Kootenai River Habitat Restoration Project Master Plan

Appendix D – Prioritized Fish and Physical Habitat Factors

Kootenai Tribe of Idaho

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Appendix D – Prioritized Fish and Physical Habitat Factors

This appendix is adapted from a draft report prepared for the Kootenai Tribe of Idaho by Paul Anders, Cramer Fish Sciences and Rich McDonald and Jon Nelson, U.S. Geological Survey, as part of the coordination activities and information gathering activities associated with this Kootenai River Habitat Restoration Master Plan project. The unpublished draft report was completed in July 2008 but has not been finalized at this point. The information in this appendix is provided as support to the aquatic limiting factors discussion presented in Chapter 2 of the Master Plan, and specifically, to provide additional background information for Section 2.6.1, Tables 2-13 through 2-18.

Introduction

As part of the Kootenai Tribe's Master Planning phase for the Kootenai River Habitat Restoration Project, the Tribe convened a multidisciplinary project design team to help provide advice, input and technical review, in the development of various work products. One of the products this design team helped to develop was a table prioritizing fish and physical habitat factors for the six focal aquatic species that are being considered in development of the Kootenai River Habitat Restoration Plan. The intent of this product was to provide a tool that could help designers identify a common suite of prioritized habitat factors that would satisfy requirements for Kootenai River fishes and could help guide the physical habitat requirements for development of appropriate habitat restoration actions.

Methods

Using a spreadsheet template developed and partially populated by Paul Anders as a starting point; a draft spreadsheet of prioritized habitat factors supporting fish and habitat design requirements was reviewed and compiled during a one-day Kootenai River Habitat Restoration Project "Design Team Plus" meeting in Spokane Washington on July 1, 2008. Participants at this meeting included: co-managers including regional fish biologists and Kootenai Tribe staff; the Tribe's river design contractors; and agency representatives from BPA, USFWS, USACE, and USGS. Participants at the meeting represented a broad range of disciplines.

To develop the 2008 draft report, the list of existing habitat factors was reviewed and prioritized for white sturgeon and design needs. Because of the central importance to this project and its role as an endangered, indicator species of Kootenai River ecosystem health, Kootenai sturgeon was presented as the primary species of concern. However, due to their ecological and management importance, quantitative information from the other focal fish species was also reviewed and included where relevant and different from (not covered by) sturgeon habitat requirements.

Critical Kootenai sturgeon life stages were identified. The matrix was then reviewed one cell at a time by life stage and assigned a "1" or a "2". A priority score of "1" represented a quantifiable factor that was supported or confirmed by empirical data, and was controllable in design. A priority score of "2" represented a quantifiable factor, controllable in design that was believed to be important but lacked empirical data ranges or confirmation. Blank cells in the matrices indicated no relation between particular life stages and habitat factor combinations.

After the July 1 meeting, the updated table was circulated for additional review and to help fill gaps left from the July meeting. A condensed matrix was subsequently produced including only habitat factors that received a ranking of a "1" or "2". Using this condensed matrix, Paul Anders produced a final spreadsheet with quantitative, life stage-specific information for Kootenai sturgeon. Behavioral and habitat use information included in this table for early life stages of Kootenai sturgeon was provided by recent empirical research outside the Kootenai River due to the absence of life stages beyond embryos in the river (Kynard and Parker 2006; Kynard et al. 2007; Kynard et al. 2008). Additional information about migrating and pre-spawning adults was provided by recent empirical work on the Kootenai River.

Results

Tables 1 through 15 in the following section present the results of these exercises. Following is an abbreviated discussion regarding the first three "roll up" tables.

White Sturgeon and Habitat Design and Evaluation Criteria

Spawning adult, embryo, and free embryo life stages of Kootenai River white sturgeon were determined to be of primary importance due to their association with long-term and ongoing recruitment failure (Table 1). Remaining life stages (non-reproductive and migrating adults, larvae and juveniles) were assigned a status of secondary importance.

A total of 15 individual habitat factors constituting aspects of substrate, cover, hydraulics, and hydrology were identified as valuable for evaluating fish (white sturgeon) and physical habitat design. Thirty-four observations for these habitat factors across white sturgeon life stages were given a ranking of "1" (a quantifiable factor for fish and physical habitat design, was supported or confirmed by empirical data, and was controllable in design), whereas 6 were scored with a "2" (a quantifiable factor, controllable in design, and thought to be important, but lacked empirical data ranges or confirmation) (Table 1).

Channel geometry habitat factors previously included in fish habitat factor analysis were determined to be larger scale habitat design features rather than specific evaluation criteria and therefore were not ranked in this habitat factor prioritization process. However they remain important features of habitat design options for biological, ecological, and physical reasons.

A condensed matrix was then produced as a more effective way to visualize prioritized, common habitat factors (Table 2). This matrix was then populated with quantitative habitat factor values ranges where available for white sturgeon (Table 3).

Additional Focal Species and Habitat Design and Evaluation Criteria

Due to their ecological and management importance, quantitative habitat requirement information for the other focal fish species was also reviewed and included where relevant to habitat factor prioritization.

Table 1. Initial prioritization of habitat factors for white sturgeon and habitat design and evaluation needs.

Legend:
- (red) Life stage of primary importance/limitation
- (yellow) Life stage of secondary importance/limitation
- **1** Quantifiable, supported or confirmed by empirical data, controllable in design
- **2** Quantifiable, controllable in design, thought to be important but lack empirical data ranges or confirmation

Species:	White Sturgeon		River Reach									Water Quality					Substrate				Cover								Hydraulics						Hydrology		Design Features: Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal extent (Length)	Interstitial Space	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Non-reproductive Adult	Rest years	Year-round	X					X		X	X																		1			1															
Migrating Adult	Within-year pre-spawner	January to May			X	X	X	X		X	X																		1			1				1											
Spawning Adult	In spawning habitat	May-July				X	X	X									1	1	1						2				1	1		1				1											
Embryo	Fertilized egg	May-July				X	X	X									1	1	1	1							2		1		2			1		1											
Free embryo	Post-hatch, endogenously feeding	June-Aug				X	X	X									1	1	1	1	1				1	2			1		2					1											
Larva	Exogenous feeding	June-Aug								X															1				1			1															
Age 0+ Juvenile	Full fin complement	~ 65 d.; fall						X		X	X														1				1			1															

Table 2. Condensed matrix of prioritized habitat factors for white sturgeon and physical habitat design.

Legend:		
	Red	Life stage of primary importance/limitation
	Yellow	Life stage of secondary importance/limitation
	1	Quantifiable, supported or confirmed by empirical data, controllable in design
	2	Quantifiable, controllable in design , thought to be important but lack empirical data ranges or confirmation

Species:	White Sturgeon		River Reach										Substrate				Cover				Hydraulics			Hydrology
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Water Temperature	Type	Particle size distribution	Longitudinal extent	Interstitial Space	Depth/ incident light	Hydraulic cover	Large woody debris	Bedforms	Velocity Varibility	Boundary sheer stress	Bedload transport	Flow duration, frequency, and magnitude
Non-reproductive Adult (yellow)	Rest years	Year-round	X					X		X	X										1			
Migrating Adult (yellow)	Within-year pre-spawner	January to May			X	X	X	X		X	X										1			1
Spawning Adult (red)	In spawning habitat	May-July				X	X	X					1	1	1			2			1			1
Embryo (red)	Fertilized egg	May-July				X	X	X					1	1	1	1				2	1	2	1	1
Free embryo (red)	Post-hatch, endogenously feeding	June-Aug				X	X	X					1	1	1	1	1	1	2		1	2		1
Larva (yellow)	Exogenous feeding	June-Aug								X								1			1			
Age 0+ Juvenile (yellow)	Full fin complement	~ 65 d.; fall						X		X	X							1			1			

Table 3. Quantitative matrix of prioritized factors for white sturgeon and physical habitat design.

Species:	White Sturgeon		River Reach										Substrate			Cover					Hydraulics			Hydrology
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Water Temperature	Type	Particle size distribution	Longitudinal extent (Length)	Interstitial Space	Depth/ incident light	Hydraulic cover	Large woody debris	Bedforms	Velocity Structure	Boundary sheer stress	Bedload transport	Flow duration, frequency, and magnitude
Non-reproductive Adult	Rest years	Year-round	X					X		X	X										1			Largely affected by hydro operations; to be taken into account regrading target design hydraulic parameter targets (Dispersal of free embryos and larvae may be affected by cover, substrate size and velocity)
Migrating Adult	Within-year pre-spawner	January to May			X	X	X	X		X	X										1			
Spawning Adult	In spawning habitat	May-July				X	X	X				9-14 C	X_1 Pebbles (30-40mm dia) but small enough to provide predation refugia		≥ 5 mi (BiOp)	X2 Need interstitial space or incubation environment for newly produced embryos (2-3 mm dia) to settle on/into that preclude suffocation and predation	ADD: BiOp Spawning depth criterion:	Areas of low velocity adjacent to spawning sites may be used during staging and spawning		Rocks, bars, bathymetric irregularities on the bed may provide desirable hydraulic conditions for spawning	0.7- 1.2 mps, but Kootenai sturgeon spawn in raches generally characterized by lower velocity; However, adeqaute hydraulics are needed to maintain suitable benthic environment; and Kootenai fish may spawn in smller scale velocity hotspots smaller thatn cu			
Embryo	Fertilized egg	May-July				X	X	X				9-16 C	X_1 Rubble (64-80 mm dia) (vs gravel and pebbles) caused increase in foraging		≥ 5 mi (BiOp)	X1 Pebbles (30-40mm dia) but small enough to provide predation refugia; X2 gravels cobbles, debris able to contain 2-3 mm dia embryos				Rocks, bars, bathymetric irregularities on the bed may provide desirable hydraulic refuge (cover) conditions for embryo and early free embryo habitat occupancy	adeqaute shear stress/velocity to maintain clean interstitial space, no sediment depositon	2	Bedload transport sufficient not to kill incubating embryos	
Free embryo	Post-hatch, endogenously feeding	June-Aug				X	X	X					X_4 Age 0 fsh preferred small substrate		≥ 5 mi (BiOp)	X3 0-6 day FE R photonegative when not dispersing seek cover, inluding interstitial space;	X3 early free embryos (day 0-6) photoneg, no substrate color preference (light/dark), late FE (days 7-14) become photo+	1	2		X4 Downstream dispersal positively affected by velocity (~ 24 cm/s vs 16)	2	Bedload transport sufficient not to kill early free embryos in hiding	
Larva	Exogenous feeding	June-Aug								X						X3 after a few weeks larvae become strongly photopositive, leave cover and forage on open bottom	X3 After day 13 develop into larvae, begin foraging, leave cover seek open bottom ; become photopositive	1		Rocks, bars, bathymetric irregularities on the bed may provide desirable hydraulic refuge (cover) conditions for larvae and juvenile habitat occupancy	X4 a positive velocity trigger for dispersal may exist for early larvae; most larve in experiments used edge not channel or eddy habitats			
Age 0+ Juvenile	Full fin complement	~ 65 d.; fall						X		X	X		Age 1 fish prefrered larger substrate (Kynard); obervations of Age 1 Kootenai and Upper Columbia fish over sand and				X4 Age 0 and 1 juvs preferred dark habitat during winter(dark substrate and low or no light)	1			1			

Table 4. Glossary of prioritized habitat factors.

Water Quality	Water temperature:	For sturgeon spawning, $\geq$ 9°C
	Nutrient availability:	Nutrient/food availability is important to all exogenously feeding life stages of all fish species, but is not directly affected by channel design
Substrate	Substrate type:	Sand, gravel, cobble, boulder, bedrock
	Particle size distribution:	D_{16} D_{50} $D_{80;}$ If the size of sturgeon embryos (~3mm diameter) is 1/6 of $D_{50,}$ then there should be adequate interstitial space; same is true for free embryo using free embryos dimensions
	Lateral extent (length):	Length or distance downstream of particular substrate type; relevant to free embryo or embryo incubation habitat
	Interstitial space:	If the size of sturgeon embryos (~3mm diameter) is 1/6 of $D_{50,}$ then there should be adequate interstitial space; same is true for free embryo using free embryos dimensions
Cover	Depth/Incident light:	For sturgeon, relevant to ~first 5 days post-hatch when they are negatively phototaxic
	Hydraulic cover:	Local areas of reduced velocity, flow, or turbulence associated with (just downstream from) bedforms, rock, large woody debris used by fish
	Large woody debris:	Although ranked as a secondary habitat factor for white sturgeon, large woody debris is an important component of habitat cover and complexity for various native resident and adfluvial salmond species life stages in the Kootenai River.
	Bedforms:	Ripples and dunes on the channel bed that are typically fairly small in height relative to the depth of water (larger features are generally called "bars"). These features are important due to their role in creating hydraulic roughness through form drag and, in at least some cases, their lee (downstream) sides are used as low-velocity refugia for certain aquatic species.
Hydraulics	Velocity structure:	Could be redefined as "velocity structure", to include velocity, velocity variability, and lateral sheer; Hydraulic cover, as well as it's described components, can be quantitatively described down to the smallest cell dimensions in the USGS modeling.
	Boundary shear stress:	Force in the downstream direction exerted by the flowing water on the bed per unit area of the channel bed. Equivalently, the actual skin friction force by the bed on the flowing water. So-called "total" boundary shear stress may also include pressure drag on bars and bedforms.
	Bedload transport:	In the braided reach, enough to not suffocate embryos and not scour them,; In meander reach: enough to scour clay layers before spawning
Hydrology	Flow duration, frequency and magnitude:	Largely determimed by hydrosystem operations in the Kootenai River downstream from Libby Dam

Table 5. White sturgeon - River Reaches, Water Quality, and Substrate. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

White Sturgeon		River Reach									Water Quality					Substrate			
Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal aspect	Interstitial Space
Rest years	Year-round	? X	? X				X		X	X	X	X	?	X	X				
Within-year pre-spawner	January to May			X	X	X	X		X	X	X	X	?		X				
In spawning habitat	May-July				X	X	X				X	X	?		X	X	X	X	X_2 Need interstitial space or incubation environment for newly produced embryos (2-3 mm dia) to settle on/into that preclude suffocation and predation
Fertilized egg	May-July				X	X	X				X	X	X		X	X	X	X	X1 Pebbles (30-40mm dia) but small enough to provide predation refugia; X2 gravels cobbles, debris able to contain 2-3 mm dia embryos
Post-hatch, endogenously feeding	June-Aug				? ?	X	X				X	X	X		X	X	X_1 Pebbles (30-40mm dia) but small enough to provide predation refugia	X	X_3 0-6 day FE are photonegative when not dispersing seek cover, inluding interstitial space;
Exogenous feeding	June-Aug					?		? X	?		X	X	X	X	X	X	X_1 Rubble (64-80 mm dia) (vs gravel and pebbles) caused increase in foraging behaviour at expense of migration	X	X_3 after a few weeks larvae become strongly photopositive, leave cover and forage on open bottom
Full fin complement	~ 65 d.; fall						X		X	X	X	X	X	X	X	X	X_4 Age 0 fsh preferred small substrate ; Age1 fish preferred larger substrate	X	?

Table 6. White sturgeon - Cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	White Sturgeon		Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Non-reproductive Adult	Rest years	Year-round	X				X	?	X	?	X	X	X	X	X	X		X	X	X	?	X					X		
Migrating Adult	Within-year pre-spawner	January to May	X			?	?	?	?	?	X	X	X	X	?	X		X		X	?	X	?				X		X
Spawning Adult	In spawning habitat	May-July					X		X	Rocks, bars, bathymetric irregularities on the bottom may provide desirable hydraulic conditions for spawning	0.7- 1.2 mps, but Kootenai sturgeon spawn in raches generally characterized by lower velocity; However, adeqaute hydraulics are needed to maintain suitable benthic environment; and Kootenai fish may spawn in smller scale velocity hotspots smaller thatn current resolution picks up	X_1	X_1	X_1	X_1	X	X	X		?	?	?					X		X
Embryo	Fertilized egg	May-July				?	?	? X	X	?	X adeqaute shear stress/velocity to maintain clean interstitial space, no sediment depositon	X	X	X	X	X	X	X	X		X	X					X		
Free embryo (FE)	Post-hatch, endogenously feeding	June-Aug	X_3 early free embryos (day 0-6) photoneg, no substrate color preference (light/dark), late FE (days 7-14) become photo+			X_3 when not dispersing, early free embryos (0 6d) seek and hide under cover					X_4 Downstream dispersal positively affected by velocity (~ 24 cm/s vs 16)	X	X	X	X	X		X		X	X	X					X		X
Larva	Exogenous feeding	June-Aug	X_3 After day 13 develop into larvae, begin foraging, leave cover seek open bottom ; become photopositive			X	X	?	?	X_1 Rubble (64-80 mm dia) (vs gravel and pebbles) caused increase in foraging behaviour at expense of migration	X_4 a psitive velocity trigger for dispersal may exist for early larvae	X 4 Most larvae used edge not channel or eddy habitat						X1 dispersal affected by cover, substrate size and velocity	?	?	?	X		?	X		X ?	?	X
Age 0+ Juvenile	Full fin complement	~ 65 d.; fall	X_4 Age 0 and 1 juvs preferred dark habitat during winter(dark substrate and low or no light)			X	X	X	X	X	X ?	X ?	X ?	X ?	X ?	X ?		X	X	X	X	X		X	X	?	X ?	?	X

Table 7. Burbot - River reaches, water quality, substrate, cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Burbot		River Reach									Water Quality					Substrate				Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ Seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal aspect	Interstitial Space	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Non-reproductive adult	Rest year individual	year-round	X				X	X		X	X	2-22°C	X		X	X					X				X				X	X	X					X		X									
Migrating adult	Reproductive migration	late fall - winter					X	X		X	X	2-8°C	X		X	X					X				X				X	X	X					X		X				?	?	X			
Spawning adult	In spawning habitat	winter, late winter				?	X	X	X		X	2-4°C	X		X	X	X	X			X				X				X	X	X					X		X				?	?	X			
Embryo	Fertilized egg	late winter				?	X	X	X		X	2-6°C	X		X	X	X	X											X	X												?	?				
Free embryo	Yolk sac (endogenous feeding)	March-June					X	X	X	X	X	6-10°C	X		X	X													X	X												?	?				
Larva	Exogenous feeding	Apr-June					X	X	X	X	X	6-10°C	X		X	X													X	X												?	?				
YOY	yearling	Jan-Dec					X	X	X	X	X	10-15°C	X		X	X													X	X			X														
Juvenile	> Age 1	year round					X	X		X	X	2-22°C	X		X	X					?								X	X																	

Table 8. Bull trout - River reaches, water quality and substrate. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Bull trout		River Reach									Water Quality					Substrate			
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal aspect	Interstitial Space
Migrating adult	Reproductive migration		X	X	X	X	X X	X X	X X		X	10-12°C (daily average)[2]			X		cobbles and boulders for cover	50% cobble and gravel/40% boulder/<10% fines		
Spawning Adult	In spawning habitat	Sept-Oct	X				X	X	X			<9°C (7DADM)[1]			X		course substrate of gravel to cobble (16-64 mm diameter)		X	
Embryo	Fertilized egg	winter	?						X			2 - 6°C(daily average)	≥ 7 mg/l	< 4.0 NTU	X	Zero to low levels of pollutants/ contaminants	X	<35-40% (< 6.35 mm) <10% fine sediment (<1.0 mm)	X	high substrate permeability to aerate eggs (<25% embeddedness)
Alevins	Pre-emergence yolk-sac stage	early spring	?						X						X		X		X	
Fry	Exogenously feeding	spring	?						X			X			Juveniles feed primarily on aquatic inverts until >100 mm at which time they become piscivorous		unembedded course substrate of gravel to cobble	50% cobble and gravel/40% boulder/<10% fines		f
Fingerling	Yearlings	summer-winter	?						X			10-13°C(daily average)[3]								juveniles over-winter in interstitial space a
Juvenile	> Age 1	Year round	X	X	X	X	X	X	X	X	X							50% cobble and gravel/40% boulder/<10% fines		

Table 9. Bull trout -Cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Bull trout		Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Migrating adult	Reproductive migration		X	X	X		X	X	?	?	fluvial adults are strongly associated with pools and low water velocity habitat within swift stream reaches	X	X	X	X	X			d	X	?	?	X	?	?	migratory bull trout are strongly associated with seasonal use of tributary habitat	low-gradient stream reaches		1:1-0.4:1 (p:riffle ratio)
Spawning Adult	In spawning habitat	Sept-Oct	X					e			X	X	X	X	?	X				X	X		X				X		
Embryo	Fertilized egg	winter									X	X	X	X	X	X	embyo survival higher in groundwater upwelling sites	Flooding every 1.5–2 years			?						X	Natural vegetatio n extends >2 active channel widths on each side	
Alevins	Pre-emergence yolk-sac stage	early spring									X	X	X	X	X	X					?						X		
Fry	Exogenously feeding	spring	X	?				X				X	X	X	X	X				X	?		X		X		X		
Fingerling	Yearlings	summer-winter	X	X	X		X	X		?	strong preference for low water velocity, juveniles use slow water pockets w/in swift stream reaches	X	X	X	X					X	?		X	?	X	migratory bull trout are strongly associated with seasonal use of tributary habitat	X		1:1 - 0.4:1 (pool:riff le ratio)
Juvenile	> Age 1	Year round	X	X	X		X	X		?		X	X	X	X	X			b	X	?	b	X	?	X		X		

Table 10. West slope cutthroat - River reaches, water quality and substrate. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Westslope Cutthroat		River Reach									Water Quality					Substrate			
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal aspect	Interstitial Space
Migrating adult	Reproductive migration		X ?	?	?				X			2 - 10°C 2	> 7 mg/l	< 4.0 NTU	X	Zero to low levels of pollutants/contaminants	cobbles and boulders for cover	50% cobble and gravel/40% boulder/<10 % fines		
Spawning Adult	In spawning habitat	March-May	X						X						X		course substrate of gravel to cobble (16-64 mm diameter)		X	X
Embryo	Fertilized egg	March-June							X						X				X	X
Alevins	pre-emergence yolk-sac stage	May-July							X						X				X	X
Fry	Exogenously feeding	May-July	?	?	?				X			10 - 17°C (daily average)1			Intact riparian corridors that provide substanital source of Terrestrial Invertebrates May-November. Terrestrial/ Aquatic interface.		course substrate of gravel to cobble			
Fingerling	Yearling	Summer-Winter	X ?	?	?				X			10 - 17°C (daily average)1								X
Juvenile	> Age 1	Year round	X ?	?	?				X											X

Table 11. West slope cutthroat - Cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Westslope Cutthroat		Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Migrating adult	Reproductive migration		X	X	X	X	?	?	?	?	X	X	X	X	?	?	?		X	0.18m	Natural channel; no evidence of human caused erosion	?	X	?	?	X	X		1:1 - 0.4:1 (pool:riffle ratio)
Spawning Adult	In spawning habitat	March-May	X	X	X	X			a		16 to 60 cm/s	X	X	X			X		X	9 to 30 cm (min)			X		a	X	X		
Embryo	Fertilized egg	March-June	X	X	X	X	X	?			X	X	X	X	X	?	X				?						X		
Alevins	pre-emergence yolk-sac stage	May-July	X	X	X	X	X	?			X	X	X	X	X	?		Flooding every 1.5–2 years			?						X	Natural vegetation extends >2 active channel widths on each side	
Fry	Exogenously feeding	May-July	X	X	X	X					X	X	X	X					X	X	?		X		X	X	X		
Fingerling	Yearling	Summer-Winter	X	X	X	X	?			?		X	X	X	?				X		?		X	?	X	X	X		1:1 - 0.4:1 (pool:riffle ratio)
Juvenile	> Age 1	Year round	X	X	X	X	?			?	11-72 cm/s	X	X	X	?				X	6 cm (min)	?		X	?	X	X	X		

Table 12. Redband trout - River reaches, water quality and substrate. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Redband Trout		River Reach									Water Quality					Substrate			
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size distribution	Longitudinal aspect	Interstitial Space
Migrating adult	Reproductive migration		X	X	X	X	X	X X	X	X	X X	10 - 130C 2	> 7 mg/l	< 4.0 NTU		Zero to low levels of pollutants/ contaminants	cobbles and boulders for cover	50% cobble and gravel/40% boulder/<10 % fines		
Spawning Adult	In spawning habitat	March-April	X ?					X	X		X	4 - 120C 2	> 7 mg/l	< 4.0 NTU	X		course substrate of gravel to cobble (16-64 mm diameter)		X	X
Embryo	Fertilized egg	March-May	?						X			5 - 110C 2	> 7 mg/l	< 4.0 NTU	X		X		X	X
Alevins	Pre-emergence yolk-sac stage	April-May	?						X			X	> 7 mg/l	< 4.0 NTU	X		X		X	X
Fry	Exogenously feeding	May-June	?	?	?	?	?	?	X			X	> 7 mg/l	< 4.0 NTU	Intact riparian corridors that provide substanital source of		course substrate of gravel to cobble (16-64 mm diameter)			
Fingerling	Yearling	Summer-Winter	X	X	X	X	X	X X	X			10 - 170C 1	> 7 mg/l	?						X
Juvenile	> Age 1	Year round	X X	X	X	X	X	X X	X	X	X X	10 - 170C1	> 7 mg/l	?						X

Table 13. Redband trout - Cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Redband Trout		Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended solids	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided, meander	Floodplain	Connection w/ off-channel habitat	Connection w/ tributary habitat	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Migrating adult	Reproductive migration		X	X	X		X	X	?	?	X	X	X	X	?	?	?	Flooding every 1.5–2 years		0.18 m	?	?	X	?	?	X	X	Natural vegetation extends >2 active channel widths on each side	1:1 - 0.4:1 (pool:riffle ratio)
Spawning Adult	In spawning habitat	March-April	X								X	X	X	X						0.15-1.2 m	Natural channel; no evidence of human caused erosion		X			X	X		
Embryo	Fertilized egg	March-May									X	X	X	X		?	X				?		X				X		
Alevins	Pre-emergence yolk sac stage	April-May									X	X	X	X		?	X				?		X				X		
Fry	Exogenously feeding	May-June	X	?				X			X	X	X	X						X	?		X		X	X	X		1:1 - 0.4:1 (pool:riffle ratio)
Fingerling	Yearling	Summer-Winter	X	X	X		X	X			48-91 cm/s	X	X	X						18 cm	?		X	?	X	X	X		
Juvenile	> Age 1	Year round	X	X	X		X	X				X	X	X							?		X	?	X	X	X		

Table 14. Kokanee - River reaches, water quality and substrate. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Kokanee		River Reach									Water Quality					Substrate			
Life Stage	Life Stage Description	Duration/ seasonality	Canyon	Braided 1	Braided 2	Straight 1	Straight 2	Meander	Tributaries	Delta	Kootenay Lake	Temperature	Dissolved Oxygen	Turbidity/SS	Nutrient availability	Other WQ factors	Type	Particle size	Longitudinal aspect	Interstitial Space
Migrating adult	Reproductive migration	late summer, early fall	X	X	X	X	X	X		X	X	7 - 15^{0}C 2 (sockeye)	> 7 mg/l	< 4.0 NTU	X	Zero to low levels of pollutants/ contaminants				
Spawning Adult	in spawning habitat	mid Aug-Sept	X						X			5 - 12^{0}C 2 (Kokanee)			X		course substrate of gravel to cobble (12-25 mm)	X	X	X
Embryo	Fertilized egg	winter							X			4.5- 10^{0}C 2 (sockeye)			X			X	X	X
Alevins	pre-emergence yolk-sac stage	early spring							X			X			X		course substrate of gravel to cobble	X	X	X
Fry	Exogenously feeding	spring		X	X	X	X	X	X	X	X	X			availability of zooplankton, plants, algae. Limited non-native species competition			X		
Fingerling	Yearling	summer-winter						X X	X X	X	X	10- 15^{0}C 2 (sockeye)								
Juvenile	> Age 1	year round						X		X	X									

Table 15. Kokanee - Cover, hydraulics, hydrology and channel geometry. Source: Habitat Suitability Matrices by Species and Life Stage (from Anders 2008).

Species:	Kokanee		Cover								Hydraulics						Hydrology		Channel geometry										
Life Stage	Life Stage Description	Duration/ seasonality	Depth/ incident light	Canopy/shade	Undercut banks	Turbidity/suspended	Hydraulic cover	Large woody debris	Bedforms	Roughness	Velocity	Velocity variability	Boundary sheer stress	Lateral sheer	Roughness	Bedload transport	In-channel groundwater/ surface water interaction	Flow duration, frequency, and magnitude	Habitat diversity	Depth	Channel stability	Eddy geometry	Single vs. braided,	Floodplain	Connection w/ off-channel	Connection w/ tributary	Slope/Gradient	Riparian Zone	Pool/Riffle/Run ratio; pool spacing
Migrating adult	Reproductive migration	late summer, early fall	X								2.13 m/s	X	X	X	?					.18 m (min depth)									
Spawning Adult	in spawning habitat	mid Aug-Sept	X								X	X	X	X				X		X	X		X			X	X		X
Embryo	Fertilized egg	winter									X	X	X	X		X	embyo survival higher in groundwater upwelling sites [1]	X			?						X		
Alevins	pre-emergence yolk-sac stage	early spring									X	X	X	X		X		X			?						X		
Fry	Exogenously feeding	spring	X	?				X			X	X	X	X				X		X	?		X		X	X	X	X	X
Fingerling	Yearling	summer-winter	X								15-23 cm/s [2]	X	X	X	?					6 cm (min depth) [2]									
Juvenile	> Age 1	year round	X									X	X	X	?														