# Appendix 4. Development Concepts for the Significant Decline Triggers and Early Warning Indicators

## Introduction

As part of the administration's review of the 2008 FCRPS BiOp (2008 BiOp), scientists suggested that a refinement of the 2008 BiOp's adaptive management and contingency planning processes could provide additional surety that the 2008 BiOp is implemented in a more precautionary fashion through 2018. Specifically, the scientists suggested that additional triggers be developed that would be sensitive to 1) unexpected declines in adult abundance and 2) environmental disasters or environmental degradation (either biological or environmental) in combination with preliminary abundance indicators. They further advised that these triggers should be based on simple metrics that are readily available.

In response to these recommendations the administration has decided to develop and implement triggers or indicators that, if tripped, would invoke appropriate contingency actions. These triggers and indicators represent refinements of the adaptive management and contingency planning processes in the 2007 Biological Assessment and 2008 BiOp. The Significant Decline Trigger will precipitate immediate implementation of Rapid Response Actions. The principle underlying the Significant Decline Trigger is that the conditions represented by this trigger would be significant deviations from the biological expectations in the 2008 BiOp and, if they were to persist despite the AMIP's short and long term contingency actions, could result in a reinitiation of consultation. The Early Warning Indicator will serve as an alert to focus more attention on potentially vulnerable listed species,[1] begin preparations for implementing Rapid Response Actions (if warranted), and determine whether the species in question is likely to decline to a level that would trip the significant decline trigger in 1 or 2 years.

A trigger or indicator should rapidly detect when a species falls to a dangerously low level and be easily interpretable and transparent. In addition, they should be developed to avoid erroneous conclusions. Once tripped, the responsive actions would be implemented and remain in effect until the precipitating condition (abundance has improved or the contributing environmental factors have improved) has passed or longer term Contingency Actions have been enacted (see AMIP).

The interim Significant Decline Trigger and Early Warning Indicator described in this document are based on four-year rolling averages of adult abundances of naturally produced fish (see data and graphics provided in the attachment). An additional trigger for assessing Significant Decline based on trends will be developed in 2010 in coordination with NOAA Fisheries, the Regional

[1] Salmon species are designates as Evolutionarily Significant Units (ESUs) and steelhead are designated as Distinct Population Segments (DPSs); however, for simplicity's sake, all of the listed ESUs or DPSs will be referred to in this document as species.

Implementation and Oversight Group (RIOG), and other regional parties. Longer-term Early Warning Indicators will also be developed in 2010 in coordination with these parties, which would rely on adult abundance and trends, but also utilize information relating to environmental conditions, significant catastrophic events, and potentially on juvenile parameters (e.g., abundance and body size).

It is important to remember that triggering the proposed Significant Decline Trigger within the term of the 2008 BiOp is not an expected or even likely outcome. Indeed, under the 2008 BiOp the abundance of the species on average are expected to increase over time. However, inclusion of these triggers as part of the 2008 BiOp's adaptive management and contingency implementation processes provides additional assurances that the2008 BiOp is implemented in a more precautionary fashion from the perspective of the ESA-listed salmon and steelhead species.

## Adult Triggers

A consideration in the development of triggers is how quickly the data will become available and the magnitude of sampling error associated with the data. In general, the most quickly available data that have relatively low sampling error is counts of adults, which are typically enumerated at dams. Unfortunately, these data can inform decisions at the species scale, but they do not typically discern among MPGs or populations. Population-level data have primarily been based on redd counts, which are less timely and more prone to sampling error. Accordingly, one of the main activities associated with the Early Warning Indicators is to provide additional resources to monitor more rigorously and quickly at the MPG and population level.

With a few exceptions, it will be difficult to monitor the status of MPGs, which are amalgamations of populations, of which only some are monitored. There is currently no mechanism in place to define which populations should be monitored to represent an MPG. Accordingly we do not present here a mechanism to define triggers at the MPG level. However, we recommend that establishing monitoring protocols at the MPG level should be considered for future RME. Once these protocols are established, we can apply similar techniques to MPGs as those applied to species in this document.

The triggers described below are based on adult abundance and trend estimates. One complication with this type of data is that salmon abundances are notorious for being highly variable (Paulsen et al. 2007), and thus short-term trends can be difficult to discern. Because of this, our abundance-based triggers are derived from four-year running averages, which smooth abundance time series (Holmes 2001). The choice of a four-year running average has several justifications and precedents. First, it approximately corresponds to the generation time of most salmon species in the interior Columbia River basin, and the International Union for Conservation of Nature (IUCN) recommends examining population declines over a time period representing one generation (Mace et al. 2008). Furthermore, the ICTRT risk assessments incorporated a quasi extinction threshold expressed in terms of a 4-year sum of abundance (ICTRT and Zabel 2008).

### *Significant Decline Trigger for Chinook Salmon & Steelhead*

The purpose of the Significant Decline Trigger is to detect significant declines in the abundance of listed species[2] so that rapid response actions can be implemented in a timely fashion to minimize or mitigate for an unforeseen downturn. Many salmon and steelhead populations experienced extremely low abundances in the 1980s and 1990s, and the triggers are designed to help head off future declines to these levels.  The interim Significant Decline Trigger is based on recent average abundance estimates of naturally produced fish at the species level.  Triggers based on a combination of abundance and trend will be developed in 2010 in coordination with the RIOG.  A combination trigger is desirable because salmon populations exhibit a significant amount of variability, and thus large increases in abundance are typically followed by declines, which can be heightened by density-dependent processes.  By combining a trend and abundance metric, the triggers will not be tripped in cases where declines have occurred, but the population or species is still at a relatively high abundance level.

Information is sufficient to suggest critical levels for the abundance component of the interim Significant Decline Trigger for Chinook salmon and steelhead,[3] based on frequencies of returns at various abundance levels observed in historic time series.  However, additional analysis is necessary before suggesting specific trigger points for trend estimates, so only limited examples of potential trend-based trigger points are described at this time.  We anticipate that, for both the abundance and trend components of the Significant Decline Trigger, additional analyses will be performed and, following review of new information and discussions with co-managers, the interim Significant Decline Trigger may be modified.

Short-term population abundance will be measured as a four-year running average.  Short-term trend will be measured with a metric such as the geometric mean of four consecutive years of relative abundance, where relative abundance is defined as the abundance in year $t$ divided by the abundance in year $t$-1.  The relative abundance metric has advantages for representing trend, compared to alternatives such as “four years in a row of decline,” because it protects against strings of declines interrupted by slight upturns that would mask the overall decline.

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[2] Species-level (i.e., ESU or DPS) adult abundance information is the most readily available information at present - excepting Mid-Columbia steelhead for which the Yakima River MPG data is most readily available.  Future refinements of the Significant Decline trigger could potentially be extended to the Major Population Group (MPG), management units (i.e., A-run vs. B-run Snake River steelhead), or key populations.

[3] The Administration does not propose any triggers for Snake River sockeye salmon at this time.  This species, after falling to extremely low levels in the early 1990s, is effectively managed under ongoing contingency actions at the present time. The contingency actions include continuation of the safety net hatchery program; further expansion of the sockeye program (up to 1 million fish released as smolts), investigation of the feasibility of transporting adults from Lower Granite Dam to Sawtooth Valley lakes or artificial production facilities; and investigation of highly variable juvenile mortality rates between Stanley Basin and Lower Granite Dam.

The trend and abundance metrics estimated during implementation of the 2008 BiOp will be compared to the distribution of these metrics represented by the historic data. In this way, the current year's value can be compared to the historic distribution to determine the proportion of historic years that the current value equals or exceeds, and the triggers will be based on these exceedence proportions.

Abundance Component of the Significant Decline Trigger

A quantitative description of the Significant Decline Trigger was developed, based on the following steps:

**Step 1:** ***Identify Available Data.*** For species level data, the proposed approach applies data (the estimated number of naturally produced adult Chinook Salmon[4] and steelhead passing a specific dam) generated by state and tribal co-managers for use in *US v. Oregon* Technical Advisory Committee (TAC) run reconstructions. Counts at Lower Granite Dam are used for Snake River species, counts at Priest Rapids or Rock Island dams are used for Upper Columbia River species and counts at Prosser Dam are used for the Yakima River MPG of Mid-Columbia River steelhead.[5] The available data varies by species within the 1975 to 2008 time frame. NOAA and the Action Agencies will further review the data used for the triggers assessments and develop a process for the regular sourcing, annual updating and public dissemination of the data used in the trigger determinations.

**Step 2:** ***Establish Distributions of Historical Abundances During the Time Periods Considered by the 2008 BiOp.*** The approach uses four-year rolling averages of abundances. Based on the historical period evaluated in the 2008 BiOp (approximately 1980 to present), the observed four-year rolling averages were sorted from high to low and plotted to create exceedence curves (cumulative density functions). These depict the percent of years in the data set in which the four-year rolling average was greater than a particular level. See Figure 1 for Chinook salmon species abundances and Figure 2 for steelhead species abundances.

[4] Chinook "Jacks" are excluded from this data as they are predominantly small males which return to spawn after spending only a single year in the ocean and generally represent a minor contribution to the viability of a population.

[5] Mid Columbia River steelhead populations pass 1-4 mainstem dams and cannot be distinguished at those dams from other listed species traveling further upstream. Prosser Dam is an adult counting site on the Yakima River that does provide a census of adults in this MPG. We acknowledge that the Yakima River MPG is a single MPG and may or may not be representative of the DPS as a whole and therefore this trigger will initiate a rapid review to determine whether the problem is limited to the MPG or represents a DPS-wide decline. In addition to the Yakima River MPG, it may be possible to develop MPG level indices for other MPGs in the relatively near future.

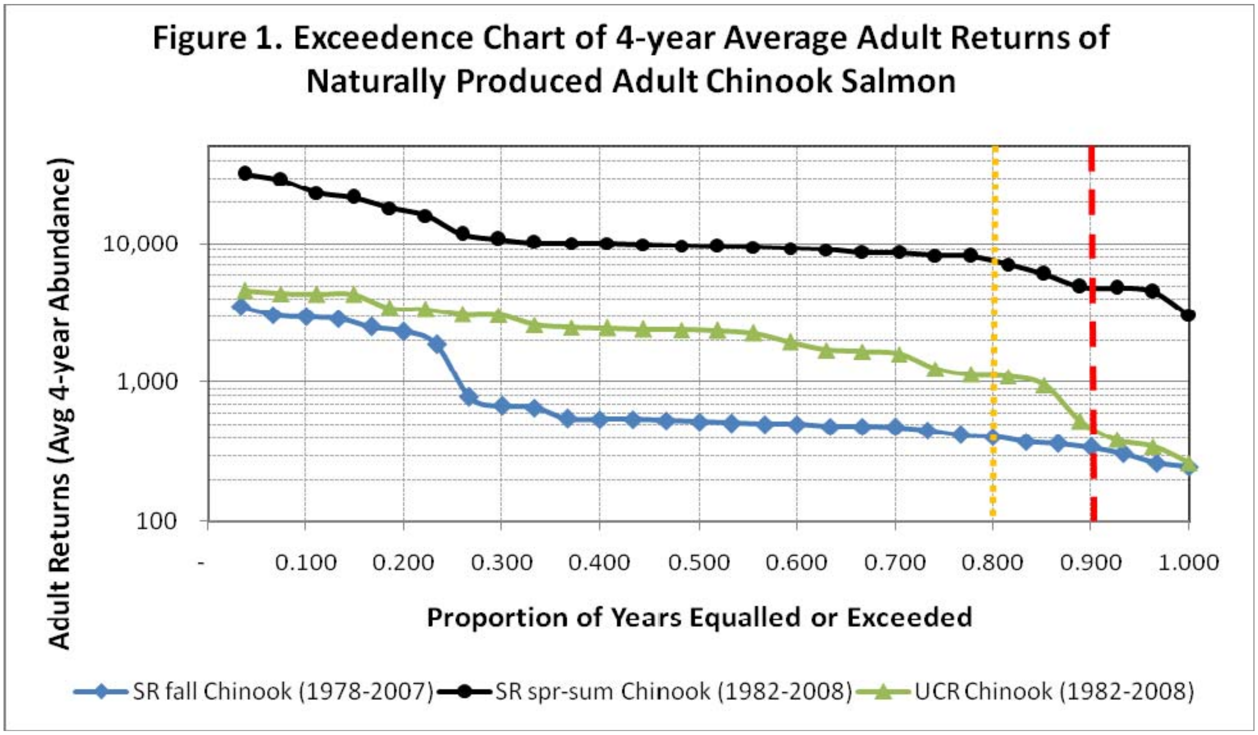

Figure 1. Exceedence Chart of 4-year Average Adult Returns of Naturally Produced Adult Chinook Salmon
Adult Returns (Avg 4-year Abundance)
10,000
1,000
100
-
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
Proportion of Years Equalled or Exceeded
SR fall Chinook (1978-2007)
SR spr-sum Chinook (1982-2008)
UCR Chinook (1982-2008)


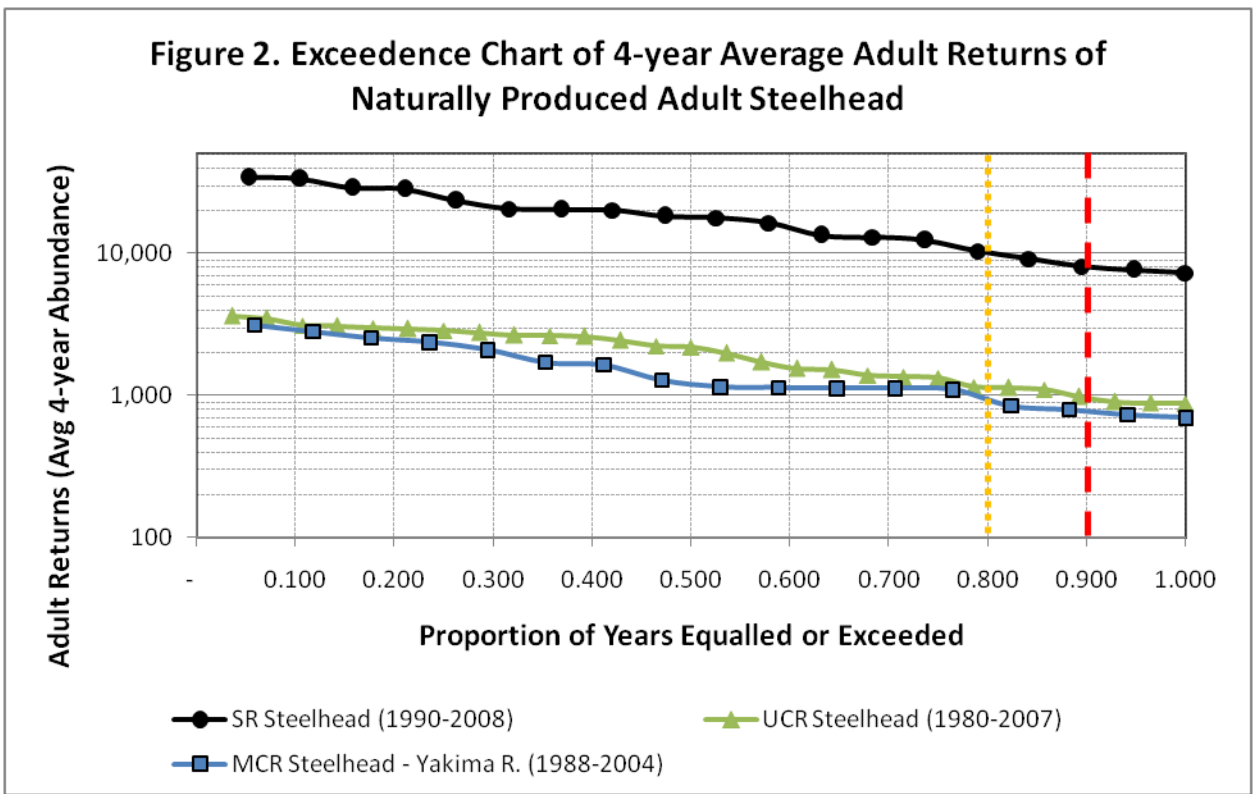

Figure 2. Exceedence Chart of 4-year Average Adult Returns of Naturally Produced Adult Steelhead
Adult Returns (Avg 4-year Abundance)
10,000
1,000
100
-
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
Proportion of Years Equalled or Exceeded
SR Steelhead (1990-2008)
UCR Steelhead (1980-2007)
MCR Steelhead - Yakima R. (1988-2004)

**Step 3:** ***Identify Abundance Levels That Were Not Expected in the 2008 BiOp.*** An examination of the resultant exceedence curves for Chinook salmon species abundances (Figure 1) indicate that, of the observed four-year average abundances, about 15-25% are relatively high, about 5-15% are relatively low, and the remainder are close to average, showing relatively little variation. The pattern is less clear for steelhead species abundances, whose distributions are more continuous (Figure 2).

**Step 4:** ***Specify the Triggers.*** For average abundance, we propose that the 90$^{th}$ percentile (dashed vertical line on Figures 1 and 2) be used as the trigger for implementing Rapid Response Actions (see AMIP); and the 80$^{th}$ percentile (dotted vertical line on Figures 1 and 2) be used as an Early Warning Indicator that would engage closer examination and potential readying of Rapid Response actions for more rapid implementation if the species(s) in question continue to decline.

The 90th percentile exceedence level of abundance was selected as a threshold level because this is a level below which mean four-year abundances for naturally produced Chinook salmon dropped rapidly (Figure 1). This level represents a marked departure from median abundance levels (especially for Chinook salmon), but is also somewhat above the lowest observed four-year period for both naturally produced Chinook salmon and steelhead (the 1990 levels that led to ESA listings). While falling to these levels is a cause for concern, they are more precautionary in that they represent species abundance that is at least 3-4 times higher than the abundance if all populations dropped to the 50 fish quasi-extinction threshold.

As an additional precaution, abundance at the 80$^{th}$ percentile will serve as an Early Warning Indicator requiring closer examination of the available data and the readying of Rapid Response actions for more rapid implementation if the species(s) in question continue to decline (see AMIP).

<u>Trend Component of the Significant Decline Trigger</u>

As described above, quantitative triggers have not yet been defined for the trend component of the Significant Decline Trigger, but will be developed in coordination with the RIOG in 2010. The trend metric will be one that is indicative of short term trend consistent with the timeframe used for the abundance metric. The same approach used for defining specific abundance triggers would also be used for defining a trend trigger. Steps 1-3, in particular, would be identical to those described above, except that a trend metric would be derived from the basic adult return data and exceedence curves would be based on the trend metric.

*Example of a Potential Trend Trigger:*

For illustrative purposes only, Figure 3 displays the percentile exceedence level for 4-year geometric means of relative abundance in the historical record for the naturally produced Snake River spring/summer Chinook species (the 90$^{th}$ percentile is represented by the dashed vertical line). If the 90th percentile exceedence threshold was adopted as a Significant Decline trend trigger, this figure indicates that four-year geometric mean relative abundances would be about 0.7. The geometric mean of 0.7 indicates a decline in abundance of about 76% ($1- 0.7^4$) from the start until the end of the four-year period. The additional use of the trend metric can result in triggers that are more precautionary than those based on abundance metrics alone. For example, in the case of SRSS Chinook in the 1990s, a 90% exceedence trend-based trigger would have been tripped two years earlier than the abundance trigger alone. In this case, the populations continued to decline to dangerously low levels, and the implementation of rapid response actions at that time as an extra precaution would have been beneficial.

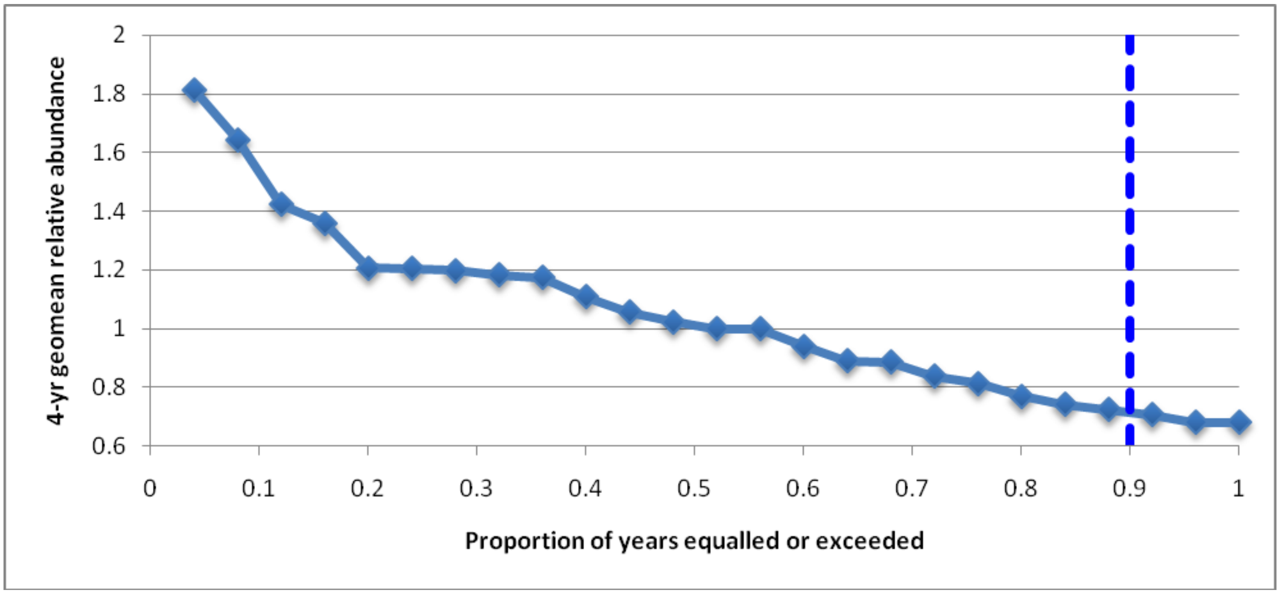


**Figure 3.** Example of exceedence chart for four-year geometric means of the relative abundance for naturally produced Snake River spring/summer Chinook salmon (vertical dashed line indicates the 90th percentile exceedence value).

<u>Potential Combination of Abundance and Trend Triggers</u>

Combinations of abundance and trend metrics can be used to further define Significant Decline and Early Warning Indicators. Figure 4 is a conceptual example of one method of combining the two types of metrics. In this example:

- the Significant Decline Trigger would be tripped if the abundance metric dropped to below the 90% percentile OR the trend metric dropped to below the 90% percentile <u>and</u> the abundance metric was below the 80% percentile; and

- the Early Warning Indicator would be tripped if the abundance metric dropped to below the 80% percentile OR the trend metric dropped to below the 90% percentile.

While other approaches are possible, this example demonstrates the types of considerations that are relevant to a combination of abundance and trend components of the Significant Decline Trigger.

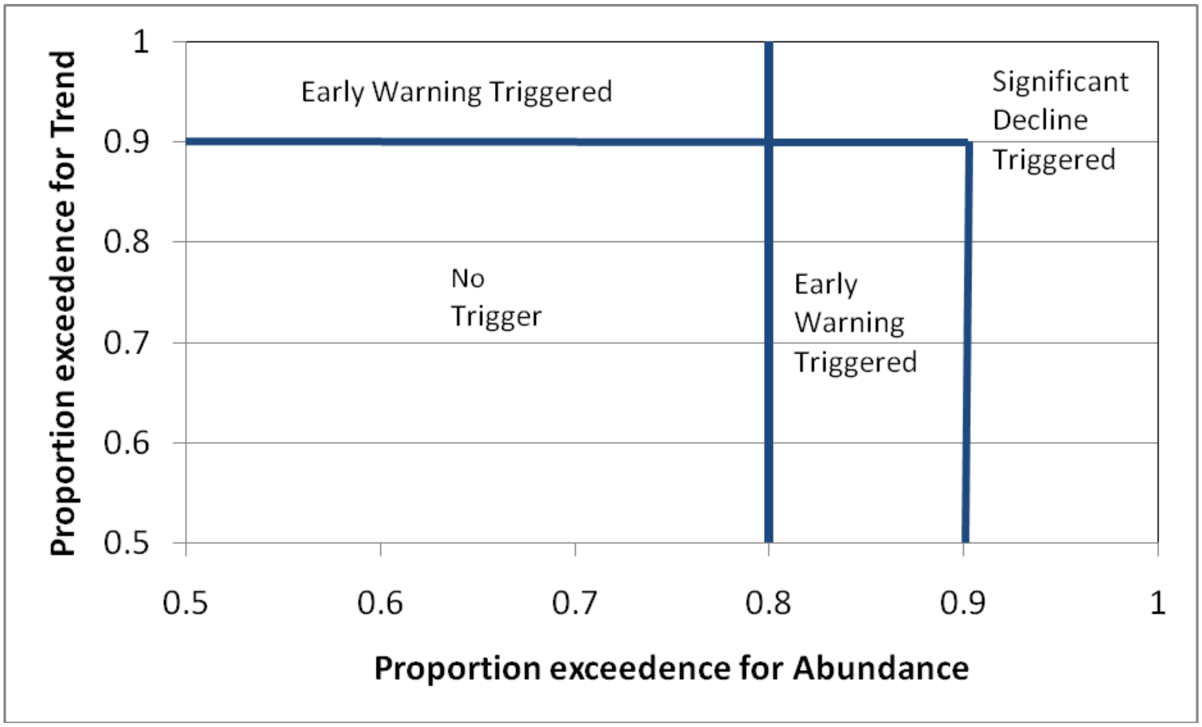


**Figure 4.** Example of Significant Decline and Early Warning Indicators based on combinations of 4-year running averages of abundance and a trend metric, such as 4-year geometric means of trend.

### *Early Warning Indicator for Chinook Salmon & Steelhead*

The purpose of the Early Warning Indicator is to detect factors indicating that the Significant Decline species[6] abundance levels are likely to be reached within one to two years so that rapid response actions can be implemented in a timely fashion to minimize or mitigate for an unforeseen downturn. It is intended to be a failsafe that could be triggered before the Significant Declines triggers are exceeded.

One Early Warning Indicators, based on 80$^{th}$ percentile values of four year average abundances of naturally produce adults, was described above. Additional Early Warning Indicators would also evaluate whether a species is likely to have substantially reduced abundance (and productivity) in the future, based on two years of adult return information, preliminary biological information and environmental indicators or known environmental disasters.  These indicators may included, but

[6] Species-level adult abundance information is the most readily available information at present. Where feasible, future refinements of the Early Warning Indicator could be informed by MPG or population level information.

are not limited to, low jack counts or juvenile migrants (biological), indicators of ocean conditions predicting very low abundance of adult returns for recent outmigrants (environmental indicators), or wide-spread forest fires, increased distribution and virulence of pathogens, new invasive species, prolonged severe droughts etc. (environmental disasters).

Initial assessments suggest that juvenile monitoring (numbers, sizes, condition, etc.) of interior Columbia River basin species (or MPGs or a subset of populations) at dams and in tributaries would likely provide information that could complement the adult monitoring information and further enhance the Early Warning Indicator in the future. Additional work will be required in order to inventory the current monitoring program, determine what additional monitoring might be needed, and assess how best to collect and use this information to inform the Early Warning Indicator at the species, MPG, or population scale.

Other than the 80th percentile average abundance trigger, specific Early Warning Indicators have not yet been defined. The Action Agencies and NOAA have committed to defining these triggers in 2010. Definition and implementation of the Early Warning Indicator would involve the following steps:

**Step 1:** Determine if the most recent two-year average of adult returns is near the threshold levels used for the Significant Decline Trigger (above).

**Step 2:** Determine if there are any biological or environmental indicators that would suggest that species are likely to experience low abundance in the next two or more years. This information could include, as an example, extremely low jack counts (a preliminary biological indicator that next year's returns will be much lower than average) and ocean indicators (both biological and environmental) that indicate that recent outmigrants are likely experiencing extremely poor ocean conditions that would be expected to result in substantially reduced numbers of naturally produced adults in the next two years.

**Step 3:** Assess whether there have been any "environmental disasters" such as wide-scale forest fires, volcanic eruptions, rapid increases in the distribution or virulence of fish pathogens, or mud-slides that would be likely to substantially reduce the productivity of freshwater habitat or severely limit the ability of adults or juveniles to migrate to or from this habitat. Responses to impacts affecting a specific MPG or subset of populations would be tailored to the appropriate scale.

After evaluating each of the factors in steps 1-3, a determination would need to be made as to whether or not there is a reasonable likelihood that future adult returns would fall to levels triggering the Significant Decline Trigger (see above) or the existing BA/BiOp trigger. If the determination is affirmative, then the Rapid Response Actions would be implemented.

### Summary of Interim Significant Decline Trigger and Early Warning Indicators

Table 1 summarizes the four-year average abundance levels of naturally produced fish corresponding to the 90th (Significant Decline Trigger) and 80th (Early Warning Indicator) percentiles (closest value or average of two nearest values rounded to the nearest 25 fish) in Figures 1 and 2.

**Table 1. Summary of Interim Species-Specific Significant Decline Trigger and Early Warning Indicator Metrics (Average 4-year Abundance of Naturally Produced Adults)[7].**

| Species | Significant Decline Trigger (90th Percentile Exceedence) | Early Warning Indicator (80th Percentile Exceedence) |
|---|---|---|
| SR fall Chinook | **350** | **400** |
| SR spring/summer Chinook | **4,850** | **7,575** |
| UCR spring Chinook | **450** | **1,125** |
| SR steelhead | **8,075** | **10,325** |
| UCR steelhead | **975** | **1,100** |
| MCR steelhead (Yakima R.) | **775** | **975** |

It is likely that during the early course of the 2008 BiOp, a species may exceed the Early Warning Indicator. This is not a function of the BiOp's conclusions, but rather the effect of variability in adult returns, the lag effect of some of the benefits of the RPA, and setting this indicator at a sufficiently high level so as to be sensitive to moderate trends or declines.

## *Consideration and Development of Future Juvenile Triggers*

The Action Agencies and NOAA Fisheries also will evaluate the potential for developing a future Significant Decline and Early Warning Indicator based on information regarding juvenile salmon and steelhead. This is a longer-term task because additional monitoring will be required to implement a juvenile trigger. Steps in the process of developing this trigger and some of the properties of a useful juvenile trigger are described below.

Establish a juvenile monitoring program for Interior Columbia basin species could provide information relevant to future Significant Decline or Early Warning Indicators with respect to changes in juvenile production or survival at the species, major population group, or population level. In addition to abundance based metrics, the program would monitor changes in parr/smolt size or timing that might translate into changes in cumulative life cycle survival or productivity.

[7] As noted above, NOAA and the Action Agencies will further review the data used for the triggers assessments and develop a process for the regular sourcing, annual updating and public dissemination of the data used in the trigger determinations.

Development of Future Juvenile Triggers

Future juvenile outmigrant metrics would complement adult based measures and should provide an early opportunity to detect patterns or trends than adult based approaches that might otherwise be masked by the relatively high year to year variation in ocean survival rates typical of salmon runs. The primary objectives for a juvenile monitoring program would be to:

- Enable detection of within species (specific to particular MPGs, populations, major life history groupings) sudden downturns in natural production levels.

- Complement environmental measures, jack return metrics etc. to detect sudden downturns in abundance at the species/MPG level.

- Detect changes in size, timing other condition factors that could be early warning signs of regional environmental impacts (e.g., local or sub regional climate change impacts, etc.)

The approach would incorporate at least three types of juvenile monitoring efforts. At the species or major population group level, the monitoring framework would incorporate estimates of aggregate juvenile abundance or productivity generated through updated sampling programs targeting the aggregate wild run from a species or MPG (e.g., Lower Granite Dam smolt sampling, Rock Island Dam juvenile sampling, Prosser Dam outmigrant monitoring in the lower Yakima River. Sampling programs designed to estimate juvenile production from a specific tributary would also be included (e.g., Grande Ronde River sampling programs, Yanke et al, 2007). A third major program component would include out-migrant marking/downstream monitoring designed to collect information on the timing/size of migration from a given reach (e.g., Achord, et al. 2007). The tributary production and out-migrant evaluation programs generate information on the size and timing of annual outmigrants. The size individuals attain during the juvenile life stage has direct consequences for fitness through size-selective mortality in later life stages (e.g., Zabel and Williams 2002) and enhanced reproductive success of larger individuals (Kingsolver & Huey 2008). Further, migration timing is related to growth, with larger individuals within a population out-migrating earlier than smaller ones (Achord et al. 2007). Thus, juvenile fish size is an indicator of habitat quality, particularly for higher elevation, lower nutrient streams found in the interior Columbia River basin. Deviation from long-term average fish size is potentially an indicator of deterioration in conditions related to juvenile fish growth.

Monitoring fish size at a specific time in the season can provide several benefits:

1) A general indication of the fish and habitat status.

2) An early indication that habitat conditions have changed for the worse and further actions are required.

3) An indication of whether habitat actions are effective.

Each population has different growth patterns, and thus annual measures of fish size should be compared to long-term patterns for the population.

A number of years of monitoring will likely be necessary before sufficient baseline information is gathered to enable us to develop juvenile triggers. Ultimately, annual results from a structured juvenile monitoring program could serve as inputs into early warning assessments. Life cycle assessment tools would incorporate results from annual juvenile modeling along with environmental indices and recent adult return data to generate probability based projections of near term risks (see *Life Cycle Modeling* attachment). A second general application would be to detect or confirm changes in production among populations within species. For example, patterns in smolt per spawner or population size characteristics could indicate impacts of changing climate conditions or the effects of local changes in habitat conditions, etc.

<u>Implementation of Future Juvenile Triggers</u>

As a first step, ongoing juvenile monitoring efforts will be inventoried and evaluated as potential contributors to the annual juvenile trigger program. Some of these metrics have been employed for past evaluations or could be implemented with information from ongoing studies. Those metrics would be verified and updated for application beginning with the 2010 out-migration.

This step would also include defining explicit technical guidelines for metrics and triggers considering each of the categories of juvenile monitoring listed above. The trigger guidelines for juvenile monitoring would include an evaluation of alternative criteria applicable to each category. For example, annual indices of total natural origin smolt production from a given region that are generated from an effort with a relatively long historical series might incorporate a trigger based on a statistical analysis of the time series or on stochastic modeling. The same general approach could also be used to define specific criteria based on the size distribution of migrants or on timing metrics. Smolt per spawner metrics could be evaluated against minimums based on past performance or estimates generated by stochastic population modeling.

The inventory of current juvenile monitoring activities would also be a starting point for identifying opportunities for expanding on the initial set to ensure appropriate coverage at least at the major population group level across each species in the Columbia River basin. The review would be used to identify additional monitoring sites or metrics for implementation, specifically identifying opportunities that could begin to generate information prior to 2013 status/implementation check-in called for in the 2008 BiOp. Selecting and implementing additional monitoring actions for the program could be carried out in conjunction with the ongoing process to develop annual population level fish-in fish-out monitoring (described in accompanying attachment *Fish In/Fish Out monitoring support to 2008 BiOp contingency planning).* The guidelines for Early Warning Indicator metrics and criteria will inform the design and selection of additional monitoring actions through that effort.