5. Monitoring and Adaptive Management

Monitoring is necessary to assess recovery of coho salmon by determining if specific recovery criteria are met. Monitoring coho salmon and their habitat will provide data on the viable salmonid population (VSP) parameters (i.e., abundance, distribution, diversity, and productivity) and the severity of limiting factors (stresses) and threats (Crawford and Rumsey 2011). Adaptive management elements will provide a feedback loop for continuous scientific evaluation of the monitoring, recovery actions, and restoration elements of this recovery plan. Both monitoring and implementation of on the ground recovery actions must be flexible to changes in the environment, status of populations, new research results, and technological advances. Adaptive management will facilitate the use of the best available information to make appropriate adjustments.

Methods for collection of the adult and juvenile coho salmon data are described in Adams et al. (2011) (for California) and Stevens (2002) (for Oregon). Methods for assessing coho salmon habitat in Oregon are described in Rodgers et al. (2005). These documents describe the ability to characterize coho salmon and its habitat at different spatial scales. For the purposes of describing SONCC coho salmon and its habitat, the spatial scale to be characterized is the population. Sampling to achieve a coarser spatial scale (e.g., diversity stratum) would not provide the information needed to assess the status and trends of SONCC coho salmon. In addition, a minimum ability to detect change with a minimal certainty is required (Chapter 4); for example, spawner abundance estimates should achieve a coefficient of variation (CV) of 15% or less at the population level (Crawford and Rumsey 2011).

5.1.1 Information needed to delist a species

Evaluating a species for potential de-listing requires an explicit analysis of both the population or demographic parameters (the biological recovery criteria) and the physical or biological conditions that affect the species' continued existence, categorized under the five ESA listing factors in ESA section 4(a)(1) (listing factor or "threats" criteria). Together these make up the "objective, measurable criteria" required under the ESA (NMFS 2007b). Chapter 4 describes the objective, measurable criteria by which NMFS will determine whether the SONCC coho salmon ESU should be removed from the list of threatened and endangered species. Specifically, the information needed to assess the biological recovery criteria are detailed in Tables 4-1 and 4-2 of Chapter 4. The information needed to assess the limiting factor (stress) and threat abatement criteria are described in Tables 4-4 and 4-5 of Chapter 4. Information on the status of the VSP parameters and the status of the threats and listing factors (which include stresses) will be considered as part of NMFS' listing status decision framework, as shown in Figure 5-1.

NMFS ultimately bases a decision to de-list an ESU on a determination that it is no longer in danger of extinction or likely to become endangered in the foreseeable future. This determination must be based on an evaluation of both the ESU's status and the extent to which the threats facing the ESU have been addressed. The decision framework is designed to elicit the information needed to meet the statutory and regulatory requirements for de-listing (NMFS 2007b). NMFS recommends the monitoring described in this chapter to obtain the necessary information to evaluate the listing status of SONCC coho salmon. Other means to obtain this information may also be appropriate.

Monitoring Parameters of Viable Salmonid Populations (VSP)

Monitoring spawner abundance, juvenile distribution, diversity, and productivity is essential for assessing progress towards recovery, as well as tracking the status of SONCC coho salmon after delisting. Recovery-based monitoring should occur in four phases: initial, intermediate, delisting, and post-delisting. Sampling intensity should increase incrementally from the initial and intermediate phases to the delisting phase. The delisting phase monitoring data will be used to determine whether the delisting criteria are met. Monitoring needs are described for each population in Table 5-4 and Table 5-5.

The initial phase should begin as soon as possible in order to increase our understanding of the status of core populations within the ESU, and continue until the intermediate phase is triggered. Specifically, the intermediate phase may begin when the 12-year geometric mean abundance of approximately 50 percent of the core populations with life-cycle-monitoring (LCM) stations meet the low risk spawner threshold (e.g., 4 out of 7 populations meet the low risk spawner threshold). Alternatively, the intermediate phase may begin when the 12-year geometric mean abundance in all seven populations with LCM stations is at least 50 percent of the low risk spawner threshold for those populations. Use of a 12-year period is based on NMFS guidance (Crawford and Rumsey 2011). The delisting phase may begin when the 12-year geometric mean abundance of approximately 90 percent of the core populations meets the low risk spawner threshold (e.g., 16 out of 18 core populations meet their low risk spawner requirement; Chapter 4). Alternatively, the delisting phase could begin when the 12-year geometric mean abundance in all 18 populations with LCM stations is at least 90 percent of the low risk spawner threshold for those populations. The post-delisting phase may begin when the SONCC coho salmon ESU is delisted. All monitoring of adult and juvenile coho salmon should strive for an average coefficient of variation (CV) of 15 percent or less at the population level and should strive to detect a 15 percent change with 80 percent certainty (i.e., have high statistical power; Crawford and Rumsey 2011).

Life Cycle Monitoring Stations

Life Cycle Monitoring (LCM) stations are places where smolt and adult abundance are monitored. LCM stations are an integral component of monitoring for SONCC coho salmon. LCM stations can be used to: (1) estimate abundance of adult coho salmon and downstream migrating juveniles; (2) estimate marine and freshwater survival rates; and (3) track abundance of juveniles coincident with habitat modifications. These stations should be located and designed for complete counts of smolts and adults using weirs, fences, traps, live mark/recapture techniques, sonar, or other techniques. Adult counts may be used to calibrate spawning ground surveys used to estimate live adult abundance, redd abundance, and carcass abundance for the "abundance" VSP parameter. One LCM station should be monitored in each diversity stratum so that a regional estimate of freshwater survival is available for every diversity stratum, and a regional estimate of marine survival is available for every coastal diversity stratum.

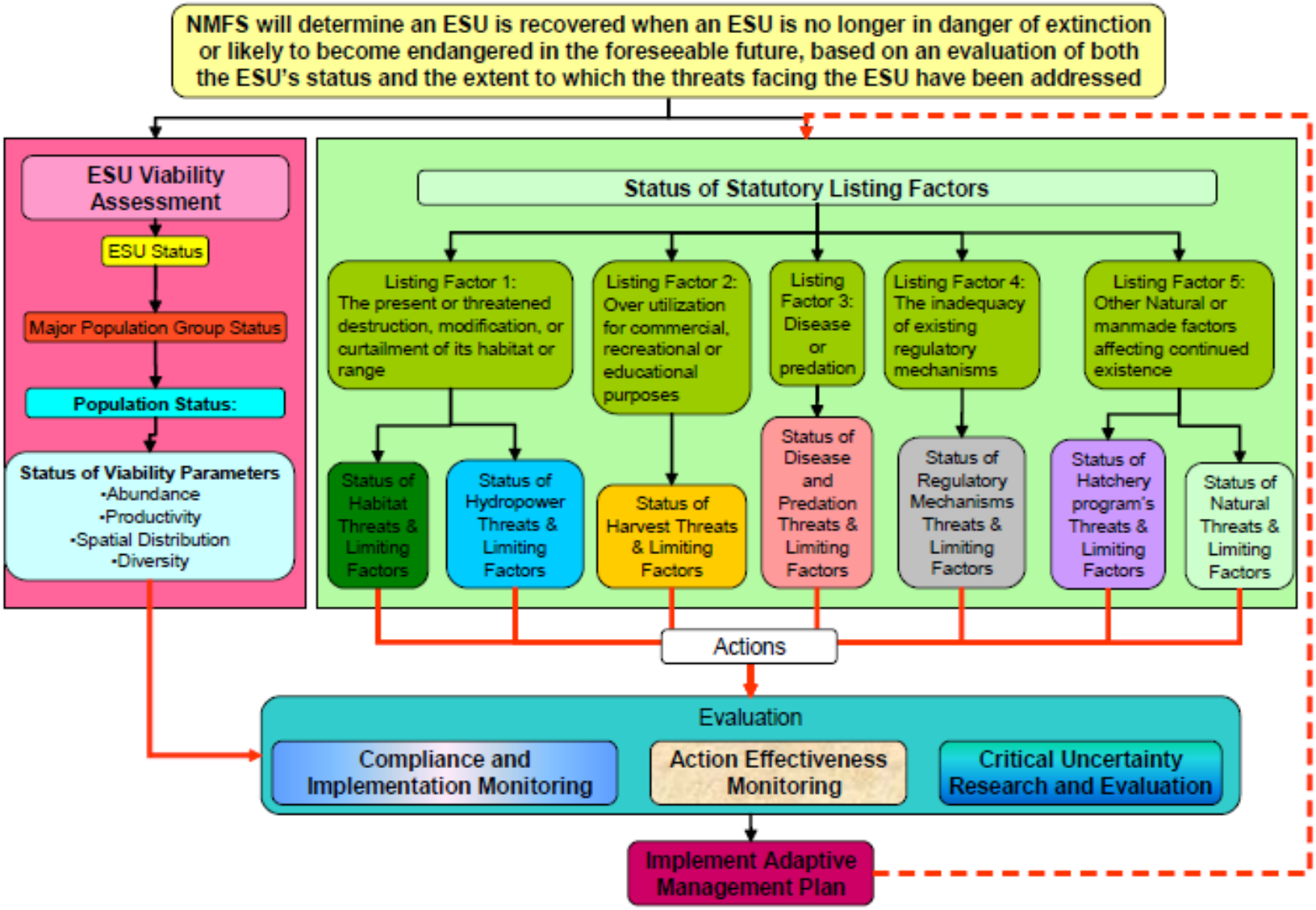

Figure 5-1. NMFS listing status decision framework. Figure taken from NMFS (2007).

Given the amount of data to be collected at LCM stations, they may serve as the focal point for evaluating the status of SONCC coho salmon populations and restoration efforts, as well as encouraging further research. LCM stations in close proximity to the ocean can be used to determine marine survival. Large rivers may not be appropriate or feasible locations for LCM stations if all coho salmon adults cannot be counted, smolt trapping efficiencies are low, or flows are too high or unsafe for operation. Alternatively, an LMC station could be established on a tributary of a large river. LCM stations are likely to be located opportunistically and at existing counting stations within each stratum. Adams et al. (2011) describes LCM stations. One LCM, located in a core population, is needed for each diversity stratum in the SONCC coho salmon ESU.

Initial Phase

During the initial phase, the number of coho salmon spawners and juveniles should be estimated or counted each year at each LCM (as described in Adams et al. 2011 and Stevens 2002). Juvenile occupancy surveys should be carried out in all independent populations without an LCM (with the exception of non-core 2 populations). Occupancy surveys will alternate with periods of 3 years on, three years off, to determine the percent of the area occupied by juveniles. Occupancy surveys allow tracking of the spatial distribution of fish at the population scale, which could be used as a surrogate for population abundance and productivity if direct monitoring of population abundance and productivity is prohibitively expensive. Joseph et al. (2006) evaluated the probability of detection between occupancy versus abundance monitoring for detecting trends under financial constraints. Their simulations suggest abundance monitoring is most effective when the target species is abundant; otherwise occupancy was best. Furthermore, they suggest when surveyors target a species that is cryptic or occurs in low-densities, leading to low observation probability, occupancy surveys should be considered over abundance surveys when financial resources are limited (Joseph et al. 2006).

Table 5-1. Sampling strategy for the initial phase of recovery monitoring.

Population Type	Monitoring Goal	Purpose	Potential Method(s)
Core with Life Cycle Monitoring (LCM) Station	Estimate annual number of wild/natural spawners	Determine population status	Total counts, mark/recapture, or spawner surveys[1] conducted in a spatially balanced probabilistic sampling design. Sampling would be limited to those areas accessible to coho salmon and would occur each year in each population.
	Estimate annual smolt abundance	Assess freshwater productivity	LCM stations in one core population per diversity stratum.
	Estimate annual marine survival	Assess influence of marine survival on coastal population's abundance	Divide smolt data by spawner abundance data, or determine PIT tag recovery ratios at each coastal[2] LCM station. If necessary, use recaptures of hatchery fish.
	Estimate migration timing, age structure, size, and behavior	Determine degree of population diversity	In LCMs, utilize data from weir counts, spawner surveys, and outmigrant traps.
	Estimate natural/hatchery ratio on spawning grounds	Determine degree of hatchery influence on spawners to assess overall genetic diversity	Weir counts, spawner surveys
Independent (except Non-Core 2) without LCM	Estimate juvenile occupancy	Track the population abundance, productivity, and spatial distribution (using juvenile presence as a surrogate)	Juvenile occupancy surveys (% area occupied) of three consecutive year classes every other generation
Dependent and Non-Core 2 Independent	None	None	None

[1] Calibrated by annual spawner: redd ratios from nearest LCM station in that diversity stratum (Gallagher et al. 2010a).
[2] Only coastal LCM stations would be used to estimate annual marine survival. Fish migrating from the ocean to inland LCM stations must migrate through miles of river before they reach the inland LCM stations, and the effect of this migration through inland areas would confound estimates of marine survival.

Intermediate Phase

During the intermediate phase of monitoring, the number of coho salmon spawners in each core population should be estimated each year. Spawner abundance in non-core 1 populations should also be tracked over time to detect trends and progress toward spawner abundance targets. Estimates of adult abundance can be very expensive because they often involve repeated, frequent surveys of the same area, or continual operation of counting weirs or stations. To reduce expense, the status of non-core independent populations may be monitored using redd counts, DIDSON units, or adult abundance surveys (Table 5-2) during every other generation for all 3 year classes (e.g., an interval of three consecutive years of monitoring followed by a break the next three years). Occupancy surveys will document the percent of the accessible area in each population that is occupied, and the trend in this indicator will reveal whether the spatial structure is improving. Spawner abundance surveys or redd counts are needed to detect when coho salmon spawner abundance approaches the numeric criteria, triggering the delisting phase. These surveys yield more detailed information than occupancy surveys. Redd counts provide reliable indices of spawner abundance during the intermediate phase. At low abundance, Gallagher et al. (2010a) found that coho salmon redd counts in Mendocino County, CA tributaries, when converted to spawner numbers using spawner to redd ratios, were statistically and operationally similar to live-fish capture-recapture estimates, cost effective, and less intrusive. In addition, Gallagher et al. (2010b) found that redd counts were not statistically different between the 10 percent random sampling design and total redd counts. The adult escapements estimated from the 10 percent GRTS (Generalized Random Tessellation Stratified) sampling were not statistically different than intensively surveyed methods (Gallagher et al. 2010b).

Table 5-2. Sampling strategy for the intermediate phase of recovery monitoring.

Population Type	Monitoring Goal	Purpose	Potential Method(s)
Core	Estimate annual number of wild/natural spawners in each population	Determine population status	Total counts, mark/recapture, or spawner surveys[1]
	Estimate annual natural/hatchery ratio on spawning grounds	Determine degree of hatchery influence on spawner population to assess overall genetic diversity	Hatchery data; weir counts, spawner surveys
Core with LCM	Estimate annual number of wild/natural spawners	Determine population status	Total counts, mark/recapture, redd counts, or spawner surveys[1]
	Estimate annual smolt abundance	Assess freshwater productivity	Life cycle monitoring (LCM) stations in one core population per diversity stratum.
	Estimate annual marine survival	Assess influence of marine survival on coastal population's abundance	Divide smolt with spawner abundance data, or PIT tag recovery ratios at each coastal LCM station. If necessary, use recaptures of hatchery fish.
	Estimate annual migration timing, age structure, size, and behavior	Determine degree of population diversity	In LCMs, utilize data from weir counts, spawner surveys, and outmigrant traps.
	Estimate annual natural/hatchery ratio on spawning grounds	Determine degree of hatchery influence on spawner population to assess overall genetic diversity	Hatchery data; weir counts, spawner surveys
Non-Core 1	Estimate annual juvenile occupancy	Track the population abundance, productivity, and spatial distribution (using juvenile presence as a surrogate)	Juvenile occupancy surveys (% area occupied) and density of three consecutive year classes every other generation
Dependent and Non-Core 2	None	None	None

[1] Calibrated by annual spawner: redd ratios from nearest LCM station in that diversity stratum (Gallagher et al. 2010a).

Delisting Phase

During the delisting phase, spawner, juvenile occupancy, and life history diversity surveys should be carried out in core and non-core 1 populations each year (Table 5-3). All monitoring begun in the initial phase should continue. This intensive sampling is necessary to demonstrate that spawner abundance, spatial distribution, productivity, and diversity meet delisting criteria. If data obtained during the delisting phase indicate that SONCC coho salmon have declined and are no longer near (e.g., within 90 percent of the delisting criteria for spawner abundance) the delisting criteria, monitoring would revert back to the initial or intermediate phase until data indicate that spawner abundance of core populations are approaching delisting criteria again.

Table 5-3. Monitoring population status and trends for the delisting phase.

Population Type	Monitoring Goal	Purpose	Potential Method(s)
Core and Non-Core 1	Estimate annual number of wild/natural spawners	Determine number spawners relative to spawner targets	Total counts, mark/recapture, or spawner surveys[1]
	Estimate annual juvenile occupancy	Track the population abundance, productivity, and spatial distribution (using juvenile presence as a surrogate)	Juvenile occupancy surveys (% area occupied) and density of three consecutive year classes every other generation
Core with LCM	Estimate annual number of wild/natural spawners	Determine number spawners relative to spawner targets	Total counts, mark/recapture, or spawner surveys[1]
	Estimate annual smolt abundance	Assess population productivity, and use smolt numbers to determine marine survival rate	Use smolt numbers from coastal LCMs to determine marine survival rate
	Estimate annual marine survival	Assess influence of marine survival on abundance of coastal population	Divide smolt with spawner abundance data, or PIT tag recovery ratios at each coastal LCM station. If necessary, use recaptures of hatchery fish. Extrapolate findings to other core populations within each coastal diversity stratum.
	Estimate annual migration timing, age structure, size, and behavior	Determine degree of population diversity	In LCMs, utilize data from weir counts, spawner surveys, and outmigrant traps.
	Estimate wild/hatchery ratio used in hatchery breeding and on spawning grounds	Determine degree of hatchery influence on spawners as way to determine overall genetic diversity	Hatchery data: weir counts, spawner surveys
Dependent and Non-Core 2	Estimate juvenile occupancy	Track the population abundance, productivity, and spatial distribution (using juvenile presence as a surrogate)	Juvenile occupancy surveys (% area occupied) and density of three consecutive year classes every other generation, in a spatially balanced random sampling design.

Post-delisting Phase

After SONCC coho salmon are delisted, post-delisting monitoring of SONCC coho salmon should continue with the same intensity as the delisting phase for another 12 years to assess whether SONCC coho salmon can continue to be viable without the protection of the Endangered Species Act. The results of the 12 years of post-delisting monitoring will guide decisions on the monitoring intensity for future years.

Table 5-4. Monitoring actions for each population in the coastal diversity strata.

Coastal Diversity Strata	Population (Location)	Initial Phase	Intermediate Phase	De-Listing Phase	Post De-Listing Phase
N. Coastal	Chetco River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Winchuck River[NC1]	J	J	A	A
	Elk River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Lower Rogue[NC1]	J	J	A	A
	Dependent Populations			J	J
C. Coastal	Lower Klamath[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Redwood Creek[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Mad River[NC1]	J	J	A	A
	Smith River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Little River[NC1]	J	J	A	A
	Dependent Populations			J	J
S. Coastal	Humboldt Bay Tributaries[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Lower Eel/Van Duzen[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Mattole River[NC1]	J	J	A	A
	Bear River[NC2]			J	J
	Dependent Populations			J	J

A = Estimate adult abundance J = Estimate juvenile occupancy (at non-LCM sites) S = Estimate smolt abundance (at selected LCM sites) M = Estimate marine survival (at selected LCM sites) D = Track life history and genetic diversity (at selected LCM sites)	C = Core LCM = Candidate for life cycle monitoring (LCM) station NC1 = Non-Core 1 NC2 = Non-Core 2

Table 5-5. Monitoring actions for each population in the interior diversity strata.

Interior Diversity Strata	Population	Initial Phase	Intermediate Phase	De-Listing Phase	Post De-Listing Phase
Interior Rogue	Illinois River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Upper Rogue River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Middle Rogue/Applegate[NC1]	J	J	A	A
Interior Klamath	Upper Klamath River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Shasta River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Scott River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Salmon River[NC1]	J	J	A	A
	Middle Klamath River[NC1]	J	J	A	A
Interior Trinity	South Fork Trinity River[NC1]	J	J	A	A
	Upper Trinity River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Lower Trinity River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
Interior Eel	South Fork Eel River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Middle Mainstem Eel[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Mainstem Eel River[C, LCM]	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D	A, J, S, M, D
	Upper Mainstem Eel River[NC2]			J	J
	Middle Fork Eel River[NC2]			J	J

A = Estimate adult abundance
J = Estimate juvenile occupancy (at non-LCM sites)
S = Estimate smolt abundance (at selected LCM sites)
M = Estimate marine survival (at selected LCM sites)
D = Track life history and genetic diversity (at selected LCM sites)

C = Core
LCM = Candidate for life cycle monitoring (LCM) station
NC1 = Non-Core 1
NC2 = Non-Core 2

5.1.2 Limiting Factor (Stress) and Threat Monitoring

In order to achieve recovery and delisting, the limiting factors (stresses) and threats faced by coho salmon populations in the ESU must be sufficiently abated to facilitate the long term sustainability of the coho salmon. The objectives for limiting factors (stresses) and threats abatement are as follows: (1) the limiting factors (stresses) currently affecting SONCC coho salmon have been sufficiently abated in target areas and (2) the threats identified at the time of listing, as well as any new threats, have been sufficiently removed or abated in target areas. Target areas are those areas which will produce the numbers of adults or juvenile occupancy

needed to meet biological recovery criteria for each population. Target areas have not yet been determined. These areas will be identified for each watershed after the comprehensive habitat survey in each watershed occurs. Monitoring can gauge progress toward meeting the stress and threat objectives. Table 5-6 describes monitoring to assess the status of limiting factors (stresses) and threats. Monitoring needs for limiting factors (stresses) and threats are described for each population in Table 5-7 and Table 5-8.

Annual, as opposed to less frequent, monitoring is recommended for those limiting factors (stresses) for which resultant habitat conditions are expected to change rapidly, or for which direct coho salmon mortality is possible. Indicators for barriers (due to sediment, dry areas, or temperature), altered hydrologic function, adverse fishery-related effects, increased disease, predation, and competition, and adverse hatchery-related effects should be monitored annually for populations that rated high or very high for these limiting factors (stresses) and threats (Table 5-6). For other limiting factors (stresses), an initial, comprehensive field-based habitat survey should be carried out for all populations (except ephemeral) as soon as possible (Table 5-6). The purpose of these surveys is to describe the current habitat conditions in each population area. The surveys should be followed by monitoring of indicators related to those limiting factors (stresses) ranked high or very high for each population. For core and non-core 1 populations, such indicators should be monitored every 10 years beginning after the initial habitat survey (Table 5-6). For non-core 2 and dependent populations, such indicators should be monitored every 15 years beginning after the initial habitat survey (Table 5-6). Monitoring needs for limiting factors (stresses) are described for each population in Table 5-7 (for coastal diversity strata) and Table 5-8 (for interior diversity strata).

Table 5-6. Monitoring for limiting factor (stress) assessment, with associated listing factors.

Listing Factor	Limiting Factor (Stress)	Monitoring
A: The present or threatened destruction, modification, or curtailment of the species' habitat or range	Lack of Floodplain and Channel Structure	Core and Non-Core 1 Independent populations: The first habitat monitoring should be comprehensive and occur as soon as possible in both freshwater and estuarine (if applicable) habitat. After the first habitat monitoring is complete[2], habitat indicators for the applicable limiting factors (stresses)[1] should be monitored every 10 years. Dependent and Non-core 2 Independent populations): The first habitat monitoring should be comprehensive and occur as soon as possible in both freshwater and estuarine (if applicable) habitat. After the first habitat monitoring is complete[2], habitat indicators for the applicable limiting factors (stresses)[1] should be monitored every 15 years.
	Altered Sediment Supply	
	Impaired Water Quality	
	Degraded Riparian Forest Condition	
	Impaired Estuarine Function[3]	
	Barriers (due to sediment, dry areas, or high temperature)	Annually monitor the extent of barriers due to sediment or seasonally dry areas in independent populations where such barriers are identified as a *high* or *very high* stress.
	Altered Hydrologic Function	Annually monitor the hydrograph, where appropriate, in independent populations where altered hydrologic function is identified as a *high* or *very high* stress.
B: Overutilization for commercial, recreational, scientific, or educational purposes	Adverse Fishery-Related Effects	Annually estimate the commercial and recreational ocean fisheries bycatch and mortality rate for wild SONCC coho salmon. Annually estimate the in-river bycatch and tribal harvest for all rivers and streams in the SONCC domain.

Listing Factor	Limiting Factor (Stress)	Monitoring
C: Disease or predation	Increased Disease/Predation/Competition	Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as *Ceratomyxa shasta*, in independent populations where diseases are identified as a *high* or *very high* limiting factor (stress).
C: Disease or predation	Increased Disease/Predation/Competition	Annually estimate the density of non-native predators, such as the Sacramento pikeminnow in the Eel River basin, in independent populations where predation is identified as a *high* or *very high* limiting factor (stress).
D: The inadequacy of existing regulatory mechanisms	Adverse Hatchery-Related Effects	Annually determine the percent of hatchery origin spawners (PHOS) in independent populations where hatchery effects are a *high* or *very high* limiting factor (stress).
E: Other natural or manmade factors affecting the species' continued existence	Climate Change	Refer to monitoring associated with Impaired Hydrologic Function and Water Quality.

[1] A list of habitat indicators is presented in Chapter 4.
[2] The first habitat monitoring should be comprehensive and occur as soon as possible, while subsequent monitoring (e.g., every 10-15 years) should use a spatially balanced probabilistic sampling design.
[3] NMFS has no recommendation regarding the habitat parameters to be measured in estuaries. A recovery action to identify the appropriate estuarine parameters is included for each population where such monitoring is needed.

Table 5-7. Limiting factor (stress) monitoring actions for each population in the coastal diversity strata.

	Northern Coastal Basins					Central Coastal Basins						Southern Coastal Basins				
Monitoring Action: Track indicators related to:	Chetco River C	Winchuck NC1	Elk River C	Lower Rogue NC1	Dependent Populations	Lower Klamath C	Redwood Creek C	Mad River NC1	Smith River C	Little River NC1	Dependent Populations	Humboldt Bay Tributaries C	Lower Eel/Van Duzen C	Mattole River NC1	Bear River NC2	Dependent Populations
Spawning, rearing, and migration	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lack of Floodplain and Channel Structure	3	3	3	3	4	3	3	3	3	3	4	3	3	3	4	
Degraded Riparian Forest Conditions	3	3	3	3	4	3	3	3		3	4	3	3	3	4	
Altered Sediment Supply		3		3	4	3	3	3		3	4	3	3	3	4	4
Impaired Water Quality	3	3	3	3	4		3	3	3		4	3	3	3	4	
Impaired Hydrologic Function	2	2	2		4	2								2		
Impaired Estuarine Function	3			3	4	3	3	3	3		4	3	3	3	4	
Adverse Fishery-Related Effects				2		2										
Adverse Hatchery-Related Effects																
Disease/Predation/Competition													2			
Barriers									3		4	3				

[1] Conduct initial comprehensive habitat survey.
[2] Monitor every year.
[3] Monitor applicable habitat indicators every ten years, to begin after initial comprehensive habitat survey completed.
[4] Monitor applicable habitat indicators every fifteen years, to begin after initial comprehensive habitat survey completed.

C = core population
NC1 = non-core 1 population
NC2 = non-core 2 population

Table 5-8. Limiting factor (stress) monitoring actions for each population in the interior diversity strata.

	Interior Rogue			Interior Klamath					Interior Trinity			Interior Eel				
Monitoring Action: Track indicators related to:	Illinois River C	Upper Rogue C	Middle Rogue/ Applegate NC1	Upper Klamath C	Shasta River C	Scott River C	Salmon River NC1	Middle Klamath NC1	South Fork Trinity NC1	Upper Trinity C	Lower Trinity C	South Fork Eel River C	Middle Mainstem Eel C	Mainstem Eel C	Upper Mainstem Eel NC2	Middle Fork Eel NC2
Spawning, rearing, and migration	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lack of Floodplain and Channel Structure	3	3	3	3	3	3		3	3	3	3	3	3	3	3	
Degraded Riparian Forest Conditions	3	3	3	3	3	3	3		3			3	3	3	3	3
Altered Sediment Supply	3	3		3		3		3	3		3	3	3	3	3	3
Impaired Water Quality	3	3	3	3	3	3	3	3	3			3	3		3	
Impaired Hydrologic Function	2	2	2	2	2	2		2	2	2	2	2	2		2	
Impaired Estuarine Function	3	3	3	3	3	3		3								
Adverse Fishery-Related Effects																
Adverse Hatchery Related Effects				2	2				2	2	2					
Disease/ predation/ competition				2	2			2		2		2	2	2	2	2
Barriers	3	3		3				3		3		3			3	

[1] Conduct initial comprehensive habitat survey.
[2] Monitor applicable habitat indicators every year.
[3] Monitor applicable habitat indicators every ten years, to begin after initial comprehensive habitat survey completed.
[4] Monitor applicable habitat indicators every fifteen years, to begin after initial comprehensive habitat survey completed.

C = core population
NC1 = non-core 1 population
NC2 = non-core 2 population

Threat monitoring is described in Table 5-9. NMFS will describe the status and trends of limiting factors (stresses) related to particular threats, along with other identified information, as part of the status review to be completed every five years.

Table 5-9. Monitoring for threats, with associated listing factors.

Listing Factor	Threat	Monitoring
A: The present or threatened destruction, modification, or curtailment of the species' habitat or range	Roads	Evaluate the status and trend of related limiting factors (stresses)[1]. Describe status and trends of road treatments and road density[1].
	Timber harvest	Evaluate the status and trend of related limiting factors (stresses)[1].
	Dams/Diversion Road-Stream Crossing Barriers	Describe status and trends of identified fish passage barriers[1]
	High Intensity Fire	Describe trends in occurrence of high-intensity fire as well as trends in change of related limiting factors (stresses)[1].
	Agricultural Practices	Evaluate the status and trend of related limiting factors (stresses)[1].
	Channelization/Diking	Evaluate the status and trend of related limiting factors (stresses)[1]. Describe new channelization/diking and changes to existing channelization/diking.
	Urban/Residential/Industrial Development	Evaluate the status and trend of related limiting factors (stresses)[1]. Describe new development and changes to existing development.
	Mining/Gravel Extraction	Evaluate the status and trend of related limiting factors (stresses)[1]. Describe any new mining or gravel extraction.
B: Over-utilization for commercial, recreational, scientific or educational purposes	Fishing and Collecting	Annually estimate the commercial and recreational fisheries bycatch and mortality rate for wild SONCC coho salmon. Annually estimate the in-river bycatch and tribal harvest for all rivers and streams in SONCC domain.
D: The inadequacy of existing	Hatcheries	Evaluate the status and trend of related limiting factors (stresses)[1]. Describe status of HGMP development and implementation.

Listing Factor	Threat	Monitoring
regulatory mechanisms	Invasive Non-Native Alien Species	Evaluate the status and trend of abundance and occurrence of invasive, non-predatory species that may adversely affect SONCC coho salmon.
E: Other natural or manmade factors affecting the species' continued existence	Climate Change	Evaluate the status and trend of related limiting factors (stresses)[1].
[1] Consult population profiles to determine related limiting factors (stresses) for each population.		

5.2 Adaptive Management

Adaptive management is the process of improving management policies and practices as conditions change. Information is rarely complete and sometimes incorrect. What is known is research, examined and tested, knowledge is extended, and management is adjusted. Adaptive management requires care and consideration both before monitoring (by employing sampling designs that adequately informs decision making) and after monitoring (by using results to improve future conservation efforts). New scientific research may provide information that may warrant adjustments to the recovery plan or implementation.

New scientific research may be a source for adjustment. In addition, adaptive management for this recovery plan relies on additional, proactive elements that track limiting factors of SONCC coho salmon and assess the effectiveness of restoration actions. Ideally, adaptive management guides the implementation of salmon recovery activities through repeated adjustments in strategies and actions, as information from monitoring and evaluation become available. Strategies and actions needed for recovery can evolve as uncertainties in the effectiveness of actions are reduced through monitoring and evaluation. Adaptive management plays a critical role in NMFS' listing status decision framework (Figure 5-1).

5.2.1 Research needs

Research is a foundation of adaptive management. Research can augment existing data and reduce uncertainty related to precision, bias, and assumptions. Additionally, research can reduce uncertainty associated with evaluating population status and trend in future assessments, and will help elucidate what changes in actions or implementation may be needed via the adaptive management framework. Critical uncertainty research verifies the basic assumptions behind effectiveness monitoring and models, prioritization of limiting factors and threats, or any other topic for which assumptions have been made, which if untrue, would significantly alter the actions identified for implementation by the recovery Plan. There are several areas of critical

uncertainty research which should be investigated to facilitate SONCC coho salmon recovery. Research needs include:

- Develop techniques to estimate adult abundance in remote areas.
- Evaluate the potential to restore extirpated populations.
- Research supplemental or alternative means to develop population targets.
- Determine best parameters to measure for monitoring estuarine habitat.
- Research supplemental means to delineate populations.
- Determine whether the low-risk threshold abundance target for core populations could be decreased if other VSP parameters are well-estimated.

Specific research needs for particular populations are described in the population profiles and associated recovery actions (Chapters 7 through 45).

5.2.2 Limiting Factors Modeling

Modeling limiting factors may provide insight into what elements of the habitat, or which life stages of coho salmon, are acting as roadblocks to recovery. Models can validate assumptions on which recovery actions are most essential to achieve recovery as well as identify factors which may have been overlooked. As recovery actions are implemented, limiting factors may change. Periodic use of and updates to the limiting factors models that are validated with habitat surveys, may help identify changes in limiting factors to help recovery practitioners to redirect their efforts where they are most needed.

A quantitative limiting factors life cycle model is designed to integrate information about the ecology of the salmon life cycle, the factors that may limit the survival of key life stages and incorporate human activities such as landscape management, habitat rehabilitation, and exploitation. Results of the model can be used to identify additional or reprioritize recovery actions to achieve SONCC coho salmon recovery.

Typically these models associate fish abundance (density) and survival with each habitat type at important life stages. Both carrying capacity and density-independent survival are affected by habitat quantity and quality. Limiting habitat analyses at the basin-level are conducted using this life-stage specific approach. Two potential approaches are simplified limiting factor models and dynamic life cycle models. Both approaches are based on the salmon life cycle, and assess current and historical habitat conditions in a basin to estimate how habitat changes may have altered salmon abundance or survival at different life stages. However, the approaches differ in two main respects. First, each approach emphasizes different parameters driving stage-to-stage survivorship. Simplified limiting factors models focus on changes in capacity at each freshwater life stage and treat density-independent stage-to-stage survival as constants. The dynamic life cycle model incorporates both capacity and survival through the use of stage to stage stock-recruitment relationships and estimates population abundance, or other VSP parameters via iterative simulations.

Such modeling efforts have implications for identifying habitats that may limit recovery of populations. They can provide a transparent framework to: (1) relate habitat to capacity and survival; (2) estimate stage specific abundance from a basin's intrinsic potential; (3) apply knowledge of the current state of the habitat to stage specific capacity, survival and abundance; (4) identify model assumptions and parameters that can dramatically alter predictions of population responses to habitat changes; (5) indicate which life stages may be most sensitive to habitat change regardless of the assumptions about density dependence and therefore shift the focus of restoration efforts; and (6) identify parameter and model uncertainties that substantially alter conclusions about which habitats limit recovery. Such analyses motivate critical research to identify and characterize poorly understood habitats, their effects on salmon abundance and survival, and the extent to which they have been modified.

An example of a simplified limiting factors model for coho salmon in Oregon coastal streams is the Habitat Limiting Factors Model (Nickelson 1998; HLFM v7). This model relies upon habitat typing information to determine total area of the various habitat types. The analyst then multiplies the area of each habitat by habitat-specific coho salmon density to estimate potential abundance. This process is done for each life stage/season using life history-specific density values.

An example of a life cycle model is RIPPLE developed by Stillwater Sciences and UC Berkley (Dietrich and Ligon 2009). RIPPLE couples geomorphic information with biological and aquatic habitat data. RIPPLE uses three sub-models: (1) a physical model that uses GIS-derived values of drainage area and channel slope to predict hydraulic geometry, bed particle size, and channel confinement; (2) a habitat model which uses the output from the physical model to define the quantity of habitat types or capacity of the channel network for different life stages; and (3) a generalized stock production model that defines the relationship between the abundance at one life stage to the abundance at the successive life stages using familiar functions such as Ricker, Beverton-Holt, and hockey stick formulations. The parameters controlling the properties of this stage-to-stage relationship can be derived from critical research, or literature. This portion of the model operates on small portions or "arcs" of the stream network, allowing fish to redistribute seasonally. Analysts are expected to ask questions like "what is the expected population response to increasing the capacity or productivity (survival) of habitat in 'X' portion of the stream?" Additionally, the analyst could compare the abundance of fish at any given stage to the intrinsic potential of the basin and the current status of the habitat within the basin.

5.2.3 Assessing Restoration Actions

The restoration of physical habitat is one of the fundamental strategies used to achieve recovery. Therefore, the effectiveness of certain habitat restoration activities in achieving the desired habitat improvements should be identified, as well as the change or response in coho salmon populations. Three types of monitoring can be employed to evaluate restoration actions: implementation, effectiveness, and validation. Each type serves a unique purpose.

Implementation Monitoring

Implementation monitoring is designed to assess whether restoration projects are carried out as planned (MacDonald et al. 1991), according to the intended purpose and design.

Effectiveness Monitoring

Effectiveness monitoring is used to determine whether restoration actions result in the expected physical effect. For instance, effectiveness monitoring could be used to assess the short-term structural integrity (e.g., instream structure anchoring) and physical objectives (e.g., scouring due to instream structure placement) of implemented restoration actions. Much of this can be done through on-site observations. Effectiveness monitoring of restoration actions has two parts: (1) pre-treatment site characterization for establishing the conditions prior to restoration and (2) post-treatment monitoring to determine if the restoration is having the intended effects.

Validation Monitoring

Validation monitoring is designed to assess whether an anticipated biological response actually occurred. Validation monitoring can range from measuring short-term response (1 to 3 years) of coho salmon to restoration actions implemented at the project level (e.g., successful passage through a former barrier). In addition, validation monitoring may evaluate the long term response of coho salmon populations to the cumulative basin restoration.

Implementation monitoring should occur in conjunction with restoration actions, while effectiveness and validation monitoring will be necessary for certain restoration actions. Many effectiveness or validation monitoring efforts should be undertaken in the same area where intense biological sampling occurs, and could result in an intensively monitored watershed (IMW). Careful planning and implementation of restoration activities within the same areas as LCMs will allow for these analyses to be conducted with little additional costs for status or biological information.

An accurate evaluation of the effectiveness of a restoration action requires a clear statement of the desired effect of the project on the environment. Restoration objectives should be expressed as quantifiable changes in environmental conditions. For example, if installation of an in-stream structure is intended to improve rearing habitat, the desired changes could be expressed in terms of pool frequency, in-stream cover, or some other measurable environmental characteristic. The objectives should be stated as desired outcomes (e.g., 50 percent of reach length in pools). If objectives are vague, it will be difficult to focus the monitoring (Harris et. al 2005).

Detecting a biological response to restoration actions may be difficult, or impossible to discern from other influences. Validation monitoring may be confounded by other potentially limiting factors or variables that are not addressed by the restoration action. Similarly, single project restoration actions may not have enough impact to see a measurable response at the basin scale (MacDonald et al. 1991). Therefore, validation monitoring may be best for restoration actions that result in a quick response to the quality of instream salmonid habitat, such as instream habitat and fish passage improvement projects. Validation monitoring of other restoration actions should occur as part of an IMW. IMWs are used to evaluate assumptions about what should be done to improve habitat and resulting fish response. IMWs also allow evaluation of critical uncertainties for the limiting factors models. Monitoring efforts conducted in IMW may find that using the Before-After-Control-Impact (BACI) approach (Stewart-Oaten et al. 1986) will provide the most useful information to evaluate biological and physical response to restoration activities. BACI study designs are often used to determine if a restoration action had

the intended effect. The spatial and temporal scale of both the treatment and response must be carefully considered for this type of design to be informative. For example, a large road decommissioning project may not reduce sediment delivery for a number of years after project implementation. Road decommissioning may have a short term negative effect on sediment delivery. The spatial scale might be considered a reach, stream, or basin while the temporal scale of response might be 10 years or more.

5.2.4 Hypothesis Testing

Ultimately, monitoring should evaluate whether populations or habitat conditions are trending in the right direction, in addition to whether they have met established criteria. Interim hypotheses can be used to assess progress towards meeting recovery criteria, and NMFS identified three such hypotheses (Table 5-10). For example, a hypothesis could seek to answer whether water temperature is cooling in a watershed. Using appropriate time scales are important in testing hypotheses and reaching conclusions based on results. For example, it may require several years, if not decades, before significant changes in many variables would be realized or detected.

Table 5-10. Example hypotheses for assessing population status and limiting factors (stresses) and threats abatement.

Viable Salmonid Population Parameter (Hypothesis 1)	Abundance	Coho salmon adult abundance in population X is increasing.
	Spatial Structure	Coho salmon spatial structure in population X is increasing.
	Productivity	Coho salmon productivity in population X is increasing.
	Diversity	Coho salmon diversity (life history and genetic) in population X is not decreasing.
Stressors (Hypothesis 2)	Habitat indicator condition	The trend in habitat indicator condition is positive (e.g., water temperature is getting cooler).
Threats (Hypothesis 2)	Threat severity	Threat severity is not increasing (e.g., the number of miles of untreated roads per square mile of a basin is not increasing).

Interim hypotheses allow evaluation of the effectiveness of implemented recovery actions. Although the abundance of adult coho salmon is not expected to quickly approach the recovery objectives, monitoring the trends in both fish abundance and the status of the threats and limiting factors (stresses) affecting SONCC coho salmon is important. If recovery efforts do not increase abundance or abate threats, adjustments can be made to the recovery plan and resources can be redirected. Alternatively, adjustments can be made to the restoration action or the perceived limiting factors and life stages.

Having a process in place before recovery efforts are underway will allow adjustments to recovery actions to achieve better results. Figure 5-2 and Figure 5-3 show the decision tree which may be used to determine how well the recovery strategy is functioning in terms of the VSP parameters, limiting factors, limiting life stages, and threat abatement. If the hypothesis

testing results indicate that certain selected core populations are not having positive VSP responses, then the selection of core populations may need to be re-visited.

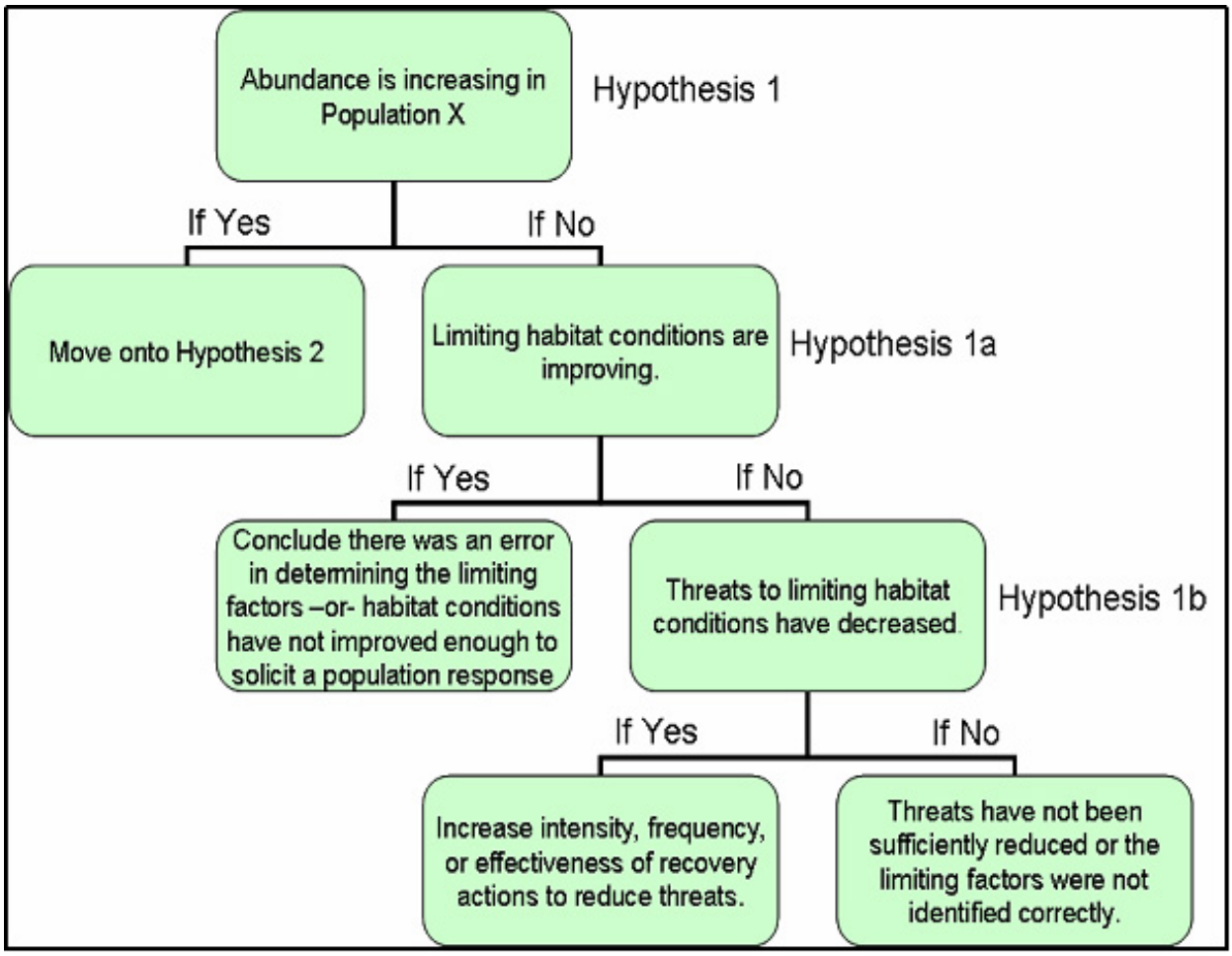

Figure 5-2. Decision tree for the adaptive management process to test hypotheses associated with limiting factors (stresses) and threats.

5.2.5 Database Management

Data on the VSP parameters, limiting factors (stresses) and threats, restoration actions, and other pertinent monitoring and adaptive management elements are expected to be collected into a single, electronic database that will be readily accessible. This database may be created to mimic an existing database. Standards for data collection methods and calculations (for example, population estimates) should be developed with resource agencies and tribes to ensure data quality and consistency.

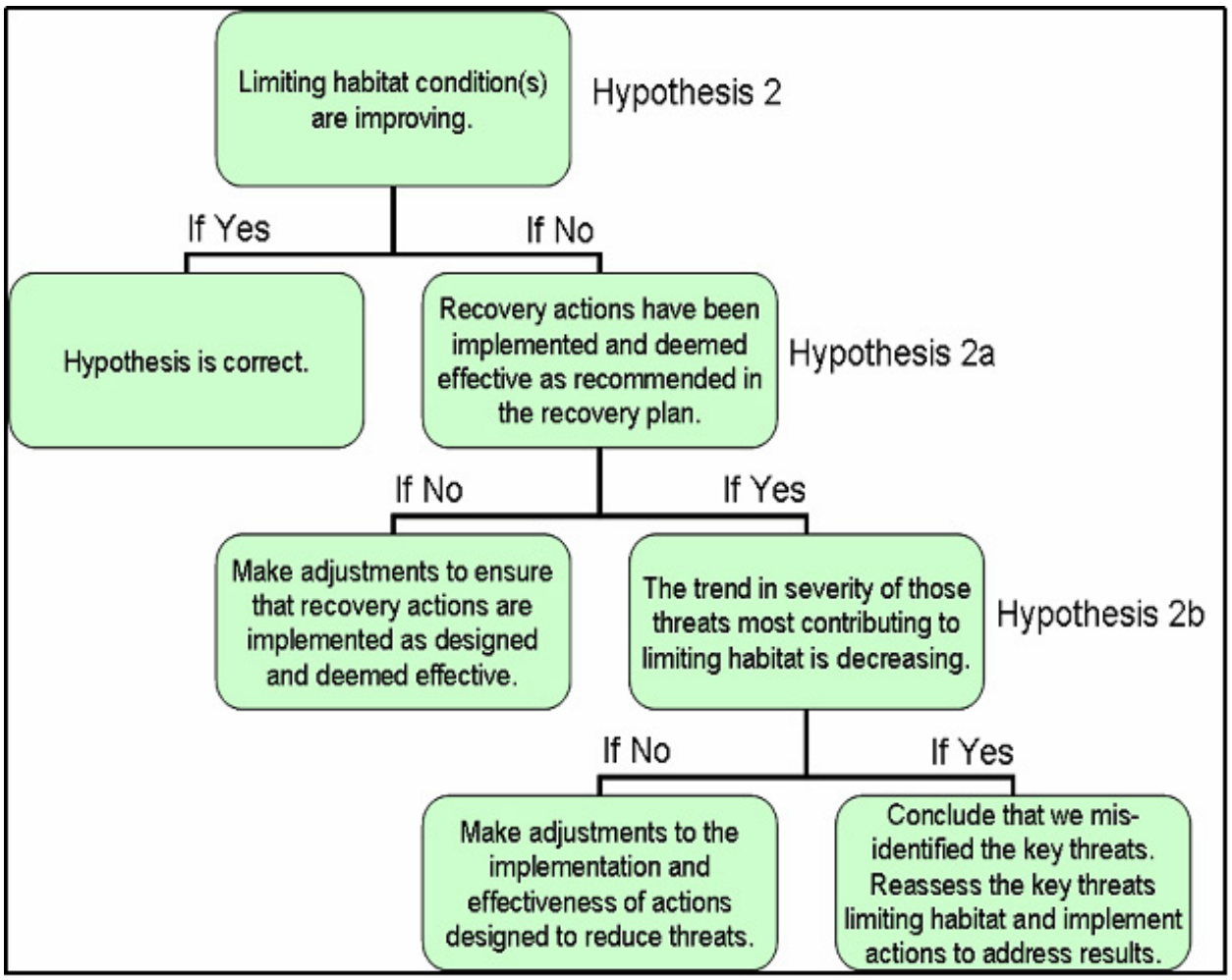

Figure 5-3. Decision tree for the adaptive management process to test hypotheses associated with limiting factors (stresses) and threats.

5.3 Future of the Recovery Plan

This plan was developed based on the information available in 2011. When appropriate, the plan may change to reflect new information as it becomes available. The modeling of limiting factors, monitoring of restoration actions, testing of interim hypotheses, and completion of scientific research are examples of sources of new information which could prompt adjustments to the recovery plan. Adaptive management requires that NMFS be prepared and willing to revise current approaches when new information indicates a revision is necessary.

Status reviews of SONCC coho salmon will occur every five years. Following these status reviews, the recovery plan will be reviewed to determine whether updates would be beneficial.

Status reviews of SONCC coho salmon will occur every five years. Following these status reviews, the recovery plan will be reviewed to determine whether the plan should be updated or revised. Plan updates or revisions may also occur at any time. Details of the plan update and revision process are provided in Section 6.5.