Submission 19

Hatchery "Extra Mortality" Hypotheses:
Response to Appendices 1&2 of the W.O.E., February 4, 1998.

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Note: most of the comments below apply directly to the NMFS hatchery hypothesis (Appendix 1), but given the similarity of the NMFS hatchery hypothesis to the Paulsen hatchery hypothesis, the comments below also apply to Appendix 2.

The hatchery hypotheses for explaining extra mortality are untenable and based on little or no direct evidence. The effects of the potential mechanisms 'hypothesized' as causing negative impacts of hatchery fish on wild fish may actually be opposite of those hypothesized. These effects are also likely to vary dramatically with a suite of other factors including the environment, life stages of the species present, their relative and total densities, and their history of co-evolution. The hatchery related mechanisms hypothesized for causing the reduction in wild salmon survival are, for the most part, inseparable from mechanisms of mortality associated with the hydrosystem. Further, the correlation of total extra mortality from the PATH BSM with hatchery releases is problematic in that the correlation does not imply a causal relationship, and extra mortality can also be correlated to numerous other parameters associated with the hydrosystem and transportation. Finally, because hatchery smolt releases are mitigation for hydropower impacts, a correlation is expected whether or not the hatchery hypothesis is true. These points are expanded on in greater detail in the following discussion.

I. Lack of strong evidence of hatchery effects on Snake River wild salmon:

There is little or no conclusive evidence of hatchery impacts on wild fish in the Columbia Basin. Recent comprehensive reviews and syntheses have concluded that overall there has been no effect of hatchery released fish on wild fish survival, or that if there has been an effect, we are unable to detect it. In 1996, CBFWA (Columbia Basin Fish and Wildlife Authority) prepared the 'Programmatic EIS entitled 'Impacts of artificial salmon and steelhead production strategies in the Columbia River Basin', for USFWS, NMFS, and BPA. This EIS includes a scientific literature search and synthesis designed to identify what we know and do not know about the interaction of hatchery fish and naturally reproducing fish as they jointly use the Columbia River mainstem migration corridor. The EIS concluded that *"while the literature was replete with warnings and cautions about possible genetic risks, there was no explicit evidence of adverse impacts caused by hatcheries in the Columbia River migration corridor…. This is not to infer that we know such adverse impacts do not occur."* Further, this report [96 EIS] noted that: *"Nuances aside, the findings in this document reinforce findings in most other recent substantive hatchery program reviews including the Northwest Power Planning Councils' Columbia River Basin and Wildlife Program (NPPC 1994); the National Fish and Wildlife Foundation's Report of the National Fish Hatchery Panel; the National Research Council's Upstream: Salmon and Society in the Pacific Northwest (NRC 1995); the Columbia River Inter-Tribal Fish Commission's Anadromous Fish Restoration Plan (Nez Perce Tribe et al. 1996); and the National Marine Fisheries Service's Proposed Recovery Plan for Snake River Salmon (NMFS 1995) among others."*

Similarly, The Independent Science Group's 'Return to the River' report concluded that: *"The ecological, behavioral, and energetic interactions of hatchery fish with native species (including wild salmon) and fish assemblages of the Columbia River ecosystem have not been evaluated. In the operation of hatcheries, those interactions are generally assumed to be inconsequential or benign …"*

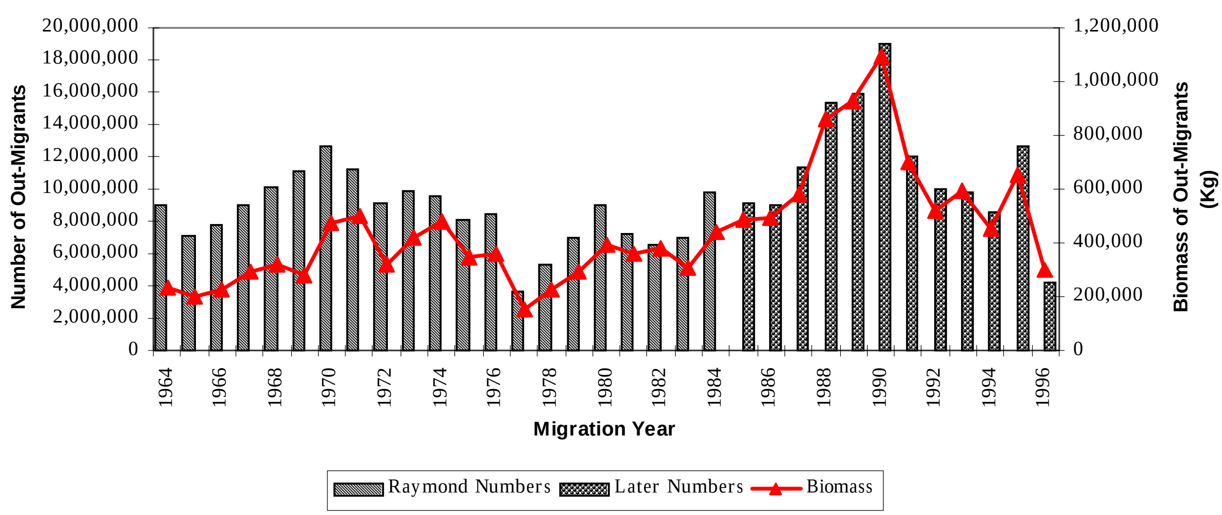
And in regard to concerns directed at hatchery and supplementation impacts, Riddell (1993) concludes: *"Regrettably, the debate has tended to be more rhetorical than empirical owing to a paucity of critical evaluations. Studies have demonstrated, however, that impacts attributable to each source can occur but that the degree of impact will vary with the scale of the project, its integration with management objectives, and the status of the natural population."*

The NMFS hatchery hypothesis (Williams et al. 1998) suggests that hatchery production has had a negative effect on wild spring/summer chinook through the mechanisms of reduced growth rate, stress, predation, and disease transmission. However, the direction and magnitude of the effects of these interactions remains unknown and could actually be opposite of those hypothesized in the NMFS hatchery hypothesis. The hatchery hypothesis suggests that hatchery fish may be out-competing wild fish through a demand on the food supply. First, this supposition requires that the carrying capacity of the system is currently being exceeded (see below), a hypothesis in itself for which there is no evidence. Second, the lower survival of hatchery smolts as compared to wild fish suggests that wild fish may actually outcompete hatchery smolts, if competition is taking place. Third, the environmental characteristics of the migration corridor, during the period of overlap for hatchery smolts and wild spring summer chinook, provides little opportunity for competition among the two.

Carrying capacity:

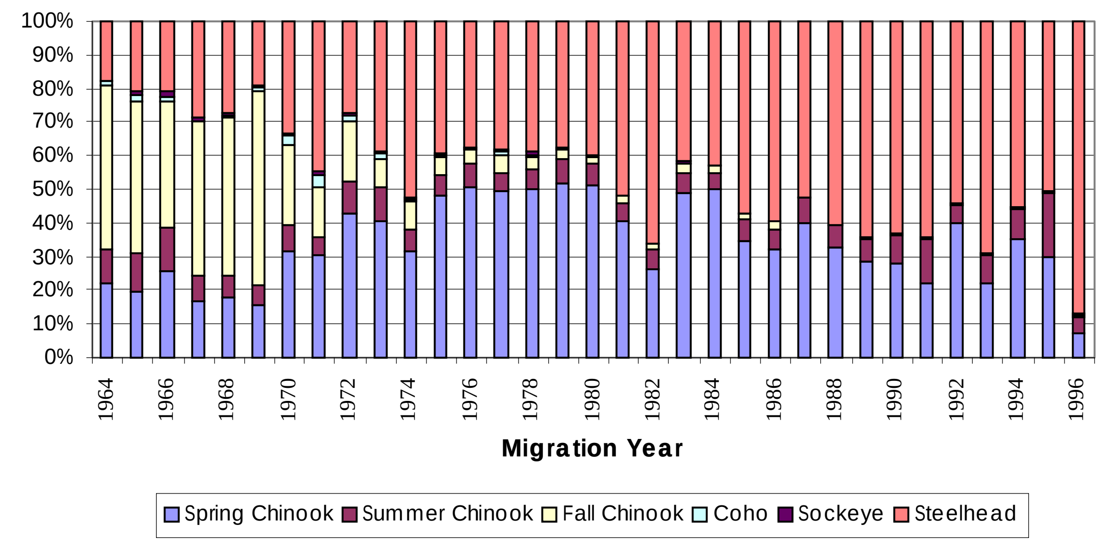
If the current 20 million Snake River smolts place severe constraints on the carrying capacity of the Snake and Columbia River migration corridor, then how did the corridor handle juvenile production from the estimated 3 to 6 million salmon and steelhead that returned to the Snake River historically (one third of the estimated 10 to16 million salmonid adult returns to the Columbia historically; ISP 1991)? A conservative estimate of Snake River juvenile migrants around the beginning of this century is 50 million smolts. This estimate is derived from Chapman's (1986) estimate of a total of 7.5 million adults as the single best estimate of total predevelopment runs to the Columbia River based on peak-period catches and probable optimum exploitation rates. Applying a conservative smolt to adult survival rate of 5%, we estimate 150 million smolts migrated out of the Columbia. About a third of the historic run originated from the Snake River, hence the 50 million estimate. Using presence/absence data, the Northwest Power Planning Council estimated current smolt capacity for wild and natural production to be in excess of 28 million (approx. 2 million sockeye, 6 million steelhead, and 20 million chinook, plus unknown coho capacity; ISP 1991). Current smolt production (hatchery and natural) is only 71% of this estimate of natural smolt carrying capacity for spawning and rearing areas.

Figure 1. Temporal pattern in number and biomass of salmonid outmigrants from the Snake River, 1964-96



In figure 1 above, we show the total number and biomass of hatchery and natural out-migrants from the area above the upper-most dam, for 1964-96 migration years. Raymond (1988) provided numbers for the pre-1985 period. Using collection numbers, spill proportions, and FGEs (from recent PATH work or the FPC), we developed comparable estimates for the 1985-96 period. Biomass is derived by multiplying the numbers by an appropriate age-specific weight (derived from numerous sources as there is little direct data available for all species, especially specific to the Snake River). With the possible exception of the 1988-90 migration years, the numbers appear to be very similar. This comparison shows that the number of out-migrants range is 7-13 million for migration years 1964 through 1975, 4-10 million for migration years 1975 through 1984, and 4-19 million for migration years 1985 through 1996. The biomass has changed relative to the numbers because of the change in the composition from the smaller subyearlings (fall chinook) to larger Age I and Age II out-migrants (Figure 2).

Figure 2. Composition of Snake River Out-migrants (pre-85 Raymond; post-84 Petrosky or Langness using passage indices and FGEs)



Coho and sockeye have not produced significant levels of out-migrants relative to other salmonids, so the recent extinction (coho) or near extinction (sockeye) status, has little relevance to the comparison of total juvenile out-migrant numbers or biomass. The stream-type chinook and steelhead have shared about equal proportions of the out-migrants with the exceptions of the 1982 and 1996 migration years.

Competition:

The hatchery hypothesis suggests that the larger number of hatchery fish and their larger biomass reduces wild smolt survival through competition for food resources. However, as indicated above survival of hatchery fish is often substantially lower than that of wild fish. Giorgi (1991) indicates that survival of hatchery fish from release to Lower Granite is less for hatchery fish as compared to wild fish as the hatchery fish are of a lower pedigree. Marnell (1986) concludes that hatchery fish are at a competitive disadvantage to wild fish and that hatchery fish do not impact the growth and survival of wild fish. Leider et al. (1990) similarly concludes that natural offspring of transplanted hatchery fish survived less well than those of wild stock. Reisenbichler and McIntyre (1976) demonstrate that wild fish have higher stream survival rates than hatchery fish or hatchery/wild crosses, and Bigelow (1995) conclude that hatchery-wild fish co-occurrence does not appear to negatively impact wild fish. Further, Connor et al. (1997) found that wild smolts, as compared to hatchery smolts, had higher condition factors, faster and earlier travel times, and faster growth rates during out-migration.

In addition, this competition hypothesis proposes a density dependent mechanism for a life-stage that is not well established in the literature (the migration corridor). There is considerable evidence for density dependence in the adult to smolt stage (e.g., Petrosky and Schaller 1996; Bjornn 1978; Lindsey et al. 1989) but little or no evidence of density dependence in smolt to adult stages (Peterman 1978, Langness 1997). And if constraints on the carrying capacity have caused an increase in extra mortality, this increase should be observable as a significant decline in freshwater adult-to-smolt survival. However, the PATH 1996 Retrospective Conclusions document 4a2 concludes: *"Though changes in the quantity and quality of freshwater spawning and rearing (FSR) and pre-spawning (PS) habitat may have contributed to production declines in some index streams, we conclude with reasonable confidence that changes in adult-to-smolt survival (presumably related to the quantity and quality of FSR habitat) do not appear to be of a great enough magnitude alone to explain the post-1974 decline in spring and summer chinook index stocks*." Corroborating evidence is listed on page 12 of the 1996 Conclusions report.

Regarding steelhead smolt releases, NMFS has implied (Appendix 1) a non-hydro interaction that would systematically cause greater extra mortality for Snake River spring/summer chinook. If this was severe, we might expect to see differences between Snake River stocks depending on whether or not steelhead were released in that tributary—none of the Idaho index stocks have steelhead releases within the subbasins, Minam and Imnaha would have in recent years (mid-1980s). Also, this thinking implies that John Day stocks would be expected to be doing better than the other three downriver spring chinook stocks that migrate with hatchery steelhead.

Similarly, Wilson et al. (1996) evaluated hatchery impacts on wild fish for two of the spring/summer indicator stocks –the Warm Springs stock as an indicator stock from the Low-Mid Columbia and the Imnaha stock as an indicator stock for the Snake R. These two stocks are comparable in that they have both been operated like supportive breeding programs and hatchery recruit-per-spawner data were available. The analysis used a regression approach to compare and index of wild stock survival [ln(R/S)] as the dependent variable and a set of quantitative independent variables intended to reflect the degree of hatchery influence. This preliminary analysis suggests that the Warm Springs stock, the low-mid Columbia River stock has been negatively affected by hatchery practices while no effect was observed for the Imnaha stock, the Snake River stock. For the Warm Springs stock, hatchery release number in combination with wild spawning escapement, appeared to make a significant contribution in explaining the variability in wild ln(R/S) and was negatively correlated with that index. This analysis also highlights the problems associated with correlating hatchery release to some measure of survival, when the hatchery programs were initiated in response to dramatically declining escapements. There will be significant downward time trends in the survival index, and release numbers are going to exhibit high negative correlation with natural spawning escapement and survival.

The authors of the hatchery hypothesis cite Dawley et al. (1986) and relate the fact that chinook were the first to show empty stomachs as compared to coho and steelhead (Dawley et al. (1986). They then extrapolate saying that this suggests coho and steelhead have a competitive advantage over chinook. Many assumptions would have to be made for this conclusion to be valid. First, the mere correlation of empty stomachs with anything is fairly difficult, if not meaningless. The cause of an empty stomach can be, among other things, a lack of food or a lack of feeding. Cannamela (1993) showed that hatchery steelhead smolts don't feed extensively until 1 week post-release and that 95% of steelhead smolts left the release area within 11 days. And in regard to the NMFS supposition that chinook are at a competitive disadvantage to coho, Nicholas et al. (1979) demonstrated that although hatchery coho were larger and consumed several similar food organisms as wild chinook, the coho had eaten fewer organisms than chinook and many coho had empty stomachs. Secondly, food sources between these species may not overlap, especially in the upper rearing areas. Third, the Dawley et al. observations can be interpreted several ways, including evidence of hydropower system effects on subsequent life stage survival. Dawley et al. reported (p. 149) that Dworshak Hatchery steelhead that were barged to a release site downstream of Bonneville Dam had significantly higher numbers of non-feeding fish (73%) than a control group (non-transported) from that hatchery (34%). They suspected that the short period between release (3 days) and the estuary sample location was insufficient for barged fish to have developed aggressive feeding behavior in the river environment. Finally, as with the freshwater stage, there is little evidence to support a hypothesis of competition among hatchery and wild salmon in the estuary (Myers and Horton 1982, Levings et al. 1986, *and above*).

Decreased growth rates and seawater transition:

The authors of the hatchery hypothesis suggest that decreased growth rates and energy reserves of wild yearling chinook likely result in the *"possibility of decreased ability to transition to seawater."* The bioenergetics argument developed in this paragraph is directed primarily at a hypothesis that there is competition for food in an altered system due to too many steelhead smolts from mitigation hatcheries (other mechanisms for delayed mortality and seawater transition have also been proposed as hydrosystem effects). Competition, if present, has not been documented, and as shown above, there are several possible interpretations of the Dawley et al. paper. Levings et al. (1986) reported that the presence of hatchery chinook salmon did not affect residency times and growth rates of wild juveniles in a British Columbia estuary and that hatchery fish used the estuary for about one-half the length of time that wild fry were present (40-50) days. Note also that the bioenergetics argument applies equally as well to the hydro hypothesis for delayed mortality with respect to a documented delayed migration due to presence of dams and stress caused delayed mortality associated with crowded conditions during bypass, collection, and transportation.

Decreased growth rates and susceptability to predation:

The NMFS hatchery hypothesis indicates that decreased growth rates of wild smolts, due to hatchery impacts, may make wild fish more susceptable to predation. However, predation is not just size dependent; it is also density dependent. And if as the authors estimated, hatchery fish are 10 times as numerous as wild fish (p. 5, A1, WOE), one would assume that northern squawfish would switch to the most abundant prey, regardless of size. Thompson and Tufts (1967) found northern squawfish switched from feeding on wild sockeye salmon (mean length, 59.6 mm) to hatchery sockeye salmon (mean length, 97.7 mm) because of density dependent factors and not size selection. Several other studies also indicate there was either no difference (Hvidsten and Lund 1988) or higher levels (Ruggles 1980) of predation on hatchery produced smolts compared to wild smolts. Additionally, predation on hatchery fish is likely greater than on wild salmonids because of unsuitable avoidance and foraging behaviors, inability to assess predation risks, and a general unfamiliarity with new surroundings for the hatchery fish (Raney and Lachner 1942; Vincent 1960; Ritter and MacCrimmon 1973; Johnson and Abrahams 1996). Several studies have demonstrated intense post-release predation on hatchery-reared salmonids (MacCrimmon 1954; Bams 1967; Larsson 1985).

Note also, Criteria i) of the W.O.E., for assessing the applicability of evidence for/against a hypothesis, asks whether *"the evidence is relevant to the hypothesis being evaluated ?"* The sources listed as evidence for the mechanism of a larger number and biomass of hatchery fish reducing the carrying capacity of the migration corridor and limiting energy reserves of spring/summer chinook (4.1 in Table 4.2.3-2 of the W.O.E. and on p. 7 of Appendix 1) are not applicable in that they (Poe et al. 1991, Ward et al. (1995) do not demonstrate that "Decreased growth rates and energy reserves of wild yearling chinook" are caused by stress from interactions with hatchery fish (i.e. they do not provide evidence for the stressor). Poe et al. (1991) provides evidence that "squawfish are size selective on smaller prey" (not why the prey are smaller), and Ward et. al. (1995) develop a predation index to compare the relative magnitude of predation on juvenile salmonids throughout the Columbia and Snake rivers. Neither of these references address the increased vulnerability of wild fish due to interactions with hatchery fish, and both are actually much more applicable as evidence for the hydrosystem hypothesis.

Characteristics of the hydrosystem during freshet and hypothesized mechanism:

The hatchery hypotheses relies heavily on the notion that competition and stressful interactions occur between hatchery smolts and wild smolts, during the spring migration. Yet interactions above the hydrosystem are limited to a short period in the spring before and during smolt migration when the environmental conditions of the migration corridor provide little opportunity for these mechanisms to occur. Spring/summer chinook migrate downstream during high flow, low water temperature, and high turbidity. Above the hydrosystem, predation rates on juvenile salmon during the spring freshet are likely insignificant due to high water velocities and turbidity (Falter 1969; Brown and Moyle 1981; Buchanan et al. 1981; Beamesderfer 1983; Dauble et al. 1984; Kirn et al. 1986; Faler et al. 1988; Beamesderfer and Rieman 1991; Tabor et al. 1993). In addition, high flows and velocities should also reduce the potential for concentration of smolts thereby making the competion and stressful interactions less likely. Further, cold water likely results in low consumption rates of both smolts and their predators thus reducing the likelihood of competion for food among smolts and predation on smolts by predators (Stewart and Johnson 1992).

II. Most hypothesized hacthery effects are actually hydrosystem effects:

Many components of the hatchery hypotheses are inseparable from the other competing hypotheses for extra mortality -- the hydrosystem hypothesis, the BKD hypothesis, and certainly the new 'multiple factor hypothesis' hypothesis. Pages 5-6 of the WOE describe 'Criterion 1)' for evaluating hypotheses and asks *whether "the stressors claimed to be driving the hypotheses represented by state variables which reflect those stressors and not other stressors that are part of competing hypotheses?"*. As most of the mechanisms (stressors) hypothesized for the hatchery hypothesis are a direct result of the hydrosystem and associated bypass and transportation, they are actually stressors for the hydrosystem hypothesis (and the 'BKD' and 'multiple factor hypothesis'). While there is no doubt that competition, disease, and predation may occur, it is extremely difficult if not impossible to identify the relationship (mechanism) between the abundance or attributes of hatchery produced fish in the corridor and some objective expression of the potential impact on naturally produced fish due to the changing environmental conditions in the hydro system (DPEIS 1996).

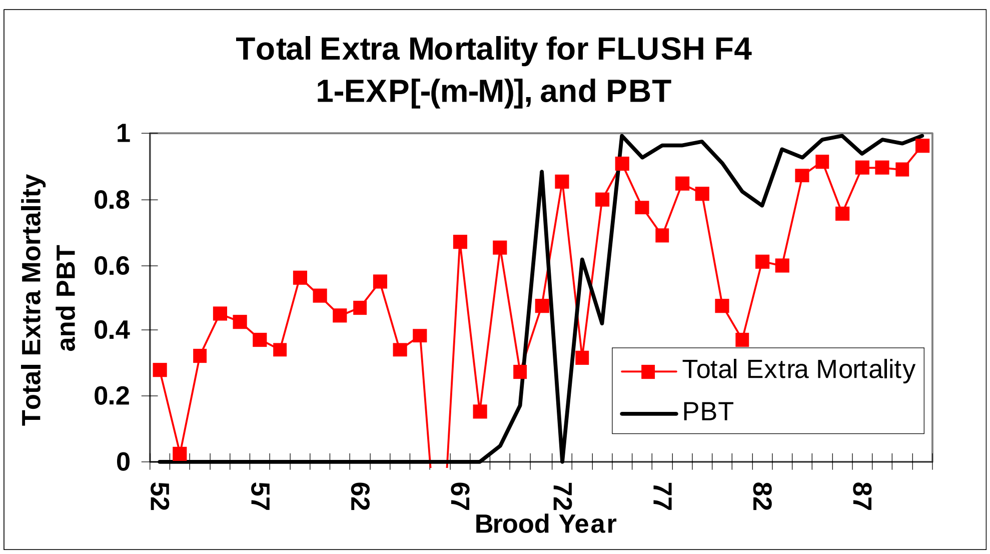
Note: the mechanisms proposed for the hatchery hypotheses should be separated into those that are thought to operate outside of the hydrosystem versus those that operate inside the hydrosystem. As written, it is difficult to decypher where the mechanisms of competition, increased suscepatability to predation, and disease transmission are hypothesized to operate (comments from PATH workshop, CRITFC, July 30-31, 1998).

The crowding and stress experienced by yearling chinook smolts, and even presence of hatchery steelhead smolts (from hydropower mitigation programs), are a <u>result</u> of the hydropower system. Williams et al. make the case that yearling chinook are more stressed when crowded with steelhead. They do not focus on other causes of stress such as contact with travelling screens, passage through fish and debris separators where fish may be delayed and crowded, holding and crowding in raceways and loading and transport in trucks or barges (Matthews et al. 1986). For example, seawater challenge tests (48 h tests; Matthews et al. 1986) of yearling chinook smolts found a progression of delayed mortality effects through the sequence of dam passage. Yearling chinook smolts taken from turbine intake gatewells had lower mortality than fish taken from raceways, trucks and barges; presence of larger steelhead smolts also increased chinook mortality. Holding density in the Matthews et al. species interaction tests was 12 g/L, roughly one chinook smolt per liter [and even less than maximum transportation densities --36-60 g/L (Larry Basham FPC, pers. comm.)]. Compared to fish densities during river or reservoir migration, the densities in raceways and transport vehicles are extremely high.

Total extra mortality vs. hatchery production:

The NMFS hatchery hypothesis is largely based on a relationship between hatchery releases of steelhead and total extra mortality (transported and inriver combined) from the PATH BSM model. However, a regression of extra mortality from FLUSH as a function of PBT (the proportion of transported fish below Bonneville) explains and equal amount of the variance (R^{2}'s are equal) to a regression of extra mortality as a function of steelhead hatchery release (Figure 1, Appendix 1, extra mortality vs. hatchery steelhead release: $R^2 = 0.41$; Figure 1 this report, n= 39, extra mortality vs. PBT: $R^2 = 0.40$, n=39). The correlation of extra mortality and hatchery production, as evidence for a hatchery hypothesis, is confounded by the relationship between extra mortality and the hydrosystem. If these correlations provide evidence for hypotheses about extra mortality, then they provide equally as good evidence for the hydrosystem hypothesis of extra mortality, particularly for transported smolts.

Further, this relationship between extra mortality and the proportion barged below **(Figure 3)** Bonneville exemplifies the inextricable link between extra mortality and the hydrosystem, passage models, and also the underlying assumptions about 'D'. Problems with the assumptions about 'D' and its implemention are discussed in detail in the STFA comments to the WOE submitted 7/27/98 and in Appendix 22 of this report. The NMFS hatchery hypothesis does not attempt to correlate hatchery releases with extra mortality of inriver smolts (*1-lambd n*). However, Paulsen and Hinrichsen (1998, Appendix 2) correlate hatchery releases of spring/summer chinook with total extra mortality and extra mortality of transported and inriver smolts (1- lambda t and 1- lambda n, repectively). We note elsewhere (Appendix 21) in our comments problems with analyses of extra mortality of inriver smolts (1-lambda n). Given the magnitude of the fish transported in the brood years 1975-1990, extra mortality is heavily influenced by the assumptions for the transport extra mortality assumptions in the passage models.



° Figure 3. Total extra mortality (1-EXP[-(m-M)]) for FLUSH F4 model run compared to proportion of smolts below Bonneville Dam that were transported (PBT), brood years 1952-1990.

Stress from bypass, collection, holding and transport:

The NMFS hatchery hypothesis suggests that stress from crowded conditions with hatchery fish during bypass, collection, holding and transport increases the suscepatbility of wild fish to disease and predation. However, these stress effects are actually hydrosystem effects as the stressful interactions occur when densities are high during bypass and associated with transportation. Criteria i) in the WOE, for assessing the applicability of evidence for/against a hypothesis asks whether *"the evidence is relevant to the hypothesis being evaluated ?"* Accordingly, the references listed under 4.2 in Table 4.2.3-2 of the W.O.E. may actually be more applicable to EM1 (the hydrosystem hypothesis) and could be moved to 1.2 (Table 4.2.3-2, p. 87-88). The limited cases where hatchery fish have been shown to have negative impacts on wild fish have been largely in artificial situations where densities are extremely high (IDFG 1988; Petrosky and Bjornn 1988; Pearson et al. 1996; *and see those references listed under 4.2 in Table 4.2.3-2 of the W.O.E.*).

Stress and disease transmission:

The hatchery hypotheses suggest that stress caused by high densities of hatchery smolts in areas where these fish congregate can result in increased mortality due to disease transmisison, primarily BKD. First, the outcome of exposing wild fish to infected hatchery fish, whether it is detrimental or benign, depends on the conditions under which the exposure occurs. If the contact occurs under stressful condition created by collection raceways or barges, it can be attributed to the conditions, not the presence or absence of BKD in hatchery or wild fish. In this case, the "extra mortality" is again attributable to the hydropower system (IDFG 1998). Second, disease and the transmission of diseases from hatchery fish to wild fish is inconclusive at best. Work by Pippy (1969), Allison (1961), and McDermott and Berst (1968) all concluded that there was little or no transmission of pathogens to wild resident fish. Also there is evidence on the other side, of horizontal transmission of BKD from wild brook trout to stocked salmonids (Mitchum and Sherman 1981).

IDFG (1998) also demonstrated that the fish health threat relates much more strongly to crowding and stress during collection/transportation than to incidental contact during in-river migration. Their review of fish health and stress literature, and new data, indicated that: 1) BKD is no more prevalent in Snake River systems than elsewhere in the Columbia Basin; 2) the disease agent, *Renibacterium salmoninarum* (RS), could be detected in the water of collection raceways and barge holds and that brook trout contracted BKD when exposed to these environments; and 3) RS was not in sufficient quantity to be detected in waters of the Snake River outside the barge holds. Their analysis indicates that the effect of stress from hatchery fish on wild fish's susceptability to disease is a hydrosystem effect that would be alleviated under A3 (drawdown). IDFG (1998), summarizes the *"stressors and the cascade of events that follow stress-related events during collection, barging, and release of anadromous fish (Congleton et al. 1984; Bjornn et al. 1984, 1986, and 1987; Wedemeyer 1985; Pascho and Elliott 1993; Schreck 1998)."* They conclude: "*Collection and barging through the upper Snake and Columbia River corridor represents the largest fish health danger to upper Snake River stocks of anadromous fish by exposing chinook to overwhelming stress and to horizontal transmission of etiologic agents, particularly Renibacterium salmoninarum (RS).*" See Appendix 20 of this report (IGFG 1998) for a detailed discussion of BKD and the effects of stress.

Stress and susceptability to predation:

The hydrosystem has altered the system such that conditions are now optimal for predation on salmonid smolts. The altered system, in addition to the stress and injury associated with the hydrosystem, causes increased vulnerability to predation, particularly by northern squawfish. Lakes (reservoirs) and artificial environments near dams are areas where predation on juvenile salmonids by squawfish has been documented to be greatest (Poe et al. 1991; Brown and Moyle 1981 ;Ward et al. 1995; Vigg et al. 1991). Salmonids are often disoriented during passage and washed back into preferred habitat areas of northern squawfish (slack areas at the face of the dam) (Long et al. 1968; Faler et al. 1988). Similarly, for channel catfish in Snake River reservoirs, Bennett et al. (1983) found that about 41% of the catfish collected in spring in tailrace areas had eaten juvenile chinook salmon and steelhead which is similar to Poe et al.'s (1991) finding that most channel catfish predation on juvenile salmonids occurred in the tailrace area and was confined to spring (Poe et al. 1991). Moreover, salmonids are not a major prey item of squawfish in free-flowing rivers as squawfish prefer low-velocity microhabitats and smolts tend to migrate in fast-flowing water (Falter 1969; Brown and Moyle 1981; Buchanan et al. 1981; Beamesderfer 1983; Dauble et al. 1984; Kirn et al. 1986; Faler et al. 1988; Beamesderfer and Rieman 1991; Tabor et al. 1993).

III. Hatchery supplementation is a mitigation measure for the hydrosystem:

Hatchery supplementation in the Snake River, as part of the 'Lower Snake River Compensation Plan' initiated in 1976, was developed to <u>mitigate</u> fish and wildlife losses caused by the four lower Snake River hydroelectric dams. Note that there is also correlation with the number of dams on the Snake and Columbia Rivers and number of hatchery fish. This last relationship has a cause and effect because the hatcheries were built as mitigation for dam losses. Yet, the NMFS hatchery hypothesis implies that if we did not have to mitigate for steelhead losses, spring/summer chinook might be doing better. If hatchery steelhead were replaced by recovered wild steelhead, under this hypothesis, there would continue to be problems with stress when wild steelhead smolts were crowded with chinook smolts in raceways and barges at the dams.

IV. Management Actions:

As hatchery impacts are hypothesized to be greatest during bypass, collection, and transportation, we would expect to see little reduction in extra mortality under A1 or A2. Hatchery production as mitigation for the hydrosystem would, in theory, be discontinued at the time the Snake River stocks were recovered. However, if steelhead are recovered, under both A1 and A2, the negative impacts of and steelhead smolts on spring/summer chinook would continue (the two species will continue to overlap spacially and temporally during migration (as they co-evolved to do) and during bypass, collection, and transportation). And, if the carrying capacity of the system is being exceeded now, it will continue to be exceeded as the Snake River stocks recover and natural production replaces hatchery mitigation production. In contrast, under A3, a large component of the mortality hypothesized to occur in response to hatchery production, will be alleviated. Under drawdown, there would be less potential for the concentration of hatchery fish and wild fish in forbays, collection raceways, barges. Thus the hypothesized increased susceptibility to disease and predation and competition among hatchery fish and wild fish would be reduced.

V. Miscellaneous Notes on Appendix 1&2:

For both Appendix 1&2 the relationship between brood year, migration year, release year, and age of release is not completely clear. To insure that hatchery release smolts are overlapping temporally and spatially, release numbers should be adjusted for their age of release, and brood years need to be lagged by release to correspond to migration year.

In regard to Figure 2. Appendix 2:
The figure legend for Figure 2b says Delta Model Extra Mortalities and Hatchery Releases, 1952-90 for transported fish. As there was no transport before brood year 1973, it is unclear how there are FLUSH estimates of extra mortality of transported fish for these early years?

In regard to all figures in Appendix 2:
The symbols in the legends keep switching around which makes it hard to follow. Eg. In Figure 2a, CRiSP is in squares, FLUSH is a line, and hatchery releases are a diamond while in Figure 2b. CRiSP is in dimonds, FLUSH is in squares, and hatchery releases are a line.

LITERATURE CITED

Allison, L.N. 1961. The Fate of kidney disease among hatchery brook trout stocked in natural waters. Progressive Fish-Culturist 23:76-78.

Bams, R.A. 1967. Differences in perfromance of naturlly and artifically propagated sockeye salmon migrant fry, as measured with swimming and predation tests. Journal of Fisheries Research Board of Canada 24:1117-1153.

Beamesderfer, R.C. and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Bennett, D. H., P.M. Bratovich, W. Knox, D. Palmer, and H. Hansel. 1983. Status of warmwater fishery and the potential of improving warmwater fish habitat in the lower Snake reservoirs. Final Report (contract DACW68-79-C0057) to U.S. Army Corps of Engineers, Portland, Oregon.

Bigelow, P. 998. Personal communication. Interaction of hatchery and wild steelhead in the Clearwater River, Idaho. Progress Report for Fish Stewardship Project. USFWS and Nez Perce Tribes.

Bjornn, T.C. and J. Mallet. 1964. Movements of planted and wild trout in an Idaho river system. Transactions fo the American Fisheries Society 43:70-76.

Bjornn, T.C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. Bulletin Number 27. Forest, Range and Wildlife Experiment Station, University of Idaho. 57 p.

Leider, S.A., M.W. Chilcote and J.J. Loch. 1986. Comparative life history characteritics of hatchery and wild steelhead trout (S. gairdneri) of summer and witner races in the Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences 43:1398-1409.84, 86, 87

Brown, L.R., and P. B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. North American Journal of Fisheries Management 1:104-111.

Brown, L.R., and P. B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. North American Journal of Fisheries Management 1:104-111.

Buchanan, D.V., R.M. Hooton, and J. R. Moring. 1981. Northern squawfish (Pychocheilus oregonensis) predation on juvenile salmonids in sections of the Willamette River basin, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:360-364.

Cannamela, D.A. 1993. Hatchery steelhead smolt predation of wild and natural juvenile chinook salmon fry in the Upper Salmon River, Idaho. Idaho Fish and Game Fishery Research, Lower Snake River Compensation Plan Hatchery Program.

Chapman, D.W. 1986. Salmon and steelhead abundance in the Columbia River in the Nineteenth Century. Transactions of the American Fisheries Society 115:662-620.

Connor, W.P., H. Burge, S.G. Smith, D.W. Rondorf and K.F. Tiffan. 1997. Post-release attributes and survival of natural and Lyons Ferry Hatchery subyearling fall Chinook salmon released in the Snake River. Pages 1-29, in J.G. Williams and T.C. Bjornn (editors) Fall Chinook salmon survival and supplementation studies in the Snake River and Lower Snake River reservoirs, 1995. Annual Report, US Army Corps of Engineers and U.S. Department of Energy, Bonneville Power

Administration, Enviromnet Fish and Wildlife, Project Number 93-029, Contract Number 93AI10891.

Dawley, E.M., R. D. Ledgerwood, T.H. Blahm, C.W. Sims, J. T. Durkin, R.A. Kirn, A. E. Rankis, G. E. Monan, and F.J. Ossiander. 1986. Migrational characteristics, biological observations, and relative survival of juvenile salmonids entering the Columbia River Estuary, 1966-1983. Final report to Bonneville Power Administration, Portland, OR, Contract DE-A179-84BP39652, Project 81-102. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

DPEIS. 1996. Draft Programmatic Environmental Impact Statement : Impacts of Artificial Salmon and Steelhead Production Strategies in the Columbia River Basin. Columbia Basin Fish and Wildlife Authority. 1996.

Falter, C.M. 1969. Digestive rates and daily rations of northern squawfish in the St. Joe River, Idaho. Doctoral dissertation. University of Idaho, Moscow.

Faler, M.P., L.M. Miller, and K.I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Giorgi, A. 1991. Mortality of yearling chinook salmon prior to arrival at lower granite dam, on the Snake River. BPA Project No. 91-051, Contract Number DE-AI79-91BP16570.

Hvidsten, N.A. and R.A. Lund. 1988. Predation on hatchery-reared and wild smolts of Atlantic salmon, Salmo salar L., in the estuary of River Orkla, Norway. Journal of Fish Biology 33:121-126.

IDFG (Idaho Department of Fish and Game). 1998. Idaho's Anadromous Fish Stocks: Their status and recovery options. Report to the Director. May 1, 1998. IDFG 98-13.

IDFG (Idaho Department of Fish and Game). 1998a. Volume 2 Appendices. Idaho's anadromous fish stocks: their status and recovery options. Report to the Director. May 1, 1998. IDFG 98-13.

ISP. 1991. Integrated System Plan for Salmon and Steelhead Production in the Columbia River Basin. Columbia Basin Fish and Wildlife Authority. 1991.

Johnson, J.L. and M.V. Abrahams. 1991. Interbreeding with domestic strain increases foraging under threat of predation in juvenile steelhead trout (*Oncorhynchus mykiss*): an experimental study. Can. J. Fish. Aquat. Sci. 48:2430247.

Langness, O.L. 1997. Spawner recruit patterns in the wild fall chinook population of NFL. Columbia River Progress Report 97-12. Washington Department of Fish and Wildlife.

Larsson, P.O. 1985. Predation on migrating smolt as a regulating factor in Baltic salmon Salmo salar L., populations. Journal of Fish Biology 26:391-397.

Leider, S.A., P.L. Hulett, J.J. Loch and M.W. Chilcotte. 1990. Electrophoretic comparison of the reporductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 88:239-252.

Levings, C.D., C.D. McAllister, and B. D. Chang. 1986. Differential use of the Cambell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (Oncorhynchus twshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 43:1386-1397.

Lindsay, R.B., B. C. Jonasson, R. K. Schroeder, and B. C. Cates. 1989. Spring Chinook Salmon in the Deschutes River, Oregon. Oregon Department of Fish and Wildlife Information Report 89-4.

Long, C.W., R.F. Krcma, and F.J. Ossiander. 1968. Research on fingerlings mortality in Kaplan turbines, 1968. Bureau of Commercial Fisheries, Progress Report, Seattle, Washington.

MacCrimmon, H.R. 1954. Stream studies on planted Atlantic salmon. Journal of the Fisheries Research Board of Canada 11:362-403.

Matthews, G.M., D.L. Park, S. Achord and T.E. Ruehle. 1986. Static seawater challenge tests to measure relative stress levels in spring chinook salmon. Transactions of the American Fisheries Society 115:236-244.

McDermott L.A. and A.H. Berst. 1968. Experimental plantings of brook trout from furunculosis-infected stock. Journal of the Fisheries Research Board of Canada 25:2643-2649.

Mitchum, D.L. and L.E. Sherman. 1981. Transmission of bacterial kidney disease from wild to stocked hatchery trout. Canadian Journal of Fisheries and Aquatic Sciences 38:547-551.

Myers, K.W. and H.F. Horton. 1982. Temporal use of an Oregon estuary by hatchery and wild juvenile salmon. Pages 377-392 in V.S. Kennedy (editor), Estuarine comparisons. Academic Press. New York, NY.

Nicholas, T.E. 1986. Influences of upwelling et al., ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kitsitch*) in Oregon Production Area. Can. J. Fish. Aquat. Sci. 42: 899-908.

Peterman, R.M. 1978. Testing for density dependent marine survival in salmonids. JFRBC. 35:1434-1450.

Petroskey, C.E. and T.C. Bjoornn. 1985. Competition form catchables-a second look. In F.Richardson and R.H. Hamer (editors), Proceedings of the Wild Trout III Symposium:63-68. Yellowstone National Park, Wyoming.

Petrosky, C.E. and H.A. Schaller. 1996. Evaluation of productivity and survival rate trends in freshwater spawning and rearing life stage for Snake River spring and summer chinook. Chapter 9 in Marmorek, D. R. and 21 co-authors. Plan for Analyzing and Testing Hypotheses (PATH): final report of retrospective analysis for fiscal year 1996. Compiled and edited by ESSA Technologies, Ltd. Vancouver, B.C.

Pippy J.H. 1969. Kidney disease in juvenile Atlantic salmon (Salmo salar) in the Margaree River, Journal of the Fisheries Research Board of Canada 26:2535-2537.

Poe, P.P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Pendergast. 1991. Feeding of predacious fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Raymond, H.L. 1988. Effects of hydropower development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journalof Fisheries Management 8:1-24.

Reisenbichler, R.R. and J.D. McIntyre. 1976. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, Salmo gairdneri. Journal of the Fishery Research Board of Canada 34:123-128.

Riddle, B. 1993. Salmonid enhancement lessons from the past and a role for the future. Chapter 19, pp 338-355 in D. Mills, ed. Salmon in the sea and new enhancement strategies. Blackwell Scientific Publications Ltd., Oxford, UK.

Ruggles, C.P. 1980. A review of the downstream migration of Atlantic salmon. Canadian Technical Report Fisheries and Aquatic Sciences 9852.

Shreck,C. B. 1998. Personal communications with Keith Johnson 14 April 1998.

Tabor, R.A., R. S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

Thompson, R.B. and D.F. Tufts. 1967. Predation by Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Transactions of the American Fisheries Society 96:424-427.

Vigg, S. T. P. Poe., L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Vincent, R.E. 1985. Effect of stocking catchable trout in wild trout populations. In W. King (editor), Proceeding of the Wild Trout Manamgenet Symposium:88-91. Trout Unlimited, Vienna, VA.

Ward, D.L., J.H. Petersen, J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the Lower Snake River. Transactions of the American Fisheries Society 124:321-334.

Williams, J., G. Matthews, J. Meyers, S.G. Smith, T. Cooney and C. Toole. 1998. Hatchery extra mortality hypothesis. WOE Appendix Submission 1. June 30, 1998.

Wilson, P. With support from the hatchery evaluation group. 1996. Chapter 11. PATH: Hatchery Impacts. In: PATH, Final Report on Retrospective Analyses for Fiscal Year 1996.