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species and how those "species" have been listed (e.g., as true biological species, subspecies, or distinct population segments of vertebrate species). Because the continued existence of listed species depends on the fate of the populations that comprise them, the probability of extinction or probability of persistence of listed species depends on the probabilities of extinction and persistence of the populations that comprise the species. Similarly, the continued existence of populations are determined by the fate of the individuals that comprise them; populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our analyses reflect these relationships. We identify the probable risks that actions pose to listed individuals that are likely to be exposed to effects of the action. Our analyses then integrate the individuals' risks to identify consequences to the populations represented by the individuals (Figure 2-1). Our analyses conclude by determining the consequences of those population-level risks to the species that the populations comprise.

To measure risks to listed individuals, we use changes in the individual's "fitness" as a metric. "Fitness" can be characterized as an individual's growth rate, survival probability, annual reproductive success, or lifetime reproductive success. In particular, during the individual response analysis, we examine the scientific and commercial data available to determine if an individual's probable response to the effect of an action on the environment is likely to have consequences for the individual's fitness.

When individuals are expected to experience reduced fitness, we expect those reductions to also reduce the population abundance or rates of reproduction or growth rates (or to increase the variance in these rates) (Stearns 1992). Reductions in one or more of these variables is a necessary condition for increases in a population's probability of extinction, which is itself a necessary condition for increases in a species' probability of extinction.

If we conclude that listed plants or animals are likely to experience reductions in their fitness, our assessment attempts to determine if those fitness reductions are likely to increase the probability of extinction of the populations those individuals represent. This can be measured using changes in population abundance, reproduction rate, diversity, spatial structure and connectivity, growth rate, or variances in these metrics. In this step of our analysis, we use the population's reference condition (established in the Status of the Species section of this opinion) as our point of reference. Generally, this reference condition is a measure of how close a species is to extinction or recovery.

An important tool in this step of the assessment is a consideration of the life cycle of the species. The consequences on a population's probability of extinction as a result of impacts to different life stages are assessed within the framework of this life cycle and our current knowledge of the transition rates between stages, the sensitivity of population growth to changes in those rates, and the uncertainty in the available estimates or information. An example of a Pacific salmonid life cycle is provided in Figure 2-3, which shows the cycle of the upstream freshwater spawning, juvenile smolitification and outmigration, ocean residence, and upstream spawning migration. Though not identical, the life history of green sturgeon are similar (i.e., spawning in upstream freshwater locations, juvenile outmigration through the riverine and estuarine areas, long ocean residence before returning to upstream spawning areas), and we take a similar approach in analyzing effects to both salmonids and sturgeon.

Various sets of data and modeling efforts are useful to consider when evaluating the transition rates between life stages and consequences on population growth as a result of variations in those rates. These data are not available for all species considered in this opinion; however data from surrogate species may be available for inference. Where available, information on transition rates, sensitivity of population growth rate to changes in these rates, and the relative importance of impacts to different life stages is used to inform the translation of individual effects to population level effects.

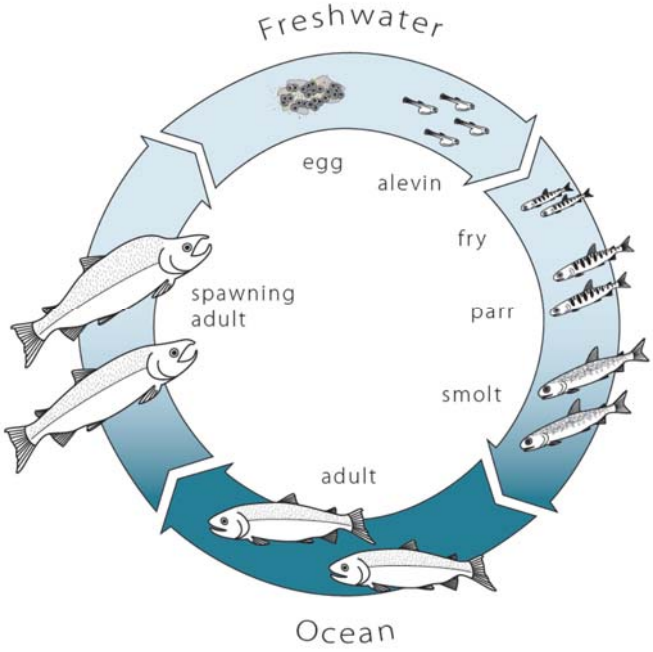

Figure 2- 3. Conceptual diagram of the life cycle of a Pacific salmonid. From (National Marine Fisheries Service 2016).

In addition, we recognize that populations may be vulnerable to small changes in transition rates. Small reductions across multiple life stages can be sufficient to cause the extirpation of a population. This is hypothetically illustrated in Figure 2-4 for two scenarios with different transition rates. For two adult salmon (a spawning pair) that produce 2000 eggs that then experience a 20 percent survival rate to the juvenile stage, a 10 percent survival to smoltification, and a 5 percent survival over several years at sea, two adult salmon will return to spawn again. However, if the survivorship is reduced to 18 percent at the juvenile stage, 8 percent at the smolt stage, and 4 percent at the sea stage, then only one adult salmon will return, leading to eventual extirpation if the trend continues.

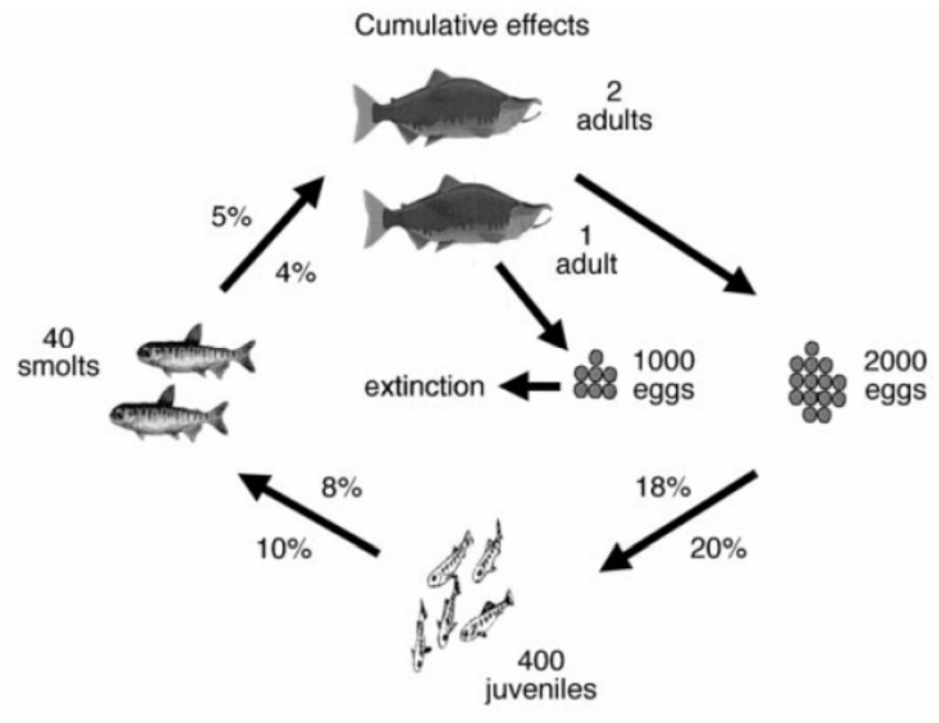

Figure 2- 4. Illustration of population vulnerability to small changes in transition rates (Naiman and Turner 2000).

Our assessment next determines if changes in population viability are likely to be sufficient to reduce the viability of the species those populations comprise. In this assessment, we use the species' status (established in the Status of the Species section of this opinion) as our point of reference. We also use our knowledge of the population structure of the species to assess the consequences of the increase in extinction risk to one or more of those populations. Our Status of the Species section discusses the available information on the structure and diversity of the populations that comprise the listed species and any available guidance on the role of those populations in the recovery of the species, noting that an action that is helping to implement recovery actions or strategies is less likely to jeopardize the species. An example of structure and diversity information used in this assessment is provided in Figure 2-5 for Central Valley spring-run Chinook salmon. This figure illustrates the historic distribution and structure of the species and notes those populations that have been extirpated. This information provides a sense of existing and lost diversity and structure within the species, which are important considerations when evaluating the recovery consequences of extinction risk or effects to current or potential habitat.

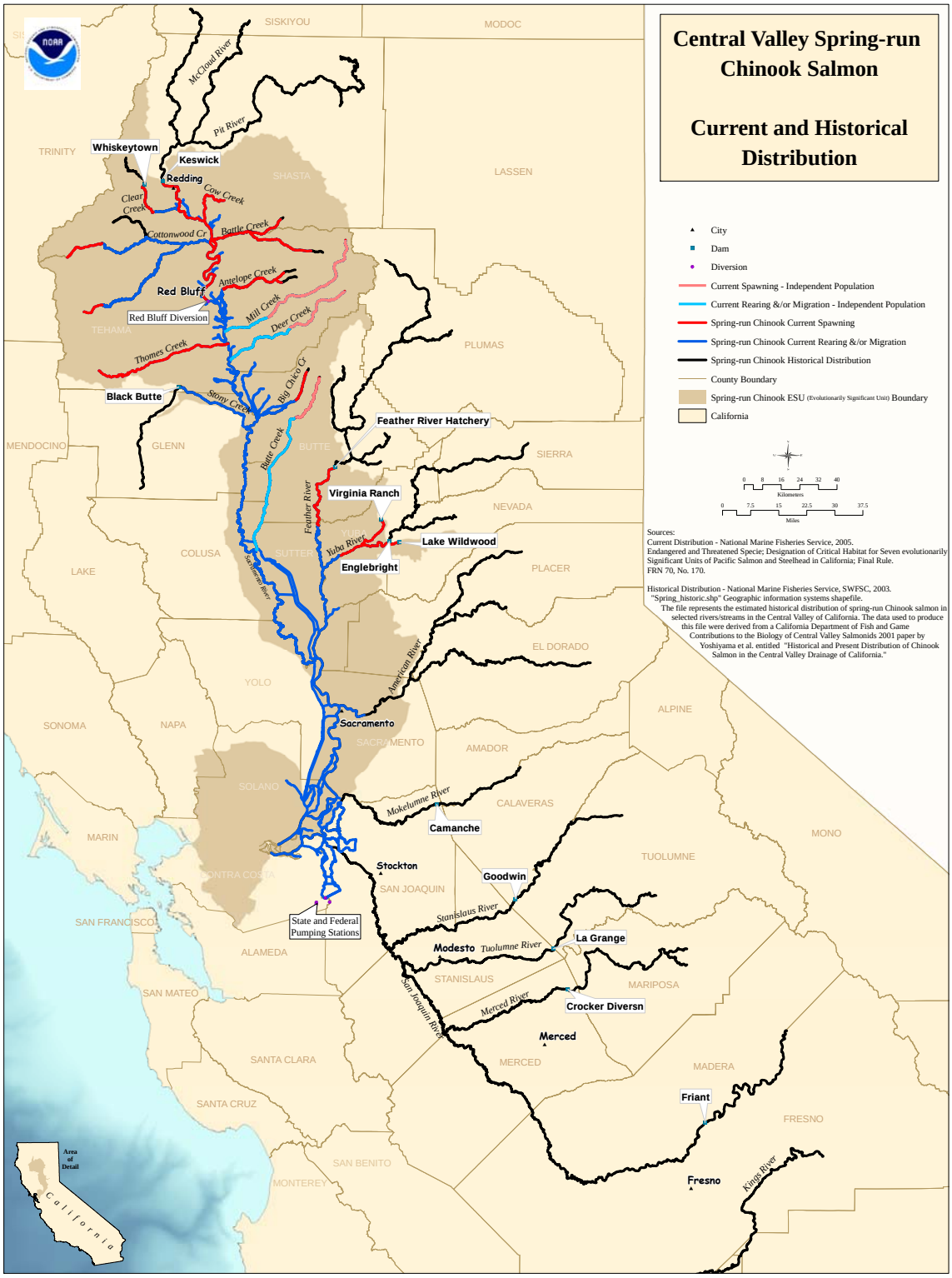

Figure 2- 5. Central Valley spring-run Chinook salmon ESU and current and historical distribution.

We used a set of tables to collect and evaluate the available information on the expected effects of each component action of the proposed action. These tables identify the stressor effect mechanism and the exposure, response, and risk posed to individuals of the species. Table 2-1 outlines the basic set of information we evaluated, and an example of the conceptual thought behind the information in the table is included in Box 1. We rank the effects to individuals on the basis of the severity of the predicted response and resulting fitness consequence within life stages.

Box 1: A example of the determination of effects to individuals of the species.

The first steps in evaluating the potential impacts a project may have on an individual fish would entail: (1) identifying the seasonal periodicity and life history traits and biological requirements of listed salmonids and sturgeon within the action area. Understanding the spatial and temporal occurrence of these fish is a key step in evaluating how they are affected by current human activities and natural phenomena; (2) identifying the main variables that define riverine or estuarine characteristics that may change as the result of project implementation; (3) determining the extent of change in each variable in terms of time, space, magnitude, duration, and frequency; (4) determining if individual listed species will be exposed to potential changes in these variables; and (5) then evaluating how the changed characteristic would affect the individual fish in terms of the fish's growth, survival, and/or reproductive success.

As an example, riverine characteristics may include flow, water quality, vegetation, channel morphology, hydrology, neighboring channel hydrodynamics, and connectivity among upstream and downstream processes. Each of these main habitat characteristics is defined by several attributes (*e.g.*, water quality includes water temperature, dissolved oxygen, ammonia concentrations, turbidity, *etc.*). The degree to which the proposed project may change attributes of each habitat characteristic will be evaluated quantitatively and/or qualitatively in the context of its spatial and temporal relevance. Not all of the riverine characteristics and associated attributes identified above may be affected by project implementation to a degree where meaningful qualitative or quantitative evaluations can be conducted. That is, if differences in flow with and without the proposed project implementation are not sufficient to influence neighboring channel hydrodynamics, then these hydrodynamics will not be evaluated in detail either quantitatively or qualitatively. The changed nature of each attribute will then be compared to the attribute's known or estimated habitat requirements for each fish species and life stage. For example, if water temperature modeling results demonstrate that water temperatures during the winter-run Chinook salmon spawning season (mid-April through mid-August) would be warmer with implementation of the proposed project, then the extent of warming and associated impact would be assessed in consideration of the water temperature ranges required for successful winter-run Chinook salmon spawning.

NMFS will then evaluate how the proposed project's effects on riverine characteristics may affect the growth, survival, and reproductive success of individual fish. For example, all of these metrics may be affected if the proposed project results in increased water temperatures during multiple life stages. Individual fish growth also may be affected by reduced availability, quantity, and quality of habitats (*e.g.*, floodplains, channel margins, intertidal marshes, *etc.*). Survival of an individual fish may be affected by suboptimal water quality, increased predation risk associated with non-native predatory habitats and physical structures, impeded passage, and susceptibility to disease. Reproductive success of individual fish may be affected by impeded or delayed passage to natal streams, suboptimal water quality (*e.g.*, temperature), which can increase susceptibility to disease, and reduced quantity and quality of spawning habitats. Instream flow studies (*e.g.*, instream flow incremental methodology studies) available in the literature, which describe the relationship between spawning habitat availability and flow, will be used to assess proposed project-related effects on reproductive success. All factors associated with the proposed project that affect individual fish growth, survival, or reproductive success will be identified during the exposure analyses.

Table 2-1. Example of information used to identify effects of the components of the proposed action to listed species.

Action Component	Life Stage/ Location	Life Stage Timing	Stressor	Response and Rationale of Effect	Magnitude of Effect (High, Medium, Low)	Weight of Evidence (High, Medium, Low)	Probable Change in Fitness

A key consideration in this assessment is the strategy of the NMFS recovery plan that "every extant population be viewed as necessary for the recovery of the ESUs and DPS," and that "wherever possible, the status of extant populations should be improved" (National Marine Fisheries Service 2014). Noted recovery actions include (but are not limited to) reintroduction of populations into key watersheds, completion of landscape-scale restoration throughout the Delta, restoring flows throughout the Sacramento and San Joaquin River basins and the Delta, reducing the biological impacts of exporting water through the CVP/SWF facilities, meeting established water quality criteria. Several of these actions could be affected by the proposed action and therefore could contribute to either recovery or jeopardy. Based on this recommendation, it was assumed that expected appreciable reductions in any population's viability due to implementation of the proposed action would also appreciably reduce the likelihood of survival and recovery of the population's diversity group and the ESU/DPS.

Table 2-2 is from NMFS section 7 ESA training materials and presents the basic set of outcomes associated with acceptance or rejection of the propositions used when evaluating effects of the proposed action. These follow a logical path and hierarchical structure that is used to organize the jeopardy risk assessment.

Table 2-2. Reasoning and decision-making steps for analyzing the effects of the proposed action on listed species. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment	True	End
		False	Go to B
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action	True	NLAA
		False	Go to C
C	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action	True	NLAA
		False	Go to D
D	Any responses are not likely to constitute "take" or reduce the fitness of the individuals that have been exposed.	True	NLAA
		False	Go to E
E		True	NLJ

	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent.	False	Go to F
F	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species.	True	NLJ
		False	LJ

The Viable Salmonid Populations Framework in Listed Salmonid Analyses

In order to assess the survival and recovery of any species, a guiding framework that includes the most appropriate biological and demographic parameters is required. This has been generally defined above. For Pacific salmonids, McElhany *et al.* (2000) defines a VSP as an independent population that has a negligible probability of extinction over a 100-year time frame. The VSP concept provides specific guidance for estimating the viability of populations and larger-scale groupings of Pacific salmonids such as ESU or DPS.

Four VSP parameters form the key to evaluating population and ESU/DPS viability: (1) abundance; (2) productivity (i.e., population growth rate); (3) population spatial structure; and (4) diversity (McElhany *et al.* 2000). These four parameters and their associated attributes are presented in Figure 2-6.

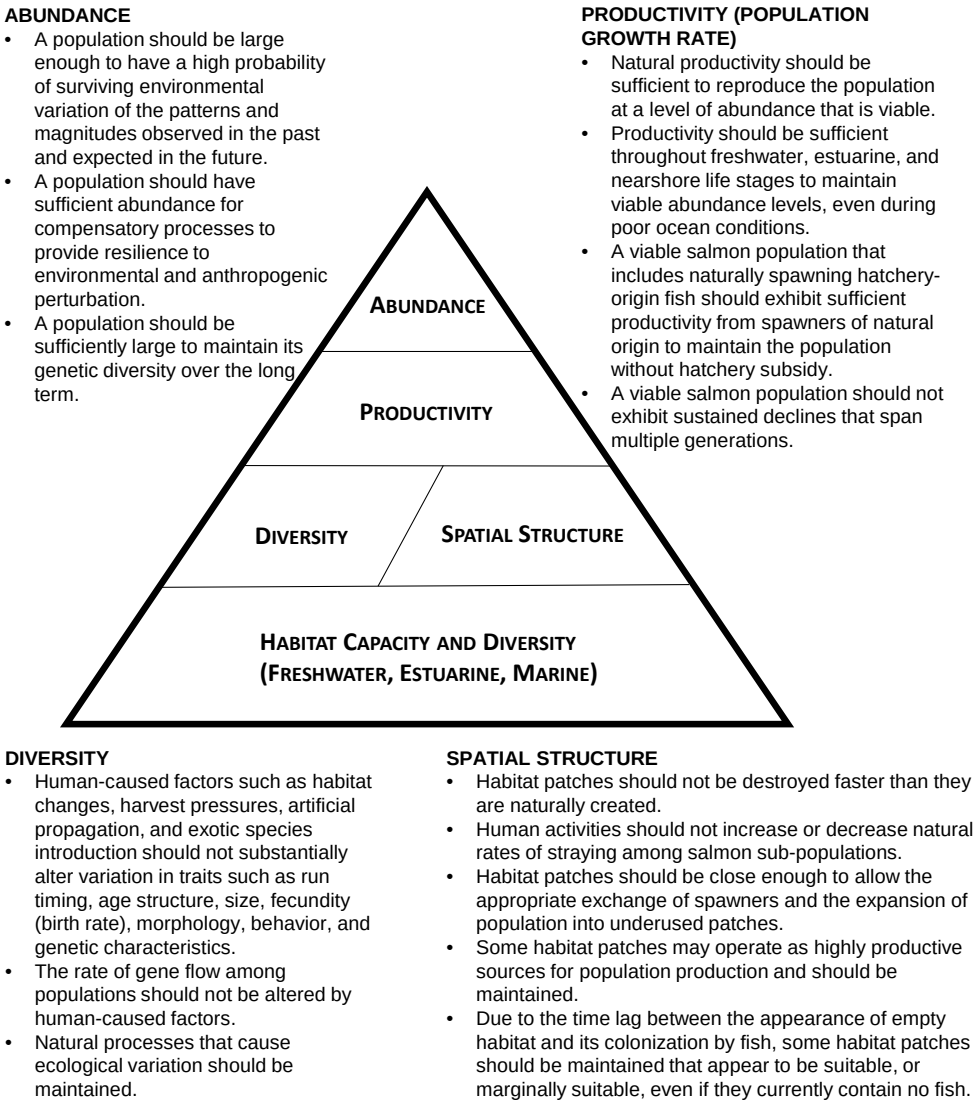

Figure 2- 6. Viable salmonid population (VSP) parameters and their attributes.

In addition to the four key parameters, the quality, quantity, and diversity of the habitat (habitat capacity and diversity) available to the species in each of its three main habitat types (freshwater, estuarine, and marine environments) is a foundation to VSP. Salmon cannot persist in the wild and withstand natural environmental variations in limited or degraded habitats. Therefore the condition and capacity of the ecosystem upon which the population (and species) depends plays a critical role in the viability of the population or species. Without sufficient space, including accessible and diverse areas the species can utilize to weather variation in their environment, the population and species cannot be resilient to chance environmental variations and localized catastrophes. Salmonids have evolved a wide variety of life history strategies designed to take advantage of varying environmental conditions. Loss or impairment of the species' ability to use these adaptations increases their risk of extinction.

As presented in National Marine Fisheries Service (2014), criteria for VSP are based upon measures of the VSP parameters that reasonably predict extinction risk and reflect processes important to populations. Abundance is critical because small populations are generally at greater risk of extinction than large populations. Stage-specific or lifetime productivity (i.e., population growth rate) provides information on important demographic processes. Genotypic and phenotypic diversity are important because they allow species to use a wide array of environments, respond to short-term changes in the environment, and adapt to long-term environmental change. Spatial structure reflects how abundance is distributed among available or potentially available habitats and can affect overall extinction risk and evolutionary processes that may alter a population's ability to respond to environmental change.

The VSP concept also identifies guidelines describing a viable ESU/DPS. The viability of an ESU or DPS depends on the number of populations within the ESU or DPS, their individual status, their spatial arrangement with respect to each other and to sources of potential catastrophes, and diversity of the populations and their habitat (Lindley *et al.* 2007). Guidelines describing what constitutes a viable ESU are presented in detail in McElhany *et al.* (2000). More specific recommendations of the characteristics describing a viable Central Valley salmon population are found in Table 1 of Lindley *et al.* (2007).

We nest the VSP concept within the hierarchy of the individual-population-diversity group-ESU/DPS relationships to evaluate the potential impact of proposed actions. For the species, the conceptual model is based on a bottom-up hierarchical organization of individual fish at the life stage scale, population, diversity group, and ESU/DPS (Figure 2-7). The viability of a species (e.g., ESU) is dependent on the viability of the diversity groups that compose that species and the spatial distribution of those groups; the viability of a diversity group is dependent on the viability of the populations that compose that group and the spatial distribution of those populations; and the viability of the population is dependent on the four VSP parameters and on the fitness and survival of individuals at the life stage scale. The anadromous salmonid life cycle (see Figure 2-3) includes the following life stages and behaviors, which are evaluated for potential effects resulting from the proposed action:

- adult immigration and holding
- spawning, embryo incubation
- juvenile rearing and downstream movement[1]
- smolt outmigration.

[1] The juvenile rearing and downstream movement life stage is intended to include fry emergence, and fry and fingerling rearing, which occurs both in natal streams and as these fish are moving downstream through migratory corridors at a pre-smolt stage. The distinction between juveniles and smolts is made because smolts have colder thermal requirements than juveniles that are not undergoing osmoregulatory physiological transformations.

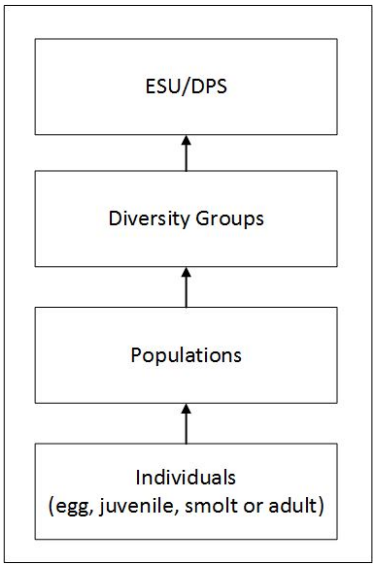

Figure 2- 7. Conceptual model of the hierarchical structure that is used to organize the jeopardy risk assessment for anadromous salmonids.

2.1.3.1.1 Approach to Southern DPS of Green Sturgeon

Although McElhany *et al.* (2000) specifically addresses viable populations of salmonids, NMFS believes that the concepts and viability parameters in McElhany *et al.* (2000) can also be applied to the Southern DPS of green sturgeon due to the general similarity in life cycle and freshwater/ocean use. Therefore, in this consultation, NMFS applies McElhany *et al.* (2000) and the viability parameters in its characterization of the environmental baseline and analysis of effects of the action to the Southern DPS of green sturgeon.

2.1.3.1.2 Approach Specific to Southern Resident Killer Whales

The General Overview of the Approach (section 2.1.3) and Application of the Approach to Listed Species Analysis (section 2.1.3.1) described above also apply to our approach for Southern Resident killer whales (Southern Residents). The Southern Resident DPS is a single population. The population is composed of three pods, or groups of related matrilines, that belong to one clan of a common but older maternal heritage (National Marine Fisheries Service 2008). The Southern Resident population is sufficiently small that the relative fitness of all individuals from each pod can influence the survival and recovery of the DPS. Southern Residents are known to prefer Chinook salmon as their primary prey (Ford and M. Ellis 2006, Hanson *et al.* 2010), and Southern Resident population dynamics have been shown to be well correlated with the abundance of Chinook populations over a broad scale throughout their range (Ward *et al.* 2013). Prior sections have discussed the analytical approach to assessing impacts to ESA-listed Chinook salmon. Similarly, an accompanying analysis of impacts to non-ESA-listed Chinook salmon will be performed as part of the Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat consultation provisions. Our analysis of effects to Southern Residents relies upon on the expected impacts of the proposed action on the abundance and availability of Chinook salmon for them, and how any expected changes in prey availability

will affect the fitness of Southern Residents and ultimately the abundance, reproduction, and distribution of the Southern Resident DPS.

2.1.3.2 Application of the Approach to Critical Habitat Analyses

The basis of the "destruction or adverse modification" analysis is to evaluate whether the proposed action affects the quantity or quality of the physical or biological features in the designated critical habitat for a listed species and, especially in the case of unoccupied habitat, whether the proposed action has any impacts to the critical habitat itself. Specifically, NMFS will generally conclude that a proposed action is likely to "destroy or adversely modify" designated critical habitat if the action results in an alteration of the quantity or quality of the essential physical or biological features of designated critical habitat, or that precludes or significantly delays the capacity of that habitat to develop those features over time, and if the effect of the alteration is to appreciably diminish the value of critical habitat for the conservation of the species (81 FR 7214, 7216; February 11, 2016) (It is noted that the concept of primary constituent elements has been replaced by the statutory term "physical or biological features" as of February 2016 (81 FR 7414; February 11, 2016). Our evaluation of the value of critical habitat for the conservation of the species entails assessing whether essential features are functioning to meet the biological requirements of a recovered species, or how far the features are from this condition. As a result, NMFS bases critical habitat analysis on the affected areas and functions of critical habitat essential for the conservation of the species, and not on how individuals of the species will respond to changes in habitat quantity and quality. If an area encompassed in a critical habitat designation is likely to be exposed to the direct or indirect consequences of the proposed action on the natural environment, we ask if physical or biological features (PBFs) or primary constituent elements (PCEs) included in the designation (depending on the designation) that give the designated critical habitat value for the conservation of the species are likely to respond to that exposure. In particular we are concerned about responses that are sufficient to reduce the quantity or quality of those physical or biological features or primary constituent elements or capacity of that habitat to develop those features over time.

To conduct this analysis, NMFS follows the basic exposure-response-risk analytical steps described in Figure 2-2 and applies a set of reasoning and decision-making questions designed to aid in our determination. These questions follow a similar logic path and hierarchical approach to the elements and areas within a critical habitat designation.

Table 2-3 is from NMFS section 7 ESA training materials and outlines the reasoning and decision-making steps in the determination of effects of the proposed action on designated critical habitat.

Table 2-3. Reasoning and decision-making steps for analyzing the effects of the proposed action on designated critical habitat. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment	True	End
		False	Go to B
B	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action	True	NLAA
		False	Go to C
C	The quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action	True	NLAA
		False	Go to D
D	Any reductions in the quantity or quality of one or more physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area	True	NLAA
		False	Go to E
E	Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species	True	No D/AD MOD
		False	D/AD MOD

Table 2-4 includes the collection of information used to evaluate the effects of components of the proposed action on critical habitat.

Table 2-4. Example of information used to identify effects of the components of the proposed action to critical habitat.

Action Component	Location of Effect	PCEs/Physical and Biological Features Affected	Response and Rationale of Effect	Magnitude of Effect (High, Medium, Low)	Weight of Evidence (High, Medium, Low)	Probable Change in Conservation Value

These tables allow us to determine the expected consequences of the action on primary constituent elements or physical and biological features, sort or rank the magnitude of those consequences, and determine whether areas of critical habitat are exposed to additive effects of the proposed action and the environmental baseline. We recognize that the value of critical habitat for the conservation of the species is a dynamic property that changes over time in response to changes in land use patterns, climate (at several spatial scales), ecological processes, changes in the dynamics of biotic components of the habitat, etc. For these reasons, some areas of critical habitat might respond to an exposure when others do not. We also considered how the primary constituent elements or physical and biological features of designated critical habitat are likely to respond to any interactions with and synergisms between cumulative effects of pre-existing stressors and proposed stressors.

At the heart of the analysis is the basic premise that the value of an overall critical habitat designation for the conservation of the species is the sum of the values of the components that comprise the habitat. For example, the value of listed salmonid critical habitat for the conservation of the species is determined by the value of the watersheds or other areas that make up the designated area. In turn, the conservation value of the watersheds or other areas is based on the quantity or quality of physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time in that area. Specifically, the Services will generally conclude that a Federal action is likely to "destroy or adversely modify" designated critical habitat if the action results in an alteration of the quantity or quality of the essential physical or biological features of designated critical habitat, or that precludes or significantly delays the capacity of that habitat to develop those features over time, and if the effect of the alteration is to appreciably diminish the value of critical habitat for the conservation of the species. The Services may consider other kinds of impacts to designated critical habitat. For example, some areas that are currently in a degraded condition may have been designated as critical habitat for their potential to develop or improve and eventually provide the needed ecological functions to support species' recovery. Under these circumstances, the Services generally conclude that an action is likely to "destroy or adversely modify" the designated critical habitat if the action alters it to prevent it from improving over time relative to its pre-action condition.

Therefore, reductions in the quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time may reduce the value of the exposed area (e.g., watersheds) for the conservation of the species, which in turn may reduce the value of the overall critical habitat designation for the conservation of the species. In the strictest interpretation, reductions to any one PBF or PCE could equate to a reduction in the value of the whole.

There are, however, other considerations. We look to various factors to determine if the reduction in the quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time would affect the value of the critical habitat for the conservation of the species. For example:

- The timing, duration and magnitude of the reduction.
- The permanent or temporary nature of the reduction.

We use the value for the conservation of the species of those areas of designated critical habitat that occur in the action area as our point of reference for our assessment of effects of the proposed action on designated critical habitat. For example, if the critical habitat in the action area has limited current value or potential value for the conservation of listed species, that limited value is our point of reference for our assessment of the consequences of the effects of the proposed action on the value of the overall critical habitat designation for the conservation of the species. In addition, we must determine whether reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are likely to *appreciably diminish* the overall value of critical habitat for the conservation of the species. A proposed action may adversely affect critical habitat in an action area without appreciably diminishing the value of critical habitat for the conservation of the species.

2.1.3.3 Characterization of the Environmental Baseline

ESA regulations define the environmental baseline as "the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR 402.02). The "effects of the action" include the direct and indirect effects of the proposed action and of interrelated or interdependent activities, "that will be added to the environmental baseline" (50 CFR 402.02). Consistent with these definitions, in *National Wildlife Federation v. National Marine Fisheries Service*, 524 F.3d 917, 929 (9th Cir. 2008), regarding NMFS' consultation on the effects of operating hydropower dams on the Columbia River, the Ninth Circuit Court of Appeals noted, "The 2004 BiOp initially evaluated the effects of the proposed action as compared to the reference operation, rather than focusing its analysis on whether the action effects, when added to the underlying baseline conditions, would tip the species into jeopardy." The court concluded that NMFS needed to consider the effects of the action in the context of the degraded baseline conditions when NMFS determined whether the proposed action would not jeopardize the continued existence of listed species. *Id*. at 929-31.

In the Environmental Baseline section, we summarize the past and present impacts leading to the current status of the species in the action area, including the effects of Central Valley Project and State Water Project (CVP/SWP) operations to date. The Environmental Baseline section also describes the future non-project stressors to which listed species and their critical habitats will be exposed. Therefore, as illustrated in Figure 2-9, the pre-consultation environmental baseline characterizes the effects of the combination of natural environmental variation, human impacts not associated with CWF or operations of the CVP/SWP, and impacts of the CVP/SWP as regulated by the 2008 USFWS and 2009 NMFS biological opinions on the CVP/SWP operations. Note that the figure blocks are illustrative of general categories of components of aggregation of effects in the analysis. The figure does not denote relative intensity of effect, or whether impacts are positive or negative; temporal variability of effect/impact is not depicted.

Implicit in both these definitions of environmental baseline and "effects of the action" is a need to anticipate future effects, including the future component of the environmental baseline. Future effects of Federal projects that have undergone consultation and of contemporaneous

State and private actions, as well as future changes due to natural processes, are part of the future baseline, to which effects of the proposed project are added.

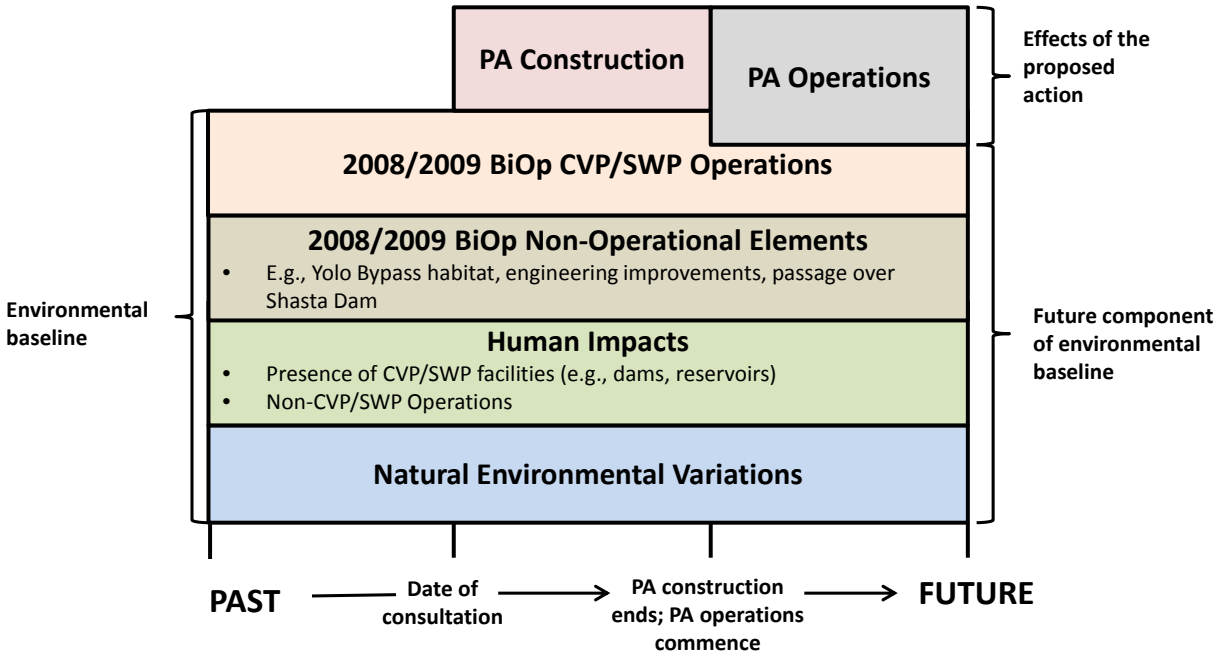

Figure 2- 8. A conceptual model of the effects of the proposed action (PA) added on top of the future component of the environmental baseline.

To consider the effects of the action in the context of environmental baseline conditions, the analysis considers future effects of Federal projects that have undergone consultation and of contemporaneous State and private actions, as well as future changes due to natural processes, along with the effects of the proposed project. Given the timeline of the proposed action and because it includes and on-going action (i.e., the future ongoing delivery of water), we analyze the entire suite of project effects (both construction- and operations-related) along with environmental baseline conditions in the future, which captures anticipated effects of non-project processes and activities. As presented in the project description of the BA, the proposed action includes Delta operations of the CVP/SWP in the future after construction of the new north Delta intakes. These future operations include modifications to some operations outlined in the 2008 USFWS and 2009 NMFS biological opinions on the CVP/SWP (i.e., CVP/SWP operations in the Delta); however, not all CVP/SWP operations are included in the CWF proposed action (i.e., CVP/SWP operations outside of the Delta). The facilities and operations included and not included in the proposed action are identified in Table 3.1-1 of the BA. Specifically, upstream operational criteria of CVP/SWP facilities at Trinity, Shasta/Keswick, Folsom, Oroville, New Melones, and Friant reservoirs are not included in the project description, and are considered part of the baseline for this analysis. Therefore, Figure 2-9 illustrates that the integrated analysis of effects of the proposed action in the future will include effects of operations governed by a combination of components of the 2009 NMFS biological opinion and the joint biological opinion issued by NMFS and USFWS for this proposed action.

2.1.4 Evidence Available for the Analysis

[Note: Since all cited evidence and data sources cannot be anticipated before completion of the consultation analyses, this section is expected to be revised and finalized with completion of the biological opinion. Revisions will include listing of all resources considered as well as a description of the literature searches completed in support of the analyses.]

The primary source of initial project-related information was the CWF BA. However, to conduct the consultation analyses, NMFS considered current literature and published information to provide a foundation for the analysis and represent evidence or absence of adverse consequences. In addition to a thorough review of up-to-date literature and publications, the following provides a list of resources that we considered in the development of our analyses:

- Final rules listing the species in this consultation as threatened or endangered;
- Final rules designating critical habitat for the Central Valley salmon and steelhead species, Southern DPS of green sturgeon, and Southern Resident killer whale DPS;
- Final rule describing the use of surrogates in Incidental Take Statements (80 FR 26832, May 11, 2015);
- Final rule defining destruction or adverse modification of critical habitat (81 FR 7214, February 11, 2016);
- CWF BA;
- NMFS 2009 biological opinions on CVP/SWP operations;
- NMFS recovery plan for Central Valley salmonids;
- Past independent peer reviews (i.e., of project operations, CVP/SWP biological opinions, and draft BDCP products);
- Scientific submissions related to State Water Resources Control Board (SWRCB) processes;
- Information included in CSAMP/CAMT process;

2.1.4.1 Primary analytical models

[Note: This section is expected to be revised and finalized with completion of the biological opinion. Revisions will include listing of all analytical methods used.]

The CWF BA includes a suite of models used in the analysis of the effects of the CWF proposed action. NMFS will rely primarily on these model results but at times will augment them with results from additional analytical methods. Figure 2-10 provides a schematic of information and results flow between the models; models specific to the biological opinion are denoted with an asterisk (*). Fundamental models used in the BA include:

- CalSimII: A hydrological planning scenario tool that provides monthly average flows for the entire SWP/CVP system based on an 82-year record.
- DSM2-HYDRO: One-dimensional hydraulic model used to predict flow rate, stage, and water velocity in the Delta and Suisun Marsh.
- DSM2-PTM: Simulates fate and transport of neutrally buoyant particles through space and time in the Delta and Suisun Marsh.

- HEC-5Q: Water quality simulation tool used to provide water temperatures for the Sacramento and American Rivers.
- DSM2-QUAL: Used to predict water temperature, dissolved oxygen, and salinity in the Delta and Suisun Marsh.
- Reclamation Egg Mortality Model: Uses CALSIM flow and climatic model output to predict monthly water temperature on the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.
- SALMOD: Predicts effects of flows on habitat value and quantity for all races of Chinook salmon in the Sacramento River.
- OBAN: A statistical modeling approach to evaluating scenarios effects to Sacramento Valley Chinook salmon populations.
- DPM: Simulates migration and mortality of Chinook salmon smolts entering the Delta from the Sacramento, Mokelumne, and San Joaquin Rivers through a simplified Delta channel network, and provides quantitative estimates of relative Chinook salmon smolt survival through the Delta to Chipps Island.
- IOS: A stochastic life-cycle model for winter-run Chinook salmon the Sacramento River.

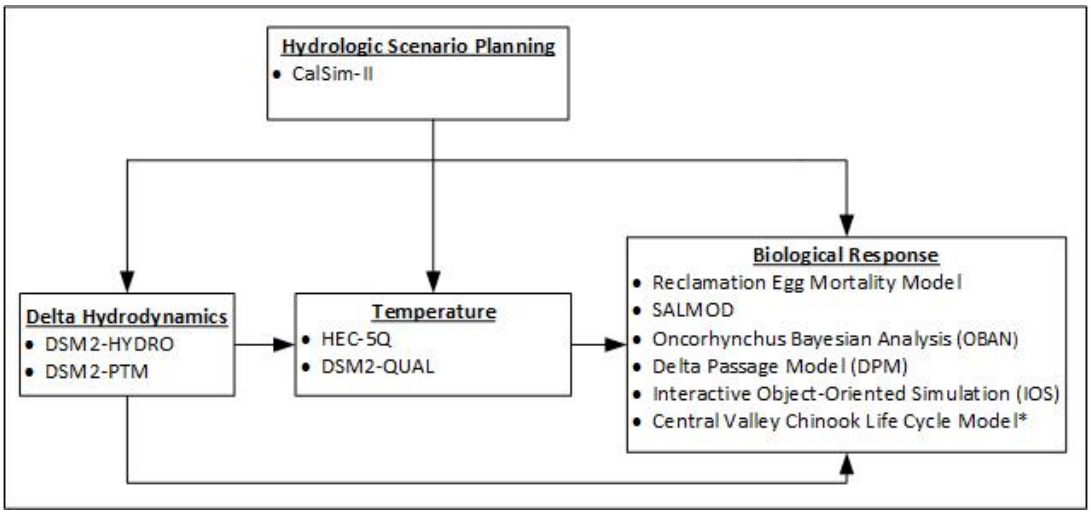

Figure 2- 9. Main models used in the development of the CWF BA and their information flow with respect to each other.

Though salmon life cycle modeling was not used in previous biological opinions on water project operations in the Central Valley (i.e.,National Marine Fisheries Service (2009)), NMFS has recognized the need to better integrate life cycle models into their assessments of the effects of water operations on the listed anadromous fish species. Peer reviews (Cummins *et al.* 2008, Anderson *et al.* 2009, National Research Council 2010) have all recommended increased use of life cycle modeling as part of the consultation analyses and have even provided general recommendations on how NMFS should proceed with further incorporating life cycle modeling into ongoing analyses (Rose *et al.* 2011).

In response, NMFS has developed a life-cycle modeling framework for Central Valley Chinook salmon that will be used in this consultation to allow better evaluation of how complex and interacting management actions affect salmon populations. Specifically, the analyses of this consultation include results from a model framework developed by the NMFS Southwest Fisheries Science Center to describe salmon population dynamics given water management, habitat restoration, and climate change scenarios (Hendrix *et al.* 2014). The framework relies upon standard Central Valley physical (i.e., CalSimII, DSM2, HEC-RAS) and chemical (i.e., temperature models, DSM2-QUAL) models to provide a characterization of abiotic conditions for a given scenario. A stage-structured population dynamics model of Chinook salmon links the habitat information to density-dependent stage transitions. These transitions describe the movement, survival, and reproduction that drive the dynamics of salmon populations.

2.1.4.2 Critical Assumptions in the Analysis

[Note: Since all assumptions cannot be anticipated before completion of the consultation analyses, this section is expected to be revised and finalized with completion of the biological opinion. Revisions will include listing of all key assumptions incorporated into the analyses.]

To address the uncertainties identified above related to the proposed action and the analysis provided in the CWF BA, NMFS established a set of key assumptions we would need to make to bridge the existing data gaps in the CWF BA that are critical to our analysis of effects. Table X provides the general assumptions that we made in filling those data gaps.

2.1.5 Integrating the Effects

The preceding discussions describe the various quantitative and qualitative models, decision frameworks, and ecological foundations for the analyses presented in this opinion. The purpose of these various methods and tools is to provide a transparent and repeatable mechanism for conducting analyses to determine whether the proposed action is likely to jeopardize the continued existence of the listed species or result in the destruction or adverse modification of designated critical habitat.

Many methods described above focus the analyses on particular aspects of the action or affected species. Key to the overall assessment, however, is an integration of the effects of the proposed action with each other and with the baseline set of stressors to which the species and critical habitat are also exposed (Figure 2-1 and Figure 2-2). In addition, final steps of the analysis require considering the effects of the action within the context of the reference (or without action) condition of the species and critical habitat as identified in the environmental baseline and status of species or critical habitat. That is, following the hierarchical approaches outlined above, NMFS integrates the effects of the action with the reference condition as the foundation to determine whether the action is reasonably expected to appreciably reduce the likelihood of both the survival and recovery of listed species in the wild and whether the action is likely to result in the destruction or adverse modification of critical habitat.

2.1.6 Presentation of the Analysis in this Opinion

Biological opinions are constructed around several basic sections that represent specific requirements placed on the analysis by the ESA and implementing regulations. These sections contain different portions of the overall analytical approach described here. This section is intended as a basic guide to the other sections of this opinion and the analyses that can be found in each section. Every step of the analytical approach described above is presented in this Opinion in either detail or summary form.

Description of the Proposed Action – This section basically summarizes the proposed Federal action and any interrelated or interdependent actions. This description is the first step in the analysis where we consider the various elements of the action and determine the stressors expected to result from those elements. The nature, timing, duration, and location of those stressors define the action area and provide the basis for our exposure analyses.

Status of the Species – This section provides the reference condition for the species and critical habitat at the listing and designation scale. For example, NMFS evaluates the current viability of each salmonid ESU/DPS given its exposure to human activities and natural phenomena such as variations in climate and ocean conditions, throughout its geographic distribution. These reference conditions form the basis for determining whether the proposed action is likely to jeopardize the continued existence of the species or result in the destruction or adverse modification of critical habitat. Other key analyses presented in this section include critical information on the biological and ecological requirements of the species and critical habitat and the impacts to species and critical habitat from existing stressors.

Environmental Baseline – This section provides the reference condition for the species and critical habitat within the action area. By regulation, the environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation (except the effects of the proposed action), and the impact of state or private actions which are contemporaneous with the consultation in process on the species and critical habitat. In this opinion, some analysis may be contained within the Status of the Species and Critical Habitat section due to the large size of the action area (which entirely or almost entirely encompasses the freshwater geographic ranges of some listed fish species). This section also summarizes the impacts from stressors that will be ongoing in the same areas and times as the effects of the proposed action. This information forms part of the foundation of our exposure, response, and risk analyses.

Effects of the Proposed Action – This section details the results of the exposure, response, and risk analyses NMFS conducted for effects of the proposed action on individuals of the listed species and physical or biological features or primary constituent elements and value for the conservation of the species of critical habitat within the action area. This will include the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Cumulative Effects – This section summarizes the impacts of future non-Federal actions reasonably certain to occur within the action area, as required by regulation. Similar to the rest of

the analysis, if cumulative effects are expected, NMFS determines the exposure, response, and risk posed to individuals of the species and features of critical habitat. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Integration and Synthesis of Effects – The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action to the environmental baseline and the cumulative effects, taking into account the status of the species and critical habitat, to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its reproduction, numbers, or distribution; or (2) appreciably diminishes the value of designated critical habitat for the conservation of the species.

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