Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance

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CONTENTS

Figures

Acronyms

CI	confidence interval
DPS	distinct population segment
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	evolutionarily significant unit
ENSO	El Niño Southern Oscillation
FGDC	Federal Geographic Data Committee
GRTS	Generalized Random-Tessellation Stratified
HUC	hydrologic unit code
MPG	major population group
NMFS	National Marine Fisheries Service
PCSRF	Pacific Coastal Salmon Recovery Fund
PDO	Pacific Decadal Oscillation
PIT	passive integrated transponders
QET	quasi-extinction thresholds
TRT	technical recovery team
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population

**Adaptive Management for ESA-Listed Salmon and Steelhead Recovery:
Decision Framework and Monitoring Guidance**

EXECUTIVE SUMMARY

Recovery planning for salmon and steelhead listed under the Endangered Species Act (ESA) is a lengthy, complex, and often costly process involving scientific and technical agencies, multiple local jurisdictions, and citizen groups. This guidance document from the National Marine Fisheries Service (NMFS) is intended to help recovery planners and others working on salmon and steelhead recovery in the Pacific Northwest with two crucial tasks: gathering the right information and then using it effectively. The research, monitoring, and evaluation programs associated with recovery planning need to gather the information that will be most useful in tracking progress and assessing the status of the listed species. Planners and managers can then use the information to guide and refine recovery strategies and actions. This document offers conceptual-level guidance, not specific instructions, on these two basic functions.

The objectives of this guidance are the following:

- To present a clear description of the information NMFS needs for its status reviews of ESA-listed salmonid evolutionarily significant units (ESUs).
- To clarify the nature and importance of adaptive management for recovery planning.
- To help recovery planners and managers think about their research, monitoring and evaluation needs in relation to their goals and resources.

Since the guidance is conceptual, its use is expected to generate questions on exactly how implementation, in relation to recovery plan objectives, local biological conditions, and economic realities, will be accomplished. NMFS staff expect to work with local planners and technical professionals to address these questions as they arise. NMFS also expects to clarify and revise the guidance in response to the feedback and questions received, and/or to develop additional guidance.

Recovery Planning and ESU Status Assessment

Section 1, Introduction, begins with a brief background on ESA recovery planning for salmon and steelhead in the Pacific Northwest and summarizes fundamental aspects of the scientific basis for assessing ESU status. To be approved by NMFS, a recovery plan must meet certain requirements as described in the Act:

- ESA section 4(a)(1) lists factors for re-classification or de-listing that are to be addressed in recovery plans:
  A. The present or threatened destruction, modification, or curtailment of [the species'] habitat or range
  B. Over-utilization for commercial, recreational, scientific or educational purposes

C. Disease or predation
D. The inadequacy of existing regulatory mechanisms
E. Other natural or manmade factors affecting its continued existence

- Further, ESA section 4(f)(1)(B) directs that recovery plans, to the extent practicable, incorporate:
  (1) a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species
  (2) objective, measurable criteria which, when met, would result in a determination, in accordance with ESA Section 4, that the species be removed from the list, and
  (3) estimates of the time required and cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal (ESA Section 4[f]).

Consequently, evaluating a species for potential de-listing requires both an explicit analysis of population or demographic parameters (biological recovery criteria) and also of the physical or biological conditions that affect the species' continued existence, categorized under the five ESA listing factors (listing factor criteria). Together these make up the "objective, measurable criteria" required under section 4(f)(1)(B).[1]

The biological recovery criteria are based on principles described in a NMFS technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al., 2000). A viable salmonid population is defined as one that has a negligible risk of extinction over 100 years. Viable salmonid populations are described in terms of four parameters: abundance, population productivity or growth rate, spatial structure, and diversity (the VSP parameters). The metrics that are needed to evaluate biological recovery are derived from these parameters. (A metric is something that quantifies a characteristic of a situation or process, e.g. the number of natural-origin salmon returning to spawn to a specific location is a metric for population abundance.) Viable ESUs are defined by some combination of multiple populations, at least some of which meet or exceed "viable" thresholds, and that have appropriate geographic distribution, protection from catastrophic events, and diversity of life histories and other genetic expression.

Listing factor criteria are based on the features that were evaluated under section 4(a)(1) when the initial determination was made to list the species for protection under the ESA, or any significant factors that have subsequently arisen. Recovery plans are required to contain criteria for evaluating the status of those listing factors. Recovery plans describe threats and limiting factors in a manner that clearly corresponds to the section 4(a)(1) listing factors. At the time of a delisting decision, NMFS will determine whether the section 4(a)(1) listing factors have been adequately addressed, i.e. whether the underlying causes of decline have been addressed and mitigated and are not likely to re-emerge.

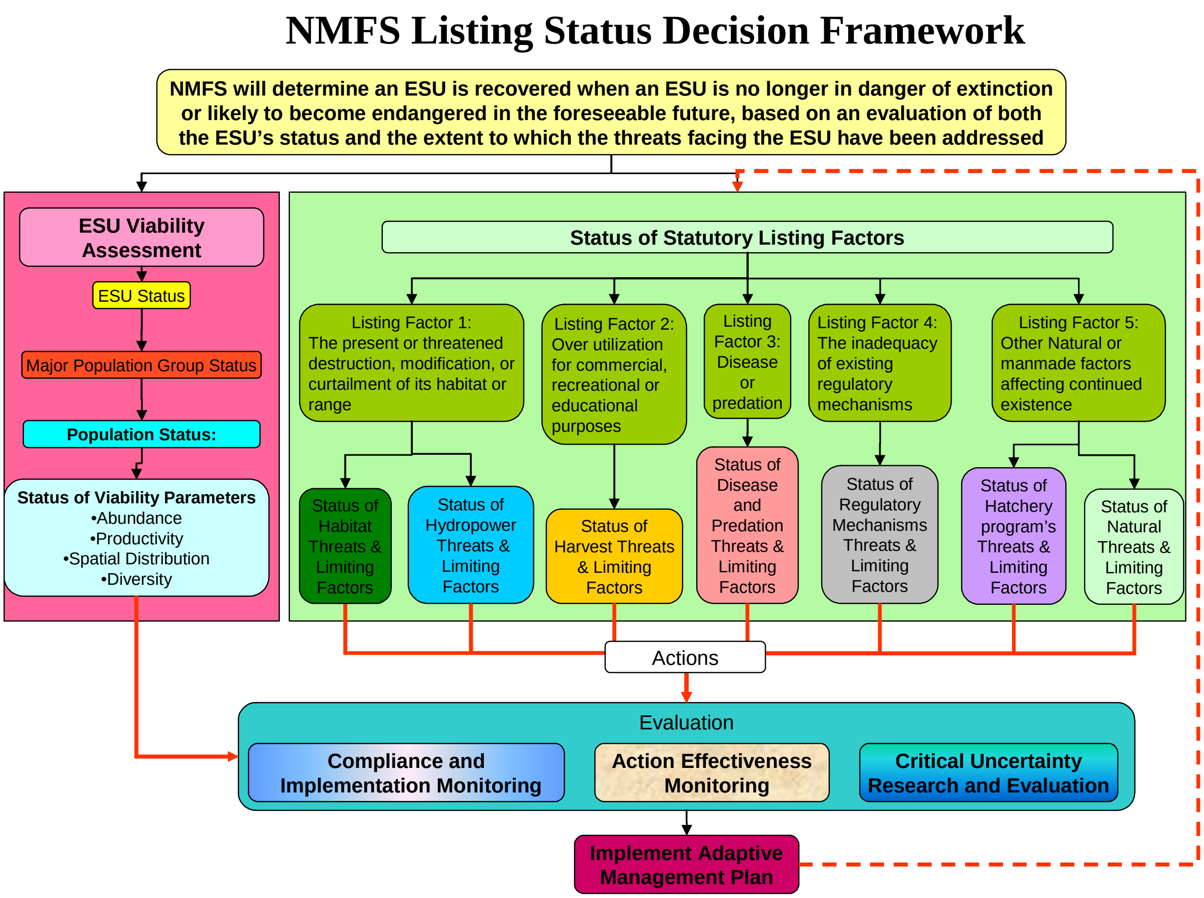
[1] See NMFS 2004 and *Fund for Animals v. Babbitt* 903 F. Supp. 96 (D.D.C. 1995, Appendix B).

NMFS Listing Status Decision Framework

Section 2 presents the NMFS listing status decision framework (decision framework) (Figure ES-1), which illustrates the key questions NMFS will consider in determining ESU status and indicates how the information derived from research, monitoring, and evaluation will be used to answer these questions. The decision framework was developed to help recovery planners design research, monitoring, and evaluation programs that will provide the information NMFS needs for listing and de-listing decisions.

The decision framework is a series of decision-question sets that address the status and change in status of a salmonid ESU, as well as the risks posed by threats to the ESU. The decision-question sets step down from ESU to major population grouping and finally to population scale. The questions at each scale should elicit information needed to make the decision(s) required at that scale.

Figure ES-1. NMFS Listing Status Decision Framework



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 (50 CFR § 424.11).

Adaptive Management

Section 3 provides a conceptual overview of adaptive management. Adaptive management is the process of adjusting management actions and/or directions based on new information. To do this, it is essential to incorporate a plan for monitoring, evaluation, and feedback into an overall implementation plan for recovery. The plan should link results (intermediate or final) to feedback on design and implementation of actions. Adaptive management works by coupling the decision-making process with collection of performance data and its evaluation. Most importantly, it works by offering an explicit process through which alternative strategies to achieve the same ends are proposed, prioritized, and implemented when necessary.

An adaptive management plan must include the following elements (Anderson, 2003):

- Management strategies that are revisited regularly;
- The use of conceptual or quantitative models of the system being managed to develop and test hypotheses and to guide strategy and action planning;
- A range of potential management actions that could be used to meet the strategy;
- Monitoring and evaluation to track progress;
- Mechanisms for incorporating learning from monitoring and evaluation into decisions on actions and strategies; and
- A collaborative structure for stakeholder participation in adjusting management strategies and actions.

Adaptive management is crucial for salmonid recovery programs because of the length and complexity of the salmonid life cycle and the uncertainties involved in improving salmonid survival and status. The key is to build explicit links between management actions, monitoring data, and biological and physical responses.

Several types of monitoring are needed to support adaptive management:

- Implementation and compliance monitoring, used to evaluate whether the recovery plan is being implemented.
- Status and trend monitoring, which assesses changes in the status of an ESU and its component populations, and changes in status or significance of the threats to the ESU.
- Effectiveness monitoring, which tests hypotheses on cause-and-effect relationships and determines (via research) if an action is effective and should be continued.

It is also important to explicitly address the many unknowns in salmon recovery – the "critical uncertainties" that make management decisions much harder. Critical uncertainty research may seem expensive or unnecessary in light of basic information needs; however, in the long run, it will reduce monitoring and implementation costs.

Monitoring and Evaluation for Adaptive Management

Sections 4, 5, and 6 discuss monitoring and evaluation for adaptive management in more detail. Section 4 describes guiding principles for the development of two types of monitoring: *status and trends monitoring* and *effectiveness monitoring*. While status and trends monitoring can produce data on population status and on the status of the potentially limiting factors, without some modeling (quantitative, qualitative, heuristic), supported by effectiveness monitoring data, it is impossible to translate between these two data sets or types, i.e. to make cause-and-effect statements. It is essential to build effectiveness monitoring into the implementation plan at the outset, because it requires explicitly coupling the monitoring design and implementation with the action design and implementation in order to detect an effect. *Recovery plan implementation should consist of action strategies that include the demonstration of effect.*

Section 5 discusses, at a conceptual level, the issues related to prioritizing monitoring in the face of resource constraints. Although Sections 2 through 4 lay out the full scope of information that would be desirable to assess the status of salmon and steelhead, the reality is that monitoring programs are developed in a world of finite resources. Local conditions may raise specific questions about how to develop a monitoring program consistent with this guidance. Many of these questions will need to be answered on a case-by-case basis.

The design of monitoring programs should begin with the data needs of management and policy decision making; these processes will determine the effort required. Management questions or decisions should also be used to determine spatial, temporal, and precision scales for all monitoring data collection. Critical uncertainties in recovery planning – the current suite of unanswered questions – can also motivate monitoring, though not by way of defining sampling effort. There is real and necessary value to data collection programs that address the critical uncertainties confounding our ability to make effective management decisions. This research-based monitoring is also driven by management questions, in a less direct, but equally important, manner. This section presents some basic design principles to guide the development of efficient and effective monitoring programs; the list is neither exhaustive nor complete, but provides some general rules and thinking for practical monitoring program design.

Section 6 illustrates how monitoring program design can affect the level of certainty that can be attained in evaluating ESU status. Decisions often must be made with incomplete information. Three hypothetical examples show how ESU-scale, ESA status assessments may play out under a range of data and information quality and quantity. Different types of incomplete information pose corresponding types of risks for de-listing decisions. The scenarios described are meant to help planners consider how their implementation and monitoring decisions may affect NMFS' assessment of ESU status, and how to balance monitoring investments.

As local recovery planners begin to design monitoring programs for salmon recovery, they will need to address the issues that are discussed conceptually throughout this document, including:

- Clarifying the questions that need to be answered for management decision making.
- Identifying which populations and associated limiting factors to monitor.
- Addressing questions of metrics and indicators – frequency, distribution, and intensity of monitoring – and the tradeoffs and consequences of these choices.
- Assessing the degree to which existing monitoring programs are consistent with this guidance document and identifying needed adjustments in those programs as well as additional monitoring needs and a strategy for filling them.
- Developing a data management plan (see Appendix B).
- Prioritizing research needs to address critical uncertainties, test assumptions, and provide other information to support decision making.

This guidance document is meant to help local planners as they frame and evaluate these questions. Again, the guidance is conceptual and does not provide specific answers to specific questions. To anticipate the range and scope of all questions that might arise as planners consider this guidance would have been impossible because of the range of local conditions and the complexities of designing monitoring programs for species as complicated as salmon. NMFS expects to work closely with recovery plan developers to contribute to the process of developing, proposing, prioritizing, and assessing alternative strategies for inclusion in adaptive management plans and recovery plan implementation.

1.0 INTRODUCTION

Recovery planning for Pacific Northwest salmon and steelhead listed under the Endangered Species Act (ESA) is a lengthy, complex, and often costly process involving scientific and technical agencies, multiple local jurisdictions, and citizen groups. This guidance document from the National Marine Fisheries Service (NMFS) is intended to help recovery planners and others working on salmon and steelhead recovery with two crucial tasks: gathering the right information and then using it effectively. The research, monitoring, and evaluation programs associated with recovery planning need to gather the information that will be most useful in tracking progress and assessing the status of the listed species. Then planners and managers can use the information to guide and refine recovery strategies and actions. This document offers conceptual-level guidance, not specific instructions, on these two basic functions.

1.1 ESA Requirements for Salmonid Recovery Plans

The ESA requires NMFS to develop recovery plans for species listed under that act. The purpose of recovery plans is to identify and implement actions needed "for the conservation and survival" (ESA Section 4[f][1]) of threatened and endangered species to the point that they no longer need the protections of the ESA. Recovery plans are being developed for 17 Pacific salmon and steelhead ESUs[2] listed in Washington, Oregon and Idaho. Although these plans are guidance documents, not regulatory, the authors of the ESA clearly saw recovery plans as a central organizing tool for recovery of listed species. Once a species has been de-listed, ESA Section 4(g) requires a program to monitor the status of the species for at least five more years.

To be approved by NMFS, a recovery plan must meet certain requirements as described in the Act:

- ESA section 4(a)(1) lists factors for re-classification or de-listing that are to be addressed in recovery plans:
  - A. The present or threatened destruction, modification, or curtailment of [the species'] habitat or range
  - B. Over-utilization for commercial, recreational, scientific or educational purposes
  - C. Disease or predation
  - D. The inadequacy of existing regulatory mechanisms
  - E. Other natural or manmade factors affecting its continued existence

- Further, ESA section 4(f)(1)(B) directs that recovery plans, to the extent practicable, incorporate:
  1. a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species

[2] NMFS revised its species determinations for West Coast steelhead under the ESA in January 2006, delineating steelhead-only "distinct population segments" (DPS). The steelhead DPS does not include rainbow trout, which are under the jurisdiction of the U. S. Fish and Wildlife Service (USFWS). In this document, however, the term "salmonid ESU" includes steelhead unless otherwise noted.

2. objective, measurable criteria which, when met, would result in a determination, in accordance with ESA Section 4, that the species be removed from the list, and
3. estimates of the time required and cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal (ESA Section 4[f]).

Consequently, 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 section 4(f)(1)(B).[3]

1.2 NMFS-Designated Recovery Domains and Technical Recovery Teams

NMFS Northwest Region has designated three "recovery domains" within the Pacific Northwest to organize recovery planning. The domains are Puget Sound, Willamette/Lower Columbia, and Interior Columbia. The Northwest Region works with the state of Oregon to conserve coho salmon in the Oregon Coast Restoration Area, where there are now no ESA-listed salmon.

For each domain, NMFS has appointed an independent technical recovery team (TRT). Each team has geographic and species expertise for its domain and can provide a solid scientific foundation for recovery plans. The charge of each TRT is to develop recommendations on biological viability criteria for ESUs and populations, provide scientific support to local and regional recovery planning efforts, and provide scientific evaluations of recovery plans. The TRTs include biologists from NMFS, other federal agencies, state, tribal, and local agencies, academic institutions, and private consulting groups.

NMFS also collaborates with state, tribal, local, and other federal stakeholders in each domain to develop a planning forum appropriate to the domain, building as much as possible on continuing, locally led efforts. The role of these planning forums is to use the TRT and other technical products to agree on recovery goals and limiting factors, and then to develop locally appropriate and locally supported actions needed to achieve recovery goals. Although these forums work from a consistent set of assumptions about recovery plan elements needed, the process by which they develop those elements, and the form they take, may differ among domains.

Once a local plan is completed and transmitted to NMFS, the agency ensures that the plan addresses ESA requirements for recovery plans, and then makes the plan available for public review and comment. At that time NMFS proposes ESA de-listing criteria for the ESUs addressed by the plan, since a determination of these criteria is a NMFS decision. While the agency intends to rely heavily on the advice of the TRTs in establishing de-listing criteria, NMFS will take into account and be informed by all relevant information, including biological and policy considerations developed throughout the recovery planning process. NMFS has clarified, through *Federal Register* notices on interim and proposed recovery plans, how it applies the TRT products to the plans (e.g. 70 FR 76445, 71 FR 13094).

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[3] See NMFS 2004 and *Fund for Animals v. Babbitt* 903 F. Supp. 96 (D.D.C. 1995, Appendix B).

1.3 Viable Salmonid Populations

All TRTs use the same biological principles for developing their ESU and population-viability criteria. These principles are described in a NMFS technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al., 2000). A viable salmonid population (VSP) is defined as one that has a negligible extinction risk over a 100-year time frame.

Viable salmonid populations are described in terms of four parameters: abundance, population productivity or growth rate, spatial structure, and diversity. The metrics that are needed to evaluate biological recovery are derived from these parameters.[4] Viable ESUs are defined by some combination of multiple populations, at least some of which meet or exceed "viable" thresholds for abundance and productivity, and that have appropriate geographic distribution, protection from catastrophic events, and diversity of life histories and other genetic expression.

Each TRT identified groupings of independent populations at the sub-ESU level, based on shared geography or ecosystems, genetic similarity, and other considerations. The Interior Columbia TRT called these groups of populations major population groups (MPGs); the Willamette/Lower Columbia TRT called them strata; and the Puget Sound TRT identified them as geographical regions. This document refers to such groupings of independent populations within an ESU as MPGs.

1.4 ESU Viability Criteria

NMFS asked each TRT to address a consistent set of questions regarding ESU viability. All TRTs define a viable ESU as one that is naturally self-sustaining and that has a negligible risk of extinction over a 100-year time frame. All TRTs designed ESU viability criteria based on the VSP parameters, such that, in most instances, there could be more than one possible combination of component population characteristics and risk levels that would result in a naturally self-sustaining ESU.

Each TRT also discussed how to evaluate the contributions of non-self-sustaining populations. Populations could be non-self-sustaining if they are either naturally non-viable (e.g., they occupy naturally marginal habitat), and/or they are sustained by hatchery supplementation. Each TRT requires that the "non-viable" populations in an ESU be at least healthy enough to provide sufficient ecological function so that the ESU as a whole can be naturally self-sustaining.

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[4] A *metric* is something that quantifies a characteristic of a situation or process. Metrics can be directly observable quantities or can be derived from one or more directly observable quantities. The term *indicator* is used to quantify metric data to provide insight into a situation, process or activity. Indicators are metrics in a form suitable for assessment or decision making. An indicator may be the behavior of a metric over time or the ratio of two metrics. Indicators may include the comparison of actual values versus expected values. Indicators are used in conjunction with one another to provide a more complete picture of process behavior and progress.

1.5 Population Viability Criteria

Populations within ESUs are the units whose risk levels collectively determine the likely persistence of the ESU. The TRTs describe, for each population, the recommended criteria needed for long-term viability, where viability is defined as a persistence probability of at least 95 percent for at least 100 years. Following McElhany et al., (2000), the TRTs describe a population's status using the VSP parameters or key characteristics of abundance, productivity, diversity, and spatial structure.

Abundance and productivity – The TRTs developed quantitative abundance and productivity criteria as combined attributes. Abundance (adults on the spawning ground) and productivity (adult progeny per parent) are closely related: unproductive populations can still persist if they are large enough, and small populations can persist if they are productive enough. Thus, a population's risk status depends on a combination of abundance and productivity. All the TRTs used multiple, independent lines of evidence to estimate the abundance and productivity needed for a viable population. All TRTs used similar demographic models that estimate persistence probability based on numbers of individuals, the trend in individual numbers over time, and variation in population growth rates. They expressed the results of these models in slightly different ways (Appendix A). Some of the model details and assumptions also differ in minor ways across domains,[5] but the basic approach is common to all TRTs.

In addition to population modeling, each TRT used estimates of historical and/or current habitat capacity to determine whether the results from the population models were reasonable. The combined results from several independent analyses added to the TRTs' confidence in recommending viability criteria.

Spatial structure and diversity – Salmonid spatial structure refers to the geographic distribution of salmon throughout their life stages. Low-risk populations have sufficient habitat quality and quantity, as well as interconnections among the habitats, to ensure their persistence as the environment changes over time.

The diversity parameter refers to varying traits among salmonids that may be genetic, phenotypic, or behavioral (such as run timing, age at maturity, ocean distribution patterns, straying, and many others). Diversity is essential to salmonid "resilience"—a population's ability to survive short-term environmental perturbations and to adapt in longer-term evolutionary processes. All TRTs specify the importance of identifying and maintaining "key" diversity types within populations. The TRTs also consider habitat diversity as a surrogate for salmon diversity. They encourage protection and restoration of an accessible and diverse array of habitats so that salmon diversity can be expressed.

The population viability criteria for spatial structure and diversity outlined by the TRTs are more qualitative than those identified for abundance and productivity. Put simply, the closer a

[5] Key assumptions affecting results of population viability modeling relate to choices about (1) quasi-extinction thresholds (QETs) or the population size below which it is considered extinct for modeling purposes, (2) natural variance in population growth rates, (3) structure of underlying model, (4) assumptions about when in the life cycle density-dependence occurs, and (5) time period over which population status is assessed.

population is to the spatial structure and diversity attributes it exhibited historically, the more certain it is that the population will be at low risk of extinction. However, species are not necessarily threatened or endangered simply because their status departs from the historical template; some might be viable with substantial reductions compared to historical conditions.

Because evolution is a dynamic process, it is not always easy to determine the appropriate time-frame to consider “historical.” Furthermore, the historical template is not necessarily static. Within certain limits, species are capable of adapting and responding to changing environmental conditions over time. The concept of historical spatial structure is still important to consider, however, because the historical template is the only one that we know was capable of ensuring long-term viability of the species in nature. The more current conditions depart from the historical template, the greater uncertainty we have that the species will remain viable into the future. If current conditions are substantially different from the historical template, it becomes increasingly important to document and test reasons for believing the species can be viable in the future under compromised conditions. Conversely, if the current situation roughly approximates the historical template, then, absent compelling evidence to suggest otherwise, it can generally be concluded that the species is not at significant short-term risk.

1.6 Adaptive Management

It is necessary to design and implement practical, effective monitoring and evaluation programs to track the progress of recovery efforts. The resulting information will be of little value, however, unless it is used to inform decisions and actions on salmon recovery. That process of adjustment based on new data is called adaptive management.

Adaptive management involves taking an experimental approach to a complex task, making assumptions clear, and continuously evaluating them in light of new information. It works best when performance data collection and evaluation methods are designed to provide the information managers need to make sound decisions.

An adaptive management plan for salmon recovery provides:
(1) a clear statement of the metrics and indicators by which progress toward achieving goals will be tracked
(2) a monitoring and evaluation plan for tracking such metrics and indicators, and
(3) a decision framework through which new information from monitoring and evaluation is used to adjust strategies or actions aimed at achieving recovery goals.

Having an adaptive management plan in place before implementing a recovery plan provides greater assurances that the recovery plan will achieve its objectives. Once the adaptive management plan is designed, it should guide implementation of salmon recovery activities through repeated adjustments in strategies and actions, as information from monitoring and evaluation becomes available. Strategies and actions needed for salmon recovery can evolve as uncertainties in the effectiveness of actions are reduced through monitoring and evaluation.

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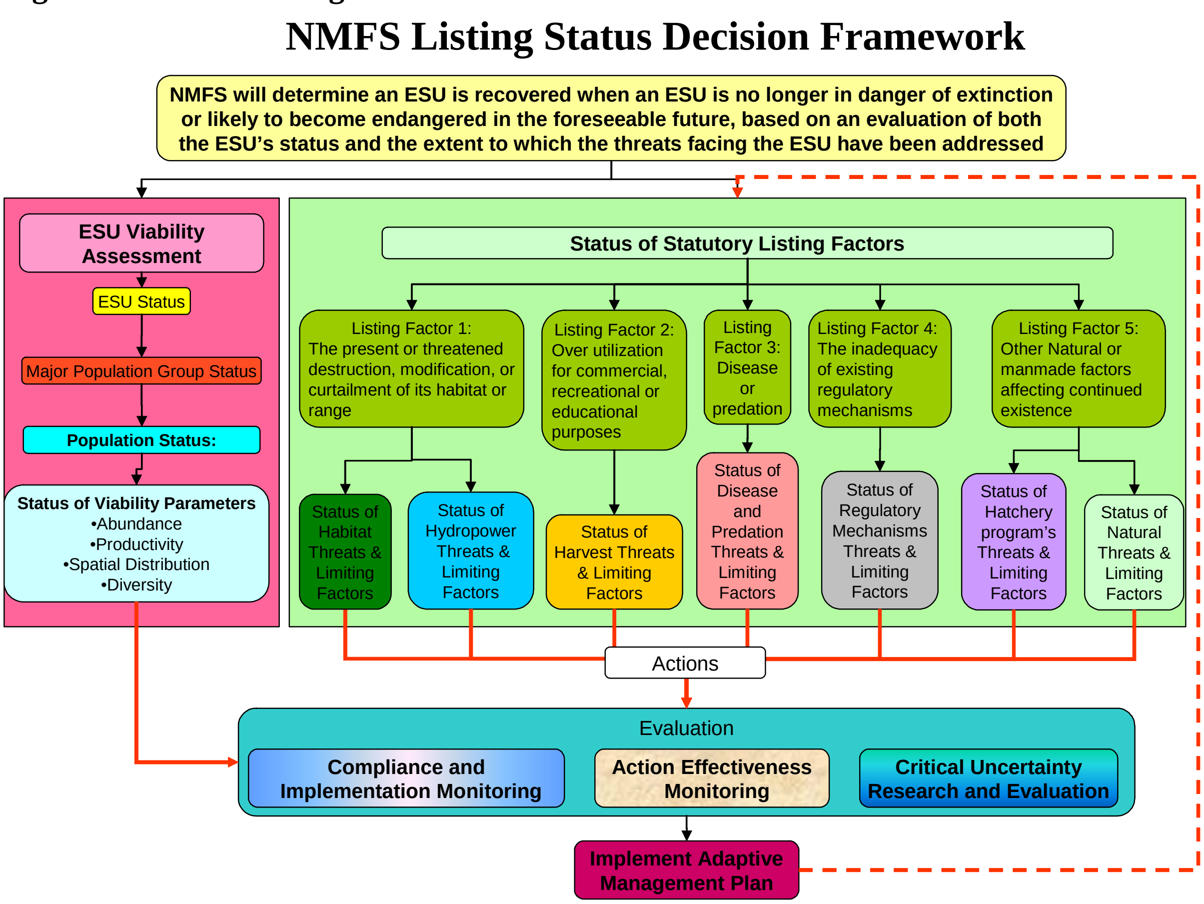
2.0 NMFS' LISTING STATUS DECISION FRAMEWORK

NMFS' listing status decision framework (Figure 1) (decision framework) is a series of decision-question sets that address the status and change in status of a salmonid ESU, and the risks posed by threats to the ESU. NMFS ultimately bases a decision to de-list an ESU on a determination that the ESU 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 (50 CFR § 424.11).

The decision-question sets step down from ESU to MPG to population scale. The questions at each scale should elicit information needed to make the decision(s) required at that scale. Although the decision framework addresses ESU biological status separately from ESU listing factor status, both sets of questions relate to the viability criteria developed by the TRTs. Both must be considered in evaluating overall ESU status and change in status.

Figure 1 – NMFS Listing Status Decision Framework



The decision framework and decision-question sets are intended (1) to inform recovery planners and implementers of how NMFS intends to evaluate ESU status and (2) to demonstrate the questions that research, monitoring, and evaluation programs for salmon recovery plans should answer, since that information will provide the basis for the status evaluations.

2.1 ESU Viability Assessment

The decision framework is based on viability parameters and metrics identified by the four Pacific Northwest TRTs. Although all the TRTs used the same principles and VSP parameters, their viability criteria differ in some details because of inherent differences in populations and ecosystems across the region, as well as the ideas and expertise of each TRT. Appendix A summarizes the population and ESU viability criteria of all four TRTs, generalized to produce a set of questions that would be applicable across all ESUs. The table thus leaves out many details that would lead to additional, finer-scaled sub-questions. These detailed questions are in each TRT's viability documents on the web at: http://www.nwfsc.noaa.gov/trt/

2.1.1 ESU-Scale Decision

This decision/question set requires aggregation or synthesis of the status of all MPGs in the ESU. Each MPG will be evaluated against ESU criteria to arrive at an overall conclusion about ESU viability.

Decision: The aggregate status and change in status of the MPGs in the ESU demonstrate a level of risk, natural sustainability, or probability of persistence sufficient to warrant a change in ESU listing status.

Question to answer to support the decision: Are all MPGs within the ESU at, or clearly trending toward, a low risk status? (What is the aggregate status and change in status of the MPGs in the ESU relative to viability criteria?)

2.1.2 MPG-Scale Decision

This decision/question set requires aggregation or synthesis of the viability of all populations in an MPG. Each population must be evaluated against population-specific viability criteria to arrive at a conclusion on overall MPG viability. The same process must be completed for each MPG in the ESU.

Decision: (For each MPG) The aggregate status and change in status over time of the populations and habitats within the MPG demonstrates a level of risk, natural sustainability, or probability of persistence sufficient to consider the MPG viable.

Questions to answer to support the decision: Is the number of populations at high viability/low risk consistent with recommended ESU viability criteria, and are the remaining populations and streams within the MPG at sufficient status or quality to meet ESU viability criteria?

1. Do at least one-half of the populations historically within the MPG (with a minimum of two populations) meet viability standards?

2. Does at least one population within the MPG meet "Highly Viable" criteria?

3. Do viable populations within the MPG include some populations classified (based on historical intrinsic potential) as "Very Large," "Large," or "Intermediate," generally reflecting the proportions historically present within the MPG? In particular, are Very Large and Large populations at or above their composite historical fraction within the MPG?

4. Are all major life history strategies (e.g. spring and summer run timing) that were present historically within the MPG represented in populations meeting viability requirements?

5. Are the remaining populations being maintained with sufficient abundance, productivity, spatial structure, and diversity to provide for ecological functions and to preserve options for ESU recovery?

2.1.3 Population-Scale Decision

This decision/question couplet considers the population status indicators (abundance, productivity, spatial structure, diversity) within the population (against population-specific viability criteria) to arrive at an overall conclusion on the population's status. This same consideration must be completed for each population in the MPG.

Decision: The status and change in status of the population's viability parameters, in the aggregate, demonstrate a level of risk, or probability of persistence, sufficient to consider that the population has achieved the viability targets established for its classification (i.e., the level of risk considered acceptable for this population).

Questions to answer to support the decision: What is the status and change in status of the population's viability parameters relative to its target viability parameters and status?

1. What is the abundance/productivity status of the population based on population change criteria or viability curves for natural-origin salmon considering historical/intrinsic capacity estimates,[6] depensation thresholds,[7] or natural return ratio?[8]

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[6] Intrinsic capacity: An estimate of the historical abundance/productivity of a specific population.

[7] Depensation threshold definition: A depensatory effect is the tendency for the population growth rate to decrease as the population abundance decreases below a certain, taxon-specific threshold. Depensatory effects heighten extinction risk. A species is endangered if it declines to a taxon-specific depensation threshold below which the demographic and genetic behavior of any given population becomes highly uncertain.

[8] Natural Return Ratio (NRR): The number of naturally produced fish that are born during a given brood year and subsequently return to spawn, divided by the total number of fish on the natural spawning grounds (including naturally spawning hatchery fish) in that brood year.

2. What is the status of the spatial structure of the population based on consideration of the existing number, size, productivity, and distribution of spawning and rearing locations relative to what is sufficient for the population to be viable?

3. What is the current state, and change in state, of the genetic diversity of the population based on consideration of natural patterns of gene flow, existing diversity, habitats, and environmental variation?

   a. What is the current fraction and change in fraction of hatchery vs. natural-origin spawners in the population?
   b. What is the origin of hatchery fish in the population?

2.2 Statutory Listing Factors and Limiting Factors Assessment

This section outlines the decisions, questions, and supporting information needed to assess the status of statutory listing factors (including any factors identified subsequent to listing). Populations may be exposed to different risks within a single MPG. The level of risk acceptable across populations within an MPG may vary.

In contrast to the viability assessment, the decision framework for listing factors does not rely on explicit criteria when considering the MPG scale, but steps down directly from the ESU to the individual population, when possible.

Decision: The statutory listing factors have been addressed such that threats to the ESU have been ameliorated and no longer pose a threat to the continued existence of the ESU.

Questions to answer to support the decision:

1. Have statutory listing factors been addressed such that threats to the ESU have been ameliorated to the extent that they no longer pose a threat to the continued existence of the ESU?

2. Is the ESU achieving or clearly trending toward a low-risk status in response to actions that have been implemented to diminish those factors limiting achievement of ESU viability criteria?

Information on the status and trend of the listing factors is an implicit requirement for answering these questions. Two more questions are also necessary:

   a. Is there an effect of the listing factor on any of the viability parameters of natural-origin fish, and if so, what is the *magnitude* of that effect?

   b. If there are effects of the listing factor on viability parameters of natural-origin fish, what is the *significance* of those effects for the viability of the population?

2.2.1 Listing Factor A: The present or threatened destruction, modification, or curtailment of an ESU's habitat or range.

Habitat and hydropower are the main categories of threats considered under Listing Factor A.

2.2.1.1 Habitat

<u>Decision:</u> Habitat-related threats have been ameliorated such that they do not limit attainment of the desired status of the population. The desired status of each population is defined by viability criteria identified in the recovery plan.

<u>Questions to answer to support the decision:</u>

1. What is the effect of present or threatened habitat degradation (limiting factors) on the observed abundance, productivity, diversity (includes run timing), and distribution of the natural-origin fish in this population? (The limiting factors below are presented as examples. Limiting factors are population-specific and will differ in number, type and specific definition.[9])

   a. **Floodplain Connectivity and Function-** The loss, impairment or degradation of floodplain connectivity; access to previously available habitats (seasonal wetlands, off channel habitat, side channels); and a connected and functional hyporheic zone.

   b. **Channel Structure and Complexity-** The loss, impairment or degradation of channels; a suitable distribution of riffles and functional pools; and functional amounts and sizes of large woody debris or other channel structure.

   c. **Riparian Areas and LWD Recruitment**- Loss, degradation or impairment of riparian conditions important for production of food organisms and organic material, shading, bank stabilizing by roots, nutrient and chemical mediation, control of surface erosion, and production of large-sized woody material.

   d. **Stream Substrate**- Altered sediment routing leading to an overabundance of fine-grained sediments; excess coarse-grained sediments; inadequate coarse-grained sediments; and contaminated sediment.

   e. **Stream Flow**- Inadequate flow, scouring flows, or changes to the hydrograph to the point that it inhibits development and survival of salmonids.

   f. **Water Quality**- Degraded or impaired water quality due to abnormal temperature, or levels of suspended fine sediment, dissolved oxygen, nutrients, heavy metals, pesticides, herbicides and other contaminants (toxics).

   g. **Fish Passage**- The total or partial human-caused blockage to previously accessible habitat that eliminates or decreases migration ability or alters the range of conditions under which migration is possible. This may include seasonal or periodic total migration blockage. This category also includes entrainment in irrigation diversions.

2. If there are habitat-related effects of limiting factors on viability parameters of the natural-origin fish, what is the significance of those effects for the viability of the population? (The

[9] Population-specific limiting factors should be identified from recovery plans and TRT products.

significance of any observed effects will be determined by considering the status and change in status of the population's viability parameters against a benchmark, such as recovery plan viability criteria/objectives.)

a. Does/will the effect of current floodplain connectivity and function on the population inhibit the population from achieving viability criteria or goals stated in the recovery plan?

b. Channel structure and complexity?

c. Riparian areas and LWD recruitment?

d. Stream substrate?

e. Stream flow?

f. Water quality?

g. Fish passage?

3. Does the status of the *other* listing factors modify the absolute risk posed by the current and potential future status of *this* listing factor?

2.2.1.2 Hydropower

Decision: Hydropower-related threats have been ameliorated such that they do not limit attainment of the desired status of the populations relative to population-specific viability criteria identified in the recovery plan.

Questions to answer to support the decision::

1. What is the effect of this threat (hydropower) on the observed abundance, productivity, diversity, and distribution of the natural-origin fish in this population?

a. What is the effect of the status and change in status of hydropower-related fish passage impairment and/or upstream and downstream habitat modification of each dam (including water quantity, quality, etc.) on the population's abundance, productivity, and escapement rate?

b. On the population's spatial distribution?

c. On the population's temporal diversity (run timing)?

2. How do hydropower-related effects on viability parameters of natural-origin fish relate to viability criteria stated in the recovery plan?

a. What is the effect of the status and change in status of hydropower-related fish passage impairment and/or upstream and downstream habitat modification of each dam (including water quantity, quality, etc.) on the population's desired abundance, productivity, and escapement rate?

b. On the population's desired spatial distribution?

c. On the population's desired temporal diversity (run timing)?

3. Does the status of the *other* listing factors modify the absolute risk posed by the current and potential future status of *this* listing factor?

2.2.2 Listing Factor B: Over-utilization for commercial, recreational or educational purposes

Harvest is the main category of threat considered under Listing Factor B.

Decision: Harvest-related threats have been ameliorated such that they do not, and will not, limit attainment of the desired status of populations relative to population-specific viability criteria stated in the recovery plan.

Questions to answer to support the decision:

1. What is the effect of this threat (harvest) on the observed abundance, productivity, spatial distribution, and diversity of the natural-origin fish in this population?

a. What is the impact of this threat, expressed in terms of current total fishery exploitation rate, on the abundance of the population?

b. What is the effect of the status and change in status of the exploitation rate on the population's productivity and escapement?

c. What is the effect of the status and change in status of the exploitation rate on the spatial distribution of the spawning population?

d. What is the effect of the status and change in status of the exploitation rate on the diversity of the population?

2. If there are harvest-related impacts on observed abundance, productivity, diversity or distribution of the natural-origin fish, what is the significance of these effects for the viability of the population?

a. Does/will the total fishery exploitation rate on the population, given observed abundance of spawners (escapement), inhibit the population from achieving viability criteria or goals for productivity stated in the recovery plan?

b. For abundance?

c. For spatial distribution?

d. For diversity?

3. Does the status of the *other* listing factors modify the absolute risk posed by the current and potential future status of *this* listing factor?

2.2.3 Listing Factor C: Disease or predation

<u>Decision</u>: Disease and predation-related threats have been ameliorated such that they do not, and will not, limit attainment of the desired status of populations relative to viability criteria stated in the recovery plan.

<u>Questions to answer to support the decision</u>:

1. What is the effect of disease on the observed abundance, productivity, spatial distribution, or diversity (including timing) of the natural-origin fish in this population?

2. What is the effect of predation on the observed abundance, productivity, spatial distribution, or diversity (including timing) of the natural-origin fish in this population?

a. Avian predators (e.g., cormorants and terns)

b. Marine mammals (e.g., pinnipeds, orcas)

c. Piscine predators (e.g., northern pikeminnow, bass)

3. If there are disease or predation-related impacts on observed abundance, productivity, distribution, or diversity of the natural-origin fish, what is the significance of these effects for the population's ability to achieve viability objectives?

a. Does/will the observed disease-related reduction in fitness limit the population's capability to achieve its viability criteria for abundance, productivity, distribution, and diversity stated in the recovery plan?

b. Does/will the predation rate on the population inhibit the population from achieving its viability criteria for abundance, productivity, distribution, and diversity stated in the recovery plan?

i. Avian predators (e.g., cormorants and terns)

ii. Marine mammals (e.g., pinnipeds, orcas)

iii. Piscine predators (e.g., northern pikeminnow, bass)

4. Does the status of the *other* listing factors modify the absolute risk posed by the current and potential future status of *this* listing factor?

2.2.4 Listing Factor D: Inadequacy of existing regulatory mechanisms

Decision: Inadequacies of existing regulatory mechanisms have been addressed such that regulatory mechanisms do not, and likely will not, limit attainment of the desired status of populations relative to viability criteria stated in the recovery plan.

Questions to answer to support the decision:

1. What is the effect of federal, state, tribal, or local regulatory mechanisms on the status of the limiting factors associated with listing factors 1, 2, 3 and 5?

   a. Habitat

      i. What were the most significant habitat-related factors limiting the population from achieving recovery plan objectives?

      ii. What is the status and change in status of those limiting factors?

      iii. Are the risks to desired population status from those limiting factors still present?

      iv. What regulatory mechanisms are in place to maintain the reduced risk or further reduce the risk of those limiting factors to desired population status in the future and how effective are they?

   b. Hydropower

      i. What were the most significant hydropower-related factors limiting the population from achieving recovery plan objectives?

      ii. What is the status and change in status of those limiting factors?

      iii. Are the risks to desired population status from those limiting factors still present?

      iv. What regulatory mechanisms are in place to reduce the risk of those limiting factors to desired population status in the future and how effective are they?

   c. Harvest

      i. What were the most significant harvest-related factors limiting the population from achieving recovery plan objectives?

      ii. What is the status and change in status of those limiting factors?

iii. Are the risks to desired population status from those limiting factors still present?

iv. What regulatory mechanisms are in place to reduce the risk of those limiting factors to desired population status in the future and how effective are they?

d. Disease and Predation

i. What were the most significant disease-related and predation-related factors limiting the population from achieving recovery plan objectives?

ii. What is the status and change in status of those limiting factors?

iii. Are the risks to desired population status from those limiting factors still present?

iv. What regulatory mechanisms are in place to reduce the risk of those limiting factors to desired population status in the future and how effective are they?

e. Hatcheries

i. What were the most significant hatchery-related factors limiting the population from achieving recovery plan objectives?

ii. What is the status and change in status of those limiting factors?

iii. Are the risks to desired population status from those limiting factors still present?

iv. What regulatory mechanisms are in place to reduce the risk of those limiting factors to desired population status in the future and how effective are they?

2. Are the regulatory mechanisms adequate? That is, is the status (effectiveness, geographical scope and certainty of implementation) or change in status of regulatory mechanism(s) addressing the limiting factors such that those limiting factors will not pose a significant threat in the future to the maintenance of the population at viability levels identified in the recovery plan?

a. Habitat
b. Hydropower
c. Harvest
d. Disease and Predation
e. Hatcheries

3. Is the significance of the combined effect of all listing factors on the population's achievement of specific viability criteria or goals established in the recovery plan affected by the cumulative effect of the other listing factors?

2.2.5 Listing Factor E: **Other natural or manmade factors affecting the continued existence of the ESU**

Other natural factors may include, but are not limited to, ecosystem interactions; ocean conditions; global climate change; and catastrophic events. Other manmade factors include, but are not limited to, various effects of hatchery operations and inter- and intra-specific forms of competition.

2.2.5.1. Natural Factors

Decision: Other natural factors have been accounted for such that they do not limit attainment of the desired status of populations relative to viability criteria identified in the recovery plan.

Questions to answer to support the decision:

1. What is the current and potential future effect of other natural factors on the observed abundance, productivity, spatial distribution, and diversity of the natural-origin fish in this population? Examples:

   a. What is the current and potential future effect of ecosystem interactions on the population's viability attributes?

   b. Of ocean conditions?

   c. Of climate change?

   d. Of any likely future catastrophic event?

   e. Of changes in the distribution or intensity of competition? (For simplicity, this includes competitive interactions from invasive species regardless of the mechanisms by which they were introduced.)

2. If natural factors affect observed abundance, productivity, distribution, or diversity of the natural-origin fish, what is the significance of those effects for the viability of the population?

   a. Does/will the effect of ecosystem interactions inhibit the population from achieving viability criteria established in the recovery plan? (Does the actual risk [probability of occurrence, magnitude of effect] warrant consideration in the recovery plan?)

   b. The effect of climate change?

   c. The effect of ocean conditions?

   d. The effect of catastrophic events?

   e. The effect of current competitive interactions?

2.2.5.2 Other Anthropogenic Factors - Hatcheries

Decision: Hatchery-related threats have been ameliorated such that they do not, and will not, limit attainment of the desired status of populations relative to viability criteria stated in the recovery plan.

Questions to answer to support the decision:

1. What is the effect of hatchery operations on the observed abundance, productivity, distribution, or diversity of the natural-origin fish in this population?

   a. What is the effect of broodstock collection on the population's abundance and productivity?

   b. What is the effect of genetic introgression/residualism on the population's diversity?

   c. What is the effect of domestication on the population's diversity?

   d. What is the effect of hatchery-related disease on the abundance, productivity, distribution or diversity of the population?

   e. What is the effect of hatchery-related competition/density-dependent effects on the abundance, productivity and distribution of the population?

   f. What is the effect of hatchery-related changes to predation rates on the abundance, productivity, distribution, and diversity of the population?

   g. What is the effect of hatchery-related changes to ecosystem nutrient dynamics on the abundance, productivity and distribution of the population?

   h. What is the effect of hatchery spawning times on the diversity of the population?

2. If there are hatchery-related impacts on observed abundance, productivity, distribution, or diversity (includes morphology and life history) of the natural-origin fish, what is the significance of these effects – do they decrease the population's ability to achieve viability criteria stated in the recovery plan or increase the risk to the population?

   a. Broodstock collection effect

   b. Genetic introgression/residualism

   c. Domestication selection on hatchery fish

   d. Hatchery-related disease

e. Hatchery-related competition/density-dependent effects

f. Hatchery-related changes to predation rates

g. Hatchery-related changes to ecosystem nutrient dynamics

h. Hatchery practice-induced changes in morphology and life history of hatchery fish

3. Is the significance of the effect of this listing factor (hatcheries) on the population's achievement of viability criteria stated in the recovery plan affected by the cumulative effect of the other listing factors?

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3.0 ADAPTIVE MANAGEMENT

The decision framework described in Section 2 is intended to facilitate adaptive management in recovery plan implementation by building an explicit link between management actions, monitoring data, and biological and physical response. In this section the elements of adaptive management are described in more detail, followed in Section 4 by a discussion of the types of monitoring most useful for adaptive management.

Adaptive management is the process of adjusting management actions and/or directions based on new information. To do this, it is essential to incorporate a plan for monitoring, evaluation and feedback into an overall implementation plan for recovery. The plan should link results (intermediate or final) to feedback on design and implementation of actions. Adaptive management works by coupling the decision-making process with collection of performance data and its evaluation. Most importantly, it works by offering an explicit process through which alternative strategies to achieve the same ends are proposed, prioritized, and implemented when necessary. (NMFS expects to work closely with recovery plan developers to contribute to the process of developing, proposing, prioritizing, and assessing alternative strategies for inclusion in adaptive management plans and the recovery plan implementation process.)

An adaptive management plan must include the following elements (Anderson, 2003):

- Management strategies that are revisited regularly;
- The use of conceptual or quantitative models of the system being managed to develop and test hypotheses and to guide strategy and action planning;
- A range of potential management actions that could be used to meet the strategy;
- Monitoring and evaluation to track progress;
- Mechanisms for incorporating learning from monitoring and evaluation into decisions on actions and strategies; and
- A collaborative structure for stakeholder participation in adjusting management strategies and actions.

Uncertainty is inherent in the assessment of salmonid status, and relating the status data to cause-and-effect questions is complex, at best. Thus, an experimental, adaptively driven framework is the most parsimonious approach. At its most basic, an experimental or *adaptive management* framework means that all assumptions underlying an assessment and decision framework are clearly stated and ultimately subject to evaluation. The management framework itself is adopted, but then questioned, evaluated, deconstructed and reconstructed as part of the ongoing implementation.

Figure 2 depicts the overall conceptual framework for the evaluation cycle at the center of all management plan implementation. Most salmon management plans are structured in the short term to answer the question in Stage A (“What are you trying to achieve?”), including discussions of the goals and objectives, threats limiting attainment of the goals, and a strategy to achieve the goals. To develop an adaptive management plan, however, it is necessary to move beyond Stage A and thoroughly address the additional, key questions (Stages B-D): How will you know you’re making progress? How will you get the information you need? How will you use the information in decision making?

A monitoring and evaluation plan to support adaptive management provides: (1) a clear statement of the metrics and indicators by which progress toward achieving goals can be tracked; (2) a plan for tracking such metrics and indicators; and (3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the plan’s goals. Once the plan is designed, it should guide implementation of salmon recovery activities through iterative adjustments in strategies and actions as information from monitoring and evaluation comes forth. Having an adaptive management plan in place at the outset of plan implementation provides greater assurances that the plan will succeed in achieving its objectives. Through the adaptive management plan, strategies and actions needed for salmon recovery can evolve as uncertainties in the effectiveness of actions are reduced through monitoring and evaluation.

An adaptive management plan can offer sufficient assurances in technical results over time because it is a strategy to explicitly address and manage the risk associated with implementing an extremely complex program. Alternatives to adaptive management are more risky in the long-term—getting it right the first time and staying lucky; being wrong and staying wrong; and just muddling through—all might work, but at what cost if they don’t? Less rigorous forms of adaptive management, such as learning from experience, after-the-fact assessment, and flexible planning, also might appear to moderate the risk in the long term. In the short term they lack the explicit feedback through an identified decision-making process that will accelerate response time and form the basis for trusting that a program is working toward its intended objectives.

Monitoring and evaluation feeds into adaptive-management-driven decision making through a simple logical chain. Such a chain begins with a problem statement. That statement must address the condition that requires monitoring, as well as the people who must evaluate the monitoring data and make decisions concerning the problem. To connect monitoring data to the decision process, the adaptive management plan must identify types of information needed to make decisions, and trigger points around which decisions are made. Given the inputs to a decision, it is then possible to specify a set of decision rules.

Decision rules must specify the spatial and temporal characteristics and the precision of input information for the trigger points. When fully specified, decision rules define the necessary and sufficient monitoring data and information. Finally, with the required information fully specified, a monitoring program can be designed. In an ideal situation the above process would be accomplished in a single pass in advance of recovery plan implementation. However, given the inherent complexity of the recovery plan implementation process, it is likely that the specification of decision information, inputs, and rules will be iterative.

The Evaluation Cycle (Yaffee et al. 2004)

Stage A: What are you trying to achieve? – Creating a situation map
What are your goals and objectives?
What threats and assets affect your project?
What strategies are needed to achieve objectives?
What are the relationships among your objectives, threats and assets, and strategies?
What process issues and concerns affect your project?

In this stage, develop a clear picture of the project's situation and define project success on multiple levels by addressing:
What are the ecological, social and economic *goals and objectives* of the project? What is the target to achieve or change?
What are the *threats and assets* affecting the project? What is preventing progress and what is moving the project forward?
What are the *strategies and activities* of the project? What are our on-the-ground approaches and how are we implementing them?
How do the strategies minimize threats and/or capitalize on assets to move us closer to the goals and objectives? That is, what is the *connected story* behind the activities and objectives within a complex system?
What *organizational process issues*, such as leadership or communication, affect our project's progress?

Stage B: How will you know you are making progress? – Developing an Assessment Framework
What do you want to know?
What do you need to know?
What will you measure to answer your evaluation questions?
How might you use the information?

In this stage, the situation map created in Stage A is used to establish a framework for measuring progress on multiple levels by answering:
What do we want to know? That is, what *evaluation questions* do we want to ask about the impact, implementation, or approach of our project or about the situation in which we work?
What do we need to know? What are our *evaluation priorities*?
What *indicators* will we measure and what will we *compare* these measure against to answer our questions and assess progress?
How might you *use this information* to affect decision making or communicate with stakeholders?

Stage C: How will you get the information you need? – Preparing an Information Workplan
Does available information suit your needs, and if not, how will you collect it?
What are your analysis needs?
How will the necessary activities be accomplished?

In this stage, prepare for the logistics of undertaking the evaluation plan. This includes thinking about:
Where will *data* come from? Is it already available or will it need to be collected, and if so, how?
How will we need to *process or analyze* the data to give us a clear answer to our evaluation question?
Who will be responsible for these activities?

Stage D: How will you use the information in decision making? – Creating an Action Plan
What are your trigger points?
What actions will be taken in response to reaching a trigger point?
Who will respond?
How will you summarize and present your findings?

In this stage, consider ways to tie the evaluation back to decision making by answering:
What will be the *trigger points*? At what level, amounts or rate of change of an indicator will we change course or reconsider our strategies?
What possible *actions* might we take if a trigger point is reached?

Figure 2. Adaptive Management: The Evaluation Cycle (Yaffe et al., 2004)

The following examples of two different types of monitoring, status monitoring and effectiveness monitoring, discussed in more detail in Section 4, illustrate the required connections between decisions, monitoring, evaluation, and actions.

Status Monitoring

Goal and Objective: State the goals and objectives of the plan

Determine the annual status of Chinook populations in the Nooksack River.

Questions: State the questions that need to be answered to track progress toward achieving goals.

What is the annual estimated spawning population size of Chinook in the Nooksack River with a specified level of certainty?

Monitoring: Collect representative data to answer the questions and quantify the uncertainty surrounding the data.

Collect redd or spawning ground survey data with a sampling design based on the specified certainty posed in the question.

Evaluation: Assess these data to answer questions relative to performance standards articulated in the question.

Generate an annual estimator of spawning Chinook in the Nooksack River.

Feedback: Apply a decision framework outlining how management decisions about strategies or actions change in response to new information.

Based on the hypotheses and strategy, does spawning population value fall within expected range? If not, how are decisions regarding the strategy designed to change in response to new data?

Action: Update the management action to reflect the input from the adaptive assessment process.

If monitoring and evaluation are sufficient to meet standards, then continue; otherwise revise monitoring approach. If population status approach is on track, then continue; otherwise trigger alternative recovery strategy or consult decision pathways.

Effectiveness Monitoring

Goal and Objective: State the goals and objectives of the plan

Restore juvenile Chinook rearing habitat in Skagit River estuary and delta.

Questions: State the questions that need to be answered to track progress toward achieving goals.

How effective is the restoration of tidal channels at generating new rearing habitat for juvenile Skagit River Chinook within specified certainty bounds?

Monitoring: Collect representative data to answer the questions and quantify the uncertainty surrounding the data.

Collect habitat use data for juvenile fish in restored, non-restored, and natural tidal channels with sufficient effort to meet error limits imposed by question.

Evaluation: Assess these data to answer questions relative to performance standards articulated in the question.

> *Generate estimates of juvenile salmon habitat use by type (restored, not restored, natural).*

Feedback: Apply a decision framework outlining how management decisions about strategies or actions change in response to new information.

> *Based on the hypotheses and strategy, does restoration action result in increased rearing habitat? If not, how are decisions regarding the actions designed to change in response to new data?*

Action: Update the management action to reflect the input from the adaptive assessment process.

> *If monitoring and evaluation are sufficient to meet standards, then continue; otherwise redesign assessment strategy. If restoration strategy is on track, then continue; otherwise either redesign, redo, or abort decision pathway.*

A final note of caution is necessary to bound the discussion of planning-action-assessment-learning feedback. All the adaptive management criteria and plans will not be helpful if the initial actions cause or allow events that preclude future options. For example, if the adaptive management plan calls for an action, and the action has some probability of (unintentionally) changing some population metric from desirable state X to undesirable state Y, then the decision whether to allow the action should not be made without considering whether the change from X-Y is reversible and, if so, with what probability and on what time frame. In such a situation, a monitoring program that can reliably detect whether state Y has been reached will be of little consolation if there is no way back to X. The key point is that, for adaptive management to be effective, there has to be some assurance that a particular action is not headed down a one-way street. If it is, this fact must be understood, and the attendant risks must be considered to be acceptable.

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4.0 MONITORING AND EVALUATION FOR ADAPTIVE MANAGEMENT

In the context of salmon recovery, a monitoring and evaluation plan provides answers to two important questions: (1) What is the status of the population/ESU for each of the four VSP parameters? (What is the condition or status of X?) and (2) Which factors among the "Hs" are limiting recovery for each population/ESU? (What is the effect of Y on the condition or status of X?). The monitoring programs that generate data to address these two classes of questions are fundamentally different. While they can be related, integrated or interconnected, they cannot be substituted one for the other. In this document, monitoring of the first type will be referred to as *status and trends monitoring*, and the second type as *effectiveness monitoring*. See Figure 3 for more detailed descriptions of other types of monitoring.

While *status and trends monitoring* can produce data on population status and on the status of the potentially limiting factors, without some modeling (quantitative, qualitative, heuristic), supported by *effectiveness monitoring* data, it is impossible to translate between these two data sets or types, i.e., to make cause-and-effect statements.

This section is focused on principles that should guide the development of status and trends and effectiveness monitoring for salmon recovery plans. It includes a brief discussion of uncertainty in salmon recovery planning, and some examples of uncertainties that might fruitfully be researched.

4.1 Status and Trends Monitoring

Status and trends monitoring is a simple compilation or data-based description of existing conditions. It may be difficult to collect these data or assess their meaning or information content, but there is very little conceptual depth to this kind of monitoring. It is important to realize that status and trends monitoring applies to much more than the assessment of populations and their habitat. Of equal importance are data on the condition of management actions (implementation and compliance monitoring), threats, and large-scale environmental context. Together all these data types represent the salmon "landscape" as a snapshot in time, or, when compiled over time, as a more complicated snapshot that includes a temporal pattern (generally quantified as trend or variability).

Types of Monitoring – Definitions

Following are commonly used definitions for the most general types of monitoring with relevance to recovery plan implementation and assessment. These definitions allow for distinctions between status and trends monitoring, and parse out the components of effectiveness monitoring into implementation, compliance, effectiveness, and validation. To simplify the discussion, these five monitoring types have been lumped into two functional groups: those involved in baseline descriptive monitoring and those involved in cause-and-effect assessment of actions.

Baseline descriptive monitoring

Status Monitoring – Status monitoring is used to characterize existing or undisturbed conditions and to establish a baseline for future comparisons. The intent of status monitoring is to capture temporal and spatial variability in the parameters of interest.

Trend Monitoring – Trend monitoring involves measurements taken at regular time or space intervals to assess the long-term or large-scale trend in a particular parameter. The measurements are usually not taken specifically to evaluate management practices; they serve instead to describe changes in the parameter over time or space.

Implementation Monitoring – Implementation monitoring determines whether activities were carried out as planned, and is generally carried out as an administrative review or site visit. This type of monitoring cannot directly link restoration actions to physical, chemical, or biological responses, as none of these parameters are measured. For example, if a restoration action is initiated to fence 20 miles of stream with the hope of reducing stream temperature and fine sediment input from run-off and bank erosion, the implementation monitoring would consist of confirming the presence of the fence.

Compliance Monitoring – Compliance monitoring determines whether specified criteria are being met as a direct result of an implemented action. The criteria can be numeric or descriptive, but result from the direct impact of the action, not the indirect impact of the action. With the fencing example, the compliance monitoring indicator would be an assessment of the project's basic intent – preventing livestock from entering the riparian corridor – and thus an appropriate metric would be the presence or absence of livestock in the fenced-off area.

Cause-and-effect monitoring

Effectiveness Monitoring – Effectiveness monitoring evaluates whether the management actions achieved their direct effect or goal. Success may be measured against "reference areas," "baseline conditions," or "desired future conditions." Effectiveness monitoring can be implemented at the scale of single actions, suites of actions across space, or for an entire strategy consisting of a diversity of actions in a single place. In the fencing example, the effectiveness monitoring indicators would be an assessment of the project's effect on the riparian habitat, given that the project was properly implemented and in compliance with expected impact. Thus an appropriate metric would be riparian vegetation recovery, since this is expected to be an effect of excluding livestock from the riparian corridor.

Validation Monitoring – Validation monitoring is research to verify the basic assumptions behind effectiveness monitoring and models. Validation monitoring is used to assess the assumed linkage between compliance and effectiveness monitoring indicators, and the assumed linkages between the effectiveness monitoring and the management objectives. In the fencing example, the validation monitoring indicators would be an assessment of two things: first that livestock exclusion results in riparian vegetation recovery so that the latter can be used as a cause-and-effect metric for the former; and second that riparian vegetation recovery results in water temperature reduction and sediment-delivery reduction, the ultimate indirect intent of the initial management action implementation.

Figure 3. Types of Monitoring

To be useful in decision making, status and trends monitoring data must be reduced from the raw data, or metrics, to a more directly applicable form or indicator. For example, if the motivating question is, “What is the size of the annual spawning population of steelhead in Myfavorite River?” the indicator would be total spawning numbers of steelhead over one season for the entire river basin. The metric, or directly measured thing, however, would be something quite different. For example, it might be steelhead redds sighted on weekly passes over known spawning grounds, or migrating fish entering a fish trap below the Myfavorite River. The metric data must be processed to translate the metric data type (e.g., redds) into the indicator data type (e.g., spawners), and then reduced to generate the indicator required (e.g., list of weekly counts on spawning grounds to annual total for watershed).

The processing and reduction of status and trends monitoring data generally takes the form of expanding or transforming based on known or presumed relationships between data types (e.g., redds to spawners), and a reduction of a large amount of data to a small set of descriptive statistics (mean, median, etc., plus a variance or confidence term), for a spatial extent (watershed, state, ESU), over a time interval (annual, average life-span). For trend data, these same descriptive statistics are compiled over multiple time or space intervals. Their resulting pattern is expressed in some reduced form (fit to a line with intercept, slope of the trend and confidence of fit, fit to a distribution of type with position and shape, both changing with trend).

One of the most important parts of the data-reduction process is to quantify the variability in the data. Since the output indicators are summaries of many individual monitoring observations, there will be variation between these observations. Capturing, reporting, and partitioning this variability is perhaps even more critical than the value of the metric itself to the utility and interpretation of the indicator.

The variability in a monitoring metric comes from two primary sources: intrinsic variability from compiling indicator values over space and time, and extrinsic variability from measurement and sampling error. It is critically important to understand the magnitude and source of variability in a monitoring metric to maximize its information content, use, and potential refinement. In reducing numerous monitoring observations (point measurements taken across a watershed throughout a monitoring interval) to a single metric (summary of monitoring observations), the variability in a metric that is naturally present spatially over a watershed and temporally across the sampling interval is compressed into a single value (e.g., mean or median).

While it is convenient to express a mass of data as a single value (mean annual water temperature, total number of spawners), separating this value from a description of the variability in the source data takes it completely out of context. For example, if mean annual average water temperature for an entire watershed is an indicator for habitat quality assessment, then two watersheds with ‘values’ of 10C and 18C might appear quite different in ‘quality’; however, looking at the variability, or the context, may tell a very different story. If we instead report these metrics as 10C (sd 8C) and 15C (sd 1.5C), we learn that in one watershed the average temperature may be 10C, but nearly 70 percent of the observations contained in the 10C metric fall in the interval [2 – 18C] and 15 percent of the observations are of temperatures greater than 18C, while in the 15C watershed, 95 percent of the observations fall in the interval [12 – 18C].

If each observation represents the temperature of a stream reach over a time interval, the context or variability about the mean tells us that the ‘cold’ watershed (10C) actually has considerably more warm water than the ‘warm’ (15C) watershed. Given the reported variability in temperature across these watersheds over a year, it is now apparent that there are very different processes at work. In one watershed the temperature varies widely over space and time (at this point it is not possible to distinguish which without further partitioning the variability), while the other has almost constant temperature within the watershed, no matter where or when it is measured. If temperature is to be used as a habitat quality indicator in these cases, it is possible that the mean and the variability, or the variability alone, is a more potent indicator of ‘quality’ than the mean.

As another example, imagine two watersheds where total escapement is monitored and reported annually. In one watershed the run size is reported as 1,000 fish (+/- 500, 95% CI), and in the other as 1,500 fish. As in the temperature example, the immediate temptation is to compare these two watersheds with respect to their population status indicators, concluding that at least for the year reported, one watershed clearly has more fish (1500 > 1000). However, given that one metric is reported with its confidence interval (CI, most likely generated from statistical data reduction of the monitoring indicator data, implying that the reported value lies within the interval 500 –1500 with 95 percent confidence) and the other as a single value without any variability or certainty, the only honest way to use these data together is to reduce the confidence levels of all data to the lowest common level, represented by an undefined confidence limit in this case.

The undefined confidence limit means that the escapement in the watershed might have been 1,500, but it might have been 100 or 3,000. There is no way (or none provided) to distinguish between 100, 1,500, or 3,000 with any confidence. In both watersheds a finite, but unknown number, of fish entered during the monitoring interval. The indicators chosen represent an estimate of the “truth”; in one case the estimate does not contain any quality control information, and in the other case, large non-confidence-inspiring intervals are generated. Therefore, the monitoring methods themselves can introduce uncertainty into the data, uncertainty that is sufficiently large to overwhelm any potentially useful information also contained therein.

While the examples above may be artificial, they are meant to illustrate three points:
(1) Monitoring metrics must include some form of variability or confidence to establish their context and utility.
(2) The variability itself can contain more information than the “metric,” though it may be more difficult to interpret.
(3) It is easier to generate monitoring data than it is to know how to make use of it.

The data processing and reduction steps arise directly from the type of questions answered by status and trends monitoring (i.e., “What is the condition or status of X?”). They do not directly inform, nor should they be expected to inform, questions of the type, “What is the effect of Y on the condition or status of X?” This is the exclusive purview of effectiveness monitoring.

4.2 Effectiveness Monitoring

Effectiveness monitoring specifically addresses cause-and-effect questions. As such it is designed more as an experiment than a set of observations and descriptions. Because effectiveness monitoring takes an experimental approach, the implementation of monitoring and action requires explicitly coupling the monitoring design and implementation with the action design and implementation to detect an effect. Therefore, approaching effectiveness monitoring as a stand-alone cannot work. Trying to add effectiveness monitoring after the fact to an action-implementation strategy will rarely, if ever, result in detection of any biological effect. Most importantly, since effectiveness monitoring makes little or no sense when separated from actions, it is perhaps most efficient not to plan, describe, regulate or call for effectiveness monitoring if it is not integrated with action design and implementation. *Recovery plan implementation should consist of action strategies that include the demonstration of effect.*

The distinction between detecting actions' effects and implementing actions that demonstrate their effect may seem to be merely semantic, but from a practical standpoint the difference is critical. In both cases, effectiveness monitoring is imposed as an assessment lens to an action, with the expectation that sufficient contrast in some relevant features of the action will develop through implementation, such that the effect (either as a before and after, or treatment versus reference) can be quantified. (An action in this case can vary from a single restoration project, to suites of similar management actions, to management of an entire watershed as a single strategy.) Most importantly, owing to the experimental design, the quantified effect can be attributed with known confidence to have resulted from the action.

However, if effectiveness monitoring is imposed on an action-implementation strategy independent of the strategy's design, the ability to detect an effect of the action could be seriously, if not fatally, compromised. This is because detecting an effect depends exclusively on establishing a contrast between the action strategies (treatment and control, types of actions, ranges of action intensity) being tested. The magnitude of the contrast between, for example, action and no-action conditions comes from two sources: the action actually changing conditions, and those conditions being differentiated from their reference, or control, state. (In the case of before-after comparisons, these two sources of contrast collapse to one, since the comparison is across time, not space, and as a result these designs are inherently less powerful and non-replicable.) An experimental framework for implementing and monitoring an action is meant to provide the maximum support for detecting contrast between action and no-action conditions. It does this by imposing a statistical design for data analysis that requires replication and randomization of the treatments and controls.

Monitoring the effect of any management action is predicated on a complex set of actions and outcomes transpiring in a predictable fashion. These actions and outcomes range from the actual implementation of the action as planned, to the action having the indirect biological effect expected. These are all set in the context of a comparison across time and space to a situation that should differ only in that it lacks the implementation of the action.

Demonstrating the direct and indirect impact of management actions requires supporting all steps in the logical chain that connects the action to its expected impact. This chain is rarely short, and in many cases, such as habitat restoration actions, it relies on indirect connections between links. The links in the chain represent the required assumptions, often posed as hypotheses and assertions that connect each stage of project design, implementation, and documentation.

For example, proposing a strategy of habitat restoration to address impaired population processes requires making the following assumptions: that the identified habitat impairment is limiting population processes; that the habitat restoration action will correct physical processes that determine biological processes and that the corrected biological processes will relax the population process limitation. Implementing the restoration strategy requires making the following assumptions: that the habitat restoration action impact will result from the action as planned, and that the restoration action will be implemented as planned. Detecting the effect of the restoration strategy requires making the following assumptions: that the reference area lacks action implementation, but contains equivalently impaired (or not impaired) population, biological, and physical processes.

Forming each of these links requires either a well-established relationship based on research literature or extensive data collection, or models (quantitative or qualitative) with on-going monitoring. Links can simply be asserted, but these will need to be revisited, especially if the outcome evaluation is not clear or the results are challenged. Any one link could be the weak point of the logical chain. Since all involve uncertainty (though of very different flavors), some form of sensitivity testing is warranted.

Forming, supporting, and testing all the links can be overwhelming if such a rigorous framework is to be applied to all management actions over all recovery domains. Such an exhaustive approach is not warranted given time and resource constraints. A triage-like prioritization could identify, by appropriately balancing risks, links that are to be asserted, monitored, or codified. Revisiting and evaluating the prioritization scheme and its resulting implementation strategy is necessary, and is a key step in an adaptively managed program. In addition to a broad-scale programmatic approach, there are several obvious efficiencies that will be useful in the short run: adopt representative or pilot-scale tests with extrapolation of results (adds an additional link to the chain, but it too can be monitored and assessed); focus first on data management, sharing, and communication to expand and refine knowledge base; and finally, accelerate the evaluation cycle of learning and modifying during implementation, based on interim performance metrics and indicators.

Understanding these linkages, their assumed, implied, and measured connections, their sensitivity to extrinsic factors, and our ability to quantify the uncertainty in each step is key to realizing the connection between monitoring and adaptive management. Monitoring and evaluation will provide answers only to the questions it was designed to address. It does not provide the framework for revising these questions if they are ill-posed, for evaluating the assumptions upon which the strategy to be monitored was built, or for incorporating learning into future decisions on actions and strategies. These are the elements of adaptive management.

4.3 Critical Uncertainty Research

Planners and managers working on salmon recovery must live with many uncertainties in the available or obtainable data and the assumed or hypothesized causal links between viability parameters and actions that affect the fish or their habitat. What are the “critical” uncertainties? This depends on the issues at hand. Having to make assumptions about any of the uncertainties or unknowns could lead to paralysis, since researching all of them before deciding or acting could be an overwhelming or impossible task. Using an adaptive management process, one would instead make the decision with the necessary assumptions, but acknowledge the uncertainties and have a strategy for getting the information to test the assumptions, in case the decision or action fails.

Following are examples of questions for research, or research directives, that would, by providing new information or reducing uncertainty, significantly enhance our ability to make management decisions, allocate resources, design actions, decrease risk, or improve the chance of achieving recovery objectives.

4.3.1 Habitat

What are the quantitative relationships between tributary in-stream flow and juvenile rearing and out-migrant survival?

What is the uncertainty associated with various models (EDT, Shiraz) used for evaluating limiting factors?

What is the relationship of habitat type and quality to a quantitative fish productivity level?

Which habitats are most important in determining juvenile and adult migration patterns and potential for increases in viability?

How are genotypic variations related to habitat use?

How can the use of ongoing PIT tagging and other tagging and marking studies and data be used to determine origin and estuarine habitat use patterns of different stocks?

How can action effectiveness be linked to changes in population and ESU status and viability (multiple scales)?

What is the effect of toxic contaminants on salmonid fitness and survival in the Columbia River estuary and ocean?

What effect do invasive species have on salmon, and how can those effects be controlled?

What are the relationships between micro- and macro-detrital inputs, transport, and end-points?

How have historical changes in estuary morphology and hydrology affected habitat availability and ecosystem processes?

4.3.2 Hydropower

What is the impact of reservoir temperature on Snake River fall Chinook?

What is the magnitude of delayed mortality of transported Snake River fall Chinook?

How can the early life history of Snake River fall Chinook be better understood?

How can better estimates of passage and survival of Snake River sockeye be obtained?

How can we better estimate kelt passage and survival of Snake, Upper Columbia River, and Middle Columbia steelhead?

What is the feasibility of re-establishing self-sustaining anadromous populations upstream of hydropower (e.g. Snake River fall Chinook)?

What are the effects of flow on habitat in the estuary and lower mainstem (e.g. Snake River fall Chinook)?

How do uncertainties in estimates of delayed mortality affect conclusions regarding population status and viability? (all ESUs)

Pre-spawning mortality (all ESUs)?

What is the cause and remedy for headburns (all ESUs)?

4.3.3 Harvest

How do uncertainties in exploitation rate estimates affect evaluations of the effects of harvest on VSP and population status?

How does uncertainty surrounding the use of indicator (hatchery) stocks to infer fishery mortality on natural-origin fish affect conclusions regarding population status and viability?

Are there gaps in quantitative data available for analyses of fishery impacts at relevant units (e.g., by population, MPG, or ESU) and if so, how does this affect the certainty of concluding the status of the population and ESU?

How have distributions (instead of point estimates) of parameter estimates been used to improve our understanding of how harvest effects impact populations, and how our management is working to reduce negative impacts?

Is the accuracy of estimates of incidental mortality related to bycatch in non-target fisheries and from specific gear types in catch and release fisheries known, and how does that affect our management?

4.3.4 Predation or Disease

Is predation by marine mammals a significant factor limiting the status of some populations, and if so, how can it be managed?

What is the rate of infection of disease in the natural population?

How is the rate of transmission of disease affected by anthropogenic impacts on physical and biological processes?

4.3.5 Natural Threats

Climate change: How will different scenarios of climate change affect ecosystem dynamics, habitat characteristics, and ultimately population condition across all life stages?

Natural cycles: How can the effects of poor ocean conditions related to the Pacific Decadal Oscillation (PDO) or El Niño Southern Oscillation (ENSO) be quantified and managed for in the future?

4.3.6 Hatcheries

How do uncertainties in estimates of reproductive success of hatchery and natural-origin fish spawning affect evaluations of the effect of hatchery practices on population status and viability?

How do surplus hatchery-origin fish on the spawning grounds affect the productivity and genetic integrity of the natural population?

What are the short- and long-term effects of hatchery fish intervention on the status of viability attributes of natural-origin populations within the sub-basins as well as within the migratory corridors?

Is early spawn time of hatchery steelhead stocks a successful management tool for segregating hatchery and natural fish?

How effective are fish culture techniques, such as acclimation, in segregating hatchery fish from natural populations?

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5.0 PRIORITIZING MONITORING

In a world of finite resources, choices must be made about what to monitor. Salmon recovery planners will be faced with a multitude of such choices as they attempt to interpret and apply this guidance to specific ESUs, watersheds, and limiting factors. Addressing the unique and detailed questions that will arise in each domain and for each ESU is beyond the scope of this conceptual guidance document. However, it is hoped that the general discussion below of prioritizing monitoring will help recovery planners frame and evaluate their decisions.

The design of monitoring programs should begin with the data needs of management and policy decision making; these processes will determine the effort required. Management questions or decisions should be used to determine spatial, temporal, and precision scales for all monitoring data collection. For example, a population may be declared “viable” if the lower bound of a 67 percent confidence interval around the geometric mean of the last 10 years of abundance estimates is above the viability threshold. However, if resources for data collection and management actions are truly limited, then it is unwise to collect more data than supported by the decision-making process, as this could negatively affect the apparent efficiency of monitoring programs region-wide. The design process must be a two-way effort. Some decision processes may not impose any constraints on data quantity or quality, or conversely may impose unachievable data standards. For example, a decision process based on population abundance that does not specify or define the metric “population abundance” can be satisfied with any data source no matter how far removed from field collection, while a parallel decision process that requires data from a population-scale census of spawning females could rarely if ever be successfully completed. In the former case, the development of data-informed decision processes may be advisable, while in the latter case, the limitations of monitoring programs must be fed back into decision making.

Critical uncertainties in recovery planning – the current suite of unanswered questions – can also motivate monitoring, though not by way of defining sampling effort. There is real and necessary value to data collection programs that address the critical uncertainties confounding our ability to make effective management decisions. This research-based monitoring is also driven by management questions, in a less direct, but equally important, manner. For example, the biological effect of tributary habitat restoration projects is rarely measured at scales as large as that of populations and ESUs; however, for management purposes the effectiveness of management actions must be assessed at these larger scales. Monitoring for population-scale effects is difficult if not impossible because of the abundance of confounding factors at large scales. On the other hand, estimating the effect of restoration actions on populations is quite tractable, being limited only by knowledge of the mechanistic connections between habitat conditions and population processes. Therefore, designing efficient population-scale effectiveness monitoring is a trade-off between costly and difficult monitoring to directly measure the effect and research-driven monitoring to elucidate mechanisms that can be generalized as process-based models used to estimate the effect.

The sections below present some basic design principles to guide the development of efficient and effective monitoring programs. The list is neither exhaustive nor complete, but provides some general rules and thinking for practical monitoring program design.

Integrate status and effectiveness monitoring. At a minimum, status monitoring forms the background or context for effectiveness monitoring. At best, status monitoring data can be used as control or reference data for actions or treatments. The temporal and spatial scales over which status monitoring data may be used to support effectiveness monitoring will be strongly dependent on the effectiveness monitoring question's spatio-temporal scale. No *a priori* guidance is possible other than to consider status monitoring designs that treat multiple spatial and temporal scales transparently. For example, the Generalized Random-Tessellation Stratified (GRTS) design that forms the basis of the U.S. Environmental Protection Agency's (EPA) environmental monitoring program is scale-independent, and can support overlapping (interpenetrating) multiple sampling intensities (spatial and temporal) within the same sampling frame. Concentrated sampling efforts to address fine-scale data-collection needs can contribute to large-scale monitoring, and conversely can make use of large-scale monitoring data.

Use spatial and temporal scales of variability to drive distribution of sampling effort. If habitat indicators change only slowly with time, annual sampling (in particular trend sites, or repeat visits to the same location) may be unnecessary, perhaps being replaced with biennial or triennial sampling. Alternatively, if temporal variation is strongly correlated with particular events rather than accumulating randomly through time, use these events to trigger sampling – e.g., sample physical stream habitat only after channel-forming flows, rather than on a regular basis.

Use extrapolation and surrogate data. Use of extrapolation and surrogate data is very powerful for natural resource monitoring, if and when the proper calibration is performed and periodically revisited. The naïve and simplistic monitoring design incorporates plans to collect the same data at a uniform spatial and temporal scale across the region of interest. However, more efficient data collection may be possible if metrics that are correlated to the indicators of interest can be collected instead. For example, it is quite common in population assessments of large mammals to run transects quantifying animal signs (e.g., browse, scat) rather than to try to directly enumerate individuals. Such surrogate metrics may meet the information needs of the decision process, although an explicit mechanism to quantify the risk associated with indirect data sources should be established.

The substitution of surrogate metrics does not have to be complete; a hybrid of direct and indirect metrics may present an acceptable compromise. The proposed population structure of interior Columbia ESUs is a perfect basis for such a design. Rather than directly monitor the population status of all independent populations, a single population within each MPG could be assessed directly, and the remaining populations represented with a less intense, indirect metric. In this example, the extrapolation is on a limited spatial extent and within a group of populations that are expected to behave similarly. However, it would be best to randomly choose the distribution of monitoring efforts across the extrapolation set. This avoids a systematic bias that might arise, for example, if the direct or most intense monitoring effort was always applied to the strongest, most accessible, or lowest elevation population within each MPG.

Consider standardizing the information needs of decision-making processes, analytical approaches, and monitoring programs. Information sharing will generate efficiencies only if the same information is needed and used by multiple entities. Standardization of data collection and communication—e.g. standardizing regional monitoring protocols across multiple agencies and programs—is the easiest form of standardization to understand, but it is not always the most efficient. Sometimes limited standardization for specific purposes is the best choice. If information standardization rather than data standardization can be achieved, then multiple programs can continue their unique data collection efforts as long as the relationships between multiple metrics (data) and the needed indicator (information) can be established. For example, adult fish abundance is a population status indicator (information) generated by the reduction of a wide range of field collected metrics (data) such as redd counts, weir counts, and carcass counts. If regional standards on population status as indicated by adult abundance were established, such as basing it on a spatially and temporally representative sampling design capable of generating estimates with variance, then monitoring programs could continue generating metrics for their own programmatic reasons and efficiencies but would be "standardized" if they were able to generate the regionally consistent indicator from these data.

Use remote sensing. Remote sensing may provide opportunities to reduce monitoring costs, or at least generate more complete and consistent coverage of data collection for the same cost. Remote sensing may present an ideal combination of extrapolation and standardization for region-wide information needs.

Research. Research may seem to be expensive and unnecessary in light of basic data and information needs, but this is a short-sighted perception. In the long run, research will reduce monitoring and implementation costs if it is able to quantify limiting factors and the management actions required to address impairments; refine monitoring indicators to increase sensitivity to management actions and biological processes; and reduce, or at least quantify, uncertainty arising from large-scale environmental factors such as climate and ocean productivity change.

Data management and communication. Data management and communication will save money. Data sharing makes it possible to avoid duplication of effort and maximize learning by mitigating the proprietary climate surrounding research, monitoring, and management data. Appendix C, Data Management Guidance for Recovery Plan Evaluation, provides suggestions to ensure that efforts to complete best available science will be supported with needed data management. A well-designed and documented data management plan can help to ensure that data of a specified quality and quantity is available, at a specified time, to meet specified data analysis needs. Appendix C initiates a discussion of appropriate steps to organize and coordinate data management, both in individual projects and more broadly.

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6.0 INCOMPLETE INFORMATION -- THREE SCENARIOS

Management decisions and de-listing decisions often must be made with incomplete information. The question is, What type of information is missing or of poor quality – is it biological status? Status of the actions planned? Or the cause-and-effect links between actions and ESU status? Different types of incomplete information pose correspondingly different types of risks for de-listing decisions. This section offers three scenarios illustrating how a range of ESU-scale, ESA status assessments may play out, given a range of data quality and quantity. This discussion is intended to help planners consider how their own implementation and monitoring decisions may affect NMFS' assessment of ESU status.

The three scenarios represent a range of potential recovery plan implementation decisions on how to balance investments in knowledge – whether to put more funding into VSP status, listing factor status, or cause-and-effect information for adaptive management. The bounding cases are (1) and (2) below, where there is considerable data on either the populations' biological status (VSP parameters) or the status of management actions (listing factors). Because of the likelihood of these cases, NMFS' decision framework needs to be capable of addressing situations where a preponderance of evidence on one side is not balanced, or potentially supported, by adequate information on the other. The three examples presented are not meant to be an exhaustive exploration of all the possible situations posed by the implementation of recovery plans. They are meant to illustrate some of the potentially necessary trade-offs between management action implementation/monitoring and VSP status monitoring.

In the first two cases, a mechanistic link is not well established between the VSP and listing factor sides (referred to as adaptive management information: effectiveness monitoring coupled with a real adaptive management program with rigorous assessment). This latter scenario is considered in example (3).

(1) Status (VSP) data is rich and listing factor data poor.
VSP indicators look good; confidence in viability is high.
Management action tracking is poor.
Connection of listing factor data to VSP data is poor.

In this case, the monitoring strategy has generated considerable biological data (VSP metrics) to describe the biological status of populations and the ESU. However, the status of the listing factors or threats is not well supported with data as a result of poor tracking of management actions, and a lack of connection between VSP metrics and recovery actions, listing factors, and threats. The monitoring strategy did not emphasize implementation and compliance monitoring, and as a result could not support effectiveness monitoring.

Here the ESU listing status decision will hinge on the robust nature of VSP data. However, the lack of good listing factor data, and especially the connection of actions to the VSP status, makes this a fairly risky decision environment. The risk arises primarily in the assessment of cause-and-effect between the VSP status and the (missing) record of actions. The risk can potentially be quantified by exploring the apparent robustness of the VSP status with simulated climate and management scenarios. This decision route is data- and model-driven, but still involves considerable leaps of faith.

(2) Status (VSP) data poor and listing factor data rich.
 VSP indicators hint at viability, but uncertainty is high.
 Management action accounting/tracking is good – lots of actions attached to listing factors.
 Connection of listing factor data to VSP data is poor.

In this case, the biological data collection has been traded off for extensive implementation and compliance monitoring. While the VSP data may hint at a viable ESU, the uncertainty is high because of incomplete spatial or temporal coverage. For example, the monitoring strategy may have focused on "indicator" populations within each MPG. While the VSP metrics for these indicator populations look good, the connection between the status of the indicator populations and the rest of the MPG or ESU is not well supported with data or analysis.

Unfortunately, the monitoring strategy primarily addressed status-monitoring data collection for both VSP and listing factor components, and did not employ effectiveness monitoring to generate cause-and-effect connections between the biological and management data. Here the decision will hinge on the robust nature of the listing factor data – lots of actions to point to, lots of money spent on doing things that were motivated by listing factors and threats, and the monitoring infrastructure to keep track of it. However, lacking VSP and especially adaptive management cause-and-effect information, decision making will be very risky. The risk in this case probably cannot be quantified because of the data and information gaps on the VSP and adaptive management sides. It might be possible to take a qualitative approach to risk accumulation such that scenarios of listing-factor data completeness and type can be accommodated. This decision-making route is supported by data, but not directly the result of models, thresholds, or numerical criteria.

(3) Status (VSP) data moderate, listing factor data moderate, adaptive management data rich.
 VSP indicators demonstrate progress towards viability.
 Management action accounting / tracking is adequate.
 Connection of listing factor data to VSP data is good.

In this case, the monitoring strategy generates a moderate level of VSP and listing-factor status data. The monitoring strategy also emphasizes the cause-and-effect connection between listing factors and VSP metrics through an effectiveness monitoring program. As a result, a quantitative, not qualitative, argument can be constructed to attribute the viability assessment to the listing-factor actions undertaken. Here the ESU status decision will hinge on the confidence in the link between the encouraging, but not convincing, VSP status information and documentation of listing-factor and threat-mitigating action. One of the potential risks in this case will be that the connections established by the adaptive management information may represent only short-term phenomena such as upturns in ocean productivity, not long-term, sustainable progress that would be best demonstrated by VSP status-monitoring data. The strength of the adaptive management program would suggest that in the long run the process will generate the answers needed.

In all three cases, ESU status was evaluated with “incomplete” information, but the status decision is riskier where adaptive management information is lacking. An iterative process that builds in testing assumptions and changing direction when necessary, works as a form of quality control. In a few cases, as a result of excellent, long-term data for both viability and mitigation of threats, a status or de-listing decision may involve little risk of being wrong. In most cases planners will need to choose how to allocate resources between monitoring, action, and assessment. NMFS decisions will have corresponding risks. Adaptive management will play an important role not only in structuring the design and implementation of recovery plans, but in how NMFS considers the resulting data.

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APPENDIX A

Generalized Viability Criteria[10]

			Lower Columbia Chinook*	Puget Sound Chinook	Interior Columbia ESUs	Oregon Coast Coho (PRELIMINARY)†	
						Persistence‡	Sustainability‡
ESU viability criteria	ESU	**ESU viability definition**	*naturally self-sustaining ESU - No quantified risk of ESU extinction	*naturally self-sustaining ESU	*naturally self-sustaining ESU	Able to persist over a 100-year period without artificial support.	In addition to persistence, able to maintain genetic legacy and long-term adaptive potential for the foreseeable future.
ESU viability criteria	MPG/strata/regions	**Strata/region/MPG criteria**	*all strata w/in ESU at low risk (viable) - Strata "Low risk" is not quantified	*all regions w/in ESU at low risk (viable)	*all extant MPGs w/in ESU and any extirpated MPGS critical for proper functioning of the ESU (guidelines are provided) must be at low risk (viable)	All biogeographic strata (BGS) persistent.	All BGS sustainable + meet ESU-level diversity criteria relating to genetic diversity, phenotypic and habitat diversity, and existence of small populations.
ESU viability criteria	MPG/strata/regions	**Sithin strata/region/MPG**	Populations scored 0-4 (0=extinct, 3=viable) - must have 2 populations >=3 AND average of all historical populations >=2.25	*2-4 low-risk pops within viable regions	1/2 of historical populations (but no fewer than 2) meeting viable criteria. At least one population must be characterized as highly viable.	Most (> ½) Independent Populations persistent.	Most (> ½) Independent Populations sustainable.
ESU viability criteria	Population	**Low-risk population types**	*consider core/genetic legacy pops w/in strata for low risk - consider catastrophes, metapopulation processes, and evolutionary process - no quantitative rules (note strata include life history diversity)	*at least 1 of each major diversity type is a low-risk pop within viable regions	Viable populations must include representation from larger historical population size categories, major life history patterns (e.g. spr vs. summer adult run timing).	No distinction among Independent Populations.	No distinction among Independent Populations.
ESU viability criteria	Population	**Higher-risk pop attributes**	*higher-risk pops provide sufficient ecological function for stratum & ESU persistence - incorporated into criteria in stratum average approach (i.e. >=2.25)	*higher-risk pops provide sufficient ecological function for stratum & ESU persistence	Populations not meeting Viability standards should be maintained so that overall MPG productivity does not fall below replacement	No criteria.	All Dependent Populations still exist.
ESU viability criteria		**Roll-up method**	evaluate scenarios against ESU criteria	evaluate scenarios against ESU criteria	In situations with only one MPG (i.e. very few total populations), standards within that MPG are higher	Formal decision-support system based on a fuzzy logic.	Formal decision-support system based on a fuzzy logic.
Population viability criteria	Abundance/Productivity	**Abundance/Productivity**	Default PCC for natural-origin salmon, historical/intrinsic capacity estimates - recommend other approaches where data allow	viability curves for natural-origin salmon, historical/intrinsic capacity estimates	viability curves for natural-origin salmon, historical/intrinsic capacity estimates	Abundance: Above depensation threshold. Productivity: Natural-return ratio (NRR) > 1.	Abundance: Sufficient to prevent loss of heterozygosity. Productivity: none.
Population viability criteria	Abundance/Productivity	**Repro success of natural spawning hatchery fish?**	No default assumptions	no explicit statements	Estimates of productivity can be adjusted if specific information is available for relative productivity	For productivity estimates, assume equal to natural fish; varied for sensitivity tests.	Not applicable.
Population viability criteria	Abundance/Productivity	**Hatchery fish in estimates of productivity?**	Must estimate natural productivity - reference PCC calculations made assuming no hatchery fish	Recent abundance should be spawners of natural origin. Productivity should consider natural returns vs total spawners	Recent abundance should be spawners of natural origin. Productivity should consider natural returns vs total spawners	Include in parent generation (standard NRR calculation).	Not applicable.
Population viability criteria	Spatial structure and Diversity	**Diversity**	maintain natural patterns gene flow, existing diversity, habitats - no quantitative criteria	maintain natural patterns gene flow, existing diversity, habitats	maintain natural patterns gene flow, habitats, environmental variation	No criteria.	Five population diversity and distribution criteria.
Population viability criteria	Spatial structure and Diversity	**Fraction natural v. hatchery spawners?**	no quantitative criteria	no explicit statements	Explicit in population risk assessment metrics	No criteria.	Sufficiently low to have no adverse effects on natural populations (range 50% to 0%).
Population viability criteria	Spatial structure and Diversity	**Origin of hatchery fish?**	no quantitative criteria	no explicit statements	Explicit in population risk assessment metrics	No distinction.	No distinction.
Population viability criteria	Spatial structure and Diversity	**Generations of hatchery influence?**	no quantitative criteria	no explicit statements	Explicit in population risk assessment metrics	No distinction.	No distinction.
Population viability criteria	Spatial structure and Diversity	**Define natural origin fish?**	Explicitly spawners whose parent spawned naturally	Implied to be spawners whose parent spawned naturally	Implied to be spawners whose parent spawned naturally	Spawned and reared in natural habitats, regardless of parental origin.	Spawned and reared in natural habitats, regardless of parental origin.
Population viability criteria	Spatial structure and Diversity	**Genetic variation**	no quantitative criteria	addressed in ESU-level diversity criteria; no quantitative criteria at population level.	Genetic criteria offer guidelines for degree of introgression/etc. consistent with various risk levels	No criteria.	Score-based metrics addressed in ESU-level diversity criteria.
Population viability criteria	Spatial structure and Diversity	**Phenotypic variation**	no quantitative criteria	addressed in ESU-level diversity criteria; no quantitative criteria at population level.	Explicit in population risk assessment metrics	No criteria.	Score-based metrics addressed in ESU-level diversity criteria.
Population viability criteria	Spatial structure and Diversity	**Life history variation**	no quantitative criteria	addressed in ESU-level diversity criteria; no quantitative criteria at population level.	Explicit in population risk assessment metrics	No criteria.	Score-based metrics addressed in ESU-level diversity criteria.
Population viability criteria	Spatial structure and Diversity	**Selectivity of anthropogenic activities**	no quantitative criteria	no quantitative criteria	Explicit in population risk assessment metrics; allow qualitative considerations, and provides a decision tree to determine whether an action is selective and what risk is associated with it	No criteria.	Score-based metrics addressed in ESU-level diversity criteria.
Population viability criteria	Spatial structure and Diversity	**Spatial Structure**	sufficient number, size, distribution of spawning and rearing locations for viable pop - no quantitative criteria	sufficient number, size, distribution of spawning and rearing locations for viable pop	sufficient number, distribution, size of defined spawning aggregations or suitable habitat (e.g., > 4 suitable patches occupied)	No criteria.	Based on watershed-level occupancy of juvenile and spawning habitat.
Population viability criteria	Spatial structure and Diversity	**Habitat Availability**	no quantitative criteria	Sufficient smolt capacity to sustain population above abundance criterion during periods of poor ocean conditions.	Ecoregion use explicitly incorporated into population risk assessment metrics	No criteria.	Sufficient smolt capacity to sustain population above abundance criterion during periods of poor ocean conditions.

* The WLC-TRT is currently revising viability criteria

† Oregon Coast Coho Criteria are PRELIMINARY

‡ The ONCC TRT evaluates two levels of "viability": "persistence", which relates to ESA Endangered status, and "sustainability", which relates to Threatened status.

[10] These criteria are expected to be refined as recovery planning proceeds. Current and more detailed TRT criteria for each domain are available at http://www.nwfsc.noaa.gov/trt/index.cfm

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APPENDIX B
Examples of Metrics

Below are examples of potential metrics/indicators that could inform the evaluation of status and trend of relevant listing factors. This is not an exhaustive list; absence of metrics in cells does not indicate a lack of appropriate metrics. Metrics may be redundant across Listing Factors.

VSP Parameter					
	Listing Factor 1		**Listing Factor 2**	**Listing Factor 3**	**Listing Factor 5**
	Habitat[2]	**Hydro**	**Harvest**	**Disease & Predation**	**Hatchery**[3]
Abundance/ Productivity: o Spawners (natural origin spawning individuals not including jacks) o Expansion factors (Redds -> Spawner) Hatchery Fraction o Recruits/Spawner (spawning ground to spawning ground) o Supporting necessary indicators: Age structure (for run reconstruction)	o Mortality due to inadequately screened diversions o Flow and effects on juvenile survival rates	o Egg-smolt survival for mainstem spawners o Juvenile migration survival o Upstream-migrating adult survival o Downstream-migrating adult survival	o Total fishery escapement rate and the abundance of spawners o Recruits per spawner	o Estimated reduction in fitness of exposed individuals o Estimated mortality in population o Change in predator and prey population size and structure	<u>Juvenile Phase</u> o Egg deposition o Fry survival o Survival to smolt/emigrant from tributary area o Survival to estuary o Prevalence of disease in natural population <u>Adult Phase</u> o Spawning ground escapement o Run size to freshwater o Migratory mortality rates
Spatial Structure o Delimitation of Major and Minor Spawning Areas o Determination of historic spawning distribution o Determination of population complexity type (e.g. simple linear, dendritic) o Spawning ground surveys, presence/absence relative to MSA, MiSA o Determination of historic and current spawning distribution o Spawning ground surveys, presence/absence relative to MSA, MiSA	o Number, distribution and quality of accessible major spawning areas	o Quantity (miles, % historic, etc.) and quality of inaccessible habitat upstream of dams o Quantity and quality of specific habitat types transformed to other habitat types by dams and dam operations (e.g., % spawning habitat inundated	o Spatial distribution across major spawning areas o Mean distances between populations	distribution and quality of accessible major spawning areas	o Contribution to specific fisheries

VSP Parameter					
	Listing Factor 1		Listing Factor 2	Listing Factor 3	Listing Factor 5
	Habitat[2]	Hydro	Harvest	Disease & Predation	Hatchery[3]
o Fine scale spawning distribution data, potentially juvenile distribution.		by reservoirs)			
Genetic Diversity o Run timing, Spawn timing, outmigrant timing from adult, smolt trap a/o weir o Fecundity, size at age, from smolt/adult trap, weir o Gametic, genotypic disequilibrium, allele frequency, non-native or rare alleles, heterozygosity o EPA Level IV Ecoregions o By "H", any data on anthropogenic impacts that would impose selective pressures (e.g., size selective harvest, broodstock mining w/ spatiotemporal bias).		o Juvenile fish travel time (in-river and by barge) o Adult passage time o % of run not subject to protective measures, such as spill	o Mean run timing (for genetics-based effects) o Mean adult size (for genetics-based size changes, i.e., gear selectivity)		o Size and age at return o Hatchery operation type for strays within or out of ESU, MPG or population
Surrogates[4]					
	o Water Quantity (adult/juvenile migration)- shape of annual or seasonal hydrograph o Water Quality- turbidity, toxics/heavy metals, dissolved oxygen, temperature, hydrogen ions (pH), fecal coliform, nutrient loading o Barriers, Connectivity (e.g., degree to which passage is blocked, passage injury occurs, or migration is delayed)	o See Habitat			

VSP Parameter					
	Listing Factor 1		Listing Factor 2	Listing Factor 3	Listing Factor 5
	Habitat[2]	Hydro	Harvest	Disease & Predation	Hatchery[3]
	o Channel Morphology and Complexity- substrate embeddedness, pool quantity/quality, bed scour, artificial confinement, over wintering/rearing habitat quantity and quality, riparian function, availability of refugia from predation o Forage Availability- reduced habitat capacity, benthic production, food availability o Estuarine habitat quantity and quality (where different from above) - pocket estuaries and connectivity, wetland loss, nearshore & marine habitat quantity and quality, flow				

[1] Listing Factor 4- Inadequacy of existing regulatory mechanisms, is not addressed.
[2] Appropriate metrics are determined by the specific factors limiting achievement of population-specific viability objectives, i.e., instream flow, sediment flux, temperature, etc.
[3] For each potential metric, need estimates for both hatchery and natural origin fish.
[4] In some cases, if mortality cannot be estimated, habitat condition may be the only available surrogate.

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APPENDIX C

Data Management Guidance for Recovery Plan Evaluation

Adaptive management and related monitoring and evaluation are essential aspects of recovery planning for Pacific salmon. A well-designed and documented data management plan can help to ensure that data of a specified quality and quantity is available, at a specified time, to meet specified data analysis needs. This document initiates a discussion of appropriate steps to organize and coordinate data management, both in individual projects and regionally.

Data management should be based on a data management needs assessment that identifies:

- roles
- responsibilities
- methods and procedures
- data quality and data assurance
- data management technology
- data access
- data sharing
- investment

It's most efficient and effective to follow a consistent data management methodology that organizes data management into distinct, iterative steps:

1. Develop a clear statement of data management goals and decision-making needs. The adaptive management and RM&E questions must be identified in order to identify underlying data needs.

2. Assess the data needs of the participants and document detailed data management requirements:

    - Ensure that actual data users (the scientists, resource managers, program managers, and any others) are in agreement on <u>what</u> data must be collected/assembled to answer their questions and <u>when</u> the data must be collected and made available.
    - Ensure that any protocols that will be used to collect, complete QA/QC, manage, or share the data have been defined and agreed upon.
    - Ensure that the needed data has been described, from a data management perspective, in the form of a data dictionary. The data dictionary describes each data element: the data element name, definition, unit of measure, level of accuracy, and any other relevant information – for example, whether the data element is required or optional.
    - Ensure that all this information is clearly documented.

3. Develop a detailed data management plan. Describe the time frame, responsibilities, and estimated cost of delivering data of the quantity and quality defined in the data management needs assessment.

- Ensure that a plan, schedule of deliverables, infrastructure, staff, and organizational arrangements are in place to deliver the needed data products.

- Ensure that data management reference materials (e.g., collection protocols, data dictionary, sharing protocols) are in place, and that where needed, there is a training program to support their use.

- Ensure that there is a written agreement defining responsibilities, cost sharing arrangements, protocols that will be used, and the rights, if any, to ownership of the data – across all parties planning to collect and use the data

- Ensure that a minimum set of required metadata will be provided with all data and derived data products.

- Ensure that any limitations with respect to the quality of the data are sufficiently documented so the data meets the standards necessary under the Federal Data Quality Act. NMFS cannot disseminate data unless there is full disclosure about any data quality limitations.

4. Put the data management plan into action.

5. Evaluate the data management plan. Evaluate success in delivering needed data of specified quality and quantity at the time needed. Make needed changes to the plan.

6. Independent validation and verification (optional). Depending on the size and scale of the effort, there can be many benefits from having an independent assessment of data management programs.

Standards and Protocols

Protocols, metrics and other data-standardization tools such as common data-entry methods are a top priority for recovery plans. Programs that collaborate to develop and use standardized approaches should benefit. Failure to provide data standards or common entry methods will either delay the final assessment because the data simply cannot be compared, or the risk of comparing disparate protocols will be too high to justify use in decision making.

The Northwest Environmental Data Network is focused on standards and protocols for sharing, exchanging, and networking data. It has developed *Best Practices for Reporting Location and Time Related Data* that will help to provide consistent reporting. The Pacific Northwest Regional Geographic Information Council is focused on developing protocols and standards for creating nationally relevant framework data sets. The Pacific Coastal Salmon Recovery Fund, working with its partners, has developed and is using and maintaining a data dictionary to report details about salmon recovery projects. These data-dictionary elements can be used to provide more consistent reporting of project implementation information. Federal Geographic Data Committee (FGDC) compliant metadata is the standard for completing metadata records.

As mentioned above there is considerable interest in, and potential benefit from, developing a regional data dictionary for the purposes of distributing and maintaining a common set of regional data collection protocols. However, the adoption of common protocols should not be delayed pending development of a region-wide data dictionary. Adoption and use of protocols needs to be assigned high priority as part of recovery planning.

There are a number of specific data-content sets that are of interest to decision-makers in the region. For example, “framework data sets” that are consistent across all geographic and jurisdictional boundaries are of national interest, while other data content sets are of particular interest to regional salmonid recovery efforts. Various groups, including the Pacific Northwest Regional Geographic Information Council, are interested in further developing some of these data sets and defining standards for inclusion of data. Following is a list of regional data sets of particular interest to regional salmon recovery efforts. Further development should be coordinated across the region:

> Roads, paved and unpaved; rivers and streams and lakes at 1;24,000; sixth field hydrologic unit codes (HUCs); land use: agriculture; forest, urban, wetlands; barriers: culverts, tide-gates; bathymetry; water quantity; water rights; water quality; land ownership; ESU and subpopulations; and critical habitat.

Inventories and Other Data Products

Effective regional coordination requires knowledge of the locations of development, monitoring and recovery projects, and project detail. Efforts to develop inventories of projects should be documented and follow a consistent data management methodology as described above. Project monitoring is essential for salmon recovery, for regional evaluation of project implementation, compliance, coordination, and effectiveness, and overall status of recovery efforts.

NMFS supports the adoption of more formal organizational and administrative arrangements for coordination of regional data management, including a process for the orderly and planned adoption of standards and protocols for data exchange and sharing as recommended to the region by the Northwest Environmental Data Network. Without these steps, regional arrangements will remain ad hoc and have little prospect of overcoming existing problems, let alone satisfying new coordination data needs emerging from recovery planning.

NMFS plans, over time, to add data other than PSCSRF project data to the PCSRF data system. The goal is a region-wide source of consistent data on regional salmonid projects and recovery. This effort will establish a common set of data definitions for projects. NMFS recognizes that programs to develop these consistent data resources are essential and must be a core part of salmon recovery programs across the region. To the maximum extent possible, the formats will be developed collaboratively. Data requirements include information needed to evaluate project implementation, project compliance with objectives, the link between actions and limiting factors and threats, and the achievement of recovery goals or benchmarks. The project inventory would track project implementation and compliance, and be used to evaluate the effects of actions on limiting factors.

Linkage between Monitoring and Data Management

A monitoring program depends on a clear description of the following:

1) The ESU and individual population(s), as defined by recovery plans and the NMFS technical recovery teams (TRTs), to which the monitoring effort relates.

2) Where applicable, the specific viable salmonid population (VSP) attributes of abundance, productivity, diversity and distribution – as defined by the TRTs – for which data is being collected.

3) The explicit biological or physical factors monitored. For recovery, these factors should be identified as limiting the ESU and the population's achievement of desired population status identified in the recovery plan.

4) The monitoring protocols used to collect data in 2 and 3.

5) The specific geographic location of the monitoring efforts, including the latitude and longitude of all monitoring sites.

6) The spatial and temporal scale of the collected data (i.e., the geographic extent and the frequency of data collection).

7) A description of the statistical method used to determine the existing spatial and temporal extent of monitoring.

8) An estimate of the error surrounding each metric.

9) Contact information for the entity conducting the monitoring effort.

10) A description of the stability of the program, such as a discussion of the probability that the program will continue into the future for a specified period of time.

11) A description of where and how the data is accessible and/or disseminated, the quality assurance and quality control procedures applied to the data, and the chain of custody for the data; as part of the metadata record.

The ability to efficiently manage data to make the most effective use of its content mandates requirements for monitoring and evaluation programs. An integrated monitoring and data management framework will support coordination across existing monitoring programs and projects. The framework would, for example, require the use of common methodologies for reporting on sample design, data collection, data validation, and data sharing to address common questions.