Futures Analysis for Wetlands Restoration in the Coquille River Basin: How many adult coho salmon might we expect to be produced?

A Report to The Nature Conservancy

Prepared by: Thomas Nickelson

November, 2012

Introduction

Coho salmon (*Oncorhynchus kisutch*) are anadromous fish; that is, they spawn if freshwater, reside in freshwater for 1-2 years then migrate to the ocean for an additional 1-2 years, where the majority of their growth takes place (Sandercock 1991; Lestelle 2007). Coho salmon migrate from the ocean during fall and winter and typically spawn in small to mid-size streams in the upper reaches of coastal rivers. Following emergence from the gravel in early spring, coho salmon fry undergo the first of two dispersals as fry (also known as "Nomads") migrate downstream to fill vacant habitats (Chapman 1962). Following a summer of rearing a second downstream dispersal occurs with the first high flows of falls, largely in response to lack of winter habitat. Overwinter survival of juvenile coho salmon in stream reaches with good protection from high stream velocities, either in the form of large wood or off-channel habitat is much higher than that in stream reaches lacking such habitat (Solazzi et al. 2000; Johnson et al. 2005). Most juvenile coho salmon migrate to the ocean during their second spring, although some spend an additional year in fresh water.

To assess factors limiting fish populations at various life history stages one must examine the habitat across a river basin (Nickelson et al. 1992a; Rabeni and Sowa 1996). Following such basin analyses, overwinter habitat has become widely recognized as the most critical factor influencing the freshwater portion of the life cycle of coho salmon.

A comprehensive limiting factors analysis conducted as part of the Coquille River Subbasin Plan (Coquille Indian Tribe 2007) determined that the only factor significantly reducing adult coho salmon abundance in the Coquille River was "depleted slow-water refugia." In the case of the Coquille, this equates to the loss of the floodplain wetlands. Less than 3% of the wetlands present in the Coquille Valley in the mid-19th century are still in existence (Benner 1992). The reconnection of isolated habitats within the floodplain has been recognized as a priority watershed restoration strategy (Roni et al. 2002; 2008).

Peterson (1982a & b) documented the use of floodplain ponds in the Clearwater River of Washington. Juvenile coho salmon in the Coldwater River, British Columbia make extensive use of off-channel ponds during winter (Swales et al. 1986; Swales and Levings 1989). In Carnation Creek, British Columbia, many juvenile coho salmon left the main channel to overwinter in small floodplain tributaries and sloughs (Tschaplinski & Hartman 1983). Also in Carnation Creek, Brown and Hartman (1988) reported that 15% of the smolt production in 1984 came from areas that were dry during summer. Similarly, Lestelle et al. (1993) estimated that 30% of the coho salmon smolts in the Queets River Washington reared in off-channel ponds. .In Oregon, Nickelson et al. (1992b) documented a shift in distribution of juvenile coho salmon from main channel pools in summer to beaver ponds and off-channel alcoves during winter.

In the Coquille Basin itself, ODFW sampled floodplain sites in the lower river following a flood during the winter of 1994-95. They found juvenile coho salmon in eight of 15 floodplain ponds and wetlands, but only areas that were over a meter deep (Crombie 1995). Several studies have found that juvenile coho salmon use these lower tidal reaches of rivers (Murphy 1984; Miller and Sadro 2003; Koski 2009).

Efforts to increase the abundance of salmonid fishes through habitat manipulation has long been a tool of fisheries managers (Smokorowski and Pratt 2007). Early efforts targeted trout production (Hubbs et al. 1932; Tarzwell 1937; Shetter et al.1949). Toward the end of the twentieth century in the Pacific Northwest, efforts began targeting Pacific salmon (House and Boehne 1985; Nickelson et al. 1992c; Beechie et al. 1994).

Restoring winter habitat has been shown to be an effective enhancement tool. Cederholm et al. 1988 found that the construction of ponds within small floodplain streams significantly increased the growth and survival of over-wintering coho salmon using the streams. In British Columbia it has been estimated that constructed off-channel ponds and channels accounted for 47% of the coho salmon smolt production of the Coquitlam River (Decker and Foy 1998), and 62% of the coho salmon smolt production of the Vancouver River [Bates (2002) as cited in Brown (2002)]. Tanner et al. (2002) reported coho salmon use of newly restored tidal wetlands in the Snohomish River estuary, Washington. Roni et al. (2006) found that coho salmon smolt densities and fish size in restored floodplain habitats "were similar to or higher than those observed in natural floodplain habitats."

Following up on the Coquille River Subbasin Plan (Coquille Indian Tribe 2007), The Nature Conservancy, with a number of partners, is involved in restoring floodplain wetlands in the lower Coquille River Watershed. This effort is largely targeted on restoration of coho salmon, a valuable resource in the Coquille Basin.

When planning wetland enhancement efforts, the question that naturally arises is how many adults can be expected to be produced from the restoration of floodplain wetlands. This report will investigate two approaches to addressing this question: one based on a literature review of densities of smolts (or late winter juveniles) observed to be produced by natural and restored wetlands, and a second based on changes in historical abundance of coho salmon in the Coquille Basin and estimated changes in the historical wetlands of the basin.

Coho Salmon Production Levels in Floodplain Habitat

Literature Review Approach

Fifteen publications that provided useful data on densities of coho salmon smolts in floodplain habitats were reviewed (Table 1). When looking at data on smolt densities found in floodplain wetland channels and ponds it quickly becomes evident that while larger areas yield more fish, the density of fish declines as area increases (Figure 1). A review by Rosenfeld et al. (2008) found a similar relationship and suggested that optimal size for off-channel habitat was below 5,000 -10,000 m^2 (1.2-2.5 acres).

Because the plans for the lower Coquille Basin involve wetlands of 300 acres or more, I eliminated all the very small sites studied in the literature, and concentrated on those of at least 10 acres that appeared to be somewhat similar in nature to the Coquille Project. However even these are much smaller than 300 acres (Table 2). The sites had from 2 to five years of data each and their average coho salmon smolt densities ranged from 23 to 777 smolts/acre. The average of the 5 sites was 270 smolts/acre.

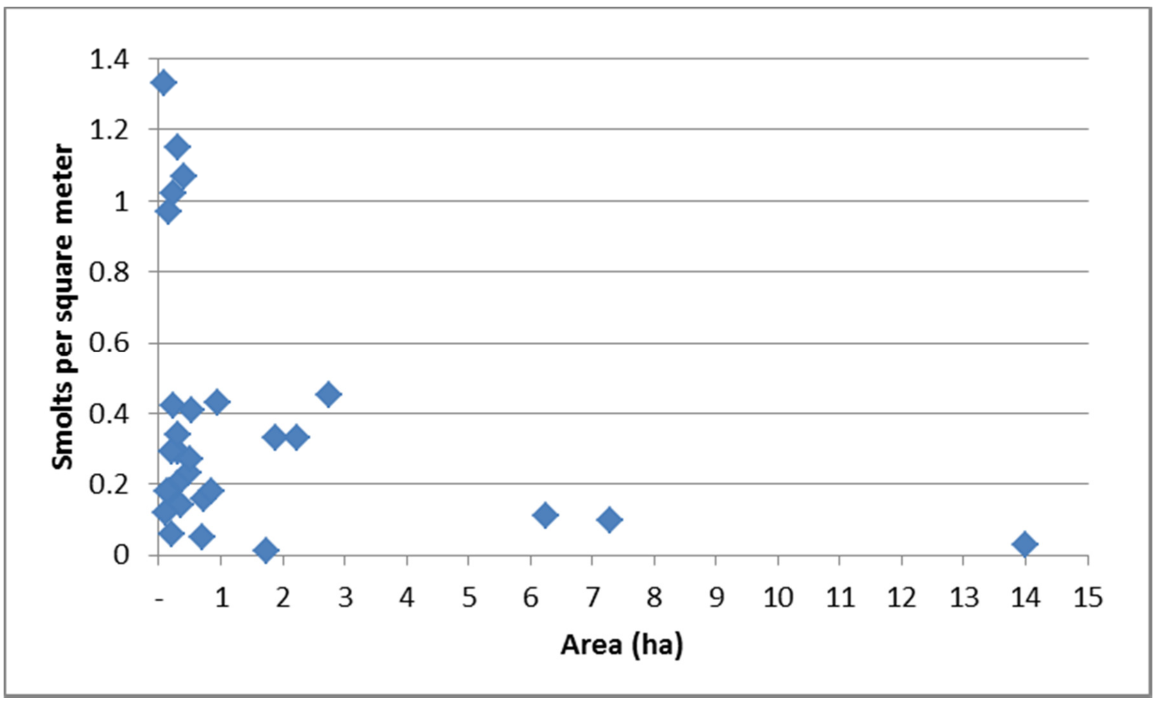

Figure 1. Coho salmon smolt density as a function of wetland area [data from Roni et al. (2006)].

Table 1. Results of studies of coho salmon use of floodplain wetlands in the Pacific Northwest.

Habitat type	**Habitat size**	**Parameter**	**Smolt Density**		**Source**
			per square meter	**per acre**	
Off-channel pond	.85 ha	Point estimate	0.42	1,700	Peterson (1982)
Off-channel pond	1.29 ha	Point estimate	0.12	486	Peterson (1982)
Ponds & small Lakes	>1 ha	Average	0.07	300	NMFS et al. (1983)
Off-channel pond	0.1 ha	Point estimate	1.5	6,070	Swales et al. (1986)
Off-channel pond	1 ha	Point estimate	0.4	1,620	Swales et al. (1986)
Off-channel pond	1 ha	Point estimate	0.126	510	Swales & Levings (1989)
Enhanced off-channel ponds & channels	<1ha	Range	0.84-2.9	3,400-11,736	Cederholm & Peterson (1989)_
Constructed pond and beaver ponds	2.5-4 ha	Range	0.09-0.39	365-1,580	Foy (1993)
Off-channel side channels	varied	Average	0.67	2,711	Keeley et al. (1996)
Off-channel ponds	varied	Average	0.69	2,792	Keeley et al. (1996)
Natural & restored l ponds & channels	.26-1.5 ha	Range	0.02-0.75	81-3,035	Picard et al. (1998),Blackwell et al.(1999), Cleary (2001)
Beaver ponds & off-channel alcoves	<0.1 ha	Average	1.6	6,475	Nickelson (1998)*
Off-channel habitat		Average	0.71	2,873	Bates (2002)**
Constructed floodplain side channels	0.1-0.7 ha	Average	0.77	3,116	Morley et al. (2005)
wetland with water control structure	7.3-14.5 ha	Average	0.007	28	estimated from data of Henning et al. (2006)
Variety of floodplain habitats	0.09-14 ha	Average	0.37	1,497	Roni etal. (2006)
Reconnected ponds	0.3-0.95 ha	Average	0.88	3,561	Roni etal. (2006)

*Based on the late winter data of Nickelson et al. (1992b) adjusted for estimation technique and survival to smolt.

** cited in Brown (2002)

Table 2. Coho salmon smolt densities reported in the literature for restored floodplain wetland habitats of at least 10 acres in size and somewhat similar to the proposed Coquille project.

Habitat type	Location	Acres	Smolts/ acre	Source
Impoundment	Washington	18	395	Roni etal. (2006)
Impoundment	Washington	35	113	Roni etal. (2006)
Off-channel pond	British Columbia	10	777	Foy (1992)
wetland w/control structure	Washington	36	23	estimated from data of Henning et al. (2006)
wetland w/control structure	Washington	18	36	estimated from data of Henning et al. (2006)

Historical Abundance Approach

Benner (1992), using the original 1857-1871 land survey notes, estimated that there were 14,440 acres of wetland in the bottomlands along the tidal reaches of the lower Coquille River. After 1870 most of the wetlands were diked and drained for farmland and tide gates were installed to prevent river water from re-entering (CCLAC et al. 2006). Today there are only 373 acres of wetland remaining (Coquille Indian Tribe 2007).

Abundance of coho salmon followed the same trend as that of wetlands since the mid-19th century (Table 3). Lawson et al. (2007) report an estimated abundance of 417,000 adult coho salmon based on GIS data of stream geomorphology, and 10% marine survival [Note: I did this analysis and I'm not sure why it was reported as 417,000 because my data shows it should be 495,000]. Because it is based on inherent stream morphology, this estimate should be considered a pre-1850 estimate. Methods based on expansion of cannery records yielded estimates of 342,000 for the late 1800s (after 1882; Meengs and Lackey 2005) and 310,000 for 1908 (Lawson et al. 2007). In 2011, the coho salmon spawning abundance of 55,667 was the peak of the last several decades. This equates to a pre-spawning abundance of about 60,000 adults is just 12% of the pre-1850s estimate. The 2011 escapement was 2-27 times larger than any year since 1994. In 2006, the previous high year, the population was at about 6% of historic levels. The population had declined 26% by 1908 and has declined an additional 62% since (Table 3). Commercial in-river catches in the Coquille River declined rapidly after 1911 (Mullen 1981). This decline coincides with the beginning of the operation of splash-dams in the basin, which lasted from 1905 to 1935 (Benner 1992).

Figure 2 shows the changes in abundance before 1910 and three sets of assumed wetland acreages for the late 1880s and 1908: 1) 3% and 3% of historical acreage based on the assumption that current levels were reached by 1880 (diamond symbols); 2) 69% and 63% of historical acreage based on the assumption that all the smolts in the basin were produced in the lowland wetlands and most of the loss of wetland habitat occurred after 1910, similar to coho abundance (triangle symbols), and; 3) intermediate levels of 50% of historical acreage in the late 1880s and 25% of historical acreage in 1908 (round symbols). It seems likely that the transition from over 14,000 acres of wetlands during winter to less than 400 acres was somewhat gradual over the first half century after Euro-American settlement, until technology improved and the systems to keep the farmland dry became more efficient,. Thus the mid-range assumptions that in the late 1800s 50% of the wetlands were still available as juvenile coho salmon habitat during winter and that in 1908 25% were still functional seems a reasonable compromise. Frissell (2012) has provided further information in support of this position. He notes that photographic and other historical documents describing railroad operations for the timber industry in the Coquille Basin during the early 20th Century (ca. 1915-1930) refer to the many miles of trestle necessary to transverse "extensive floodplain wetlands present at that time."

Table 3. Trends in estimated abundance of adult coho salmon produced from the Coquille River

Time Period	Adult abundance	Source	Wetland acres	Source
Pre-1850	495,000*	My analysis	14,440	Benner (1992)
Late 1800s	342,000	Meengs and Lackey (2005)		
1908	310,000	Lawson et al. (2007)		
2011	60,000	Based on ODFW data	373	Coquille Indian Tribe (2007)

*This value is reported as 417,000 in Lawson et al. (2007) but is a typo.

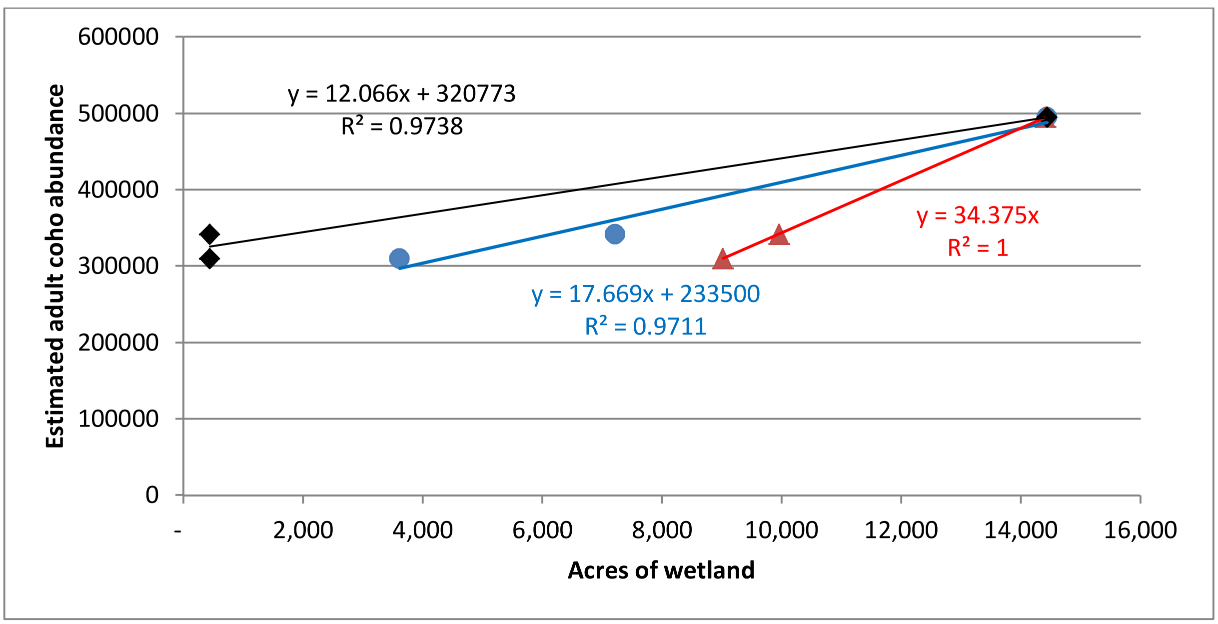

Figure 2. Relationships between estimated abundance of adult coho salmon before 1910 and estimated and assumed acreage of wetlands in the lower Coquille River watershed given three different scenarios for the assumed wetland values: rapid decline (diamonds), slow decline (triangles), and gradual decline (rounds) (*See* text).

These mid-range assumptions are extrapolated to the present day in Figure 3. This figure shows a precipitous decline in coho salmon abundance in the 20th Century that was probably due to a combination of impacts from logging and splash dams in conjunction with continued loss of wetlands. Frisell (2012) suggests that an additional factor could be loss of life history diversity.

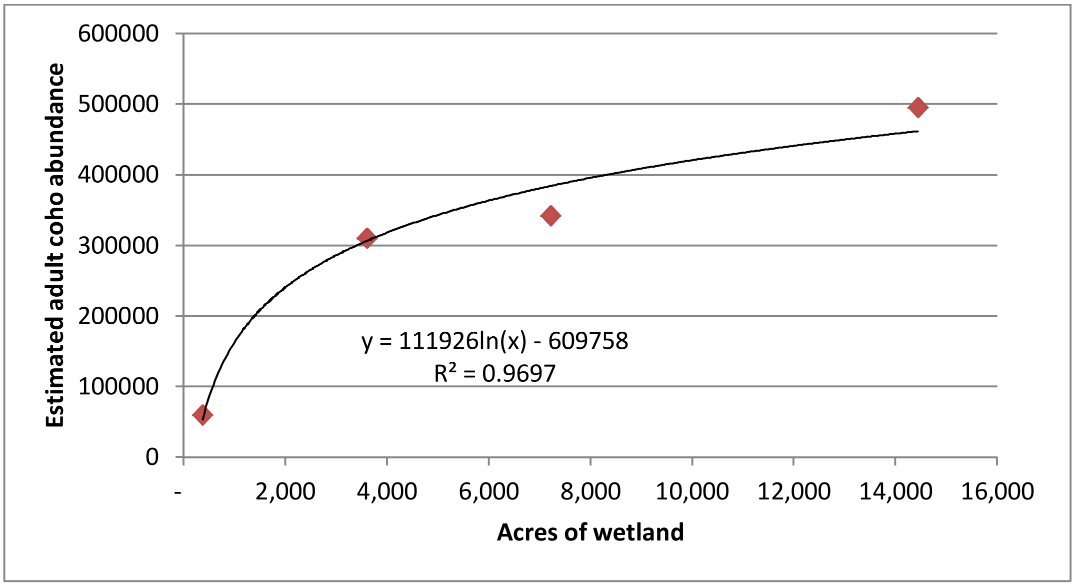

Figure 3. Relationship between estimated abundance of adult coho salmon and estimated acreage of wetlands in the lower Coquille River watershed assuming 50% of the wetlands were functional in the late 1800s and 25% in 1908. Also included are current area of wetlands and estimated abundance.

It seems reasonable to conclude that changes in wetland habitat were the principle cause of declining populations during the period prior to 1910. Therefore, the slopes of the linear relationships in Figure 2 represent the density of adults produced per acre of wetland and the intercepts the number of adults produced in the rest of the basin.

The density of adults estimated by this method can be converted to smolts/acre by dividing by 10% marine survival, the value used by Lawson et al. (2007) to convert estimated smolts to adults. Thus this method yields 180 smolts/acre for the middle of the road assumption with values of 120 smolts/acre and 340 smolts/acre on the extremes. The mid-range value, although lower, is in the same “ballpark as average value the derived from the literature and the mid-range and high-range values bracket the value from the literature.

Application of Smolt Densities

If we use the middle value from the historical abundance approach and the average from the literature we get a range of 180 to 270 smolts per acre of restored wetland. Over the past decade, given observed marine survival rates, these values would have yielded an average of 11 and 17 adults/acre, respectively (Table 4). **Using this as a range, a restored wetland of 100 acres would on average have produced 1,100 - 1,700 adults annually**. Freshwater coho salmon fisheries can be expected to generate a 10% harvest rate (personal communication with Robert Buckman, ODFW, March 2011). **Thus a 100 acre restored wetland could, on average, be expected to contribute 110-170 coho adults to in-river sport fisheries each year.**

In addition to freshwater harvest, fish from restored wetlands would also contribute to ocean fisheries in some years. Because of the complexities in the harvest matrix of Amendment 13 to the Pacific Coast Salmon Plan (PFMC 1999) and the uncertainty of future forms of this matrix (currently being proposed for revision) it is difficult to estimate the ocean fishery contributions. Total allowable harvest in any given year is dependent on seeding levels and predicted marine survival. However, current allowable harvest rates in years when there would be allowable fisheries would probably range from 20-35%. Subtracting the 10% freshwater harvest rate leaves a 10-25% harvest rate for ocean fisheries. This would equate to a harvest in the range of 110-425 fish per 100 acres of restored wetland (assuming 3.9% marine survival for the low end and 9.8% marine survival for the high end). To add to the complexities of estimating harvest, in years when ocean fisheries occur, freshwater harvest expectations would be somewhat reduced.

Table 4. Estimated adults that would have been produced from an acre of restored wetland during the past decade. Marine survival rates are based on ODFW life cycle monitoring sites. (ODFW unpublished data).

Return year	**Marine survival**	**Adults/a @ 180 smolts/a**	**Adults/a @ 270 smolts/a**
2001	10.0%	18	27
2002	8.4%	15	23
2003	8.9%	16	24
2004	4.6%	8	12
2005	4.6%	8	12
2006	2.8%	5	8
2007	1.9%	3	5
2008	5.9%	11	16
2009	7.8%	14	21
2010	7.0%	13	19
Average		11	17

Summary

Given the importance of off-channel wetlands to the over-winter rearing of coho salmon (*See* Introduction), restoring the wetlands of the lower Coquille River River should be the highest priority action to recover the coho salmon population of the basin, which is currently at about 6-12% of historic levels. Two approaches were used to estimate expected coho salmon production resulting from restoring the wetlands of the Coquille Basin. One approach used values from the literature while the other approach was based on observed changes in wetlands and coho salmon abundance in the Coquille Basin. A reviewer suggested that the density values for wetlands in the literature may not be representative of the wetlands in the Coquille. While this may be an issue, the congruity of the two approaches suggests that it is not a problem.

Based on these analyses, each acre of restored wetland would be expected to produce on average 11-17 adult coho salmon; 18-27 in good ocean years. A 100 acre restored wetland would produce an estimated 1,100-1,700 adults and a harvest of 110-170 adults in the in-river sport fishery.

It should be noted that the estimated benefits presented here only take into account increased smolt production resulting from the spatial increase in quality winter habitat provided by wetland restoration. As such, these are probably conservative estimates of the benefits accrued to the coho population as a whole because they don't account for potential demographic and ecological complexities such as improved growth and the possible recovery of lost or depleted life history types within the population. Frissell (2012) suggests that "restoration of floodplain wetland habitats could have more than a linear, additive influence on recovery of coho, because populations might be changed qualitatively as well as quantitatively."

A number of studies have documented increased growth of juvenile coho salmon wintering in floodplain wetland habitats compared to fish wintering in main channel habitats (Swales et al. 1986; Quinn and Peterson 1996; Hiner et al. 2011). Factors influencing this growth include warmer temperatures (Giannaco and Hinch 2003) and greater food availability (Limm and Marchetti 2009) in off-channel habitats. Increased growth would result in larger smolts emigrating from off-channel habitats and large smolts survive better than small smolts in years of poor ocean survival (Holtby et al. 1990).

A possible additional benefit to restoring wetlands is the recovery of life history types that have been lost from the population. A diversity of life history types allow a population to flourish under varying environmental conditions because a particular set of conditions will favor one life history over another (Lichatowich 1999; Lestelle 2007). Thus, a population with a wide diversity of life history types will be much healthier than one with little diversity.

Fortunately the coho salmon population in the Coquille River appears to still have a life history pattern geared toward rearing in the lower basin during summer, and winter. Juvenile migrant trapping in the North Fork Coquille River by the ODFW Life Cycle Monitoring Project in 1998 found very large numbers of fry migrating downstream during spring (180,000 fry and only 2,500 smolts) and large numbers of parr migrating downstream during fall (12,500 from 4 Nov-16 Nov; about 1,000 fish/day). Today most of these migrating fish are probably lost because of the lack of habitat, particularly over-winter habitat, in the lower river. Wetland restoration will remedy this problem and result in increased survival of these migrants.

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