Iteroparity in lower Columbia River Steelhead (*Oncorhychus mykiss*): a review of research in relation to B2CCoperations from 1 March to 10 April

This paper provides a brief review of scientific information regarding iteroparity rates of Columbia River steelhead populations in relation to the BiOp FCRPS operations (NMFS 2008). The specific objectives are to review the scientific record regarding kelts from the mid Columbia and Snake rivers and apply this knowledge to early spring operation of the Bonneville (BON) Dam Powerhouse II Corner Collector (B2CC) to benefit ESA-listed lower Columbia River (LCR) steelhead.

Steelhead in the LCR differ from upriver stocks. Both ESA-listed winter (ocean maturing) and summer (stream maturing) steelhead varieties spawn in tributaries that discharge into the reservoir created by BON, the sole FCRPS reservoir affecting both steelhead varieties (Withler 1966; Busby et al. 1996). Iteroparity rates in a tributary discharging into the reservoir created by BON have been reported at over 9% for summer and over 13% for winter steelhead; whereas, iteroaprity rates over 15% for summer and over 21% for winter steelhead have been measured in tributaries to the unimpounded reach below BON (Leider et al. 1986; Olsen 2004).

The hypothesis being addressed is that B2CC operation prior to 10 April would benefit wild LCR steelhead iteroparity rates for stocks originating upstream of BON. This hypothesis if founded on the assumption that like upriver kelts - LCR kelts are: 1) in good morphological condition, 2) female (> 80%), and 3) naturally produced (Evans et al. 2004; Boggs et al. 2008). Coupled with swift gonadal re-maturation and returns from kelts (consecutive and skip [ocean overwintering] spawning cycles) these fish presumably provide the potential for a rapid influx of desirable genetic material to typically male-skewed populations (e.g., Keefer et al. 2008). Assumptions fundamental to obtaining a benefit from B2CC operations include: 1) Rapid conveyance (reduce passage delay), 2) Benign or 'optimal' conveyance compared to other BON routes, and 3) adequate numbers to justify operations. An assessment of data in relation to these assumptions will provide insight into whether B2CC March operations are warranted.

Rapid Conveyance

Results demonstrate that median forebay residence times at B2 with the B2CC operating in 2004 were significantly shorter relative to 2002 when the sluiceway was not operating (Wilcoxon rank-sum test: $P < 0.0001$). Average river discharge at B2 during the study period (April to June) in 2004 was 101.9% (3,048 m^3/s) of the 2002 average (2,991 m^3/s), indicating nearly identical conditions, making such a direct comparison reasonable (Wertheimer 2007). Median times were reduced from roughly 6 hours (h) in 2002 to 0.3 h in 2004; whereas, the third quartile (75%) was reduced from > 23 h to 1 h during the same period. It is unclear whether such reductions in residency time affect kelt outmigration survival or return rates.

Benign Conveyance

Boggs et al. (2008) provided the first quantitative data regarding return rates from upriver summer steelhead with known FCRPS dam passage routes, including route-specific passage and returns from kelts passing BON. However, due to the number and complexity of factors affecting returns rates from these upriver summer steelhead stocks (e.g., Keefer et al. 2008), caution should be applied when assigning a return probability to one known dam passage event, after multiple unknown dam passage events.

Return rates were variable within and among BON routes from 2001 to 2004 (Table 1, modified from Boggs et al. 2008). The range of return rates – by route – in descending magnitudes were: 1) juvenile bypass system (JBS, 0% to 23.3%), 2) Sluiceway (0% to 18%), turbine units (TU, 3% to 13%), and spillway (5% to 8%). Cumulative return proportions ranged from 2001 (11.7%) to 2004 (5.7%).

Samples sizes of kelts passing BON TU were similar in 2001 (n=38) and 2004 (n=31). Return proportions from TU were roughly 3% in 2001 and 9% in 2004, indicating the effects of small numbers of returnees from 2001 (n=1) and 2004 (n=3) on TU return proportions. In 2001, 38% of all passing kelts navigated BON via TU; whereas, in 2004 only 9% of kelts passed BON via TU. Operation of the B2CC in 2004 was a likely mechanism for the low proportion of kelts passing BON TU in 2004 (Wertheimer 2007).

Table 1: The population of kelts passing specific Bonneville Dam (BON) routes (N), the percentage of the fish subsequently detected passing upstream at BON (%), and the sample size of kelts detected passing upstream at BON (*n*); (N; %; *n*).

	2001	2002	2004	Route - Totals
JBS	30; 23%; 7	31; 13%; 4	15; 0%; 0	76; 14%; 11
Spill	24: 8%; 2	144; 6%; 8	97; 5%; 5	265; 6%; 15
Sluiceway	11; 18%; 2	15; 0%; 0	15; 0%; 0	41; 5%; 2
Turbines	38; 3%; 1	23;13%; 3	32; 9%; 3	93; 8%; 7
B2CC	NA	NA	191; 6%; 12	191; 6%; 12
Totals	103; 12%; 12	213; 7%; 15	351; 6%; 20	667; 7%; 47

Screened bypass systems with orifices were designed with criteria for passing juveniles, not pre-spawn adult salmonids or steelhead kelts (Boggs et al. 2004). Wagner (1991) estimated that 40% of adult fallback at McNary Dam had fresh injuries, in varying degrees of severity; that were attributed to bypass system passage. During kelt sampling at FCRPS facilities (2001–2002), fresh injuries (e.g., head scrapes, damaged fin rays, descaling) were identified on roughly 30% of sampled kelts (Wertheimer et al. 2002; 2003). Based upon the placement and types of injuries most were attributed to screen and orifice passage. Subsequent recaptures of injured fish at downstream facilities indicate the fate of an unknown percentage of these injured kelts was mortality; attributed to the rapid spread of fungi (*Saprolegnia spp*.) on injured areas.

Inferring a benefit from B2CC operations - for LCR steelhead - from studies of upriver steelhead stocks alone is problematic. Determination is even more difficult as data from these summer steelhead stocks are characterized by: 1) small sample size, 2) return variability by passage route, 3) return variability by passage year, 4) return variability by passage timing, 5) unreported morphometrics (e.g., origin, sex, condition), and 6) unknown prior passage histories to tagging (i.e., dam passage routes). Passing salmonids using a surface flow as compared to other routes (i.e., spill, screened systems, TU) is hypothesized to reduce stress as a result of decreases in pressure changes and turbulence (ISG 2000; Budy et al. 2002). Data supporting this hypothesis for TU are provided by Coutant and Whitney (2000), which indicate larger fish suffer greater mortality during turbine passage than smaller fish. Despite this; results do indicate that kelts passing all BON routes – including TU – are returning on subsequent spawning migrations.

Kelt Use During B2CC Early Operations

The effects of B2CC operations during March on LCR steelhead return rates have not been evaluated. However, adult steelhead B2CC passage during March was enumerated using hydroacoustics in 2007 and 2008 (Weiland et al. 2008; 2009). In these studies, 172 and 223 kelt-sized fish were estimated to have passed the B2CC from 1 March to 10 April in 2007 and 2008, respectively. Daily passage ranged from 4 to 7 fish per day. Temporal passage appeared fairly constant through the study period with some higher peaks in early April.

Visual counting of downstream passing adult steelhead and salmon at the B2 SMF Primary Dewatering Structure (PDS) occurs intermittently 24 hours day; providing a potential presence/absence index of passing kelts. Visual enumerations of kelts at the B2 PDS indicate significant variability in yearly passage numbers (Table 2). Passage numbers at the PDS range from five-steelhead in 2008 to over 450 in 2003. In the absence of B2CC operations approximately 50% of kelts would be expected to pass via TU (Table 3). Thus, data from the PDS in 2003 conservatively suggest approximately 600 adult steelhead passed via TU during the period from 1 March to 10 April, 2003.

Table 2. Bonneville B2 PDS Fallback Data 2003-2008. Data acquired at Bonneville Juvenile Fish Monitoring Facility PDS Adult Fish and Debris Separator

		Adult Fish ByPassed		
Year	Period	Sthd	Sal	Unk Sal
*2003	10 March to 10 April	458	122	15
2004	2 March to 10 April	33	4	1
2005	2 March to 10 April	145	0	2
2006	2 March to 10 April	40	1	0
2007	2 March to 10 April	40	0	0
2008	3 March to 10 April	5	1	0

*B2CC became operational in 2004

Table 3[1]: Kelt guidance efficiency (GE) at Bonneville (BON) in 2001, 2002, and 2004.

Project	*Year*	*n*	GE %	Comments
BON	2001	55	47	Non-Spill
BON	2001	27	70	Spill
BON	2002	50	58	
BON	2004	43	35	

[1]Wertheimer 2007 and Wertheimer and Evans 2005.

Operational Cost

Determining the cost of operating B2CC relates directly to the value of water from power generation. During March, revenues for a Megawatt-hour (mw/h) of power generation typically range from a low of approx $30 mw/h up to $85 mw/h and beyond. Assuming an average of $45 mw/h and based upon 960 hours of time during the preseason period (1 March to 10 April) B2CC operational costs are qualitatively estimated to average roughly $1,000,000 but can range anywhere from a low of approximately $600,000 up to $1.7 million and above (BPA personnel personal Communication). An analysis of the costs of operating the B2CC from 1 March to 10 April of a given water year would add insight into actual costs.

Water Management Concerns

Since, the operation of the B2CC can generate increased TDG levels in the vicinity of the chum redds downstream of the Bonneville Dam additional flow from Bonneville may be required to provide sufficient depth compensation to remain within the Oregon water quality standards. Approximately 1 foot of depth compensation is required for a typical B2CC operation when operating the project near the chum protection level. To provide the additional 1 foot of tailwater (TW) approximately 10 to 15 kcfs additional outflow may be required. There are many variables that determine what actual discharge is required from Bonneville Dam to provide the TW and also how much flow augmentation may be required from storage projects upstream to support any additional outflow. A condition of low streamflows in March and April can occur regardless of the expected water supply condition. Therefore, the additional water to support the required outflow from Bonneville Dam may require flow augmentation volumes that would otherwise be delivered to the Mid-Columbia during the April 10 to April 30 period.

Benefits

Benefit to LCR steelhead stocks from March B2CC operations are the ‘delta’ or difference in return rates between TU, JBS, and the B2CC. In fact, little is known regarding behaviors and characteristics of the target steelhead populations for these operations. More quantitative field studies of passage route effects on return rates are needed to understand benefits of BON configurations and operations on kelt return rates and return timing. The use of passive and or active tags (e.g., PIT, JSATS) may be one means of beginning to obtain such data for LCR steelhead populations passing BON.

Conclusions

The intent of this review was to evaluate assumptions fundamental to operating the B2CC for kelt prior to operations for juvenile salmonid passage. Results demonstrate that the B2CC provides the most rapid conveyance mechanism for adults passing BON. Based upon design criteria it is presumable the B2CC represents the most benign or ‘optimal’ adult fish passage system available at BON. Fundamentally, the issue becomes the level of kelt passage that warrants operation. As discussed earlier, kelt presence at BON, whether observed in the JBS or B2CC, appears to be highly variable between years. In 2003, the B2CC would have been expected to pass in excess of 1000 steelhead during 1 March to 10 April (based upon 50 % FGE from Table 3), passage numbers (Table 2), and B2CC kelt Passage efficiency (0.82) from 2004 (Wertheimer 2007). In other years, even when corner collector flow was provided (e.g., 2007 & 2008) the numbers of kelts present during March are greatly reduced. Future data that would be helpful to address outstanding technical questions to develop management alternatives could also include determining stocks representation and their composition (e.g., kelts v. fallbacks).

Literature Cited

Boggs, C. T., M. L. Keefer, C. L. Peery, T. C. Bjornn, and L.C. Struehrenberg. 2004. Fallback, reascension, and adjusted fishway escapement estimates for adult Chinook salmon and steelhead at Columbia and Snake River dams. Trans. of the American Fisheries Society 133:932–949.

Boggs, C.T. and 7 Co-authors. A multi-year summary of steelhead kelt studies in the Columbia and Snake rivers. Submitted by Idaho Cooperative Fish and Wildlife Research Unit Technical Report 2008-13.U.S. Army Corps of Engineers Walla Walla District

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27. Northwest Fisheries Science Center, Seattle. Available: http://www. nwr.noaa.gov. (September 2004).

Cada, G.F. 2001. The development of hydroelectric turbines to improve fish passage survival. Fisheries 26:14–23.

Coutant, C.C. and R.R. Whitney. 2000. Fish behavior in relation to passage through hydropower turbines: a review. Transactions of the American Fisheries Society 129:351–380.

ISG (Independent Science Group). 2000. Return to the river: restoration of salmonid fishes in the Columbia River. ISG, Report 2000-6, for NPPC Portland, Oregon.

Keefer, M., R. Wertheimer, A. Evans, C. Boggs, and C. Peery. 2008. Iteroparity in Columbia River summer-run steelhead (Oncorhynchus mykiss): implications for conservation. Canadian Journal of Fisheries and Aquatic Sciences. 65: 2592-2605.

Leider, S. A., M. W. Chilcote, and J. J. Loch. 1986.`Comparative life history characteristics of hatchery andwild steelhead trout (Salmo gairdneri) of summer and winter races in the Kalama River, Washington. CanadianJournal of Fisheries and Aquatic Sciences 43:1398–1409.

NMFS (National Marine Fisheries Service). 2004. Endangered Species Act status of west coast salmonids, June 17, 2004. NMFS, Northwest Region, Portland, OR. Available: http://www.nwr.noaa.gov (accessed 30 September 2004).

Olsen, E. A. 2004. Hood River and Pelton Ladder evaluation studies. Final Report to the Bonneville Power Administration, Contract DE-BI-89BIP00632, Portland, Oregon.).

Wagner, P. 1990 Evaluation of the use of the McNary Bypass System to divert adult fallbacks from Turbine Intakes. Washington Department of Fisheries Habitat Management Division, Olympia, WA 98504. Final Report to the U.S. Army Corps Contract DACW68-82-C-0077. Task Order 9.

Wertheimer, R.H., P.L. Madson, M.R. Jonas, and J.T. Dalen. 2002. Evaluation of Steelhead Kelt Project Abundance, Condition, Passage, and Conversion Rates through Lower Columbia River dams, *in* 2001. U.S. Army Corps of Engineers, Portland District Fish Field Unit, Bonneville Lock and Dam, Cascade Locks, OR.

Wertheimer, R.H., P.L. Madson, and M.R. Jonas. 2003. Evaluation of Steelhead Kelt Project Abundance, Condition, Passage, and Conversion Rates through Lower Columbia River dams, *in* 2002. U.S. Army Corps of Engineers, Portland District Fish Field Unit, Bonneville Lock and Dam, Cascade Locks, OR.

Wertheimer, R. H., and A. F. Evans. 2005. Downstream passage of steelhead kelts through hydroelectric dams on the lower Snake and Columbia rivers. Transactions of the American Fisheries Society 134:853–865.

Wertheimer, R.H. 2007. Evaluation of a surface flow bypass system for steelhead kelt passage at Bonneville Dam, Washington. North American Journal of Fisheries Management 27:21-29.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific Coast of North America. Journal of the Fisheries Research Board of Canada 23:365–393.