Smolt-to-Adult Return Rate Estimates of Snake River Aggregate Wild Spring and Summer Chinook

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This paper provides draft documentation of the methods and results of our estimates of smolt-to-adult return rates (SARs) for aggregate wild spring and summer chinook from the Snake River that were used in the steelhead draft Biological Opinion (NMFS 1998). SAR estimates for both wild spring/summer chinook and wild steelhead (Petrosky 1998) will be reviewed and revised in the PATH process during 1998-1999.

Raymond (1988) estimated SARs for wild and hatchery spring and summer chinook and steelhead from the Snake River, smolt migration years 1964-1984. Raymond's numbers were based on estimates of smolts at the uppermost dam, and estimates of adults (ages 3-5) returning from each year's migration to Ice Harbor dam plus prior harvest in the Columbia River zones 1-6.

Until recently, there had been no updated SAR estimates since Raymond (1988) for wild steelhead or spring/summer chinook from the Snake River. Petrosky (1998) updated estimates of wild steelhead SARs for smolt years 1985-1993. In this paper, we present updated estimates of wild spring/summer chinook SARs for smolt years 1992-1994, and adjusted estimates for smolt years 1964-1975 based on our estimates of age structure from naturally spawning Snake River index stocks.

NMFS (1998) compared the ratio of wild spring/summer chinook SARs in a recent period (smolt years 1992-1994) and SARs in a historical period (smolt years 1964-1969) when Snake River stocks were considered to be healthy. The ratio of SARs between periods for spring/summer chinook was then contrasted with that for wild steelhead. NMFS (1998) used this comparison to make inferences about the relative health of the two species, and the potential need for additional management measures for steelhead. Ratios of SARs between periods were estimated (NMFS 1998) based on two methods of adult accounting: 1) adults returns to the uppermost dam; and 2) adults returning to the river fishery (zone 1-6 catch plus upper dam escapement).

Methods

Smolt Abundance

Smolt abundance estimates of wild spring/summer chinook smolts in this analysis were from Raymond (1988) for smolt years 1964-1984 and from Petrosky and Schaller (1996) for smolt years 1992-1994. For the recent years (1992-1994), we assumed an FGE of 0.56 at Lower Granite Dam (Table 8 in Petrosky and Schaller 1996). This FGE estimate was similar to the PATH hydro work group estimates of 0.55 FGE for this project in these years (Table A.2.2-3 in Marmorek and Peters 1998). Raymond (1988) partitioned the smolt abundance estimates into spring and summer components. We did not attempt to partition springs and summers for recent years.

Raymond (1988) SARs

Age structure estimates are needed to adjust Raymond's (1988) SARs for zone 1-6 harvest rates to get an accounting of adults entering the Snake River Basin. Raymond (1988) presented the estimated total adult returns (catch plus escapement) by smolt migration year, but not the separate estimates for catch and escapement or estimates of age structure. However, Raymond (1975; 1979) did provide age structure estimates for Snake River aggregate spring and summer chinook for smolt years 1964-1975. Raymond's age composition data were from: Idaho spawning ground carcass surveys plus fish counts (jacks and adults) at Ice Harbor Dam in 1968-1970; and the adult separator at Little Goose Dam, fish counts, spawning ground surveys, and hatchery returns in 1971-1974. We have been unable to locate the age structure information used for Raymond's SAR estimates in smolt years 1976-1984.

We also estimated age structure for Snake River aggregate spring/summer chinook from age data for 17 naturally spawning index stocks, brood years 1957-1990, from Beamesderfer et al. (1997) and unpublished data. The aggregate age structure by brood year and return year was determined weighted by the age structured estimates of total recruits from each stock to the Columbia River mouth (PATH data file SVR8.xls; 8/25/97) (see Table 3). Stocks used in the analysis were: Bear Valley/Elk Cr., Marsh Cr., Sulphur Cr. and upper Big Cr. (Middle Fork Salmon spring chinook); Poverty Flat, Johnson Cr., and Secesh R./Lake Cr. (South Fork Salmon summer chinook); upper Valley Cr. and Lemhi R. (Salmon spring chinook); Imnaha R. and Big Sheep/Lick Cr. (Imnaha spring/summer chinook); and upper Grande Ronde R., Catherine Cr., Lookingglass Cr., Lostine R., Minam R., and Wenaha R. (Grande Ronde spring chinook).

We estimated adult plus jack returns by smolt migration year by two methods of accounting: 1) returns to the uppermost dam; and 2) returns to the river fishery (zone 1-6 catch plus upper dam escapement). The estimation procedure involved four steps.

First, we calculated the number of recruits to the upper dam by return year from Raymond's (1988) SAR estimates, using his (1975; 1979) reported age structure. The estimated number of returning spring chinook adults from brood years 1962-1973 (Table 2 in Raymond 1988) was multiplied by the proportions of age 3, age 4 and age 5 fish in the brood year returns (App. Table 1 in Raymond 1975; Table 13 in Raymond 1979). The resulting age-structured brood year recruit estimates were then multiplied by [1 - harvest rate] for spring chinook for the year of return to estimate age structured returns to Ice Harbor Dam (IHR). Summer chinook adult returns (Table 4 in Raymond 1988) were adjusted similarly. Annual harvest rate estimates used in this analysis were from Beamesderfer et al. (1997; Table A.1; parameter pEc.y).

Second, we re-allocated the return year totals in step 1 into brood years, using our return year age structure estimates. Estimated recruits to IHR for return years 1965-1976 were multiplied by the return year age composition proportions from our 17 Snake River index stocks. The age-structured return year recruits to IHR were then assigned to the correct brood years, and recruits to the upper dam from each brood year were summed across ages. Separate estimates were made for spring chinook and summer chinook.

Third, we estimated the SAR to IHR from the brood year return estimates. Brood year recruits to IHR were divided by the smolt abundance estimates for each brood year, 1962-1971. SAR estimates were obtained for spring chinook, summer chinook and for aggregate spring/summer chinook.

The final step was to estimate SARs based on catch plus escapement by expanding the age structured recruits in step 2 by the appropriate annual Zone 1-6 harvest rates. The age-structured brood year recruits to the upper dam were divided by [1 - harvest rate] for each year of return.

The total brood year recruits based on catch and escapement were divided by the smolt abundance estimates for each brood year, 1962-1971. SAR estimates were obtained for spring chinook, summer chinook and for aggregate spring/summer chinook. These SAR estimates were compared to those of Raymond (1988).

Updated SARs

The age 3-5 returns of wild spring and summer chinook to Lower Granite Dam (LGR) for 1993-1997 return years were derived from estimates by TAC (1997). The TAC estimates exclude jacks, whereas SAR estimates have included jacks. The respective numbers of age 4 and age 5 spring and summer chinook returning to LGR were partitioned from the total by multiplying the run size by the following proportions:

[(age 4)/(age 4+5)] and [(age 5)/(age 4+5)]

Total LGR return including jacks for return years 1993-1997 was estimated by dividing the TAC estimate (age 4+5) by [1 - proportion jacks]. Age composition was from the 17 Snake River index stocks described above. Age-structured returns to LGR were then assigned to the appropriate brood years.

We estimated the SAR to the upper dam from the brood year return estimates. Brood year recruits to LGR were divided by the smolt abundance estimates for each brood year, 1990-1992 (smolt years 1992-1994). SAR estimates to the upper dam were obtained for the aggregate wild spring/summer chinook.

The age-structured brood year recruits to the upper dam were divided by [1 - harvest rate] for each year of return. Zone 1-6 harvest rates were from TAC (1997). The total brood year recruits based on catch and escapement were divided by the smolt abundance estimates for each brood year, 1990-1992. SAR estimates including catch and escapement were obtained for the aggregate wild spring/summer chinook.

We compared geometric means of SARs: wild spring/summer chinook and wild steelhead between time periods. The historic time period was 1964-1969 smolt years for both species. The recent time period was 1992-1994 smolt years for spring/summer chinook; and 1989-1993 smolt years for steelhead.

Results and Discussion

Numbers of wild spring and summer chinook smolts from the Snake River during 1964-1995 ranged from less than 0.6 million in 1994 to 3.2 million in 1972 (Table 1). There are no estimates for wild smolt abundance from 1985 to 1991. Also, Raymond (1988) partitioned wild yearling chinook smolt abundance estimates into spring and summer components in 1964-1984; we have not attempted to partition our more recent estimates. We plan to explore the feasibility of estimating wild smolt abundance for the 1985-1991 migrations in future analyses.

Raymond's (1975; 1979) age-structured return estimates of Snake River wild spring and summer chinook are presented in Table 2. Age 4 adults generally dominated the Raymond age structure in run years 1965-1975 and smolt years 1964-1975. In contrast, age structure from the naturally spawning index stocks tended to be weighted more heavily to age 5 adults (Table 3) for smolt years 1964-1992, as well as for the years in Raymond's analysis. We suspect that Raymond's age structure estimates were biased to age 4, due to his inclusion of hatchery fish in the age structure composition. Our age structure proportions were calculated from a large number of naturally spawning index stocks; and the data were collected with fairly consistent sampling for the entire time series. However, future age structure sensitivity analysis may be explored in PATH in order to vary the weight of contribution of index stocks to the aggregate age structure.

Results of the first step (and intermediate calculations) of adjusting Raymond's adult return and SAR estimates to the index stock age structure are shown in Table 4. In this step, Raymond's total return (escapement + catch) and age structure were adjusted for Columbia River harvest rates to yield return year escapement to the IHR. For return years 1965-1976, IHR escapements ranged from 15,400 to 55,700 for wild spring chinook, and from 6,100 to 38,500 for wild summer chinook (Table 4).

Adjusted to the index stock age structure, SARs to Ice Harbor Dam of spring/summer chinook remained above 2% through the 1969 smolt year and decreased to 0.7% in 1973 (Table 5). Summer chinook SARs based on escapement were higher than those of spring chinook in all years except the 1973 smolt migration, in part due to lower mainstem harvest rates on summer chinook. Spring chinook SAR ranged from 1.7% to 3.4% for the pre-1970 period, while summer chinook SAR ranged from 2.7% to 4.6%.

Adjusted SARs based on catch and escapement of spring/summer chinook remained at or above 3.9% through the 1969 smolt year, and decreased to 0.7% in 1973 (Table 6). Summer chinook SAR based on catch and escapement was again higher than that of spring chinook in all years. Spring chinook SAR ranged from 3.1% to 5.5% for the pre-1970 period, while summer chinook SAR ranged from 5.1% to 7.4%.

Recent year SAR estimates for wild spring/summer chinook have been much lower than those in the pre-1970 period (Tables 7 and 8; Fig. 1). SARs to the upper dam ranged from 0.21% to 1.02% in 1992-1994 (Table 8). SARs based on catch and escapement were only slightly higher, 0.23% to 1.05% (Table 8). Differences between the two methods of indexing were slight because harvest rates were very low during this period, 0.06-0.12 for spring chinook and 0.01-0.04 for summer chinook (Table 7). Our adjustments to Raymond's (1988) SAR estimates (catch and escapement) resulted in subtle changes in the pre-1970 SAR estimates (Fig. 1); the adjusted estimates for the historic period tended to be slightly higher than those reported by Raymond.

Large incremental improvements are needed in recent SARs for wild spring/summer chinook to attain the productivity levels observed before 1970. For example, if recent SARs were 2%, and historic SARs were 6%, a three-fold incremental increase would be needed to restore the historic survival rates. Historic (pre-1970) SARs of spring/summer chinook to the upper dam (SAR1) were 2.83%, and recent (1992-1994) SARs were only 0.43%; thus a 6.6 fold incremental increase is required to restore historic survival rates (Table 9). If mainstem harvest is taken into account (SAR2), the required increase for spring/summer chinook is more dramatic: respective historic and recent SARs were 4.85% and 0.45%, thus a 10.7 fold incremental improvement is needed (Table 9).

Incremental improvements needed in recent SARs for wild steelhead to attain the productivity levels observed before 1970 are not quite so large as for spring/summer chinook. Historic (pre-1970) SARs of steelhead to the upper dam (SAR1) were 3.80%, and recent (1992-1994) SARs were only 0.83%; thus a 4.6 fold incremental increase is required to restore historic survival rates (Table 9). If mainstem harvest is taken into account (SAR2), the required increase for steelhead decreases slightly: respective historic and recent SARs were 5.55% and 1.47%, thus a 3.8 fold incremental improvement is needed (Table 9). Mainstem harvest rates for wild steelhead since 1989 have ranged from 0.11 to 0.17 for A-run, and 0.25 to 0.39 for B-run (TAC 1997), higher than those of spring and summer chinook.

Wild steelhead have demonstrated higher SARs (catch plus escapement) than wild spring/summer chinook, historically and in recent years (Table 9; Fig 1). In the pre-1970 period, steelhead SARs were 1.15 fold higher than those of spring/summer chinook. In the recent period (1992-1993), steelhead SARs (although poor) were 3.7 fold higher than those of spring/summer chinook.

Our SAR estimates for wild Snake River spring/summer chinook appear to be consistent with earlier findings in PATH. The PATH hydro work group made a preliminary recommendation for SARs to be within a 2% to 6% range for spring/summer chinook recovery (Toole et al. 1996). This was based in part on the estimates of Raymond (1988) in the pre-1970 period (when Snake River stocks were believed to be productive and stable), and in part on the recent performance of a healthy downriver stock (Warm Springs River). The preliminary prospective analysis for spring/summer chinook also indicated that the long-term ESA survival standard was met only by those combinations of actions and hypotheses that achieved 2% to 7% SAR in the future (Marmorek and Peters 1998; Fig. B.5-2). Our results indicate that Snake River wild spring/summer chinook have not survived at the pre-1970 levels since the completion and operation of the Federal Columbia River Hydropower System.

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