Summer and Winter Steelhead in the Upper Willamette Basin: Current Knowledge, Data Needs, and Recommendations

Final Report to:

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Table of Contents

Summary

1) Large numbers of hatchery-produced steelhead *Oncorhynchus mykiss* smolts have been shown to negatively affect native conspecifics under some circumstances through density-dependent effects. The characteristics and importance of these effects are currently unknown for upper-basin Willamette steelhead.

2) Hypothesized effects of hatchery released summer steelhead smolts on native winter steelhead include: direct competition for food, displacement from preferred habitats, indirect predation effects, reduced physiological condition, changes in migration timing, and disease transmission and susceptibility.

3) Current data on hatchery steelhead smolt releases include the dates, numbers, approximate size, location, and method (e.g. forced or volitional). Additional data needs from the hatchery program are primarily the rates of river entry when volitionally released, estimates of proportional residualism, and final disposition of residual hatchery fish (retained and diverted to a terminal water body or other). Additionally, disease load and physiological condition influence steelhead behavior, but have not been quantified. In some cases, the introduction of additional pathogens into streams by released steelhead may be of greater concern than any direct effects.

4) Requirements for understanding interaction effects of summer (non-native) smolts on native steelhead include: a) reach scale habitat-specific density estimates of both hatchery and wild smolts and juveniles, and residual hatchery steelhead, b) tracking of both hatchery and native smolts to estimate both spatial distribution and movement downstream, c) diet comparisons of both hatchery smolts and native juveniles and smolts, d) relative physiological condition of both native and hatchery steelhead before and after release, e) comparative behavioral observations of both native and hatchery smolts, f) potential for lateral disease transmission.

5) **Summary conclusions**: a) among the few studies that have examined performance indicators (e.g. straying, return rates, physiological condition) between steelhead released volitionally, forced, or directly, no significant differences among release strategies have been identified; b) currently, disease transmission from hatchery steelhead to wild steelhead is not an identified concern in the upper Willamette basin, and c) currently there is no evidence that density-dependent effects are operative between hatchery and wild steelhead in the upper Willamette basin, although data are extremely limited.

6) **Recommendations**: a) increase ongoing monitoring efforts (e.g. seining and snorkel surveys) in areas where juvenile steelhead could be expected to rear; b) complete genetic analysis of both summer (marked) and winter (unmarked) outmigrating steelhead smolts to estimate both the extent of genetic introgression (ongoing), and production by hatchery adults on natural spawning grounds; and c) monitor out-migration of steelhead smolts by enhancing monitoring capability in the mainstem Willamette, or by developing index sections on sub-basin tributaries.

Introduction

The rationale behind a comprehensive review of the summer steelhead (*Oncorhynchus mykiss*) hatchery program is similar to that described for Willamette spring Chinook salmon *O. tshawytscha* (Johnson and Friesen 2010), with the exception that in this case intraspecific effects among out-migrating (released) hatchery summer steelhead and wild winter steelhead are of particular concern. This report primarily addresses the possible effects of hatchery-produced smolts on native juvenile steelhead. Other important issues involving adult steelhead and genetic introgression are considered separately in an expanded form (Keefer and Caudill 2010), which addresses the following subjects with respect to upper Willamette basin steelhead.

- Historical distribution
- Introductions of early winter and summer (extra-basin) steelhead stocks
- Hypothesized effects of competition among adults and among smolts
- Introgression effects from hatchery introductions on the fitness of winter steelhead
- Population trends in the upper Willamette basin
- Reasons for overall declines in population abundance

History and Background

The upper Willamette River summer steelhead hatchery program was implemented in the late 1960s by the Oregon Department of Fish and Wildlife (ODFW) to provide an enhanced sport fishery and to mitigate for loss of native winter steelhead angling opportunities. There are a number of possible causes for the reduction in native winter steelhead population abundance, but the most compelling is loss of habitat in the basin. Approximately 70% of the historical upper Willamette winter steelhead spawning habitat is no longer available to the species either because of direct blockage to passage or habitat degradation (Steel et al. 2004, Sheer 2006).

Summer steelhead were first introduced in the South Santiam River by ODFW to mitigate for lost winter steelhead production in areas inundated by Foster and Green Peter reservoirs. The Skamania "summer" stock was used originally because the native winter steelhead spawn late in the spring making one-year smolt production impractical, and because the winter steelhead adults are generally present in the system when angling conditions are less attractive (ODFW 2004). The program was subsequently expanded to include annual smolt releases into other major tributaries of the Willamette basin including the North Santiam, McKenzie, and Middle Fork Willamette rivers.

The 2004 Hatchery Genetic Management Plan (HGMP) for upper Willamette summer steelhead includes the following Oregon Administrative Rules statement from ODFW (1998) intended in part to minimize impacts from introduced summer steelhead on native winter steelhead. Policies 3-6 are explicitly intended to minimize potential adverse effects of summer steelhead on native winter steelhead populations.

1. Summer steelhead shall be managed for production and harvest of hatchery fish. The Department shall monitor the run for possible natural production.

2. Summer steelhead smolts shall be released into streams that have suitable adult holding habitat throughout the summer and where adults will provide optimum recreational opportunity.

3. Summer steelhead in the South Santiam River shall be confined to releases at South Santiam hatchery to protect native winter steelhead production in the upper and lower South Santiam.

4. Summer steelhead in the North Santiam shall be released at or near Minto hatchery to protect native winter steelhead production in the North Santiam subbasin. No summer steelhead shall be released into Little North Fork Santiam River.

5. Only smolt-sized fish shall be released to minimize competition with native salmonids.

6. Brood stock shall be collected May through October to maintain broad run-timing while reducing overlap with the run timing of the native winter steelhead stock.

Approximately 602,500 steelhead smolts are produced annually from an extra-basin (Skamania 024) stock and released into the upper Willamette basin. Approximately 160,000 are released into the North Santiam River, 111,000 into the McKenzie River, 148,000 into the South Santiam River, 43,000 into the mainstem Willamette River at Eugene, and 140,500 into the Middle Fork Willamette River.

Current knowledge

Intraspecific effects associated with relative steelhead densities include direct competition, indirect predation effects (e.g. predator aggregation), lateral disease transmission, increased per capita pathologies resulting from various stressors, reduced per capita physical condition (as inferred from measures including lipid content, cortisol, ATPase, etc.) and changes in migration, movement, and displacement from preferred habitats.

Studies in other areas have not shown significant negative effects from hatchery steelhead on native steelhead, although effects may be latent and complex, making them difficult to test (McMichael et al. 2000, McLean et al. 2004, Reisenbichler 2004). Juvenile steelhead are territorial and intraspecific competition and agonistic behaviors can be strong in streams where they are rearing, in addition to responses to physical changes (Reeves et. al. 2009). In an analysis of adult steelhead returns, Kostow (2009) concluded that there were significant deleterious effects from hatchery introductions on native steelhead populations in specific examples where hatchery fish were present in high numbers. It is likely that relative density is a controlling factor in the importance of direct intraspecific interactions. These direct effects are typically difficult to quantify because the fish are difficult to systematically observe in native habitat and effect outcomes may be cumulative, infrequent, and subtle.

There are current records in digital form from at least 1977 describing the date, number and location of hatchery smolt releases in the upper Willamette basin, although not all records are complete. Hatchery releases are in three general forms: 1) *direct* release where fish are placed into a body of water manually, 2) *forced* release, where fish are pushed out of an impoundment, and 3) *volitional* release, where a gate is opened from a holding area and fish are allowed to enter the river under their own volition over a period of days to weeks. At the end of this period, fish remaining in the holding facility are either forced out into the river or assumed to be expressing a residual life history form and are diverted to other purposes (generally, release into non-flowing waters with no potential for anadromous life histories). For some analyses, historical records are critically important. However, because there have been major physical and biological changes in the upper Willamette basin over relatively short time scales, historical data may be of limited use with respect to current management strategies; in short, there is a rapidly shifting baseline. This report is primarily concerned with forced and volitional release strategies, since this is in general the current practice, and in areas where direct contact at high densities with wild steelhead is most likely.

Winter steelhead are native to the upper Willamette basin and are currently considered threatened with extinction under the Federal Endangered Species Act (NMFS 1999). One potential risk to native steelhead populations is from the effects of relatively large numbers of hatchery steelhead entering the river system. Potential effects include competition for food and space (including agonistic interactions from territorial defense) and the forced migration or downstream displacement of native steelhead that would not have otherwise migrated at that time.

The following statements on the current status and recommendations for improving hatchery operations with respect to Willamette steelhead are from the most recent draft report of the ODFW *Willamette Steelhead Workgroup*.

Excerpted from the 'Willamette Steelhead Workgroup' report

2000 NMFS BiOp

In 2000 NMFS issued a BiOp (NMFS 2000) on the impacts of the Willamette hatchery program on the upper Willamette spring Chinook ESU and winter steelhead DPS. Because hatchery summer steelhead are introduced fish they have the potential to interact negatively with Upper Willamette River (UWR) spring Chinook and UWR winter steelhead. The 2000 BiOp required the U.S. Army Corps of Engineers (USACE) to collect information and conduct studies to describe the nature and extent of these potential effects. Some of the information collected described incidental catch of ESA-listed species during the summer steelhead recreational fisheries; incidence of summer steelhead spawning in the wild; and predation by summer steelhead smolts on juvenile UWR spring Chinook. Results of these studies are discussed in the 2007 Supplemental BA and described in several ODFW reports (Firman et al. 2005; Schroeder et al. 2006). In summary, it was determined that:

1. approximately 10%-30% of all summer steelhead passing Willamette Falls spawn naturally
2. summer steelhead spawn in the same areas used by ESA-listed winter steelhead;
3. summer steelhead smolts likely consume juvenile UWR spring Chinook salmon; and
 some naturally produced summer steelhead smolts successfully out-migrate in the McKenzie Basin.

2007 Supplemental BA

In 2007 the Action Agencies prepared a Supplemental BA (USACE 2007) for the continued operation of the Willamette Project, as required under Section 7 of the ESA. Specifically the Supplemental BA proposed the following actions with regard to the summer steelhead hatchery program:

- Continue current operations, production schedules, and releases as described in the draft Upper Willamette Summer Steelhead HGMP and summarized in Section 3.4.10.3 of the Supplemental BA. However, the Action Agencies propose to work with ODFW and the FPHM Committee of WATER to develop potential changes in the release strategies, or production levels that could reduce impacts of the summer steelhead program on wild winter steelhead, such as scatter-planting smolts to increase harvest opportunities.

- To the extent feasible (given infrastructure constraints), remove "non-migrants" from hatchery release groups to reduce residualism of fish that do not volitionally emigrate and potentially reduce adverse interactions with rearing winter steelhead.

- Beginning no later than 2008, scale back summer steelhead recycling efforts in the North Santiam Basin where the potential for adverse interactions with ESA-listed UWR winter steelhead are most significant.
    - Incorporate recycling protocol into the North Santiam/Minto Pond FPMP.

- Assess the recycling program in the South Santiam basin to determine the extent to which early cessation of the recycling program would alleviate impacts to winter steelhead populations and impact fishery opportunities.
    - Incorporate current protocol for recycling into the South Santiam/Foster Dam FPMP.
    - Incorporate any changes in recycling protocol into the FPMP and implement changes beginning in 2009.

- Conduct short-term RM&E (in collaboration with other funding entities) to further define effects of the Upper Willamette Summer Steelhead Program on ESA-listed species. RM&E activities will focus on the following objectives:
    - Determine the extent of natural production of summer steelhead (potentially by collecting genetic sampled from juvenile steelhead).
    - Determine the extent to which juvenile summer steelhead and winter steelhead compete for resources, and ultimately determine if naturally produced summer steelhead are impacting productivity of winter steelhead.
    - Continue monitoring returns of summer steelhead and the incidence of summer steelhead spawning in the wild.
    - RM&E activities will be incorporated into the overall RM&E plan.

- Form an interagency Summer Steelhead Working Group (as a subgroup of the WATER FPHM Team) to discuss options for long-term management of the summer steelhead program in light of ESA requirements and harvest goals. The group should seek input from non-governmental entities, such as sport fishing groups, and contain representation from other funding entities. This effort should also be informed by the Columbia Basin Hatchery Reform Project and other efforts. The Summer Steelhead Working Group will, among other things:
    - Discuss the feasibility of implementing changes to the program as identified in the HGMP;
    - Review results from the Columbia Basin Hatchery Reform Project;
    - Review additional RM&E results that will inform priorities for shifts in management;
    - Prioritize implementation of hatchery reform actions;
    - Strive to develop a reform implementation plan that all funding entities agree to implement. If the entities cannot agree, then the USACE will propose reform actions for its portion of the production to meet NMFS BiOp requirements and potentially reinitiate consultation.

- The Action Agencies will begin programming funding for hatchery reform efforts according to the implementation plan and implement actions as fund become available.

2008 NMFS BiOp

In 2008 NMFS issued a Biological Opinion (NMFS 2008) on the continued operation of the Willamette Project, which included a reasonable and prudent alternative (RPA) to the proposed action, since the BiOp concluded that the proposed action alone would jeopardize the continued existence of UWR Chinook salmon and UWR steelhead. The RPA contains a suite of actions that are required to be carried out by the Action Agencies in the areas of fish passage, water quality, flow, water contracts, habitat, and hatcheries. Several hatchery RPA actions (6.1.6, 6.1.7, 6.1.8, and 6.1.9) specifically targeted the summer steelhead hatchery program:

1. RPA 6.1.6 - Improve Summer Steelhead Release: The Action Agencies, in cooperation with ODFW, will improve the release of hatchery summer steelhead smolts by allowing volitional emigration from the point of release over an extended period of time (e.g. 2-4 weeks) with any non-migrants being removed and not released into free flowing waters below the Projects, to extent possible given constraints on the current infrastructure. When the facilities are reconstructed, the Action Agencies will ensure that any new acclimation facilities allow for this operation.

2. RPA 6.1.7 - Reduce Summer Steelhead Recycling in the Santiam Basin: The Action Agencies, in cooperation with ODFW, will stop recycling adult summer steelhead for fishery harvest purposes by September 1st of each year in the North Santiam and South Santiam rivers. The Action Agencies will continue to operate fish collection traps on a weekly basis through October 15th in order to maximize the collection of summer steelhead, to the extent possible with the current facilities. These fish will then be held at the hatchery for spawning, unless determined otherwise by the FPHM committee.

3. RPA 6.1.8 - Adjust Releases of Summer Steelhead in the Santiam Basin: The Action Agencies, in cooperation with ODFW, will reduce the hatchery summer steelhead release in the North Santiam River to 125,000 smolts. To offset this reduction, summer steelhead releases may be increased in one or more of the following subbasins: South Santiam, McKenzie, and Middle Fork Willamette (up to a total of 36,000 fish) to maintain the existing hatchery mitigation in the Willamette Basin. The revised HGMP for summer steelhead will identify how these production changes will be allocated among the different rivers.

4. RPA 6.1.9 - Future Summer Steelhead Management Actions: The Action Agencies, in cooperation with ODFW, will implement future management actions aimed at reducing the impacts of the summer steelhead hatchery program on ESA-listed species. These actions will be developed according to the process described in section 3.4.10.2 of the Supplemental BA (USACE 2007), which called for the formation of an interagency Summer Steelhead Working Group (as described above), and will incorporate the results of research, monitoring, and evaluation.

In addition, RPA 9.5.2 called for several RM&E actions to evaluate the effects of spawning hatchery steelhead in the wild and to determine whether interbreeding between hatchery and wild fish is occurring. Hatchery RM&E activities will be incorporated into an overall Willamette RM&E plan being developed by the USACE.

Current status of efforts to improve the summer steelhead hatchery program

To date, the following changes to the summer steelhead hatchery program have been implemented, or are planned for implementation in the near term:

<u>Angling regulations</u>

1. Change existing regulations to allow harvest of fin-clipped trout in North and South Santiam rivers. These regulations went into effect on January 1, 2009.

2. Allow harvest of unmarked summer steelhead in the McKenzie and Middle Fork Willamette rivers. This regulation went into effect on January 1, 2009.

<u>Hatchery management</u>

1. Implement a true volitional release of summer steelhead over an extended period of time (e.g. 2-4 weeks) and remove any non-migrants (implemented in 2008).

2. Reduce the hatchery summer steelhead release in the North Santiam River to 125,000 smolts and increase summer steelhead releases in one or more of the following subbasins: South Santiam, McKenzie, and Middle Fork Willamette (up to a total of 36,000 fish) to maintain the existing hatchery mitigation in the Willamette basin. This is particularly important given the fact that the Minto fish collection facility will be out of commission for at least two years while a new trap is being constructed. The change in releases was implemented in 2010.

3. Stop recycling adult summer steelhead by September 1st in the North and South Santiam rivers.

4. Do not allow passage of summer steelhead above Leaburg Dam beginning in 2012. The purpose of this action is to reduce interactions with Chinook salmon and reduce disease concerns at Leaburg Hatchery.

Upper Willamette winter (wild) – summer (hatchery) steelhead smolt interaction effects

Currently there are very few data from the upper Willamette River that describe interactions between wild and hatchery steelhead smolts. Moreover, documentation of changing hatchery practices, which have involved releases of non-native stocks at various juvenile stages, has not always been complete. The primary identified source of risk to wild steelhead populations is with respect to loss of habitat from either direct blockage or habitat degradation, and landscape features such as alluvium, gradient, landslide history, forest age, etc. can be used in landscape models to accurately predict the density of potential steelhead redds in the upper Willamette basin (Steel et al. 2004). Additional habitat can be created in areas with high potential, as indicated by these models, through direct restoration and passage into currently blocked stream sections. With additional actions the amount of available habitat could increase substantially.

Since density is defined as a relationship between area and abundance, by increasing the area available to winter steelhead, any density-dependent effects could be further alleviated. There are currently few data describing how hatchery-released steelhead use different habitats during out-migration. Information on post-release residualism or emigration rates is also lacking. Preliminary data suggest that while out-migration of steelhead smolts at Willamette Falls overlaps, marked and un-marked fish are not synchronous. Additionally, the general appearance with respect to length and weight relationships between hatchery and naturally-produced steelhead is far more similar than for out-migrating juvenile Chinook salmon (ODFW, unpublished data).

Wild – hatchery steelhead interaction effects (all regions, all life history stages)

Intracohort interactions between wild and hatchery steelhead have been widely studied, even by comparison to other salmonid species. In general, large numbers of hatchery steelhead of all life history stages have a potential negative effect on wild steelhead adults and juveniles. Kostow (2006) demonstrated that in the Clackamas River, large numbers of hatchery smolts significantly reduced the production of wild steelhead. The specific mechanisms are not well understood. A tracking and comparative physiology study found significant differences in physiological condition with respect to saltwater tolerance and resilience after challenge, but did not detect displacement of wild fish by hatchery smolts from preferred habitats (Hill et al. 2006). In addition to physiological factors involving osmoregulation, a difference in brain structure between wild and hatchery rainbow trout has been identified and is hypothesized as a mechanism for reducing at-large survival of hatchery fish relative to wild counterparts (Marchetti and Nevitt 2003).

Displacement from preferred habitats, or forced migration, of wild steelhead smolts by introduced hatchery smolts through agonistic interactions is a negative effect that has been shown to operate under certain conditions (Berejikian et al. 1996). However, the manifestation of negative effects is dependent on relative densities and resource abundance, both of which are highly variable. Additionally, hatchery fry have been shown to be more susceptible to predation and the same may be the case for smolts (Berejikian 1995). Tatara et al. (2008) found hatchery and wild fry to be comparable with respect to aggressiveness and territory size, after accounting for the effect of body length. However, hatchery fish may be larger than their wild counterparts in the upper Willamette basin (ODFW, unpublished data).

Wild – hatchery steelhead genetic introgression / differential selection effects

The specific mechanism(s) of genetic effects on wild steelhead populations from hatchery or hatchery-derived steelhead are currently unknown, but indirect evidence has consistently shown a negative effect on the population dynamics of wild fish. The effects of volitional vs. forced release of hatchery smolts are poorly understood, but forced release may, for unknown reasons, actually improve adult return rates (Evenson and Ewing 1992). This may be because of different selection pressures influencing predator avoidance behaviors (Wiese et al. 2008). With respect to genetic effects, naturally spawning hatchery steelhead have lower adult return rates than wild fish (Kostow 2003; Araki et al. 2010) and different selection pressures have been shown to rapidly produce different phenotypes between hatchery and wild fish (Waples 1991; Kostow 2004).

Recent research has been conducted to characterize the genetic structure of steelhead in the Willamette basin. Among unmarked steelhead smolts collected at Willamette Falls in 2009, approximately 8% were of summer (Skamania stock) origin; the remaining 92% were winter stocks found in the upper Willamette basin (Van Doornik and Teel 2010). There was no evidence of introgression between summer and winter steelhead. Currently, there is some doubt that summer steelhead are successfully spawning at biologically significant levels, but additional sampling and analysis is needed to adequately address this question.

General steelhead – direct competition, density-dependent effects, disease

Numerous studies have examined various forms of density-dependent mortality in steelhead. In general, negative effects from hatchery steelhead have been shown in other salmonids, but not wild steelhead (but see Kostow 2009). This is probably because of the way steelhead use space in streams. However, the magnitudes of any effects, either positive or negative, are highly dependent on relative density. Dietary overlap has been found to be significant between hatchery and wild juvenile steelhead (Simpson et al. 2009), suggesting that there is a potential for direct competition for food. However, evidence for strong direct interaction effects between hatchery and wild steelhead is lacking (McMichael et al. 1999; Mackey et al. 2001; Bohlin et al. 2002).

The hypothesized “carrying capacity” (defined here as the maximum sustainable number of organisms per unit area) with respect to steelhead is influenced primarily by a combination of food and space (Keeley 2000, 2001) and habitat complexity (Tinus and Reeves 2001). Weber and Fausch (2003) point out that most tests of competitive effects between hatchery and wild salmonids have not controlled properly for the effect of density relative to other variables. Empirical evidence for a realized competitive effect in either direction (in favor of either hatchery or wild steelhead) is currently lacking.

Disease (manifestation of pathology) has been shown to be related to a variety of environmental (e.g. temperature) and behavioral (e.g. territorial defense) stressors (Tinus and Reeves 2001). Anecdotal evidence suggests that hatchery steelhead are more likely to show pathologies relative to wild counterparts. However, disease transmission exacerbated by a particular release strategy is not currently an identified concern in the upper Willamette basin (T. Amandi, ODFW, personal communication).

General salmonid wild – hatchery effects

In general, hatchery-derived salmonids have been demonstrated to have lower reproductive success, and cause other deleterious effects (e.g. predation) on wild counterparts (McMichael et al. 1997; Cooney and Brodeur 1998; Einum and Fleming 2001; Levin et al. 2001; Reinhardt et al. 2001; Levin and Williams 2002; Chilcote 2003; Brannon et al. 2004; Myers et al. 2004; Mobrand et al. 2005; Araki et al. 2007; Araki et al. 2008; Kostow 2009). But there is currently little direct evidence for density-mediated effects of hatchery steelhead on wild counterparts. There is, however, evidence for differential reproductive success between hatchery and wild steelhead; the reproductive success of hatchery-origin fish is consistently lower (McLean et al. 2004).

Data needs

Information about relative densities, behavior, movement, competitive effects, relative physiological condition, disease, predation and diet is currently lacking for both hatchery released and native steelhead at and below release sites in the upper Willamette basin. Additionally, it is necessary to complete the ongoing genetic analysis of summer and winter steelhead (see Van Doornik and Teel 2010).

Specific data needs with respect to hatchery releases include rates of river entry by volitionally released hatchery smolts. Additionally, estimates of residualism and final disposition of either late-migrating or residual fish have been inadequately recorded for what would be required to complete an analysis of those effects. For density-mediated effects to be understood, the distribution and movement patterns (i.e. habitat-specific densities) need to be known. This would require either an active tracking effort of both wild and hatchery-released steelhead smolts, or an intensive passive tracking effort with greater capacity for recapture (observation), or a combination of both.

Conclusions

Available data with respect to hatchery releases of steelhead smolts are currently adequate with respect to numbers and physical description of fish, date, and release location with the exception of rates of river entry during volitional release. While a volitional release may occur over a period of days or weeks there are currently no data describing the rates of fish entering the river through these release periods. Additionally, current estimates of residualism may be inadequate. If summer steelhead juveniles are found to co-occur with winter steelhead juveniles in rearing habitats, the question becomes: what proportion of summer to winter juveniles is acceptable without causing further risk? After controlling for other factors such as stocking densities and food availability (i.e., not limiting as shown by Marschall and Crowder 1995), densities of juvenile steelhead were shown to be inversely related to average mass by the exponent -0.74 within a relatively wide confidence interval (Keeley 2003). This finding indicates that steelhead are “self-thinning” through density-dependent processes. As a provisional guide, for example, if the number of summer steelhead juveniles does not exceed 75% of the native winter juveniles and the total number does not exceed a theoretical carrying capacity for juveniles in a particular habitat type (Grant and Kramer 1990), it may be assumed there is not current jeopardy. Current stocking of other steelhead stocks (e.g. Cape Cod rainbow, whether triploid or not) should also be considered in any analysis of potential effects.

The following statements on the current status and recommendations for improving hatchery operations with respect to Willamette steelhead release strategies suggest there may not currently be sufficient evidence of significant steelhead residualism, regardless of release strategy, to produce interactions between hatchery and wild fish (Cannon et al. 2010).

“One of the RPAs in the Willamette Project Biological Opinion is to improve summer steelhead releases by implementing volitional emigration of 2–4 weeks and removing non-migrants (RPA 6.1.6). The rationale and effect of this RPA is to reduce the percentage of residual hatchery steelhead. Because of concern about potential negative effects that residual hatchery steelhead may have on naturally produced salmonids, changes in release strategies have been implemented in several basins to reduce the number of residual fish. For example, non-migrant steelhead were retained in an acclimation pond in the Tucannon River following a volitional emigration period to reduce the number of residual steelhead in the river (Viola and Schuck 1995). In the Imnaha Basin, the density of residual hatchery summer steelhead at index sites close to release locations was generally higher than wild steelhead juveniles, but was lower in the Grande Ronde Basin (e.g., Flesher et al. 2009). Steelhead that remained in acclimation ponds in the Tucannon River were predominantly male (4:1 ratio of males to females) and were a mix of transitional, parr, and precocious male stages (Viola and Schuck 1995). Residual hatchery steelhead captured in the Imnaha and Grande Ronde basins were largely male (Flesher et al. 2005, 2009). The level of precocious males in WDFW hatcheries have been 1–5% (Tipping et al. 2003).

We compiled data collected during seining for spring Chinook salmon to assess the relative abundance of residual hatchery steelhead. Sections of the Santiam Basin and Willamette and McKenzie rivers were sampled with beach seines in 2004–2009, one to three months after hatchery steelhead were released. Sampling in the North Santiam extended upstream to Mehama, but was more extensive downstream of Stayton. In the South Santiam, sampling extended to Pleasant Valley Bridge but was more extensive downstream of Lebanon. Sampling in the McKenzie began at Leaburg Dam but was more extensive downstream of Hendricks Bridge.

The catch of hatchery steelhead was very low throughout the Willamette Basin, as was the catch of naturally produced steelhead (Table 1). We used a smolt-like appearance to identify steelhead and an adipose fin clip to differentiate hatchery fish from naturally produced fish. The relative catch of juvenile steelhead (fish per seine set) was much lower than that of rainbow trout in all areas except the Willamette River downstream of the Santiam confluence (Figure 1). Salmonids classified as rainbow trout included adult and juvenile fish, and among the juvenile fish some were likely naturally produced steelhead that would smolt the following spring or later. Fish classified as trout were generally too small to be accurately identified as rainbow trout or cutthroat trout, and in the North Santiam, upper Willamette, and McKenzie rivers, these fish were more abundant than juvenile steelhead.

These data suggest that the presence of residual hatchery steelhead is limited in the areas and time of year we sampled. Therefore, the underlying rationale RPA 6.1.6 may not be valid, and effect of implementing this RPA may not yield expected benefits.

A potential negative effect of implementing a strategy to release only volitional migrants into free-flowing water downstream of Willamette projects and putting remaining fish elsewhere is a reduction in adult returns. In addition, the cost of implementing the proposed release strategy may outweigh the benefits. One study comparing adult returns of volitionally migrating and forced (after five weeks) non-migrating steelhead showed no difference in adult returns between the two groups in four years and a significantly higher return of the forced released release in one year (Tipping 2006). Although releases of forced non migrating steelhead from Winthrop National Fish Hatchery did not migrate or survive as well within the Columbia River as either the volitional or forced released groups, no difference in adult returns was reported between volitional and forced release strategies (Gale et al. 2009). Other studies have shown that steelhead from forced releases return better than fish from volitional releases (Wagner 1968; Evenson and Ewing 1992). In Northeast Oregon, the return rate of steelhead from forced releases was slightly higher than for volitional releases for the May release groups, but the April release groups showed no difference (data from Carmichael et al. 2005a, 2005b; Flesher et al. 2005, 2009; Gee et al. 2007).”

Table 1. Catch of trout in Willamette Basin beach seining samples, 2004–2009. Steelhead were those with smolt-like appearance, and an adipose fin clip was used to differentiate hatchery and naturally produced fish. Some rainbow trout juveniles could be juvenile (parr) steelhead (from Cannon et al. 2010).

						Steelhead		
Area, year	Start date	Sets	Rainbow trout	Cutthroat trout	Trout fry	naturally produced	hatchery	capture date[a]
North Santiam								
2004	Jun 29	25	108	2	64	0	0	
2005	Jul 12	18	159	8	155	0	0	
2006	Jun 8	145	820	14	189	0	0	
2007	Jun 4	272	508	6	144	1	18	Jun 25[b], 26
2008	Jul 2	138	396	14	415	2	0	
2009	Jun 8	178	1,006	26	25	0	0	
South Santiam								
2004	Jun 3	28	10	10	0	0	0	
2005	Jul 14	13	22	2	0	0	0	
2006	May 30	160	250	122	6	2	1	Jun 15
2007	Jun 11	121	101	27	6	5	2	Jun 19, 22
2008	Jul 2	169	9	17	1	0	0	
2009	May 27	138	87	23	0	0	0	
Santiam								
2004	Jun 1	22	17	3	0	0	0	
2005	Jun 6	34	39	6	0	1	0	
2006	May 25	94	61	28	1	2	1	Jun 19
2007	May 23	66	86	16	0	10	0	
2008	Jul 2	41	33	8	0	2	0	
2009	Jun 2	61	110	27	0	4	0	
Middle Willamette								
2004	May 26	61	5	1	0	0	0	
2005	May 25	53	7	0	0	0	0	
2006	Jun 13	39	0	1	0	0	2	Jun 14, 26
2007	May 16	90	3	0	0	9	4	May 16, 17, 31
2008	Jun 2	203	4	0	2	1	1	Jun 4
2009	May 4	217	14	5	11	2	0	
Upper Willamette								
2004	May 19	95	47	30	23	6	2	May 19
2005	May 26	156	55	284	23	14	1	Jun 13
2006	May 24	199	262	552	2	0	7	Jun 1, 15, 16, 21, 29
2007	May 14	197	191	471	22	1	3	Jun 14, Jul 18
2008	May 27	370	65	253	93	4	3	May 27, Jun 10, 17
2009	May 7	222	54	130	3	0	2	May 7, 18
McKenzie								
2004	May 20	88	69	165	24	4	0	
2005	Jun 9	110	130	287	7	0	0	
2006	Jun 6	195	441	346	5	0	0	
2007	Jun 19	153	321	269	62	0	10	Jun 27, Jul 9, 11, 16
2008	Jul 9	236	151	222	198	0	0	
2009	Jun 4	137	104	90	26	0	0	

[a] *Date(s) when hatchery steelhead were caught.*

[b] *17 of 18 hatchery steelhead were caught in one seine set on June 25.*

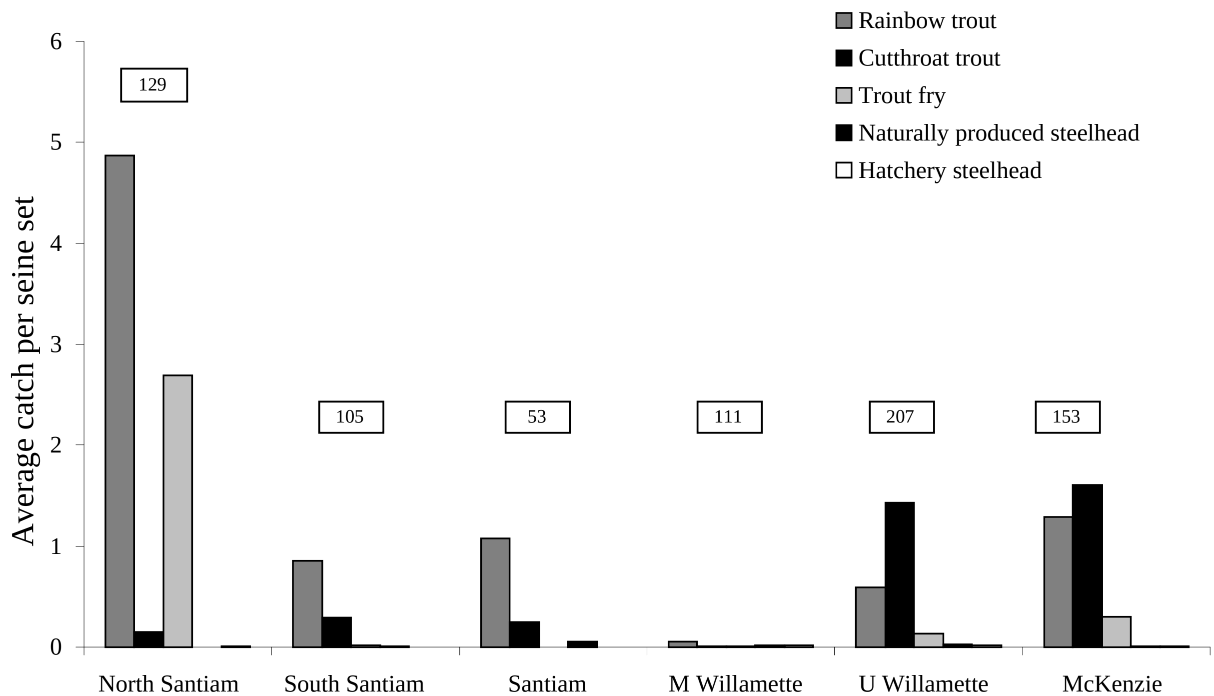

Figure 1. Average catch per seine set of trout in Willamette basin beach seining, 2004–2009. Numbers in boxes are the average number of seine sets in each sampling area (from Cannon et al. 2010).

Concepts such as carrying capacity (the hypothesized sustainable maximum density in a particular ecosystem) are often invoked to describe the potential effects of very large point introductions of hatchery fish to rivers and streams on native fish. However, these effects are poorly understood, as are the constituent factors of a particular carrying capacity. Measurable criteria need to be identified to quantify the relevant effects of such large introductions; these include relative habitat-specific densities in focal reaches, movement patterns, and relative conditions of native and hatchery fish before and after introduction. These criteria should be generalized among basins and specific values can be expected to vary widely with local conditions.

Any effects of hatchery released fish may be linear, or non-linear and density dependent. In this respect release strategies may require modification to reduce identified negative density-dependent effects. However, at this time neither the characteristics, nor the importance, of any hatchery smolt release effects on naturally-produced fish are known for upper Willamette steelhead.

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