Lower Spokane River Redband Rainbow Trout

Spokane River Forum

April 26, 2023

Chris Moan, Fisheries Habitat Biologist

Redband Rainbow Trout

- Species of Greatest Conservation Need, Species of Concern, culturally significant

- Populations throughout the Spokane River, with a valuable spawning habitat in Spokane River below Spokane Falls

Avista's Spokane River Hydroelectric Developments

Avista's Washington 401 Certification

Goal: Additional information is needed to better understand how the following specific factors relate to trout spawning success between Monroe Street Dam and the Nine Mile Dam Reservoir.

a) **Quantify the quality and quantity of trout spawning habitat**: determine the most productive and least productive spawning areas by developing quality strata at all flow/discharge elevations.

b) **Quantify spawn to emergence success**: determine survival from egg to emergence by strata using artificial redd construction. Correlate egg-to-emergence survival for each stratum with corresponding flow/discharge and include velocity, depth, and temperature as variables.

c) **Quantify redd dewatering at different flow/discharge elevations for each habitat quality stratum**.

d) **Determine redband trout abundance estimates annually (for 10 years) to assess year class association with flow/discharge levels**. Correlate year class strength with flow/discharge and egg to emergence survival. Determine overall spawning success with regard to flow/discharge levels and timing.

Avista's Washington 401 Certification

Parts a, b, c

- Lower Spokane River Redband Trout Spawning Habitat: Monroe Street to Nine Mile Pool (2011)

- **Part d**
  - Redband Trout Spawning and Fry Emergence Study: Abundance and Year Class Strength (2010-2019)
  - Lower Spokane River Redband Rainbow Trout Abundance and Spawning Habitat Data Analysis (2022)

Redband Spawning Habitat

- Largest concentration of spawning patches was around TJ Meenach Bridge
- Average water depth of redds was 3.51 feet and observed at up to 5.3 feet.

Spawning Discharge (cfs)	Ending Incubation Discharge (cfs)																							
	25,000	24,000	23,000	22,000	21,000	20,000	19,000	18,000	17,000	16,000	15,000	14,000	13,000	12,000	11,000	10,000	9,000	8,000	7,000	6,000	5,000	4,000	3,000	2,000	1,000
25,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	81	75	68	61	54	47	41	34	30
24,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	81	75	69	62	54	47	41	34	30
23,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	81	75	69	62	55	47	41	34	30
22,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	82	76	69	62	55	48	41	34	30
21,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	82	76	69	62	55	48	41	34	30
20,000	100	100	100	100	100	100	100	100	99	99	98	96	94	92	89	86	82	76	69	62	55	48	41	34	30
19,000	100	100	100	100	100	100	100	100	100	99	98	96	94	92	89	86	82	76	69	62	55	48	41	34	30
18,000	100	100	100	100	100	100	100	100	100	99	99	97	94	92	89	86	82	76	70	63	56	48	41	35	31
17,000	100	100	100	100	100	100	100	100	100	100	99	97	95	93	90	87	83	77	70	63	56	49	42	35	31
16,000	100	100	100	100	100	100	100	100	100	100	99	97	95	93	90	87	83	78	71	64	57	49	42	35	31
15,000	100	100	100	100	100	100	100	100	100	100	100	98	96	94	91	88	84	79	72	65	58	50	43	36	32
14,000	100	100	100	100	100	100	100	100	100	100	100	100	98	96	93	90	86	80	73	66	58	51	44	36	32
13,000	100	100	100	100	100	100	100	100	100	100	100	100	100	98	95	92	88	81	74	66	59	51	43	36	31
12,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	94	89	82	75	67	59	51	43	35	30
11,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	91	84	75	67	59	51	43	34	29
10,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	94	85	76	67	59	51	43	34	29
9,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	91	81	72	63	54	46	36	30
8,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	89	79	70	61	51	40	33
7,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	89	80	71	61	49	40
6,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	91	81	71	57	48
5,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	78	64	54
4,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	88	73	61
3,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	84	71
2,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	84
1,000	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note:

100%
90%
80%
70%
60%
50%
<50%

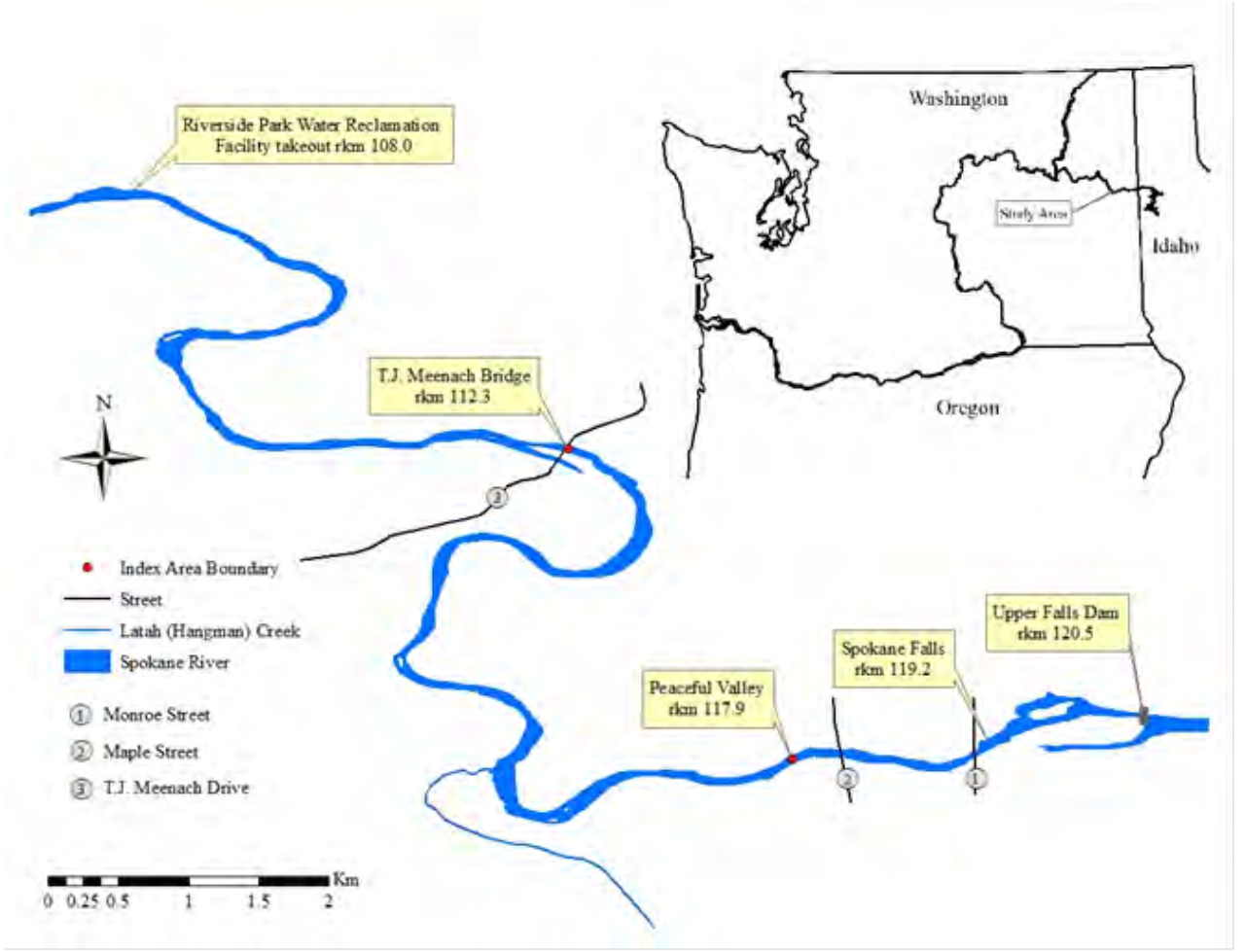
Avista's Washington 401 Certification

Parts a, b, c

- Lower Spokane River Redband Trout Spawning Habitat: Monroe Street to Nine Mile Pool (2011)

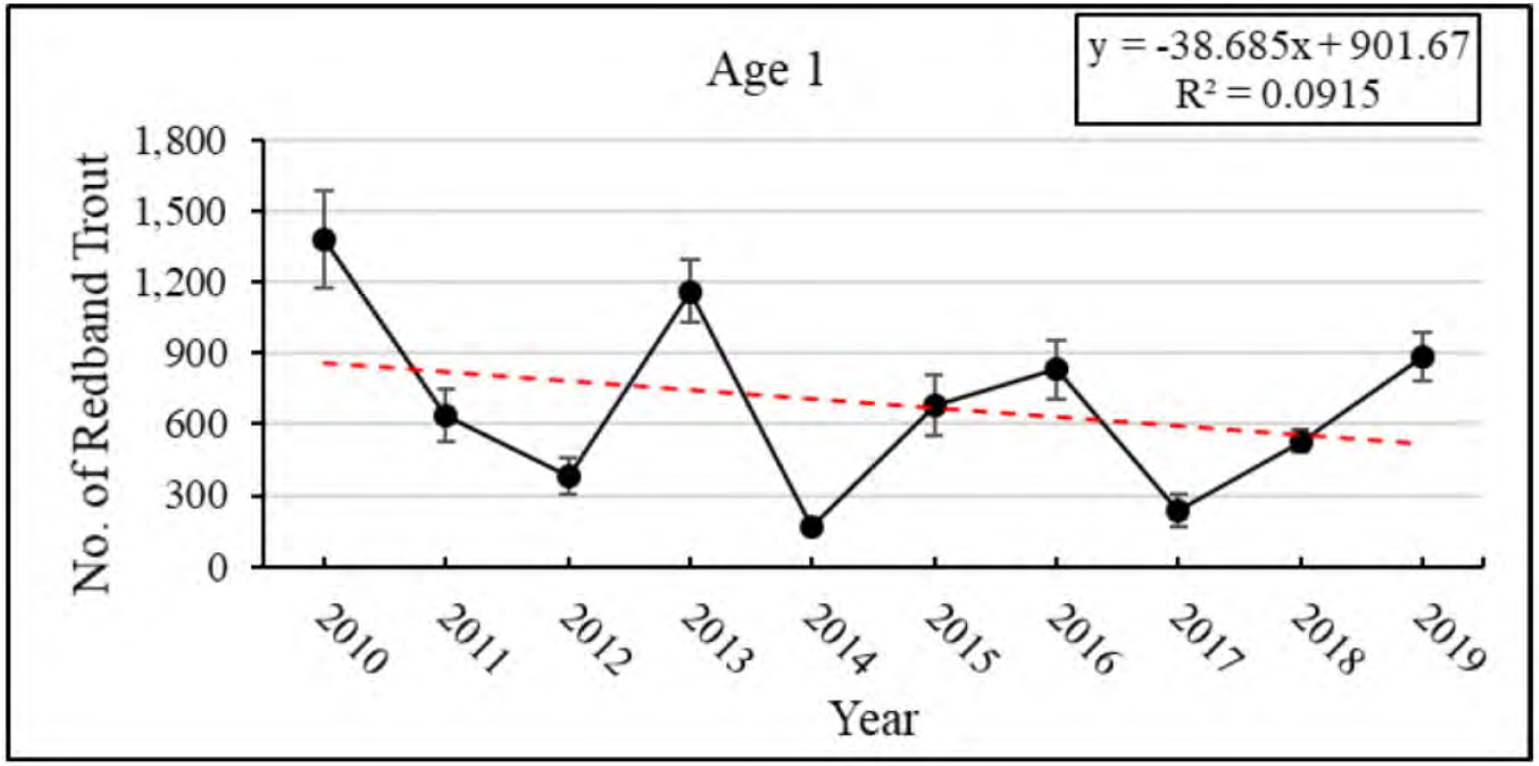
- **Part d**
  - Redband Trout Spawning and Fry Emergence Study: Abundance and Year Class Strength (2010-2019)
  - Lower Spokane River Redband Rainbow Trout Abundance and Spawning Habitat Data Analysis (2022)

Survey Area



- Peaceful Valley to TJ Meenach Bridge

Redband Age 1 Abundance



- Age 1 abundance has followed a cyclic pattern with relatively strong year classes observed every three years, and subsequent strong year classes observed when abundant cohorts reached maturity

Avista's Washington 401 Certification

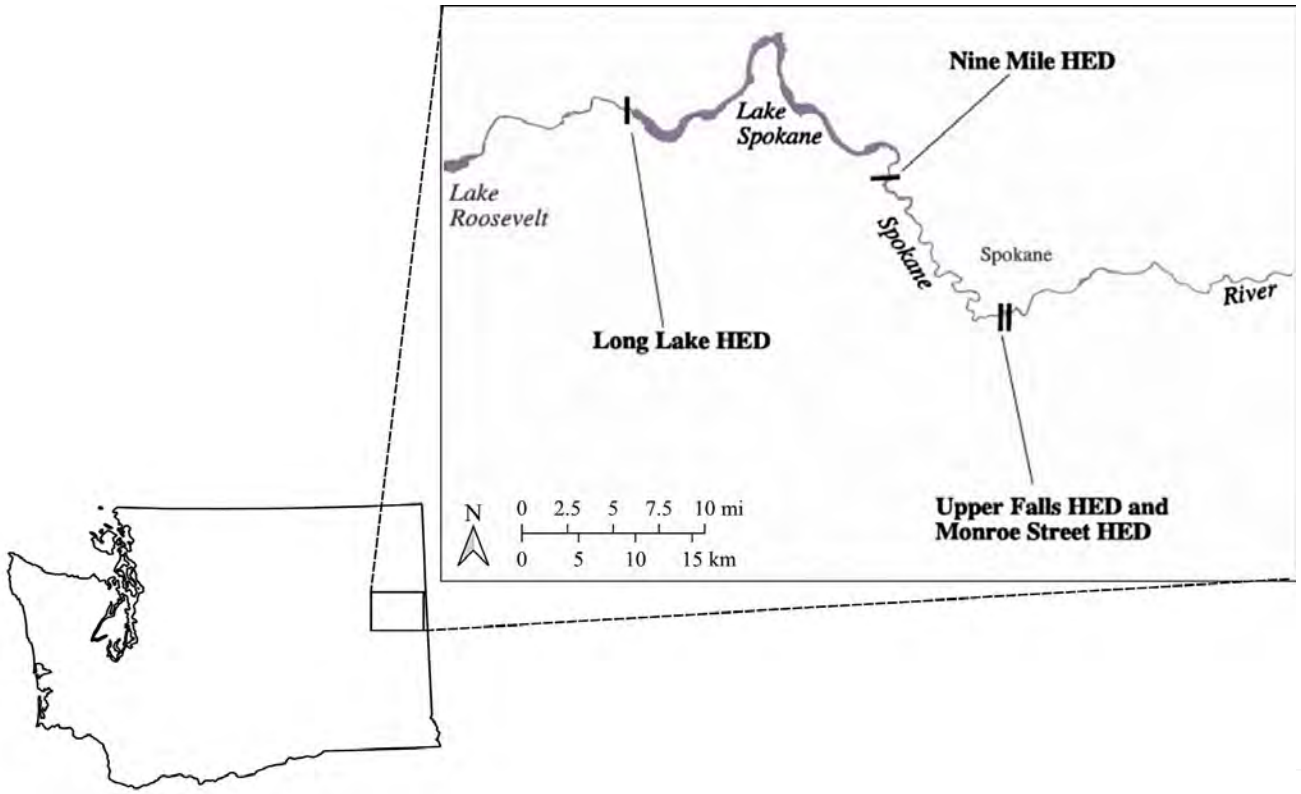
Parts a, b, c

- Lower Spokane River Redband Trout Spawning Habitat: Monroe Street to Nine Mile Pool (2011)

- **Part d**
  - Redband Trout Spawning and Fry Emergence Study: Abundance and Year Class Strength (2010-2019)
  - Lower Spokane River Redband Rainbow Trout Abundance and Spawning Habitat Data Analysis (2022)

Objectives

- Relate river flow levels and timing to redband trout spawning and fry emergence success and age-1 abundance (year-class strength)
  - Did not evaluate other variables that affect abundance
- Estimate carrying capacity to compare to the current abundance



Year-Class Strength

- Back-calculated age 0
  - Cohort method (longitudinal catch-curve method)
- Empirically estimated age 1
- Relationship between year class strength and environmental variables evaluated using regression models.

Variable	Source	Hypothesis
Minimum spawning flow (cfs)	USGS	Spawning habitat availability limits recruitment
Flow variability during incubation (cfs)	USGS	De-watering events limit recruitment
Minimum summer flow (cfs)	USGS	High temperatures and reduced summer habitat increase stress and predation risk
Maximum winter flow (cfs)	USGS	Winter flood events can cause juvenile mortality
Effective habitat available (%)	Addley and Peterson 2011	Habitat limitation during spawning and incubation limit age-0 recruitment
Spawning habitat available (m^2)	Addley and Peterson 2011	Spawning habitat availability limits recruitment
Incubation habitat available (m^2)	Addley and Peterson 2011	Incubation habitat limits recruitment
Optimal carrying capacity	EDT (Section 2.2)	Age-0 (inactive) carrying capacity limits recruitment
Bedload transfer volume (m^3)	Avista	Monroe St. HED forebay rock relocation may decrease age-0 survival in the year when they occur or could increase egg survival in following year by improving habitat

Year-Class Strength Age 0

- Intercept-only top-ranked model
  - Average value was best predictor

- Effective habitat percent second highest, but not statistically different from zero

Model	Estimate[a]	Mean ΔAICc	Mean Rank	Mean R^2
Intercept only	8.51 (7.71, 9.29)	0.32	1.3	0
Effective habitat percent	-0.25 (-1.36, 0.89)	2.80	4.2	0.15
Minimum summer flow	-0.18 (-1.11, 0.77)	3.05	4.8	0.13
Spawning habitat area	0.31 (-0.21, 0.79)	3.32	5.1	0.11
Maximum winter flow	-0.30 (-0.73, 0.15)	3.59	5.6	0.09
Optimal carrying capacity	0.17 (-0.67, 1.00)	3.92	6.4	0.06
Incubation habitat area	0.00 (-0.65, 0.67)	3.90	6.4	0.06
Volume dredged material	-0.12 (-0.72, 0.48)	4.04	6.9	0.05
Incubation flow variation	0.00 (-0.71, 0.71)	4.08	7.0	0.05
Minimum spawning flow	0.11 (-0.35, 0.56)	4.17	7.3	0.04

Year-Class Strength Age 1

- Intercept-only top-ranked model

- Effective habitat percent second highest, explaining 22% of the variation in age-1 year-class strength

Model	Estimate[a]	Mean ΔAICc	Mean Rank	Mean R^2
Intercept only	6.41 (6.30, 6.53)	0.04	1.1	0
Effective habitat percent	0.32 (0.19, 0.46)	1.80	2.4	0.22
Incubation flow variation	0.26 (0.13, 0.4)	2.29	2.9	0.18
Volume dredged material	0.18 (0.1, 0.26)	3.19	4.7	0.11
Incubation habitat area	0.20 (0.09, 0.31)	3.21	5.0	0.10
Optimal carrying capacity	-0.24 (-0.38, -0.11)	3.26	5.2	0.10
Minimum spawning flow	0.07 (-0.02, 0.16)	4.15	8.0	0.02
Spawning habitat area	-0.05 (-0.14, 0.05)	4.20	8.3	0.01
Maximum winter flow	-0.03 (-0.13, 0.08)	4.23	8.7	0.01
Minimum summer flow	0.03 (-0.12, 0.18)	4.23	8.7	0.01

Year-Class Strength

FOUR PEAKS ENVIRONMENTAL
Science & Data Solutions

Year Class Strength Estimates Based on Effective Spawning and Incubation Habitat

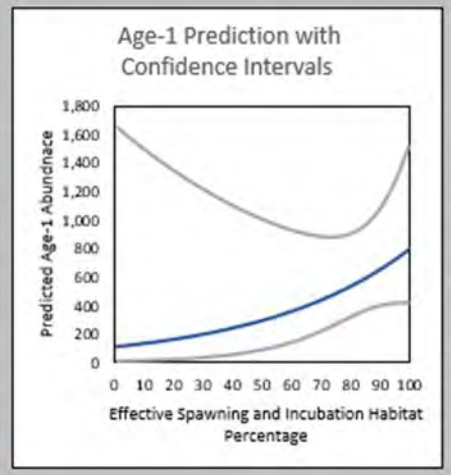
Spawning Discharge (CFS)	13,000	Enter Spawning Discharge (CFS) in multiples of 1,000 CFS (Range: 1,000 to 25,000 CFS)
Incubation Discharge (CFS)	6,000	Enter Ending Incubation Discharge (CFS) in multiples of 1,000 CFS (Range: 1,000 to 25,000 CFS)
Effective Spawning Habitat Percentage	66%	

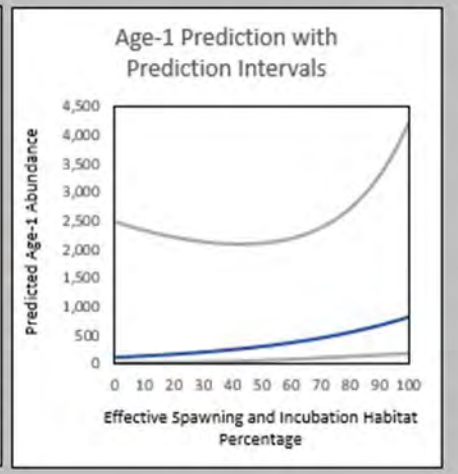
Age-0 Estimate: Intercept-Only Model

Abundance Prediction	4,955
95% Prediction Interval Lower	183
95% Prediction Interval Upper	134,285

Age-1 Estimate: Effective Spawning and Incubation Habitat Model

Abundance Prediction	404
95% Prediction Interval Lower	72
95% Prediction Interval Upper	2,276
% of Maximum Predicted Abundance	51%

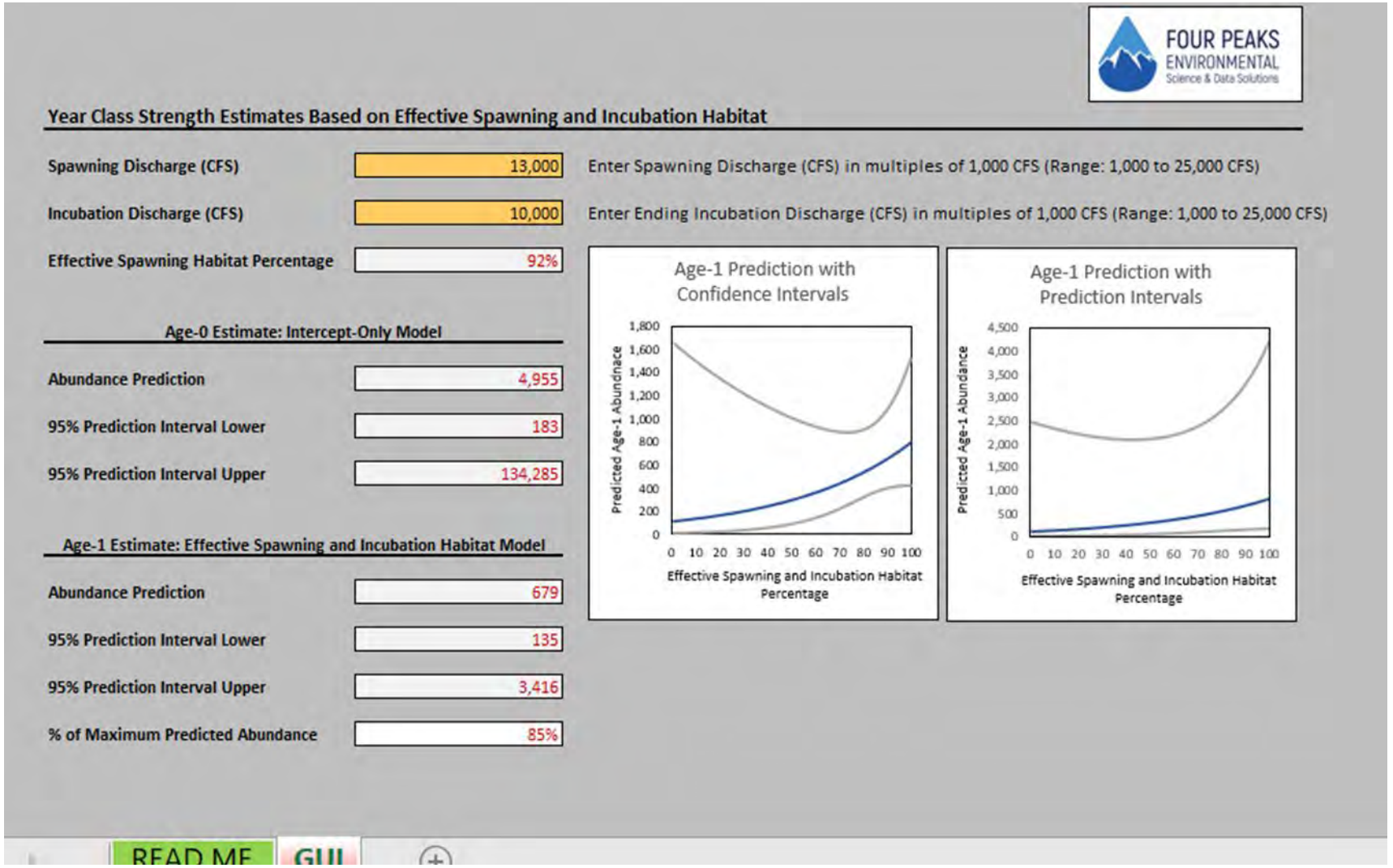




READ ME | GUI

AVISTA

Year-Class Strength



Optimal Carrying Capacity

- Stock-recruitment framework
  - Beverton-Holt model used
- Abundance by life stage
- Applied optimal life stage density, survival benchmarks, and habitat capacity rules from EDT model

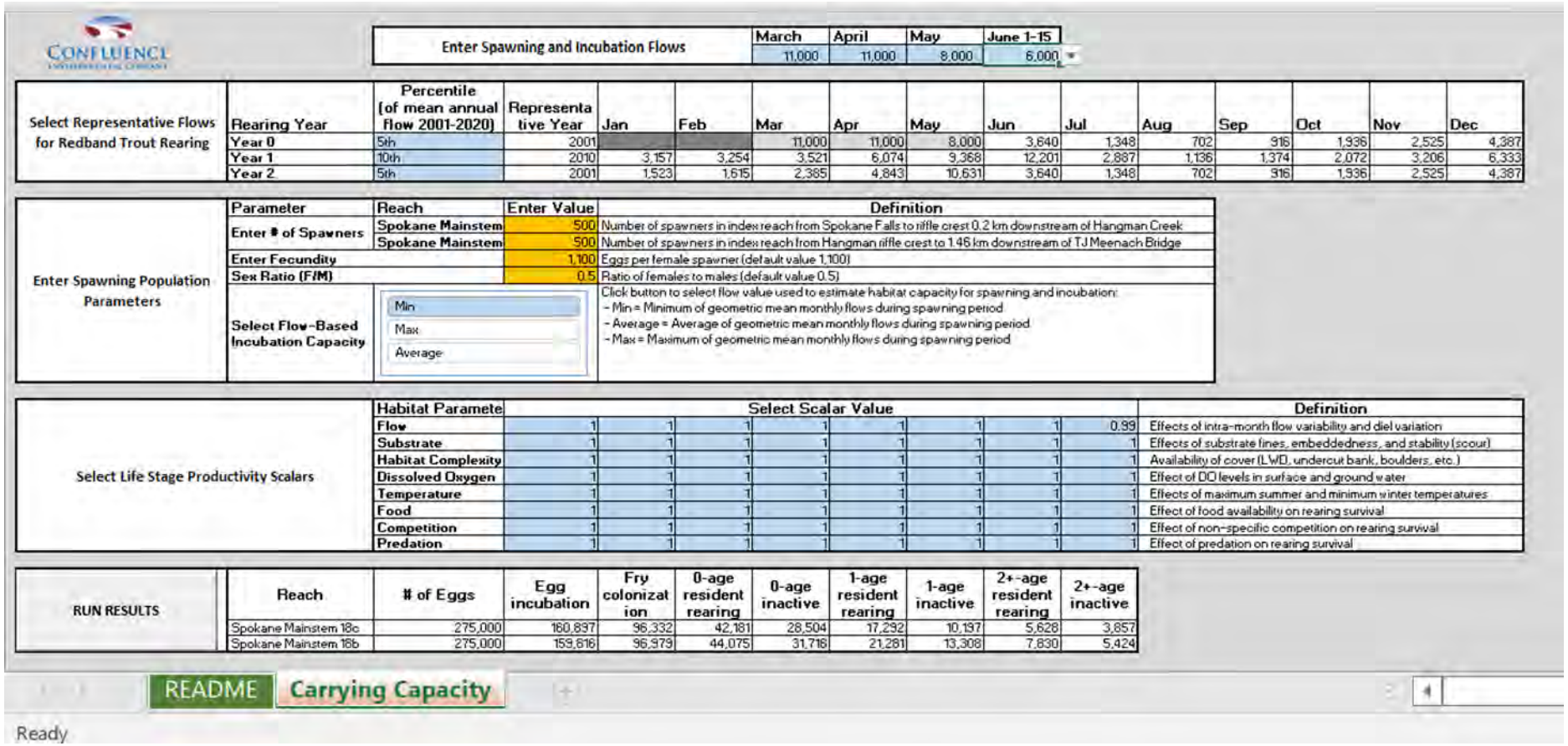
Life Stage	Months of Occurrence	Benchmark Density in Suitable Habitat	Benchmark Survival
Spawning	March to May	0.84 fish/m^2	1
Egg incubation	March to July	500 eggs/ m^2	0.7
Fry colonization	June to July	26 fry/ m^2	0.75
0-age resident rearing	June to October	2.52 parr/ m^2	0.78
0-age inactive	November to March	1.51 parr/m^2	0.70
1-age resident rearing	April to November	0.40 fish/m^2	0.85
1-age inactive	November to March	0.21 fish/m^2	0.85
2+-age resident rearing	April to November	0.11 fish/m^2	0.9
2+-age inactive	November to March	0.11 fish/m^2	0.93

Optimal Carrying Capacity

- Year-to-year variation in flow conditions, expressed as the geomean of average daily flows per month over the period of record, have a limited effect on optimal carrying capacity.

Reach	Brood Year	Spawners	Egg Incubation	Fry Colonization	0-Age Resident Rearing	0-Age Inactive	1-Age Resident Rearing	1-Age Inactive	2+-Age Resident Rearing	2+-Age Inactive
Spokane River Mainstem 18b	2001	500[a]	160,875	97,578	44,322	31,237	20,737	13,727	7,931	5,464
	2002	500[a]	161,387	98,129	44,096	31,847	21,528	13,944	8,017	5,601
	2003	5,464	1,432,637	566,917	177,296	87,128	39,311	20,337	10,145	6,355
	2004	5,601	1,466,759	576,829	178,932	89,902	40,972	19,484	9,333	6,069
	2005	6,355	1,603,033	611,475	189,121	87,880	37,895	19,051	9,367	5,887
	2006	6,069	1,562,812	602,126	178,240	86,186	38,193	18,161	8,545	5,593
	2007	5,887	1,523,660	587,290	179,857	82,811	34,801	17,646	8,806	5,889
	2008	5,593	1,452,045	581,284	169,495	81,336	36,278	18,937	9,393	5,847
	2009	5,889	1,516,088	586,029	174,356	86,319	38,468	17,982	8,556	5,498
	2010	5,847	1,505,416	602,118	185,159	83,130	35,101	17,229	8,377	5,616
	2011	5,498	1,452,949	596,998	171,871	79,943	34,512	18,085	9,036	5,879
	2012	5,616	1,472,396	586,860	168,955	83,285	37,215	18,590	8,957	5,882
	2013	5,879	1,516,554	586,737	176,392	84,539	36,531	18,606	9,253	6,019
	2014	5,882	1,532,690	595,173	174,502	84,775	37,898	18,979	9,270	5,859
	2015	6,019	1,502,595	576,668	186,975	88,236	38,245	18,235	8,590	5,537
	2016	5,859	1,510,398	582,990	179,813	83,045	34,972	17,316	8,483	5,677
	2017	5,537	1,454,239	569,978	166,945	79,146	34,740	18,202	9,052	5,862
	2018	5,677	1,462,130	571,465	169,350	83,617	37,218	18,468	8,994	n/a
Spokane River Mainstem 18c	2001	500[a]	159,661	95,650	41,920	27,805	16,229	10,018	5,487	3,739
	2002	500[a]	160,040	96,011	40,717	27,612	16,932	10,306	5,581	3,840
	2003	3,739	995,673	422,460	128,409	60,830	26,175	13,464	6,620	4,155
	2004	3,840	1,019,402	429,561	127,685	62,012	27,215	12,859	6,070	3,961
	2005	4,155	1,080,017	446,863	135,666	60,484	25,073	12,567	6,080	3,960
	2006	3,961	1,045,312	437,534	125,374	58,856	25,140	12,557	5,670	3,747
	2007	3,960	1,044,292	435,370	131,514	60,293	23,497	11,996	5,757	3,883
	2008	3,747	994,820	425,396	115,099	55,427	23,638	12,526	6,208	3,918
	2009	3,883	1,025,013	430,331	124,163	59,997	26,012	12,275	5,633	3,695

Optimal Carrying Capacity



CONFLUENCE

Enter Spawning and Incubation Flows	March	April	May	June 1-15
	11,000	11,000	8,000	6,000

Select Representative Flows for Redband Trout Rearing	Rearing Year	Percentile (of mean annual flow 2001-2020)	Representative Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Year 0	5th	2001			11,000	11,000	8,000	3,640	1,348	702	916	1,936	2,525	4,387
	Year 1	10th	2010	3,157	3,254	3,521	6,074	9,368	12,201	2,887	1,136	1,374	2,072	3,206	6,333
	Year 2	5th	2001	1,523	1,615	2,385	4,843	10,631	3,640	1,348	702	916	1,936	2,525	4,387

Enter Spawning Population Parameters	Parameter	Reach	Enter Value	Definition
	Enter # of Spawners	Spokane Mainstem	500	Number of spawners in index reach from Spokane Falls to riffle crest 0.2 km downstream of Hangman Creek
	Enter # of Spawners	Spokane Mainstem	500	Number of spawners in index reach from Hangman riffle crest to 1.46 km downstream of TJ Meenach Bridge
	Enter Fecundity		1,100	Eggs per female spawner (default value 1,100)
	Sex Ratio (F/M)		0.5	Ratio of females to males (default value 0.5)
	Select Flow-Based Incubation Capacity	Min / Max / Average		Click button to select flow value used to estimate habitat capacity for spawning and incubation: - Min = Minimum of geometric mean monthly flows during spawning period - Average = Average of geometric mean monthly flows during spawning period - Max = Maximum of geometric mean monthly flows during spawning period

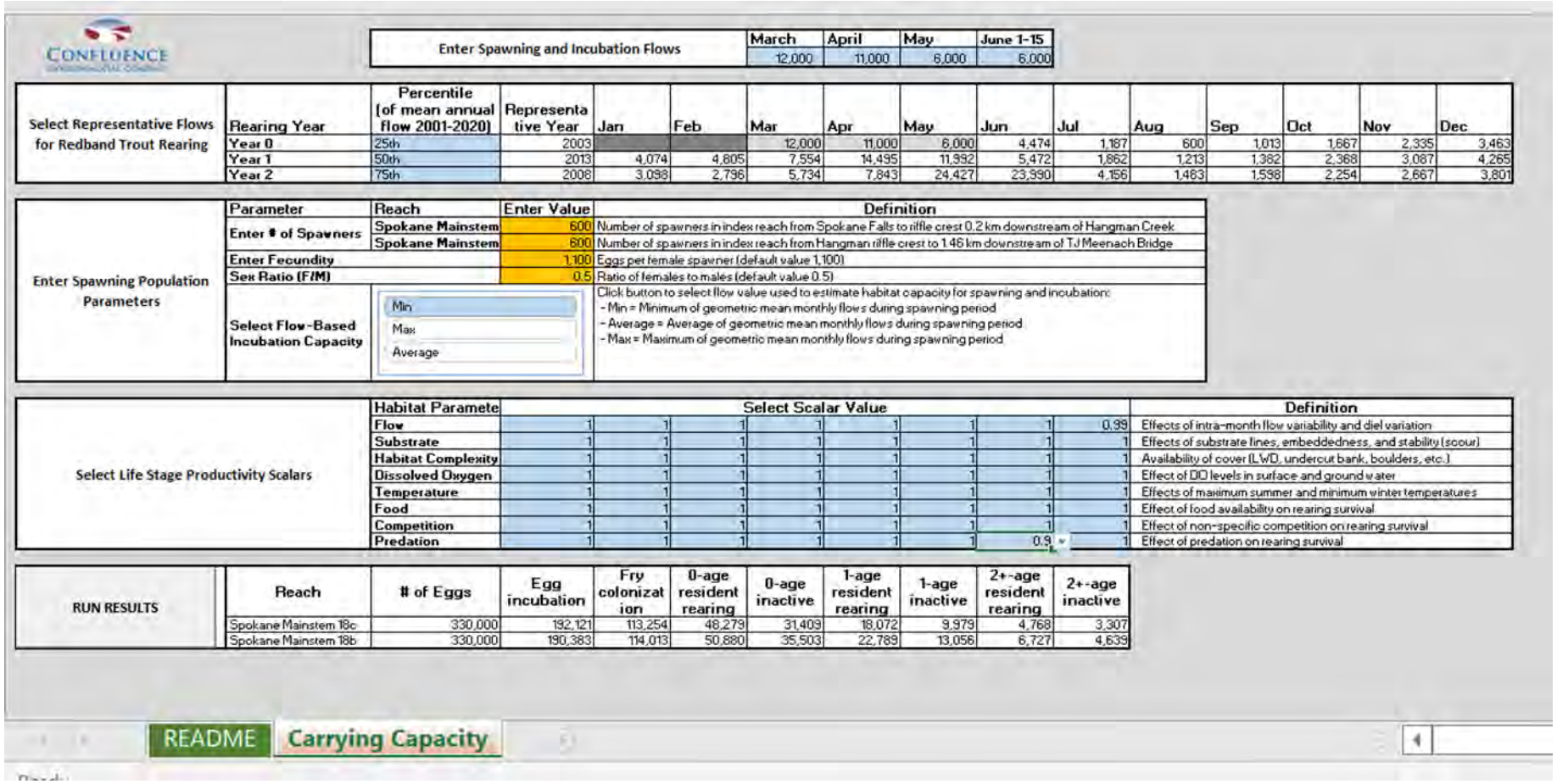
Select Life Stage Productivity Scalars	Habitat Parameter	Select Scalar Value								Definition
	Flow	1	1	1	1	1	1	1	0.99	Effects of intra-month flow variability and diel variation
	Substrate	1	1	1	1	1	1	1	1	Effects of substrate fines, embeddedness, and stability (scour)
	Habitat Complexity	1	1	1	1	1	1	1	1	Availability of cover (LWD, undercut bank, boulders, etc.)
	Dissolved Oxygen	1	1	1	1	1	1	1	1	Effect of DO levels in surface and ground water
	Temperature	1	1	1	1	1	1	1	1	Effects of maximum summer and minimum winter temperatures
	Food	1	1	1	1	1	1	1	1	Effect of food availability on rearing survival
	Competition	1	1	1	1	1	1	1	1	Effect of non-specific competition on rearing survival
	Predation	1	1	1	1	1	1	1	1	Effect of predation on rearing survival

RUN RESULTS	Reach	# of Eggs	Egg incubation	Fry colonization	0-age resident rearing	0-age inactive	1-age resident rearing	1-age inactive	2+-age resident rearing	2+-age inactive
	Spokane Mainstem 18c	275,000	160,897	96,332	42,181	28,504	17,232	10,197	5,628	3,857
	Spokane Mainstem 18b	275,000	159,616	96,979	44,075	31,718	21,281	13,308	7,830	5,424

README | Carrying Capacity

Ready

Optimal Carrying Capacity



CONFLUENCE

Enter Spawning and Incubation Flows	March	April	May	June 1-15
	12,000	11,000	6,000	6,000

Select Representative Flows for Redband Trout Rearing	Rearing Year	Percentile (of mean annual flow 2001-2020)	Representative Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Year 0	25th	2003			12,000	11,000	6,000	4,474	1,187	600	1,013	1,667	2,335	3,463
	Year 1	50th	2013	4,074	4,805	7,554	14,495	11,392	5,472	1,862	1,213	1,382	2,368	3,087	4,265
	Year 2	75th	2008	3,098	2,796	5,734	7,843	24,427	23,990	4,156	1,483	1,598	2,254	2,667	3,801

Enter Spawning Population Parameters	Parameter	Reach	Enter Value	Definition
	Enter # of Spawners	Spokane Mainstem	600	Number of spawners in index reach from Spokane Falls to riffle crest 0.2 km downstream of Hangman Creek
		Spokane Mainstem	600	Number of spawners in index reach from Hangman riffle crest to 1.46 km downstream of TJ Meenach Bridge
	Enter Fecundity		1,100	Eggs per female spawner (default value 1,100)
	Sex Ratio (F/M)		0.5	Ratio of females to males (default value 0.5)
	Select Flow-Based Incubation Capacity	Min / Max / Average		Click button to select flow value used to estimate habitat capacity for spawning and incubation: - Min = Minimum of geometric mean monthly flows during spawning period - Average = Average of geometric mean monthly flows during spawning period - Max = Maximum of geometric mean monthly flows during spawning period

Select Life Stage Productivity Scalars	Habitat Parameter	Select Scalar Value							Definition
	Flow	1	1	1	1	1	1	0.99	Effects of intra-month flow variability and diel variation
	Substrate	1	1	1	1	1	1	1	Effects of substrate fines, embeddedness, and stability (scour)
	Habitat Complexity	1	1	1	1	1	1	1	Availability of cover (LWD, undercut bank, boulders, etc.)
	Dissolved Oxygen	1	1	1	1	1	1	1	Effect of DO levels in surface and ground water
	Temperature	1	1	1	1	1	1	1	Effects of maximum summer and minimum winter temperatures
	Food	1	1	1	1	1	1	1	Effect of food availability on rearing survival
	Competition	1	1	1	1	1	1	1	Effect of non-specific competition on rearing survival
	Predation	1	1	1	1	1	1	0.9	Effect of predation on rearing survival

RUN RESULTS	Reach	# of Eggs	Egg incubation	Fry colonization	0-age resident rearing	0-age inactive	1-age resident rearing	1-age inactive	2+-age resident rearing	2+-age inactive
	Spokane Mainstem 18c	330,000	192,121	113,254	48,279	31,409	18,072	9,979	4,768	3,307
	Spokane Mainstem 18b	330,000	190,383	114,013	50,880	35,503	22,789	13,056	6,727	4,639

README | Carrying Capacity

AVISTA

Conclusions

- Redband abundance is below carrying capacity; Redband population does not currently appear to be affected by density dependence
- Variations in flow during spawning and incubation had a moderate effect on age 1, not age 0
- Generally, incubation flows should be within 2,000 cfs of the spawning flows to maximize age-1 recruitment
- Spawning flows above 18,000 cfs provide no additional habitat or recruitment benefit
- At spawning and incubation flows below 10,000 cfs, age-1 recruitment begins to drop off precipitously

Questions?