Chapter 6 Appendix 3
An Analysis Of Spring Chinook Survival In The Mainstem Columbia And Snake River Hydropower System

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Reach survival studies have been conducted by the National marine Fisheries Service (NMFS) since the mid 1960s. Since these studies began, there have been many changes in the Columbia River Federal Power System (CRFPS) including, on one hand, an increase in the number of hydropower projects and, on the other, improvements in operations and facilities aimed at increasing the survival of juvenile and adult salmon. As a result, there is interest in determining to what degree the recent survival estimates for spring chinook that were made with PIT tags[1] differ from those made with older tagging and statistical methodologies (Raymond data)[2].

Direct comparisons of the PIT tag survival studies and the Raymond studies are potentially misleading because the reaches studied are not the same. The PIT tag studies have estimated survival through only the uppermost two or three projects while the Raymond studies estimated survival through five or six projects somewhat lower in the system. One simple solution is to estimate per-project survival and raise it to the eighth power but this approach ignores differences in dams and their operations and, more importantly differences in reservoirs. For example, the PIT tag studies do not include the John Day Project whose storage volume exceeds those of the four Snake River projects combined and where fish travel times are typically much longer than other reservoirs. In addition, John Day Reservoir, like the other Columbia River reservoirs, has a considerably higher predator concentration than the Snake River reservoirs (Ward et al 1995).

The purpose of this analysis is, first, to estimate system survival by expanding reach survival estimates to the entire system on the basis of effective fish travel time which is fish travel time modified by the predator index in Ward et al. (1995)and thus take differences in reservoirs into account. Second, the sensitivity of survival estimates to different assumption of dam parameters is provided.

METHODS

The key element of this analysis is the separation of overall annual mainstem survival into dam and reservoir components. Dam survival is estimated for each project based on the proportion of fish passing the project via the spillway, the bypass system or the turbines each year. The survival for each dam is estimated by the estimated survival through each of three routes past the dam weighted by the proportion of fish utilizing the three routes.. Dam survival for a reach is simply the product of the applicable dam survival for all dams in the reach, either the study reach or the entire eight dam reach. Project specific data on flows and spill were obtained from the Army Corps of Engineers data base.

Reservoir survival is assumed to be the residual left over after dam survival is removed from annual reach survival estimates. Reservoir survival is typically regarded as being related to time: all regional models have as an explicit or implicit assumption that the longer the fish remain in the system the lower their survival will be. Therefore, the lower the flow rate in a given reservoir, the slower the water, and the fish, move. For this analysis water travel time (WTT) was estimated by the volume replacement method which is the time it takes a flow of a given rate to replace or fill a reservoir of a given volume. The fish travel times (FTT) used are based on a variety of studies linking FTT with WTT[3]. FTT relationships are available for three reaches:

1. Lower Granite (project 1) FTT = -.224 + 2.248 WTT

1 Survival estimates for 1993 through 1995 are reported in Muir et al (1996)
2 Survival estimates for 1970 and 1973-1980 are in Raymond (1979), Sims and Ossiander (1981) and Sims et al. (1983).
3 Data provided by Fish Passage Center, Portland OR.. Relationships calculated by P. Wilson, Columbia Basin Fish and Wildlife Authority, Portland OR.

2. The four project reach including Little Goose Pool through McNary Pool (projects 2 -5)
   FTT = 5.859 + .508 WTT
3. John Day (project 6) FTT = -.498 + 1.136 WTT

FTT in The Dalles and Bonneville Pool (projects 7 & 8) was calculated with the John Day relationship apportioned on the basis of their respective volumes relative to John Day's volume.

Finally, because predator abundance, as well as FTT, affects the survival of migrating juvenile chinook salmon, a modified version the predator index in Ward et al. (1995) was used to adjust FTT and produce effective fish travel time (EFTT). The Ward index (Table 1) provides the estimated consumption rate of northern squawfish, by reservoir, relative to John Day Reservoir The modification increased the predator index in the Columbia River reservoirs to account for walleye. Predation studies in John Day indicate northern squawfish account for 89% of spring chinook migrants with walleye accounting for an additional 8%. (Beamesderfer pers. comm.) The Ward index was therefore apportioned upward accordingly for the Columbia River projects but not those in the Snake River where walleye do not appear to be as numerous. The consumption of spring chinook by other predators is thought to be minor and no adjustment to the Ward index was made for them. Effective fish travel time was calculated by multiplying the FTT in each reservoir, each year, by the modified Ward predator index for that reservoir.

Table C6 A3.1: Ward predation index and modified predation index.

Project	Ward Predation Index	Modified Index
Lower Granite	0.24	0.24
Little Goose	0.57	0.57
Lower Monumental	0.22	0.22
Ice Harbor	0.11	0.11
McNary	0.31	0.35
John Day	1.00	1.09
The Dalles	1.05	1.14
Bonneville	0.83	0.90

Given the reservoir survival for the reach studies (reservoir reach survival or RRS) and the EFTT for all reservoirs, reservoir survival for the entire system is estimated as follows:

$$\text{Total reservoir survival} = RRS^{(EFTTtot/EFTTreach)}$$

Total system survival is the total reservoir survival multiplied by the total dam survival.

Because assumptions about dam mortality affect estimates of reservoir and system survival, the sensitivity of the survival estimates to changes in dam survival was also explored. The two dam parameters about which the most uncertainty exists are turbine mortality and fish guidance efficiency (FGE) which is the proportion of fish entering the powerhouse at each dam that are diverted from the turbine entrance by a juvenile bypass system. The default turbine mortality used was 92% but a commonly used value of 89% was also used as a sensitivity analysis. Recently derived FGEs based on PIT tag detection probabilities were chosen as default values but older estimates based on fyke net studies were used for sensitivity purposes. Times series of both FGE data sets are shown in Table 2.

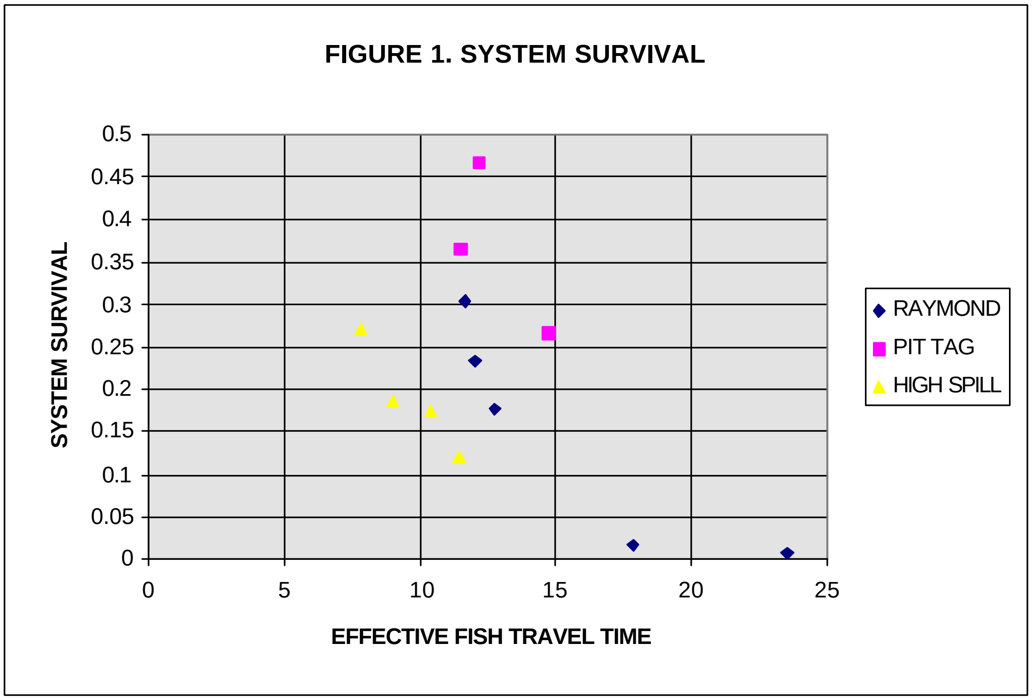
Table C6 A3.2: Two alternative FGE data sets by project and year.

1. FGEs based on PIT tag detection probabilities.								
YR\DAM	LGR	LGS	LOM	ICE	MCN	JDA	TDA	BON
1970	0.02	0.07	0.02	0.02	0.02	0.02	0.34	0.12
1973	0.02	0.07	0.02	0.02	0.02	0.02	0.34	0.12
1974	0.02	0.07	0.02	0.02	0.02	0.02	0.34	0.12
1975	0.07	0.12	0.02	0.02	0.02	0.02	0.34	0.12
1976	0.07	0.27	0.02	0.02	0.02	0.02	0.34	0.12
1977	0.46	0.44	0.02	0.02	0.02	0.02	0.34	0.12
1978	0.46	0.44	0.02	0.02	0.02	0.02	0.34	0.12
1979	0.46	0.44	0.02	0.02	0.02	0.02	0.34	0.12
1980	0.46	0.44	0.02	0.02	0.02	0.02	0.34	0.12
1993	0.46	0.49	0.52	0.52	0.52	0.58	0.34	0.33
1994	0.46	0.45	0.52	0.52	0.52	0.58	0.34	0.33
1995	0.46	0.45	0.52	0.52	0.52	0.58	0.34	0.33

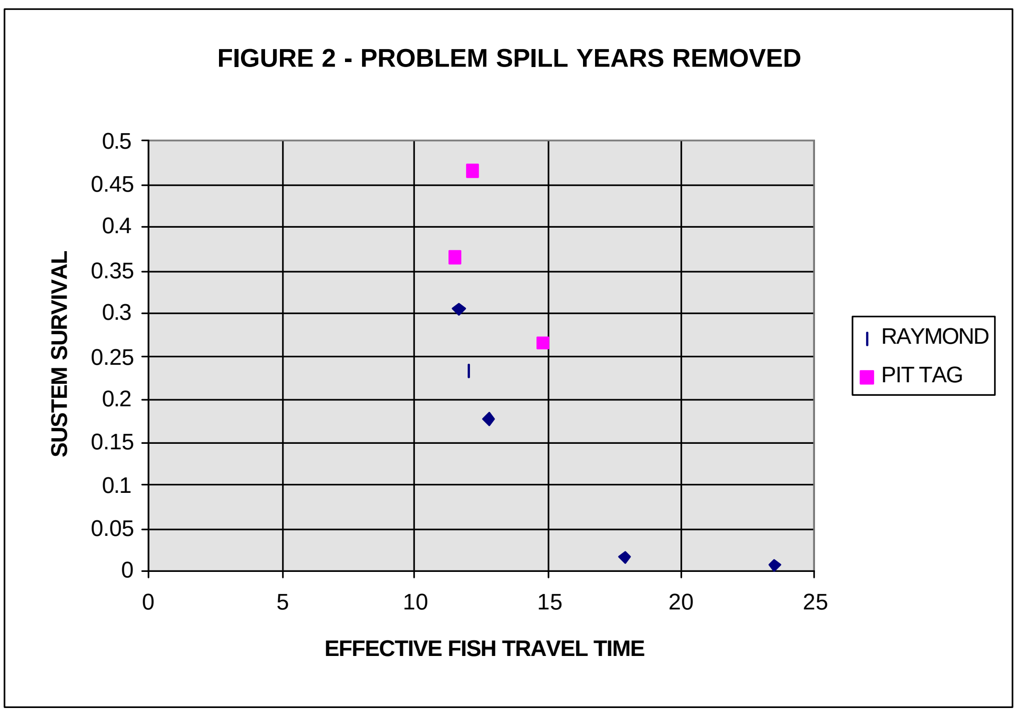
2. FGEs based on fyke net studies.								
YR\DAM	LGR	LGS	LOM	ICE	MCN	JDA	TDA	BON
1970	100	0.02	0.02	0.02	0.02	0.02	0.43	0.2
1973	100	0.02	0.02	0.02	0.02	0.02	0.43	0.2
1974	100	0.02	0.02	0.02	0.02	0.02	0.43	0.2
1975	0.19	0.41	0.02	0.02	0.02	0.02	0.43	0.2
1976	0.53	0.41	0.02	0.02	0.02	0.02	0.43	0.2
1977	0.53	0.6	0.02	0.02	0.02	0.02	0.43	0.2
1978	0.53	0.6	0.02	0.02	0.02	0.02	0.43	0.2
1979	0.53	0.6	0.02	0.02	0.13	0.02	0.43	0.2
1980	0.53	0.6	0.02	0.02	0.34	0.02	0.43	0.2
1993	0.56	0.65	0.65	0.77	0.7	0.72	0.43	0.46
1994	0.56	0.65	0.65	0.77	0.7	0.72	0.43	0.46
1995	0.56	0.65	0.65	0.77	0.7	0.72	0.43	0.46

RESULTS

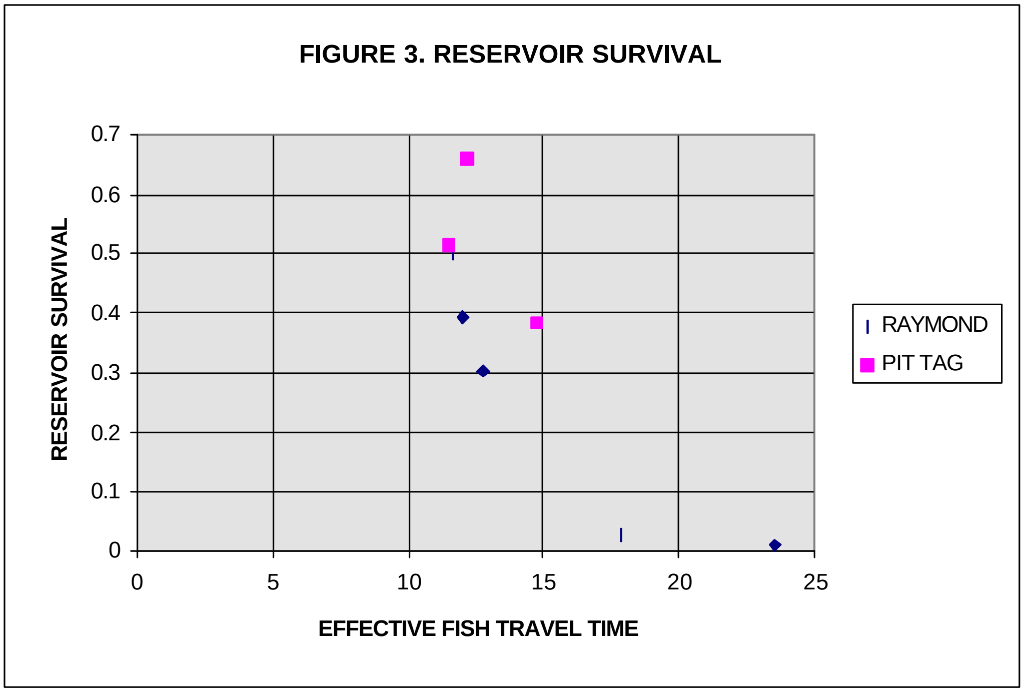
Annual system survival estimates for all years considered are shown in Figure 1.



Estimated system survival appears to have increased in recent years (PIT tag data) relative to earlier years (RAYMOND). Those years labeled HIGH SPILL (1970, 1974, 1975 & 1976) probably produced anomolously low survivals either because of fairly high spills accompanied by a lack of spill deflectors (flip lips) as occurred prior to 1975, or because of extremely high spill levels that occurred in 1975 and 1976 when turbines were being installed in some Snake River projects and spill levels at many projects averaged in excess of 80 thousand cubic feet per second (KCFS) a rate much higher than levels considered safe. Annual system survival estimates without the potentially problematic spill years appear in Figure 2.

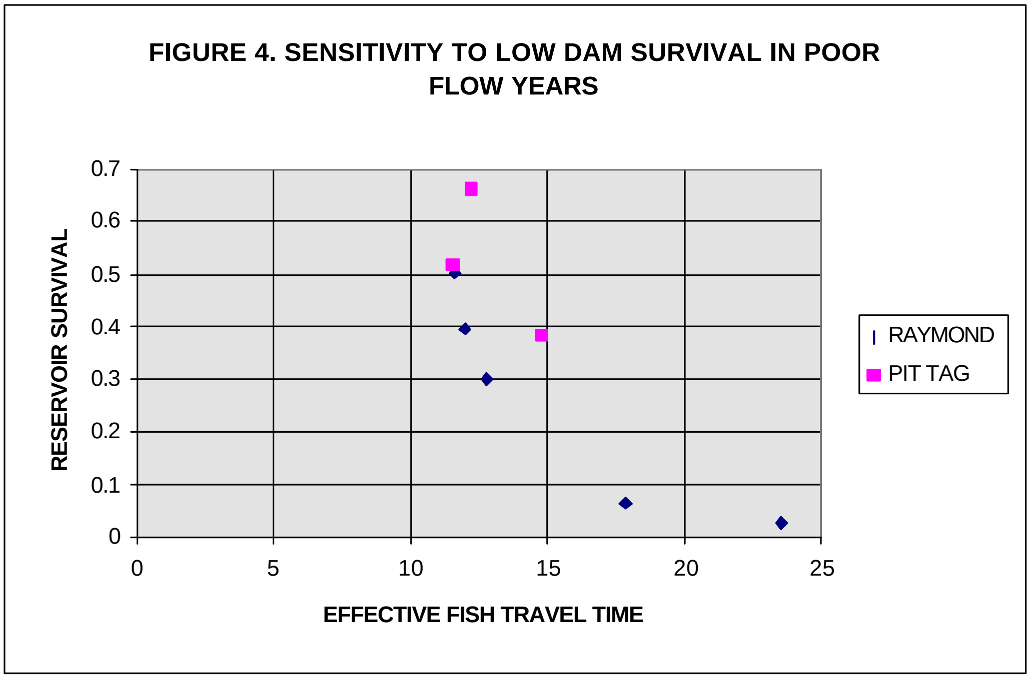


To determine the extent to which the apparent increases are due to improvements at the dam, in the reservoirs or both, the estimated annual reservoir survivals (with the dam effects removed) are shown in Figure 3.



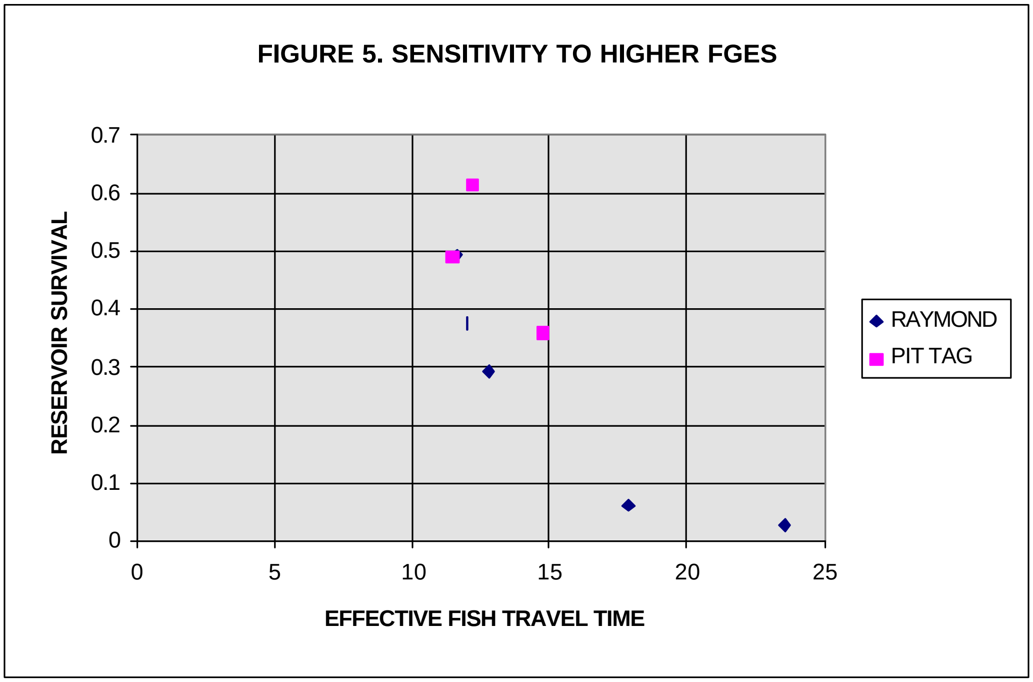
These results indicate the apparent survival improvements in moderate flow years are primarily due to improvements at the dam such higher spill levels and higher Fish Guidance Efficiencies (FGEs) and improved bypass systems in general.

Considerable attention has been devoted to the two data points lying close to the X axis that occurred in two years with low flows and hence high water travel times. 1977 was the lowest flow year on record with an estimated water travel time of 39 days while 1973 was somewhat better with a water travel time of 32 days. While there is general agreement within the region that survival was extremely poor in both these years, some scientists believe that poor bypass conditions at the dams themselves were to blame. In particular, accumulated debris in the trash racks that protect the turbine intakes has been identified a the reason for high descaling those years at the uppermost dam. In 1973 the uppermost dam was Little Goose Dam with a descaling rate of approximately 20% and in 1977 it was Lower Granite Dam with a desclaring rate of approximately 30%. To evaluate how this descaling may have affected system survival estimates and the resulting reservoir estimates, a simulation was conducted that assumed 50% dam mortality at the first project encountered in 1973 and 1977. This value was suggested by Raymond (1979) for mortality at Little Goose Dam in 1973. Results appear in Figure 4.



The assumption of high dam mortality in poor flow years increases the reservoir survival considerably in a relative sense but not very much in an absolute sense.

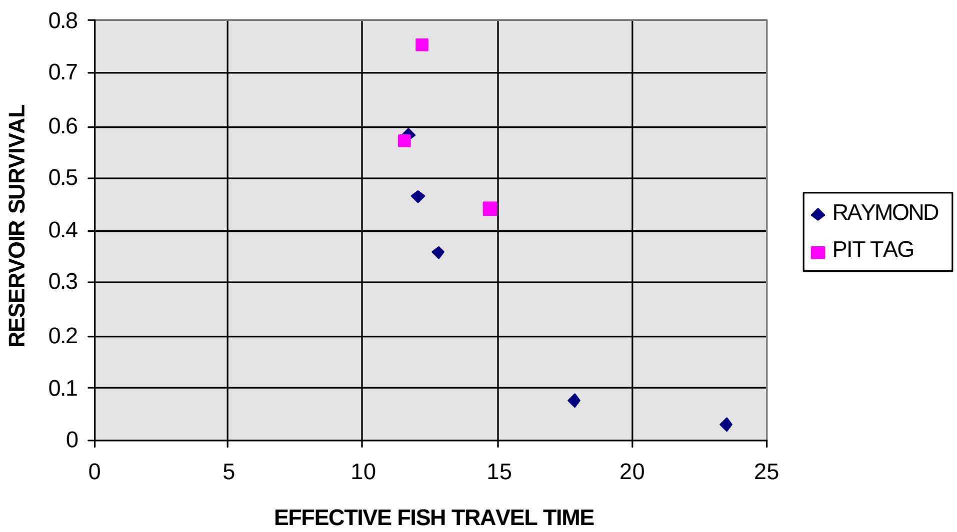
Because the level of reservoir mortality in any given year is wholly dependent on assumed dam passage assumptions, it is useful to look at the sensitivity of reservoir mortality to alternative assumptions about FGEs and dam mortality. The sensitivity on reservoir survival of assuming that Fyke net studies are more accurate estimators of FGE than the PIT tag detection probabilities used as default values herein, is shown in Figure 5.



Assuming a higher dam survival results in slightly lower reservoir survival

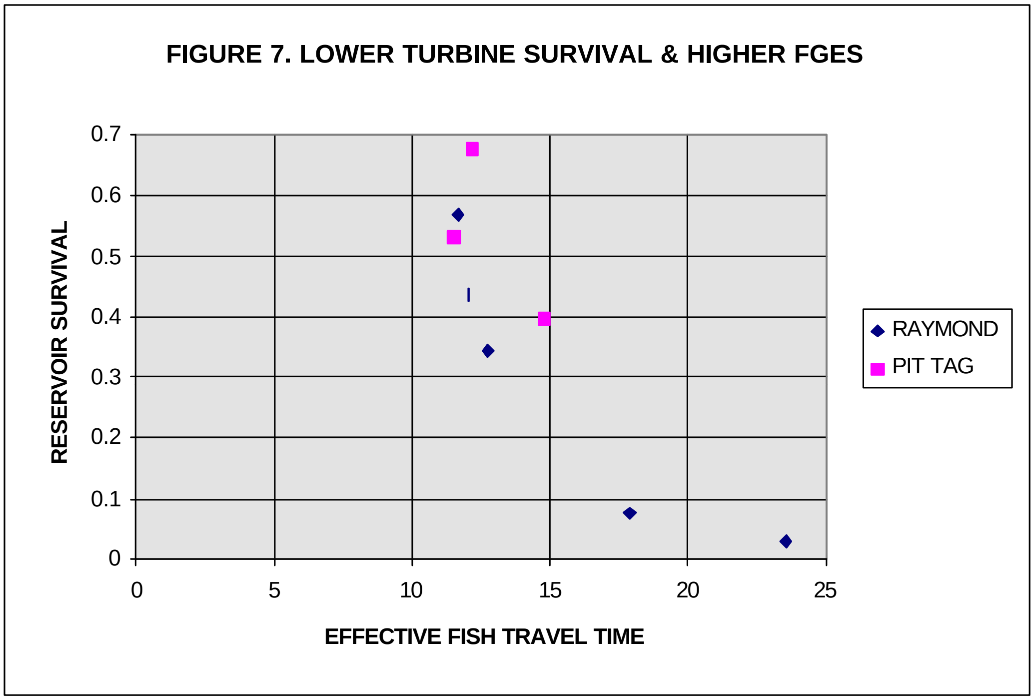
The range of turbine survival values is considered to be 85% to 93%. The reservoir survival values that result from assuming a lower value for turbine survival (89%) rather than the 92% used as the default herein are shown in Figure 6.

FIGURE 6. SENSITIVITY TO LOWER TURBINE SURVIVAL



Because the fyke net based FGEs are higher than those derived from fyke net studies, dam survival goes up and, consequently, reservoir survival goes down.

Simultaneous decreases in turbine survival and increases in FGEs offset each other to a large extent (Figure 7).



The net effect is reservoir survival estimates increases slightly over those shown in Figure 5.

DISCUSSION

Results of PIT tag studies have yielded limited information to date because the reaches studied have been short, the years studied have been few and the range of passage conditions during those years have been narrow. In addition, the reaches used in the PIT tag studies and those conducted by Raymond are not congruent. Despite these shortcomings, it is encouraging that the PIT tag results have largely corroborated the older studies.

Pit tag data indicate moderate increases in system survival through the entire system of eight dams and reservoirs relative to the early years. The highest estimated system survival was approximately 30% during the course of the Raymond studies compared with 47% in the PIT tag era. This analysis indicates increases are largely explained by improvements at the dams, most notably increases in spill levels and FGEs.

The two data sets are in fairly close agreement with respect to the estimated levels of reservoir survival (i.e. the residuals after estimated dam survivals have been backed out of annual survival estimates). The estimated reservoir survivals resulting from the PIT tag studies are only slightly higher than those from the later Raymond years. These improvements in reservoir survival are plausible, because of predator reduction efforts in that began in the early 1990s. Both data sets yield a substantial residuals after dam survival is accounted for indicating that reservoirs should continue to be seen as significant sources of mortality, particularly in low flow/high travel time situations.

However, the early years of the Raymond studies in which nitrogen supersaturation was potentially problematic do not comport with the later Raymond years or the PIT tag data. In the early 1970s high levels of gas supersaturation were linked with Gas Bubble Trauma (GBT) This discovery led to the installation of flip lips in 1975. However the closing of power houses for turbine installation in the newly constructed Snake River dams in 1975 and 1976 resulted in forced spills, often in excess of 80 KCFS, far higher than the even most enthusiastic spill supporter would consider safe. Given the agreement among the later Raymond years and the PIT tag studies, the years before 1977 could be considered outliers except for 1973 when almost no spill occurred.

The PIT tag studies have not shed light on survival in the controversial low flow, high travel time years during which extremely low survival values were recorded in the past. For good or for bad, there have not been mainstem conditions (flows and temperatures) in the PIT tag era that were poor enough to determine if such descaling and low survival would occur in the system as it exists today. There is no doubt that in 1973 & 1977 the fish were in poor condition. The question is whether their poor condition was due to circumstances unique to those years such as debris in the trash racks or, instead, related to a combination of longer migration times and higher temperatures.

On the basis of two sensitivity analyses performed (low bypass and low dam survival) there is reason to assume that the same poor conditions repeated today would produce survivals that while considerably higher in a relative sense, would not be appreciably higher an absolute sense. All the authors who studied survival and passage conditions in 1973 and 1977 concluded that the poor survival was due to the poor condition of the fish attributed to low flow and holdoverism (Ebel et al. 1973; Park et al. 1978; Sims et al. 1978) Of these report, only one mentions trash rack debris (Park et al. 1978) and note that “Trash racks were cleaned but descaling did not subside.” This indicates that the debris was not the only problem even though it probably aggravated a bad situation. These authors also pointed to an almost complete lack of spill in low flow years as contributing to low survival.

It should be noted. however, that because the PIT tag studies all occurred in moderate flow years, there is no way they can be used to corroborate or contradict the 1973 or 1977 data points. Neither have the PIT tag studies to date helped to define the expected survival in high flow/low travel time conditions.

CONCLUSIONS

This analysis indicates the PIT tag studies have largely corroborated reservoir survival estimates from the earlier Raymond studies within the usual range of passage conditions but sheds little light on survivals outside this range. Survival gains appear to be due to improvements at dams, ostensibly due to increases in FGEs and spill proportions, and to a lesser extent in the reservoirs where increased survivals are plausible because of recent efforts to reduce predator levels. However, apparent increases may be due to differences in the scopes of the two estimation methods.

Assumed decreases in survival due to debris in the trash racks at the first dam encountered in the low flow years 1973 and 1977 resulted in major relative, but minor absolute changes in reservoir survival. More substantial changes in reservoir survival occur if the problem spill years are ignored. It is difficult to assess the effects of low spills and zero night time flows but these too may have contributed to prolonged migrations in 1973 and 1977. Although it appears enhanced levels of flow and spill optimize survival under the current hydropower configuration, those survivals are probably not high enough to rebuild stocks even if those conditions could be assured every year.

While there would likely be some increases in system survival if conditions that occurred in 1977 and 1973 were to occur in this era, there is no reason to reject the conclusion of the many authors that studied survival in those years, vis poor survival was due to poor fish condition.

Note, however, that the proposed sensitivities, while increasing absolute survival, may not produce significant relative changes. Because the regional life cycle modeling frameworks are driven by relative changes, the changes indicated in this analysis (eliminating problem spill years and assuming higher reservoir survival in poor flow years) may produce only slight changes with respect to management advice. More importantly, because poor flow years occur only rarely in the historic record, and because poor water years are minimized or eliminated in all proposed management plans, the right side of the curve does not come into play very often and the two data points that define it (1973 & 1977) may not be as important as often assumed as judged by the attention they have received over the years.

The most important conclusion is that the two data sets are in fairly close agreement with respect to reservoir survival. The estimated reservoir survivals from the PIT tag studies are only slightly higher than those from the later Raymond years. These improvements in reservoir survival are plausible because of predator reduction efforts in recent years. Both data sets yield a substantial residuals after dam survival is accounted for indicating that reservoirs should continue to be seen as significant sources of mortality, particularly in low flow/high travel time situations.

RECOMMENDATIONS

The fact that the PIT tag data tend to corroborate the Raymond data is encouraging because it lends support to management decisions based on those data. And while somewhat limited, the additional information provided by the PIT tag data presents opportunities for sensitivity analyses to be addressed in the near term.

It is widely believed that passage past the Snake River dams , particularly the first dam encountered, was very poor in some years immediately after construction The changes in reservoir survival resulting from assumptions about poor dam passage in poor flow years should be incorporated in any alternative reservoir survival function.

The development of one or more reservoir survival relationships has the potential to result in substantial changes relative to current reservoir mortality assumptions. However, because the STFA modeling framework is driven by relative changes, the expected survival over the full range of conditions must be defined before it can be determined whether any of the changes would lead to different management advice. Thus as alternative relationships are developed to reflect changing information or alternative views, the alternatives should be assessed with both passage and lifecycle models to determine if they change the projected management advice.

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