Tributary Assessment for Potential Chinook Salmon Rearing Habitat and Recommendations for Prioritizing Habitat Protection and Restoration

Ed Connor and Erin Lowery, Seattle City Light
Devin Smith and Kate Ramsden, Skagit River System Cooperative
Brett Barkdull and Bob Warinner, Washington Department of Fish and Wildlife
Rick Hartson, Upper Skagit Indian Tribe
Richard Brocksmith, Skagit Watershed Council

February 4, 2015 – FINAL DRAFT

We developed several alternative assessment and modeling approaches for identifying, estimating and ranking tributaries in the Skagit River basin according to their intrinsic ability to support Chinook salmon rearing habitat, which is the major habitat limiting factor for abundance and productivity (Zimmerman et al. in press). We relied on spawner abundance observations and modeled potential as screening tools given the relationship of spawning and rearing areas as well as data availability and quality relative to limited rearing habitat data. This effort focused on intrinsic habitat potential as opposed to current conditions in an effort to assess the future potential for stream habitat restoration and protection. Recommendations are made for incorporating these tributaries into the Tier 2 Target Area in the Skagit Watershed Council 2010 Strategic Approach.

Multiple Regression Approach using Spawner Abundance

The first method is a multiple regression approach that predicts the number of spawners in Skagit tributaries based upon several key watershed variables. Out of the watershed variables previously identified, a couple were "no brainers" because they made biological sense. First among these was drainage area, since Chinook are big fish and thus more spawners should be found in larger streams. The second was length of the channel accessible to spawning Chinook, since a longer channel should support more fish. One of the first "rules of thumb" to developing a meaningful regression analysis is to first include those variables that make the most sense for biological reasons. We removed three statistical outliers flagged by the statistics program during the analysis: Nookachamps Creek, North Fork Sauk, and Goodell Creek. These streams were clearly outliers in looking at the spawner number versus drainage area graph. The resulting multiple regression with just two "no brainer" variables, drainage area and channel length, explains 82% of the variability in Chinook spawner abundance among the tributaries with a high level of statistical significance (RSQ = 0.82; $p < 0.001$). We could easily get by with these two variables alone.

We then tried adding some more watershed variables to see if this already good regression relationship could be improved. Two additional variables were added based upon their significance in the regression (variable p-value < 0.05): forest canopy cover and mean basin slope. Adding these two variables to the previous two variables resulted in a regression model that had the lowest Akaike Information Criterion (AIC) score of all the regression models (different combinations of variables) considered. The AIC is a metric commonly used to select the "best" regression model based upon the amount of information explained by the model, with a lower AIC score explaining more information. A regression equation including four variables – drainage area, channel length, forest canopy cover, and mean basin slope – explained 87% of the variability in Chinook spawner numbers observed among the Skagit tributaries (RSQ = 0.87; $p < 0.001$). This looked like a good subset of variables to work with, and most of them actually made biological sense which is the best test of all.

The four-variable regression resulted in the following equation that could be used to predict the number of spawners supported by a tributary:

$$Spawners = -142.4 + (1.31 \times Area) + (18.47 \times Length) + (0.83 \times Canopy) + (1.14 \times Basin\ Slope)$$

This equation was then used to predict the number of spawners for all the Tier 2 candidate streams we have identified in the Skagit River watershed. The results are provided in Table 1, which is sorted according to the number of spawners that a tributary is expected to produce if restored. For outlier streams including Goodell and Nookachamps Creek, the estimated number of spawners would be those expected if the spawning impairments to the stream were addressed.

Table 1. Multiple regression predictions of spawner abundance according to key watershed variables for Skagit River tributaries.

Tributary Name	Run Type	Drainage Area (sq-mi)	Forest Canopy (%)	Spawning Length (mi)	Basin Slope (%)	Potential Spawners	PS Rank
White Chuck River	Upper Sauk Spring	85.7	66.2	10.00	55.4	273	1
Finney Creek	Skagit Fall	54.0	78.7	7.65	44.0	185	2
Illabot Creek	Skagit Summer	46.2	70.7	5.59	54.4	142	3
Bacon Creek	Skagit Summer	51.0	54.1	5.11	64.1	137	4
Nookachamps Creek	Skagit Fall	69.0	62.9	5.10	17.9	115	5
Day Creek	Skagit Fall	35.0	79.6	5.70	31.1	110	6
North Fork Sauk	Upper Sauk Spring	81.2	68.5	1.05	58.2	106	7
South Fork Sauk	Upper Sauk Spring	41.7	58.8	2.64	70.8	90	8
Downey Creek	Suiattle Spring	35.8	58.7	2.30	65.3	70	9
Goodell Creek	Skagit Summer	38.9	37.2	1.71	79.8	62	10
Buck Creek	Suiattle Spring	34.0	66.7	1.90	59.6	61	11
Diobsud Creek	Skagit Summer	26.6	68.8	1.76	58.9	49	12
Sulphur Creek	Suiattle Spring	33.0	51.5	1.20	69.2	45	13
South Fork Cascade	Cascade Spring	36.4	49.6	0.86	71.7	44	14
Dan Creek	Sauk Summer	17.0	82.4	2.46	38.5	38	15
Jackman Creek	Skagit Fall	24.1	78.0	1.43	46.7	34	16
Tenas Creek	Suiattle Spring	10.5	81.1	1.60	54.0	30	17
Lime Creek	Suiattle Spring	17.7	78.0	1.00	57.1	29	18
Hansen Creek	Skagit Fall	12.1	51.7	5.26	13.4	29	19
Straight Creek	Suiattle Spring	11.6	76.9	1.11	59.7	25	20
Big Creek	Suiattle Spring	21.6	71.5	0.60	58.6	23	21
Grandy Creek	Skagit Fall	18.1	62.4	3.01	29.3	22	22
Pressentin Creek	Skagit Fall	12.6	81.8	0.72	53.1	16	23
Pugh Creek	Upper Sauk Spring	6.8	67.6	0.65	70.2	15	24
Mill Creek	Skagit Fall	4.7	82.0	0.95	53.5	10	25
Marble Creek	Cascade Spring	17.6	45.5	0.40	72.8	9	26
North Fork Cascade	Cascade Spring	22.0	42.4	0.20	67.2	2	27
Andersen Creek	Skagit Fall	3.6	79.5	1.68	23.9	0	28
Sorenson Creek	Skagit Fall	1.7	70.4	0.74	26.6	0	28
Jones Creek	Skagit Fall	9.0	73.9	1.45	26.3	0	28
Alder Creek	Skagit Fall	11.3	77.5	1.60	20.6	0	28
O'Toole Creek	Skagit Fall	5.6	81.2	0.38	51.3	0	28
Milk Creek	Suiattle Spring	14.5	59.4	0.10	61.5	0	28

The top ten ranking tributaries using the multiple regression estimation method are:

1) White Chuck River
2) Finney Creek
3) Illabot Creek
4) Bacon Creek
5) Nookachamps Creek
6) Day Creek
7) North Fork Sauk
8) South Fork Sauk
9) Downey Creek
10) Goodell Creek

Of the top six streams ranked by this method, all but the Whitechuck River and Nookachamps Creek are presently designated as Tier 2 tributaries in the Skagit Watershed Council 2010 Strategic Approach. The South Fork Sauk River is also already designated a Tier 2 large river floodplain due to the presence of floodplain habitat as determined from the Skagit Watershed Council's GIS floodplain layer.

Intrinsic Potential Approach based upon Spawner Densities

The second method used was the Intrinsic Potential (IP) methodology that has been used by NOAA, U.S. Forest Service, and others to identify the best streams in a large basin for salmon and steelhead production. The IP approach identifies productivity based upon key watershed and channel variables, and can be used to predict the best areas for spawning and rearing under historic (pre-disturbance) conditions. We employed the same IP methods used in the lower Columbia River drainage for Chinook salmon (Busch et al. 2011) and for steelhead in the Puget Sound (Waldo et al. 2013). Most of these IP models are based upon measured or professional judgment estimates of spawner densities (e.g., redds per mile). For this reason, the tributary Chinook spawner density data provided to us by WDFW were used as the basis for developing the Skagit IP model.

The IP model previously developed for Chinook salmon in the lower Columbia River basin (Busch et al. 2011) used three channel variables to predict intrinsic potential: stream gradient, stream width, and stream confinement. Most of the other IP models developed for Chinook salmon in western Oregon and northern California have used these same three variables. The stream confinement variable did not look like a good variable for use in the Skagit River basin because the three Spring Chinook populations spawn in relatively confined systems. For example, some of the highest spawner densities in the Skagit occur in streams like Downey Creek that are highly confined (i.e., they don't have a wide floodplain). The Puget Sound Steelhead TRT had this same problem developing an IP model for steelhead, and dropped the confinement variable from the model (Waldo et al. 2013). We evaluated the statistical significance of adding other watershed and stream channel variables to the model and found that mean basin elevation increased the significance of the model. Thus, the Skagit IP model ended up with three variables: stream gradient, stream width, and mean basin elevation.

Following the IP methods for Chinook salmon described by Busch et al. (2011), we defined suitability categories and IP scores for the three watershed and stream channel variables using WDFW's Chinook spawning density data for the Skagit tributaries. IP suitability criteria range from 0.0 to 1.0, with 0.0 indicating zero suitability for spawning Chinook and 1.0 indicating optimal suitability. IP categories or "suitability bins" were then developed for each variable to describe if conditions are "very low", "low", "medium", or "high" in terms of spawning potential for a specific reach. These categories are typically mapped on a reach by reach basis to describe IP conditions throughout a river basin.

The IP categories and scores developed from the Skagit redd density data are shown in Table 2. The highest IP ratings for gradient occurred between 2 and 4%, with medium ratings defined for gradients between 0 and 2%, and between 4 and 7%. These IP ratings are largely consistent with the ratings defined for gradient in prior IP models for Chinook (Busch et al. 2011), except that gradients between 4 and 7% in the Skagit basin receive a relatively high rating. This is a consequence of the presence of Spring Chinook populations in the Skagit that spawn in higher gradient streams. Streams that are less than 10 ft wide are considered to have zero potential for spawning, while widths between 10 and 30 ft are considered to have low spawning potential (Table 2). Streams that have widths greater than 80 ft are considered to have the highest spawning potential. Tributaries that had mean basin elevations less than 2,000 ft were found to have the lowest redd densities (Table 2), and subsequently received the lowest IP scores. Streams having mean basin elevations of 4,000 ft and greater were observed to have the highest redd densities in WDFW's data set, and subsequently had the highest IP ratings.

Table 2. Intrinsic potential categories and suitability scores for Chinook salmon in Skagit tributaries.

Stream Gradient	Threshold	IP Category	IP Score
0 - 2%	0	Medium	0.70
2 - 4%	2	High	1.00
4 - 7%	4	Medium	0.75
> 7%	7	Low	0.05

Stream Width		IP Category	IP Score
0 - 10 ft	0	Very Low	0.00
10 - 30 ft	10	Low	0.25
30 -80 ft	30	Medium	0.60
> 80 ft	80	High	1.00

Mean Basin Elevation		IP Category	IP Score
0 - 2000 ft	0	Low	0.10
2000 - 4000 ft	2000	Medium	0.65
> 4,000 ft	4000	High	1.00

A composite IP score was then calculated with the three variables for each tributary using the equation:

$$IP = (\text{Gradient IP} \times \text{Width IP} \times \text{Mean Basin Elevation IP})^{1/3}$$

This equation was the same as that used in earlier IP studies employing three variables (Busch et al. 2011). IP scores for each Skagit tributary and category are shown in Table 3.

Table 3. Intrinsic potential (IP) values and rankings for Chinook salmon spawner productivity in Skagit tributaries.

Tributary Name	Reach Length (mi)	Gradient IP	Width IP	Elev IP	Reach IP Value	Reach IP Rank
White Chuck River	10.0	High	High	High	10.00	1
Finney Creek	7.7	Medium	High	Medium	5.88	2
Illabot Creek	5.6	High	High	Medium	4.84	3
Bacon Creek	5.1	Medium	High	Medium	3.93	4
Day Creek	5.7	Medium	Medium	Medium	3.70	5
Goodell Creek	2.4	High	High	High	2.40	6
Downey Creek	2.3	High	High	High	2.30	7
South Fork Sauk	2.6	High	High	Medium	2.29	8
Buck Creek	1.9	High	High	High	1.90	9
Nookachamps Creek	5.1	Medium	Medium	Low	1.77	10
Dan Creek	2.5	Medium	Medium	Medium	1.60	11
Hansen Creek	5.3	Medium	Low	Low	1.37	12
Grandy Creek	3.0	High	Medium	Low	1.18	13
Tenas Creek	1.6	High	Medium	Medium	1.17	14
Diobsud Creek	1.8	Medium	Medium	Medium	1.14	15
Sulphur Creek	1.2	Medium	High	High	1.09	16
North Fork Sauk	1.1	High	High	High	1.05	17
Jackman Creek	1.4	High	Medium	Medium	1.04	18
South Fork Cascade	0.9	High	High	High	0.86	19
Straight Creek	1.1	High	Medium	Medium	0.81	20
Lime Creek	1.0	Medium	Medium	High	0.77	21
Pressentin Creek	0.7	High	Medium	Medium	0.53	22
Mill Creek	1.0	High	Low	Medium	0.52	23
Pugh Creek	0.7	Medium	Medium	High	0.50	24
Big Creek	0.6	High	Medium	Medium	0.44	25
Andersen Creek	1.7	Medium	Low	Low	0.44	26
Alder Creek	1.6	Medium	Low	Low	0.42	27
Sorenson Creek	0.7	High	Low	Medium	0.40	28
Jones Creek	1.5	Medium	Low	Low	0.38	29
Marble Creek	0.4	Medium	Medium	High	0.31	30
O'Toole Creek	0.4	Medium	Low	Medium	0.19	31
North Fork Cascade	0.2	Medium	Medium	High	0.15	32
Milk Creek	0.1	Low	Medium	High	0.03	33

The "Reach IP" value was then calculated by multiplying the IP score for each tributary category by the length (miles) of the tributary accessible to spawning Chinook salmon. The Reach IP is the value used to rank tributaries according to total spawning potential. Table 3 provides the Reach IP values for each Skagit Tributary. The streams listed in this table are ranked in order from the highest to the lowest Reach IP values.

The top ten tributaries with the highest Reach IP scores were:

1) White Chuck River
2) Finney Creek
3) Illabot Creek
4) Bacon Creek
5) Day Creek
6) Goodell Creek
7) Downey Creek
8) South Fork Sauk
9) Buck Creek
10) Nookachamps Creek

Similar to the previous assessment outcomes, all of the top five highest ranking tributaries, except the White Chuck River, are already designated as Tier 2 tributaries in the Skagit Watershed Council's 2010 Strategic Approach. As mentioned earlier, the South Fork Sauk River is also already designated a Tier 2 large river floodplain due to the presence of floodplain habitat as determined from the Skagit GIS floodplain layer.

Percent of Spawners Contributed by Tributary

The third method we employed for screening tributaries for Tier 2 Target Area status was based upon the percentage of spawners in a Chinook population that are contributed by a specific tributary. The Skagit basin supports six independent populations (stocks) of Chinook salmon: upper Skagit summer run; lower Sauk summer run; lower Skagit fall run; Cascade spring run; upper Sauk spring run; and Suiattle spring run. Tributaries contribute a large percentage of the spawners in some of these populations, especially for the Suiattle River where most Chinook spawning occurs in the lowest sections of tributaries rather than in the mainstem river. Tributaries that support a substantial portion of spawners within a given population may require special consideration in determining Tier 2 status, since these tributaries may be critical to the long-term viability of that Chinook population. This is especially relevant to the Suiattle River, which is a currently a high risk population that needs to be reduced to a low risk population in order to meet NMFS's Evolutionarily Significant Unit (ESU) viability goals for Puget Sound Chinook Salmon recovery (NMFS 2006).

We calculated the percent of the total spawning run for each of the six independent Chinook populations in the Skagit that is supported by a given tributary. This analysis was conducted from spawner estimates obtained from Chinook redd data collected by WDFW in each tributary, and dividing this by the total run size for each of the six independent populations. We used seven years of tributary redd and population spawning run size data for this evaluation. It should be noted that the results are specific to that time period, and while giving us insight into relative proportion of tributary spawners per population, are dynamic over time. This is especially relevant to the Suiattle spring run which varies spawning area depending on which tributary spawning habitat occupies lower gradient Suiattle floodplain habitat rather than being entrained into the mainstem immediately at their confluence.

The results of this analysis are provided in Table 4. The tributary that contributed the greatest proportion of spawners to a Chinook population was Downey Creek, with an estimated 43.3 percent of all Suiattle spring run adults spawning in this stream. The second and third most important tributaries in terms of spawner percentages were Buck Creek and Tenas Creek. These two streams provide 16.5

percent and 16.2 percent of the spawners to the Suiattle spring run population, respectively. Finney Creek was found to be the highest ranking stream for Lower Skagit Fall Chinook, contributing 11.4 percent of the spawners in this population. Taken in sum, the Suiattle tributaries provide virtually 100% of the spawning opportunities for that population.

Table 4. Percent of total spawners contributed by tributaries for the six independent Chinook salmon populations in the Skagit basin.

Tributary Name	Chinook Population	Number of Tributary Spawners	Average Population Run Size	Percent of Run in Tributary	Rank
Downey Creek	Suiattle Spring	132	306	43.3	1
Buck Creek	Suiattle Spring	50	306	16.5	2
Tenas Creek	Suiattle Spring	50	306	16.2	3
Finney Creek	Lower Skagit Fall	193	1,694	11.4	4
Sulphur Creek	Suiattle Spring	32	306	10.6	5
South Fork Sauk	Upper Sauk Spring	72	807	8.9	6
Day Creek	Lower Skagit Fall	119	1,694	7.0	7
North Fork Sauk	Upper Sauk Spring	40	807	5.0	8
Dan Creek	Lower Sauk Summer	21	430	4.9	9
Lime Creek	Suiattle Spring	13	306	4.2	10
Milk Creek	Suiattle Spring	12	306	3.8	11
Big Creek	Suiattle Spring	10	306	3.4	12
Straight Creek	Suiattle Spring	7	306	2.4	13
Bacon Creek	Upper Skagit Summer	138	7,616	1.8	14
Illabot Creek	Upper Skagit Summer	130	7,616	1.7	15
Pressentin Creek	Lower Skagit Fall	25	1,694	1.5	16
Marble Creek	Cascade Spring	4	320	1.4	17
Hansen Creek	Lower Skagit Fall	18	1,694	1.1	18
Grandy Creek	Lower Skagit Fall	13	1,694	0.8	19
Diobsud Creek	Upper Skagit Summer	57	7,616	0.7	20
Jackman Creek	Lower Skagit Fall	12	1,694	0.7	21
Nookachamps Creek	Lower Skagit Fall	11	1,694	0.6	22
North Fork Cascade	Cascade Spring	2	320	0.6	23
O'Toole Creek	Lower Skagit Fall	9	1,694	0.5	24
Mill Creek	Lower Skagit Fall	7	1,694	0.4	25
Alder Creek	Lower Skagit Fall	1	1,694	0.1	26
Goodell Creek	Upper Skagit Summer	6	7,616	0.1	27
Jones Creek	Lower Skagit Fall	0	1,694	0.0	28
Andersen Creek	Lower Skagit Fall	ND	1,694	-	-
Sorenson Creek	Lower Skagit Fall	ND	1,694	-	-
Pugh Creek	Upper Sauk Spring	ND	807	-	-
South Fork Cascade	Upper Sauk Spring	ND	807	-	-
White Chuck River	Upper Sauk Spring	ND	807	-	-

ND = No spawner data for tributary

Comparison of these Three Methods for Screening Tributary Rearing Habitat

The three modeling approaches provide the same rankings for the Chinook spawning potential for the four highest ranking streams: Whitechuck River, Finney Creek, Illabot Creek, and Bacon Creek. The multiple regression approach ranks Day Creek fifth place, while the IP model places Nookachamps Creek in fifth place. Tenas Creek, which was a medium ranked stream using the regression and IP approaches, was the third highest ranking stream identified in the percent spawner analysis. Because of the importance of this tributary to Suiattle Spring Chinook, it was added to the final list of tributaries to be considered for Tier 2 status.

The top 15 tributaries identified by these three screening criteria are:

1) White Chuck River
2) Finney Creek*
3) Illabot Creek*
4) Bacon Creek*
5) Day Creek*
6) Nookachamps Creek
7) Downey Creek
8) South Fork Sauk**
9) Goodell Creek
10) Buck Creek
11) North Fork Sauk
12) Dan Creek
13) Diobsud Creek
14) Tenas Creek
15) Hansen Creek

* Currently designated as Tier 2 tributary by Skagit Watershed Council 2010 Strategic Approach
** Currently designated as Tier 2 mainstem floodplain habitat for single Chinook population

Juvenile Chinook Salmon Rearing Analysis

The Skagit Chinook Recovery Plan (SRSC and WDFW 2005) identified freshwater rearing as an important limiting factor so an additional analysis was completed to evaluate the streams screened above specifically for rearing habitat potential. The Chinook Yearling Study (Lowery et al. In development) determined that the primary habitat variables associated with juvenile Chinook salmon rearing were season, distance upstream from the nearest major confluence, wetted width, proportion of wood cover, proportion of vegetation cover, and sub-dominant substrate size. The mean relative densities were greatest in mainstems, log jams, and floodplain channels. Increased densities were observed when channel width was greater than 7.3 m, the vegetation cover was less than 58% of the reach surveyed, and the subdominant substrate was less than 64 mm in diameter. It should be noted that vegetation provides multiple functions for salmon and trout and that this association with open canopy cover is more related to the geomorphic conditions present at a site in relatively wide rivers.

To think about this conceptually we considered the processes that lead to greater densities of Chinook juveniles. First, there needs to be active spawning in or above the habitats where juveniles rear. They need channels greater than 7.3 m, which have an open canopy, and smaller substrate. This typically describes a depositional zone of a river channel which can be multi-channel, braided, or composed of large meander bends. In streams where spawning habitat is not limited, an increase in some of these habitat metrics should result in greater juvenile production. Therefore, it was assumed that lower gradient stream reaches with floodplains were most likely to include habitat suitable for Chinook rearing. To find these reaches with existing information, we used the following data sources:

- NWIFC SSHIAP data (2009)
- Floodplain layer (2005 Chinook Plan)
- Anadromous zone layer (1998 SWC Strategic Approach)
- USGS Stream Stats online tool

SSHIAP stream segments contain information on gradient and stream confinement taken from USGS topographic maps. We considered stream segments to have suitable rearing habitat if they had a gradient of 4% or less and were classified as moderately confined or unconfined. The confinement rating indicated the stream segments had valley widths that were > 2 channel widths and therefore likely had a floodplain. We measured the total length of stream segments that met these criteria along the main channel of the tributary from the edge of the adjacent Tier 2 floodplain to the upper extent of likely anadromous fish usage. We excluded the South Fork Sauk from further analysis given its current Tier 2 Target Area status as a mainstem floodplain.

The yearling analysis estimated that streams less than 7.3 m (24 ft) in width were less likely to support increased Chinook densities. We used the USGS Stream Stats online tool to determine basin size and average precipitation for each of those tributaries, and used that information estimate channel width. We excluded tributaries that were less than 7.3 m (24 ft) in width from the analysis because they were less likely to support increased Chinook densities. For each tributary we multiplied the length of the habitat that met the gradient and confinement criteria by the estimated channel width to get an estimate of the amount of rearing habitat that may be available. While this was likely an overestimate of actual rearing area because widths were estimated only for the downstream end of the tributary, it was assumed to be sufficient for making relative comparisons of rearing habitat potential. The tributaries are provided in order in Table 5.

Table 5. Estimated relative rearing habitat area for pre-screened tributaries in the Skagit River.

Tributary Name	Drainage Area (sq-mi)	Mean Precip (in)	Est. Channel Width (ft)	Low Gradient Length (ft)	Length X Width (ft^2)
White Chuck River	85.7	137.0	140	37,396	5,235,440
Finney Creek	54.0	89.7	82	62,141	5,092,407
Nookachamps (EF/WF) **	30.8/36.3	41.9/50.2	36/44	48,706/23,734	2,797,712
Bacon Creek	51.0	111.0	93	29,194	2,726,153
Illabot Creek	46.2	112.0	90	15,708	1,408,021
Day Creek	35.0	77.2	60	21,395	1,274,635
Diobsud Creek	26.6	115.0	70	7,962	557,340
Hansen Creek	12.1	48.8	25	21,341	542,754
North Fork Sauk River	81.2	146.0	143	3,631	519,233
Dan Creek	17.0	109.0	54	1,943	104,922
Goodell Creek	38.9	113.0	83	234	19,440
Tenas Creek	10.5	124.0	47	0	0
Downey Creek	35.8	140.0	94	0	0
Buck Creek	34.0	138.0	90	0	0

** For Nookachamps Creek, the East Fork and West Fork were calculated separately and then added together.

Discussion and Recommendations

Table 5 is a step-wise synthesis of the multiple regression, IP model, tributary spawning percentage by population, and juvenile Chinook salmon rearing analysis. All of these streams have active Chinook salmon spawning, are predicted to support juvenile rearing and most have direct observations of stream type Chinook salmon from the Skagit Yearling Study (Lowery et al. In development). While there are many other tributaries available to Chinook salmon spawning and juvenile rearing, our analyses suggest there will be significantly diminishing returns beyond the 14 tributaries in Table 5, within the constraints outlined herein. Our recommendation is to designate all of the streams in Table 5 as Tier 2 based on their function as spawning and rearing habitats for Chinook salmon.

Of note on this table is the low ranking of Suiattle River tributaries. This is likely an artifact of the limitations in the data available to us and our methodology, and does not reflect true tributary rearing area. For example the gradient used was calculated from topographic maps which may not provide the scale sufficient for measuring biological responses of fishes to habitats. Some of these tributaries were also ranked relatively low because a high proportion of their available rearing habitat potential is contained within the floodplain of an adjacent mainstem channel that is already included as a Tier 2 priority. The use of more precise tools such as LIDAR or direct measurements could refine these results and allow us to calculate habitat area more precisely. Results from the Yearling Study indicate that stream type Chinook salmon do rear in Buck creek, therefore we should acknowledge that we are limited by the precision of the dataset used and should take advantage of other sources and types of data when determining the appropriateness of a selection criteria.

A secondary question studied by our working group was how far up these tributaries should we prioritize for consideration of future restoration and protection actions. Given the lack of site-specific information relevant to Chinook rearing habitats, the working group recommends using the upstream distribution of documented presence of Chinook as that upstream extent of project eligibility within the Tier 2 Target Areas.

Previous Skagit Watershed Council documents and the Skagit Chinook Salmon Recovery Plan (SRSC and WDFW 2005) prioritized floodplain habitats within this fish distribution for their ability to create and maintain dynamic and functional rearing areas for Chinook salmon. Because there is not a complete data set that identifies floodplains in the tributaries identified here our working group further recommends defining eligible floodplains for tributary areas as those identified as moderately confined or unconfined valleys wider than 2 channel widths (Pleus and Schuett-Hames 1998). Until specific mapping products are available to implement this screening criterion, each proposed project should be evaluated on a case by case basis for eligibility.

References

Busch, D.S., M. Sheer, K. Burnett, P. McElheny, and T. Cooney. 2011. Landscape-level model to predict spawning habitat for lower Columbia River Fall Chinook (*Onchorhynchus tshawytscha*). River Research and Applications (2011).

Lowery, E., J. Thompson, J.P. Shannahan, E. Connor, D. Pflug, B. Donahue, C. Torgersen, and D.A. Beauchamp. In development. Seasonal Distribution and Habitat Associations of Salmonids with Extended Juvenile Freshwater Rearing in Different Precipitation Zones of the Skagit River, WA.

NMFS. 2006. Final supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan. National Marine Fisheries Service, Northwest Region, Seattle, Washington. 43 p.

Pleus, A.E. and D. Schuett-Hames. 1998. TFW Monitoring Program methods manual for stream segment identification. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-98-001. DNR #103. May.

Waldo, T., C. Clark, and B. Jones. 2013. Applying the NOAA-Fisheries threshold intrinsic potential model from NHD Plus (100K) to NHD high resolution (24K or higher resolution): Puget Sound steelhead trout (Onchorynchus mykiss). Report to Puget Sound Partnership. Northwest Indian Fisheries Commission, Salmon and Steelhead Inventory Assessment Program.

Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor and D. E. Pflug. In press. Abundance, survival and life history strategies of juvenile migrant Chinook salmon in the Skagit River, Washington. Transactions of the American Fisheries Society.