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RECOVERY PLANNING FOR ENDANGERED SALMON:A MULTIPLE ATTRIBUTE ANALYSIS

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RECOVERY PLANNING FOR ENDANGERED SALMON: A MULTIPLE ATTRIBUTE ANALYSIS

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EXECUTIVESUMMARY

This analysis addresses multiple dimensions or attributes of recovery planning for endangered Snake River chinook stocks. We present a range of biological, economic, and social attributes for a number of recovery actions, and discuss aspects of the recovery actions that relate to each attribute. The emphasis on multiple attributes rather than on narrower biological measures alone reflects our belief that biological issues are only one of several sets of concerns that warrant attention in developing a recovery plan. Furthermore, we focus on both qualitative and quantitative factors because a lack of numerical information on certain attributes and recovery actions does not justify ignoring the non-numerical attributes or actions.

After introducing our approach and providing background in sections 1 and 2, we define the attributes in section 3. Attributes addressed include stock and species potentially affected, lead time from implementation of an action to the appearance of biological effects, scope of direct biological effects, scope of indirect biological effects, potential for producing acceptable population survival, economic costs, geographic distribution of adverse socio-economic impacts, temporal distribution of adverse socio-economic impacts, design and construction time before implementation of a recovery action, whether the action attempts to restore or substitute for natural processes and functions, and institutional considerations.

Section 4 provides an overview of the biological modeling embedded in the analysis. The model used, the Stochastic Life Cycle Model (SLCM), determines the survival changes (relative to a base case) necessary to meet several biological criteria. These criteria reflect both the likelihood of population extinction (where we define extinction as falling below a threshold of 100 spawners for 4 consecutive years) and the projected population abundance 100 years into the future, relative to the initial abundance.

Section 5 discusses the potential recovery actions. These actions fall into three categories:

- flow and other passage actions
- harvest restrictions
- habitat enhancement

Of these three categories, passage actions represent the majority of the potential recovery actions. Most of the passage actions entail different flow regimes. These include current operations, flow augmentation, decreasing the elevation of the lower Snake reservoirs to levels approaching the original riverbed, lowering the'lower Snake reservoirs to fixed elevations below the minimum operating pool, and increasing spill at mainstem projects. These constitute a subset of the hydrosystem actions analyzed in the System Operation Review (SOR) process. In addition, passage actions include an upstream collector, which involves the construction and operation of a new smolt collection facility at the upper end of Lower Granite reservoir above Lower Granite dam. Harvest restrictions entail eliminating the ocean and/or in-river non-Treaty commercial chinook harvests in U. S. waters. Habitat enhancement involves actions which increases salmon production potential in individual subbasins. (Because of data limitations, the analysis of habitat enhancement actions is much less developed than the analysis of passage and harvest actions.)

The bulk of our evaluation lies is sections 6 through 10, and takes several forms. First, we discuss how the different recovery actions introduce concerns with each attribute. Second, after discussing all of the attributes we classify all of the passage and harvest actions with respect to the attributes that lend themselves to classification (in the case of the numerical attributes, we extend this classification to a ranking). Third, for those recovery actions with numerical estimates of survival changes, we evaluate the likelihood that these recovery actions by themselves can yield the survival changes deemed necessary to meet our biological criteria. Fourth, we combine passage and harvest actions to form recovery strategies and develop a cost-effectiveness analysis that compares the financial costs of recovery strategies with the strategies' potential for producing acceptable survival changes. We extend the cost-effectiveness analysis to include qualitative attributes, and highlight changes in the relationship between cost and effectiveness that result from considering these attributes. Fifth, we discuss the uncertainties associated with an analysis of potential recovery strategies, and examine how the results of our analysis may change under different assumptions.

The analysis highlights a host of thorny biological and non-biological issues that arise when contemplating the potential recovery actions. For example, the recovery actions that appear most biologically effective (e.g., harvest restrictions and increased smolt transportation) often fare poorly or ambiguously on other grounds (e.g., geographic distribution of economic impacts, degree of institutional change associated with the action, and reliance on measures that do not attempt to restore natural functions and processes). No single recovery measure is clearly preferable across all of the attributes.

Survival improvements necessary to avoid extinction at high likelihood levels (in 95 percent of model replications) and to avoid declining populations at medium to high likelihood levels (in 50 percent and 90 percent of model replications, respectively) differ significantly among the stocks.

- The base case density-independent survival for spring chinook appears sufficient to avoid extinction over the next 100 years, although slight improvements in survival (3 percent above base case) are needed to attain the goal of non-declining population abundances at a 90 percent likelihood level.
- Summer chinook require less than a 10 percent increase to meet the extinction-avoidance goal, and a 15 to 25 percent increase to meet the population abundance goals at the two likelihood levels.
- 0 Fall chinook require density-independent survival increases of nearly 45 percent above base case to avoid extinction and increases of 25 to 45 percent above base case to meet population abundance goals (at the 50 percent and 90 percent level, respectively).

We also examined the criterion of doubling population abundance at a 50 percent likelihood level. In all cases, this provides a less stringent survival criterion than that of a non-declining population at the 90 percent likelihood level.

Our cost-effectiveness analysis of 64 recovery strategies, which are defined by combining each of 16 passage actions with one of 4 harvest actions, suggests the following points:

- of the 64 strategies, only 22 increase survival above the base case for all stocks, and of these 22 strategies, only 4 include base case harvest.
- It appears that no strategy that contains fixed drawdown increases survival above the base case for all stocks, unless smolt transportation at Lower Granite continues, even with optimistic assumptions about the efficacy of drawdown.
- Only 2 of the 22 strategies that increase survival for all stocks meet the most stringent criteria for the biological goals discussed above.
- Strategies that eliminate non-Treaty commercial harvest in U. S. waters exhibit the greatest increase in survival, and harvest reductions have a far larger effect on fall chinook than on spring and summer chinook
- For fall chinook, strategies that do not include smolt transportation as a class tend to be less effective than those that do include smolt transportation. For spring and summer runs, some of the most biologically effective strategies do not include transportation given certain assumptions about dam passage mortality. However, they tend to cost more than strategies which provide similar survival improvements with smolt transportation.

We omit potential habitat actions from our cost-effectiveness analysis because although estimates exist of the biological effectiveness of habitat enhancement for the Snake Basin in total, we cannot identify a specific package of actions associated with these estimates. However, the relatively low cost of habitat enhancement actions suggests that they may warrant serious consideration even though we do not know the specific actions nor their potential biological effects.

The final part of the analysis extends the classification developed for the actions to a classification for the strategies. As with the classification of actions on different attributes, no class of strategies dominates the others on all attributes. Furthermore, the performance of a strategy on some attributes is often not correlated with its performance on other attributes. Passage actions determine the classification of the strategies on the cost, implementation lead time, and restorative attributes; the degree of harvest restriction determines the classification on the institutional attribute.

All of our conclusions need to be qualified with the understanding that many of the model results reflect challengeable assumptions about the response of salmonids to recovery actions. The uncertainty around the average estimates of biological effectiveness that we use in our analysis can be significant. The degree of uncertainty depends on the type of action; we suggest that the effects of reservoir drawdown scenarios and habitat enhancement are more uncertain than the other types of actions. For proposed drawdown actions, projections of passage survival from the CRiSP model based on optimistic assumptions about their effectiveness are 17 to 35 percent greater than the projected survivals based on pessimistic assumptions. For total Snake Basin habitat enhancement, estimates of the likely increase in egg-to-adult survival range from 1 to 15 percent. It is absolutely critical to supplement model results with other types of information (e.g., experimental results, qualitative assessments, expert opinion) in the evaluation of prospective recovery actions.

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ACKNOWLEDGMENTS

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1. INTRODUCTION

Planning for the recovery of endangered and threatened wild chinook and sockeye salmon stocks in the Pacific Northwest must confront a wide array of biological, economic, and social challenges These challenges are unavoidable given the complexity and visibility of the problems that the stocks face. For example, on the biological side, uncertainty abounds as to both what survival increases are necessary to avoid extinction and what the efficacy of possible recovery actions might be. On the economic front, the implementation of many possible recovery actions may entail large direct and indirect economic benefits and costs in the region, with different groups or economic sectors experiencing the benefits and costs to different degrees depending on the recovery options implemented. From a social perspective, many believe that wild salmon are of significant intrinsic importance to the region, and an effective plan directed at salmon preservation needs to be cognizant of both this intrinsic valuation and the importance that many attach to institutions that may be threatened by some recovery options.

The analysis developed below attempts to address these multiple dimensions or attributes of recovery planning for endangered Snake River chinook stocks. We present a range of biological and non-biological attributes for a number of recovery options, and discuss aspects of the recovery options that relate to each of these attributes. We have adopted this multiple attribute approach for three reasons. First, notwithstanding the oft-cited claim that a recovery plan for endangered species needs to be "based solely on the best possible biological science," it is clear that other factors enter into the debate on how to recover an endangered population. As witnessed with the deliberations on recovery of the spotted-owl, as the effects of potential recovery actions touch more and more lives, the debate over the most appropriate measures of effectiveness widens beyond an argument over biological standards to include more economic, social, and broader ecological issues. Second, to the best of our knowledge, other efforts to inform recovery planning for the endangered salmon stocks lack the breadth of the multiple-attribute approach that we present here. We have designed our work to complement the strengths of these other approaches by providing a larger context for recovery planning. Third, the paucity of quantitative information to support recovery planning even on strict biological grounds is striking. In our minds, this indicates a need for an approach that can thoroughly combine quantitative and qualitative information, without implicitly lending more weight to the either side.

The remainder of this report describes the approach and conclusions of our multiple attribute analysis. Section 2 provides an overview of the evaluative framework. Section 3 presents in more detail the attributes included in the assessment. Section 4 digresses slightly to explain the modeling approach used to develop estimates of the survival increases necessary to meet several biological goals. Section 5 outlines the recovery options. Section 6 characterizes the passage and harvest actions across the attributes developed in section 3, and provides a classification of the actions on five of the attributes. Section 7 assesses the life-stage survival improvements deemed necessary to avoid extinction and comments on the likelihood of meeting these improvements with the proposed actions. Section 8 provides a cost-effectiveness analysis of the recovery strategies. Section 9 extends the classification of actions in section 6 to a classification of strategies on four attributes. Section 10 discusses uncertainty and offers some final observations. [1]

2. EVALUATIVE FRAMEWORK

Our evaluative framework of recovery actions can be envisioned as a matrix of recovery options (rows) and attributes (columns), with each row-column entry thus representing the characteristics of the recovery option with respect to the attribute.[2] Attributes of each recovery

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[1] We discuss habitat enhancement actions only generally and do not include them in the modeling, classification scheme, and cost-effectiveness discussion developed in sections 6 through 9. Unfortunately, we lack requisite information on the costs and biological effects of specific habitat enhancement actions to do so. We do include them, however, in our discussion of uncertainty in section 10.

[2] One could graphically portray such a matrix and fill it with information for all individual recovery actions and all attributes. However, in practice we have not literally constructed such a matrix, since its size and utility would be problematic. Instead, our analysis presents a descriptive section that discusses for each attribute aspects of the recovery options that relate to each attribute. For an alternative approach that does actually develop a multiple attribute matrix, see May (1991). May's work is oriented toward Columbia basin system planning in general, which differs from this analysis's focus on endangered stocks.

option (discussed more fully in the next section) include quantitative information on biological effects and financial costs (e.g., survival parameters and annualized costs), as well as qualitative information on biological effects, costs, and social issues (e.g., scope of biological effect, geographic distribution of economic impacts, and degree of institutional change associated with the option). Recovery actions (described in section 5) include changes in hydrosystem operations and other passage actions, harvest restrictions, and habitat enhancement.

Although the simplest level of a recovery effort is a recovery action we present information on both recovery actions and recovery strategies (combinations of passage and harvest actions). The evaluation takes several forms. First, we develop for each attribute a discussion of how the different recovery actions introduce concerns associated with that attribute. Second, after discussing the attributes and recovery actions, we classify the passage and harvest actions within each attribute for those attributes that lend themselves to classification. For the numerical attributes, we provide rankings in classes (e.g., 'low', 'high') rather than in a full ordinal scale. It is important to note that the ranks do not compare recovery actions across attributes and therefore one can not combine the ranks and attributes to determine the action(s) with the highest overall ranking.[3] Third, for all recovery actions with quantified hypotheses about survival changes (excluding habitat enhancement), we evaluate whether the action meets the survival changes that the modeling exercise (described in Section 4) indicates may be necessary to avoid extinction. Fourth, we develop a cost-effectiveness analysis that compares the economic costs of recovery strategies (combinations of passage and harvest actions) with the strategies' potential for producing acceptable survival changes.

[3]We can not combine ranking across attributes for two reasons. First., the rankings for each attribute are on different scales, so a high rank on one attribute does not necessarily mean the same thing numerically as a high rank on another attribute. Second, the weighting of attributes obviously is the purview of the policy maker, not the analyst. We hope to provide information about the multi-dimensional effects of prospective recovery actions, but we see little utility in providing our opinions on which attributes are more important.

3. DEFINITIONS OF ATTRIBUTES

We have chosen eleven attributes that highlight information -- both quantitative and qualitative -- that we believe to be central to the characterization and evaluation of alternative recovery options. These attributes fall into three categories: biological, economic, and social. We do not pretend that the eleven attributes capture all important aspects of recovery planning, but we do think that they represent a range of critical issues.

In this section, for each of the categories, we define the attributes. For each attribute and recovery measure, the information may be qualitative or quantitative depending on the state of knowledge with respect to the recovery measure.

3.1 Biological Issues

Biological issues broadly refer to attributes which reflect biological characteristics of the recovery measures. The five attributes in this category are stocks and species potentially affected, lead time to realization of effects, scope of direct effects, scope of indirect effects, and potential for producing an acceptable increase in population survival.

A biological effect of an action must be defined relative to a reference case. One can think of the reference case as a system identical in every way to the real system except that it does not contain the action of interest. Although the ideal of such a control is unattainable for our system, the concept is useful for discussing potential effects of actions.

- **Stock and species potentially affected:** Strategies implemented in locations where different salmon stocks or different species mix have the potential to affect several stocks or species simultaneously. This may be desirable, as with a passage action benefiting several salmon stocks, or undesirable, as with a drawdown action having adverse effects on resident fish in the reservoir.
- **Lead time from implementation to biological effects** Immediate effects of an action are those that theoretically can be evaluated immediately after implementation by noting a

change in the proportion of the population surviving.[4] Often, such actions directly affect a source of mortality for individual fish. For example, as soon as an irrigation diversion screen is in place, fish previously entering an irrigation canal and dying will now survive passage past the diversion (all else held constant). Some immediate effects of an action may be detrimental to the target population, such as an increase in disease transmission during barging, or hindrance of upriver passage of adults due to flow options designed to benefit smolt passage.

At least two factors may cause a lag in the time between action implementation and the realization of a biological effect. First, actions that affect smolt production, such as removal of barriers to upstream spawning grounds, may have lagged effects because some time is needed for fish to colonize newly-opened areas. Second, effects on mortality may require the occurrence of a particular set of conditions, and these conditions may occur only at certain times. For example, flow enhancement may have a beneficial effect only in dry years. Some lagged effects may be detrimental to the population in the long-term, even though the immediate effects may be beneficial. An example is a hatchery program that increases production over the short term but decreases the genetic variation among individuals, which may have negative implications under future environmental states (Lichatowich and Watson 1993, p. 15).

- **Scope of Direct Effects:** Direct biological effects refer to the first-order effects of a recovery measure on mortality or production. For example, a flow action may affect a source of mortality for individual fish, and thus increase the proportion of fish surviving in the population, and a habitat enhancement action may increase the rate of production of smolts per-spawning-adult.
- **Scope of Indirect Effects:** Indirect effects are linked to mortality or production through some indirect causal mechanism. Although we do not analyze them quantitatively, they may

[4] This attribute says nothing about whether a real effect can be detected; it is concerned only with when an effect may occur.

be important to keep in mind. These effects may occur when a recovery measure influences population characteristics such as size or age distribution, allele frequency, or genetic variation among individuals, and these characteristics, in turn, affect mortality or production. For example, a change in harvest may alter the age distribution of spawners. The age distribution may influence the average number of eggs produced by a given number of female spawners, since fecundity is related to age.

- **Potential for producing acceptable population survival:**[5] This attribute addresses the main quantitative criterion of our biological evaluation, which is whether a recovery strategy is capable of producing the change in population survival necessary to achieve an acceptable probability of extinction or change in abundance. We assess this by running the Stochastic Life Cycle Model (SLCM) for each stock (section 4 provides the details of this modeling exercise).6 We compare the model-generated estimates of the survival increases produced by each action or strategy to the survival increase deemed necessary by the SLCM.[7]

3.2 Economic Issues

The major economic issues of recovery planning relate to the economic impacts associated with the recovery measures. This class of attributes includes direct costs, geographic distribution of adverse impacts, and temporal distribution of adverse economic effects. We also include the lead time required to implement each recovery measure under this class of attributes.

- Costs: For those measures with numerical costs, we use secondary sources (see Appendix A) to estimate costs associated with passage and harvest actions and then annualize these at

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[5]We evaluate the actions with respect to this attribute in a separate section (section 7), because the discussion is lengthy. Section 6 provides information on the other ten attributes.
[6]For general model documentation see Lee and Hyman (1992).
[7]One biological attribute that we considered for inclusion but rejected is the potential for long-term recovery of salmon populations. Some actions may be implemented as short-term fixes, designed to halt a population decline but not to provide a long-term solution. We omitted this attribute because we believe the evidence on which to base this attribute is too limited and full of uncertainty. Many would argue that all of the actions we consider are intended to be long-term solutions.

a three percent real discount rate. The components of each measure's total costs include financial costs of structural modifications, operation and maintenance, and, in the case of harvest restrictions, changes in gross income associated with the implementation of recovery measures. We also include the opportunity costs of lost hydropower generation and the cost of water purchases in the case of flow-related recovery measures. Potential costs due to lost recreation opportunities, navigation curtailments, and increased potential pumping costs from the Columbia and Snake rivers are excluded, due to both insufficient cost data and some evidence that suggests that the economic costs of many of these potential impacts are relatively low compared to the cost of the passage strategies.8

- **Geographic Distribution of Adverse Impacts:** Costs and impacts of recovery strategies are typically spread unevenly across geographic areas. This attribute provides information on the distribution of impacts across space. The net impacts that any subarea will experience obviously will be determined by both positive and negative impacts. On the positive side of the ledger, in addition to the obvious potential gain from enhanced salmon populations that all areas may experience, some may benefit from increased construction spending, demand for alternative forms of transportation, enhanced environmental quality, and possible monetary compensation. In this attribute, however, we describe the distribution across space of some of the major adverse impacts that may occur in the absence of mitigation (i.e., we assume for the purpose of discussion that mitigation of the adverse impacts will not take place). Most of the information that we present is qualitative.
- **Temporal Distribution of Adverse Impacts:** The economic effects of recovery measures may occur in the short-run and/or long-run. Although the threshold between short-run and long-run is indefinite, the distinction is that short-run effects occur during or immediately

[8] For example, estimates reported in Northwest Economic Associates (1993, pp. 23,27) suggest that incremental pumping and transportation costs associated with drawdowns increase annualized costs of drawdown by $6.3 million and $2.3 million, respectively. This represents less than 7 percent of the power costs of drawdown.

after project implementation, and by definition disappear after an adjustment period. Long-run effects show up later in the project time horizon and persist.

- **Lead Time to Implement Recovery Measure:** This attribute is not really an economic issue. Instead, it depicts the time (after securing appropriations if necessary) from initial design work of a recovery measure to full initiation of the recovery measure. It is included in this category strictly for convenience. It differs from the lead time identified in the biological effects section in that the latter relates to the time from completion of a measure to emergence of biological effects. For example, the lead time for implementation of drawdown may be fifteen years after securing appropriations, due to significant design requirements and a long construction period. The lead time for biological effects may be immediate once the drawdown measure is fully initiated.

3.3 Social Issues

Social issues relate to the possible preference for restorative kinds of recovery measures and the degree of institutional change associated with implementation of a recovery measure.

- **Restorative Recovery Measures:** Individuals and organizations prefer certain recovery measures for a number of reasons including, most obviously, costs and immediate biological effects. An additional factor relates to whether a recovery measure is more- or less-restorative with respect to a reference state. We define a more-restorative measure as one that attempts to restore some of the functions and characteristics of the natural environment as it would exist in a reference case without relying on human control. In contrast, less-restorative measures seek to substitute for these functions and characteristics, using some type of human control. In this discussion, we define the reference case as a hypothetical landscape where humans exist but have minimal control over the functions and characteristics of the ecosystem. The effect of a recovery action in moving the ecosystem toward this reference case distinguishes more-restorative actions from less-restorative actions.[9]

The acceptability of restorative options may be influenced by several factors. For example, less-restorative options may be unacceptable if one places little faith in human institutions to sustain these options through time or in current human knowledge to produce successful results. This may prompt a "nature knows best" policy. Also, some may view less-restorative measures unfavorably because they preclude a number of desirable properties that are associated with the uncontrolled state (possibly wilderness preservation or a more free-flowing river). In contrast, others may find more-restorative solutions unfavorable because they preclude desirable features of a controlled state (for example, economic growth or flood control).

- **Institutional Considerations:** A recovery measure may both require institutional changes in order to be implemented, and lead to institutional changes after implementation. We define institutions to include laws, rights, privileges, organizations, agreements, and responsibilities, or more broadly, the set of ordered relationships among people (Schmid 1972). For example, large-scale transfers of water from irrigation to in-stream flow may require a significant alteration in the missions of state agencies and their responsibilities to serve the public interest. This may require changes prior to the initiation of the transfer. It also may serve as a catalyst for organizational changes after implementation, perhaps in response to the demands of a new group of constituents for the organization's redefined mission.

In section 6, we discuss for each attribute characteristics of the recovery actions related to that attribute. As noted above, much of this discussion is necessarily qualitative, although we include quantitative information when available. Section 6 also will provide a partial classification of the recovery measures with respect to some of the attributes.

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[9]We do not ascribe a normative value to the reference case. For our purposes, the reference case is neither superior nor inferior to other possible states of nature.

4. OVERVIEW OF BIOLOGICAL MODELING OF SNAKE RIVER STOCKS

In this analysis, we apply a life-cycle model in a manner that we believe helps the reader to conceptually separate the estimates of the effectiveness of proposed recovery actions and their uncertainties from the details of the model itself. Our application follows three major steps:

1. Develop criteria that can serve as indicators of the success of achieving the goals of recovery (i.e., sustain the populations);
2. Determine the survival increase (relative to a base case) necessary to meet these criteria;
3. Gather evidence, both quantitative and qualitative, for the likelihood that each particular strategy will meet this survival increase.

Step 1 uses two criteria. The first rests on the likelihood of population extinction, defined as falling below a threshold of 100 spawners for 4 consecutive years. Our extinction criterion is a 5 percent chance of extinction (or a 95 percent chance of population persistence) over 100 years. The National Marine Fisheries Service adopted this probability and time horizon as delisting criteria in its Biological Opinion (National Marine Fisheries Service 1992). As pointed out by Cramer and Neeley (1993), the chance of extinction is highly sensitive to the threshold used to define extinction. Figure 1 displays the results of our modeling of Snake River fall chinook (given current populations and base case conditions), and as the graph clearly shows that the probability of extinction increases dramatically as the threshold increases. For example, if we increase the threshold from 16 spawners to 32 spawners, the probability of extinction increases from roughly 0.1 to roughly 0.25. This is because it is more likely that the spawning population will fall below 32 spawners for 4 consecutive years than it is that it will fall below 16 spawners for 4 consecutive years. We believe that 100 spawners is a reasonable threshold, given the possibility of genetic effects at small population sizes and the inability of our life cycle model to capture these potential negative effects.

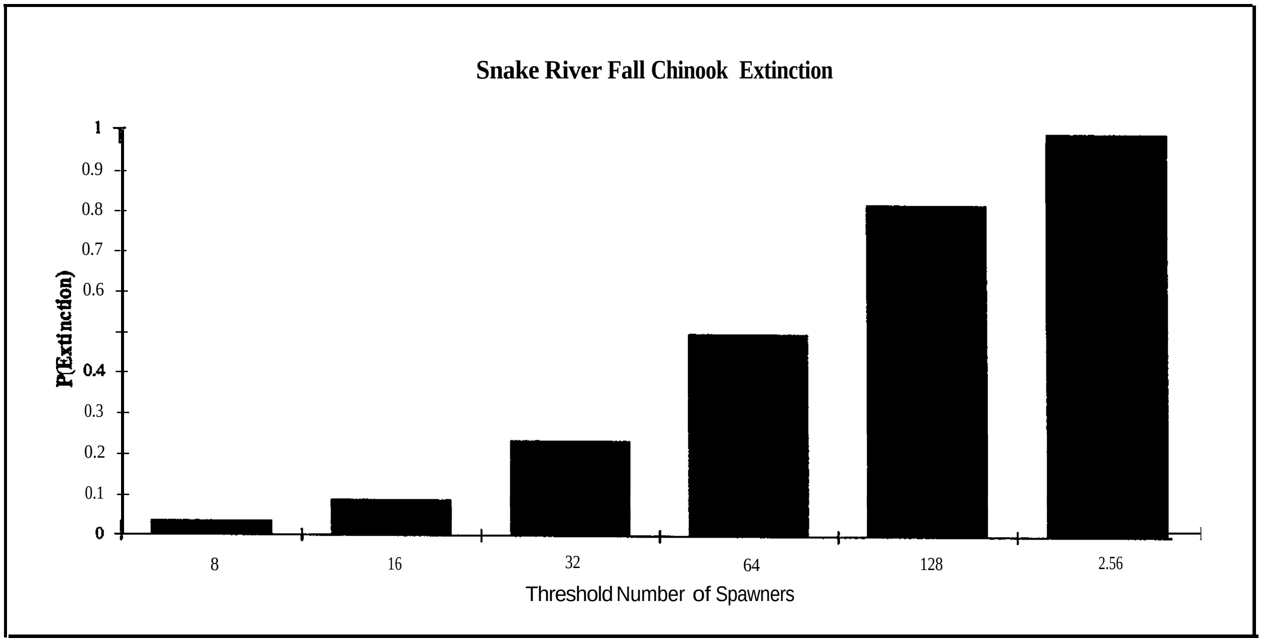

Figure 1: Probability of Extinction as a Function of the Extinction Threshold Chosen.

Our second criterion for a recovery goal is based on model projections of population abundance (number of spawners) 100 years into the future, relative to the initial abundance. We analyze abundance over the 100 year horizon and then determine the 10th percentile and median abundance across all games for each year between year 90 and year 100. The 10th percentile abundance represents the abundance that is met or exceeded in 90 percent of the modeling replications or games; the median abundance is met or exceeded in 50 percent of the games. We next calculate the average 10th percentile and the average median abundance over years 90 through 100.

We then use these average abundances in two ways. First, we assess whether the future population abundance is higher or lower than the initial abundance. If the average 10th percentile abundance is at least as high as the initial abundance, we say the population is non-decreasing with 90 percent likelihood; if the average median abundance is at least as high as the initial abundance, we say the population is non-decreasing with 50 percent likelihood. Second, we assess whether the average median abundance is at least double the initial abundance. This doubling of initial abundance is intended as a reference value, not necessarily as a reflection of a desirable goal for the listed stocks.

In step 2, we rely on the Stochastic Life Cycle Model (SLCM) to evaluate the percentage survival improvements necessary to avoid extinction and to achieve different abundance levels with specified likelihoods. This resembles the approach of Cramer and Neeley (1993) and Emlen (1993), who used population models to determine the survival improvements necessary to achieve different rates and levels of stock recovery. The SLCM produces trajectories of population size over time, where each trajectory (or replication) is intended to reflect a unique scenario of environmental conditions over time. The basic output is a distribution (over all replications) of population size for each year simulated. Unlike the model used by Cramer and Neeley (1993), the SLCM does not distinguish between good and poor habitat.

For each Snake River stock, we increased the density-independent part of salmon survival in the SLCM -- the survival from the migrant smolt stage to the adult spawner stage -- and examined how the extinction likelihood and spawner abundance discussed above varied as a function of density-independent survival. All fixed parameter values included in our modeling come from either BPA's Biological Assessment (1993) or the System Operation Review (1993a) process.[10] We calculated the chance of extinction as the percentage of replications where the population goes extinct according to the definition of extinction given above, and expressed population sizes at the 10th percentile and 50th percentile as just described. The 10th percentile allows a more biologically conservative judgment to be made about the effects of a survival increase than does the median. These projected abundances, when examined relative to initial population size, are likely to be of importance to recovery planning.

In step 3, our objective is to assess whether an action or strategy is capable of producing the change in population survival necessary to achieve an acceptable chance of extinction and an acceptable range of population sizes. For this task we have gathered quantitative estimates of the effectiveness of passage and harvest actions and habitat enhancement. As will be discussed in following sections (most fully in section l0), some estimates of effectiveness are more uncertain than others.

5. RECOVERY OPTIONS

The recovery measures analyzed include passage actions[11] and harvest restrictions. We also investigate habitat enhancement actions, although since we lack the data to model these

[10] Some parameter values come from model calibration to fit observed escapement data. Table B-l provides the SLCM parameter values and identifies their source.

1 *Throughout this paper, we use the term ***passage*** action somewhat loosely. Technically speaking, passage actions may include flow actions such as augmentation or drawdown, different levels of smolt transportation, installation or improvement of bypass structures, increases in collection efficiencies, and predator control, for example. Although we toggle transportation on and off, we focus our attention on flow actions. We do not vary the other factors across passage actions, with the exception of the different assumptions that we make to investigate the sensitivity of drawdown to different dam passage assumptions. Our focus on flow derives from our dependence on passage modeling from the SOR, a process designed primarily to investigate the implications of alternative hydrosystem operating strategies. The SOR, in turn, relied on a complex model of the hydrosystem (HYSSR) to

actions in the same fashion as we do passage and harvest, we treat these somewhat differently. Table 1 displays the individual actions. Passage actions are numbered 1 through 16 and harvest actions HC, HO, HR, and HX. We discuss characteristics of the actions in the following three subsections.

5.1 Flow Actions

The flow actions included here constitute a subset of the SOR actions modeled in the SOR process.[12] We start with ten different SOR actions in our analysis. In addition, we analyze the effects of no-transportation variants for a number of the SOR actions that assume continued operation of smolt transportation. In total, we include fifteen variants of SOR passage actions in our analysis, plus a passage action that includes an upstream collector and transport from upper Lower Granite reservoir.

Each of the sixteen passage actions fall into one of six classes. We describe the six classes of passage actions and define the specific actions that fall in each class in the following subsections. We number the actions 1-16 and provide the SOR identifier(s) in the parentheses after each class's title (for the fifteen SOR actions).[13]

- Pre-ESA Operation (la): Reflects systems operations before changes were made to protect the listed stocks (operations from 1983 through the 1990- 1991 operating year). Action 01 includes transportation at all Columbia-Snake projects and action 02 includes no transportation at any Columbia-Snake project.14

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provide regulated flows for the downstream passage model used in all SOR strategies. Appendix D provides a short discussion of the passage-related assumptions for the base case.

[12]The SOR refers to passage "strategies" rather than passage "actions," since each SOR passage strategy consists of several components. However, to promote consistency with our use of the term recovery strategy (composed of passage, habitat, and harvest actions), we use the term passage action.

[13]The descriptions of the SOR strategies are taken from SOR (1993a).

[14]For the purposes of this discussion, ***all Columbia-Snake projects*** mean the subset of Columbia and Snake river projects with currently operating transportation facilities. Lower Granite, Little Goose, Lower Monumental, and McNary constitute this subset,

Table 1
Recovery Actions With Corresponding SOR System Operating Strategy Designation

Action Number	SOR System Operating Strategy or Description of Action
01	SOR la with transport
02	SOR la without transport
03	SOR 2c with transport (Base Case)
04	SOR 2c without transport
05	SOR 3b with transport
06	SOR 3b without transport
07	SOR 5a without transport
08	SOR 5b without transport
09	SOR 6a without transport
10	SOR 6b without transport
11	SOR 6c, no LGR transport
12	SOR 6c w/ LGR transport
13	SOR 6d, no LGR transport
14	SOR 6d with LGR transport
15	SOR 7a with transport
16	SOR 2c flows, upstream collector, transport
HC	Base Case Harvest (1987-92)
HO	No non-treaty U. S. Commercial Ocean Harvest
HR	No non-treaty Commercial In-River Harvest
HX	No non-treaty U. S. commercial Harvest

SOR alternatives taken from SOR (1993a). All SOR alternatives assume no change in mortality due to predation. Harvest alternatives derived from data in Lestelle and Gilbertson (1993).

- Current Operations (2c): Reflects current system operations specified in the Corps of Engineers 1993 Supplemental Environmental Impact Statement (SEIS) for interim flow improvements. These flow improvements were adopted in response to the ESA listings, Action 03 represents the final SEIS operations and includes smolt transportation at all Columbia-Snake projects. Action 04 is the same as action 03 except without transportation at the Columbia-Snake projects. Action 03 serves as the base case for passage cost and biological estimates; that is, we assume a zero cost for action 03 and estimate the **marginal** cost of all other actions in relation to action 03, and use the survival in action 03 as the base case survival (i.e., we express the biological effects for the passage actions relative to the passage survival in case 03). See Appendix D for a discussion of the assumptions of the base case.
- Flow Augmentation (3b): Provides higher water volumes to move smolts downstream more quickly. Action 05 set monthly flow targets at Priest Rapids and Lower Granite and assumes an additional 1.4 million acre feet of water from the upper Snake River. Action 06 is the no-transportation equivalent of action 05.
- Natural River Oneration (5a. 5b): Increases river velocity by drawing down all four lower Snake projects to near original riverbed levels and John Day reservoir below minimum irrigation pool. Transportation at all Columbia-Snake projects is eliminated. Passage mortality at each of the four lower Snake projects is also eliminated, although reservoir mortality remains. Action 07 provides for a two-month drawdown and action 08 for a four and one-half month drawdown.
- Fixed Drawdown (6a. 6b. 6c. 6d): Increases river velocity by drawing down the lower Snake river projects to fixed elevations below the minimum operating pool (33 foot drawdowns, resulting in elevations sixty to eighty feet above the elevations in the natural river option) and John Day reservoir below minirnum irrigation pool. Actions 09 and 10 involve drawdowns at all four lower Snake reservoirs, the former a two-month drawdown

and the latter a four and one-half month drawdown. In both cases, transportation ceases at all Columbia-Snake projects. Actions 11,12, 13, and 14 entail drawdown only at Lower Granite and all include continued transportation at Little Goose, Lower Monumental, and McNary. Actions 11 and 12 provide a two-month drawdown of Lower Granite and actions 13 and 14 a four and one-half month drawdown of Lower Granite. Actions 12 and 14 also include transportation at Lower Granite.

- Enhanced Spill (7a): Increases the amount of spill at mainstem Columbia-Snake projects for the purpose of enhancing smolt survival. Action 15 continues smolt transportation at all Columbia-Snake dams.
- Upstream Collector (not an SOR action): The Corps of Engineers has investigated the possibility of installing an upstream collector for smolts at the upper end of Lower Granite reservoir. This collector would collect downstream migrating smolts for subsequent conveyance (via canal, pipeline, or barge) to below Bonneville Dam. We assess the implications of the upstream collector across the attributes using model results presented in Anderson (1993) in action 16. Although several options exist for the collector and conveyance system, we evaluate a single primary collection, sorting, and holding facility and subsequent barge transport.[15]

5.2 Harvest Actions

We analyze four mutually exclusive chinook harvest actions.

- continue current harvest levels (no change in ocean or in-river commercial harvest rates)
- elimination of all non-Treaty chinook ocean commercial harvest in the U. S. (southeast Alaska and coastal Washington, Oregon, and California)
- elimination of in-river non-Treaty chinook commercial harvest

[15]The hydrosystcm operation used to evaluate this action is the current operation, SOR passage action 2c (action 03 in Table 1).

- elimination of all U. S. ocean and in-river non-Treaty chinook commercial harvest

As Table 1 shows, we designate these as harvest actions HC, HO, HR, and HX, respectively. Appendix C presents details on these harvest cutbacks.

Harvest restrictions HO, HR, and HX are obviously draconian. In reality, the likelihood of completely eliminating the United States non-Treaty ocean commercial harvest in the short-run, in particular, is small. However, we model an extreme harvest restriction because it provide a defensible limit on the biological, economic, and social effects of harvest restrictions.[16] Realistic harvest restrictions (at least for present) obviously lie between the extremes of no change in harvest restrictions and the elimination of all non-Treaty United States commercial harvest.

5.3 Habitat Enhancement

In the category of habitat enhancement we include the following types of measures: land management measures that address mining, logging, grazing, and agricultural practices; removal of barriers to migration; instream flow enhancement; riparian protection and enhancement; placement of instream structures; and screening of irrigation canal intakes (Chapman and Witty 1993; CRITFC 1992). Although specific habitat enhancement actions have been proposed throughout the Columbia-Snake Basin for a number of stocks, we do not model any specific habitat action for the endangered Snake River stocks. We lack sufficient information on the scope, effects, costs, and spatial distribution of actions targeted at these stocks to do so. We do, however, discuss the hypothesized biological effects of habitat enhancement that targets the listed stocks. Section 10 furnishes more information on this.

[16] The upper bound on the effects of non-Treaty, commercial chinook harvest restrictions would include elimination of sport harvest and the substantial commercial chinook harvest in Canada, as well.

6. EVALUATION OF RECOVERY OPTIONS ACROSS ATTRIBUTES

The recovery actions depicted in Table 1 differ in their biological, social, and economic dimensions. These differences constitute the main subject of our report. In this section, we discuss characteristics of the actions identified in Table 1 for ten of the eleven attributes presented in section 3.[17] We discuss the eleventh attribute, the potential for producing an acceptable increase in population survival, in section 7.

6.1 Stocks and Species Potentially Affected

Passage actions 01 through 16 potentially affect all yearling Snake River salmon stocks. Fall chinook are also potentially affected by all passage actions. However, the 2-month (mid-April to mid-June) drawdown and natural river operation actions (07 and 08) will have little beneficial effect on fall chinook since fall chinook begin migrating past Lower Granite dam in mid-June, the end of the drawdown period (SOR 1993a, Chapter 2). In addition, some passage actions may affect non-salmon species. The reservoir drawdown actions 09 through 14, and the natural river actions 07 and 08 probably will adversely affect resident fish and wildlife.

All commercial harvest cuts can affect both wild and hatchery components of each Snake River stock. Although these cuts in theory can be directed toward individual stocks, insufficient information and/or a high degree of mixing of populations (particularly in the ocean) probably will make some stock-specific cuts impractical. Habitat actions potentially affect several stocks simultaneously, and broad-scale actions such as improved land management may also benefit non-salmon species.

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[17] Although we do not include habitat enhancement actions in Table 1 for reasons noted above, we discuss characteristics of habitat enhancement across the various attributes.

6.2 Lead Time from Implementation to Biological Effects

Commercial harvest cuts and some habitat actions, once implemented, potentially would generate effects that could be evaluated immediately. The screening of irrigation canal intakes provides one example of an habitat action with immediately-observable effects. The effects of removing migration barriers and opening up new habitat to salmon, on the other hand, may be impossible to evaluate until straying fish colonize the newly-opened areas. Other habitat actions such as riparian plantings and fencing, land management, and placement of instream structures also would require some time before effects could be observed.

Juvenile passage actions can promote both immediate effects and lagged effects, depending on the life stage affected and the type of effect. The effects of increased river velocity or spill on migrating adults can be immediate; adults may die or not spawn if upriver passage is delayed (because of a potentially higher expenditure of energy per unit migration time), or if nitrogen super-saturation becomes a problem. However, the effects of increased flow on migrating smolts may not appear for several years after implementation for at least two reasons. First, for actions 05 and 06, flow augmentation may not be implemented in high runoff years and thus its effects would not be observable. Second, for all passage actions designed to increase water velocity, the asymptotic shape of the flow-travel time and flow-survival relations (Giorgi 1993) may mean that at higher base flows an increase in flow over base may have no effect on survival. In this case an effect may not appear until a year of sufficiently low base flow.

6.3 Scope of Direct Effects

Although the ultimate objective of all passage actions is to increase smolt survival, the immediate objective of flow actions is to speed the downstream migration of smolts.[18] However, flow actions may also have other direct effects beyond the effect on smolt migration rate. They

[18] Although some researchers focus on a potential relation between flow and migration *timing* (e.g., McNeil 1992), migration rate appears to be more commonly used to reflect the efficacy of flow actions for enhancing the downstream migration.

may affect fall chinook rearing, survivals past dams, predation rates, and the upstream migration of adults. Table 2 notes some of the possible positive and negative direct qualitative effects, but because the magnitude of many of these side effects are speculative, they are not modeled formally.

The objectives of habitat enhancement are more diverse than for passage actions. Habitat actions are intended to increase egg-to-smolt survival, survival of overwintering smolts, and the survival of pre-spawning adults. Yet habitat actions also may have effects beyond those intended. For example, Chapman and Witty (1993, p. 61) point out that there are no data to support the common assumption that screening of irrigation ditches has only benefits for fish production. The available evidence is too limited to suggest which of these possible effects occur.

6.4 Scope of Indirect Effects

The direct effect of harvest cuts on adult survival is obvious, but harvest actions potentially can act on the population indirectly as well. For example, cutting harvest may lessen selective pressure against larger returning fish. Average age, size, and age of maturity may increase. All of these have decreased historically in part due to selection from harvest. A shift toward older, larger fish can lead to higher egg deposition by increasing both the proportion of females in the population and the number of eggs per female (Lestelle and Gilbertson 1993, p. 24). Also, a harvest cut may alleviate loss of genetic diversity within stock due to disproportionate harvest on different stock components (Lestelle and Gilbertson 1993, p. 25). We do not have quantitative estimates of these effects and thus do not include them formally in the modeling exercise.

6.5 Costs

The marginal costs of hydrosystem actions range from minus $170 million per year (savings from base case) to **$570** million per year. Table **3** shows a range of costs for the

Table 2
Some Potential Qualitative Effects of Juvenile Passage Strategies Not Incorporated Into Quantitative Survival Estimates

Positive or negative effect	Type of passage strategy (w/ a&ion numbers)	Life stage affected	Effect
Positive	Plow Augmentation (01,03,05,06)	Juvenile	Altered distribution of predators in tailrace of dam may reduce predation (also may increase it).
		Adult	Releases of cool water could encourage upstream movement.
	Drawdown (09 through 14)	Juvenile	Altered distribution of predators in tailrace of dam may reduce predation. Suspended sediments may reduce predation.
	Natural River Option (07,08)	Juvenile	Altered distribution of predators in tailrace of dam may reduce predation. Suspended sediments may reduce predation.
		Adult	Reduced risk of dissolved gas problems. Reduced delay at dams.
Negative	Plow Augmentation (01,03,05,06)	Adult	Increased fallback and delay at dams.
	Drawdown (09 through 14)	Juvenile	Decreased volume may increase predator concentration and juvenile mortality
		Adult	Excessive spill can cause delay at ladders. Increased gas saturation problems. Suspended sediments may decrease migration rate.
	Natural River Option (07,08)	Juvenile	Can affect rearing of fall chinook in reservoirs. Decreased volume may increase predator concentration and juvenile mortality
		Adult	Suspended sediments may decrease migration rate

downstream passage and harvest actions formally modeled.[19] The base case from which costs are calculated consists of passage action 03 (SOR alternative 2c) and harvest at levels that prevailed in the 1987-92 period (harvest action HC).[20]

The table includes a range of cost estimates for each action. For downstream passage, we developed lower-bound and upper-bound cost estimates based on alternative assumptions about how the power will be replaced.[21] It is important to note that in comparing costs among actions, one should be careful to compare low costs with low costs and high costs with costs, since we used different estimating techniques to assess the costs. However, while it is readily apparent that the different methods for calculating power costs result in very large differences in cost estimates for any given downstream passage action, the two methods yield the same ranking of the passage actions. For harvest, we estimated costs of harvest elimination as the ex-vessel gross value of the respective chinook commercial harvests in U. S. waters (Pacific Fisheries Management Council 1993; Lestelle and Gilbertson 1993), and (arbitrarily) doubled this figure to get an upper-bound estimate. Appendix A provides details on methods and data sources for the cost estimates. Note that we do not include the costs (or benefits) of potential irrigation, navigation and recreation restrictions associated with the recovery measures.

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[19]As noted earlier, we annualize costs at a 3 percent real discount rate. Other analysts involved in the SOR process have used higher discount rates for some of the passage actions (e.g., an 8 percent discount rate for the Corps of Engineers structural modifications needed to implement drawdown and the natural river option). Higher discount rates will yield higher annualized costs. Therefore, our numbers may differ from those presented in SOR reports. See Appendix A for a more complete discussion of this and other issues connected with the cost estimates.

[20]The base case is defined to represent flow conditions as they existed after the ESA listings, and include some physical facilities (e.g., improved bypasses) which are not yet in place. See Appendix D for further discussion of the base case.

[21]With the exception of passage actions 01 through 04, the low cost of a passage action corresponds to the assumption that power purchases will make up for the power shortfall that results from altered hydrosystem operation, while the high cost of power replacement assumes that new combustion turbines will be needed to replace the power. In addition, two other features distinguish low cost from high cost estimates for other passage actions. First, for those actions which do not require additional upper Snake River water ***(i.e., they*** do not require the additional upper Snake River water needed in the base case) , we assume that in some years no water purchases are saved relative to the base case (high cost) and in some years the entire complement of water needed in the base case but not needed in the passage action will be saved (low cost). Second, the costs of dam structural modifications that are necessary to support a passage action are low or high, the difference being that the high estimate includes a contingency factor for unforeseen design or construction difficulties.

Table 3
Costs of Potential Recovery Actions
($ million per year, 3% Discount rate)

No.	Description	Low-Cost Assumption Purchased Power	High-cost Assumption Purchased Power	Low-Cost Assumption Combustion Turbines	High-cost Assumption Comb&ion Turbines	Cost Rank
01	SOR la with transport	-60	-50	-170	-160	15
02	SOR 1 a without transport	-60	-50	-170	-160	15
03	SOR 2c with transport (Base Case)	0	0	0	0	13
04	SOR 2c without transport	0	0	0	0	13
05	SOR 3b with transport	260	290	350	380	4
06	SOR 3b without transport	260	290	350	380	4
07	SOR 5a without transport	210	260	350	400	2
08	SOR 5b without transport	240	290	350	400	2
09	SOR 6a without transport	90	110	180	200	6
10	SOR 6b without transport	90	110	180	200	6
11	SOR 6c, no LGR transport	40	50	125	135	10
12	SOR 6c w/ LGR transport	40	50	125	135	10
13	SOR 6d, no LGR transport	50	60	140	150	8
14	SOR 6d with LGR transport	50	60	140	150	8
15	SOR 7a with transport	370	380	560	570	1
16	Upstream collector, transport	30	40	30	40	12
		Low cost Estimate		**High cost Estimate**		**Cost Rank**
HC	Base Case Harvest (1987-92)	0		0		4
HO	No non-treaty US Ocean Commercial harvest	40		80		2
HR	No non-treaty In-River Commercial harvest	1		2		3
Hx	No non-treaty US commercial Harvest	40		80		1

System operations costs from SOR (1993b).
Harvest costs derived from data in Pacific Fishery Management Council (1993).
See text and Appendix A for details.

The lowest cost flow actions, actions 01,02,03, and 04, not surprisingly correspond to pre-listing or base case, current operations (interim flow improvements resulting from the Supplemental EIS) and costs of these range from well below zero (savings) to zero (no additional cost above base case). The highest cost flow action, action 15, entails spill, and costs for $370 million to **$570** million per year. The other flow actions, actions 05 through 14, involve flow augmentation, stable storage, and drawdowns, and cost $40 million to $400 million per year.

Harvest restrictions cost roughly $1 million per year for commercial in-river harvest elimination and $40 million for commercial ocean harvest elimination, based on gross at-dock value.[22] Ocean harvest restrictions entail elimination of alI commercial non-Treaty chinook harvest in southeast Alaska and the Oregon, Washington, and California coast within the PFMC jurisdiction. In-river harvest restrictions eliminate the non-Treaty commercial harvest of spring and fall chinook in the Columbia River. The annualized capital, operation, and maintenance costs of action 16, the upstream collector above Lower Granite (single collector with barge transport), are $30 million to $40 million, depending on whether one includes contingencies for unanticipated project costs in the estimate.

6.6 Geographic Distribution of Adverse Impacts

Such measures as monetary compensation and job retraining in theory could evenly distribute many of the impacts of recovery actions across the Pacific Northwest. However, in the absence of such measures the impacts of recovery measures can be geographically distributed unevenly through the Pacific Northwest for several reasons. First, some recovery measures will affect some parts of the region more than other parts because some sub-regions have a higher concentration of activities that absorb the direct costs of the recovery measures. For example, SOR actions that impose high costs on the federal hydropower system (e.g., passage actions 05, 06,07,08, and 15) may require significant wholesale electricity rate increases. The effects of

[22]Note that the cost estimates of harvest restrictions do **not** include any reduction in coho harvest. If coho harvests need to he curtailed to protect chinook stocks, the costs of harvest restrictions could escalate quickly.

residential electricity rate changes are spread in rough proportion to population through Washington and Oregon, since much of the area lies within the BPA service area, with some exceptions. Most of the major urban residential loads are served by investor owned utilities (Portland, Seattle, Spokane) or by public utilities or cooperatives that receive less than one-half of their power from BPA (Seattle, Tacoma). In addition, customers in the mid-Columbia public utility districts generally purchase little BPA power, and Idaho and Montana lie largely in investor owned utility service areas (Carlson 1993; BPA 1987). Residents in these areas are somewhat less vulnerable to the price increases than are residents who receive BPA power.[23] In addition, the effects on particular electricity-intensive industries may be concentrated, and smaller communities with less diversified economic bases will experience higher relative impacts. To take the most obvious case, the aluminum industry, the impact of rate increases will be felt most acutely in smaller inland communities which have aluminum plants and generally limited employment bases, such as Goldendale, Longview, Wenatchee (all in Washington), The Dalles, Oregon, and Columbia Falls, Montana.

A second mechanism that potentially can drive an unequal distribution of impacts is that recovery measures may restrict certain activities in some areas and thus affect the income of residents in those areas. Actions 05 and 06 augment river flows and may involve lower water elevations at Grand Coulee thus affecting recreation, wildlife, and tourism at those sites. Actions 07 through 14 (particularly 07 and 08) also decrease the recreation and tourism potential in the lower Snake reservoirs. These actions also potentially increase the transportation costs of farmers in southeast Washington, northeast Oregon, and central-northern Idaho, although adjustments to a different marketing period may mitigate this. On the other hand, southern Idaho may gain because it is less reliant on barge transportation and may benefit from price increases resulting from supply cutbacks in the rest of the region and a shift toward higher value crops such as

[23] Because of the BPA Residential Exchange program, even residential customers of investor owned utilities throughout the region may be affected by higher BPA rates. The program offers to serve at BPA preference rates the qualified residential and irrigation load of private utilities in the region.

potatoes and sugar beets. In general, farmers closest to the river and grain terminals and port districts on the river will experience the greatest impacts (Hamilton, Martin, and Casavant undated).

All harvest restrictions obviously decrease the gross fishing income of in-river and/or ocean harvesters, although the distribution of net income reductions is difficult to predict given the apparent over-capitalization in the industry and the negative net income of many commercial harvesters (Mendelsohn, Whitelaw, and Niemi 1988). Habitat enhancement actions are not specific, so the distribution of impacts is unclear, but some estimates can be made of the distribution of potential impacts from the Huppert, Fluharty, and Kenney (1992) study of critical habitat designation in national forests in the region. The reduction in permitted grazing levels that may result from such habitat protection will be highest in eastern Oregon and Washington, followed by southern Idaho, and then northern Idaho, although mitigation costs per animal unit month (e.g., for range improvement) are highest in northern Idaho and eastern Oregon, Timber sale reductions resulting from protection of salmon habitat probably will be highest in northern Idaho and thus this region may experience the largest job and gross income losses, while at the same time the region may benefit from timber sale reductions (due to current below-cost timber sales, net income flows from curtailment of timber sales in northern Idaho may be positive).

A third cause of unequal distribution of impacts is that users of an activity affected by a recovery measure may come from a small number of areas. For example, more users of Grand Coulee come from the Puget Sound area than any other area (Northwest Economic Associates 1993, p. 36), so the decreased recreation opportunities at Grand Coulee potentially associated with actions 05 and 06 affect these users. In addition, the area around Grand Coulee, the second-highest source of Grand Coulee users, clearly will experience a loss of recreational opportunities in addition to the income losses associated with recreation and tourism reductions.

Although we concentrate on the distribution of impacts across space, we can comment briefly on the distribution of impacts across income classes as well. For example, rate increases resulting from expensive changes in hydrosystem operations (e.g., action 15) most likely will affect lower income households relatively more that middle- and higher-income households since expenditures on electricity typically constitute a higher proportion of total expenditures in a lower-income household than in a middle- or higher-income household (see, for example, Energy Information Administration 1993, p. 292). In addition, lower-income households may have fewer opportunities or financial resources for conservation, although existing low income weatherization programs address this problem. Changes in income from in-river or ocean harvest restrictions (HO, HR, HX) or from land use restrictions imposed for habitat enhancement, if uncompensated, will probably affect lower-income households more since such income is more important to lower-income households than to middle- and higher-income households (Wernstedt 1991, p. 73).

6.7 Temporal Distribution of Adverse Impacts

A number of possible recovery actions may have short-run non-biological impacts that differ from long-run non-biological impacts. For example, passage actions which may decrease the amount of water available for irrigation to upstream users through purchase or leasing of water (e.g., passage actions 05 and 06) in the short-run may decrease income from farming. In the long-run, however, increased irrigation efficiency and a shift to alternative crops may mitigate this problem.[24] In a similar vein, passage actions that depend on lower river elevations (e.g., passage actions 07 through 14) may make irrigation impossible in the immediate short-run, but in the middle to long-run pump extensions clearly may obviate this problem (the pump modifications likely will be subsidized). These latter passage actions also may lead to short-run transportation bottlenecks. If barge hauling becomes impossible during a portion of the year, the truck and railroad infrastructure capacity may be reached if farmers do not adjust their market timing and switch their marketing modes. In the long-run, however, the necessary infrastructure may

[24]Increased irrigation efficiency does not itself necessarily mean that more water will stay in the river. Farmers may increase irrigation efficiencies on their farms and use the "saved" water to increase yields or grow new high water using crops. In addition, the water previously lost through inefficient irrigation practices may have augmented surface water flows after storage in groundwater. It thus may have been removed from the surface water supply only temporarily (Barron 1992).

develop to serve the demand and/or agricultural producers may position themselves differently and move their products to market before the drawdown period (Hamilton, Martin, and Casavant undated). Hydrosystem operation actions that promote wide fluctuation in reservoir elevations also may severely impact tourism in the short-run (marinas get stranded or damaged, boat ramps left short of the shoreline, unappealing mud flats are exposed). In the long-run, affected parties can extend marinas and boat ramps.

Flow actions that lead to increased electricity costs also may have different implications in the short- and long-run. In the short-run, electricity consumers have little time to adapt to price increases so the total amount that they spend on electricity probably will increase. In the long-run, however, they may adapt to the new prices (with conservation, for example), so the amount of electricity that they purchase (and therefore the amount that they spend on electricity) probably will be lower than in the short-run immediately after the rate increase (see, for example, Bohi and Zimmerman 1984, pp. 116-l 17).

Harvest and habitat enhancement actions also may have different non-biological effects in the short-run than in the long-run. In some ways, elimination of commercial harvest would be only the continuation of a long-term trend toward decline of the fishing industry. With or without harvest restrictions, alternative employment opportunities probably will develop in the long-run. In the short-run, however, the cessation of commercial harvest could have devastating impacts on small fishing communities. Similarly, restrictions on private use of public lands will immediately alter the livelihoods of ranchers and loggers, as well as the communities in which they live. As with harvest restrictions, one can believe that much of this is occurring regardless of habitat enhancement actions aimed at endangered and threatened salmon stocks. In the long-run, the economic base of communities that depend on the consumptive use of land and water resources may evolve toward non-consumptive uses.[25]

[25]See, for example, Timothy Egan, "Timber Country Sees a Vacation Land," The New York *Times,* September 2, 1993, p. A-14.

6.8 Lead Time to Implement Recovery Measure

The time from initial design work associated with an action to the full initiation of the action may not be an issue for some actions. For example, harvest and some passage actions can be implemented immediately (after necessary appropriations) or over the course of several seasons, at least in concept.[26] However, a number of other passage actions clearly do require significant lead times before the action comes on line. The Corps of Engineers' estimates of the time from design to implementation of the natural river option and four-dam drawdown are 17 years and 14 years, respectively. The lead time estimate for the Lower Granite only drawdown is 11 years after appropriations. Construction of an upstream collector at the top of Lower Granite reservoir would require roughly 8 years.[27] All of these estimates assume no resource limitations or unforeseen technical problems and do not include the time to secure necessary appropriations (Corps of Engineers 1992a, pp. 5-5 to 5-7,5-23 to 5-24; Corps of Engineers 1992b, p. 66).

The long lead time for the natural river and drawdown options results from the detailed design and modeling work initially required, as well as a lengthy construction schedule. Construction can take place only during low water periods from August to March and must be carried out so as to minimize disruption to adult fishway operations. The Corps of Engineers bases its estimates of the lead times on the assumption that construction activities also must be phased to minimize spillway capacity reductions and to ensure that powerhouse and spillway capacity reductions do not occur simultaneously. In its estimates of the four-dam drawdown and natural river options, the Corps of Engineers also envisions a two-year evaluation period between completion of construction at Lower Granite and Little Goose and initiation of construction at Ice Harbor and Lower Monumental.

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[26] Harvest restrictions in theory could occur in a single season, although most realistic reductions will require time for negotiations, monitoring, and design and implementation of management strategies to implement the restrictions. Habitat enhancement actions probably require significant lead times, particularly if new management plans need to be drafted or physical structures built. Unfortunately, we have no estimates of these lead times.

[27] This would involve construction of a bypass channel, low head lock, fish screens, and sorting and transfer stations.

6.9 Restorative Recovery Measure

The line between more-restorative and less-restorative actions is subjective and not clear cut, and in reality the two types of measures grade into each other, In general, however, we believe that those passage actions which rely on full smolt transportation (passage actions 01,03, 05, 12, 14, 15, and 16) are less-restorative because they are attempting to replace the natural function of the river in moving the smolts to the estuary. Actions 02,04, and 06 through 10, which do not rely on barge transportation, are more-restorative (particularly 07 and 08) because they are attempting to improve smolt survival through what are arguably more natural means.[28] Actions 11 and 13 have both more-restorative and less-restorative elements since they include drawdown but also rely on transportation at the pools that are not drawn down, but in general we consider these to be less-restorative.

We view harvest restrictions and habitat enhancement as being restorative because they attempt to restore some of the natural function and characteristics of the ecosystem without exerting more control. This is admittedly problematic, since human harvest of salmon is arguably an integral part of the ecosystem. Nonetheless, we believe that a reduction in the current level of harvest loosens human control of the ecosystem and moves it toward the reference case. Habitat enhancement belongs much more cleanly in the restorative camp, since many (although not all) of the habitat enhancement actions are attempting to restore degraded habitat to something more akin to its original condition.

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[28] We recognize that all of the passage actions attempt to control nature and manage the hydrosystem to enhance smolt passage. No passage action is truly restorative and many actions which we call restorative (e.g., natural river option and drawdowns) have a high level of human control. However, we place an action in the restorative camp if it appears that the action attempts to modify the river so that it can function more like it would in an uncontrolled state, even if modifications necessary to return the river to its natural functions rely on a high degree of control. There is clearly an arbitrary element to this approach.

6.10 Institutional Considerations

Nearly all of the passage, harvest, and habitat enhancement actions entail some form of institutional change insofar as most actions involve changes from current operations or practices to something new. For example, all of the passage actions with the exception of action 03 and 16 (the base case, which consists of the Corps' 1993 final supplemental EIS flows, and the addition of the upstream collector) would involve alterations in the timing, amount, or location of flows, even if no formal agreements would need to be modified. We do not focus on these kinds of changes in this attribute, however. Rather, we look at the broader institutional implications associated with changing missions, responsibilities, or relationships among individuals or groups.

Harvest restrictions and flow changes involve the largest institutional changes. Harvest restrictions would involve extraordinary changes in the responsibilities and mission of the salmon management councils and agencies, from an orientation historically built on strong-stock management and high harvest to one much more specifically geared toward protecting weak stocks.[29] Restrictions on commercial ocean harvest, which although unlikely in the extreme (elimination of all U. S. commercial ocean harvest), would need to confront issues of international law, inter-state relations, property rights and compensation if they entail any reduction of significance. In-river restrictions likewise would raise many of these institutional concerns, as well as further complications with Treaty fishing rights. Conflicts between commercial and recreational fishing interests also would need attention.

Passage actions that entail significant changes in flows likewise may involve issues of property rights and compensation from several different directions. Actions 05 and 06 require new water from the middle- or upper-Snake River in Idaho, perhaps by purchase or leasing of water rights from farmers, or by assertion of prior rights to instream flow and concomitant legislation of instream flow requirements. Purchase or leasing may require a further development

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[29] Lestelle and Gilbertson (1993) discuss a number of possible harvest management strategies -- single weak stock management, multiple weak stock management, time-area separation, selective harvest fisheries, ceiling fisheries, and increased hatchery and catch ceilings. One of the factors needed to support these alternative strategies is an institutional mission that is more concerned with monitoring and information gathering than with production.

of water rights markets to transfer water from agriculture to instream use. Although Idaho courts have established the equality of diversionary and in-stream uses, the state traditionally has subordinated instream uses (e.g., hydropower generation) to diversionary uses such as agriculture, even if in-the stream use has an earlier claim to the water. However, an emphasis on the instream use of upper Snake water challenges the state's traditional preference for allocating water to agriculture activities.[30]

Actions 07 through 14 also pose property rights and compensation challenges, insofar as navigators, irrigators, and the tourist industry may press for compensation if the lower reservoir elevations associated with these strategies threaten river navigation, irrigation pumping, or recreation, respectively. Property damage that could result from drawdowns to near the original riverbed level (actions 07 and 08) or to fixed elevations below minimum operating pool (actions 09 through 14) also may demand attention. In all these cases, compensation poses questions for existing institutions in the region. Even if no net economic impact results from altering hydrosystem operating strategies, communities that view the river as a indispensable community resource may feel threatened by (and thus resistant to) hydrosystem changes. The natural river option (actions 07 and 08), in particular, may shift the dominant use of the Columbia River system away from a historical pattern of exploitation of the river resources for economic development.

Other possible recovery actions also may present institutional problems. The cessation of smolt transportation (actions 02,04, and 06 through 10) would eliminate one of the major roles that the Corps of Engineers plays in mitigating the damage caused by the hydrosystem. The movement from barge transport to rail or truck transport of agricultural commodities and other goods associated with the natural river or drawdown option (actions 07 through 14) would

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[30]Although not of immediate importance for the endangered Snake River stocks, the relicensing of the trio of Idaho Power dams above Hells Canyon in Idaho will emphasize the potential influence of institutional change in controlling water allocation. These three Snake River dams have explicitly subordinated instream uses *(i.e.,* hydropower) to irrigation withdrawals in their water rights and FERC licenses, yet relicensing may challenge this subordination. The increasing value of hydropower and instream uses for salmon protection, coupled with potential mandates from the ESA, may force new responsibilities on such institutions as the Idaho Deparunent of Water Resources.

obviate for at least part of the year the institutions built on having a navigable waterway open for grain transportation. The higher spill contained in action 15 clearly elevates the importance of controlling flows for the benefit of fish, at the expense of the historical mission of power production. Finally, habitat enhancement actions that alter range or forest use may compel fundamental shifts in the relationships and expectations which govern the use of public land. Prospective alterations in land use activities to benefit the threatened anadromous stocks may negate the prevailing multiple use doctrine that guides the management of federal forest lands.

6.11 Partial Classification of Recovery Actions

Table 4 shows a classification of the recovery actions for five attributes (the biological effects attribute occupies three columns). The table summarizes information presented in subsections 6.5,6.8,6.9,6.10, and 7.2. The classification of biological effects, costs, and construction lead times is normative, in the sense that classes of '+', 'low', and '0' are better than classes of '-', 'high', and 'lo-20', respectively. For the restorative and institutional change attributes the classification is not meant to suggest a ranking or preference. Some individuals may prefer 'more' restorative measures, while others may not care if a measure is 'more' or 'less' restorative. Similarly, some may prefer options that bring 'minor' institutional change, while others may favor or view neutrally options that bring 'significant' institutional change. We make no attempt to include all attributes or to aggregate ranking across attributes.[31]

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[31]We classified tbe attributes rather simply. The construction lead times classification is obvious. For the biological effects attribute, we assigned a '+' if the biological effects for the three stocks (estimated in the SLCM modeling exercise) exceeded the base case biological effects, and a '-' if the effects did not exceed the base case. For the cost attribute, we ranked tbe recovery actions by annualized costs, plotted the ranks against tbe costs, connected the points, and developed classes based on the largest changes in slope between the points. We classified the actions on the restorative attribute by classifying an action as 'more' restorative if it did not involve transportation or moved away from current levels of harvest. Other actions received a 'less' restorative designation. We classified actions on the institutional change attribute based on our perception that harvest, natural river, and drawdown actions will require or promote significant institutional change, and therefore warrant a 'significant' designation. Other actions appear to require only minor institutional change and therefore receive a 'minor' designation. For all attributes in Table 4, the classification of base case actions is not applicable ('N/A').

Table 4
Partial Classification of Recovery Actions by Attribute

No.	Description	Spring Chinook Effectsa	Summer Chinook Effects[a]	Fall Chinook Effects[a]	Cost[b]	Const. Time (Years)[c]	Restorative[d]	Institutional Changee
01	SOR la with transport				Low	o-1	Less	Minor
02	SOR la without transport				Low	o-1	More	Minor
03	SOR 2c with transport (Base Case)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
04	SOR 2c without transport				Low	o-1	Less	Minor
05	SOR 3b with transport	+	+	+	High	O-l	Less	Minor
06	SOR 3b without transport				High	O-l	More	Minor
07	SOR 5a without transport	+	+		High	10-20	More	Significant
08	SOR 5b without transport	+	+		High	10-20	More	Significant
09	SOR 6a without transport				LOW	10-20	More	Significant
10	SOR 6b without transport				LOW	10-20	More	Significant
11	SOR 6c, no LGR transport				LOW	10-20	More	Significant
12	SOR 6c w/ LGR transport	+	+	+	LOW	10-20	Less	Significant
13	SOR 6d, no LGR transport				LOW	10-20	More	Significant
14	SOR 6d with LGR transport	+	+	+	Low	lo-20	Less	Significant
15	SOR 7a with transport				High	o-1	Less	Minor
16	Upstream collector, transport	+	+	+	Low	1-9	Less	Minor
HC	Base Case Harvest (1987-92)	N/A	N/A	‘N/A	N/A	N/A	N/A	N/A
HO	Eliminate Non-Treaty U. S. Commercial Ocean Harvest	+	+	+	Low	1-9	More	Significant
HR	Eliminate Non-Treaty Commercial In-River Harvest	+	0	+	Low	l-9	More	Significant
Hx	Eliminate Non-Treaty U. S. Commercial Harvest	+	+	+	Low	l-9	More	Significant

Legend:

N/A signifies base case conditions (SOR alternative 2c, 1987-92 harvest)

a. "-" indicates no effect or negative effects, “+” indicates increased survival

b. “Low” indicates annual cost less than $100 million, “High” indicates annual cost greater than $100 million, using low purchased power estimates, from Table 3. Note that using high purchased power cost estimates would push actions 9 and 10 into the “High” cost category, while using high combustion turbine estimates would push all drawdown actions into the “High” category.

c. Construction lead time shown in years. Includes time to change harvest regulations, as applicable.

d. “Less” and “More” restorative are relative to reference case (see subsection 3.3).

e. “Minor” and “Significant” institutional change are relative to base case.

The table is generally self-explanatory, but three points bear noting. First, the biological effects (columns 3 through 5) of the recovery actions for the three stocks generally receive the same ranks; that is, a recovery measure that garners a '+' biological effects rank for spring chinook also generally will receive a '+' biological effects rank for summer chinook and fall chinook. This reflects the systemic nature of the actions that we chose (e.g., flow measures for all stocks or harvest restrictions on all commercial harvest). Second, the classification of biological effects requires careful interpretation, insofar as a '-' designation does not necessarily signify negative effects. It can mean no change in survival from the base case; the base case itself provides higher survival than current conditions due to the assumptions that we include in the base case (see Appendix D for a discussion of the base case assumptions). Third, no recovery measure receives a consistently good score on the three normative attributes.

To amplify this last point, consider that the ideal action would receive the highest rank possible on each of five indicators.[32] No action reaches this ideal. Seven actions (05,12,14, 16, HO, HR, and HX) receive the highest ranking on all but one of the indicators, with the majority of these receiving less than the highest rank on the construction lead time indicator. No actions receive less than the highest ranking on just two of the indicators, but five actions (01,02,04,07, and 08) receive less than the highest rank on three of the indicators. Six actions (06,09, 10, 11, 13, and 15) receive less than the highest rank on four of the indicators. The difficulty in designing a recovery measure that performs well on all of the attributes for each stock is the primary reason why we believe it is critical to evaluate the recovery measures on a wide range of attributes.[33]

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[32]For purpose of this discussion, we refer to five indicators that we rank for each action. These five indicators are costs, construction lead times, spring chinook biological effects, summer chinook biological effects, and fall chinook biological effects. In the rest of the paper, of course, we collapse the biological effects for each of the three stocks into a single 'biological effects' attribute.

[33]This divergence between ranks on different attributes likely would intensity if we brought in the other attributes that we include in our evaluation. For example, as noted earlier, the qualitative effects included in Table 2 include negative effects which may run counter to the anticipated positive effects of passage actions. In addition, the distributional implications of some recovery actions (e.g., harvest elimination) arguably may lessen the desirability of the actions on grounds of lower costs.

7. POTENTIAL FOR PRODUCING ACCEPTABLE POPULATION SURVIVAL

The potential for producing an acceptable population survival is the main biological attribute that we include in our analysis. This section discusses both the numerical survival improvements necessary to achieve an acceptable probability of extinction or increase in abundance, and the likelihood that the potential recovery actions will suffice to achieve these improvement.

7.1 Necessary Survival Improvements

Table 5 shows the survival improvements needed to reach four biological objectives for the Snake River stocks that reflect the biological criteria described in section 4. Figures 2 and 3 show the likelihood of extinction and spawner abundance, respectively, after 100 years as a function of a survival increase from the base case. As noted earlier, we used the passage survival calculated by CRiSP for action 03 as the base case survival. The base case includes planned actions that have not yet been implemented, so it is important to note that the base case itself presents higher survival values than are currently observed (see Appendix D). The table and figures show the following points:

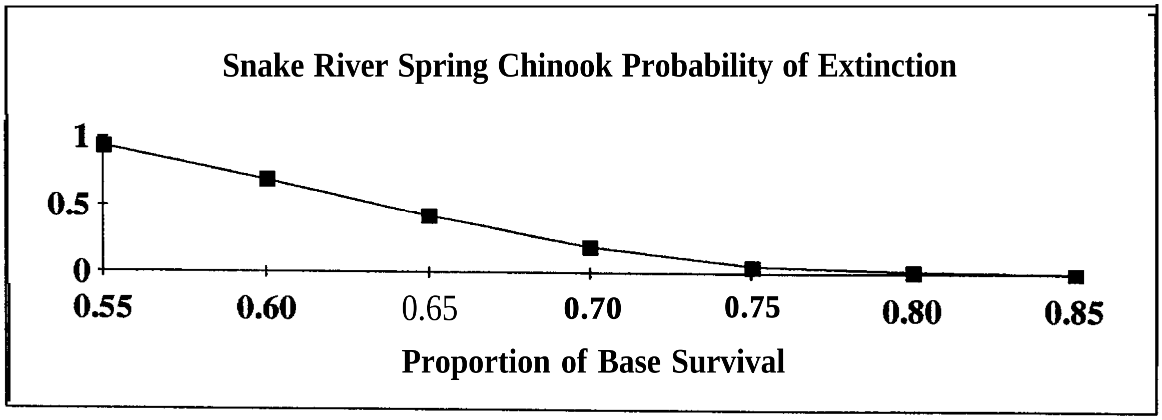
7.1 a Spring Chinook:

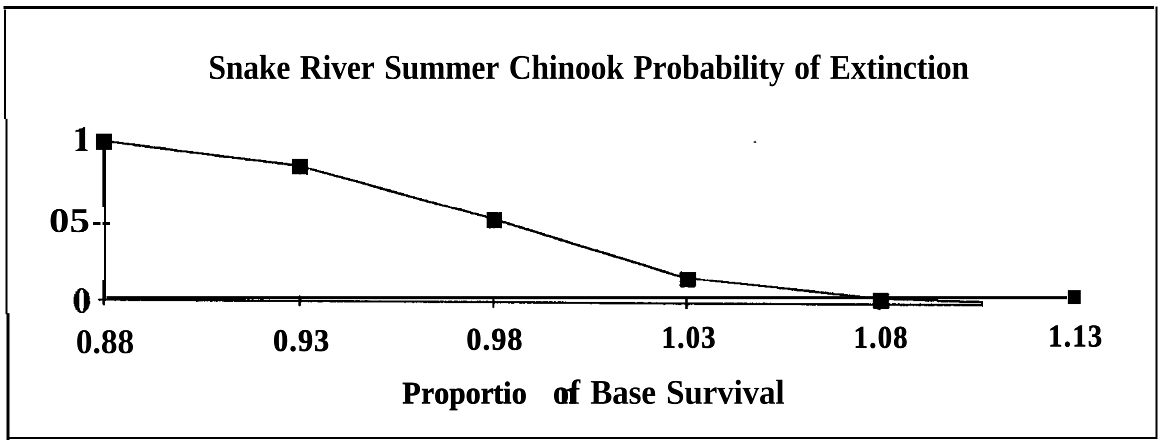
- The base-case density-independent survival for Spring Chinook appears sufficient to assure population persistence over the next 100 years. This was also the conclusion of Emlen (1993).
- The base-case density-independent survival appears sufficient to assure a non-declining population in 50 percent of model replications, but a 3 percent increase over base survival is needed to reach a non-declining population in 90 percent of model replications. The base case appears sufficient to at least double the initial population size in 50 percent of model replications.

Table 5
Survival Needed to Meet Biological Objectives
(survival as a multiple of base case)[a]

Objective	Spring Chinook	Summer Chinook	Fall Chinook
<05% probability of extinction, 100 yrs. (>95% probability of persistence)[b]	1.00	1.07	1.44
Non-Declining for 50% of replications	1.00	1.15	1.25
Non-Declining for 90% of replications	1.03	1.25	1.45
Double spawners for 50% of replications	1.00	1.22	1.35

a The base case uses SOR alternative 2c and base case harvest (1987-92 average).
b Extinction is defined as less than 100 spawners for 4 or more consecutive years.





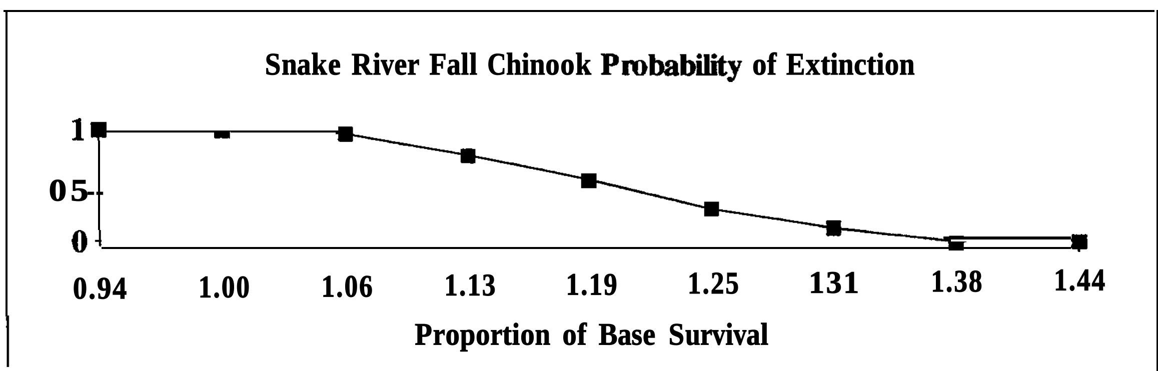


Figure 2: Probability of Extinction as a Function of an Increase in Survival Relative to the Base Case. Base case is action 03 (SOR alternative 2c) and 1987-92 harvest. Extinction is defined in Section 4.

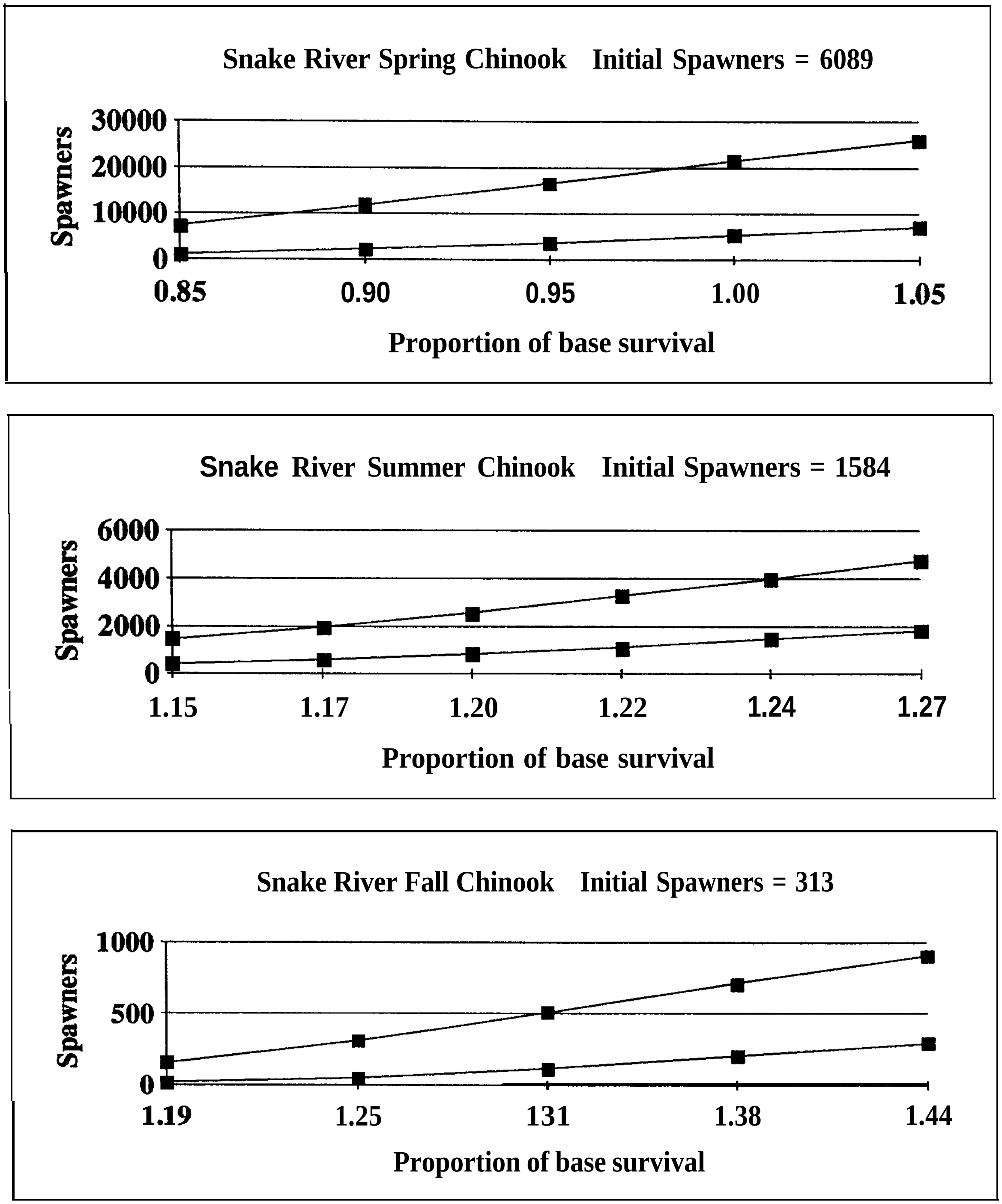


Figure 3: Averages Over Years 90 to 100 of the 10th Percentile (lower line) and Median (upper line) of the Distribution of Spawners as a Function of an Increase in Survival Relative to the Base Case. As relative survival increases, both spawner abundance and the difference between the 10th and median percentiles increases. Base case is action 03 (SOR alternative 2c) and 1987-92 harvest.

7.1 b Summer Chinook:

- An increase of approximately 7 percent over base-case density-independent survival is required to attain population persistence over 100 years in 95 percent of the model replications.
- A 15 percent and a 25 percent increase in density-independent survival over base is needed to attain a non-declining population in 50 percent and 90 percent of model replications, respectively. A 22 percent increase over base is needed to at least double the initial population size in 50 percent of model replications.

7. lc Fall Chinook:

A paucity of data on passage survival of subyearlings (Giorgi 1993) makes it more difficult to estimate survival changes from passage actions. Inputs to and thus results of the CRiSP model are more uncertain for fall chinook and engender less confidence than those for spring and summer chinook

- Using a base case passage survival of 0.48, an increase in density-independent survival of approximately 44 percent over base-case is required to attain population persistence over 100 years in 95 percent of the model replications.
- Using a base case passage survival of 0.48, a 25 percent and a 45 percent increase in density-independent survival over base is needed to attain a non-declining population in 50 percent and 90 percent of model replications, respectively. About a 35 percent increase over base survival is needed to at least double the initial spawning count for 50 percent of model replications.

7.2 Likelihood of Meeting These Survival Improvements

Many types of information should be brought to bear in determining whether particular actions are likely to provide survival improvements needed to meet given criteria. Sources of information include experimental results, evidence from past applications in similar systems, and results of models. For salmon recovery planning in general, and especially for passage actions, we must rely mainly on the results of computer models. We stress, however, that the results of computer models reflect the quality of the information put into the models.

Table 6 shows the average estimates of biological effects of the passage and harvest actions.[34] (We will discuss the ranges for some of these estimates in section 10.) We express the average effects of the actions relative to the base case survival. A '1.0' signifies no change from the base case (as defined in section 5.1 and Appendix D), numbers greater than 1 .O represent an increase in survival, and numbers less than 1.0 a decrease in survival. Average estimates for the survival changes came from several sources. Passage actions were modeled with the CRiSP passage model. Lestelle and Gilbertson (1993) inferred the effects of harvest restrictions (shown here in spawner equivalents) from coded wire tag recoveries of hatchery stocks, since no data are available for tagging of wild Snake River chinook stocks. We explain our calculation of the effects of harvest restrictions in Appendix C. Because we have no data on the linkage between changes in model parameters and detailed actions or costs, we handle the effects of habitat enhancement in the Snake Basin using a sensitivity analysis, discussed in Section 10.

According to CRiSP simulation results for spring chinook, one-half of the passage actions, including the base case SEIS operations, can achieve the persistence criterion, assure a non-declining population 50 percent of the time, and double the spawning count 50 percent of the time, even in the absence of harvest or habitat actions. The actions that cannot meet these criteria are the alternatives that involve fixed drawdowns on the Snake reservoirs without any transportation (actions 09,10, 11, and 13), others that do not transport fish (actions 02,04, and 06), and the spill proposal (action 15). These all result in survivals significantly lower than the base case. Passage alternatives 05,07,08,12,14, and 16 can by themselves produce the 3 percent increase over base survival needed to attain a non-declining population 90 percent of the time (Table 6), as can the harvest reduction alternatives HR and HX.

[34]This section considers the effects of actions in isolation from one another. The sixteen passage actions are mutually exclusive and the four harvest actions are mutually exclusive. However, since we can combine passage actions with harvest actions, we can generate 64 passage/harvest strategies (16 times 4). Section 8 looks at the effects of these 64 strategies.

Table 6
Survival Effects of Actions
(proportion of base case survival)[a]

Action Number	Action Description	Spring Chinook Effect	Summer Chinook Effect	Fall Chinook Effect
1	SOR la with transport	1.00	1.00	1.00
2	SOR la without transport	0.63	0.76	0.23
3	SOR 2c with transport (Base Case)	1.00	1.00	1.00
4	SOR 2c without transport	0.63	0.76	0.23
5	SOR 3b with transport	1.03	1.02	1.04
6	SOR 3b without transport	0.68	0.73	0.25
7	SOR 5a without transport	1.18	1.24	0.71
8	SOR 5b without transport	1.20	1.24	0.75
9	SOR 6a without transport	0.69	0.75	0.19
10	SOR 6b without transport	0.69	0.75	0.20
11	SOR 6c, no LGR transport	0.78	0.77	0.51
12	SOR 6c w/ LGR transport	1.05	1.05	1.06
13	SOR 6d, no LGR transport	0.79	0.78	0.52
14	SOR 6d with LGR transport	1.05	1.05	1.09
15	SOR 7a with transport	0.88	0.90	0.62
16	Upstream collector, transport	1.23	1.23	1.95
HC	Base Case Harvest (1987-92)	1.00	1.00	1.00
HO	No non-treaty US Ocean Commercial	1.02	1.02	1.21
HR	No non-treaty In-River Commercial	1.03	1.00	1.29
HX	No non-treaty US commercial Harvest	1.05	1.02	1.57

a The base case uses SOR alternative 2c and base case harvest (1987- 1992 average).

According to CRiSP simulation results for summer chinook, actions 07,08 and 16 are the only passage measures we consider that by themselves can meet the persistence criterion and the survival increases that would be necessary to assure a non-declining population for 90 percent of the time or to at least double the initial population size 50 percent of the time (Table 6). None of the remaining passage actions meet any of the criteria. Moreover, none of the harvest reduction alternatives meet any of the criteria.

CRiSP simulation results also indicate that, of the 16 passage actions, only action 16 can by itself come close to meeting our persistence and spawning abundance criteria for fall chinook. This is the case largely because the passage alternatives are designed to increase downstream survival of juveniles primarily during the spring (before fall chinook juveniles have begun migrating). Similarly, although the high harvest rates for Snake River fall chinook mean commercial harvest restrictions are particularly effective, only the simultaneous restriction of both ocean and in-river harvest meets all of the fall chinook biological criteria, unless passage actions beyond the base case are implemented.

8. COST-EFFECTIVENESS ANALYSIS

In this section, we analyze some of the numerical survival effects and financial costs of recovery strategies. The available information suggests that some strategies are more likely to be cost effective than others. We discuss this in some detail in this section, by focusing on the subset of recovery strategies which appear to increase survival for all three listed chinook stocks. It is important to note, however, that we do not attempt to use the cost-effectiveness analysis to determine the single "best" strategy for Snake River chinook stocks. We avoid such an approach for two reasons. First, as noted earlier, other attributes of recovery strategies (e.g., institutional change or restorative nature) may be important considerations in the choice of recovery strategies. Second, the quality of the numerical data on both effects and costs is uncertain. At the very least, the data do not support selecting one strategy to the exclusion of research or testing of other strategies. We touch on some of the uncertainty of the numerical data in this section, but defer further discussion of it until section 10.

8.1 Passage and Harvest Strategies

As shown in previous tables, we have delineated 16 passage actions and 4 harvest actions. Since the passage actions are mutually exclusive and the harvest actions are mutually exclusive, the combination of passage and harvest yields 64 different recovery strategies (16 times 4). The total cost for a strategy is simply the sum of the passage cost and harvest cost, while the total survival effect is the product of the passage and harvest effects. In Figures 4 through 6, we display the annualized costs and survival effects for all strategies and stocks. As the figures show, the costs and effectiveness of the strategies vary widely; some yield significant survival improvements, but nearly two thirds of the strategies exhibit a decrease in survival relative to the base case. Therefore, in the discussion, we concentrate our analysis on the 22 strategies that our modeling indicates increase survival. We assume that regional decision-makers will not recommend a strategy that would decrease survival relative to the base case for any of the stocks.

Table 7 displays cost and survival information for the 22 strategies which appear to increase survival for all three stocks. In the table, we report two sets of costs -- low-cost purchased power and high harvest costs on the one hand, and high-cost combustion turbines with low harvest costs on the other hand.[35] These two combinations should yield total cost rankings that differ more than any other combination of power and harvest costs. However, as the table shows, the rankings of the strategies according to total costs (with one being highest cost and 22 being lowest cost) do not differ greatly between the two sets of costs.[36] Therefore, we discuss only one of the cost measures (low-cost purchased power and high harvest costs).

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[35] See Appendix A for details of the cost calculations.

[36] The minor differences between rankings result from the fact that although the base case has a cost of zero (by definition), passage action 01 (SOR altemative la) has a much lower (negative) cost for the low power cost assumption than for the high power cost assumption. Note that the difference between the two assumptions in the ranks that they yield hold for strategies with passage action 01, even though the cost rankings for passage action 01 itself are identical under the two assumptions, as shown in Table 3.

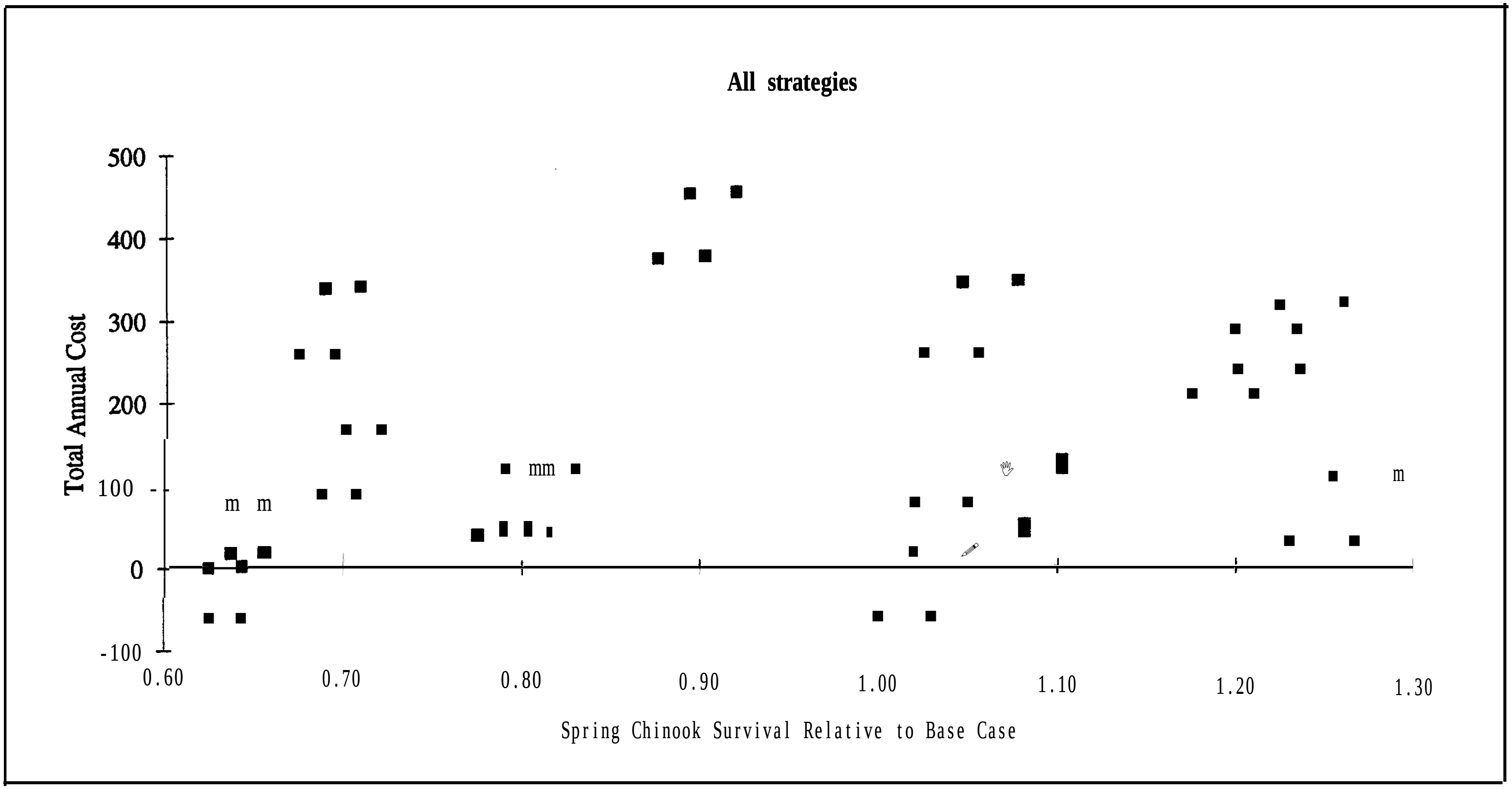

Figure 4. Costs and Survival Effects for 64 Passage/Harvest Strategies, Spring Chinook. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Negative Costs indicate savings relative to base case. Survival Change less than 1 indicates a decrease in survival relative to base case.

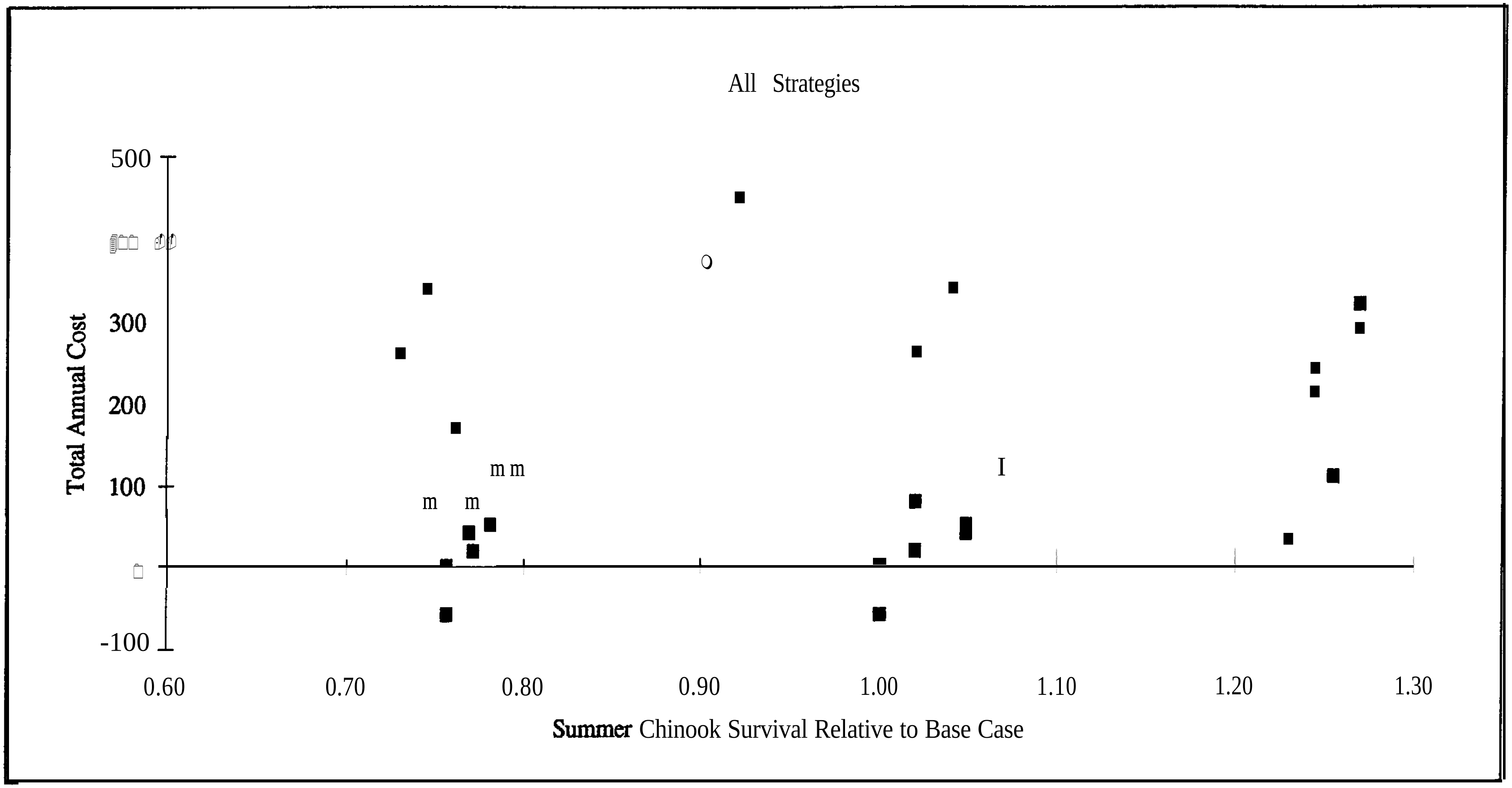

Figure 5. Costs and Survival Effects for 64 Passage/Harvest Strategies, Summer Chinook. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Negative Costs indicate savings relative to base case. Survival Change less than 1 indicates a decrease in survival relative to base case.

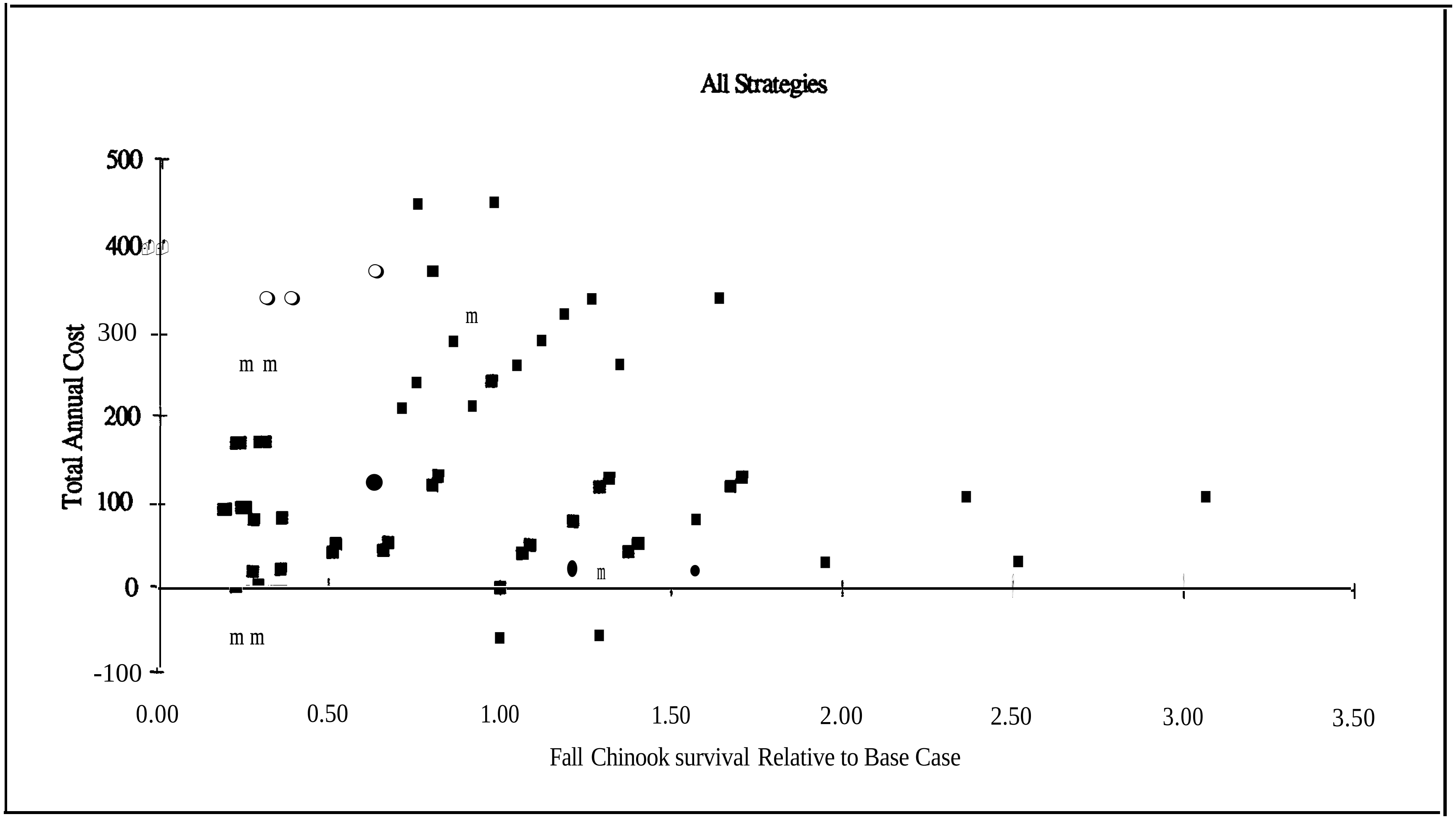

Figure 6. Costs and Survival Effects for 64 Passage/Harvest Strategies, Fall Chinook. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Negative Costs indicate savings relative to base case. Survival Change less than 1 indicates a decrease in survival relative to base case.

Table 7
Cost and Effectiveness of Strategies
Having Increased Survival over the Base Case

No.	Downstream Action	Harvest Action[a]	High Harvest/ LOW Power Cost[b]	cost Rank	Low Harvest/ High Power Cost[b]	cost Rank	Spring Chinook Effect[c]	Summer Chinook Effect[c]	Fall Chinook Effect[c]
1	SOR la with transport	No Harvest	20	21	-120	21	1.05	1.02	1.57
1	SOR la with transport	No Ocean	20	21	-120	21	1.02	1.02	1.21
3	SOR 2c with transport (Base Case)	No Harvest	80	13	40	17	1.05	1.02	1.57
3	SOR 2c with transport (Base case)	No Ocean	80	13	40	17	1.02	1.02	1.21
5	SOR 3b with transport	Base	260	5	380	5	1.03	1.02	1.04
5	SOR 3b with transport	No Harvest	340	1	420	3	1.08	1.04	1.63
5	SOR 3b with transport	No In-River	260	5	380	5	1.06	1.02	1.34
5	SOR 3b with transport	No Ocean	340	1	420	3	1.05	1.04	1.26
7	SOR 5a without transport	No Harvest	290	4	440	1	1.23	1.27	1.11
8	SOR 5b without transport	No Harvest	320	3	440	1	1.26	1.27	1.18
12	SOR 6c with LGR transport	Base	40	17	140	13	1.05	1.05	1.06
12	SOR 6c with LGR transport	No Harvest	120	9	180	9	1.10	1.07	1.67
12	SOR 6c with LGR transport	No In-River	40	17	140	13	1.08	1.05	1.37
12	SOR 6c with LGR transport	No Ocean	120	9	170	10	1.07	1.07	1.29
14	SOR 6d with LGR transport	Base	50	15	150	11	1.05	1.05	1.09
14	SOR 6d with LGR transport	No Harvest	130	7	190	7	1.10	1.07	1.70
14	SOR 6d with LGR transport	No In-River	50	15	150	11	1.08	1.05	1.40
14	SOR 6d with LGR transport	No Ocean	130	7	190	7	1.07	1.07	1.31
16	Upstream collector, transport	Base	30	19	40	17	1.23	1.23	1.95
16	Upstream collector, transport	No Harvest	110	11	80	15	1.29	1.25	3.06
16	Upstream collector, transport	No In-River	30	19	40	17	1.27	1.23	2.52
16	Upstream collector, transport	No Ocean	110	11	80	15	1.25	1.25	2.36

Notes:

a. Harvest regimes are base case (1987-92), no U. S. non-Treaty commercial ocean, no non-Treaty commercial in-river, and no U. S. non-Treaty commercial chinook fisheries.

b. Cost in Millions per year, relative to SOR alternative 2c and base case (1987-92) harvest.

c. Effects are changes in survival relative to base case (SOR alternative 2c and 1987-92 harvest).

Table 7 presents several noteworthy items. First, no strategy in the table contains drawdown actions without transportation. This occurs because all of the drawdown actions substantially decrease survival relative to the base case according to the CRiSP model results, especially for fall chinook[37] Although the projected decrease in downstream survival can be compensated for to some degree by an increase in survival due to harvest reductions, the compensation is not sufficient to give a net increase in survival above the base case for all three stocks. Second, only four strategies in Table 7 include base-case harvest. Two of the four base-case harvest strategies use Lower Granite drawdown with transportation at Lower Granite, one uses flow augmentation with transportation (SOR strategy 3b), and one uses the upstream collector and transportation. All of the other strategies that increase survival for all stocks include non-Treaty commercial harvest restrictions. This suggests that most passage actions may require harvest restrictions to increase survival. Third, of the 22 strategies that do increase survival for all stocks, only two meet the more stringent criteria for the biological objectives that are summarized in Table 5 in section 7.1. Figures 7 through 9 display cost and effectiveness information for the 22 strategies with survival greater than the base case.

Looking at the relative costs and biological effectiveness of the strategies, there is not a simple relationship between cost and survival. For spring chinook the most effective strategy costs approximately 60 percent less than the most costly strategy, and is about 25 percent more effective. A similar though less pronounced relationship also prevails for summer chinook, where the most effective strategy costs roughly 20 percent less than the most costly strategy, and is about 20 percent more effective. For fall chinook, the relationship is even more remarkable: the most effective strategy costs about 60 percent less than the most costly strategy, and is about 250 percent more effective. These results would be even more striking if the high-power-cost

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[37]The reader should keep in mind that the ability of the CRiSP passage model to predict the effects of conditions so far removed from current operations is **limited** at best. Therefore, all of the following points should he regarded as hypotheses rather than strong conclusions. This particularly applies with respect to drawdown and the natural river option, since these passage measures involve hydrosystem operations far removed from current and recent practices.

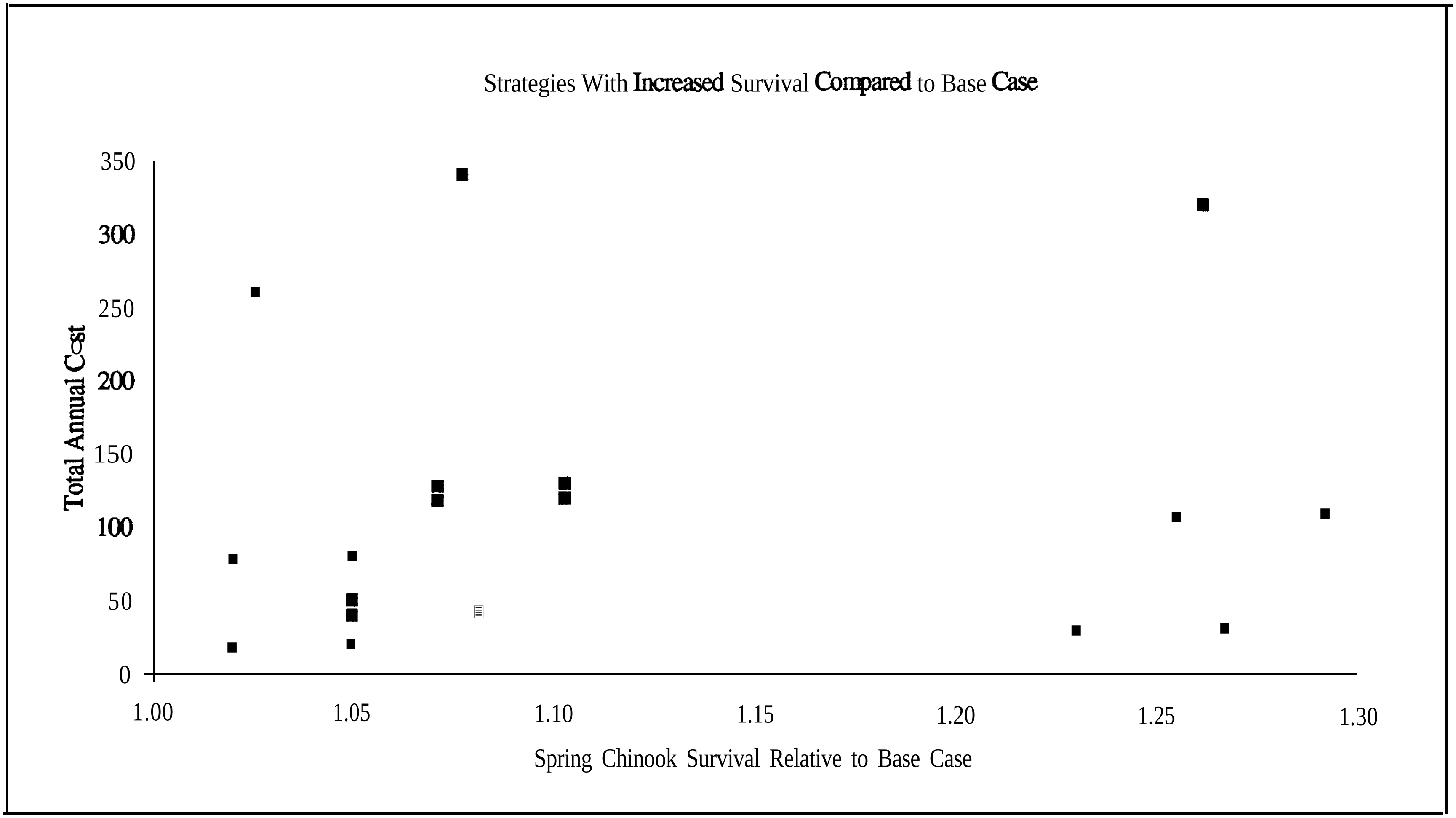

Figure 7. Costs and Survival Effects for 22 Passage/Harvest Strategies, Spring Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest.

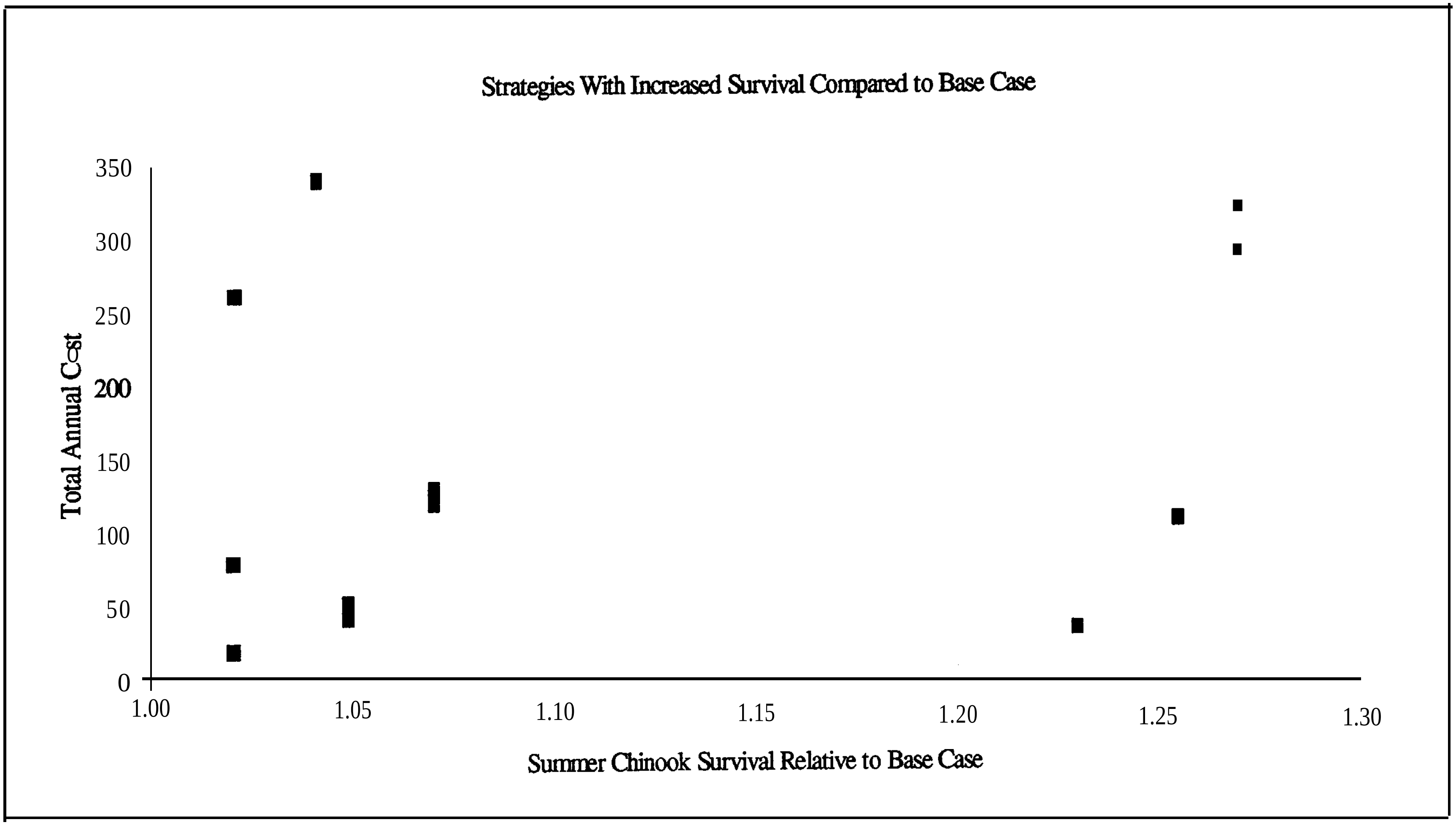

Figure 8. Costs and Survival Effects for 22 Passage/Harvest Strategies, Summer Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest.

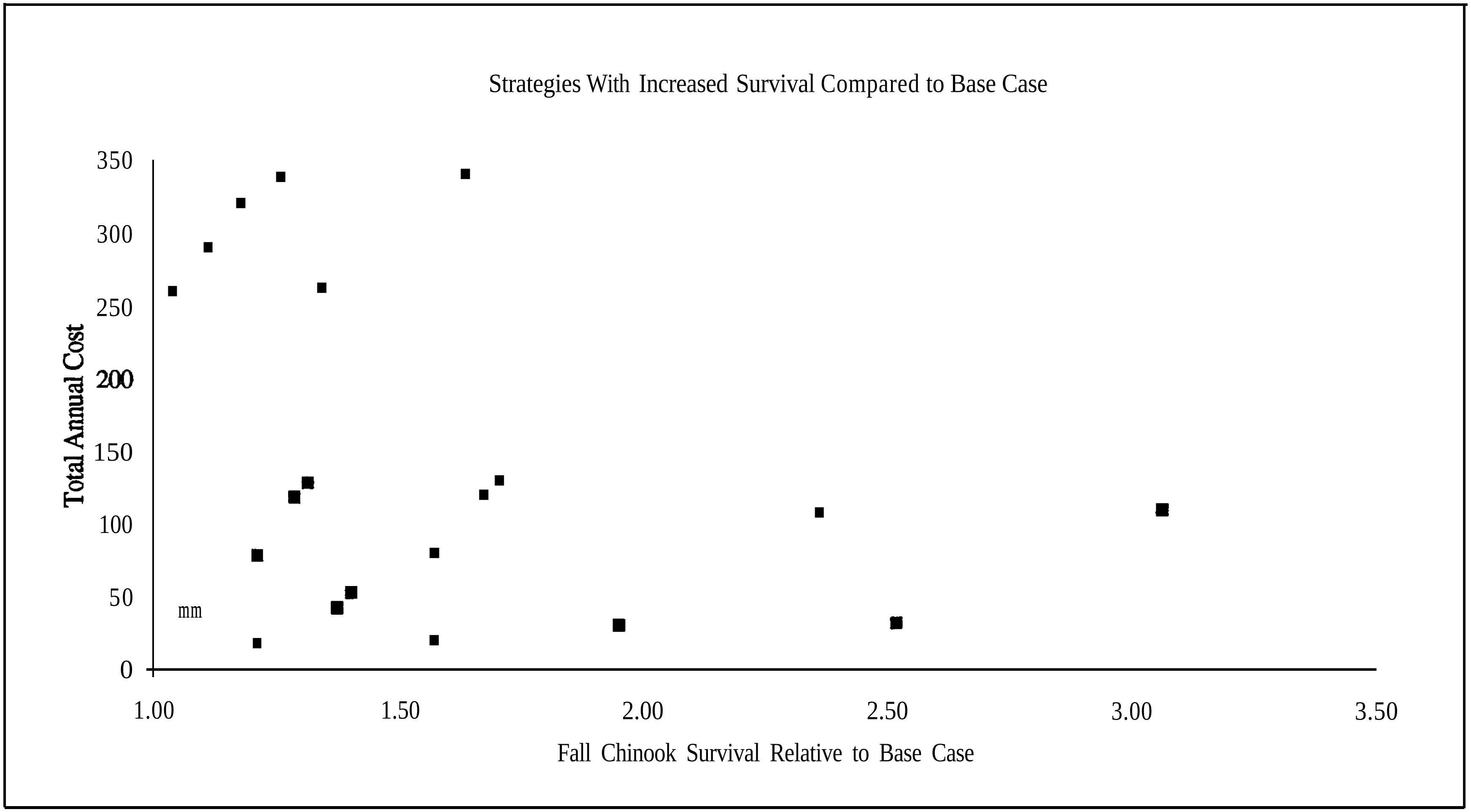

Figure 9. Costs and Survival Effects for 22 Passage/Harvest Strategies, Fall Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest.

scenario actually prevails in practice. While the cautions on data reliability and other attributes obviously still apply, it is clear that greater expenditures do not necessarily translate into increased survival.

8.2 Passage and Harvest Actions

Figures 10 through 12 break out the different harvest regimes for the three stocks. As might be expected, strategies that eliminate all non-Treaty U. S. commercial harvest show the greatest increase in survival. For spring and summer chinook, the harvest action that increases survival the most elevates survival by about 5 percent over the base case. The passage action that increases survival the most augments passage survival by about 20 percent. Together, the harvest and passage actions increase survival over 25 percent. For fall chinook, harvest reductions have a far larger effect. The harvest reduction that yields the largest survival increase boosts survival by about 60 percent. The passage that improves survival the most increases survival by about 90 percent. When applied in combination, the two yield a survival increase of over 200 percent. As noted in section 7.2, complete elimination of non-Treaty U. S. ocean and in-river commercial harvest would be required to meet the survival change goals in Table 5 if passage survival does not change. Conversely, if harvest continues at the rates used in the base case, the upstream collector is the only passage strategy that will meet the survival goals for all stocks.

Figures 13 through 15 show the differences among strategies that employ drawdown and the natural river option. For spring chinook, strategies with drawdown are considerably less effective than strategies with the natural river option, and these in turn are less effective than non-drawdown strategies. For summer chinook, strategies with the natural river drawdown are somewhat more effective than the next-best strategies, which include the upstream collector. The strategies with drawdown actions are substantially less effective than strategies with either natural river or non-drawdown (i.e., upstream collector) actions. In contrast, for fall chinook the strategies with natural river actions are less effective than those with drawdown. Strategies with

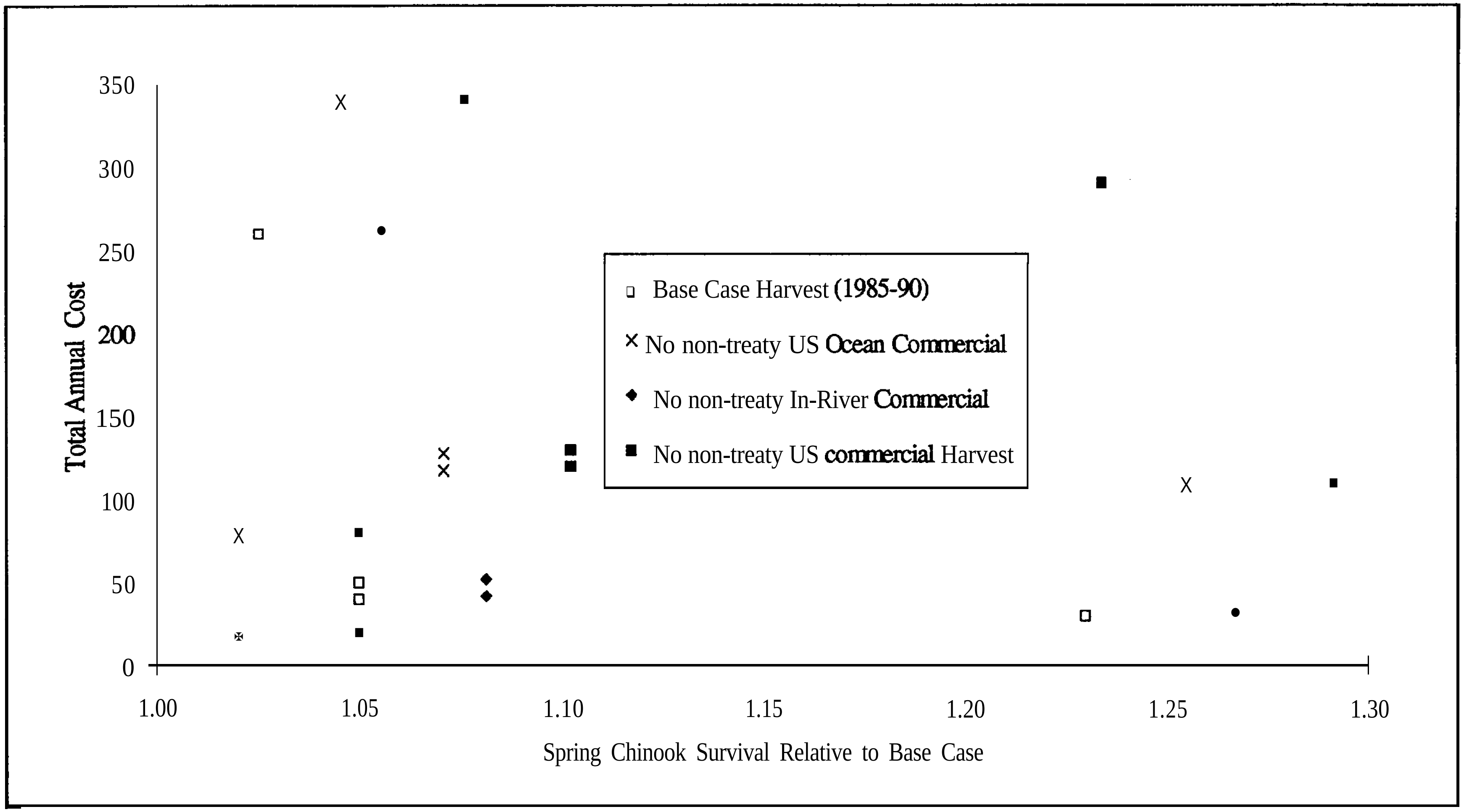

Figure 10. Costs and Survival Effects for 22 Passage/Harvest Strategies, Spring Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by harvest action.

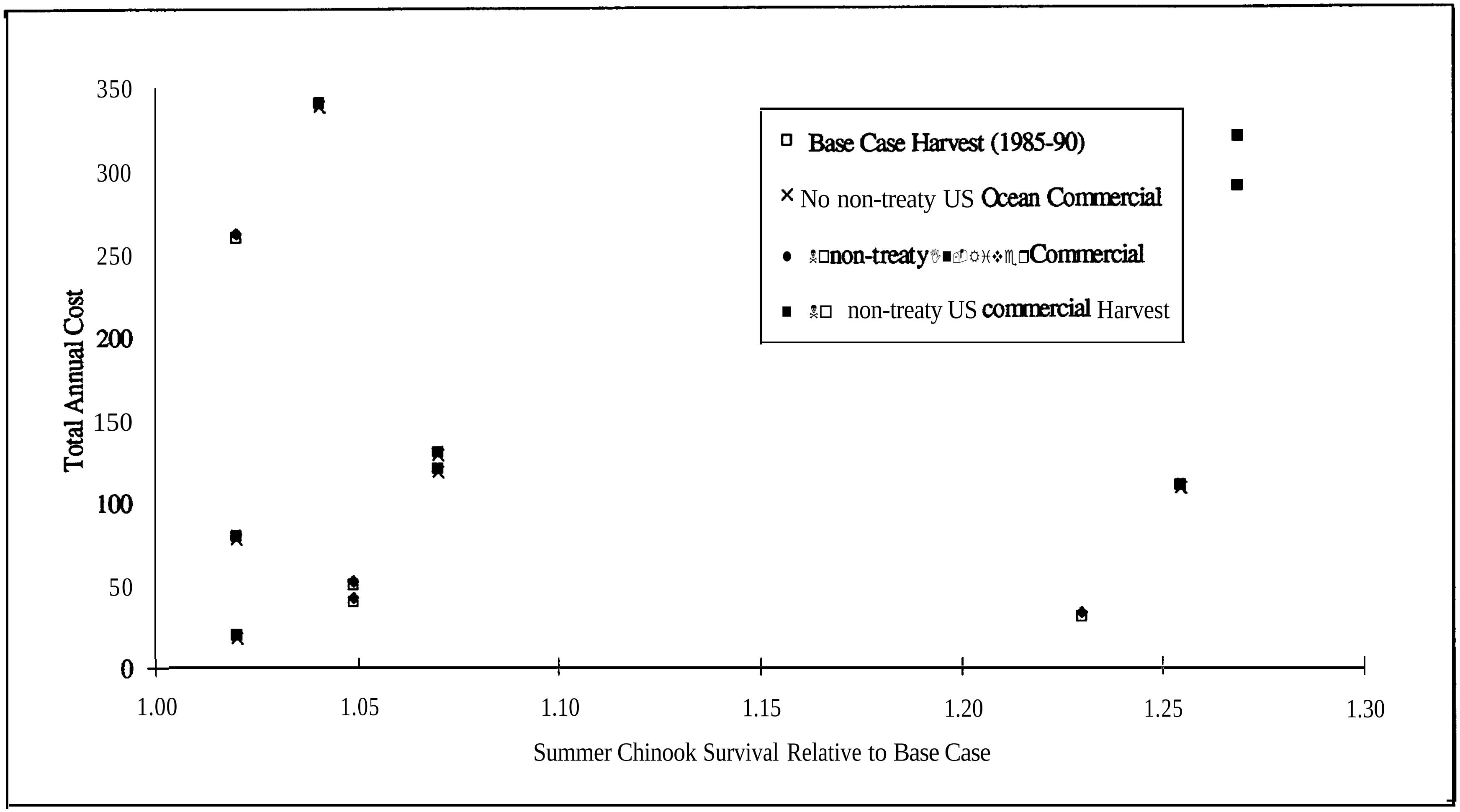

Figure 11. Costs and Survival Effects for 22 Passage/Harvest Strategies, Summer Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by harvest action.

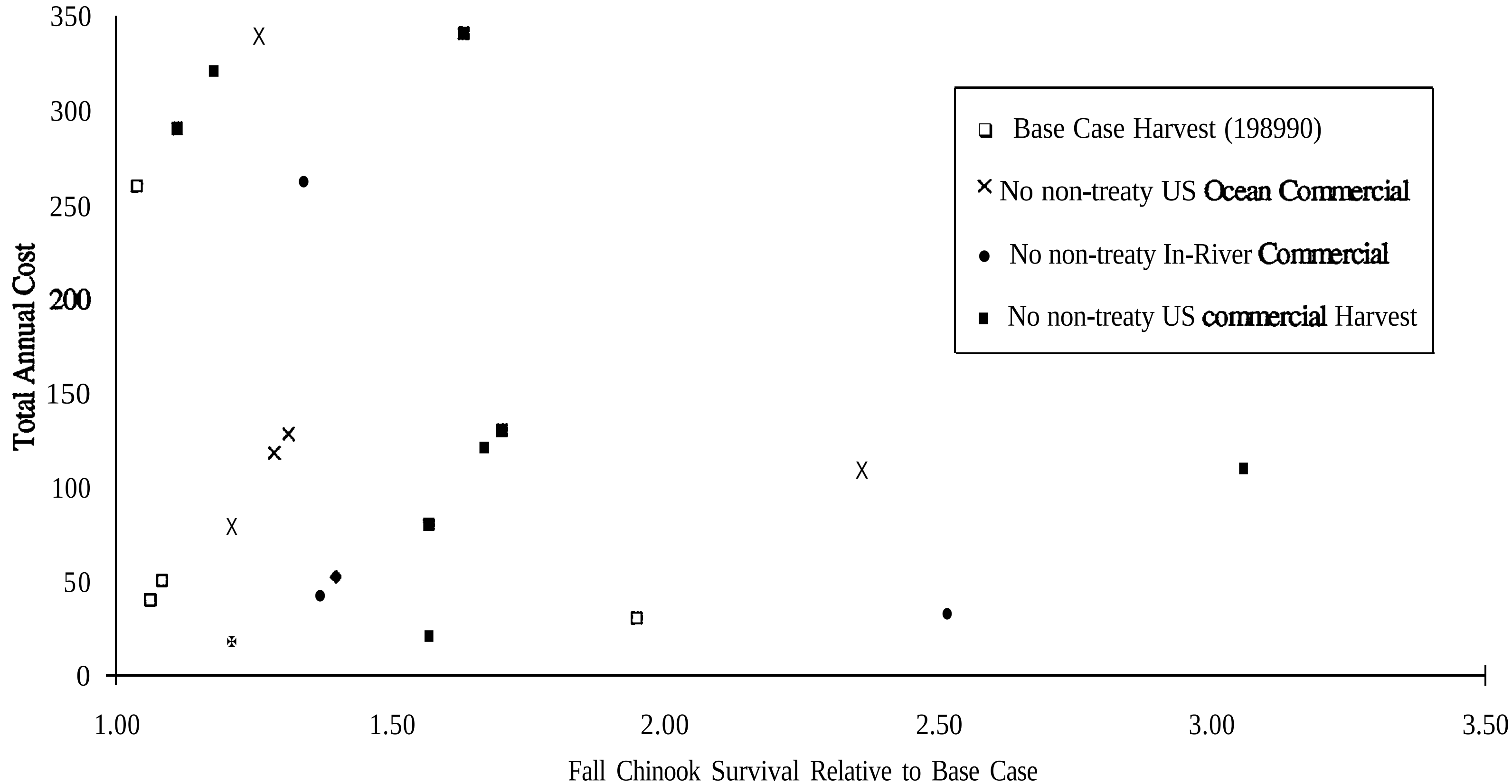

Figure 12. Costs and Survival Effects for 22 Passage/Harvest Strategies, Fall Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millioris per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by harvest action.

drawdown, in turn, are less effective than the best of the non-drawdown strategies, specifically those that contain the upstream collector.

In selecting the 22 alternatives discussed above, we used a simple criterion: projected survival for all three stocks should equal or exceed survival in the base case. If instead we had chosen the most stringent criteria in Table 5 (survival 3 percent greater than the base case for spring chinook, 25 percent greater for summer chinook, and 45 percent greater for fall chinook) only two strategies meet these criteria for all three stocks. Both use the upstream collector (passage action 16); one allows no U. S. non-Treaty commercial harvest, while the other restricts non-Treaty commercial ocean harvest and leaves commercial in-river harvest at base case levels.

8.3 Habitat Enhancement

We omit habitat enhancement from our cost-effectiveness analysis for two reasons. First, although substantial amounts of data have been collected and incorporated into the CRiSP and chinook harvest models used to evaluate the passage and harvest actions, quantitative relationships between habitat management actions and Snake River chinook survival (e.g., egg-to-smolt survival rates) are lacking. Estimates of the effectiveness of habitat actions tend to be undocumented. While much uncertainty also surrounds model estimates of some passage actions such as drawdown, at least the assumptions behind these model estimates are documented. We believe this places habitat enhancement in a different category than passage and harvest actions. Second, the estimates of the effectiveness of habitat enhancement for the listed stocks do not lend themselves to a cost-effectiveness analysis. In section 7 we alluded to estimates for the Snake Basin in total, but we cannot at this time identify a specific package of actions associated with these estimates. While the subbasin plans sponsored by the Northwest Power Planning Council (Columbia Basin Fish and Wildlife Authority, 1990) contain estimates of the effects of specific and localized habitat actions, we think it unwise to put these actions together into what we judge is an appropriate habitat package for the listed stocks. Thus, although we have cost and effectiveness estimates for localized actions and effectiveness estimates for total habitat

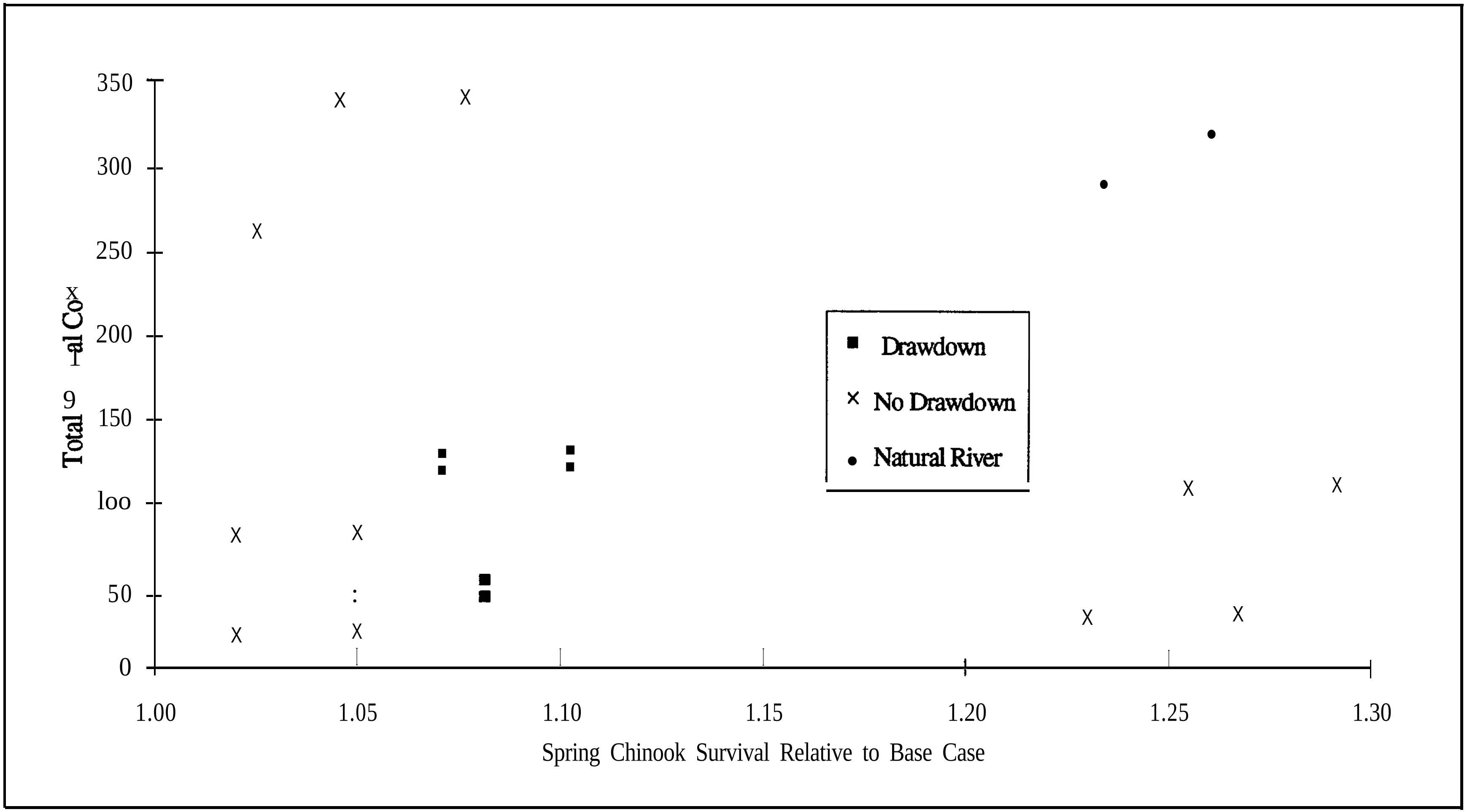

Figure 13. Costs and Survival Effects for 22 Passage/Harvest Strategies, Spring Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by passage action.

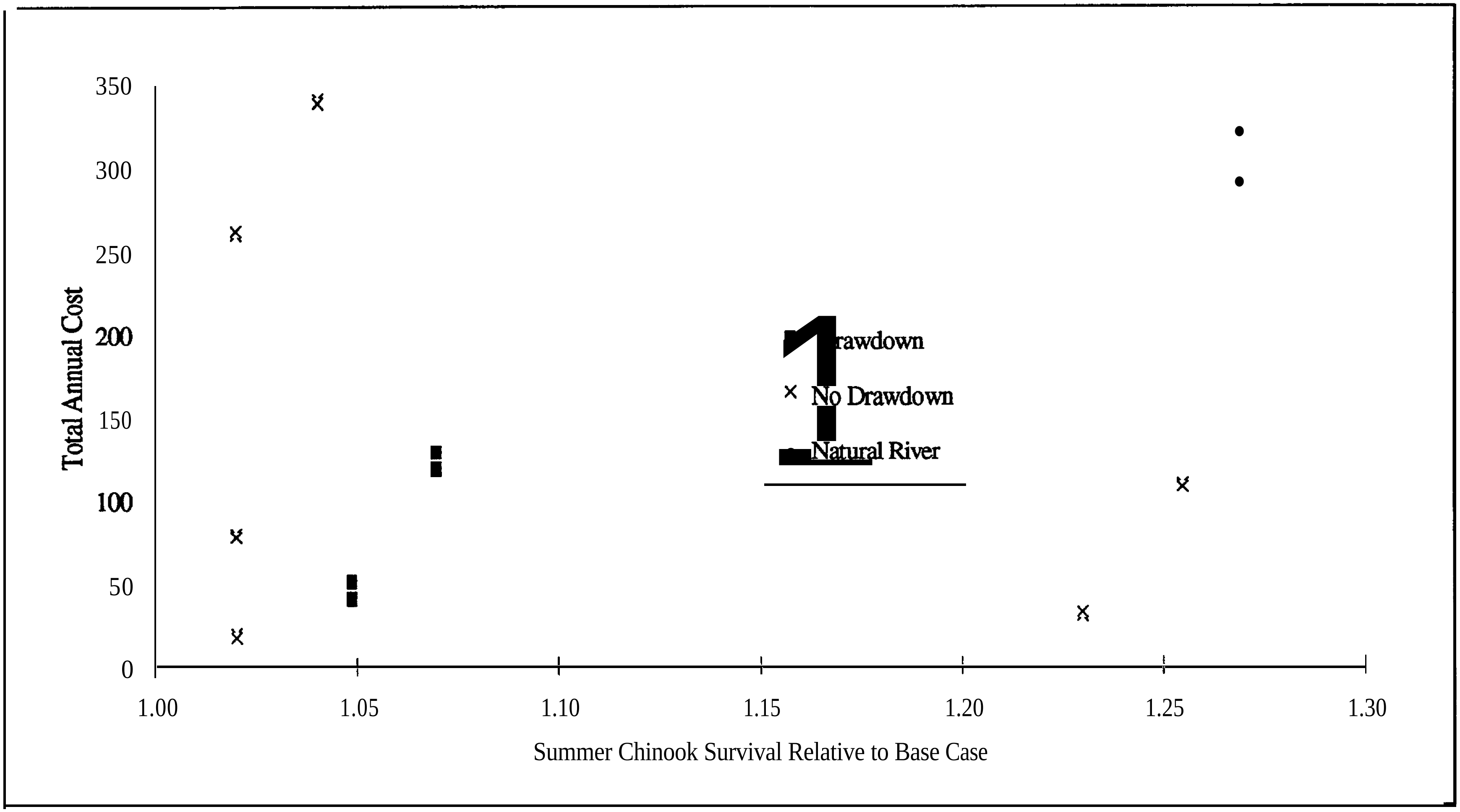

Figure 14. Costs and Survival Effects for 22 Passage/Harvest Strategies, Summer Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by passage action.

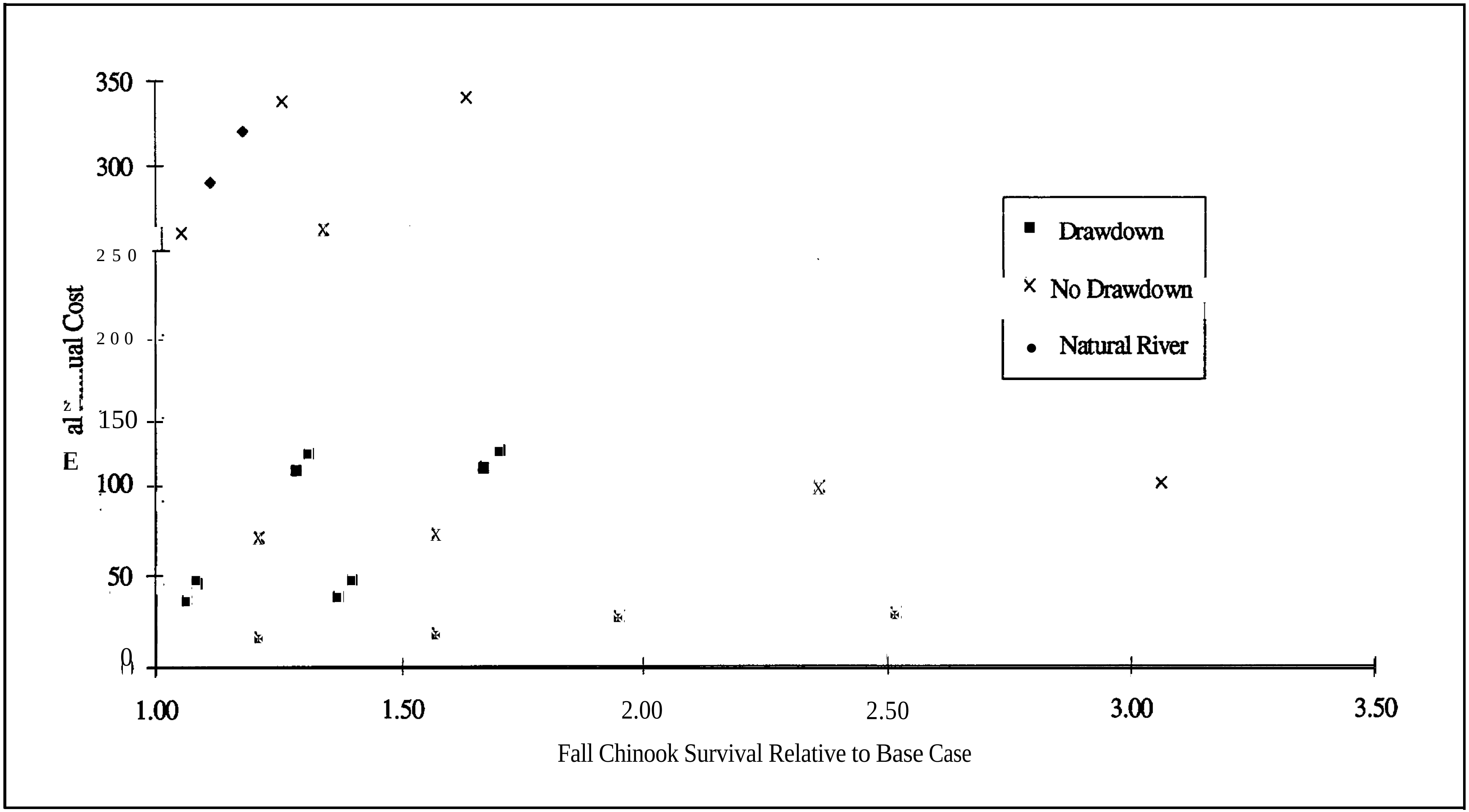

Figure 15. Costs and Survival Effects for 22 Passage/Harvest Strategies, Fall Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies Are Classified By Passage Action.

enhancement, we can not link these two sets of estimates in a defensible way. Therefore, we do not include habitat enhancement actions in our cost-effectiveness analysis.

9. MULTI-ATTRIBUTE COMPARISON OF STRATEGIES

In this section, we compare the recovery strategies across four attributes: cost, survival effects, restorative nature, and construction lead time. As in Section 8, the discussion concentrates on the 22 strategies that increase survival for all three stocks, relative to the base case. Table 8 shows the costs, survival effects, restorative, and construction time attributes for each of the 22 strategies, and figures 16 through 21 display these data, classified by the restorative and construction time attributes.

Figures 16- 18 display a breakdown of the 22 strategies using three classes of the restorative attribute: more-restorative, less-restorative, and mixed (a combination of more- and less-restorative). The relationship of this attribute to cost and survival for each of the three stocks varies considerably. For spring chinook (Figure 16), the less-restorative strategies tend to appear in the lower right in the graph. This is of particular interest since the lower right quadrant contains those strategies that are inexpensive and effective in increasing survival, relative to the other strategies.[38] Mixed strategies cluster in the left half of the graph, with effectiveness ranging from roughly 1.0 to 1.1, and widely varying costs. The more-restorative strategies tend to be either relatively inexpensive and only moderately effective, or nearly as effective as less-restorative strategies but quite costly.

In contrast, for summer chinook (Figure 17) the less-restorative strategies are not necessarily the most effective.[39] For example, of the four strategies with survival greater than 1.10, the less-restorative strategies are somewhat less effective than the two more-restorative strategies. However, although the more-restorative strategies are somewhat more effective at

[38] The caveats mentioned earlier regarding effectiveness obviously apply here as well, especially for the strategies with drawdown and natural river actions.

[39] Because the strategies' differences in effectiveness is often quite low for summer chinook, several points on the graph overlap one another.

Table 8
Multi-Attribute Comparison of Strategies

No.	Downstream Action	Harvest Action[a]	Cost[b]	Spring Chinook Effect[c]	Summer Chinook Effect[c]	Fall Chinook Effect[c]	Restorative Classification[d]	Const. Time (Yrs)
1	SOR la with transport	No Harvest	20	1.05	1.02	1.57	Mixed	2-9
1	SOR la with transport	No Ocean	18	1.02	1.02	1.21	Mixed	2-9
3	SOR 2c with transport (Base Case)	No Harvest	80	1.05	1.02	1.57	Mixed	2-9
3	SOR 2c with transport (Base Case)	No Ocean	78	1.02	1.02	1.21	Mixed	2-i
5	SOR 3b with transport	Base	260	1.03	1.02	1.04	Less	o-1
5	SOR 3b with transport	No Harvest	340	1.08	1.04	1.63	Mixed	2-9
5	SOR 3b with transport	No In-River	262	1.06	1.02	1.34	Mixed	2-9
5	SOR 3b with transport	No Ocean	338	1.05	1.04	1.26	Mixed	2-9
7	SOR 5a without transport	No Harvest	290	1.23	1.27	1.11	More	10-20
8	SOR 5b without transport	No Harvest	320	1.26	1.27	1.18	More	10-20
12	SOR 6c w/ LGR transport	Base	40	1.05	1.05	1.06	Mixed	10-20
12	SOR 6c w/ LGR transport	No Harvest	120	1.10	1.07	1.67	More	10-20
12	SOR 6c w/ LGR transport	No In-River	42	1.08	1.05	1.37	More	1 O-20
12	SOR 6c w/ LGR transport	No Ocean	118	1.07	1.07	1.29	More	10-20
14	SOR 6d with LGR transport	Base	50	1.05	1.05	1.09	Mixed	10-20
14	SOR 6d with LGR transport	No Harvest	130	1.10	1.07	1.70	More	10-20
14	SOR 6d with LGR transport	No In-River	52	1.08	1.05	1.40	More	10-20
14	SOR 6d with LGR transport	No Ocean	128	1.07	1.07	1.31	More	10-20
16	Upstream collector, transport	Base	30	1.23	1.23	1.95	Less	2-9
16	Upstream collector, transport	No Harvest	110	1.29	1.25	3.06	Less	2-9
16	Upstream collector, transport	No In-River	32	1.27	1.23	2.52	Less	2-9
16	Upstream collector, transport	No Ocean	108	1.25	1.25	2.36	Less	2-9

Notes:

a. Harvest regimes are base case (1987-92), no US non-Treaty ocean, no non-Treaty in-river, and no US non-Treaty chinook fisheries.

b. Cost in Millions per year, relative to SOR alternative 2c and base case (1987-92) harvest. Costs estimated using high harvest-low purchased power scenario.

c. Effects are changes in survival relative to base case (SOR alternative 2c and 1987-92 harvest).

d. Restorative classification is relative to base case.

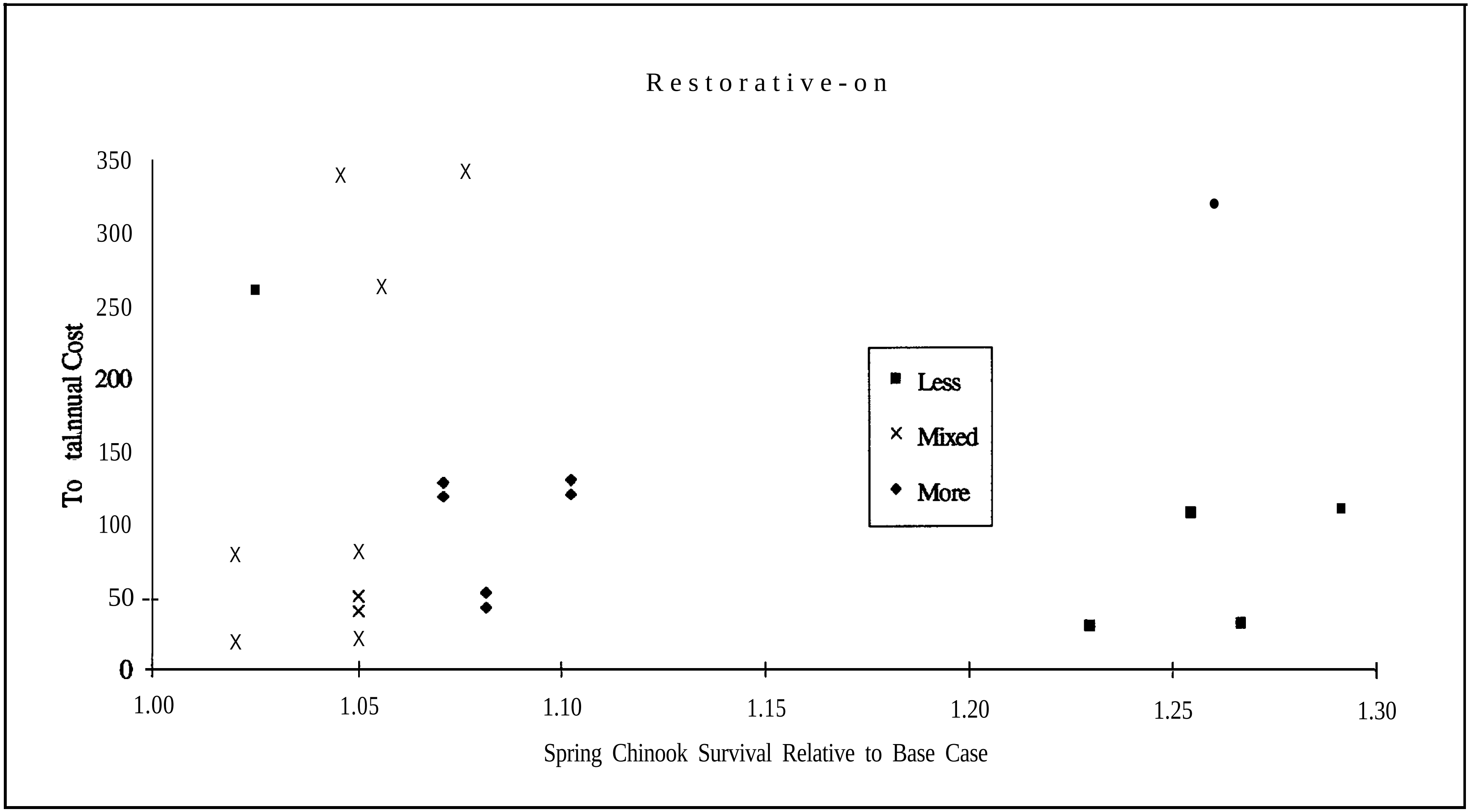

Figure 16. Costs and Survival Effects for 22 Passage/Harvest Strategies, Spring Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by restorative attribute.

Figure 17. Costs and Survival Effects for 22 Passage/Harvest Strategies, Summer Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by restorative attribute.

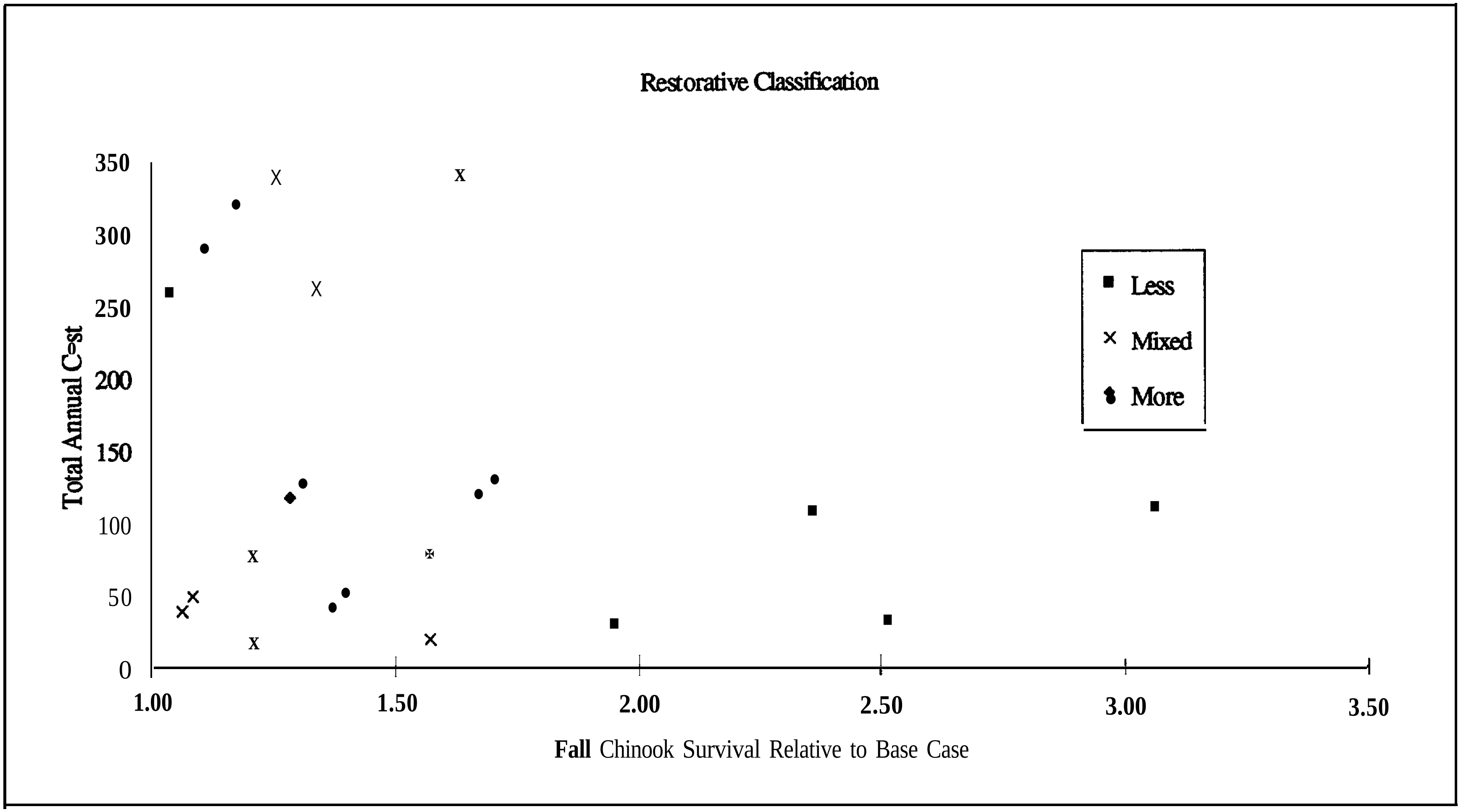

Figure 18. Costs and Survival Effects for 22 Passage/Harvest Strategies, Fall Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by restorative attribute.

high survival levels (and far more expensive) and equally effective at some of the lower levels, from survivals above 1.05 to survivals of about 1.23, the more-restorative strategies appear to be dominated by other strategies. Mixed strategies tend to be more expensive and less effective than do either of the other classes, except at very low survival increases.

Fall chinook, as seen in Figure 18, differ from both the spring and summer stocks. The less-restorative strategies provide the only survival increases greater than about 1.7. With one exception, the more-restorative strategies both cost more and provide less survival enhancement than the less-restorative ones. The mixed strategies are the most cost-effective up to a survival of about 1.6.

Figures 19-21 display a breakdown of the 22 strategies using three classes of the construction lead time: 0 to 1 years, 2 to 9 years, and 10 to 20 years. The construction lead time for the strategies is simply the maximum of the lead-times for the actions that compose the strategies. Perhaps the most striking aspect of this attribute is that only one of the 22 strategies has a lead time of O-l years (i.e., SOR 3b with base case harvest), and this yields only a modest survival improvement. Strategies with lead times from 2 to 9 years frequently provide relatively high survival increments at relatively low cost. These strategies generally dominate strategies with long construction lead times at most effectiveness levels, for spring and fall chinook stocks. In general, the construction lead-time closely parallels the restorative attribute, since the more-restorative measures, particularly drawdown and the natural river actions, have l0-20 year lead times, based on Corps of Engineers (1992a) estimates.

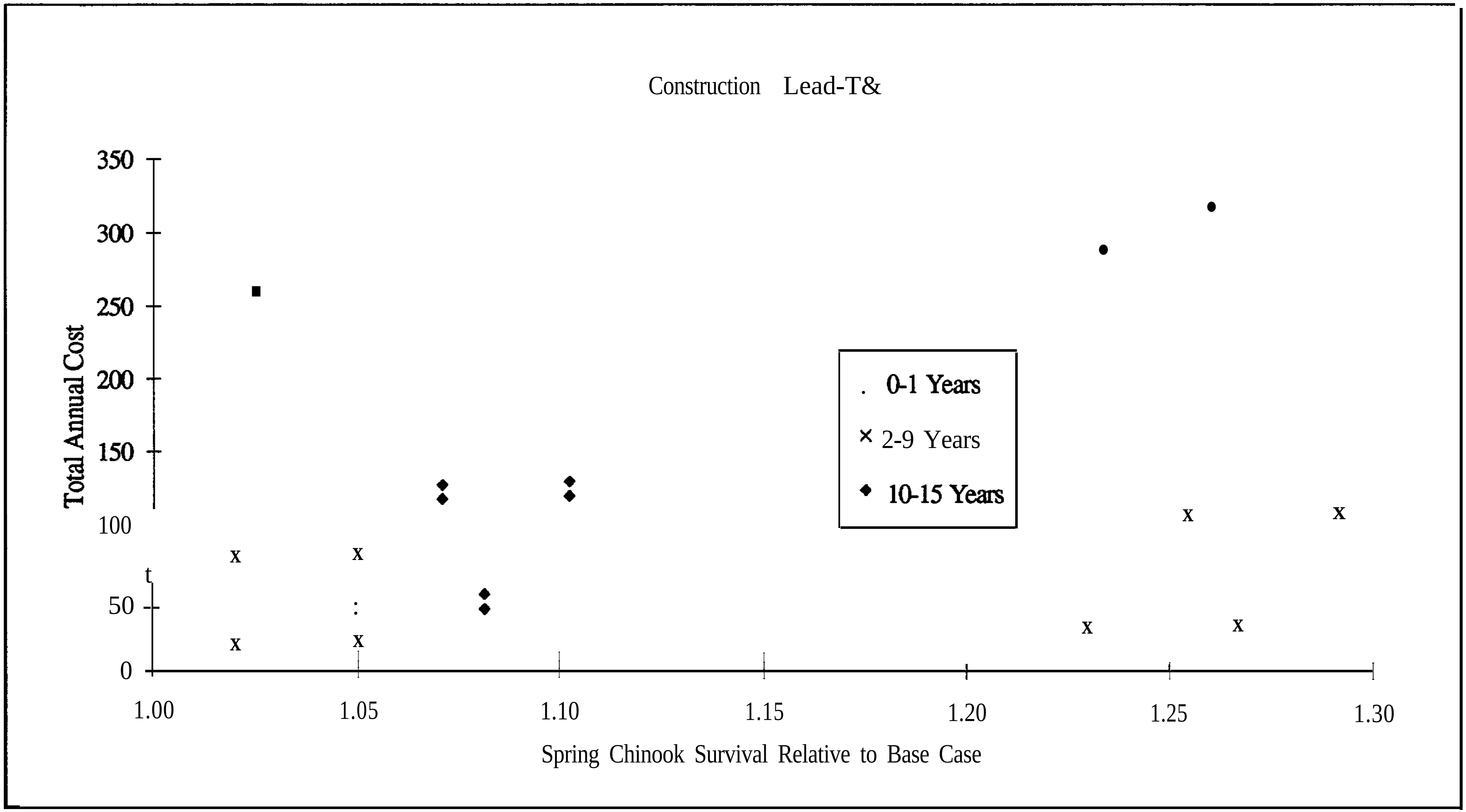

Figure 19 Costs and Survival Effects for 22 Passage/Harvest Strategies, Spring Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by Construction Time attribute.

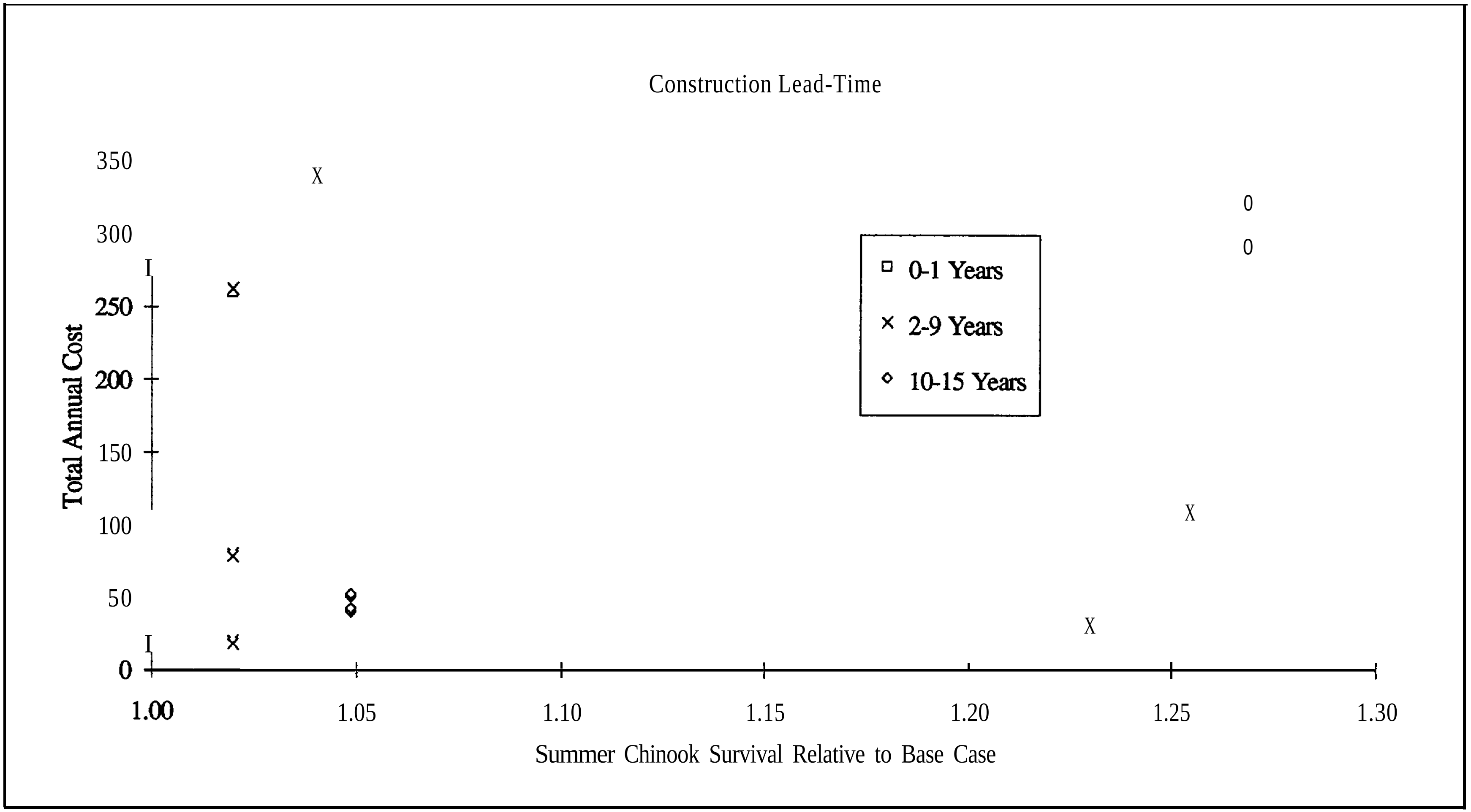

Figure 20 Costs and Survival Effects for 22 Passage/Harvest Strategies, Summer Chinook. Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by Construction Time attribute.

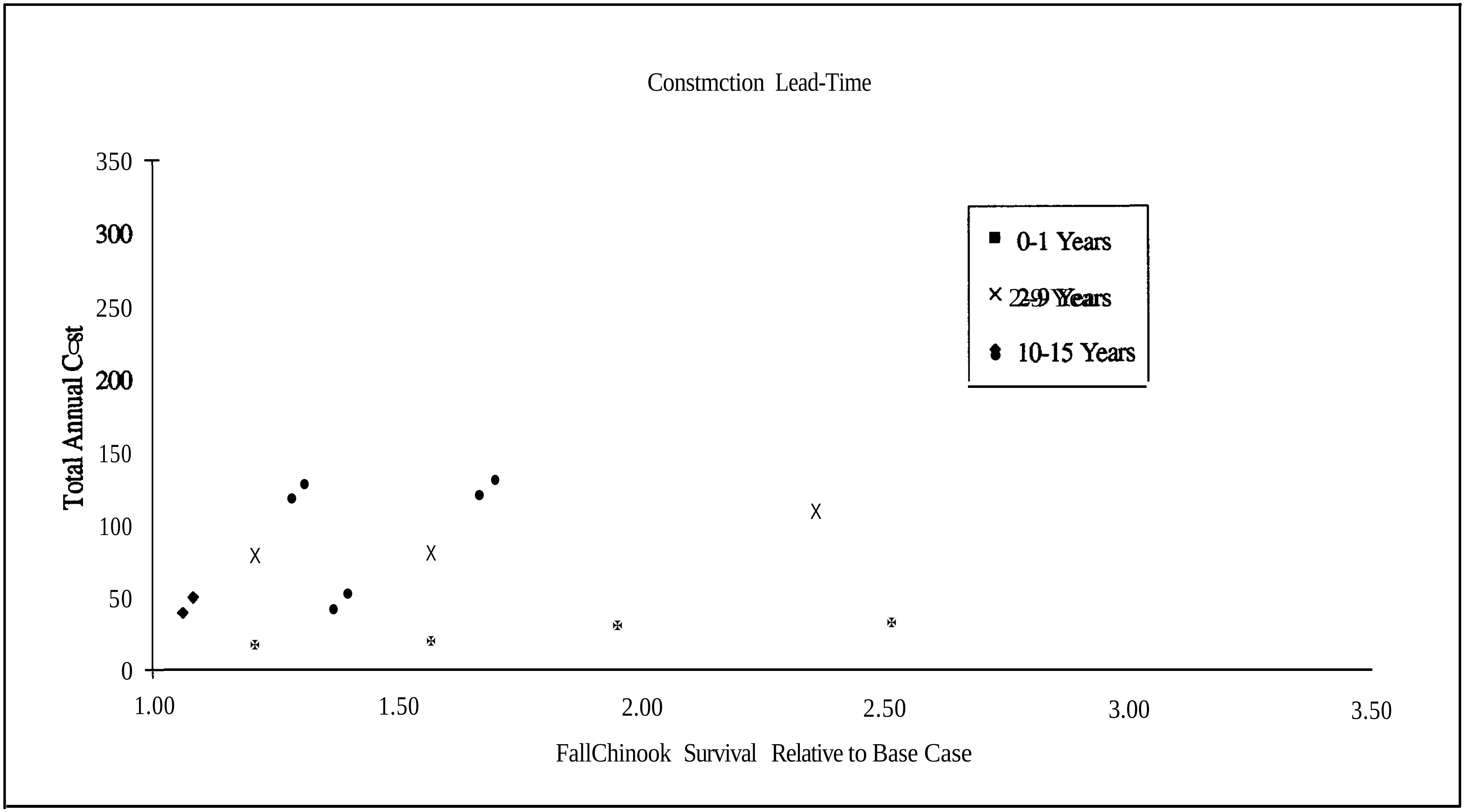

Figure 21. Costs and Survival Effects for 22 Passage/Harvest Strategies, Fall Chinook, Includes only Strategies with Increased Survival for all stocks relative to Base Case. Costs in Millions per year. Cost and survival are relative to SOR alternative 2C and 1987-92 harvest. Strategies are classified by Construction Time attribute.

10. BIOLOGICAL UNCERTAINTY AND SENSITIVITY OF RESULTS TO ASSUMPTIONS

The subject of uncertainty warrants its own section in this report. Whereas uncertainty is sometimes discussed as a caveat to model projections, we view it as an integral part of the modeling process. There are several sources of uncertainty: we are uncertain about the life-history parameters of fish populations, the future natural environment (e.g., tomorrow's weather), the effect of the total environment (human actions included) on fish survival, the number of fish in the river, and the future management and legislative context for salmon protection. Up to this point we have focused on average or mid-point values for estimates of the biological effectiveness of alternative measures. But frequently these average estimates are taken from ranges of effects that are estimated based on alternative sets of assumptions. Our objective in this section is to examine the uncertainty expressed in these estimated ranges where they have been presented, and discuss how our conclusions may change under alternative assumptions.

10.1 Uncertainty Incorporated in CRiSP Model Estimates of Juvenile Passage Survival

The survival estimates generated by models described in this report reflect a high degree of uncertainty about the life-history parameters of salmon populations and their responses to recovery actions. This is particularly noteworthy in the downstream passage modeling. The CPiSP (Center for Quantitative Science, 199 1) model results that we used incorporate three major sources of uncertainty: uncertainty about future hydrologic conditions in the Columbia-Snake River Basin; uncertainty about dam-related survivals; and uncertainty about the effects of potential recovery actions on salmon survival.

The output from CRiSP model runs used in the life-cycle modeling is the mean survival and coefficient of variation (CV) for each passage strategy (the CV is the standard deviation of survivals over a number of years divided by the mean survival of those years). Because the hydrologic conditions in future years are unknown, in each year in the simulation CRiSP chooses water conditions from a past water record, to produce projected survivals. We used a 50 year

(1929 - 1978) water record to arrive at the survival increases discussed in section 7. In addition to variability introduced by water conditions, for alternatives involving flow control, CRiSP randomly chooses values for fish guidance efficiency and spillway, bypass, and turbine mortality from a range of likely values. For fixed drawdown options, spillway and bypass mortality are varied.[40] The mean survival and CV for each passage strategy thus mirror several sources of uncertainty.

For fall chinook, the coefficients of variation average about 50 percent for inriver actions and 15 percent for actions with transportation. For spring and summer chinook, the CV's average about 25 percent to 35 percent for inriver actions and 8 percent for actions with transportation. This variation for inriver actions is relatively large, and suggests that only fairly large survival differences between these actions be deemed significant

Because our greatest concern with juvenile passage is during years of low flow, a set of CRiSP model runs was executed using a selection of eight low-water years (1929,1930,193 1, 1937, 1941, 1944, 1973, and 1977) rather than the 50 year water record. This is a worst-case scenario with regard to water flows, since we do not expect every year in the future to be as bad as these eight years. Table 9 shows the absolute differences between the means and coefficients of variation based on the 50-year record and these statistics based on the low-water years. The differences in the means range from 2 to 35 percent of the 50-year record, and are not large enough to change our conclusions about the relative efficacy of the different types of passage actions. Some of the differences, however, may suggest alternate conclusions about the ability of actions to meet our biological criteria. For example, the absolute difference in mean survival for summer chinook between the 50- and 8-year scenarios is 0.04 for action 07 (SOR5b). This changes the survival effect of this action, as a proportion of base-case survival, from 1.24 (Table 6) to 1.14. Whereas all our abundance criteria were met by this action in the scenario using the 50-year water record, these criteria are no longer met under the low-flow scenario (see Table 5).

[40] Dam-related mortality is assumed to be zero in the natural river option. Therefore, no uncertainty in spillway, bypass, and turbine mortality is modeled in the natural river option.

The differences between these scenarios are important when the two estimates straddle the criteria, as for action 07 (SOR5b), but this is a rare occurrence. The coefficients of variation differ by less than 10 percent between the low-flow scenario and the 50-year flow scenario -- this is not a biologically significant difference. The CV's are both higher (negative sign in Table 9) and lower in the 8-year low-water record, depending on the action.

In addition to concern over low-water year survivals, we addressed the uncertainty associated with the efficacy of drawdown. Since the region lacks data on the effects of drawdown, we used the average survival from two different sets of assumptions regarding fish guidance efficiencies and turbine, bypass, and spillway mortality under two of the drawdown actions (actions 11 and 13). Table 10 presents the survivals estimates from the two sets of assumptions (referred to as high and low case). Projections of passage survival in the high case (optimistic assumptions) are 17 to 35 percent higher than projections in the low case (pessimistic assumptions). Because these drawdown alternatives reduce survival relative to the base case, our conclusions about the effectiveness of the drawdown alternatives discussed in section 7 (which are based on the average of the high and low cases) do not change when the high and low estimates are considered separately. However, for actions that come close to meeting the biological objectives, the range of effectiveness obviously may be an important consideration. Such ranges should in the future be produced for all passage alternatives.

10.2 Uncertainty Not Incorporated in Model Results

The CRiSP passage model leaves out some biological effects that may be important for some strategies (Table 2). The available evidence is too limited to suggest which of these possible effects will occur. Because of the lack of data on these possible effects, they should probably be omitted from the model when it is used to make survival projections.

Table 9
Comparison of Juvenile Passage Survivals from CRiSP For the 50 Year Water Record and the Eight Year Low-Flow Record

Passage Action	Spring Chinook		Summer Chinook		Fall Chinook	
	Mean	c v	Mean	c v	Mean	CV
SOR 2c with transport	0.03	0.5%	0.03	0.7%	0.05	1.5%
SOR 3b with transport	0.01	0.4%	0.02	0.8%	0.03	1.2%
SOR 5b without transport	0.03	-2.3%	0.04	-0.9%	0.07	-1.4%
SOR 6a without transport	0.05	-6.2%	0.06	-5.4%	0.06	-0.6%
SOR 6c, no LGR transport	0.03	-2.6%	0.04	-0.9%	0.07	-0.7%
SOR 7a with transport	0.03	0.75%	0.04	1.2%	0.03	2.1%

Difference between 50-year and 8-year mean survivals and coefficients of variation.
50-year means always > 8-year means; 50-year C.V.'s may be larger or smaller than 8-year C.V.'s.

Table 10
Average Effects of Fixed Drawdown Actions on Juvenile Passage Survival:
Best and Worst Case Scenarios
(proportion of base case survival)

Action Number	SOR Action Description	Spring Chinook	Summer Chinook	Fall Chinook
11	SOR 6c no transport, HIGH	0.85	0.83	0.56
11	SOR 6c no transport, LOW	0.65	0.68	0.46
13	SOR 6d no transport., HIGH	0.88	0.83	0.56
13	SOR 6d no transport, LOW	0.65	0.66	0.48

"High" uses optimistic assumptions regarding FGE's and turbine, bypass, and spillway survivals
"Low uses pessimistic assumptions regarding FGE's and turbine, bypass, and spillway survivals

10.3 Effects of Habitat Enhancement

Documents published by Northwest Power Planning Council (Anderson and McConnaha 1992, p. 24), BPA (Fisher, Lee, and Hyman 1993, Table 4), and NMFS (1993) provide numerical estimates of the effect of habitat enhancement in the Snake Basin on egg-to-adult survivals. For this analysis, the effect of habitat enhancement represents the change in egg-to-adult survival, which is the product of egg-to-smolt, overwintering, and adult pre-spawner survival changes. The enhancement actions may include land management actions, barrier removal, instream flow enhancement, riparian protection and enhancement, placement of instream structures, and the screening of irrigation canal intakes. Two of our three sources for the average estimate of effectiveness of habitat enhancement (BPA and NMFS) originally presented high and low estimates along with the mid-point estimate (Table 11). Because these estimates are not the result of a documented modeling process (in contrast to the estimates for passage survival), the differences in the assumptions between high and low cases have not been articulated.

The likelihood of meeting the biological criteria based on the mid-range or average estimates (from Table 11) usually does not differ from the likelihood based on high and low estimates (Table 12). For survival increases projected for Snake River spring chinook, the only difference in the results based on the high and low estimates from those based on the mid-point is due to NMFS' low estimate of zero increase -- the criteria of a non-declining population at 90% likelihood is not met. For summer chinook, the main difference is that the persistence criterion is not met by the low estimate, but it is met by the mid-range and high estimates. Habitat enhancement has a negligible effect on fall chinook regardless of the estimate used -- none of the criteria are met by even the high estimate of survival increase.

10.4 Summary

We remind the reader that the criteria we use here represent minimum short-term objectives, and are not nearly as stringent as the recovery criteria suggested by the Snake River Salmon Recovery Team. Our analysis supports the view that at least for summer and fall chinook,

Table 11
Ranges of Estimates for Survival Effects of Habitat Enhancement
(proportion of base case survival)

Source of Estimate	Life Stage of Survival Increase	Spring Chinook Low /MedMgh Estimate	Summer Chinook Low /Med/High Estimate	Fall Chinook Low /Med/High Estimate
Fisher et al. 1993 (BPA)	Egg to pre-smolt	1.01 / 1.055 / 1.1	1.01 / 1.055 / 1.1	
	pre-smolt to outmigration	1.02 / 1.035 / 1.05	1.01 / 1.018 / 1.025	
	pre-spawning			1.0 / 1.025 / 1.05
	TOTAL	1.03/1.09/1.155	1.02/1.074/1.13	1.0/1.025/1.05
NMFS 1993 1	egg to outmigration	1.0 / 1.076 / 1.15	1.0 / 1.076 / 1.15	l.O/ 1.005 / 1.01
	pre-spawning	1.0 / 1.01 / 1.02	1.0 / 1.01 / 1.02	1.0/ 1.01 / 1.02
	TOTAL	l.O/ 1.0868 / 1.17	l.O/ 1.0868 / 1.17	1.0 / 1.015 / 1.03

1 **NMFS** suggests using zero improvement over baseline as a low estimate of effects and double the mid-range estimates as a high estimate of effects (NMFS 1993, p. 11).

Table 12
Summary of Whether High, Mid-range, and Low Estimates of Survival Increases Due to Habitat Enhancement Meet Biological Criteria: Yes if Estimate Meets Criterion, No if Criterion is Not Met.[1]

Criterion	Spring Chinook			Summer Chinook			Fail Chinook		
	Low	Med	High	Low	Med	High	Low	Med	High
>95% probability of persistence, 100 yrs.	Yes	Yes	Yes	No	Yes	Yes	No	No	No
Non-Declining for 50% of replications	Yes	Yes	Yes	No	No	Yes	No	No	No
Non-Declining for 90% of replications	No	Yes	Yes	No	No	No	No	No	No
Double spawners for 50% of replications	Yes	Yes	Yes	No	No	No	No	No	No

[1]Based on either NMFS or BPA estimates from Table 11. “Low” is the lowest estimate of total survival effects provided by either NMFS or BPA, “High” is the highest estimate provided by either organization. “Med” is the midpoint of the estimates.

population recovery can not be produced by focusing on a single stage of the life cycle. This conclusion is not changed by considering the uncertainty that has been documented to date on the effects of proposed actions.

APPENDIX A. COST ESTIMATES

This appendix describes the estimation of the costs of passage and harvest actions. We calculated capital, operation, and maintenance costs and annualized these at a 3 percent real discount rate. For major structural modifications (e.g., for drawdown and the natural river option), we used a fifty-year planning horizon. Table A-l reports the component annualized costs of each recovery measure. All costs are expressed as the difference between the cost of each recovery measure and the cost of the base case (SOR 2c and 1987-1992 average harvest levels).

Estimates of the cost of passage actions include costs for replacing lost energy and capacity, structural modifications to dams, and augmenting water flows. Energy and cost estimates come from the SOR Power Work Group (SOR 1993b), which uses two measures to estimate the costs for both energy and capacity. (We report both sets of estimates.) The first measure, combustion turbines, assumes that new combustion turbines will supply the energy and capacity lost due to passage actions. The second measure, power purchases, assumes that the energy and capacity will be purchased in the power market The value of energy depends on the time of year, amount of energy available, and a number of other variables. Capacity is valued at $5.OO/kW-month. Both the combustion turbine and power purchase estimates are rough and are most appropriately used to assess the power-related costs of the recovery actions with respect to each other (rather than as absolute estimates of the cost of the lost power). We rounded all power cost estimates to the nearest $10 million. Costs of structural modifications for passage actions 07 through 14 and 16 come from the Corps of Engineers (1992a, pp. C-l, C-37, C-44; 1992b, pp. 97, 107). Lower bound estimates do not include project contingencies while upper bound estimates do. The cost of purchasing water for augmentation in the base case and passage actions 05 and 06 come from Huppert, Fluharty, and Kenney (1992, p. 3-53) and are based on purchasing water from Idaho water banks and from Idaho farmers (through temporary interruption of water supplies for irrigated farming). Our estimates assume that the potential power gains associated with augmentation that Huppert, Fluharty, and Kenney report are already included in the power cost estimates; therefore, we use the net farm income loss as the cost of purchasing water for augmentation. We base our lower bound estimates on a 10 percent probability of interruption of irrigated agriculture and our high estimates on a 100 percent probability of interruption of irrigated agriculture (permanent retirement of farm land from irrigation). In most years, the quantity of water needed (and therefore the value and cost) would lie between the extremes depicted in Table A- 1.

We base estimates of the cost of harvest restrictions on average annual catch data from the Pacific Fishery Management Council (1993) and information reported in Lestelle and Gilbertson (1993). As noted in the text, we assume that the elimination of U. S. non-Treaty commercial ocean and in-river chinook harvests will not curtail harvest in other fisheries. Based on Lestelle and Gilbertson (1993, pp. 56,61) and Pacific Fishery Management Council (1993, pp. I-6, I-9, IV-4, IV-5) the average (1987-1992) commercial ocean harvest of chinook in southeast Alaska and the Washington-Oregon-California coasts exceeded 1.2 million fish, with a ex-vessel value of over $40 million. Commercial in-river chinook harvest added nearly $1 million more annually on average to this total (Pacific Fishery Management Council 1993, p. IV-12). We round the average values to the nearest $5 million for a lower estimate of the cost and (arbitrarily) double it to get an upper bound estimate.

As noted above, we annualize all costs at a 3 percent real discount rate. Other analysts may adopt a higher rate (e.g., the Corps of Engineers uses an 8 percent discount rate), in which case the absolute annualized costs of an action increase (assuming capital expenditures exist). However, the important change in our analysis is the change in the cost of an action relative to the costs of other actions. For example, if we use an 8 percent rate, the cost of actions with significant structural expenditures (i.e., natural river option, fixed drawdowns, and the upstream collector) become more expensive relative to the other activities. Flow-related actions without significant structural expenditures (e.g., actions 05,06, and 15) become less expensive in a relative sense. Even these actions, however, move up or down at most only 3 ranks in total costs. The use of a 8 percent discount rate would not significantly alter our conclusions.

Table A-l
Costs of Recovery Actions

Action	Description	Structural Lower $mill/yr	Structural Upper $mill/yr	Capacity purchase $mill/yr	Capacity CTS $milll/yr	Energy purchase $mill/yr	Energy CTS $mill/yr	Wtr Purch Lower $mill/yr	Wtr Purch Upper $mill/yr	Harvest $mill/yr (1)	low purchase $mill/yr TOTAL	high purchase $mill/yr TOTAL	low cts $mill/yr TOTAL	high cts $mill/yr TOTAL
1,2	SOS la			-10	10	-40	-170	-10	0		-60	-50	-170	-160
3,4	SOS 2c			0	0	0	0	0	0		0	0	0	0
5,6	SOS 3b			210	120	50	230	0	30		260	290	350	380
7	SOS5a	90	130	70	10	60	260	-10	0		210	260	350	400
8	SOS 5b	90	130	70	10	90	260	-10	0		240	290	350	400
9	SOS6a	30	40	50	0	20	160	-10	0		90	110	180	200
10	SOS 6b	30	40	40	-10	30	170	-10	0		90	110	180	200
11,12	sos6c	10	10	30	-15	10	140	-10	0		40	50	125	135
13,14	SOS 6d	10	10	40	0	10	140	-10	0		50	60	140	150
15	SOS 7a			220	50	160	520	-10	0		370	380	560	570
16	Collector	30	40								30	40	30	40
HC	no harvest reduction (1987-1992 level)													
HO	eliminate U. S. commercial ocean chinook harvest									40				
HR	eliminate U. S. commercial spring and summer in-river chinook harvest									1				
HX	eliminate U. S. commercial ocean and in-river chinook harvest									40				

* costs are marginal from base case action 03 (SOS 2c) and harvest at 1987 to 1992 levels
(1) coho harvest assumed to be unaffected

APPENDIX B. STOCHASTIC LIFE CYCLE MODEL PARAMETERS

Parameter	Spring	Summer	Fall Chinook	Source of Parameter
ffem	0.5	0.35	0.583	Biological Assessment
PrsPsv	0.6	0.7	0.85	Biological Assessment
egfem	5176	4423	4297	Biological Assessment
stdegg	400	300	233	Biological Assessment
jackspn	0	0	0	Biological Assessment
logtscl	1	0.75	1	Biological Assessment
alpha	-2.20	-1.73	-1.73	Biological Assessment
beta	-3.36E-09	-1.5OE-08	-8.41E-08	Biological Assessment
cvegsv	20%	20%	20%	Biological Assessment
stay1	1	1	0.15	Biological Assessment
stay2	0	0	0	Biological Assessment
stay3	0	0	0	Biological Assessment
inbsmsv	0.95	0.95	0.25	Biological Assessment
adtrecv	0.038	0.034	0.069	Calibration
cvadtrv	70.0%	29.4%	49.7%	Calibration
ocnlhar	0.001	0.002	0.031	Calibration
ocnlrvh	0.011	0.029	0.032	Calibration
oculsuv	0.875	0.678	0.927	Calibration
ocn2har	0.004	0.005	0.344	Calibration
ocn2rvh	0.110	0.015	0.077	Calibration
ocn2suv	0.301	0.296	0.486	Calibration
ocn3har	0.000	0.009	0.555	Calibration
ocn3rvh	0.389	0.046	0.234	Calibration
ocn3suv	0.009	0.002	0.115	Calibration
ocn4har	0.000	0.000	0.465	Calibration
ocn4rvh	0.800	0.000	0.424	Calibration
ocnlsbe	0.113	0.290	0.010	Calibration
OCIl2Sk	0.585	0.684	0.093	Calibration
ocn/3Sbe	0.602	0.943	0.096	Calibration
ocn4sbe	0.200	1.000	0.111	Calibration
termhar	0.000	0.000	0.000	Biological Assessment
msurv	0.323	0.344	0.333	SOR
passcv	12%	6%	33%	SOR
hattake	0	0	0	Biological Assessment
subesp	4910	3768	470	Calibration
subharv	0	0	0	Biological Assessment
olsbe	1563	1418	18	Biological Assessment
o2sbe	857	1633	152	Biological Assessment
o3sbe	2484	716	289	Biological Assessment
o4sbe	6	1	10	Biological Assessment
olsuv	12074	3312	1648	Biological Assessment
o2suv	440	707	797	Biological Assessment
o3suv	35	1	349	Biological Assessment
recruits	16516	3326	2719	Biological Assessment
presmt0	1610078	268418	16732	Calibration
presmtl	0	0	0	Calibration
presmt2	0	0	0	Calibration
smt_bon	439489	98805	39386	Calibration
spawners	6089	1584	313	Biological Assessment

APPENDIX C. SURVIVAL CHANGES FROM NON-TREATY COMMERCIAL HARVEST RESTRICTIONS

This appendix presents details on the source data used to calculate the survival changes attributed to restrictions in commercial harvest. It relies heavily on data in Lestelle and Gilbertson (1993). The main difference between our harvest restriction scenarios and those of Lestelle and Gilbertson is that they concentrate on changes in total adult equivalent (AEQ) mortality due to total harvest elimination, while we concentrate on AEQ changes from three specific harvest restrictions:

1. Elimination of U. S. non-Treaty commercial ocean chinook harvest;
2. Elimination of U. S. non-Treaty commercial in-river chinook harvest;
3. Elimination of both U. S. non-Treaty commercial ocean and in-river chinook harvest

Tables C. 1 through C.5 provide background material on data and calculations used to model harvest restrictions for spring, summer, and fall chinook. The first section of Table C. 1 contains ocean harvest data on fall chinook, broken down by fishery. To calculate the U.S. commercial portion of the harvest, we first estimate Snake River fall chinook catch by fishery, then calculate the U.S. commercial portion of this (excluding southeast Alaska [SEAK] net catch, where chinook are a small fraction of total catch). The U.S. portion is about 34 percent of total ocean harvest. We then calculate the ocean exploitation rate in the absence of the SEAK troll, Washington and Oregon and California troll, and Puget Sound non-treaty commercial fisheries. Since the base case AEQ exploitation rate is about 38 percent (from Lestelle and Gilbertson), the exploitation rate in the absence of the afore-mentioned fisheries is 38 percent times (100 percent minus 34 percent), or approximately 25 percent.

An important assumption inherent in this calculation is that other ocean fisheries will not change their harvest regimes in response to a closure. This assumption directly influences the calculated effectiveness of harvest restrictions. If, for example, harvest in the west-coast Vancouver Island (WCVI) fishery increases as a result of decreased chinook harvest in Alaska, the positive effects of U. S. ocean harvest reductions in increasing fall chinook escapement will obviously be reduced. Therefore, the results developed below and used in the cost-effectiveness analysis should be interpreted as one possible outcome of harvest restrictions. More definitive results require work beyond the scope of this analysis.

We address the effects of non-Treaty commercial in-river harvest restrictions in a similar fashion as ocean harvest restrictions. Table C.2 shows fall chinook in-river harvest patterns. As the table displays, if non-Treaty commercial in-river harvest were eliminated, the in-river AEQ exploitation rate would drop from 39 percent to 21 percent. This assumes that other in-river fisheries do not change their exploitation rates in response to changes in commercial harvest. Therefore, once again the results should be taken as indicative or as an example, since the assumptions behind them are probably over-simplified.

Table C.3 converts the effects of harvest reductions into changes in survival. The first section of the table repeats base-case exploitation rates from Lestelle and Gilbertson. The second traces the changes in harvest into changes in exploitation rates. The third translates changes in exploitation rates into survival changes, while the fourth converts the survival changes into multipliers with respect to base-case survival.

For both spring and summer chinook, we assume that the base-case ocean exploitation rate is 10 percent of that for fall chinook, or roughly 4 percent (10 percent times 38 percent).[1] We assume further that the rate at which spring and summer chinook are caught in a fishery is 10 percent of the rate at which fall chinook are caught in the fishery. For example, instead of being taken at a rate of 0.3/1000 in the SEAK stroll fishery, we assume that they are taken at a rate of 0.03/1000. For in-river fisheries, spring chinook have a 12 percent base-case in-river exploitation rate, according to Lestelle and Gilbertson. Based on this, we estimate that summer chinook have a roughly 1 percent in-river exploitation rate. Because of the low exploitation rates for spring and summer chinook, it seems likely that harvest restrictions have a far smaller effect on these stocks, when compared to fall chinook. While we do not include detailed calculations for these stocks,

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[1] This follows a suggestion by Lestelle and Gilbertson (1993). Note that in tables C.4 and C.5 the 4 percent exploitation rate appears as 5 percent, due to rounding.

tables C.4 and C.5 show the changes in exploitation rates and survival for spring chinook and summer chinook, respectively.

Table C. 1 Fall Chinook Ocean Harvest Data

Fishery	Data Source	Chinook catch	Snake River Fall Chinook /1000
SEAK troll	Lestelle & Gilbertson Table. 7	272,200	0.3
SEAK net (exclude per PSC 91 p 3)	Lestelle & Gilbertson Table. 7	26,500	0
SEAR Sport	Lestelle & Gilbertson Table. 7	38,640	0.4
BC WCVI troll	Lestelle & Gilbertson Table 8	304,589	1.5
BC N/C Table	Lestelle & Gilbertson Table 8	207,650	0.6
BC Other	Lestelle & Gilbertson Table 8	342,932	0.1
WA & OR N of Cape Falcon-Troll	Lestelle & Gilbertson Table 9	74,400	1.8
WA & OR N of Cape Falcon-Sport	Lestelle & Gilbertson Table 9	24,967	2.2
Puget Sound sport + treaty	Lestelle & Gilbertson Table 9	288,567	0.3
Puget Sound non-treaty commercial	PFMC, 87-92 Avg., Table B-37	42,333	0.3
CA & OR S of Cape Falcon-sport	Lestelle & Gilbertson Table 10	169,133	0.2
CA & OR S of Cape Falcon-troll	Lestelle & Gilbertson Table 10	893,133	0.2
Total Ocean Harvest		2,685,045	
U.S. Commercial as percent of total ocean		34%	
Ocean Total AEQ Exploitation rate (base Case, from Lestelle & Gilbertson)		38%	
Ocean Total AEQ Exploitation rate (After Eliminating U.S. non-Treaty Commercial Harvest)		25%	

Table C.2. Snake River Fall Chinook In-River Harvest Data
All Data from Lestelle and Gilbertson (1993)

Year	Treaty	Commercial	Sport	Total	SnakeRiver Fall Chinook/1000	Comm. total	Comm. /Total
87	145,400	326,500	56,900	528,800	2.4	784	62%
88	152,600	318,700	45,100	516,400	3.8	1211	62%
89	134,800	131,300	38,500	304,600	2.3	302	43%
90	84,800	44,700	17,200	146,700	1.4	63	30%
91	56,300	40,500	20,700	117,500	4.2	170	34%
92	29.200	16,900	18,200	64,300	3.9	66	26%
87-92 average	100,517	146,433	32,767	279,717	3	439	54%

87-92 Snake River Fall In-River AEQ Exploitation Rate	39%
Snake River Fall Chinook AEQ Exploitation Rate After Eliminating In-River Commercial non-Treaty Harvest	21%

Table C.3. Changes in Snake River Fall Chinook Survival From Harvest Restrictions
Data from Lestelle and Gilbertson and Preceding Tables

Base Case AEQ Exploitation Rate	
Ocean	38%
In-River	39%
Total Exploitation Rate	62%
Exploitation Rate After Eliminating U.S. Commercial non-Treaty Harvest:	
Ocean AEQ Exploitation Rate with no U.S. Commercial harvest	25%
Total Exploitation Rate w/ no U.S. non-treaty commercial ocean harvest	54%
In-River AEQ Exploitation Rate with no non-Treaty commercial harvest	21%
Total Exploitation Rate w/ no comm. River harvest	51%
Total Exploitation Rate w/ no commercial ocean or in-river	41%
Change in Survival from Eliminating:	
U.S. Commercial Ocean harvest	21%
Commercial In-River harvest	29%
Both Ocean and In-River U.S. Commercial harvest	56%
Multipliers for use in Effectiveness Modeling	
Eliminate U.S. Commercial Ocean harvest	1.21
Eliminate Commercial In-River harvest	1.29
Eliminate Both Ocean and In-River U.S. Commercial harvest	1.56

Table C.4. Changes in Snake River Spring Chinook Survival From Harvest Restrictions
Data from Lestelle and Gilbertson and Preceding Tables

Base Case AEQ Exploitation Rate	
Ocean	5%
In-River	12%
Total Exploitation Rate	16%
Exploitation Rate After Eliminating U.S. Commercial non-Treaty Harvest:	
Ocean AEQ Exploitation Rate with no U.S. Commercial harvest	3%
Total Exploitation Rate w/ no U.S. non-treaty commercial ocean harvest	15%
In-River AEQ Exploitation Rate with no non-Treaty commercial harvest	9%
Total Exploitation Rate w/ no comm. River harvest	14%
Total Exploitation Rate w/ no commercial ocean or in-river	12%
Change in Survival from Eliminating:	
U.S. Commercial Ocean harvest	2%
Commercial In-River harvest	3%
Both Ocean and In-River U.S. Commercial harvest	5%
Multipliers for use in Effectiveness Modeling	
Eliminate U.S. Commercial Ocean harvest	1.02
Eliminate Commercial In-River harvest	1.03
Eliminate Both Ocean and In-River U.S. Commercial harvest	1.05

Table C.5. Changes in Snake River Summer Chinook Survival From Harvest Restrictions
Data from Lestelle and Gilbertson and Preceding Tables

Base Case AEQ Exploitation Rate	
Ocean	5%
In-River	1%
Total Exploitation Rate	6%
Exploitation Rate After Eliminating U.S. Commercial non-Treaty Harvest:	
Ocean AEQ Exploitation Rate with no U.S. Commercial harvest	3%
Total Exploitation Rate w/ no U.S. non-treaty commercial ocean harvest	4%
In-River AEQ Exploitation Rate with no non-Treaty commercial harvest	1%
Total Exploitation Rate w/ no comm. River harvest	6%
Total Exploitation Rate w/ no commercial ocean or in-river	4%
Change in Survival from Eliminating:	
U.S. Commercial Ocean harvest	2%
Commercial In-River harvest	0%
Both Ocean and In-River U.S. Commercial harvest	2%
Multipliers for use in Effectiveness Modeling	
Eliminate U.S. Commercial Ocean harvest	1.02
Eliminate Commercial In-River harvest	1.00
Eliminate Both Ocean and In-River U.S. Commercial harvest	1.02

APPENDIX D. BASE CASE ASSUMPTIONS FOR DOWNSTREAM PASSAGE

Our base case reflects operations of the Columbia River system consistent with the 1992-1993 operations specified in the Corps of Engineers' 1993 Interim Columbia and Snake River Flow Improvement Measures Supplemental Environmental Impact Statement. It matches the decision made as a result of the Supplemental EIS, which includes the existing water budget on the Columbia and Snake Rivers, an additional amount of water up to 3 million acre feet depending on runoff forecasts, and up to 427 thousand acre feet of additional Upper Snake River water. It is the same base case used by the System Operation Review. It does not include possible survival increases due to current predator control measures. For all other stages of the life cycle, we use the base case parameter values (Table B- 1). Thus, survival increases that may have accrued since 1990 due to actions such as habitat enhancement, harvest restriction, or upstream passage enhancement are not included in the base case. Some planned system improvements in downstream passage, however, are included in the base case. For example, fish guidance efficiencies (fge) in the base case are higher than at present. On the other hand, as noted, the analyses assume no effect of current predator control options.

Table D. 1 summarizes the CRiSP model parameters corresponding to the base case. The mean transportation survival was calculated by multiplying the modeled estimate of in-river survival by the observed mean 1986 Transport Benefit Ratio. There is no spill at transportation sites (Lower Granite, Little Goose, and Lower Monumental).

It is important to note that these parameters may change with different passage strategies. Spill, for example, will be much higher with SOR alternative 7a (action 15), while dam mortality is assumed to equal zero under natural river alternatives. In addition, in fixed drawdown actions 09 through 14, the spill efficiency, turbine mortality, spillway mortality, and fge are the means of pessimistic and optimistic assumptions, as described in section 10. In the natural river option, dam-related mortality is assumed to equal zero.

Table D. 1
Average Values for Key CRiSP Parameters Used to
Produce Estimates of Juvenile Passage Survival, Base Case

Parameter	Spring chinook	Summer chinook	Fall chinook
Spillway Survival per Project	.98 (1.00-0.93)	.98 (1.00-0.93)	.98 (1.00-0.93)
Bypass Survival per Project	.98(1.00-0.92)	.98 (1.00-0.92)	.98 (1.00-0.92)
Turbine Survival per Project	.90(0.98-0.76)	.90(0.98-0.76)	.90 (0.98-0.76)
Mean Transport Survival	.56	.56	1.00
Fish Guidance Efficiency			
Lower Granite	.56 (0.36-0.85)	.56 (0.36-0.85)	.35 (0.20-0.40)
Little Goose	.70 (0.52-0.81)	.70 (0.52-0.81)	.35 (0.20-0.40)
Lower Monumental	.65 (0.57-0.71)	.65 (0.57-0.71)	.31 (0.29-0.35)
Ice Harbor	.71 (0.67-0.79)	.71 (0.67-0.79)	.31 (0.29-0.35)
Wells	.96 (0.95-0.97)	.96 (0.95-0.97)	.96 (0.95-0.97)
McNary	.70 (0.36-0.91)	.70 (0.36-0.91)	.47 (0.10-0.81)
John Day	.72 (0.55-0.78)	.72 (0.55-0.78)	.26 (0.13-0.54)
Spill Requirements			
Ice Harbor (4/15 to 5/31)	.60	.60	.60
Ice Harbor (6/1 to 8/15)	.30	.30	.30
Wells	.07	.07	.07
Rocky Reach	.10	.10	.10

Notes: Ranges for parameter estimates are in parentheses.
Base case uses SOR alternative 2c and base case harvest (1987-1992 average).

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