A Review of the Washington State
Steelhead Management Plan

***Photo**: Hoh River spawning steelhead,*
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Introduction

The Wild Steelhead Coalition (WSC) commissioned Dr. Rick Williams and Dr. Eric Knudsen to provide an independent review of the Washington Statewide Steelhead Management Plan (SSMP) developed by the Washington Department of Fish and Wildlife (WDFW). The purpose of this public comment document is to provide a reasoned, scientifically sound critique of the scientific information, analyses, and assumptions presented by WDFW as the basis for the SSMP.

In order to accomplish the review, we examined the following documents prepared by the Washington Department of Fish and Wildlife:

- WDFW. 2006. *Oncorhynchus mykiss*: Assessment of Washington State's Anadromous Populations and Programs. Ed., James B. Scott, Jr., William T. Gill. Prepared by the Washington Department of Fish and Wildlife. July 21, 2006. (http://wdfw.wa.gov/fish/papers/steelhead/).

- WDFW. 2007. Statewide Steelhead Management Plan: Statewide Policies, Strategies, and Actions. Prepared by the Washington Department of Fish and Wildlife. December 5, 2007. (http://wdfw.wa.gov/fish/steelhead/steelhead_management_plan_05dec07.pdf).

- WDFW. 2007. Preliminary Final Environmental Impact Statement: Statewide Steelhead Management Plan (SSMP). Prepared by the Washington Department of Fish and Wildlife. December 5, 2007. (http://wdfw.wa.gov/fish/steelhead/preliminary_feis_05dec07.pdf).

Our review focuses on the 2006 scientific assessment paper (hereafter referred to as The *O mykiss* Report), with the 2007 SSMP reviewed only to the extent necessary to critique how well the management prescriptions presented are supported by the *O mykiss* Report. We also examined the proposed shift from segregated to integrated hatcheries for both harvest supplementation and recovery (conservation) goals, given the limited research available on the impacts of integrated hatchery types on wild stock health. Finally, we express concerns that the documents do not provide adequate description of existing and potential opportunities for wild-fish-only steelhead management options.

Executive Summary – Review Results

The 2006 WDFW Scientific Assessment paper (the *O mykiss* Report) "*Oncorhynchus mykiss*: Assessment of Washington State's Anadromous Populations and Programs") is generally a well-written and thoughtful assessment of the status and threats to Washington state steelhead populations. The *O mykiss* Report incorporates much of the more recent thinking on Pacific Northwest salmon and steelhead management and recovery (e.g. Brannon et al. 1999; Knudsen et al. 2000; Lichatowich et al 2006a; Liss et al. 2006; Williams 2006), including much recent literature (but missing important 2007 citations). As such, the *O mykiss* Report represents a step forward for salmon and steelhead management in moving toward holistic ecosystem-based management and away from a strictly harvest-hatchery-habitat-abundance management paradigm.

The *O mykiss* Report and the Statewide Steelhead Management Plan (SSMP) are both generally lacking in specific detail for planned activities, research programs, and monitoring and evaluation methods – the SSMP more so than the *O mykiss* Report. In this way, both serve more as planning templates than as implementation documents, with much of the implementation detail for both future research and management actions yet to be developed. This situation makes it difficult to constructively review specific implementation details of the SSMP, but will provide an opportunity for continued input from groups like the Wild Steelhead Coalition as those specific plans are developed by WDFW.

The lack of specific research details in the *O mykiss* Report and implementation details in the Statewide Steelhead Management Plan raises an additional concern, which is how to ensure that the eventual translation of these planning documents into specific research and management implementation activities remains faithful to the science described in the *O mykiss* Report. These are important documents in that they should guide future planning. The *O mykiss* Report is a stronger document than the SSMP, which focuses more on planning and process and has much less detail on implementation activities or methodologies. Consequently, a leap of faith is required to accept that what is presented in both documents, but particularly the SSMP, will be adequately developed further and implemented rigorously so that program objectives reflect good science and have a strong likelihood of being realized.

A summary of our major findings follows, with details on each topic provided in the sections below:

Issue 1. Linking management action to the conceptual foundation

- Explicitly describe the conceptual foundation used to manage steelhead populations, their habitat, and their escapements.
- The lack of a clear linkage between the information on steelhead and their habitats (*O mykiss* Report) and the proposed management actions (SSMP) is a significant omission that needs to be addressed.
- Greater attention needs to be placed in the *O mykiss* Report and the SSMP on managing salmon and steelhead habitat and managing for salmonid life history diversity.
- Greater emphasis is needed on identifying and protecting remaining wild populations of steelhead that can serve either as diversity reserves or genetic reserves
- Include monitoring of life history diversity metrics in the evaluation of the performance of integrated hatchery programs

Issue 2. Habitat and Steelhead production

2a. The management linkages among habitat, production, and harvest, are not explicitly addressed in either the *O mykiss* Report or in the SSMP.

- No discussion or recognition of past MSH management or how MSH management can or has contributed to the decline of steelhead stocks.
- No basis for future assessment of 1) escapement targets, 2) methods for establishing escapement targets, or 3) stock performance relative to the targets
- No identification of the methods for future VSP based escapement goals.

2b. No basis in the SSMP for implementing a consistent habitat template approach in support of estimating expected carrying capacity.

Issue 3. Habitat protection and restoration

Habitat protection and restoration are not addressed in detail in the *O mykiss* Report.

- The SSMP section on habitat could also have additional specific guidance on the types of restoration projects that are recommended to be implemented.
- There is no mention in either document of the anticipated effects of climate change.

Issue 4. Assessing the status and health of stocks

- The SSMP does not sufficiently specify the metrics for measuring what constitutes a "healthy" steelhead population or the process for determining the population status relative to such metrics.
- PVA is not designed to assess fully functional, "healthy" status, as is implied in the SSMP. Specific guidelines should be presented in both the *O mykiss* Report and the SSMP for how RMPs will implement an evaluation of stock "health".
- Comparing Current Production Potential to recent observed abundance has the potential to provide an accurate picture of steelhead population status relative to "healthy" levels, but neither the *O mykiss* Report nor the SSMP prescribe such an application.

Issue 5. Wild steelhead management

The *O mykiss* Report and the SSMP fail to provide a clear picture of the opportunities for (or potential magnitude of wild fish only steelhead management in Washington. A prioritized list of natural populations that can fulfill the promise of the HSRG's Wild Steelhead Management Zones of WDFW's wild stock gene bank should be developed.

5a. The ultimate focus of the integrated programs needs to be on the wild stock, rather than on the hatchery program, as is suggested by the emphasis given in both the *O mykiss* Report and the SSMP.

5b. The *O mykiss* Report recommends initiating a program to monitor genetic characteristics of steelhead populations. This program should be given high priority. Productivity and life history diversity metrics need to be assessed in addition to genetic characteristics.

5c. The attempt to link genetic markers to abundance and productivity should be a low priority activity, as it is likely to have a low probability of success and could be a drain on time and resources.

5d. The *O mykiss* Report concluded that hatchery steelhead potentially pose a competitive risk to wild steelhead, but provided no guidance on what should be done to reduce the risk. The topic of ecological interactions deserves a much expanded and more thorough treatment in the *O mykiss* Report.

Issue 6. Artificial production and the integrated approach

- Literature published since the completion of the *O mykiss* Report casts increasing doubt upon the ability of integrated programs to assist managers in reaching salmon and steelhead rebuilding goals. Hood River steelhead showed an average decrease in reproductive success of 37.5% for each generation in captive breeding (Araki et al 2007c).
- Measuring the effects of integrated hatchery production on the fitness of wild fish will require monitoring of a much broader suite of phenotypic and behavioral characteristics than merely relying on a narrow range of genetic attributes (allelic differences or genetic distance measures) (ISAB 2003).

Issue 7. Life history and genetic diversity

- The *O mykiss* Report and the SSMP fall short of explaining which life history diversity traits have been lost or reduced. These traits should be listed, examples of the changes that have occurred since the 1950s should be shown or estimated.
- The SSMP should incorporate basic life history diversity metrics, which would be expected to show increases as population recovery and expansion occurs or as the relationship between anadromous steelhead and non-anadromous rainbow trout becomes better understood. The SSMP is deficient in this regard, and as such is inconsistent with its stated goals.

- Only a small portion of the Washington steelhead populations (11%) that are associated with hatchery programs have been surveyed for loss of diversity. There is a need to expand this dataset to include a larger percentage of the steelhead populations associated with artificial production programs. This work needs to be a high and immediate priority for WDFW.

Issue 8. Linking the Science Plan to the Management Plan

- There are only weak linkages between Chapter 3 and Sections 4.6 and 4.7 in the *O mykiss* Report with the Steelhead Management Plan, which could lead to undirected implementation actions.
- We believe the strong scientific process for evaluating the relative merits of segregated vs. integrated programs in Chapter 3 should be used as a basis for an overarching plan on which watersheds should have integrated, segregated, or no hatchery facilities.
- Sections 4.6 and 4.7 of the *O mykiss* Report provide good discussion of tradeoffs among habitat, harvest, hatchery abundance, and fitness, but are largely conceptual in nature; there are no specific recommendations in Chapter 4 to guide the SSMP, nor does the SSMP appear to follow through with the process presented in Chapter 4.

Issue 1. Linking Management Actions to the Conceptual Foundation

Without specifically naming it as such, the WDFW *O mykiss* Report embraces a conceptual foundation for steelhead trout that links habitat diversity to natural processes, and then links steelhead diversity and productivity to habitat diversity. This same view of habitat-driven salmonid abundance and productivity underlies the NW Power and Conservation Council's Fish and Wildlife Program (NPCC 2000). This conceptual foundation was originally described by the Council's Independent Scientific Group (ISG 1996), and later articulated more fully in Williams et al. (2006a). It is representative of current best science on issues of salmon and steelhead abundance and persistence as related to habitat diversity and connectivity.

It is important to realize that when we manage natural resources, we always rely on a conceptual foundation. The conceptual foundation may be explicitly described in planning and vision documents dealing with the resource, but more often than not (as in the case of WDFW's *O mykiss* Report), it exists in an unstated implicit form within the planning documents and culture of the management institution(s). The real questions with respect to the use of a conceptual foundation here are: is the one we are currently using helpful for solving steelhead management problems; and does it reflect our current best understanding of how steelhead-producing ecosystems actually function? In retrospect, it is clear that the traditional conceptual foundation that has guided salmon and steelhead management for most of the last century greatly oversimplified the relationship of salmon to their ecosystem, and in the case of hatchery-origin fish, abstracted them from the natural ecosystem (Lichatowich 1999).

While the conceptual foundation broadly described in the *O mykiss* Report is reflective of current best scientific thinking on the relationship of steelhead with their habitat (and with long-term persistence), the presence of the conceptual foundation and its implications are almost completely lacking from the SSMP. The lack of a clear linkage between the information on steelhead and their habitats presented in the *O mykiss* Report and the proposed management actions in the SSMP is a significant omission. Addressing this omission is a significant need.

1a. The Value of a Conceptual Foundation for Steelhead Production

A conceptual foundation is a description of how we believe an ecosystem works. For steelhead, a conceptual foundation describes their life histories and how they interact with their ecosystem over the course of their lives and across multiple generations.

Conceptual foundations are important because they compose the set of scientific principles and assumptions that give direction to management activities, including restoration programs, such as the Washington Statewide Steelhead Management Plan. A conceptual foundation determines how information is interpreted, determines what problems (e.g., limitations on fish production) are identified, and as a result, establishes the range of appropriate solutions and implementation actions (Lichatowich et al. 2006a). Because it influences how we interpret information, identify problems, and select approaches to their resolution, the conceptual foundation is a powerful scientific element of management and restoration plans and can determine the success or failure of those plans.

A key assumption in the old conceptual foundation (pre-1996) was that artificial production activities could be managed independently from ecosystem processes and used to offset habitat loss or degradation. Production activities, both artificial and natural, need to be linked with the new conceptual foundation and integrated into a larger set of restoration, recovery, and management actions that encompass the steelhead's ecosystem and diverse life history patterns. The foundation is based on the concept of a "normative river", which can be defined as a river system – the river and its valley and watershed – in which natural production is conserved where possible and artificial production, where necessary, does not interfere with natural production. Further, artificial production will not significantly impede the restoration of ecosystem processes needed to allow natural production to become self-sustaining.

1b. Why a New Conceptual Foundation is Needed

The new conceptual foundation proposed by Williams and colleagues (Liss et al. 2006; Williams 2006) focuses on the steelhead and salmon's ecosystem and includes the linked continuum of freshwater, estuarine, and ocean habitats (Bottom et al. 2005; Bottom et al. 2006; Stanford et al. 2006) where salmonid fishes can complete their life histories. The new conceptual foundation can be used as a tool to integrate natural and artificial production at various scales ranging from a local tributary to a subbasin to major watersheds (e.g., Columbia River basin) to regions (Puget Sound or the Olympic Peninsula) (Williams et al. 2003). Presently, wild stock management actions better reflect the new conceptual foundation than do many artificial production activities, which rely more on the old conceptual foundation, than on the new one. This is a concern because hatchery production related activities constitute one of the largest expenditures in salmon and steelhead management with the majority of funding in the Columbia River Basin supporting artificial production projects and programs through the Fish and Wildlife Program (~35-40% of the annual budget), the Mitchell Act, and the Lower Snake River Compensation Program (ISRP 2005a).

The new conceptual foundation promotes diversity where the old one ignored it, thereby leading to reductions in salmonid life history and habitat diversity (Lichatowich et al. 2006a; Liss et al. 2006). Sustained salmonid productivity requires a network of complex and interconnected habitats, which are created, altered, and maintained by natural physical processes in freshwater, the estuary, and the ocean (Stanford et al. 1996). These diverse habitats are crucial for salmonid spawning, rearing, migration, maintenance of food webs, predator avoidance, and maintenance of biodiversity. The expression of diversity at genetic, life history, and population levels are ways salmonids express adaptation to their complex and interconnected habitats. Life history diversity and population diversity – both distinguishing features of salmonid species – are the basis for sustainable salmonid productivity and contribute to the ability of salmonids to cope with environmental variation that is typical of freshwater and marine environments (Bottom et al. 2006; Liss et al. 2006; Williams et al. 2006b). Protection of this capacity for adaptation is crucial in an era of climate change.

Application of the new conceptual foundation to salmonid conservation directs us to focus on the protection and restoration of physical processes that create diverse habitats and biological processes that allow individuals, populations, and population complexes to persist in those habitats and maintain their evolutionary capacity. Artificial production activities have historically operated outside of this perspective, but increasingly, studies are showing reduced behavioral, ecological, and reproductive performance by hatchery-origin fish that breed in the wild as a consequence of this disconnect (Chilcote 2003; Kostow et al. 2003; Kostow 2004; Miller et al. 2004; Myers et al. 2004; Kostow and Zhou 2006; Araki et al. 2007a, 2007b, 2007c). These results argue that greater attention needs to be placed on managing salmon and steelhead habitat and managing for salmonid life history diversity.

1c. Links to Natural Production and Wild Fish Management

The linkage of the new conceptual foundation to natural production and wild fish management is relatively straightforward, as the conceptual foundation focuses on natural riverine habitat-building processes, habitat diversity, the expression (and maintenance) of salmonid life history diversity, and salmonid abundance (Liss et al. 2006). The ecological and life history parameters associated with these factors are well-recognized within the fisheries and scientific communities (e.g., McElhany et al. 2000) and are the subject of considerable ongoing work (e.g., PNAMP activities; NOAA Fisheries involvement in the Intensively Monitored Watershed (IMW) projects in the Salmon, John Day, and Wenatchee watersheds through the Council's Fish and Wildlife Program). Therefore, designing monitoring protocols and projects for these factors will also be relatively straightforward. Monitoring of these factors will help elucidate steelhead population responses to habitat-based management activities; indeed, this is one of the purposes of the IMW projects (ISRP and ISAB 2005).

1d. Links to Artificial Production

The linkage of the new conceptual foundation to artificial production and mixed natural-origin and hatchery-origin fish management is equally important for their informed management, although the link may not be as obvious and straightforward at first glance as it is for wild fish management. For decades, the working assumptions of the old conceptual foundation led fisheries managers to believe that hatchery-origin fish (and their management) are largely divorced from the natural river and ocean systems where they co-occur with wild fish (Lichatowich 1999; Lichatowich et al. 2006a). This makes little sense, as hatchery-origin fish, whether returning to the hatchery or becoming naturalized, also have a life history pathway, most of which occurs outside the hatchery in a natural environment (Lichatowich et al 2006b). The new conceptual foundation recognizes this linkage.

Artificial production activities within the Pacific Northwest (and elsewhere) should be used in a manner consistent with the new conceptual foundation. At the subbasin level (and above), the role and scale of artificial production should be consistent with rebuilding goals for natural production. In many of Washington's steelhead watersheds, goals for artificial production programs are primarily focused on releasing fish for harvest and are in direct conflict with goals for wild fish maintenance when hatchery fish cause unwanted reductions in the fitness of recovering wild stocks. Application of the new conceptual foundation to natural AND artificial production goals within a watershed will identify areas where the programs are complementary or are in conflict. In 1996, scientists working through the National Academy of Sciences cautioned that artificial propagation must be viewed as an experiment to be implemented within an adaptive management framework (NRC 1996). Their caution remains as relevant today, as it was a decade ago (RASP (Regional Assessment of Supplementation Project) 1992; Lichatowich et al. 2006b).

It is also vitally important to recognize that the future of salmonid artificial production activities over the long-term, whether for harvest production or for the rebuilding of numerically depressed native stocks, lies in our long-term stewardship of wild stocks. Wild stocks serve as gene banks and seed sources for biological and genetic diversity. This perspective is well-recognized in the agricultural world, where new discoveries of wild maize varieties in Central America are heralded in national media outlets. This relationship – of a sustainability linkage between wild stocks and artificial stocks – is much less well recognized and appreciated in fisheries management.

To address the concerns listed above, WDFW should do the following:

1) Explicitly describe the conceptual foundation used to manage steelhead populations, their habitat, and their escapements.
2) Place greater emphasis (than is demonstrated in either the *O mykiss* Report of the SSMP) on identifying and protecting remaining wild populations of steelhead that can serve either as diversity reserves or genetic reserves
3) Include monitoring of life history diversity metrics in the evaluation of the performance of integrated hatchery programs

Issue 2: Habitat and Steelhead Production

2a: Linking Habitat with Production and Harvest

The direct management linkages among habitat, production, and harvest are not explicitly addressed in either the *O mykiss* Report or in the SSMP. Following on the Conceptual Foundation described above, we find that there is no specific description in Section 4 or 7 in the *O mykiss* Report, or anywhere in the SSMP, about how habitat-related production estimates, and resulting escapement goals, have been, are currently, or will be estimated and set (except a citation to Gibbons et al. 1985 in Chapter 4 of the *O mykiss* Report). This lack of specificity makes it impossible to assess whether the proposed SSMP will in fact reach its stated goal to "*Restore and maintain the abundance, distribution, diversity, and long-term productivity of Washington's wild steelhead…..*" (SSMP p. 3). While there are numerous references in the preliminary FEIS (none in the *O mykiss* Report or the SSMP) to "*VSP based escapement goals*" being applied in the future, there is no specificity in either document about how those are to be calculated for steelhead. (There are also references to population viability analysis (PVA) in both documents, but PVA is used to assess the likelihood of extinction which, while important for that purpose, does not address the issue of habitat-based escapement goals for informing managers of target levels to achieve fully functional stock productivity.)

While much is written in the two documents about current steelhead abundances and the steelhead stock declines, it is surprising that there is a lack of discussion in either document about past escapement goal procedures and associated management decisions have influenced the current status. In general, Washington steelhead stocks that have sufficient data have been managed by either assessing a stock's potential capacity to produce parr and then setting an escapement goal using a multi-stock spawner-recruit relationship (Gibbons et al. 1985) or, more recently, by spawner-recruit relationships. Recent spawner-recruit analyses are apparently performed internally in the Department and the tribes, and there is apparently no public information about how escapement goals are set. Importantly, none of those processes were described in the *O mykiss* Report.

Numerous questions remain about the origin of escapement goals that are currently used for steelhead management targets. The methods for 17 steelhead escapement goals established by Gibbons et al (1985) are clearly spelled out. However, since then, four of those goals have been decreased, one has a lower goal set by a tribe, and one has been increased, as shown in the Steelhead Historical Database (e.g. http://wdfw.wa.gov/fish/papers/steelhead/oly_pen_esu.pdf). Furthermore, there are a number of other stocks shown in the database that have escapement goals, but with no indication of how they were established. Lastly, it is important to note that many other stocks have no management targets.

Table 1. Comparison of escapement goals generated by Gibbons et al. (1985) and those reported in the Steelhead Historical Database.

	Gibbons et al	SW Historical database
Chehalis System	8600	8600
Humptulips	1600	1600
Nisqually	1700	2000
Hoh	2900	2400
Quinault	1200	1200[a]
Snohomish	6500	6500
Puyallup	5900	2000
Nooksack	3700	3700
Samish	700	700
Skokomish	1400	1400
Green	2000	2000
Skagit	10300	6000+16%
Queets	4200	4200[b]
Quillayute	5900	5900
Kalama	2000	1000

[a] Includes Upper Quinault only

[b] Tribal S/R-based goal 2500

According to the 1997 Wild Salmonid Policy (http://wdfw.wa.gov/fish/wsp/joint/final/fwsptoc.htm) "*MSH shall be calculated by using long-time series of accurate spawner and recruit statistics for each population. When such statistics are not available, MSH may be calculated by using historical production, habitat availability, or the best available methods for calculation*." A growing body of fisheries science literature has revealed that MSH-based escapement goals and related parameters can lead to management decisions that do not reflect the true production capacity of the managed stock (e.g., Hilborn and Walters 1992, Knudsen 2000). First, the application of spawner-recruit methods often does not meet all the model assumptions (Hilborn and Walters 1992). Second, when short-term, recent S-R data is employed, it is possible that the resulting escapement target can be substantially less than the actual production potential of the stock. This is because using recent data only may reflect the population performance in a depressed state (Knudsen 2002). This same concept raises some questions about the results of Gibbons et al. (1985) which are based on observations of parr production. Although they took measures to assess potential production at "full seeding", what if those observations represented some lowered production state, say in the chronic absence of marine-derived nutrients form other salmon species? Third, there are an array of issues about the numbers used for estimating escapement, harvest, and escapement goals: some of these are actual fish numbers, some are estimates, and many are indices.

For Washington steelhead, one of the main problems is that, for many stocks, either the habitat has been dramatically altered, the abundance of fish is too low, or both. We have lost our production frame of reference (see template discussion below). It is therefore necessary to explore and develop an entirely new way of establishing natural production targets. This should be done in the *O mykiss* Report.

Expanding the background, technical bases, and proposed methods for setting escapement objectives, and other VSP attributes, in the *O mykiss* Report would provide a much better basis for more complete prescriptions of these issues in the SSMP. Currently, instead of directly addressing the issues of target levels, or specific methods for doing so, the SSMP only generally prescribes that *"..... the development of watershed and regional management plans (RMPs). RMPs will identify the long-term goals, benchmarks for modifications to management actions, escapement objectives, and the expected trajectory for the diversity, spatial structure, productivity, and abundance of each wild stock within its management are*a." (SSMP p. i). In the SSMP, under Natural Production, Action Item 3 states: "*Develop and implement regional management plans that identify the long-term goal, benchmarks for modifications to management actions, escapement objectives, and the expected trajectory for the diversity, spatial structure, productivity, and abundance of each wild stock (based on TRT viability analyses and productivity graphs where applicable)*." (SSMP, P.6-7). However, there is no citation or other background given for "*TRT Viability Analyses and productivity graphs*", and therefore no way to assess whether these vaguely proposed methods will satisfy the need for setting abundance recovery goals and fully functional stock target levels. The proposed methods for managing for abundance and other VSP parameters should be fully transparent. In addition, there is no guidance in the SSMP for how managers would implement new goals.

2b: Habitat Actions and Carrying Capacity

There is no basis in the SSMP for implementing a consistent habitat template approach in support of estimating expected carrying capacity. Chapter 7 of the *O mykiss* Report included the use of EDT (Mobrand et al. 1997) as a method for estimating the pre-settlement and current production potential of steelhead (*O mykiss* Report, Chapter 7, p. 5 and Box 7-3). Comparing the pre-settlement and current production potential provides an assessment of how anthropogenic changes have affected the ability of the population to support fisheries and maintain abundance and productivity consistent with a viable population (SSMP, Chapter 7, p.12). Comparing the current production potential to the actual observed production can provide a measure of current performance relative to the expected production in the now altered habitat.

While this approach was validated and applied in Chapter 7 of the *O mykiss* Report, there is no similar approach recommended or even mentioned in the SSMP. We suggest that the SSMP sections on Natural Production and Fishery Management include Strategies and Actions based on a carrying capacity template, such as EDT or its antecedents. This guidance can be used as a basis for the development of the RMPs.

EDT is currently considered the state of the art method for assessing both historical production and current expected conditions. Without such a reference to the habitat template, expectations for future steelhead production will continue to be based primarily on observations of recent production with all the inherent pitfalls (usually underestimates), as described above. Results from EDT, as described in the *O mykiss* Report, Chapter 7, p. 5, can be used to predict the number of spawners at equilibrium under current habitat conditions. The same results can be used to estimate the number of spawners at equilibrium harvest, if the stock is being fished, by

$$Smsy = \left(\sqrt{1/a}\right) - \left(b/a\right)$$

where S_{msy} = spawners at maximum sustained yield, *a* = intrinsic production potential, and *b* = maximum number of recruits (Hilborn and Walters 1992). This S_{msy} can then be used as a metric to connect the habitat-based production expectation to the observed stock performance. (However, an important caveat is that EDT-based production estimates are subject to the same concerns about production observations derived from currently underutilized habitats as described above.)

Currently, the only SSMP reference to this concept is found under Research, Action item 2: "*Expand and support research to define the relationship between habitat and steelhead productivity*" (SSMP, p. 29). There is also a mention that RMPs will be "*based on TRT viability analyses and productivity graphs where applicable*", under the SSMP Natural Production Action Item 3 (SSMP, p. 6). This could potentially be taken to imply that an EDT-process similar to that applied in the Lower Columbia Salmon Recovery Plan (LCFRB 2004) would be applied in RMPs. However, the current SSMP language is too vague and should be improved to specify whether RMPs will in fact be required to include a habitat-based production template as a point of reference for each stock and provide more specificity about the techniques to be used. Indeed, this is precisely the type of guidance the SSMP should provide so that there is consistency across regions.

While it is recognized that implementing EDT or other related approaches is expensive and time-consuming, the stated goal should include developing a habitat template as a reference point for all future production expectations and evaluations of production performance. Without such a step, the RMPs will not have a clear and consistent definition of what constitutes a "healthy" steelhead population or the true production potential of their respective steelhead populations. Without this metric, there is no clear basis upon which to prioritize management actions and locations.

Issue 3: Habitat Protection and Restoration Issues are treated superficially

Habitat protection and restoration are not addressed in detail in the *O mykiss* Report. For example, there is no scientific description of what specific impacts result from each type of habitat degradation or how the extent of each type of degradation translates into numbers of lost steelhead. Likewise, there is no mention of the likelihood of restoration benefits from specific habitat restoration types (e.g., restored flows, added large woody debris, etc.).

The *O mykiss* Report addresses habitat but not sufficiently to set the stage for later specific prescriptions in the SSMP. A summary of habitat passages from the *O mykiss* Report follows:

- In Chapter 2, Recommendation 2-1 notes habitat as important: "*Pursue opportunities to preserve and restore population structure, spatial structure, and within-population diversity through careful review of harvest, hatchery, and habitat management and implementation* *of improved strategies*", but the *O mykiss* Report does not allude to any recommendation about methods for how habitat can and should be protected or restored.

- Chapter 4: "*Strategies for habitat, harvest, and hatchery production, often referred to as the all-h sectors, have often been developed and evaluated in isolation*." (*O mykiss* Report Chapter 4, p.33) and "*Achieving management goals for steelhead will be promoted by an integrated strategy for habitat protection and restoration, hatchery practices, and harvest management*" (*O mykiss* Report Chapter 4, p.52). However, nowhere is there a recommendation for a technical process for achieving the integration or the resulting prescriptions for habitat protection or improvement.
- Several criteria for maintaining habitat that support steelhead diversity are listed in Chapter 6: "*Habitat patches should not be destroyed faster than they are naturally created*" and "*Some habitat patches should be maintained that appear to be suitable or marginally suitable, but currently contain no fish*." (*O mykiss* Report Chapter 6, p. 5)
- In recognition that habitat has been altered, habitat quality is assessed and then summarized in Section 6.3.
- From Chapter 7: "*Finding 7-2. Degradation of riverine, estuarine, and nearshore habitat has resulted in the loss of an average of 83% of the potential production of the 42 steelhead populations assessed in Washington. Improvements in habitat protection measures and restoration of degraded or inaccessible habitat are essential to assure the long-term viability of natural populations of steelhead in Washington*." (*O mykiss* Report, Chapter 7, p.51) and *"Recommendation 7-4. Through a recently initiated project to evaluate the feasibility of developing habitat conservation plans for the Hydraulic Project Approval (HPA) program, and for WDFW owned and managed wildlife areas: a) assess the potential impacts of WDFW land management activities on steelhead; b) assess the potential impacts of HPA-permitted activities on steelhead; c) evaluate potential conservation measures to fully mitigate for adverse impacts resulting from HPA permitted activities; d) identify HPA activities that will require new research or monitoring efforts to assess impacts and potential mitigation measures; and e) develop tools and strategies to facilitate the monitoring, tracking, and adaptive management of HPA activities.*" (*O mykiss* Report, Chapter 7, p.52)

Through all these passages from the *O mykiss* Report, there is recognition that habitat degradation is a problem, and some recommendations are made for habitat management actions that can help. However, habitat protection and restoration are largely overlooked. There is an extensive body of habitat protection and restoration literature that was ignored in the *O mykiss* Report. That literature provides copious information on steelhead habitat requirements and numerous alternatives for implementing beneficial restoration. We therefore recommend that a habitat protection/restoration chapter is needed in the *O mykiss* Report. We suggest the additional chapter include (1) a description of steelhead habitat from the estuary to the upper riverine limit of the species, (2) what impacts the various activities (dams, logging, development, agriculture, etc) have had on steelhead habitat and watersheds, and (3) what changes in the above activities are needed to recover and maintain steelhead habitat/watersheds.

We also find that, while the SSMP section on habitat generally addresses some approaches for habitat protection and restoration, it could have additional specific guidance on the types of restoration projects that are recommended to be implemented for the maximum benefit.

We also note that neither of the documents addresses the issues of changing climate. What are the anticipated effects of differing water flows and temperatures, for example, on the various stocks? What kinds of actions could be taken now to ameliorate those climate-induced changes? Both the *O mykiss* Report and the SSMP should be upgraded to address these issues.

Issue 4: Assessing the Status and Health of Stocks.

We have concerns about the criteria and methods for evaluating the status and health of steelhead stocks as the SSMP is implemented. We agree with the SSMP statement under Natural Production that "*A healthy wild stock meets viable salmonid population parameters (VSP): abundance, productivity, diversity and spatial structure to be resilient through environmental fluctuations, to perform natural ecological functions in freshwater and marine systems, provide related cultural values to society, and sustain tribal and recreational fisheries*." (SSMP, p. 5). However, the SSMP does not sufficiently specify 1) the metrics for measuring what constitutes a "healthy" steelhead population or 2) the process for determining the population status relative to such metrics.

With regard to abundance, there are two critical thresholds that must be monitored for each steelhead stock: abundance levels sufficient to minimize the risk of extinction, and levels necessary for the attainment of "health", as defined above.

Population Viability Analysis (PVA) can and has been broadly used to address the first threshold – risk of extinction - in the context of the Endangered Species Act recovery. In fact, PVA was conducted in Chapter 7 of the *O mykiss* Report for 83 stocks and used to determine the risk of extinction for each of those stocks. Importantly, PVA is recommended to assess the extinction risk of every stock, every 4 to 8 years, under Monitoring and Evaluation, Action Item 10 (SSMP, p. 26).

PVA is not, however, designed to assess the second threshold, that of fully functional, "healthy" status, as is implied in the SSMP. Further, there is no guidance in the SSMP for assessing, via consistent metrics or a pre-defined process, whether a given stock has attained "health". This is a significant deficiency because, while many populations may hover just above a threshold of being at risk of extinction, the SSMP has not really made progress until most of the stocks have achieved "health". Specific guidelines should be presented in both the *O mykiss* Report and the SSMP for how RMPs will implement such an evaluation of stock "health".

Furthermore, the *O mykiss* Report did not necessarily set a prescription for how these evaluations should be conducted. The *O mykiss* Report used four methods in Chapter 7 to evaluate current status: 1) Historical and Current Production Potential; 2) SaSI Status and Short Term Abundance Trends; 3) Smolt-to-Adult Return; and 4) PVA. While all these methods taken together are useful in evaluating status, all except Historical and Current Production Potential are based solely on recent, observed abundance trends which, as described above, are often clearly biased toward underperformance, since many stocks are chronically depressed. The method of comparing Historical and Current Production Potential, or better yet, comparing Current Production Potential to recent observed abundance has the potential to provide a much more accurate picture of status relative to "healthy" levels, but neither the *O mykiss* Report nor the SSMP prescribe such an application.

Issue 5. Wild Steelhead Management

The *O mykiss* Report and the SSMP contain little information on the management of wild steelhead populations, but rather focus almost exclusively on management of steelhead populations where either segregated or integrated artificial production programs will co-occur with wild populations. This approach to managing overall steelhead production is not consistent with recommendations from several advisory scientific panels (HSRG 2004; ISAB 2003; ISRP 2005) that recommend a diverse production portfolio that includes production from natural populations as well as from systems that contain natural-origin and hatchery-origin fish. This requires identification and designation of wild fish only management areas. For example, the HSRG recommended development of a series of wild steelhead management zones, where entire sub-regions or portions of large watersheds are not planted with hatchery-origin fish, but are managed for wild steelhead only (HSRG 2004). The HSRG recommended at least one wild steelhead management zone for each of the ten Puget Sound and Coastal regions. This is consistent with other calls for wild fish reserves as part of a larger conservation and management strategy (Williams 2001; Lichatowich et al. 2006b).

The *O mykiss* Report (Chapter 3, pp. 50-51) and the SSMP (Natural Production, p. 6) indicate that at least one wild fish population in each regional management unit will be identified and managed as a wild fish only population. This is consistent with the HSRG's recommendation (at a minimum level!); however, language describing this differs significantly between the *O mykiss* Report, which relies on the HSRG's Wild Steelhead Management Zone (WSMZ) concept – a seeming geographical context – while the SSMP appears to be more population based and uses the phrase "wild stock gene bank" as the proposed population management unit. Definitions in both reports are quite vague, need to be more explicitly described, and need to be consistent with one another.

Chapter 5 of the *O mykiss* Report reviews population genetic analysis for all the extant populations in Washington State by region. Table 5-7 (p.41) presents the number of historical populations in each of seven regions within Washington State, totaling 144 historical populations of which 130 (90%) remain extant. The analysis stops well short of identifying natural populations that might be candidate populations for either WSMZ or wild stock gene bank status.

Chapter 7 of the *O mykiss* Report presents escapement, growth rates, and relative risk of extinction for populations in each of the seven regions within Washington State. Again, there is substantial information presented here, but it does not lead to any clear listing of potential candidate natural populations for WSMZ or wild stock gene bank status. The choice of presenting status on Washington steelhead populations in chapters 5-7 through the VSP criteria of population structure, diversity, and abundance was an interesting one. Much information is presented there, but much further synthesis will be required to distill a list of natural populations and a prioritized list of management options by population that can fulfill the promise of the HSRG's Wild Steelhead Management Zones or WDFW's wild stock gene bank. One is left at the end of these three chapters without any real sense of the opportunities or potential magnitude of wild fish only steelhead management in Washington.

5a: Assess the Effects of Integrated Programs on Natural Steelhead Populations

There is a need to evaluate the effects of integrated programs on the diversity, spatial structure, abundance, and productivity of the indigenous natural steelhead populations in the state of Washington. In Chapter 3 of the *O mykiss* Report (Artificial Production chapter) – Recommendation 3-6 under Finding 3-7 (p. 53-54) represents one of the most critical findings and recommendations in the entire *O mykiss* Report. Indeed, it lies at the heart of the Integrated Approach and the assumptions about its likely efficacy. Recent work in the Hood River by Araki and Blouin (2005) and Araki et al (2007a; 2007b; 2007c) raise unsettling questions about the effects of supplementation-style artificial production programs (such as the integrated programs proposed in the *O mykiss* Report and the SSMP) on reproductive fitness of hatchery-origin steelhead and the natural population with which they are interbreeding (see additional discussion in Issue 6 below).

Recommendation 3-6 states the following: *Evaluate the potential effects of integrated programs on the diversity, spatial structure, abundance, and productivity of the indigenous natural population. Carefully consider the size of the program and characteristics of the release strategy (location, time, size of fish) to assure that potential genetic and ecological risks are consistent with policy objectives.*
This is an appropriate and scientifically-sound recommendation, yet the *O mykiss* Report and the SSMP contain virtually no details about how this is to be achieved. A considerable amount of work has been devoted to these same questions in the Columbia Basin, including work done by Todd Pearson and others within the Yakima Basin in Washington State that should be incorporated into the development of appropriate metrics needed to evaluate the integrated programs (McMichael et al 1999; 2000; Pearsons and Hopley 2002). Unsettlingly, the SSMP (Strategy 6 in the Artificial Production section) reiterates the points made in Recommendation 3-6 from the *O mykiss* Report and then prescribes three actions related entirely to assessing the specific artificial production program linked to the wild stock and modifying hatchery program operations, rather than focusing on the wild stock's attributes and data collections needed to answer the questions posed by Recommendation 3-6. The ultimate focus of these integrated programs needs to be on the wild stock, rather than on the hatchery program. This means having adequate data collection protocols in place that will confidently detect any negative effects on the wild stock of the hatchery program, and then having adequate operational pathways defined *a priori* that can be instituted to respond to new information from the analysis (i.e., adaptive management).

Issue 5b: Genetic Assessments of Steelhead Populations

Ch 3 (*O mykiss* Report) – Recommendations 3-1 and 3-2 under Finding 3-5 (pp. 52-53) are appropriate and necessary to define opportunities and actions to reduce genetic impacts of artificial production activities upon remnant native wild steelhead populations. Recommendation 3-2 calls for the design and initiation of a program to monitor genetic characteristics of steelhead populations. This program would prioritize watersheds that contain a hatchery program and a significant natural population in order to assess the potential loss of diversity associated with the hatchery program.

These are good recommendations and it is vital that they be implemented – the sooner the better. It is entirely possible, given WDFW's long investment in its own salmonid genetics laboratory and staff that samples from wild and hatchery steelhead populations in some of these watersheds may already be in hand or have even been analyzed, so that the level of genetic impact can be quickly assessed and hatchery program operations modified as needed. As noted previously however, it is increasingly clear that the narrow range of genetic metrics used to identify population relationships are not necessarily meaningful measures of population productivity and diversity. The recommendation should expressly state that productivity and life history diversity metrics will be assessed in addition to genetic characteristics.

Issue 5c: Linking Genetic Markers to Abundance and Productivity of Steelhead Populations

Ch 3 (*O mykiss* Report) – Recommendation 3-3 under Finding 3-5 (p. 53) attempt to link specific genetic markers to fitness-related traits. This is a laudable objective; however, in practice this objective is not likely to be achievable within a meaningful timeframe. This type of exercise is a "needle-in-the-haystack effort"; a long shot that is quite worthwhile if successful, but most likely constitutes a dead end or near dead end and a potential waste of staff time and expense. Efforts to accomplish Recommendations 3-1 and 3-2, initiation of a program to monitor genetic characteristics of steelhead populations, are far more critical to the informed management of steelhead populations managed under both the segregated and integrated approach and they should receive the priority for funding and staff time. Recommendation 3-3 can be pursued in a background effort that does not detract from the importance or timely completion of Recommendations 3-1 and 3-2.

Issue 5d: Ecological interactions between hatchery and wild steelhead, among all steelhead, between species, and with the environment

There is only limited consideration in the *O mykiss* Report of ecological interactions between hatchery and wild steelhead and between all steelhead and their environment. Hatchery steelhead have myriad and complex ecological effects on wild steelhead (not including genetic effects, treated elsewhere in this report). Several, but not all, of these effects were reviewed in the *O mykiss* Report. Section 3.3 of the *O mykiss* Report reviewed the literature on juvenile competition, and concluded that hatchery steelhead potentially pose a competitive risk to wild steelhead, but it provided no guidance on what should be done to reduce the risk. Section 3.4 of the *O mykiss* Report reviewed predation issues and reported that, in two food studies of adult steelhead, they only infrequently preyed on juveniles. Section 3.4 also reviewed hatchery-produced steelhead smolts' feeding habits. However, this section did not discuss, draw any conclusions, nor make any recommendations regarding the potential impacts of hatchery steelhead predation on wild steelhead fry, an important consideration. *O mykiss* Report Section 3.5 generally reviews the potential effects of hatchery facilities and disease on wild fish but draws no conclusions and makes no recommendations with regards to how these effects can be avoided and minimized. Likewise, there is no mention of hatchery-wild interactions in Section 3.8, Findings and Recommendations. Furthermore, we find no discussion anywhere in the *O mykiss* Report about the effects of non-hatchery-wild ecological interactions with conspecifics or other species, such as predation, competition, and/or marine-derived nutrients, or with the environment (e.g. environmental variability or climate change).

We believe the topic of ecological interactions deserves a much expanded and thorough treatment in the *O mykiss* Report. Such an analysis would then provide a better basis for addressing hatchery-wild ecological interactions, and ecological interactions in general, in the SSMP. Our suggestions for a more complete coverage and subsequent development of comprehensive recommendations to limit hatchery-wild interactions, and address ecological effects that influence both wild and hatchery fish, are listed in the following annotated outline:

1) **Juveniles.** See Pearsons and Hopley (2002) for a comprehensive overview of the ecological interactions and steps that can be taken to reduce impacts.
    a. **Competition in freshwater** – Literature review covered reasonably well in Section 3.4.
        i. **Food competition**
        ii. **Space**
            1. **Rearing/feeding/territorial space.** Detailed coverage in McMichael et al (1999, 2000, and others).
            2. **Pied-piper effect.** – The tendency of locally rearing wild salmonids to prematurely follow a large release of hatchery fish migrating downstream (Hillman and Mullan 1989).
    b. **Competition in estuarine and marine environments** – This has never been addressed for steelhead, but see Levin et al. 2001 and Ruggerone et al (2003)

c. **Predation** (covered partly in 3.5)
    i. **Of pre-smolts and smolts on fry and fingerlings** – Studies are scarce but see Sholes and Hallock (1979) and Beauchamp (1995).
    ii. **By other species** – See Antolos et al. (2005).
    iii. **Attraction of predators** (vs. predator swamping) – See Hillman and Mullan (1989) and Pearsons and Hopley (2002).
d. **Disease** – Disease transmission from hatchery fish cited as an ecological risk to wild fish by the HSRG (2004)

2) Adult returns:
    a. **Competition for spawning space between wild, hatchery, and supplementation fish** -- Mentioned in section 3.4. Also see Mackey et al. (2001).
    b. **Effects of adults on ecosystem** – See Cederholm et al. (2000)
        i. **Reduced fitness** – Results in fewer adults returning and contributing to the ecological aspects of the aquatic environment (Araki et al. 2007c)
        ii. **Losses of marine-derived nutrients (MDN) from adults that die after spawning** – (Cederholm 1999; Bilby et al. 2003)
    c. **Predation of adults** – Attraction of predatory species such as seals and sea lions caused by large numbers of hatchery fish (e.g., Beamesderfer 2000)
3) **Environmental Variability**
    a. **Interannual variation** – Factors like temperature affect survival and behavior (e.g. McMichael et al. 2000)
    b. **Climate change** – Long term effects may influence water flows, temperatures, etc, and therefore affect steelhead production
4) **Hatchery Facility effects** – Partly Covered in Section 3.6
    a. Block access to upstream areas – Hatchery barriers block upstream migration
        i. Adult spawning – Reduces all species access to upstream areas
        ii. MDN deliveries – Same as above
    b. **Influence of hatchery on downstream water quality** – Start with http://www.ecy.wa.gov/biblio/8917.html.

We see a major oversight in the fact that there has never been a thorough ecological evaluation of the steelhead hatchery program, including many of the topics listed above, as alluded to in Levin et al. (2001). We recommend that the *O mykiss* Report and the SSMP include analysis and prescriptions for evaluating the full ecological effects of all hatcheries on steelhead. Such reviews have also been recommended by the HSRG (2004).

In regard to the SSMP, there are some general references to ecological interactions of hatchery and wild steelhead, and with the rest of the aquatic environment. However, the SSMP could be vastly improved if the basis for its guidelines had been more rigorously developed in the *O mykiss* Report. The most specific SSMP guidance is given for segregated hatcheries as: "*Evaluate the potential effects of competition of hatchery-origin juveniles, adults, and the progeny of naturally spawning hatchery adults with wild-origin stocks*." (SSMP, p. 20). However, the SSMP does not address the other effects of hatcheries on wild stocks, or the ecological limiting factors for both wild and hatchery steelhead with other species' or their environment, as outlined above.

Issue 6: Artificial Production and the Integrated Approach

The Integrated Approach (essentially a supplementation strategy relying on local indigenous natural fish as broodstock source) lies at the heart of the SSMP and WDFW's proposed steelhead management plans. The SSMP (p. 21) identified the three key risk factors associated with integrated programs as a loss of diversity, loss of fitness, and a reduction in the number of wild spawners. Recent literature on supplementation programs suggest that the long-term outcomes of these programs are uncertain, and short terms effects frequently include decreased reproductive performance and reduced fitness for hatchery-origin fish (Waples and Do 1995; Waples 1999; Flagg et al. 2000; Ford 2002; Chilcote 2003; Kostow et al 2003; McLean et al. 2003; Goodman 2005). The interbreeding of hatchery-origin fish with natural-origin fish – the goal of supplementation and integrated programs – may in turn, reduce the fitness of the natural population (Araki et al. 2007c). These results suggest that the integrated approach be relied on cautiously to achieve the management goals identified by WDFW in the *O mykiss* Report and the SSMP. Rigorous monitoring will need to be implemented for each integrated program in order to detect any adverse effects on natural population fitness. Alternative management plans for each natural population should be developed *a priori* in case negative effects occur from the integrated program.

The *O mykiss* Report does a good job in reporting on recent advances in our understanding of some of the limitations of hatchery-origin fish integrating into a wild fish population, particularly where the hatchery-origin fish are not of local origin, such as Chambers Creek winter-run steelhead and Skamania summer-run steelhead. Recent studies are increasingly showing reduced behavioral, ecological, and reproductive performance by hatchery-origin fish that breed in the wild (Chilcote 2003; Kostow et al. 2003; Kostow 2004; Miller et al. 2004; Myers et al. 2004; Kostow and Zhou 2006; Araki et al. 2007c), with the greatest reductions coming from hatchery fish that are not of local origin. The *O mykiss* Report discusses some of the potential shortcomings of the integrated approach, but shows insufficient appreciation for the differences in genetics and fitness that could accrue between the hatchery-origin population and the natural-origin population that reduce the overall fitness of the conjoined population.

The Integrated Approach described by the HSRG (2005; 2007) and selected by WDFW for rebuilding a wild steelhead population as part of the SSMP intends to use naturally returning indigenous wild fish as broodstock for hatchery production within a watershed. By relying on conservation hatchery principles, effects on diversity, fitness, and wild spawners are expected to be minimized. One of the guiding principles in this set of assumptions is to use an average PNI of 70% or greater as the monitoring benchmark. PNI is the *proportionate natural influence* (PNI) and is based on modeling by Lynch and O'Hely (2001). Mathematically, PNI = *pNOB /pHOS + pNOB*, where *pNOB* is the proportion of natural-origin fish in the hatchery broodstock and *pHOS* is the proportion of hatchery-origin fish on the spawning grounds. Biologically, PNI is a measure of the proportion of time the population spawns in the wild, where it is subjected to natural selection.

The integrated approach relies on the same assumptions about the efficacy of so-called "conservation hatcheries"[1] that guide many of the region's supplementation hatcheries (ISRP 2005; Lichatowich et al 2006b); however, recent literature published since the completion of the *O mykiss* Report cast increasing doubt upon the ability of integrated programs to assist managers in reaching salmon and steelhead rebuilding goals (Araki and Blouin 2005). Initial work by Araki et al (2007b) showed that first generation captive-reared fish had natural reproductive success indistinguishable from wild fish in two out of three years; however, recently, they extended that study into the third generation and observed an average decrease in reproductive success of 37.5% for each generation in captive breeding (Araki et al 2007c). This is a dramatic decrease in fitness and bodes ill for the expected efficacy of supplementation programs to rebuild natural populations, unless the hatchery intervention is of very short (< 2 generations) duration. Particularly powerful

[1] There is an increasing literature and interest in using hatcheries in a way that minimizes negative effects on fitness; however as yet there is no uniform set of principles or guidelines that rigorously define what constitutes a 'conservation hatchery'.

was the additional analysis done by Araki et al using data from other supplementation programs (Figure 2B in Araki et al. 2007c). Data from those programs fit the decreasing exponential curve developed by Araki et al and showed a similar rapid loss of fitness with increasing time in captivity. The studies by Araki and Blouin show how strong fitness effects can be and how quickly they can accumulate. They conclude their studies by saying "*To supplement declining wild populations, therefore, repeat use of captive-reared organisms for reproduction of captive-reared progenies should be carefully considered*".

Another concern is that evaluation of the integrated approach often relies on genetic discrimination between the hatchery-origin fish and indigenous natural-origin fish. Where non-local hatchery fish are used, substantial genetic differences between the hatchery and wild fish often occur; however, when indigenous natural-origin fish are used as broodstock source (as proposed in the integrated approach), detectable genetic differences between hatchery-origin and natural origin fish may become small or non-existent. It is important to remember; however, that failure to detect genetic differences between hatchery-origin fish and natural-origin fish in the integrated approach does not mean the two groups of fish are identical or equivalent. Genetic detection occurs at a small suite of (generally) neutral markers and there may easily be genetic differences between the two groups of fish that are not detected by whatever screening process (SNPs or microsatellites) is used. Additionally, different gene regulatory pathways may have occurred in natural fish or hatchery fish, cued in response to the wild or hatchery environment, respectively.

Merely relying on a narrow range of genetic attributes (allelic differences or genetic distance measures) is therefore insufficient to measure the effects of integrated hatchery production on the fitness of wild fish. Rather, it is necessary to monitor a much broader suite of phenotypic and behavioral characteristics (ISAB 2003). Indeed, observations of lowered reproductive success of some hatchery-origin fish even when derived from local indigenous stock (Kostow et al. 2003; Araki et al 2007) suggest an interaction between developmental pathways and rearing environment that profoundly affects fitness. This difference in fitness is not necessarily reflected by the PNI metric. Indeed, the behavioral and reproductive metrics are likely to be the most important and most telling, though frequently they are the most expensive and most difficult to collect. Support for this suggestion comes by comparing the results of Araki et al.'s preliminary results in the Hood River (Araki and Blouin 2005) versus the second generation (F_2) data (Araki et al. 2007c). Fitness impacts of the first generation data were largely non-significant between hatchery and natural origin fish, while fitness loss at the 2nd generation level were calculated at 38% per generation as compared to wild fish.

Finally, stronger linkages need to be developed between the population-based chapters (5, 6, and 7) and their principles in the *O mykiss* Report and the Artificial Production Strategies and Guidelines in the SSMP. For example, Strategy #6 in the AP chapter of the SSMP calls for the development and implementation of regional management plans that identify the long-term goals, benchmarks for modifications to management actions, escapement objectives, and the expected trajectory for the diversity, spatial structure, productivity, and abundance of each wild stock, yet the three actions listed under the strategy all have to do with assessing the specific artificial production program linked to the wild stock and modifying hatchery program operations, rather than focusing on the wild stocks attributes and needs – which is what is required if the primary goal is the protection of and restoration of wild stocks. Artificial production program elements should come after this assessment and be designed to bridge the difference between the potential production performance of the wild stock and the program's production goals for steelhead within that watershed, to the extent that hatchery production is consistent with rebuilding healthy wild stocks.

Issue 7: Life History and Genetic Diversity

Salmon and steelhead populations have not been managed for life history diversity, until recently, and ideas and metrics are still developing on how this might best be accomplished (McElhaney et al 2003). Much work toward standardizing data types and data collection methods dealing with salmon, steelhead, and aquatic systems has been done by groups such as the Pacific Northwest Aquatic Monitoring Partnership (PNAMP; see www.pnamp.org) and others.

There has been significant loss of life history and genetic diversity in Pacific Northwest salmon and steelhead over the last century or more (Lichatowich et al. 2006a; Williams et al. 2006b). Management has primarily focused on abundance (and harvest-related issues) and rarely on life history diversity. Because we have not managed to conserve (or promote) life history diversity, loss of life history patterns has decreased diversity in many stocks and is linked to decreases in the abundance and productivity of almost all steelhead populations/river runs. An example is the effective extirpation of the early run component of many winter steelhead populations in Washington State due to the combined effects of hatchery production and incidental mortality from intensive harvest pressure on early run hatchery fish.

The *O mykiss* Report and the SSMP fall short of explaining which traits (e.g., run timing, size and age at reproduction, population age structure, life history diversity measures, etc.) have been lost or reduced. These traits should be listed, examples of the changes that have occurred since the 1950s should be shown or estimated. Where recovery of these diversity traits is possible, management measures and recommendations should be provided to support their recovery. This will then provide at least some basis for the SSMP and the RMPs to manage for recovery and conservation of steelhead diversity.

Studies in Kamchatka, where steelhead exhibit 2-5 times greater diversity in life history patterns than in the Pacific Northwest, are providing a sense of how much life history diversity has been lost (Savvaitova et al. 1995). Equally important, these studies give insights into what extirpated life history patterns might re-emerge as habitat improvements occur and populations rebuild. An example of this occurs in the Columbia River, where fall Chinook in the Lower Snake River are showing re-emergence of a yearling life history pattern. Previously, fall Chinook in the Snake River were assumed to all exhibit an ocean-type life history characterized by a subyearling juvenile life history. As fall Chinook numbers have expanded in the Lower Snake River, particularly in the tailrace sections of mainstem dams and in the lower Clearwater River mainstem, a yearling juvenile life history has emerged. Early data from Willis Rich (1920; 1939) documenting annual juvenile migrations past the Dalles area, showed juvenile Chinook moving downriver during all months of the year (indicative of a yearling juvenile life history pattern, since sub-yearling juveniles outmigrate on the spring freshet). Re-emergence of the fall Chinook yearling life history came as a surprise to Columbia River researchers, but it shouldn't have! It should have been a logical prediction based on fall Chinook populations expanding numerically and spatially and researchers should have been looking for it as a consequence of that expansion.

This development suggests a similarly hopeful future for wild steelhead, provided they are given the chance to express their remarkable evolutionary and adaptive capacity. A precautionary approach to wild steelhead management, based on the goal of recovering healthy populations, should provide the conditions for diversity to recover. Moreover, the SSMP should incorporate basic life history diversity metrics, which would be expected to show increases as population recovery and expansion occurs or as the relationship between anadromous steelhead and non-anadromous rainbow trout becomes better understood (see MacMillan et al. 2007). The SSMP is deficient in this regard, and as such is inconsistent with its stated goals.

Chapter 6 of the *O mykiss* Report includes a good discussion of life history and genetic diversity issues. Table 6-1, for example, contains logical and moderately conservative criteria for categorizing changes in diversity. Similarly, the analysis section on diversity in Chapter 6 is also well-done. It was not surprising that greater than 50% of the WA steelhead populations showed high loss of spatial structure; however, it is a concern that only 11% of the populations where artificial production programs are underway have been surveyed for loss of diversity. The *O mykiss* Report itself, notes that this result identifies the need for enhanced data collection and consistent reporting and improved analyses. This work needs to be a high and immediate priority for WDFW.

Issue 8: Linkages between Science Plan and Management Plan

There are only weak linkages between Chapter 3 and Sections 4.6 and 4.7 in the *O mykiss* Report with the Steelhead Management Plan, which could lead to undirected implementation actions. Specifically, the science paper does a poor job of internally linking the information it presents into a coherent foundation for management, and the SSMP is weakly linked to this inadequate foundation. Chapter 3 contains some specific management Recommendations that apply to implementing the SSMP. However, there is too little specificity in the Artificial Production Section of the SSMP. For example Action Item 4 is "*Select either an integrated or segregated reproductive strategy for the operation of each hatchery program based upon watershed goals, program objectives (harvest, conservation, research, or education), facility capabilities, and a scientific assessment of the potential risks and benefits of an integrated or a segregated strategy.*" (SSMP p. 19-20). We believe the strong scientific process for evaluating the relative merits of segregated vs. integrated programs in Chapter 3 should be used as a basis for an overarching plan on which watersheds should have integrated, segregated, or no hatchery facilities. These concepts should bridge over to a comprehensive strategy for evaluating integrated vs. segregated in the SSMP. In other words, too much leeway could lead to essentially "business as usual" and less rebuilding of wild stocks.

Sections 4.6 and 4.7 provide good discussion of tradeoffs among habitat, harvest, hatchery abundance, and fitness, but are largely conceptual in nature; there are no specific recommendations in Chapter 4 to guide the SSMP. Likewise, little of the technical basis for considering management trade-offs described in Sections 4.6 and 4.7 have been included in the SSMP. The only instance where reference was made in the SSMP to these concepts is in the Artificial Production Section under, Action Item 5 (Integrated) c: "*Evaluate the PNI and the effect of annual variations in wild stock abundance, potential range of changes in productivity of wild spawners, and demographic risks and benefits. Where risks are shown to be inconsistent with watershed goals, modify the size, fish culture practices, release strategy, or other characteristics of the program, reduce fishery harvest rates on wild-origin steelhead and increase fishery harvest rates on hatchery-origin steelhead, and/or enhance the productivity of the natural habitat*." (SSMP. p. 21). Although this provides general guidance to "evaluate", there is no guidance provided in the SSMP (or in the *O mykiss* Report) on how, when, or how often.

Section 4.7 of the *O mykiss* Report also lacks a solid basis for scientific review. It states that the process reported "*relies primarily on a model that incorporates population dynamics for adults spawning in the hatchery and natural spawning areas (specify a and b parameters of a Beverton-Holt stock-recruit function), population fitness, and rules that prescribe the artificial production and harvest management actions that will be taken under alternative resource conditions*." (*O mykiss* Report, Chapter 4, p.35-36). However, we found no reference to, or documentation for, the model used in Section 4.7. The model should be supported by scientific documentation and some indication that it is backed by peer-reviewed, best available science. A more detailed discussion of the model or a reference to the source publication for the model is essential for understanding the results presented in Section 4.7.

Literature Cited

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