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ANALYSIS OF HISTORIC DATA FOR JUVENILE & ADULT SALMONID PRODUCTION: PHASE I

FINAL REPORT

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KEY WORDS

chinook salmon, coded-wire-tag, Columbia River, Generalized Linear Models, power, Virtual Population Analysis

EXECUTIVE SUMMARY

Survival of hatchery reared Columbia River chinook (*Oncorhynchus tshawytscha*) salmon from release to return is highly variable and thought to be related to river flow during juvenile outmigration in the spring. The purpose of this project is to examine the relationship between survival of coded-wire-tagged (CWT) Columbia River salmonids and in-river flow and other freshwater factors. This report covers Phase I, in which two methods to estimate survival were developed and evaluated, and criteria for data selection were established.

Method 1, Virtual Population Analysis (VPA), used by the Pacific Salmon Commission, is a method to obtain absolute estimates of survival; this method depends on estimates of natural mortality and escapement, both poorly known. Method 2, Generalized Linear Models (GLIM), can be used to obtain relative estimates of survival and can be applied to partial data, such as commercial catch alone.. For the purposes of this study, relative estimates of survival are as good as absolute estimates. An advantage of GLIM over VPA is that escapement data and in-river catch data are not necessarily needed. Methods to determine confidence intervals about VPA survival estimates were also developed. Demonstration examples for each method are given.

A critical problem in determining the relationship between in-river variables (such as flow) and survival is obtaining tagged groups that experienced different conditions. There are two ways to obtain such contrast. The first method involves between-year comparison. Between-year effects may be due to differential ocean conditions, so we have chosen tag groups from lower river hatcheries as controls on ocean conditions. The alternative is to compare mark groups released in the same year at different conditions. Some limitations were found in the number of tagged groups available for our analysis, particularly upriver spring chinook, where poor survival produced very few recoveries; fall chinook CWT groups of adequate sample size are available for both upriver and downriver hatcheries; fewer releases of summer chinook are available. The number of CWT groups of coho and steelhead are few and, therefore, we will not consider these species in our analysis. We anticipate that a main task of Phase II will be a detailed search to extend the numbers of in-river groups to be included in the analysis. Presently, we have data on flow, and another task in Phase II will be the acquisition of data on other factors that might impact survival of juvenile salmon in the river. Examples of factors that will be explored are temperature, transportation, and flow.

A power analysis to determine the probability of detecting a significant relationship between in-river variables, specifically relative flow, and survival was performed. Results indicate that if survival is twice as high in the highest flow years compared with the lowest flow years, then we have a 55% probability of detecting that flow is a significant factor at the 0.15 significance level.

1. INTRODUCTION

1.1. PROBLEM FORMULATION

The Columbia River salmon have been fished for hundreds, perhaps thousands of years. With the arrival of western European settlers, the magnitude of the exploitation increased dramatically. At its peak, the Columbia River salmon stocks produced catches of over 6 million fish from 5 species with total returns (catch and escapement) estimated to be 7.5 million fish (Chapman 1986). There are five species of salmonids native to the Columbia River (Chapman 1986), steelhead trout (*Oncorhynchus mykiss*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), and chinook salmon (0. *tshawytscha*). The chinook salmon are further classified into three races: spring, summer, and fall (Thompson 1951), based on the time the adults move into and up the river to spawn. The peak catches for each of the salmonid species occurred at different times over a period of about 30 years, centered around 1900. These levels of production have not been seen since.

The decline in abundance may have only been partially due to exploitation. The 20th century brought not only increasing fishing pressure, but it entailed the development of the Columbia River Basin in other ways. As early as the 1940s, the decline in chinook runs was attributed to a number of factors related to the development of the basin, such as deforestation, pollution, over-fishing, unscreened water diversions and construction of dams (Laythe 1948). The latter was considered a major cause of the declines. To overcome these problems, a program was proposed that would remove obstructions to fish passage in tributary streams, screen water diversions, instigate pollution abatement, construct fishways, establish fish refuges where conflicting developments would not be allowed, and construct fish hatcheries. Almost all of this activity was to be undertaken in the lower river.

The operation of hydroelectric projects began in 1938 with Bonneville Dam and in 1941 with the Grand Coulee Dam. While outmigrating smolts were able to pass through Bonneville Dam, the dam was nevertheless recognized as a barrier, and plans were made to replace any eventual loss of fish by the construction of hatcheries (Wahle and Smith 1979) and protection of natural spawning below Bonneville. The Grand Coulee Dam was considered too high for the upstream passage of fish, and fish from stocks that migrated above that location were transplanted to hatcheries of tributary rivers below the dam (Laythe 1948).

The plan suggested by Laythe in 1948 was never fully implemented. By the mid-1970s, more dams had been constructed, and the runs of chinook salmon to the mid-Columbia River continued to decline. The use of hatcheries to increase the runs had proved only partially successful. If salmon were to be preserved, some action was required. In 1980 the Pacific Northwest Electric Power Planning and Conservation Act (more commonly known as the Northwest Power Act) was passed by the United States Congress. The act authorized the states of Idaho, Montana, Oregon and Washington to create an entity to plan for two important resources on the Columbia River basin: electricity., and fish and wildlife. The entity created was the Pacific Northwest Electric Power and Conservation Planning Council, best known as the Northwest Power Planning

Council. To emphasize the importance of fish and wildlife, Congress mandated that the Northwest Planning Council develop the Columbia River Basin fish and Wildlife Program before development of a power plan.

The Northwest Power Planning council has established the doubling of the **salmonid** runs of the Columbia River as a goal of its Fish and Wildlife Program. This objective could in theory be achieved by (1) increasing the production of hatchery salmon, (2) increasing the production of natural spawning salmon, and (3) increasing the survival of outmigrating juveniles. All three factors are likely to be involved in a truly successful **stock** rebuilding effort.

Many management actions are presently being taken in order to increase downstream survival, including the following:

1. Fish bypass facilities: this usually takes the form of screens that divert juvenile fish from the turbines and pass them through the dam in a separate water system
2. Transportation: fish are collected at the fish bypass facilities, placed in barges, and transported below Bonneville Dam, where they are released.
3. Increased flow during periods of smolt migration. Augmented flow is thought to pass fish through the river system faster and, thus, some water is often spilled over the dam instead of passing through the turbines.
4. Predator control: programs **are** now underway to reduce the population of northern squawfish ***(Ptychocheilus oregonensis)*** in several of the reservoirs.

Each of these actions is directed toward increasing the survival of fish from the time of release until they enter the lower river, below Bonneville Dam. Most evaluation of fish bypass facilities has been focused on in-river survival using fin-clipped or freeze-branded fish. Transportation has been evaluated primarily by examination of coded-wire-tag **(CWT)** results. There have been studies to evaluate the impact of changes in flow on both outmigration rate and survival of juveniles, and large-scale squawfish removal programs have been initiated and will he evaluated to determine changes in smolt survival as related to predator abundance. Attempts to evaluate the effect of changes in flow or predator control efforts on survival of adults have been unsuccessful.

One of the guiding principles of the Fish and Wildlife Plan is adaptive management, that is, learning by past actions. Until managers are able to reliably evaluate the effectiveness of their actions, learning will be slow. Changes in factors associated with downstream survivals can, to some extent, be evaluated by in-river mark/recapture experiments, and such experiments **are** certainly an essential part of any well-designed attempt to evaluate factors such as **water flow**. However, this is not practical given the scale necessary to encompass all hatchery stocks, nor would such an in-river mark recovery program measure an impact that occurs once the fish leave the river. Moreover, the collection of this information is relatively recent, providing a short time series of data for the evaluation of the effect of in-river factors on **fish** survival. A methodology to estimate the survival rate of Columbia River salmonids from the time they leave the hatchery or stream until they are either captured or return to the river as adults will assist managers in Ending the best strategy to influence survival and thus increase production of **recruits from** the **Columbia** River. These methodologies could then be used to

1. potentially evaluate survivals in relation to freshwater management actions,

2. determine systematic time trends in survival, and
3. determine the historic production of adult salmonids from the Columbia River.

The ability to perform the above evaluations would be of enormous benefit to the Fish and Wildlife Plan-indeed such information must be available to achieve the goal of doubling the run sizes.

A very much underutilized source of information with potential for evaluating the effects of in-river factors on the survival of outmigrating fish is provided by CWT groups. Beginning in the early 1970s, millions of wild and hatchery juvenile salmon have been tagged and subsequently recaptured at fishing grounds and hatcheries. At the present time, CWTs provide the single most extensive source of information about salmon survival, distribution, and contribution to fisheries. Unfortunately, the development of statistical methods for analyzing CWT data has not kept pace with the accumulation of information. This project explores different statistical methods for analyzing CWT information on Columbia River salmon and their usefulness to examine the interconnection between in-river factors and early salmon survival.

1.2. BACKGROUND

A number of research projects have explored the relationship between in-river factors and juvenile behavior and survival. This chapter enumerates some of their findings.

Raymond (1968, 1979, 1988) investigated survival of wild and hatchery stocks and studied the effects the dams had on the travel time of the outmigrant smolts. Two major findings from his work were that (1) the wild stocks had higher survival than the hatchery stocks, and (2) impoundment of water behind the dams slowed outmigration. Thus, water impoundments and consequent reductions in water velocity were thought to be detrimental to outmigrating salmon.

The direct effect of river discharge on downstream movement of juvenile fry has been the focus of a number of studies. Park (1969) studied the seasonal changes of outmigrant O-age chinook salmon in the mid-Columbia River. He observed that before the impoundments were constructed, the downstream migration occurred at the time of high flows, when the water was turbid. The dams led to a reduction of the peak flows, and the water became less turbid and warmer. Park hypothesized that, as a result, predation and disease increased, endangering the existence of the chinook salmon in the [mid] Columbia River. Raymond (1969) found that the John Day Reservoir increased the travel time of outmigrant smolts from 14 days to 22 days for that section of the river. Irvine (1986) found that fluctuating discharge appeared to increase the number of fry moving downstream provided the water velocity exceeded 25 cm sec^{-1}. This study was conducted on imported stocks in New Zealand. Giorgi et al. (1990) investigated the relation of flow to travel time of subyearling chinook salmon and were unable to conclude that changes in travel times were related to changes in flow; however, they did note that fish outmigrating early in the summer had higher survival to adulthood than those outmigrating later. Bentley and Raymond (1976) found that for each dam constructed on the Snake River above Ice Harbor the travel time was increased by over 50%, producing an average delay of 8 days per reservoir. In a later study, Raymond (1968) estimated juvenile migration rates to be on the order of 40 to 55 km day^{-1} for both freeflowing and impounded stretches of the Columbia River at moderate river flows (about 8,500 m^3 sec^{-1}) and in the range of 24 to 27 km day^{-1} at low flows (about 4,250 m^3 sec^{-1}).

However, the relationship between flow and migration rate for spring chinook salmon is not as clear as it may first appear. Bentley and Raymond (1976) found migration rates of 8 and 13 km day-l for both low and moderate flows in the McNary Reservoir, suggesting site-specific effects on the travel rates independent of the flow. The travel times are also affected by the smolts' physiological condition (Giorgi et al. 1990), which is affected by water temperature, which in turn is a function of the time of the year. Giorgi et al. (1988) also found that the higher the ATPase levels in juvenile salmon, the more likely they were to be guided away from the power turbines by screens.

A considerable amount of evidence has been accumulated to show that downriver travel time for yearling chinook salmon is inversely related to flow. Different investigators have analyzed the migratory characteristics of subyearling chinook salmon in the Columbia River. Some investigators have shown a significant relationship between flow and travel time, while other studies have concluded that the relationship does not exist (Sims and Ossiander 1981; Sims and Miller 1982; Miller and Sims 1983, 1984; Giorgi et al. 1990; Bergren and Filardo, in press). Nevertheless, the evidence that flow and travel time are inversely related for some species/races is used as a basis for present in-river water management. The methods we present in the body of the report provide survival estimates. We believe that such methods applied to fish groups outmigrating during varying river conditions provide the type of estimation framework necessary to investigate the relationship between in-river factors and survival.

1.3. OBJECTIVES

The purpose of this study is to develop methodology for analyzing CWT information that can be used to relate in-river factors (such as flow, temperature, transportation, etc.) to survival of chinook salmon. We will both examine the currently available data to see what is possible now, and make recommendations about how best to design CWT tagging programs to make future data most useful. This report covers Phase I, in which we develop and compare methods for analysis of survival and provide some examples of their application (See Appendix 1, Objective 1, Tasks 1.1 to 1.4 for more details.).

A further objective was to make a preliminary exploration of the CWT database, searching for appropriate code groups to analyze and evaluate the different methods. This activity will be fully developed in Phase II (Appendix 1, Objective 2, Tasks 2.1 to 2.3.). We report some of the weaknesses and strengths found in the database so far. We have also produced an analysis of the statistical power to detect a relationship between flow and survival as suggested by the available information (Appendix 1, pertinent to Task 1.4. and 4.1.). During Phase II, which is currently underway, we will produce a full data assembly and will perform the statistical analysis to see if the existing data may be used to relate adult survival to in-river effects (Appendix 1, Objectives 2 to 4).

1.4. OVERVIEW OF METHODS

Before we provide detailed descriptions of the methods used in the analysis of CWT data, a brief overview of four approaches to the analysis of these data is appropriate.

1. Comparison of escapements. Escapement data from CWT groups can be used as a measure of the survival of the CWT group. The obvious problem with this method is that it does not take account of fishing mortality; thus one group may have a greater percentage returning to the hatchery simply because it is not fished as intensely.
2. Comparison of total returns. A common method of CWT data analysis is to simply add the returns of tags to the fisheries and to the escapement. Naturally the tag returns are corrected for the proportion of the catch and escapement that was samples for the tags. The disadvantage of this method is that some natural mortality takes place between ocean catch and escapement. This is most important for chinook and steelhead, which are exposed to ocean fisheries for several years. A CWT group that was fished very hard at young ages would produce more CWT returns than a stock that faced no ocean fisheries, even if the two stocks had the same survival.
3. Virtual Population Analysis (VPA). VPA (also known as cohort analysis) is a method for correcting total returns of tags for natural mortality. VPA was first used on Pacific salmon by Johnson (1974) and Argue et al. (1983), and is now the method used by the Pacific Salmon Commission (PSC) for the analysis of chinook salmon data. Two potential problems exist with VPA in the context of the Columbia River salmon. First, an estimate of natural mortality must be assumed, and these estimates are very poorly known. Second, the escapement data is considered one of the weakest links in the data, and VPA builds all of the estimates of survival on an initial base of the escapement data
4. Generalized Linear Models (GLIM). Green and MacDonald (1987) proposed using GLIMs for analyzing CWT data. GLIMs are a statistical framework for analyzing CWT returns that considers the return of CWTs to fisheries and escapements to arise from a log-linear statistical process that can include survivals, fishing mortalities, and catch sampling. The potential advantage of GLIMs over VPA is that a GLIM analysis can be performed without escapement data. Thus if escapement data are thought to be unreliable, the GLIM may detect changes in survival that would be masked from the VPA by highly variable escapement data.

2. THE CODED WIRE TAG DATABASE AND CRITERIA FOR DATA SELECTION

2.1. CODED-WIRE-TAG DATA

Most hatcheries mark some of their fish every year with coded-wire-tags (CWTs), and many hatcheries have been using this tagging technique since the early 1970s. The CWT database thus holds the potential to provide considerable information on how past management action and natural events have influenced the survival'of Columbia River salmonids.

CWTs are stainless steel, binary-coded tags imbedded in the nose cartilage of juvenile salmon (Jefferts et al. 1963). Fish from the same group share the same code; therefore the tag identifies each fish to a specific treatment group from a specific. hatchery or release site. The presence of the CWT tag is indicated by the removal of the adipose fin in all anadromous salmonids except steelhead. All hatchery-produced steelhead have the adipose fin removed whether they have a CWT or not. CWT-tagged steelhead are identified by removal of a ventral fin. Some juvenile salmonids from natural spawning have been caught and tagged with CWTs, but the temporal and spatial coverage is not very extensive. Commercial and recreational catches (often 10-20%) of salmonids are sampled for the presence of CWTs by fisheries management agencies. When adult fish return to the hatchery, they are also examined for the presence of tags. The CWT information consists of the number of juvenile salmonids tagged and released at different times and locations, the recoveries of tagged fish in commercial/recreational fisheries and in the escapement, and the proportion of the fish in each time-space stratum that was inspected for tags. Additional information is provided, such as size at release and recapture, and total number of fish released that are identified with the same treatment as the coded group.

The CWT information originates from various state, federal, and international fishery and wildlife agencies along the northeastern Pacific Ocean, many of which have their own hatchery facilities. In the Columbia River basin, about 85 hatcheries and rearing ponds have released CWT fish at one time or another. The Pacific States Marine Fisheries Commission (PSMFC) keeps a permanent CWT database comprising release and recovery information from all the agencies involved.

The CWT data can be used to examine the impacts of in-river factors on survival, but because the measure of survival is from time of release until the fish become vulnerable to fisheries, we cannot use CWT data to directly isolate in-river factors from those affecting the fish in the early ocean stages. This is both good and bad: It is good because there is concern that downstream passage may delay mortality. Fish may be weakened by the downstream trip and die after entering the ocean. While methods that rely on direct in-river measures of survival would not reflect such effects of downstream passage, analysis of CWT data would The disadvantage of using CWT data is the observed overall survival includes ocean survival, which is known to be quite variable. Thus we must try to detect in-river survival effects against the background of noisy ocean survival.

2.2. DATA SELECTION CRITERIA

As was already pointed out, CWT data originates from an array of agencies, which use them for various purposes. The information obtained is sometimes not applicable to exploring the relationship between early survival and in-river factors. The power of this type of analysis is greatly affected by the information used. Therefore, a crucial step is the establishment of appropriate data selection criteria.

We begin by delineating how the ideal data set should look:

1. Groups from hatcheries in the lower and upper river would be included; the lower-river groups would operate as controls for factors affecting mortality, which are unrelated to riverine life stages (e.g., early ocean mortality). Groups from various upriver and downriver hatcheries would be included.
2. The groups selected would have had similar hatchery treatment; individual groups reared under experimental conditions (e.g., "atypical" time of release or feeding experiments) would be discarded. These experiments are expected to affect survival, and therefore, they would introduce an extra source of variability, possibly masking the effects of in-river factors on fish survival. The effect of the experiment itself could be tested for significance if replication over time and within season was available.
3. Many different groups for a particular hatchery and for a specific year would be included. They would provide replication and, therefore, a way to control for intrinsic variability within treatments.
4. The release groups would encompass a time series sufficient to cover as wide a range as possible of contrasting in-river conditions at the time of outmigration. The existence and amount of this contrast is the single most important key to success. It is obvious that no analysis could be made if flows were regulated to be constant over the years.
5. The code groups selected would have releases large enough (in number of tagged individuals) to provide a significant number of recoveries. Small release groups give a very distorted (variable) picture of the structure of the group's contribution rates to fisheries and hatcheries.

The points above are the basic ingredients of any good "experiment," and will directly affect its power. They can be synthesized ***as replication, control, contrast between treatments,*** and ***adequate sample size.***

The tagging programs developed by the different agencies have varied goals, such as evaluating the effects of different hatchery practices on the contribution rates of adult fish to the fisheries. Such treatment characteristically consist of different time of release and different diets. Groups raised under standard hatchery practices (known as production groups) are also tagged; these are the preferred groups. Unfortunately, not all hatcheries tag production groups every year, and very few hatcheries release truly replicated code groups., Additionally, there are few long- established hatcheries in the upper Columbia and Snake river basins, and very few provide a significantly long time series of releases. The lower Columbia hatcheries have specialized in fall chinook salmon, while upper Columbia and Snake river hatcheries tend to rear spring chinook salmon. Since 1982, some hatcheries began to tag production groups considered characteristic stocks for the region, called 'index' groups (e.g., Cowlitt and Priest Rapids hatcheries). At present, they do not offer a time series of recoveries sufficient to have a great impact in the exploration of the relationship between survival and in-river factors, but they will provide crucial information in the future. These weaknesses compromise the degree of replication and control provided by the CWT database.

Another problem found in the database is that many release groups consist of few individuals. Low release numbers (<50,000) provide a very distorted picture of the contribution rate of a group to the different recovery strata (e.g., Snake River spring chinook salmon).

Yet another problem found is the reduced amount of contrast provided by the time series of flows at different dams. Figure 2.1 shows the time series of average daily flow at Priest Rapids and John Day dams during the months of June and July, when juvenile fall chinook salmon are migrating out of the river. While a good contrast of flows is available for the 1970s, the amount of variability decreased during the 1980s (Figure 2.1) and is likely to continue low into the 1990s. Early evidence for a decreased survival at low flows led to negotiations between the energy production and the fisheries agencies over the spring water budget. One implication of this action is a loss of statistical power to test for the significance of flow as a factor affecting salmon survival, presumably because the variation in flow would be reduced.

One of the main tasks of Phase I of this project was to develop the selection criteria and to extract some groups of codes that could allow us to apply the different methods (see Appendix 2 for description of all the groups that were explored). By far the best time series of fall chinook salmon comes from the Priest Rapids Hatchery releases, which extend through the 1970s to the present, providing replication and large releases together with high recovery rates. Downriver fall chinook salmon releases are well represented by various hatcheries (e.g., Cowlitz and Abernathy). Upriver spring chinook salmon releases have very low contribution rates and recoveries are rare (e.g., Rapids River). A few groups of summer chinook are available from upper Columbia (e.g., Wells Channel, Winthrop)

One of the main tasks in Phase II (Appendix 1, Objective 2) is to extend the number of groups to be considered by incorporating experimental groups where the specific experiment did not significantly affect mortality.

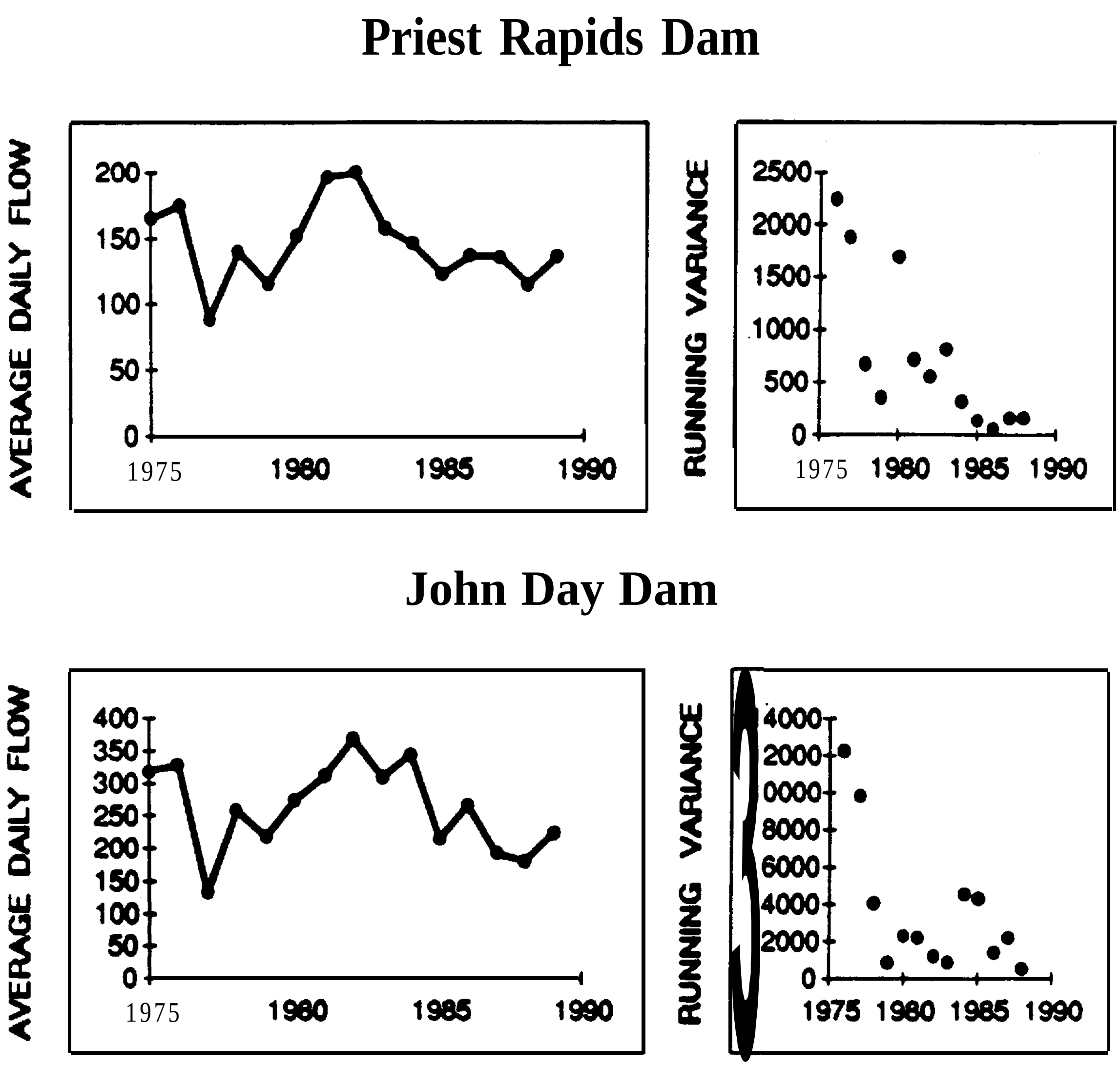

Figure 2.1. Time series of average daily flow during June and July and corresponding running variance at Priest Rapids Dam and John Day Dam.

3. VIRTUAL POPULATION ANALYSIS

3.1. METHODOLOGY

Virtual Population Analysis (VPA; Gulland 1965, Pope 1972) is a technique for estimating fishing mortality and population size at a specific age given an estimate of natural mortality and information on catch at age. The Chinook Technical Committee of the Canada/United States Salmon Treaty has adapted this technique for chinook salmon and it has become the primary stock assessment technique for managing this species, VPA consists of a backward reconstruction of the 'cohorts' or 'generations'; beginning with the spawning escapement in the oldest age group (for most chinook stocks this is age 5 or 6). The terminal catch is then added to the spawning escapement for the same age group. The total is then expanded by an estimated (usually assumed) natural mortality. Subsequent cohort sizes are calculated in the same way, always adding in the cohort size of the next older age group. The basic equation representing this procedure is

$$\text{Cohort (a)} = \frac{\sum^{f} \text{catch } (f,a) + \text{escapement (a)} + \text{cohort } (a+1)}{1\text{-}M(a)} \tag{3.1}$$

where a = age,
f = fishery, and
M = estimate of the natural mortality rate at age a.

Once the population at age a is obtained, the ratio between it and the release size gives an estimate of the survival up to age a:

$$\text{Survival (a)} = \frac{\text{cohort (a)}}{\text{release size}}. \tag{3.2}$$

These estimates of survival at a given age a for different cohorts can then be related to in-river factors such as flow during the outmigration.

This procedure is straightforward, except for estimating the catch where some extra fishing-induced mortality occurs. Many fisheries have a minimum size limit that directs fishermen to release sub-legal fish (called 'shakers'), some of which presumably die. Since these fish are never reported, the result is an underestimation of the fishing mortality and of the population size.

The Chinook Technical Committee (CTC) has developed a procedure to correct for this bias based on estimates of the proportion that is 'vulnerable' by age and fishery (PV(fish,age), subsequently called **PV(f,a)),** which is an estimate of the proportion of the population at a specific age above the minimum size limit for that fishery. A simple way to correct the catch would be to expand it by the following **PVs:**

$$\text{TotFishMort}(f,a) = \frac{\text{catch}(f,a)}{PV(f,a)}. \tag{3.3}$$

However, for some strata **(fish,age)** there is no catch reported, but presumably there is 'shaker' by-catch and mortality. The CTC method allows us to iteratively estimate this 'shaker' mortality in the following way. Let N(age a) be the number of **fish** at age a; then the number of small sub-legal fish for all ages **(NNV(f))** is

$$\mathbf{NNV(f)} = \sum^{a} \mathbf{N(a,f)} * (1\text{-}PV(f,a)) \tag{3.4}$$

and the number of vulnerable **fish** (all ages, NV(f)) is

$$NV(f) = \sum^{a} \mathbf{N(a,f)} * (PV(f,a)). \tag{3.5}$$

We can then calculate the proportion of sub-legal fish of all ages that encounter the fishery (ER) as:

$$\mathbf{ER(f)} = \frac{\mathbf{NNV(f)}}{\mathbf{NV(f)}}. \tag{3.6}$$

The estimated number of fish that are shaken and die for all ages in the fishery is then:

$$\mathbf{Shak(f)} = catch(f) * \mathbf{ER(f)} * \mathbf{(1\text{-}Surv(f))} \tag{3.7}$$

where **Surv(fish)** = the survival of the freed fish.

An estimate of the number of dead shakers by age and fishery can be derived from the previous two equations:

$$Shak(f,a) = \mathbf{shak(f)} * \left(\frac{\mathbf{N(f,a) * (1 - PV(f))}}{\mathbf{NNV(f)}}\right) \tag{3.8}$$

This series of equations provides a way to iteratively estimate the number of shakers at age in the fisheries and include them in the catch. Equations **(1), (4), (5), (6),** (7) and (8) are performed iteratively **until** the cohort sizes at age stabilize. The procedure above assumes that different stocks contribute at the same rate to incidental mortality in each given fishery-age combination.

3.2. EXAMPLES

The following data (Table 3.1) are extracted **from** CWT information. They refer to 152,412 tagged fall chinook released in July 1976 from Priest Rapids hatchery (code **13-** 12-02, brood year 1975; more details about this and other code groups are given in Appendix 2). Table 3.2 demonstrates the results of applying equation (3.1) to the data in Table 3.1 beginning with age 6 and repeating the application up to age 2.

Table 3.1. Age, catch, escapement and natural mortality of tagged fall chinook released in July 1976 from Priest Rapids hatchery (code 13-12-02, brood year 1975).

Age	Catch	Escapement	Natural mortality
2	49.60	139.26	0.4
3	849.42	87.11	0.3
4	1562.54	339.54	0.2
5	254.35	109.97	0.1
6	2.71	0	0.1

Table 3.2. Age, population size, and survival estimates derived from the application of equation 3.1 to the data set contained in Table 3.1.

Age	Population size	Survival (Pop/Rel. size)
2	9420	0.06181
3	5464	0.03585
4	2888	0.01895
5	408	0.00268
6	3	0.00002

This is a simple example in which the 'shaker' mortality was not taken into account. There are two lines of arguments supporting the above-defined procedure. Fist, such a procedure is still valid if we assume that the rate of incidental mortality for all groups considered is the same; in this case the survival estimates at age 2 must be considered as relative survival rates and are still useful for comparisons among groups. Second, there is recent evidence (R. Hilbom, Univ. Washington, personal observation) indicating that the survival of caught and freed sub-legal fish is much higher than initial data suggested.

When the survival at age 2 for this group (0.0618 1) is compared with the survival of groups belonging to other brood years, we expect the survival differences (if any) to be explained in part by the effect of in-river factors encountered by the smolts during outmigration. Table 3.3 contains (1) the survival at age 2 estimated by VPA for 21 code groups for Priest Rapids fall chinook salmon (including the one above) belonging to brood years 75-85, (2) the date of release, and (3) daily average flow in the month following the release of the fish.

The relationship between the survivals at age 2 and the average daily flows during the first month of the outmigration are shown in Figure 3.1. There is a large dispersion of the data, and the relationship between flow and survival is not significant (P-O.21 1 for Priest Rapids flow data). However, some positive signals can be taken from these data. The survival estimates for different

Table 3.3. Fall chinook salmon CWT groups, brood year, survival to age 2, date of release, and average daily flow at three dams used in the analysis of survival and flow.

			Date of release		Average daily flow		
Code	Br. Yr.	Surv	From	To	Priest R.	McNary	John Day
131202	75	0.0618	07/76		196.71	238.15	237.61
131101	75	0.0501	07/76		196.71	238.15	237.61
631662	76	0.0224	06/77		73.24	100.55	102.46
631741	77	0.0128	06/78		122.59	214.73	220.58
632017	78	0.0016	06/79		90.78	141.05	142.13
631958	78	0.0029	06/79		90.78	141.05	142.13
63 1957	78	0.0036	06/79		90.78	141.05	142.13
631821	78	0.0196	05/79		119.85	220.55	231.56
631948	79	0.0 139	05/80	06/80	168.83	281.82	284.84
632261	80	0.0337	05/8 1		203.91	312.96	331.17
632155	80	0.0140	06/81		221.84	288.03	295.89
632456	81	0.0261	05/82		197.80	342.65	361.11
632252	81	0.0 160	05/82	06/82	209.10	367.02	383.64
632612	82	0.0690	06/83		117.19	217.04	221.31
632611	82	0.0217	05/83		168.71	324.47	339.39
632860	83	0.0384	06/84		157.31	305.09	313.42
632859	83	0.0442	06/84		157.31	305.09	313.42
632848	83	0.0487	06/84		157.31	305.09	313.42
633222	84	0.0388	06/85		98.91	142.41	142.56
63322 1	84	0.0363	06/85		98.91	142.41	142.56
634102	85	0.0046	06/86		108.15	169.27	170.47

groups released at the same time are very similar. This suggests that some other factors associated with the brood year, and not only random noise associated with the survival estimation procedure, are responsible for the observed dispersion of the data. We plan to refine this analysis in three ways: (1) Include some other in-river factors that may be important in determining the survival during outmigration (e.g., temperature, predator densities, transportation systems); (2) include downriver stocks in the analysis to serve as controls; and (3) extend the analysis to consider migration timing for different stocks as a basis for selecting flow, specific dam, and time period.

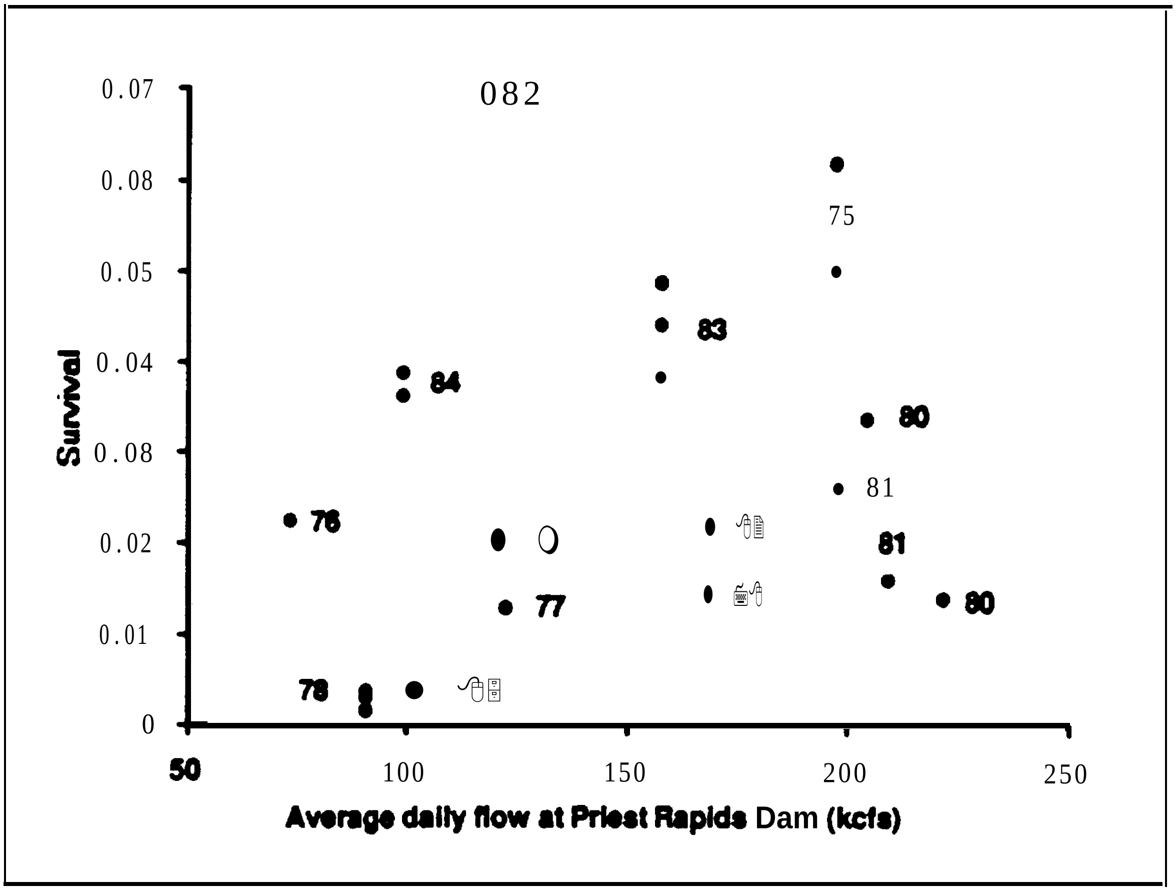

Figure 3.1. Estimated survival from release to age 2 (from VPA) of Priest Rapids fall chinook salmon plotted against average daily flow during the outmigration period at Priest Rapids Dam. Numbers indicate brood year.

4. CONFIDENCE LIMITS FOR SURVIVAL ESTIMATES FROM VIRTUAL POPULATION ANALYSIS

4.1. METHODOLOGY

VPA is a reconstruction of the cohort and not an estimation procedure based on an underlying probability model. Therefore, it does not provide a variance for the estimates of population size and survival. When comparing the survival of different stocks, or among different years, sites, or flow regimes, we should obtain confidence intervals of the estimates to test for the significance of an observed difference.

Two sources of error will produce variability in the estimates of population size at age: (1) The population size will be affected by changes in natural mortality and escapement rate between years (process error); (2) the information used for producing the estimate of the population size at age (i.e., release size, catch-at-age, sampling fractions, natural mortality, and escapement) is measured with some error (measurement error) and will affect the estimated population size. A measure of the variance in the estimate due both to ***process*** and ***measurement*** error can be derived by a Monte Carlo simulation procedure. Given estimates for ***measurement error*** (e.g., variance in the escapement counts or in release **counts), and** given a model for ***the process error*** (e.g., multinomial or Poisson occurrences of fish over space, binomial probability of survival), we can numerically simulate the process of release and recovery of tagged fish. After generating n replicates of tag recoveries in this fashion, we estimate n population sizes at age by applying VPA to each data set. A Monte Carlo variance estimate is then provided by the variance among replicates.

4.2. EXAMPLES

This procedure was applied to the same data given in Table 3.1 (code 13-12-02, 152,412 fish released). Process error was included by considering the occurrences of unexpanded tags per time-space strata (year-state) as Poisson random variables. Log-normal measurement errors were added to the unexpanded counts (C.V. 0. 1), to the sampling fractions (C.V. 0.1), to the escapement counts (C.V. 0.1). and to the release size (C.V. 0.1). The resulting population size, survival, and corresponding variance and empirical confidence limits for 100 iterations are given in Tables 4.1 and 4.2

4.3. MEASUREMENT ERRORS IN CWT INFORMATION

The main difficulty in using the Monte Carlo approach to obtain variances for the survival estimates lies in deciding the magnitude of the process and measurement sources of error. Our task is then to separate the sources of error for a given data set. One approach is to assume process error but no measurement error. This is unrealistic since measurement error is known to exist. A second approach is to assume some structure for the process error (e.g., based on data sets with little measurement error) and estimate the measurement error by assuming that it produces all the over-dispersion observed. A third and more direct approach consists of obtaining independent

Table 4.1. Results of the Monte Carlo simulation procedure showing population size and variance for each age.

Age	Population size	Variance	C.V.	Confidence Limit 1	Confidence Limit 2
2	9420	3207277.50	0.19	7346.24	13526.27
3	5464	1148112.50	0.20	4143.28	7893.37
4	2888	461861.16	0.24	2052.67	4462.62
5	408	17363.91	0.32	223.99	669.90
6	3	17.04	1.38	0.00	11.47

Table 4.2. Results of the Monte Carlo simulation procedure showing survival estimates and variance for each age.

Age	Survival	Variance	C.V.	Confidence limits Limit 1	Confidence limits Limit 2
2	0.06181	0.00081025	0.46	0.0392520	0.1477274
3	0.03585	0.00027712	0.46	0.0227333	0.0864311
4	0.01895	0.00008541	0.49	0.0098915	0.0453274
5	0.00268	0.00000132	0.43	0.0014178	0.0055754
6	0.00002	0.00000000	0.00	0.0000000	0.0000843

information about measurement errors. Field data consisting of repeated measurements of escapement, release size and counts of tags in the catch provide this type of information. When this information is not available for a specific stock, cautious application of information from other stocks is required Upper bounds for the variance can always be derived by using the highest measurement errors observed for any stock. Schnute et al. (1990) applied an "error-in variables" model and found that the hatchery estimates of survival in British Columbia for coho and chinook based on CWT are 22% lower than counting estimates. We are in the process of compiling information concerning the magnitude of these errors, and three examples of our findings are given below.

4.4. EXAMPLES

Example 1. The Washington Department of Fisheries (WDF) has tested the reliability of the traditional bookkeeping method of counting the number of fish released from specific ponds at different hatcheries in different years. The experiments consisted of comparing the traditional counts with those obtained with an automatic counter (Tables 4.3). The counter measurements are considered unbiased and precise.

Example 2. WDF has used the automatic counter to evaluate fish predation and compared the results with the bookkeeping method at the Puyallup hatchery. The difference between the results of the bookkeeping and the counter methods were interpreted as losses to bird predation (Table 4.4).

Example 3. The efficiency of observers at detecting marks on fish returning to Lower Fraser Valley in 1988 is shown in Table 4.5.

Table 4.3. Estimated numbers of fall chinook salmon, from bookkeeping and counters methods, released from Grays River, Kalama Falls, Klickitat and Elokomin hatcheries by brood year. (Source: A. Appleby, Washington Department of Fisheries.)

Hatchery	Brood year	Bookkeeping	Counter	Error (%)
Grays R	83	79,109	74,579	6.07
"	84	127,200	127,200	0.00
"	85	128,047	128,100	-0.04
Kalama F	83	169,310	167,003	1.38
"	84	151,500	135,095	12.41
"	85	149,000	140,200	6.28
Klickitat	83	1,286,100	1,184,988	8.53
"	84	1,411,400	1,170,425	20.59
"	85	1,387,900	1,223,308	13.45
Elokomin	83	1,722,000	1,714,000	0.47
"	84	1,738,500	1,737,794	0.04
"	85	830,100	751,540	10.45

Table 4.4. Results of the experiment to estimate losses due to bird predation from the Puyallup Hatchery by brood year. (Source: A. Appleby, Washington Department of Fisheries.)

Brood year	Bookkeeping	Counter	Losses
81	767,000	647,266	15.6%
82	738,300	558,120	24.4%
83	848,000	772,934	8.8%

Table 4.5. Experimental results of detecting marked fish returning to the lower Fraser Valley, listed by hatchery and species. (Source: K. Wilson, Canada Dept. Fisheries and Oceans, British Columbia.)

Hatchery	Species	Days	Pieces	Detected	Undetected	Missing
Inch Creek	Coho	11	1,684	247	4	1.6%
"	Chum	12	5,752	39	3	7.7%
Chehalis	Coho	18	4,363	237	27	11.4%
"	Chum	11	7,714	196	43	21.9%
Chilliwack	Coho	12	20,476	773	121	15.7%

4.5. THE EFFECT OF PROCESS AND MEASUREMENT ERRORS ON SURVIVAL ESTIMATES

The CTC time series of survival estimates for several stocks in the Northwest Pacific coast provides a maximum bound for the variances of the estimates of survival due to process error and measurement errors. Table 4.6 summarizes the available information for Columbia River chinook salmon stocks.

A simulation using the methods described in the chapter on confidence bounds for VPA enables us to investigate how much process and measurement error is required to produce survival estimates similar to those actually observed. This type of analysis allows us to derive upper bounds for the different sources of errors. This is a particularly important analysis given the skepticism that some people working with CWT data express about its reliability. For our analysis, we generated 100 replicates of mark-recapture data sets for a chinook type life history and for different levels of measurement error. The process error was assumed to be distributed as a negative binomial; that is, the number of tag occurrences in each space-time strata was assumed to have a negative binomial distribution. Measurement error was added to the (1) number of tags detected in the sample for each strata, (2) sampling fraction, (3) escapement rate, and (4) release size. For each data set generated in this way, a VPA was performed and an estimate of the survival at age 2 obtained. The results are summarized in Table 4.7.

A number of interesting conclusions can be drawn from these results. First, the estimates of survival are particularly sensitive to measurement errors in the release size. This sensitivity to the different sources of information provides guidelines for improvements in the collection of information. Second, considering that the time series of survivals presumably contains some extra process error (i.e., interannual variation due to changing environments, such as in-river flow) and some measurement error associated with the estimation of fishing-induced mortality, it can be concluded that the variance estimates obtained from the simulations at moderate levels of measurement error are comparable to those in the observed data. This indicates that the measurement error in the currently available information may not be as large as is commonly assumed

Table 4.6. Survival estimates, variance, and coefficient of variation, for Columbia River chinook salmon (calculated from CTC data).

Stock	Mean survival at age 2	Variance	Coefficient of variation
Bonneville tules	0.0280	0.027 1	0.59
Stayton tules	0.0700	0.4700	0.98
Upriver brights	0.1190	1.8900	1.16
Lewis River wild	0.0350	0.0800	0.80
Columbia River summer	0.0029	0.0005	0.80
Cowlitz tules	0.0280	0.0700	0.93
Spring Creek	0.0730	0.3800	0.84

Table 4.7. Results of a VPA simulation to estimate process and measurement error associated with survival estimates for different levels of measurement errors.

Measurement error (C.V.)				Survival estimates		
Counts	Fraction	Escapement	Release	Mean	S.D.	C.V.
0.0	0.0	0.0	0.0	0.050	0.0019	0.038
0.5	0.1	0.1	0.1	0.050	0.0062	0.124
0.1	0.5	0.1	0.1	0.056	0.0069	0.125
0.1	0.1	0.5	0.1	0.050	0.0090	0.180
0.1	0.1	0.1	0.5	0.064	0.0356	0.554
0.2	0.2	0.2	0.2	0.052	0.0011	0.215
0.3	0.3	0.3	0.3	0.056	0.0180	0.324
0.4	0.4	0.4	0.4	0.06 1	0.0264	0.434
0.5	0.5	0.5	0.5	0.069	0.0374	0.545
0.8	0.8	0.8	0.8	0.117	0.1062	0.905
1.0	1.0	1.0	1.0	0.212	0.253 1	1.195

5. GENERAL LOG LINEAR MODELS

5.1. METHODOLOGY

As an alternative to the Virtual Population Analysis (VPA)-Monte Carlo simulation procedure, log-linear models allow us to analyze the number of fish recaptured in terms of such factors as brood year, age, group, areas (whether state, fishery, region, or management statistical area), time of release, and a number of continuous variables such as flow, size at release, etc. (Green and MacDonald 1987, Cormack and Skalski 1992). One of the advantages of the general linear model over VPA is that it can be performed by using partial information. With VPA, all sources of loss must to be taken into account; in contrast, the general linear model approach can be performed on catch data alone, excluding escapement data if they are considered inaccurate. Moreover, only the catch in some areas may be considered, excluding sport catches, which are always poorly estimated.

The model representing the occurrence of tags over space and time is:

$$E(n_{ij}) = R_i f_j \theta_{ij} \quad (5.1)$$

where i = group,
j = time-space strata,
$E(n_{ij})$ = expected number of tags of group i recovered in strata j,
R_i = release size of group i,
f_j = sampling fraction at strata j, and
θ_{ij} = probability that a fish with code i contributes to catch j.

This probability is usually called the contribution rate and is a function of the survival, distribution, fishing effort, and vulnerability. A statistical model for distribution is needed to estimate θ_{ij} and test whether it differs significantly among groups, areas, age, etc. A natural choice for the distribution of n_{ij} is the Poisson distribution, considering that it is discrete and the probability of occurrence per stratum is low. For fitting purposes, equation (5.1) can be rewritten as a log-linear model:

$$\log_e (E(n_{ij})) = \log_e (R_i f_j) + \log_e (\theta_{ij}) \quad (5.2)$$

where $\log(\theta_{ij})$ can be further partitioned as an additive factorial model including all factors under scrutiny, such as code, group, area, age, time, etc. The model fitting can be done using commercial software (such as Generalized Linear Models [GLIM], Royal Statistical Society), which allows the fit of alternative models by iteratively re-weighted least squares, and then comparison of alternative models by examination of the differences in the deviance. This procedure is analogous to the stepwise comparison of sum of squares in the analysis of variance. The deviance is a measure of the discrepancy of a fit in the same way that the residual sum of squares is for an ANOVA and is defined as:

$$\text{deviance} = -2(l(\mu;y) - l(y;y)) \tag{5.3}$$

where $l(\mu;y)$ = the likelihood of the model under consideration, and
$l(y;y)$ = the likelihood of the full model.

The deviance for a Poisson distribution is:

$$\text{deviance} = 2\sum^{i}(y_i \log_e \frac{y_i}{\mu_i}). \tag{5.4}$$

The deviance, as well as the change in deviance from one model to other, is distributed asymptotically as a chi-square random variable, providing a reference distribution that allows for assessment of the merits of alternative models.

The use of a Poisson distribution assumes equality between the mean and the variance:

$$\sigma^2 = \mu. \tag{5.5}$$

However, preliminary analysis of typical coded-wire-tag (CWT) data sets suggests that the assumption of a Poisson variance structure may not be realistic since over-dispersion is generally observed. In this case, the Poisson assumption can be relaxed for one of proportionality between mean and variance:

$$\sigma^2 = a\mu. \tag{5.6}$$

This error structure can be used within GLIM and provides a more realistic approximation to cluster distributions, such as a negative binomial where the mean and variance are related as

$$\sigma^2 = \mu \frac{1+\mu}{k}. \tag{5.7}$$

Ideally the analysis should include (1) stocks from downriver hatcheries that presumably are unaffected by water conditions above Bonneville Dam (upriver) such as temperature or flow, and (2) stocks from upriver hatcheries where survival is more likely affected by these conditions. Inclusion of downriver hatcheries allows for control of factors associated with particular years independent of upriver conditions, such as early marine survival. Several groups per hatchery should be included to minimize the effects of in-hatchery variability arising from the specific rearing or release conditions of a particular group of fish; also, several brood years exposed to as wide a range of conditions as possible should be included to increase the likelihood of detecting an effect. A model is then fit to these data that includes the following factors: hatchery, brood year, time of release, age, and area (or fishery). However, the factors considered will depend on the type of information available. Plow and other in-river factors can be included in the analysis in different ways. Two examples are provided as illustrations.

5.2. EXAMPLES

Example 1. Seven groups of CWT fall chinook salmon from Priest Rapids Hatchery, corresponding to seven consecutive brood years (76-82), were analyzed. The tag recoveries were pooled by age, area, and season (semesters in the calendar year). Appendix 2 shows the data set in the format used within GLIM and Appendix 1.1 contains additional information about the code groups considered. Alternative models were then fitted to the recovery data to test the significance of the different categorical factors under consideration: brood year, age, area, season, and corresponding interactions. Table 5.1 shows the analysis of deviance, analogous to the stepwise procedure used in multiple regression. This process consists of a series of pairwise comparisons between models of increasing complexity and leads to select the model that best represents the data. Appendix 4 shows the complete GLIM procedure for fitting this model.

From this procedure, a model including brood year, age, season, area, and the interactions age-area, season-area, brood year-area, and brood year-season, is selected. A biological interpretation of this model is attempted Table 5.2.

If we assume that the level of exploitation for each brood year analyzed was similar, then the “brood year” effect tells us something about its relative abundance and therefore something about its early survival. Given these assumptions, we can use the brood year estimates for the model fitted above (contained as a result of the fitting procedure in Appendix 3) as surrogates of initial mortality for the different brood years; we can then attempt to relate them to the flow at the time of the outmigration. Because of the paramaterization within GLIM, these estimates represent the additive effect (in the log scale) of each one of the brood years over a specific brood year taken as the standard, in this case 1976. Figure 5.1 shows a plot of these estimates (standard brood year estimate + brood year estimate) against the average daily flow at Priest Rapids hatchery in June and August of the corresponding year of outmigration.

Table 5.1. Results of the analysis of deviance procedure applied to the Priest Rapids Hatchery fall chinook salmon data. For deviance, see eq. 5.3; scale factor is an estimate of (a) in eq. 5.6.

Factor	Deviance	D.F.	Scale factor	Change dev.	Change d.f.	95% sig. level
none	2485.2	143	17.38			
+brood year	2257 .O	137	16.47	-228.2	-6	Y
+season	1849.0	136	13.60	-408 .O	-1	Y
+age	1168.8	133	8.79	-680.1	-3	Y
+area	1006.0	130	7.74	-162.81	-3	Y
+age.area	870.3	121	7.19	-135.73	-9	Y
+season.area	631.7	118	5.35	-238.6	-3	Y
+season.age	597.96	115	5.20	-33.7 1	-3	N
+brood.area	420.26	100	4.20	-211.4	-18	Y
+brood.age	298.47	82	3.64	-121.79	-18	Y
+brood.season	270.63	76	3.56	27.84	-6	N

Table 5.2. Biological interpretation of log-linear model.

Effect	Indication
Brood year effect	The level of tag occurrence in the catch for the brood years is different, suggesting that either the vulnerability of the groups was different, fishing pressure changed over time, or tagged fish were differentially abundant due to differential mortality in life history stages prior to entry into the fishery.
Season effect	This is attributed to a more conspicuous occurrence of tags in the second semester of the year.
Age effect	Some ages are more vulnerable than others
Area effect	Catches are higher (e.g., fish are more abundant) in some regions than in others
Age-area interaction	Occurrence over space varies with age, which is expected if migration occurs
Season-area interaction	suggests that this effect can be detected in even shorter time intervals
Brood year-area	A differential use of space by each brood year exists
Brood year-age	Brood years were differentially abundant over time

Example 2. The previous analysis had two notable shortcomings: (1) only a single hatchery was analyzed, which is a problem if the differences observed among brood years are due to factors unrelated to in-river stages (e.g., early marine survival); and (2) tag recoveries for each brood year will be affected by varying levels of exploitation over time. In an attempt to control these types of effects, we analyzed a more extensive data set, which includes Priest Rapids hatchery groups (brood years 78-81) together with code groups from downriver hatcheries (Abernathy, Bonneville, Spring Creek and Cowlitz). Appendix 5 shows the data set in the format used within GLIM and Appendix 1.1 contains additional information about the code groups considered. The categorical factors explored were brood year, year of recapture, age, area, and hatchery. The inclusion of downriver hatcheries was expected to control for factors that are associated with the brood year and are common to all the stocks in the river. The inclusion of a year effect allows control for varying levels of exploitation. Appendix 6 contains a transcript of the GLIM session, essentially similar to that shown for the previous example. Table 5.3 shows the results of the model selection procedure.’

The stepwise procedure of model selection can be initiated with an intermediate model and then tested for the significance of the included factors by analyzing the change in deviance as each factor is excluded. This procedure is equivalent to that used in the previous example. The model selected includes all the main effects, which suggests differences in the rates of tag recapture among hatcheries, years, brood years, and ages. If the interaction terms are significant, then:

1. there is differential distribution at age (age-area),
2. there is a differential distribution of catches by area in different years (year-area),
3. fish from different hatcheries have different spatial distributions (hatcheries-area),
4. stocks from different hatcheries have different age distributions, and
5. in different years the representation of fish from different hatcheries varies (hatcheries-year).

In this example, an estimate which could be used as a “surrogate” for in-river mortality does not exist for the Priest Rapids groups. However, we can do a somewhat more indirect exploration of the relationship between flow and survival by looking for correlations from the previous fitting (unexplained variability) with flow. Figure 5.2 shows a plot of the residuals corresponding to Priest Rapids hatchery groups against the corresponding mean daily flow at the

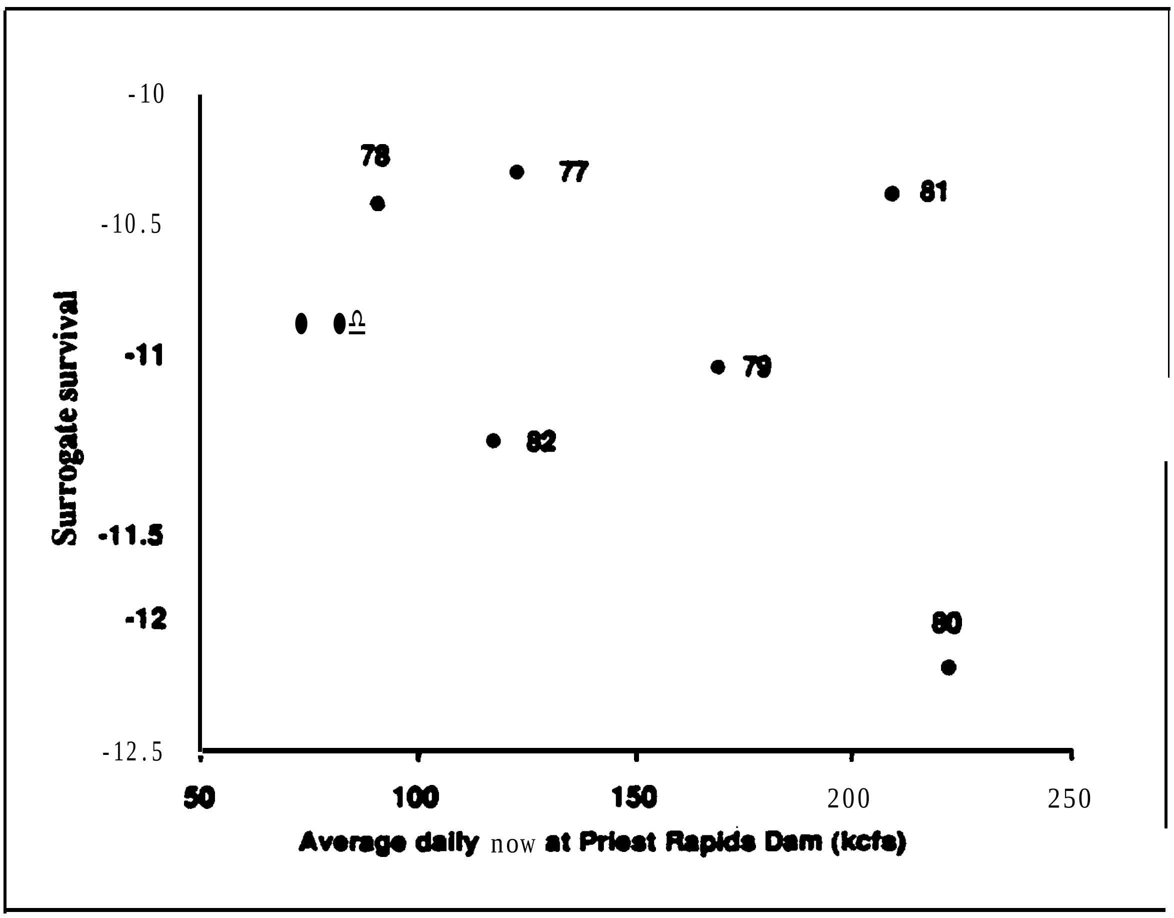

Figure 5.1. **Estimated** relative **survivals from release to age 2 (from GLIM) of seven** Priest **Rapids** fall chinook salmon code groups plotted against **average daily flow in** June at the year of outmigration **at** Priest **Rapids Dam. Numbers indicate brood year.**

Table 5.3. Results of the analysis of deviance procedure applied to fall chinook salmon data from Priest Rapids, Abernathy, Bonneville, Spring Creek and Cowlitz hatcheries. Scale factor is a measure of the observed over-dispersion, calculated as the ratio between the residual variance and the expected counts by strata.

Factor	Deviance	D.F.	Scale factor	Change dev.	Change d.f.	95% sig. level
hat+age+area+year	43 18.0	348	12.41			
-hat	4974.8	352	14.13	+657.0	+4	Y
-age	5068.7	349	14.52	+751.0	+1	Y
-area	6538.0	351	18.63	+2220.0	+3	Y
-year	4786.1	351	13.64	+468.0	+3	Y
+age.area	3874.9	345	11.23	-443.0	-3	Y
+year.area	3285.9	337	9.75	-589.0	-8	Y
+year.age	3252.0	335	9.71	-34.0	-2	N
+hat.area	2382.0	325	7.33	-903.9	-12	Y
+hat.age	1730.2	321	5.39	-651.9	-4	Y

time of outmigration. The residuals from the model are in expected recovery units. Single points represent the difference between the observed recovery in the time-area stratum and the expected recovery from a model, including hatchery, brood year, and age effects plus interactions. Negative residuals, then, result from lower occurrences than those expected by the model.

Figure 5.2 shows what appears to be a low occurrence of tags for groups outmigrating at low flow levels, but no relationship is evident at higher flow levels. Residuals corresponding to early and late release groups appear dissimilar, with early release groups showing consistently higher representations in the catches (i.e., higher contribution rates) and, therefore, possibly'higher survival. The next logical step would be to include time of release as a new variable and test for its significance.

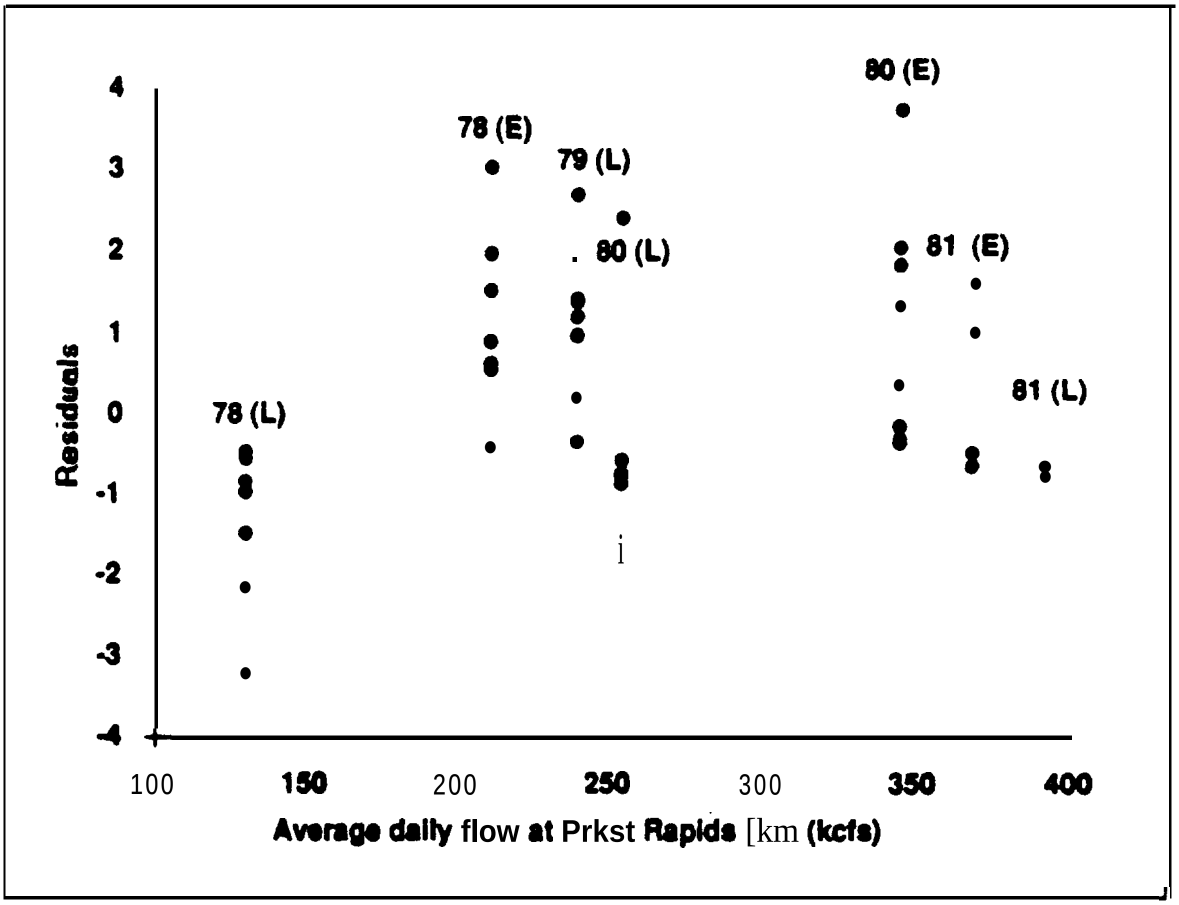

Figure 5.2. Residuals from fitting a log-linear model to Priest Rapids fall chinook recovery data plotted against daily average flow at Priest Rapids Dam at the time of outmigration. Numbers indicate brood year; E and L indicate early and late releases. Each residual is generated from the model fit for each space-time recovery component of each CWT group. Therefore, the number of residuals depends on the number of areas and ages of each CWT group at recapture.

6. POWER ANALYSIS

6.1. MOTIVATION

Before proceeding on to Phase II, we want to maximize the likelihood of detecting a relationship between in-river factors and survival. This chapter examines the power of the statistical tests we will employ in Phase II by analyzing simulated (manufactured) data.

In Phase XT, we will examine many possible factors that may impact survival, including in-river flow. Figure 3.1 shows the relationship between survival estimates of CWT groups and flow. In this particular case, the groups are from the Priest Rapids Hatchery and flow at the Priest Rapids Dam, but this figure is typical of the type of data we expect to examine during Phase II. We want to know if survival increases as flow increases. The simplest statistic is to compute a least squares regression through the data and determine the estimated slope of the line and the likelihood that the slope is significantly different from zero.

In the language of statistics, the null hypothesis is that the slope is zero; the working hypothesis is that the slope is non-zero. In statistical tests of hypotheses, we normally define an alpha (a) level as the probability of rejecting the null hypothesis if it is true, such as $\alpha = 0.05$ or a = 0.1. Thus there is a 5% or 10% chance of determining a non-zero slope when the slope is really zero. This is the so-called Type I error, the probability of rejecting the null hypothesis when, in fact, it is true. The other type of error in hypothesis testing, the Type II error, is the probability of accepting the null hypothesis when, in fact, it is false. In the context of flow/survival testing, this would be rejecting a relationship between flow and survival when there was one.

Power is one minus the probability of making a Type II error. A powerful test is one that has a high probability of rejecting the null hypothesis when it is false. In examining the flow/survival relationship, we need to know the likelihood of detecting an existing relationship.

The statistical analysis in Phase II will be much more extensive and detailed than this type of simple linear regression; nevertheless, the test of hypothesis and the associated power of this test is a good indication of the overall power of any attempt to examine flow/survival relationships.

6.2. METHODOLOGY

The power of a linear regression depends upon (1) the alpha level chosen, (2) the strength of the relationship between the dependent and independent variables (e.g., survival and flow) (the steepness of the line), (3) the amount of variation in flow seen in the data, (4) the amount of variability in survival not explained by flow, and (5) the number of data points available. If we have a linear regression of the form:

$$Y_i = \beta_0 + \beta_1 X_i + e_i. \tag{6.1}$$

The test for significance of the estimated slope (b_1) is based on the following **statistic:**

$$t = \frac{b1}{s(b1)}$$

which is distributed as **t(n-2),** where n is the number of **data** points and

$$b1 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})Y_i}{\sum_{i=1}^{n}(X_i - \overline{X})} \qquad (6.3)$$

and

$$s(b1) = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{(n-2)\sum_{i=1}^{n}(X_i - \overline{X})^2}} \qquad (6.4)$$

The five factors mentioned previously show up in equations 6.1 through 6.4 as follows: (1) the a level chosen determines the probability level at which t will be significant; (2) the strength of the relationship between x and y is the real value of the slope, **$\beta 1$,** and the larger **$\beta 1$** the greater the expected value of bl; (3) the amount of variation in the flow data is given by the term **$(x_i - \bar{x})$** in equations 6.3 and 6.4; (4) the amount of variation in survival due to factors other than flow shows up in the numerator of equation 6.4, which is the 'residual' variation; and (5) the number of data points, n, affects the significance level of the t statistic.

Of these five factors, three are known or determined by the analysis. We select **α;** if we make a small (e.g., from 0.1 to 0.05). then the power of the test decreases. We know how many data points we have available; this will increase as years and data accumulate, but in general we are dealing with about 15 data points. Finally, we know how much historical variation we have seen in flow. As 6 rough guide, the flow at Priest Rapids dam has been more or less uniformly distributed between 100 and 300 thousand cubic feet per second **(kcfs).**

Two of the five factors are unknown or difficult to determine: (1) the real slope of the flow/ survival relationship, and (2) and the amount of unexplained variation about this relationship. We will see later that we do have some information about the unexplained variation, but for our initial analysis we determine the power of the regression test given a specific a level, 15 data points, with flow uniformly distributed between 100 and 300 kcfs (which is comparable to Priest Rapids data), and for a range of values for real slope and unexplained variation.

Our methodology was to employ Monte-Carlo simulation. For any specific set of parameters, we generated 100 simulated data sets, and then examined how many times out of the 100 trials the slope was significantly different from zero. The x values for each data set were generated using the following equation:

$$x_i = 100 + 200U, \tag{6.5}$$

where U = a uniform random number between zero and one.

The y values were generated from the following equation:

$$y_i = s + b\,(X_i - 200) + \sigma N), \tag{6.6}$$

where s = the expected survival at 200 kcfs (assumed **0.7%),**
b = the slope of the flow/survival relationship,
a = standard deviation of the unexplained variation, and
N = a random number with a mean of zero and a standard deviation of 1.0.

From each simulated data set, 15 data points were generated, (i goes from 1 to 15). These 15 data points were then passed to a linear regression package, which determined the value oft. This process was repeated 100 times for each value of b and s.

6.3. RESULTS

Figure 6.1 shows simulated sets of data with a small variance (0.1 coefficient of variation = **$(MSE^{1/2})$/mean** flow) and where survival is 0.5% at 100 kcfs and 1% at 300 kcfs. This corresponds to a 50% increase in survival from average flow (200 kcfs) to high flow (300 kcfs). The relationship between flow and survival in this example is clear. In contrast, Figure 6.2 shows a simulation with a steep slope but high variance. In this case, the relationship between flow and survival is not clear. These figures illustrate that detecting the flow/survival relationship is easier when variance is low or the slope of the relationship is high.

In order to thoroughly examine the probability of detecting the flow/survival relationship for different variances and slopes, we systematically explored different levels of these two parameters. We expressed slope as a percentage increase in survival from low flow to average flow (100 to 200 kcfs; these flows generally represent conditions during the summer months for the lower Columbia River). The variance is expressed as the observed CV in survival, ranging from 0.1 to 1.0.

Table 6.1 shows the results of these Monte-Carlo trials for a = 0.15. The number in each element of the table is the number of times out of 100 trials that the slope was significantly different from zero. For example, let us assume we would use a = 0.15 and that we believe that the CV in survival is 0.8. Then if there was a 11.11% increase in survival **from** low to average flow, 22 times out of 100 we would detect a flow/survival relationship. If the real increase from low to medium flows was **50%,** then 54 times out of 100 we would detect a significant flow/survival relationship. Tables 6.2 to 6.3 show the same results for a levels of 0.1.. 0.5 and 0.01.

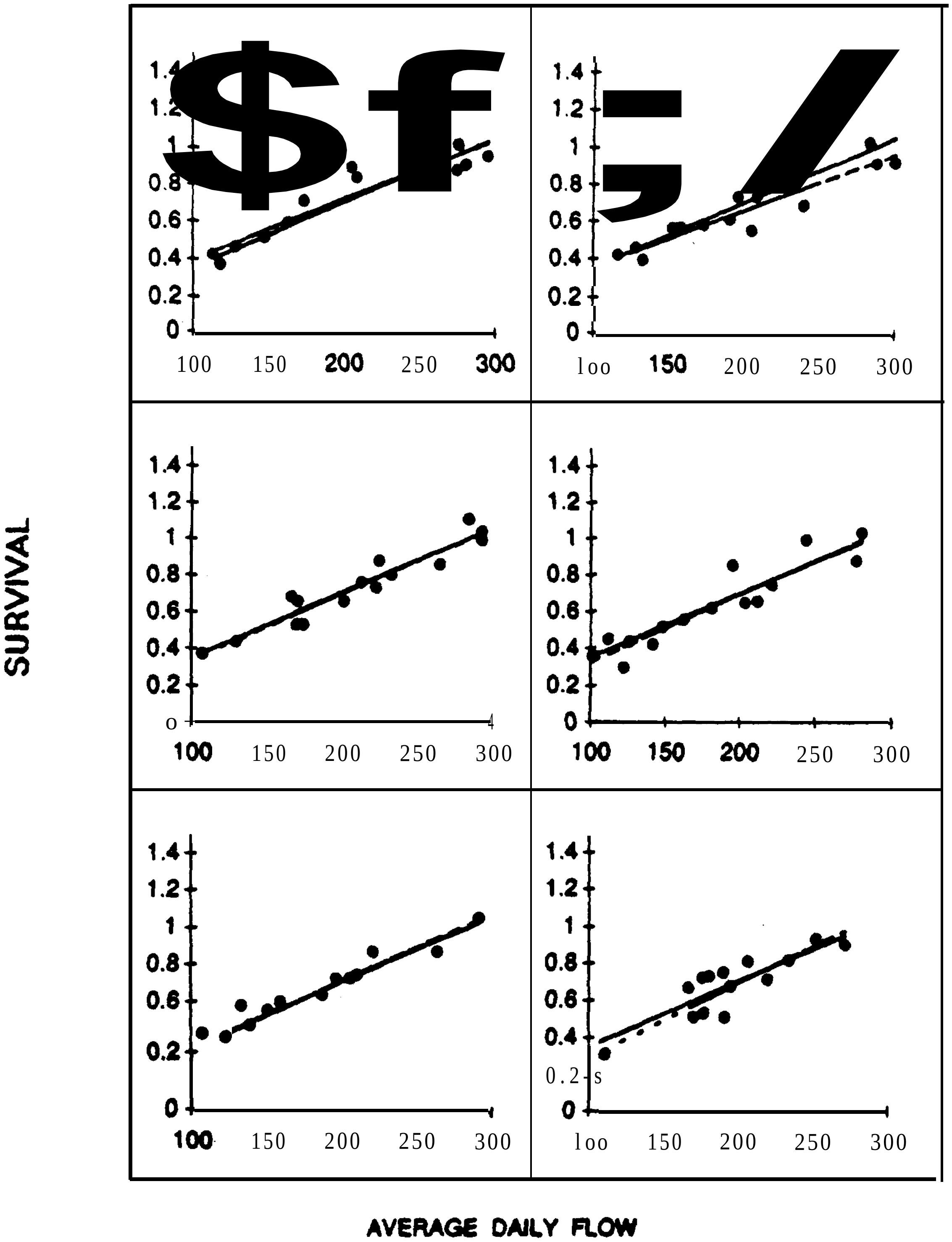

Figure 6.1. Six data sets of flow/survival data, randomly simulated with a low variance (coefficient of variation [$(MSE^{1/2})$/mean flow] = 0.1) and steep slope (survival at 100 kcfs = 0.55, survival at 300 kcfs = 1%). Solid line represents expected flow/survival relationship and dotted line represents the estimated flow/survival relationship.

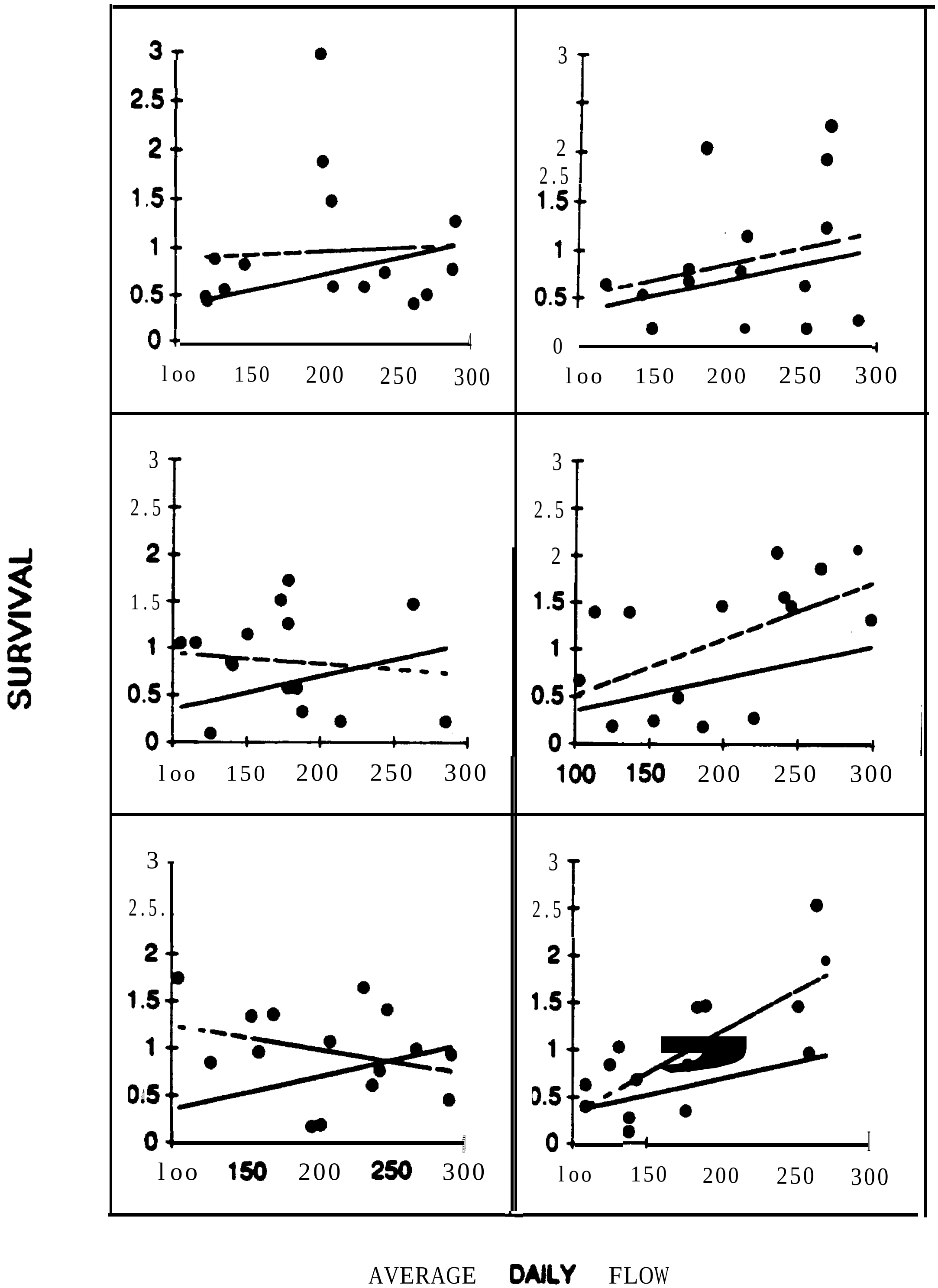

Figure 6.2. Six data sets of flow/survival data, randomly simulated with high variance (coefficient of variation [$(MSE^{1/2})$/mean flow] = 0.1) and steep slope (survival at 100 kcfs = 0.596, survival at 300 kcfs = 1%). Solid line represents expected flow/survival relationship and dotted line represents the estimated flow/survival relationship.

Table 6.1. Results of the Monte Carlo simulations: percentage of times the slope of the relationship between flow and survival was significantly greater than zero (a = 0.15).

	Percentage change in-survival from mid- to low flow									
C.V.	**0.00**	**5.56**	**11.11**	**16.67**	**22.22**	**27.78**	**33.33**	**38.89**	**44.44**	**50.00**
0.1	19	51	85	loo	loo	loo	loo	loo	loo	loo
0.2	19	28	51	68	85	100	100	100	100	100
0.3	19	22	39	51	61	78	85	99	100	100
0.4	19	22	28	42	51	59	68	79	85	96
0.5	19	21	2.5	33	43	51	58	64	75	79
0.6	19	21	22	28	39	46	51	56	61	68
0.7	19	21	22	25	31	40	46	51	55	61
0.8	19	20	22	24	28	36	42	46	51	54
0.9	19	20	22	22	25	31	39	42	47	51
1.0	19	20	21	22	25	28	33	39	43	48

Table 6.2. Results of the Monte Carlo simulations: percentage of times the slope of the relationship between flow and survival was significantly greater than zero (a = 0.10).

	Percentage change in survival from mid- to low flow									
C.V.	**0.00**	**5.56**	**11.11**	**16.67**	**22.22**	**27.78**	**33.33**	**38.89**	**44.44**	**50.00**
0.1	14	41	80	loo	loo	100	loo	loo	100	100
0.2	14	21	41	60	80	99	loo	loo	100	loo
0.3	14	20	25	41	54	64	80	93	100	100
0.4	14	18	21	30	41	51	60	69	80	87
0.5	19	18	21	22	32	41	50	56	63	71
0.6	14	18	20	21	25	32	41	49	54	60
0.7	14	18	18	21	22	29	33	41	48	53
0.8	14	17	18	21	21	22	30	34	41	48
0.9	14	17	18	20	21	22	25	30	35	41
1.0	14	17	18	18	21	21	22	27	32	36

Analysis of the observed CV in survival from the Columbia River chinook CWT groups (Table 4.6) indicates most stocks have a CV in survival of about 0.8. ***Thus*** as an ***a priori*** assumption, we should perhaps view the CV line of 0.8 in Tables 6.1 to 6.4 as the most likely. If we accept 0.8 and use α=0.15, then we conclude that unless survival increases 50% from low to mid-flows we have less than a 50% chance of detecting a significant flow/survival relationship.

Table 6.3. Results of the Monte Carlo simulations: percentage of times the slope of the relationship between flow and survival was significantly greater than zero (cc = 0.05).

	Percentage change in survival from mid- to low flow									
C.V.	0.00	**5.56**	**11.11**	**16.67**	**22.22**	**27.78**	**33.33**	**38.89**	**44.44**	**50.00**
0.1	9	23	64	loo	**100**	100	**100**	loo	**loo**	**100**
0.2	9	16	23	48	64	**loo**	**loo**	**100**	**loo**	**loo**
0.3	9	12	19	23	39	**55**	64	**84**	**99**	**100**
0.4	9	11	16	19	23	34	48	59	64	'81
0.5	9	11	12	19	21	23	34	44	**55**	62
0.6	9	10	12	16	19	21	23	33	39	48
0.7	9	10	11	14	18	19	21	23	32	34
0.8	9	10	11	12	16	19	19	21	23	32
0.9	9	10	11	12	15	18	19	m	**21**	**23**
1.0	9	9	11	11	12	16	19	19	21	21

Table 6.4. Results of the Monte Carlo simulations: percentage of times the slope of the relationship between flow and survival was significantly greater than zero (**a =** 0.01).

	Percentage change in survival from mid- to low flow									
C.V.	0.00	**5.56**	**11.11**	**16.67**	**22.22**	**27.78**	**33.33**	**38.89**	**44.44**	**50.00**
0.1	4	10	42	99	**100**	loo	**100**	loo	loo	**loo**
0.2	4	6	10	19	42	70	99	**loo**	**loo**	**loo**
0.3	4	6	9	10	16	26	42	62	80	99
0.4	4	6	6	9	10	15	19	30	42	57
0.5	4	6	6	9	9	10	14	16	**22**	32
0.6	4	6	6	6	9	9	**10**	**14**	16	19
0.7	4	6	6	6	8	9	9	10	14	16
0.8	4	6	6	6	6	9	9	9	10	14
0.9	4	6	6	6	6	7	9	9	10	10
1.0	4	6	6	6	6	6	9	9	9	**10**

We believe this is unduly pessimistic. First, in many years we have multiple CWT groups, resulting in more than 15 data points, and in some years we will have CWT groups released at different times and therefore subject to different flows. Second, the power analysis done above assumes only two sources of variation in survival: variation due to flow and 'unexplained' variation in survival. In the statistical analysis to be performed, we will use downriver code groups in an attempt to 'control' for variation in ocean conditions. Third, the appropriate α level for fisheries management purposes is probably greater than 0.15—it may be 0.5. Indeed as discussed in Chapter 7.5, we do not believe the final analysis of the flow/survival relationship should be presented as a test of hypotheses.

In summary, these Monte-Carlo analyses of power indicate that a strong relationship between flow and survival will likely be seen by using the crudest statistical methods; in reality we are even more likely to detect a flow/survival relationship if it is present.

7. DISCUSSION

7.1. ALTERNATIVE APPROACHES

The survival of downstream migrating salmonids is one of the most contentious issues in the Columbia Basin. The flow regime today is drastically different from that experienced by the downstream migrants prior to the construction of the hydroelectric system. The economic and social cost of increasing flows during the spring and summer migration might be very high. Yet unless survival of upstream stocks is improved, those stocks, along with their genetic and cultural value, are in great danger. Thus the social, genetic, cultural, and economic benefits of understanding the relationship of survival to in-river variables are quite large.

In this project, we are attempting to understand the relationship of survival to in-river variables using coded-wire-tag (CWT) data to estimate survival. This is only one of the several methods being used to assess these relationships. Using CWT data has the intrinsic benefit of including mortality that takes place after the fish leave the river, which may be due to migration induced stress. However, CWT data has the disadvantage of adding year to year variability in ocean survival on top of other variability to make the data noisier. It is certainly too early to determine if analysis of CWT data is more likely to detect a relationship between survival and in-river variables than other methods. We hope to have a better answer to this question at the end of Phase II.

7.2. EXPERIMENTAL DESIGN CONSIDERATIONS

We hope to see the strength of a relationship between survival and in-river variables amid the noise of variability in survival due to hatchery treatments, ocean conditions, and a host of other factors difficult to describe and control. We have attempted to eliminate hatchery treatment effects as much as possible by using hatchery production groups and not experimental groups. Most CWT groups are experimental, and thus our potential sample size would be much larger if we did use experimental groups. We are currently exploring in detail some of the experimental groups to see if the experimental methods are similar enough to normal hatchery practice to be included in the analysis. This work is currently underway, but we do not have a final answer on experimental group viability.

Using only production groups is not a perfect control on hatchery treatments. Normal hatchery practice does differ from year to year and hatchery to hatchery such that production groups are not necessarily given the same treatment.

The second big source of 'uncontrolled' variability is the effect of oceanic conditions on survival. In general, some years are clearly better than others for fish. If in years following those with high river flows, ocean conditions were good, then we might *falsely* deduce a strong relationship between flow and survival. Similarly, if flow does strongly benefit survival, but the years of high flow happen to coincide with years of poor ocean survival, we might see no relationship between flow and survival. We have identified two approaches to overcome this problem.

First, we can use CWT groups from hatcheries below the major dams as reference groups on upriver hatcheries. Our best data are for fall chinook, with the Priest Rapids hatchery providing the best upriver CWT database. Several lower river fall chinook facilities (such as Bonneville, Spring Creek, and Abernathy) are available for reference groups. There are two considerations when using this type of reference group. The availability of year-by-year matches of Priest Rapids with downriver hatchery CWT groups reduces the number of years of usable data. Second, the ocean distribution pattern for the upriver fish may be different from the lower river fish. Priest Rapids fish are thought to be caught in more northerly fisheries than are lower river fish, and one could then argue that they are therefore subject to different ocean conditions (Botsford 1983).

The second method is to look for within-year contrast in flow for the same hatchery. For the Priest Rapids hatchery, this involves looking at May and June releases. River flow in May vs. June varies from year to year. If flow, rather than time of release, were the important factor, we would expect years of high flow in May and low flows in June to show higher survival in May than June, and less difference in years when May and June fish saw the same flow. The size of the fish at release (usually later groups are bigger) and river temperature may confound this analysis. Plow and river temperature are correlated, further complicating the analysis.

7.3. Methods of Measuring Survival

We have implemented two methods for the analysis of survival: virtual population analysis (VPA) and generalized linear models (GLIM). VPA is computationally simpler and provides a direct measure of survival. GLIM is a formal statistical procedure that provides considerable flexibility in choosing data. Whereas VPA must have all catch and escapement data, GLIM can work on any subset of recovery data. Thus if the escapement or in-river catch data are missing or unreliable, VPA will not be reliable. At present, we are unable to say if one method is superior to the other. We plan on continued analysis to understand the performance of both methods, and most likely we will do the analysis of Phase II using both methods.

7.4. Availability of Data

The search for CWT groups usable for analysis of the relationship between in-river variables and survival has been disappointing. We initially considered coho, steelhead, and fall, spring, and summer chinook. Insignificant numbers of upriver coho releases obviate any analysis. Upriver tag groups of spring chinook show so few recoveries that it appears they are not usable for analysis of flows. Downriver spring chinook generally have much better survival than upriver, but determining if upriver stocks have better survival in high flow years would require many more recoveries than are currently available. Steelhead also have few recoveries for upriver stocks, even though return abundance is at or near record levels in recent years. The two races that do appear to have enough data for analysis are fall and summer chinook. Fall chinook data are the most promising since there are many downriver hatcheries with good tagging histories, and Priest Rapids hatchery has many production codes available as an upriver stock.

A limitation of Priest Rapids hatchery is its location-above four dams on the lower Columbia River. CWT groups from Priest Rapids will not be able to provide any information about the flow/survival relationship for the Snake River or upper Columbia River. The number of upriver and downriver CWT groups for summer chinook is smaller than for fall chinook, but may prove usable.

There are two main factors affecting how many code groups are usable. First, the type of comparison made will have a critical effect. If we seek upriver-downriver comparison on a year-by-year basis, then we find reasonably few matches. If we just want to look at flow vs. survival for Priest Rapids without a downstream control, then we have more code groups. The second factor is the use of experimental groups. Thus far, we have used only production groups. However, many experimental groups exist, and many of them may represent such minor experimentation that we can use them in our analysis. We are currently contacting agency staff to find out the exact nature of the experimentation to determine which experimental groups we can include.

7.5. HYPOTHESIS TESTING-PRESENTATION OF RESULTS

We wish to understand the relationship between in-river variables and survival. The traditional approach to this question would be to pose it as a test of a hypothesis: can we reject the null hypothesis of no relationship? As we saw in our power analysis, there are two key questions: which alpha level do we use and what are the consequences of making a Type I or Type II error? We reject this as the appropriate methodology for the final analysis of in-river factors and survival. As an alternative, we will explore the use of Bayesian posterior distributions in which the likelihood of a relationship will be expressed as a probability (e.g., small, medium, or large).

That there is a relationship between in-river factors such as flow and survival seems self-evident; however, the question is not whether there is a relationship, but rather what is the strength and functional form of the relationship. Further complicating the issue are the drastic modifications that the river ecosystem has undergone: impoundments, water removal for irrigation, pesticides from agricultural run-off, etc. Therefore, complicating factors might add considerable noise to the data, limiting our ability to detect any flow/survival relationship. We believe that the final result of Phase II should be an analysis of the relative likelihood of different relationships between in-river factors and survival. This is analogous to presenting confidence bounds for the estimated slope, but philosophically and computationally a bit different. During Phase II, we will be discussing the exact form of final analysis with the oversight group to ensure that the final report will provide the most useful possible information.

&SUMMARY

1. Criteria for selection of coded-wire-tag groups within each species and race were estab lished. Important criteria include length of the time series, whether the groups were reared under standard hatchery production techniques, and whether upriver and downriver groups from the same brood year were available.

2. Preliminary analysis indicates that fall chinook meets the data selection criteria. Chinook salmon with a yearling freshwater life history present some limitations, and their value for our analysis will be further tested in Phase II of the project. Coho salmon production above Bonneville Dam is negligible; recovery of tagged steelhead from upriver production is very small.

3. Two methods were considered for the calculation of survivals: Virtual Population Analysis (VPA) and General Linear Models (GLIM). VPA is used by the Pacific Salmon Commission and produces absolute estimates of survival, but it must use all escapement and catch data. GLIM is a statistical procedure that calculates relative estimates of survival, and it can be applied to any subset of the data (e.g., does not need escapement data). Examples of the application of both VPA and GLIM techniques to standard data sets are given. A set of Appendices is included to show the application of GLIM to two different data sets.

4. A technique to estimate variance and thus confidence intervals for VPA estimates of survival was developed. This method was applied to a standard data set. We began the compilation of information about the measurement errors associated with the CWT information, which serves as input information for the variance calculation.

5. A power analysis was performed to explore the probability of detecting a flow/survival relationship and the effect that different levels of variability in the data have on the power to detect the relationship. We concluded that there are reasonably good chances of detecting the relationship.

6. In the second phase, we will be using a new approach. Instead of the traditional hypothesis testing (i.e., testing for a positive flow/survival relationship) for a particular significance level, we will be exploring Bayesian methodology to determine the likelihood of different hypotheses (e.g., different slopes in flow and survival) given the data. This approach will offer a way 'to ponder' alternative management options.

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10. APPENDICES

APPENDIX 1. OBJECTIVES

Objective 1: Evaluation of methodologies to determine survival

Task 1.1: Implement to Virtual Population analysis **(VPA)** techniques currently used by the Pacific Salmon Commission (PSC). The VPA technique must be documented, and all of the assumptions, especially shaker mortality, understood.

Task 1.2: Develop confidence bounds for VPA. VPA calculates cohort size at each age by using catch, escapement and mortality rate data or estimates. By assigning variances to each of these inputs, the variance of the survival rate can be estimated by standard Monte Carlo procedures. Computationally this is quite simple, the only difficulty is assigning variances to'the catch, escapement, and mortality estimates.

Task 1.3: Implement Generalized Linear Models (GLIM) methodology to estimate relative survival rates of CWT groups. The GLIM methodology provides a framework for statistical comparison of CWT survivals. This approach will provide a well-accepted statistical approach to estimation and comparison of survival rates. The **GLIM** approach will permit us to use all of the CWT code groups from a hatchery and brood year, see if they are different, and find out which codes are similar and which are different. We can then examine the groupings of survivals and compare them to hatchery practice. This should, in principle, greatly facilitate assignment of survival groups to 'production' releases. For instance, if there turns out to be no significant differences in survival, we can sue the mean survival of all CWT groups.

Task 1.4: Evaluate the ability of each method to detect survival differences using Monte Carlo techniques. Simulated data sets with known differences in survival will be evaluated by each method to see how small a difference in survival can be detected.

Objective 2: Data Assembly

Assembling the data for this analysis is a major undertaking. In principle we envision assembling **CWT** data for every species and stock at every Columbia Basin hatchery over the past 15 years. Emphasis will be placed on compiling the existing CWT data for upriver hatcheries above the Dalles Dam before doing lower-river hatcheries.

Task 2.1: Assemble CWT release and catch data. CWT data are currently available on the Pacific States Marine Fisheries Commission (PSMFC) database.

Task 2.2: Assemble CWT recoveries **from** in-river catches and escapement data. It is generally recognized that the consistency of records of **CWTs** recovered at hatcheries is much more problematic than ocean catches and the PSMFC database on hatchery recoveries is not uniformly reliable. Assembly of these data will require extensive personal visits to hatcheries **and** to agencies. It will also require going over raw data records **and** discussion of hatchery procedures with hatchery staff. A key question is what percentage of marked fish were detected at the hatchery.

Task 2.3: Assemble data available on passage losses and straying. An additional difficulty is determination of passage mortality and straying once **fish** 'disappear' between dam counts. We will attempt, using the best available methodology, to assess these **losses** and **put** confidence bounds on the reliability of the estimates. Straying and passage losses (as well as shaker and gill net drop-outs) do pose a challenge and undoubtedly add uncertainty to the analysis. However, the VPA technique applied to several Columbia **River** stocks is recognized as the best available methodology to determine if ocean harvest changes are effective and indeed a large portion of the PSC regulations are driven by such analysis.

Objective 3: Calculate Survival and Confidence Bounds on Survivals

Task 3.1: Perform calculations. Once that data are assembled and the methods developed, we can precede to actually perform the analysis. This will require two parts: **first,** we must examine each brood year for each hatchery to determine which CWT groups are representative, and second we must calculate the estimates. What should emerge is a series of tables for each hatchery, for each brood year, and for each species, a total adult production, a survival rate, and a variance of the survival rate. If large numbers of releases were treated in different ways, we may have more than one survival rate estimate and we would calculate that. We are assuming that we can also tabulate the number of juveniles released.

Objective 4: Calculate the Ability to Determine Survival Changes

Task 4.1: Calculate the size of the survival change and probability of detecting the change at specified levels of significance. Given the levels of variance in survival estimated under Objective 3, we can now calculate the probability of determining that survival changed due to **a** factor in the fresh water life history. For any level of significance **(0.1. 0.5,** etc.), we will be able to see how large a change in survival must occur to be considered significant.

APPENDIX 2. CODE GROUPS ANALYZED

Appendix 2.1. Fall chinook code groups analyzed. Release and recovery information, together with VPA survival estimates up to age 2 arc provided.

HATCHERY: ABERNATHY SCDC
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
050450	78	APR79	MAY79	0 4 0	75.3	82	so	316.57	77.82	0 0149
050451	78	APR79	MY79	4 0 0	75.3	58	40	207.71	57.28	0.0128
050644	79	APR80	MAY80	36335	27.0	59	31	19 .83	.32	0.0148
050646	79	APR80	MAY80	114891	70.0	154	113	. .10	1: .84	0.0144
050744	80	APR81	MAY81	19091	0.0	49	42	. .98	6 .13	0.0277
050745	80	APR81	MY81	63536	0.0	135	146	47 .38	21 .50	0.0219
051058	81	APR82	JUN82	90643	55.0	36	31	12 .53	4 .54	0.0041
051059	81	APR82	JUN82	29796	55.0	9	13	3 .56	2 .55	0.0046

HATCHERY: BONNEVILLE
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
071842	78	MAY79	MAY79	287916	67.9	223	4	851.77	4.06	0.0073
071843	78	MAY79	MAY79	15102	80.0	2	0	5.41	0.00	0.0010
072157	79	MAY80	MAY80	121071	73.9	36	12	138.82	12.22	0.0032
072156	80	APR81	APR81	129961	73:0	72	90	236.25	97.82	0.0061
072329	80	MAY81	MAY81	75717	67.7	37	52	149.29	52.92	0.0065
072407	81	APR82	APR82	105872	so.0	85	77	267.84	77.06	0.0075
072408	81	MAY82	JUN82	96798	10.0	13	8	58.87	8.00	0.0016
072663	81	APR82	APR82	102386	92.0	143	3	399.28	3.04	0.0091

HATCHERY: COWLITZ
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
631942	78	JUN79	OCT79	143568	54.5	75	105	246.87	140.19	0.0072
632154	79	JUN80	JUL80	244267	128.4	102	65	257.08	103.17	0.0040
632137	79	MAR81	APR81	20719	9.4	93	96	269.37	122.11	0.0488
632156	80	JUN81	JUN81	153216	86.8	164	248	524.17	278.17	0.0141
632255	80	JUN81	JUN81	121271	80.3	53	81	183.73	105.17	0.0066
632032	81	JUN82	JUL82	41295	97.9		0	9.47	0.10	0.0005
632462	81	JUN82	JUL82	199176	88.1	2:	23	61.77	27. 5	0.0010
632603	81	SEP82	SEP82	47450	30.5	4	8	19.28	14.17	0.0014

HATCHERY: GRAYS RIVER
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS CATCH		EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
631603	76	JUN77	JUN77	135781	74.0	32	8	112.58	10.06	0.0024
131615	76	AUG77	AUG77	15197	24.0	7	0	44.96	0.00	0.0085
631743	77	MAY78	MAY78	143182	72.6	16	4	44.17	4.64	0.0008
631937	78	JUN79	JUN79	68115	92.0	19	7	41.99	7.60	0.0019
631833	78	JUN79	JUN79	7635	92.0	2	2	3.65	2.1	0.0023
631646	78	JUN79	JUN79	73872	92.0	10	7	21.54	8.5	0.0012
632043	79	JUN80	JUN80	37456	77.1	20	7	63.96	16.4	0.0059
632263	80	JUN81	JUN81	64096	84.4	41	24	111.26	23.8	0.0061
632459	81	JUN82	JUN82	45361	87.1	6	7	12.86	11.1	0.0014
632458	81	JUN82	JUN82	27460	87.2	2		6.40	0.0	0.0006
632237	82	JUN83	JUN83	97135	97.0	7s	7:	a9 .'0	72.4	0.0105

HATCHERY: PRIEST RAPIDS
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
131202	75	JUL76	JUL76	152412	37.0	658	412	2718.08	676.08	0.0618
131101	75	JUL76	JUL76	132004	95.0	485	266	1636.73	606.49	0.0501
631662	76	JUN77	JUN77	147338	96.0	271	81	821.41	321.44	0.0224
631741	77	JUN78	JUN78	152532	90.0	149	147	480.09	254.55	0.0128
632017	78	JUN79	JUN79	82242	77.0	12	16	26.27	19.54	0.0016
631958	78	JUN79	JUN79	5316	77.0	2	1	5.31	1.02	0.0030
631857	78	JUN79	JUN79	17467	77.0	4	3	11.75	10.65	0.0036
631821	78	MAY79	MAY79	40138	74.0	60	48	144.65	193.97	0.0196
631948	79	MAY80	JUN80	147145	76.5	201	159	444.18	305.18	0.0139
632261	80	MAY81	MAY81	42089	67.0	107	85	314.97	222.41	0.0337
632155	SO	JUN81	JUN81	194649	91.0	222	154	696.37	236.69	0.0140
632456	ii	MAY82	MAY82	48700	67.0	117	77	355.11	100.21	0.0261
632252	81	MAY82	JUN82	262176	86.0	347	212	1132.67	353.48	0.0160
632612	82	JUN83	JUN83	202388	63.0	1029	404	3741.40	1190.65	0.0690
632611	82	MAY83	MAY83	204141	84.0	362	262	1154.00	458.56	0.0217
632860	83	JUN84	JUN84	74170	76.0	269	111	916.33	143.62	0.0384
632859	83	JUN84	JUN84	74392	76.0	303	121	1000.97	228.94	0.0439
632848	83	JUN84	JUN84	74170	76.0	328	130	1160.63	194.97	0.0485
632330	ii	APR86	APR86	107461	8.0	239	39	828.96	61.23	0.0232
633222	84	JUN85	JUN85	105224	54.0	375	82	1200.81	154.87	0.0354
633221	84	JUN85	JUN85	103665	54.0	331	80	1152.48	123.93	0.0321
634102R4	85	JUN86	JUN86	203534	58.4	29	0	107.29	0.00	0.0013

HATCHERY. SPRING CREEK
SPECIES: FALL CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
051002	75	OCT76	OCT76	47929	9.0	278	0	1056.99	0.30	0.0553
050902	75	AUG76	AUG76	49860	11.3	284	1	1057.95	1.00	0.0525
150802	75	MAY76	MAY76	96964	57.0	227	0	903.82	0.00	0.0217
050702	75	MAY76	MAY76	100653	57.0	253	1	1076.15	1.00	0.0252
150602	75	APR76	APR76	96117	72.0	205	2	883.52	2.00	0.0220
050502	75	APR76	APR76	101080	10.0	197	2	760.03	2.00	0.0179
050402	75	APR76	APR76	99647	87.0	206	0	840.58	0.00	0.0199
050102	75	APR76	APR76	96016	'9.0	149	2	622.90	2.00	0.0155
050202	75	MA76	MAR76	100605	115.0	171	1	601.64	: 00	0.0157
050102	75	MAR76	WI76	96753	19.0	164	0	680.37	a.00	0.0163
054901	76	APR77	APR77	75822	79.0	269	39	983.74	49.00	0.0333
054601	76	MAY77	MAY77	141161	42.0	50	14	174.28	14.00	0.0034
054501	76	APR77	APR77	95813	80.0	335	46	1279.50	46.00	0.0341
054401	76	APR77	APR77	96769	8b.0	334	52	1267.12	52.00	0.0336
054301	76	MAR77	MAR77	146403	101.0	S 0	76	1980.93	86.80	0.0339
054201	76	APR77	APR77	91428	81.7	115	15	433.69	29.51	0.0126
OS4101	76	APR77	APR77	87701	77.2	158	24	581.83	57.40	0.0181
050341	71	AUG78	AUG78	50565	16.0	137	37	435.29	17.00	0.0235
050340	77	AUG78	AUG78	52092	16.0	175	57	604.30	57.00	0.0312
050339	77	AU276	AUG78	49920	16.0	128		447.60	46.00	0.0247
OS6201	77	APR78	APR78	92214	66.0	338	1::	1172.61	126.68	0.0328
OS6001	77	APR78	APR78	98122	64.0	449	188	1558.80	188.00	0.0417
055701	1 1	MAY78	MAY78	155177	56.0	202	82	755.12	82.00	0.0130
055601	77	MAR78	MAR78	149725	104.0	318	83	1225.71	83.00	0.0204
OS0446	78	MAR79	MAR79	245981	125.0	378	152	1206.45	152.00	0.0134
050445	78	AUG79	AUG79	55635	14.0			1.89	0.00	0.0001
050444	78	APR79	APR79	135537	78.0	69:		2313.75	303.00	0.0464
050434	78	APR79	APR79	95581	87.0	420	::I	1305.27	195.0	0.0385
050433	78	MAY79	MAY79	140948	52.0	447	202	1509.24	208.15	0.0294
050642	79	AUG80	AUG80	23563	19.0	34	16	97.37	16.79	0.0125
050641	79	MY80	MAY80	61771	51.0	401	126	1183.72	128.11	0.0476
050640	79	APR80	APR80	77720	83.0	416	163	1227.56	182.68	0.0415
050639	79	MAR80	MAR80	130208	123.0	387	158	1126.19	167.87	0.0225
050752	80	AUG81	AUG81	7182	15.2	4	5	14.25	5.00	0.0069
050751	80	MAR81	MAR81	15378	102.0	5	0	12.79	0.00	0.0019
050750	80	MAR81	MAR81	11765	121.0	0	3	0.00	3.00	0.0005
050749	80	APR81	APR81	30911	71.0	19	14	70.93	14.02	0.0068
050748	80	MAR81	MAR81	28025	118.0	8	1	27.72	1.00	0.0022
050746	80	APR81	APR81	150544	75.0	388	9	1204.73	15.21	0.0196
050743	80	APR81	APR81	25723	75.0	58	2	220.86	2.33	0.0206
050742	80	MAY81	MAY81	63119	65.4	37	22	135.36	22.02	0.0061
050741	80	APR81	APR81	76731	71.0	36	37	121.42	37.00	0.0049
050740	80	MAR81	MAR81	104666	90.0	36	23	115.18	23.02	0.0033
051057	81	APR82	APR82	102331	79.0	182	a	537.22	3.30	0.0122
051052	81	MAY82	MAY82	58312	48.6	108	69	350.78	69.00	0.0172
051051	81	APR82	APR82	38854	78.0	21	26	59.09	27.35	0.0053
051050	81	MAR82	MAR82	151366	110.0	103	60	311.53	60.06	0.0057
050851	81	APR82	APR82	46707	79.0	69	0	201.62	0.00	0.0100
051145	82	APR83	APR83	52282	55.0	121	99	346.29	102.98	0.0209
051144	82	APR83	APR83	51716	55.0	115	82	407.27	82.00	0.0233
051143	82	APR83	APR83	51266	55.0	138	121	416.63	121.00	0.0249
051141	82	APR83	APR83	49749	54.0	145	94	483.49	94.00	0.0277
051152	83	APR84	APR84	46899	69.0	22	4	67.98	4.00	0.0037
051151	83	APR84	APR84	44500	68.0	21	6	61.19	6.00	0.0034
051150	83	APR84	APR84	48695	68.0	23	7	68.07	7.00	0.0037
051146	83	APR84	APR84	48730	68.0	15	3	56.79	3.00	0.0029
051539	84	FEB85	FEB85	36912	145.0	7	4	19.50	4.00	0.0015
051538	84	FEB85	FEB85	37373	145.0	5	0	16.86	0.00	0.0009
051537	84	FEB85	PO.5	42707	147.0	9	3	32.01	3.00	0.0018
051536	84	FEB85	FEB85	41826	147.0	4	2	13.71	2.00	0.0010
051535	84	FEB85	FEB85	53653	167.0	4	2	6.81	2.00	0.0004
051534	84	FEB85	FEB85	47467	167.0	.	3	14.45	3.00	0.0010
050209	85	MAY86	MAY86	52508	37.8	.	0	14.10	0.00	0.0007
050208	85	MAY86	MAY86	41980	37.8	5	1	18.24	1.00	0.0011
050115	85	APR86	APR86	51921	68.2	5	0	13.96	0.00	0.0006
050114	85	APR86	APR86	43406	67.2	5	1	16.30	1.00	0.0010
050113	85	MAR86	MAR86	51218	121.6	32	0	115.41	0.00	0.0055
050112	85	MAR86	MAR86	44147	125.0	22	5	75.27	5.00	0.0045
050111	85	MAY86	MAY86	96854	37.8	13	1	43.25	1.00	0.0012
050110	85	APR86	APR86	93292	67.2	20	1	78.18	1.00	0.0021
050109	85	MAR86	MAR86	91229	121.6	44	3	156.38	3.00	0.0041

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Appendix 2.2. Spring chinook code groups analyzed. Release and recovery information, together with VPA survival estimates up to age 2 are provided.

HATCHERY: CARSON RIVER
SPECIES: SPRING CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
140203	74	MAR76	MAR76	50663	19.5	1	0	2.00	0.00	0.0001
140101	74	APR76	APR76	46736	11.1	3	0	15.00	0.00	0.0010
141211	75	APR77	APR77	37086	18.0	4	4	4.00	12.05	0.0003
141111	7s	MAR77	MAR77	94519	21.4	5	4	10.56	6.03	0.0004
140303	75	SEP76	SEP76	89033	45.3	3	J	3.09	11.01	0.0004
7697	77	APR79	APR79	39114	19.8	0	11	0.00	13.00	0.000~
7672	77	MAY79	APR79	36274	19.5	0		0.00	4.00	0 0002
768686	77	MAY79	MAY79	40372	19.6	1	1:	1.03	15.00	0.0007
760601	77		MAY79	39794	18.5	0	8	0.00	10.00	0.0004
767076	77	APR79	APR79	38293		0	9	0.00	9.99	0.0004

HATCHERY: LEAVENWORTH NFH
SPECIES: SPRING CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
130712	74		MAY76	101110	15.4	3	6	6.88	6.20	0.0004
130711	75	APR76	APR76	100447	15.1	33	63	95.73	65.20	0.0040
131213		APR77	APR77	98212	19.3	2	33	6.34	40.51	0.0013
131212	75	MAY77	MAY77	98835	17.3	2	23	9.87	28.76	0.0010
131211	76	APR77	APR77	99561	19:o	14	124	24.03	132.42	0.0048
631704	76	MAY78	MAY78	94645	14.4	1	123	2.60	144.41	0.0027
631701	76	APR78	APR78	94359	14.6	6	69	8.31	84.91	0.0015
631702	77	APR78	APR78	95228	14.6	12	170	17.05	196.46	0.0054
631810		APR79	APR79	100388	15.5	0	94	0.00	123.37	0.0021
631809	77		APR79	97517	16.5	8	163	8.07	198.12	0.0044
631808	78	MAY79	MAY79	94004	16.0	0	174	0.00	206.48	0.0037
036102		APR80	MAY80	96638	18.0	1	1	1.01	2.01	0.0001
035402	70	MAY80	MAY80	32641	10.0	0	2	0.00	4.02	0.0002
035202	70	APR80	APR80	32960	18.0	2	2	1.00	2.00	0.0001
035002	70	APR80	APR80	35439	18.0	0	2	0.00	3.02	0.0001
034902	78	APR80	APR80	32649	18.0	1	1	1.01	1.01	0.0001
034502	78	MAY80	MAY80	32464	10.0	1	0	1.05	0.00	0.0001
034302		APR80	APR80	32441	18.0	0	2	0.00	2.03	0.0001
051041	80	APR82	APR82	43523	19.3	1	15	2.42	15.15	0.0000
051339	81	APR83	APR83	94199	19.5	11	72	27.39	78.48	0.0022
051338	81	APR83	MAY83	94539	17.6	11	52	30.91	54.54	0.0020
051533	83	APR85	APR85	43297	19.7	18	0	44.03	0.00	0.0032
051532	83	APR85	APR85	40437	20.1	10	0	26.77	0.00	0.0021
051530	83	NOV84	NOV84	101000	20.7	6	0	21.52	0.00	0.0007
051575		SEP84	SEP84	93064	24.5	9	0	22.14	0.00	0.0007
051528	83	JUN84	JUN84	93582	70:o	2	0	6.60	0.00	0.0002
051223	84	APR85	APR85	24917	10.1	4	0	9.25	0.00	0.0012
051551	84	MAR86	MAR86	29092	17.1	1	0	1.00	0.00	0.0001
051550		MAR86	MAR86	35715	17.0	2	0	6.04	0.00	0.0005
05150			MAR86	46017	11.4	2	1	4.02	1.02	0.0001
051547	84	NOV85	NOV85	95431	21.4	4	0	6.02	0.00	0.0002
051259	84	OCT85	OCT85	25695	22.0	2	0	6.04	0.00	0.0007

HATCHERY: RAPIDS RIVER
SPECIES: SPRING CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
100102	74	APR76	APR76	127425	18.4	13	0	Jb. 18	0.00	0.0009
100207	75	APR77	APR77	125600	15.9	2	6	25.99	20.06	0.000~
100206	75	NOV76	APR77	127600	24.0	0	7	0.00	29.05	
100214	76	OCT77	MAR78	127900	14.0	2	37	2.11	49.44	0.0004
100424	77	NOV78	MAR79	122000	15.0	20	50	27.07	60.12	0.00075
100415	77	NOV78	MAR79	127275	15.0	29	32	42.23	38.09	0.0015
101114	78	NOV79	APR80	39100	14.3	2	6	3.15	7.06	0.0006
102113	78	NOV79	APR80	39200	14.3	4	1	9.67	1.01	0.0000
102238	79	FEB81	APR81	51925	14.8	1	10	8.51	20.00	0.0000
102237	79	FEB81	APR81	44250	14.8	0	7	0.00	13.02	0.0005
102236	79	FEB81	APR81	49000	14.8	2	3	2.00	5.01	0.0001
102415	80	MAR82	APR82	41425	28.0	1	15	1.00	22.20	0.0010
102414	80	MAR82	APR82	42100	28.0	4	11	4.63	12.11	0.0008
102318	81	MAR83	MAR83	40300	27.0	6	1	11.32	2.01	0.0009
102717	81	MAR83	MAR83	41075	27.0	11	0	30.19	0.00	0.0023
102705	82	MAR84	MAR84	41175	27.0	5	0	10.93	0.00	0.0008
102704	82	MAR84	MAR84	41900	27.0	2	0	12.00	0.00	0.0009
102815	83	MAR85	APR85	19725	23.0	10	0	40.05	0.00	0: 0066
102811	83	MAR85	APR85	40850	23.0	19	0	51.73	0.00	0.0041
102810	83	MAR85	APR85	39425	23.0	18	0	55.33	0.00	0.0046
103015	84	MAR86	APR86	99950	21.8	20	0	51.48	0.00	0.0015
103014	84	MAR86	APR86	103125	21.8	9	0	19.10	0.00	0.0006
103013	84	MAR86	APR86	103275	21.8	9	0	23.73	0.00	0.0007

Appendix 2.3. Summer chinook code groups analyzed. Release and recovery information, together **with** VPA survival estimates up to age 2 **are** provided.

HATCHERY WELLS CHANNEL
SPECIES SUMMER CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP	SURVIVAL (to age 2)
110511	74	MAR76	MAR76		9.0	54	53	219.34	57.08	0.0068
131203	75	JAN77	APR77	189348	9.9	95	130	119.00	147.81	0.0156
130910	75	JUN76	JUN76	91574	110.0	21	20	62.02	22.33	0.0026
130710	75	JUN76	JUN76	122961	33.0	70	112	541.89		0.0144
631654	76	JUN77	JUN77	132677	34.0	51	11	137.47	130.27 15.34	0.0042
631643	76	MAY78	MAY78	149308	8.5	244	400	769.59	484.91	0.0267
631642	76	JUN77	JUN77	153604	160.0	23	81	178.59	103.02	0.0057
631607	76	MAY77	MAY77		32.0	26	22		24.47	0.0019
631762	77	JUN78	JUN78		43.0	21	53	82.27	56.27	0.0024
631749	77	JUN78	JUN78	194060	45.0	26	24	81.35	28.97	0.0015
632326	83	APR85	APR85	202276	12.0		11	79.35	11.33	0.0014
632845	83	MAY84	MAY84	53040	46.0	23	14	82.24	15.71	0.0012
633234	84	JUL85	JUL85		35.0		2	63.09	2.04	0.0031
633225	84	APR86	APR86	50075	12.5	18	0	34.59		0.0070
633224	84	APR86	APR86	104678	10.6	30	0	30.34	0.00 0.00	0.0018
633220	84	MAY85	MAY85	102605	72.0	32	4	105.86	4.08	0.0027
633219	84	MAY85	MAY85				4	106.70	4.08	0.0029
810310	85	APR87	APR87	51135	73.0	11	0	30.41		0.0014
810309	85	APR87	APR87	51178	9.5		0	24.33	0.00 0.00	0.0011
810308	85	APR87	APR87	48447		19	0	7.42	0.00	0.0003
633463	85	MAY86	MAY86	49996	[illegible]	1	0	3.37	0.00	0.0002
633462	85	MAY86	MAY86		56.0	1	0	2.41	0.00	0.0001
633460	85	MAY86	MAY86	49996	56.0	1	0	0.00	0.00	0.0000

HATCHERY: WINTHROP NFH
SPECIES: SUMMER CHINOOK

CODE ID	BROOD YEAR	RELEASE TIME from	to	RELEASE SIZE	SIZE (ind/lb)	TAGS RECOVERED CATCH	ESCAP.	EXPANDED RECOVERIES CATCH	ESCAP.	SURVIVAL (to age 2)
131113	75	APR77	APR77	93537	11.5	3	3	10.09	7.02	0.0009
130701	75	APR77	APR77	99185	11.7	12	14	58.78	20.97	0.0019
130513	75	MAY77	MAY77	95603	10.5	2	10	7.90	23.30	0.0006
631731	76	MAY78	MAY78	91395	13.5	2	121	7.21	152.91	0.00~1
631724	76	APR78	APR78	86733	14.0	7	40	19.39	51.49	0.0017
631723	76	APR78	APR78	80542	13.5	44	50	135.80		0.0066
631820	77	MAY79	MAY79	77602	13.0	10	77	23.94	57.73 90.17	0.0029
631812	77	APR79	APR79	67320	14.0	0	25	0.00	J1.49	0.0009
631811	77	APR79	APR79	86237	12.0	7	48	16.19	61.12	0.0019

APPENDIX 3. PRIEST RAPIDS FALL CHINOOK RECOVERIES AS USED AS INPUT TO GLIM

EXAMPLE 1.

COLUMN	VARIABLE	CODING/COMMENTS
1	Code group(brood year)	1=631662(76), 2=631741(77), 3=631821(78), 4=631948(79), 5=632155(80), 5.632156(81), 7=632611(82).
2	Age	1=2yr, 2=3yr, 3=4yr, 4=6 y r .
3	Seasonal time	1=JAN1-JUN30, 2=JUL1-DEC31.
4	Recovery area(State)	1=Alaska, 2=British Columbia, 3=Washington, 4=Oregon.
5	Number of fish release	
6	Tags recovered in sample	
7	Expanded number of tags	
9	Sampling fraction	Tags recovered/Expanded number

1	1	2	2	147338	6.00	16.99	.3531489
1	1	2	3	147338	6.00	24.13	.2486531
1	2	1	2	147338	3.00	11.01	.2724796
1	2	1	3	147338	3.00	12.32	.2435065
1	2	2	1	147338	1.00	7.30	.1369863
1	2	2	2	147338	23.00	128.13	.1795052
1	2	2	3	147338	15.00	37.18	.4034427
1	2	2	4	147338	16.00	57.42	.2786486
1	3	1	1	147338	20.00	55.87	.3579738
1	3	1	2	147338	23.00	92.55	.2485143
1	3	2	1	147338	25.00	95.72	.2611784
1	3	2	2	147338	17.00	76.69	.2216717
1	3	2	3	147338	46.00	164.18	.2801803
1	3	2	4	147338	25.00	53.47	
1	4	1	1	147338	14.00	43.93	.3186888
1	4	1	2	147338	5.00	21.80	2293578
1	4	2	1	147338	9.00	63.93	:140779
1	4	2	2	147338	4.00	19.87	2013085
1	4	2	3	147338	23.00	131.09	:175452
1	4	2	4	147338	9.00	18.48	.487013
2	1	1	3	152532	1.00	3.09	.3236246
2	1	2	2	152532	6.00	12.47	.4811548
2	1	2	3	152532	37.00	71.41	.5165433
2	1	2	4	152532	3.00	13.89	.2159827
2	2	1	1	152532	1.00	1.13	.8849558
2	2	1	2	152532	6.00	20.95	.2863962
2	2	1	3	152532	1.00	3.26	.3067485
2	2	2	1	152532	5.00	27.10	.1845019
2	2	2	2	152532	9.00	58.07	.1549854
2	2	2	3	152532	31.00	64.04	.4840725
2	2	2	4	152532	9.00	25.51	.3528028
2	3	1	1	152532	16.00	45.06	.3550821
2	3	1	2	152532	7.00	27.60	.2536232
2	3	2	1	152532	14.00	81.88	.1709819
2	3	2	2	152532	14.00	70.49	.1986097
2	3	2	3	152532	74.00	116.31	.6362307
2	3	2	4	152532	18.00	37.33	.4821859
2	4	1	1	152532	3.00	4.83	.621118
2	4	2	1	152532	2.00	7.12	.2808989
2	4	2	2	152532	3.00	19.45	.1542416
2	4	2	3	152532	10.00	19.18	.5213764
2	4	2	4	152532	1.00	2.22	.4504505
3	1	2	2	48130	2.00	8.39	.238379
3	1	2	3	48130	3.00	15.99	.1876173
3	1	2	4	48130	2.00	2.97	.6734007
3	2	1	2	48130	1.00	4.84	.2066116
3	2	2	2	48130	2.00	9.59	.2085506
3	2	2	3	48130	16.00	54.30	.2946593
3	2	2	4	48130	2.00	5.48	.3649635
3	3	1	1	48130	18.00	38.39	.4688721
3	3	1	2	48130	3.00	11.72	.2559727
3	3	2	1	48130	2.00	9.94	.2012073
3	3	2	2	48130	5.00	20.53	.243546
3	3	2	3	48130	28.00	99.46	.2815202
3	3	2	4	48130	5.00	10.74	.464684
3	4	1	1	48130	3.00	5.27	.5692599
3	4	1	2	48130	1.00	4.68	.2136752
3	4	2	1	48130	1.00	5.89	.1697793
3	4	2	3	48130	4.00	30.42	.1314925
4	1	2	1	147145	1.00	4.60	.2173913
4	1	2	2	147145	1.00	3.91	.2557545
4	1	2	3	147145	32.00	48.82	.6554692
4	2	1	1	147145	1.00	1.56	.6410257
4	2	1	2	147145	2.00	6.68	.2994012
4	2	1	3	147145	3.00	8.53	.3516999
4	2	1	4	147145	1.00	2.31	.4329004
4	2	2	1	147145	5.00	13.28	.376506

4	2	2	2	147145	9.00	58.38	1541624
4	2	2	3	147145	47.00		.5680856
4	2	2	4	147145	7.00	121.16	.3308128
4	3	1	1	147145	21.00	38.58	.5961638
4	3	1	2	147145	8.00	29.23	.2736914
4	3	1	3	147145	1.30	2.19	.456621
4	3	2	1	147145	18.00	74.31	.2422285
4	3	2	2	147145	5.00	27.97	.178763
4	3	2	3	147145	61.00	141.16	.4300014
4	3	2	4	147145	11.00	54.86	.6015311
4	4	1	1	147145	10.00	30.44	3285151
4	4	1	4	147145	2.00	2.00	1
4	4	2	1	147145	1.00	0.58	1.724138
4	4	2	2	147145	4.00	23.64	1692047
4	4	2	3	147145	10.00	14.31	6988121
4	4	2	4	147145	15.00	21.12	7102273
5	1	2	1	194649	1.00	0.12	1.219512
5	1	2	2	194649	4.00	12.03	3325021
5	1	2	3	194649	9.00	9.00	i
5	2	1	2	194649	1.00	a.11	.4329004
5	2	2	1	194649	2.00	6 . 0	.3007519
5	2	2	2	194649	12.00		.1714041
5	2	2	3	194649	36.00	94.00	.3829787
5	2	2	4	194649	0.00	18.16	.4405286
5	3	1	1	194649	26.00	68.09	.3818476
5	3	1	2	194649	5.00	17.15	.2915452
5	3	2	1	194649	16.00	0 . 62	.2514933
5	3	2	2	194649	28.00	163.78	.1709611
5	3	2	3	194649	71.00	79.00	.8987343
5	3	2	4	194649	35.00	80.93	.4324725
5	4	1	1	194649	10.00	26.38	.3790751
5	4	1	2	194649	2.00	7.99	.2503129
5	4	2	1	194649	4.00	16.26	.2460025
5	4	2	2	194649	12.00	53.18	.2256487
5	4	2	3	194649	37.00	62.61	.5909599
5	4	2	4	194649	16.00		
6	1	2	2	48700	6.00	64.81	.4398827
6	1	2	3	48700	2.00	13.64	
6	2	1	1	48700	1.00	10.16	.2314815
6	2	1	2	48700	3.00	10:.68	.2808989
6	2	2	1	48700	2.00	5.69	.3514938
6	2	2	2	48700	5.00	24.12	.2072969
6	2	2	3	48700	25.00	38.31	.6525711
6	2	2	4	48700	18.00	41.91	.4292869
6	3	1	1	48700	7.00	17.77	.3939223
6	3	1	2	48700	2.00	5.11	.3913894
6	3	2	1	48700	8.00	23.46	.341006
6	3	2	2	48700	14.00	66.20	.2114803
6	3	2	3	48700	45.00	50.07	.8987418
6	3	2	4	48700	25.00	82.18	.3042102
6	4	1	1	48700	1.00	2.50	.4
6	4	2	1	48700	2.00	13.60	.1470588
6	4	2	2	48700	3.00	10.39	.2887392
6	4	2	3	48700	6.00	6.48	.9259259
6	4	2	4	48700	6.00	20.50	.2926829
7	1	2	1	204141	1.00	4.29	.2331002
7	1	2	2	204141	a.00	8.94	.2237136
7	1	2	3	204141	21.00	81.23	.2585252
7	1	2	4	204141	3.00	8.07	.3717472
7	2	1	1	204141	1.00	1.76	.5681818
7	2	2	1	204141	9.00	39.61	.2272153
7	2	2	2	204141	24.00	112.74	.2128792
7	2	2	3	204141	121.00	137.45	.880128
7	2	2	4	204141	57.00		
7	3	1	1	204141	11.00	196.83	.3540393
7	3	1	2	204141	6.00	31.07	
7	3	1	3	204141	1.00	22.96	.4444444
7	3	1	4	204141	1.00	1.00	1
7	3	2	1	204141	19.00	55.55	.3418496
7	3	2	2	204141	40.00	175.00	.2285714
7	3	2	3	204141	128.00	263.02	.486655
7	3	2	4	204141	83.00	265.75	.3123236
7	4	1	1	204141	7.00	24.02	.2914238
7	4	2	1	204141	7.00	18.25	.3835616
7	4	2	2	204141	9.00	29.40	.3061225
7	4	2	3	204141	1.00	4.47	.2237137
7	4	2	4	204141	26.00	115.29	.2255183

APPENDIX 4. TRANSCRIPT OF GLIM ANALYSIS OF DATA IN APPENDIX 3, EXAMPLE 1

(Comments are added as a guide to the fitting process.)

```
[o] GLIM 3.77 update 1 (copyright) 1985 Royal Statistical Society, London
[o]
[i] ? $C This c indicates comment. Commands ('Directives' in GLIM) are $
[i] ? $C shown in capital letters$
[o] ?
[o] ?
[i] ? $C*************DATA SPECIFICATION.................*******************$
[i] ? $C Declare the length of the data sic Co use and the variables' names$
[i] ? $C as they will appear in the input file$
[i] ? $UNITS 144$DATA by ago sea area rel counts expn frac$
[i] ? $C declare chr data input channel. It will ask for the Inpuc file name$
[i] ? $C and will read it with the format given above$
[i] ? $DINPUT 21$
[a] ? $C Define the categorical variables and the number of levels ... rch$
[i] ? $FACTOR by 7 ago 4 sea 2 area 4$
[o] ?
[o] ?
[i] ? $C************MODEL SPECIFICATION.........*************************$
[i] ? $C Define the response variable$
[i] ? $YVAR counts$
[i] ? $C Define the 'link' function (makes ... ffocts ... ddiclvol as logarithmic$
[i] ? $LINK 1$
[i] ? $C Define the error structure: Poisson error with scale Csccor (Deviance/DF)$
[i] ? $C co be estimated from the fitting$
[i] 7 $ERR p$SCALE $
[i] ? $C Calculate and define an offset (release sit8 by sampling fraction)$
[i] ? $C to standardize chr occurrences in the catch according to the initial$
[i] ? $C abundance
[i] ? $CAL off=%log(rel*frac)$OFFSET off$
[o] ?
[i] ? $C*********FITTING PROCEDURE AND MODEL SELECTION.....................**$
[i] ? $C Models of increasing complexity will be tried$
[i] ? $C Flc 8 modal consisting of the 'grand mean'; the deviance is the$
[i] ? $C total variability in the data set$
[i] ? $FIT $
[o] deviance = 2485.2 at cycle 4
[o]      d.f. =  143
[o]
[i] ? $C Add the BROOD YEAR effect co chr modal; between parenthesis are$
[i] ? $C the changes in deviance and degrees of freedom with respect co $
[i] ? $C the previous model$
[i] ? $FIT +by$
[o] deviance = 2257.0 (change =  -228.2) at cycle  4
[o]      d.f. =  137   (change =    -6  )
[o]
[i] ? $C The SCALE FACTOR (stored in %sc after each fitting) is the ratio$
[i] ? $C between deviance and degrees of freedom and gives an ... of$
[i] ? $C the overdispersion w/r co a Poisson error structure. The change $
[i] ? $C in deviance 'corrected' by this factor has a Chi-square distribution$
[i] ? $C with change in degrees of freedom, what enables Co test for the $
[i] ? $C new factor significance$
[i] ? $CAL %z=228.2/%sc$print %z$
[o]    13.8$
[i] ? $C Compare this value rich the Chi-square critical value for a $
[i] ? $C 0.05 alpha level and 6 degrees of freedom. This value is 11.07 $
[i] ? $C and we keep BROOD YEAR in chr model$
[o] ?
[i] ? $C Display the current model$
[i] ? $DIS m$
[o]
[o] Current model:
[o]   terms =  ... + BY
[o]
[i] ? $C Add seasonal time (semester) and fit the model$
[i] ? $FIT +sea$
[o] deviance = 1849.0 (change = -408.00) at cycle 4
[o]      d.f. =  136   (change =    -1   )
[o]
[i] ? $CAL %z=408/%sc$print %z$
[o]    30.0J.
[i] ? $C The table value for 1 d.f. is 3.84. We keep SEASONAL TIME$
[i] ? $DIS m$
[o] Current model:
```

```
[o]    terms =  1 . BY . SEA
[o]
[i] ? $C Add AGE to the model$
[i] ? $FIT +age$
[o] deviance = 1168.8 (change =  -680.11 at cycle 4
[o]      d.f. =  133   (change =     -3   )
[o]
[i] ? $CAL %z=680.1/%sc$print %z$
[o]      77.39
[i] ? $C Table value 7.81. Keep AGE in the model$
[o]
[i] ? $DIS m$
[o] Current model :
[o]    terms =  1 . BY . SEA . AGE
[o]
[i] ? $C Add AREA to the model$
[i] ? $FIT +area$
[o] deviance = 1006.0 (change = -162.81) at cycle 4
[o]      d.f. =  130   (change   =  -3   )
[o]
[i] ? $CAL %z=162.81/%sc$print %z$
[o]      21.04
[i] ? $C Table value 7.81. Keep AREA.$
[o]
[i] ? $DIS m$
[o]
[o] Current model:
[o]    terms =  1 . BY . SEA + AGE . AREA
[o]
[i] ? $C Add AGE-AREA interaction to the model$
[i] ? $FIT +age.area$
[o] deviance  = 870.3 (change = -135.73) at cycle 4
[o]      d.f. =  121    (change =  -9    ) )
[o]
[i] ? $CAL %z=135.73/%sc$print %z$
[o]      18.87
[i] ? $C Table value 16.92. Keep the interaction$
[o]
[i] ? $DIS m$
[o]
[o] Current model:
[o]    terms =  1 . BY + SEA . AGE + AREA + AGE.AREA
[o]
[i] ? $C Add SEASONAL TIME-AREA interaction$
[i] ? $FIT +sea.area$
[o] deviance = 631.67 (change  = -238.6) at cycle 4
[o]     .d.f.. = 118     (change =        -3   )
[o]
[i] ? $CAL %z=238.6/%sc$print %z$
[o]      44.57
[i] ? $C Table value is 7.81.  Keep the interaction$
[o]
[i] ? $DIS model$
[o]
[o] Current model:
[o]    terms =  1 + BY  + SEA + AGE + AREA + SEA.AREA + AGE.AREA
[o]
[i] ? $C Add SEASONAL TIME-AGE interaction$
[i] ? $FIT +sea.age$
[o] deviance = 597.96 (change =  -33.71) at cycle  4
[o]      d.f. = 115    (change =    -3    )
[o]
[i] ? $CAL %z=33.71/%sc$print %z$
[o]      6.483
[i] ? $C Table value is 7.81. NON-SIGNIFICANT$
[i] ? $C Drop the interaction$
[i] ? $FIT -sea.age$
[o] deviance = 631.67 (change =   +33.7) at cycle 4
[o]      d.f. = 118    (change =    +3   )
[o]
[i] ? $C Add BROOD YEAR-AREA interaction$
[i] ? $FIT +by.area$
[o] deviance  = 420.26 (change =  -211.4) at cycle 4
[o]      d.f. = 100    (change =   -18   )
[o]
[i] ? $CAL %z=211.4/%sc$print %z$
[o]      50.11
[i] ? $C Table value 21.07. Keep the interaction$
[o]
[i] ? $DIS m$
[o] Current model:
```

```
[o]   terms =  1 + BY + SEA + AGE + AREA + BY.AREA + SEA.AREA + AGE.AREA
[i] ? $C Add the BROOD YEAR-AGE interactions
[i] ? $FIT +by.age$
[o] deviance = 298.47 (change = -121.79) at cycle 5
[o]      d.f. =  82     (change =  -18    )
[o]
[i] ? $CAL %z=121.79/%sc$print %z$
[o]    33.46
[i] ? $Table vaiue is 28.87. Keep the interactions
[o]
[i] ? $C Dis e shows the estimates corresponding to this model$
[i] ? $DIS m e$
[o]
[o] Current model:
[o]   terms =  1 + BY + SEA + AGE + AREA + BY.AGE + BY.AREA + SEA.AREA + AGE.AREA
[o]
[o]            estimate        s.e.      parameter
[o]     1       -10.30         1.336     1
[o]     2        0.5870        0.7694    BY(2)
[o]     3        0.4724        1.081     BY(3)
[o]     4       -0.1429        0.7791    BY(4)
[o]     5       -1.283         0.8672    BY(5)
[o]     6        0.5141        1.034     BY(6)
[o]     7       -0.4259        0.8007    BY(7)
[o]     8        0.2632        0.2157    SEA(2)
[o]     9        1.179         1.361     AGE(2)
[o]    10        3.268         1.308     AGE(3)
[o]    11        2.547         1.332     AGE(4)
[o]    12        0.2104        1.303     AREA(2)
[o]    13       -0.8767        1.368     AREA(3)
[o]    14       -4.501         1.733     AREA(4)
[o]    15       -0.9125        0.7152    BY(2).AGE(2)
[o]    16       -1.030         0.6773    BY(2).AGE(3)
[o]    17       -2.354         0.8260    BY(2).AGE(4)
[o]    18       -0.4175        1.038     BY(3).AGE(2)
[o]    19       -0.3815        0.9822    BY(3).AGE(3)
[o]    20       -1.003         1.192     BY(3).AGE(4)
[o]    21       -0.1214        0.7316    BY(4).AGE(2)
[o]    22       -0.4673        0.7125    BY(4).AGE(3)
[o]    23       -1.626         0.7909    BY(4).AGE(4)
[o]    24        0.7091        0.8529    BY(5).AGE(2)
[o]    25        0.6468        0.8102    BY(5).AGE(3)
[o]    26        0.7746        0.8526    BY(5).AGE(4)
[o]    27       -0.4608        0.9559    BY(6).AGE(2)
[o]    28       -0.6767        0.9263    BY(6).AGE(3)
[o]    29       -1.724         1.037     BY(6).AGE(4)
[o]    30       -0.05402       0.7479    BY(7).AGE(2)
[o]    31       -0.2786        0.7307    BY(7).AGE(3)
[o]    32       -1.073         0.3013    BY(7).AGE(4)
[o]    33       -0.1494        0.5432    BY(2).AREA(2)
[o]    34        0.1936        0.4004    BY(2).AREA(3)
[o]    35        0.1341        0.5883    BY(2).AREA(4)
[o]    36       -0.6019        0.7490    BY(3).AREA(2)
[o]    37        0.6217        0.6082    BY(3).AREA(3)
[o]    38       -0.3289        0.8602    BY(3).AREA(4)
[o]    39       -0.2837        0.5535    BY(4).AREA(2)
[o]    40        0.5982        0.4483    BY(4).AREA(3)
[o]    41        0.7273        0.5090    BY(4).AREA(4)
[o]    42        0.1164        0.4801    BY(5).AREA(2)
[o]    43       -0.03672       0.4408    BY(5).AREA(3)
[o]    44        0.6285        0.5084    BY(5).AREA(4)
[o]    45        0.2632        0.6377    BY(6).AREA(2)
[o]    46        0.1921        0.5769    BY(6).AREA(3)
[o]    47        1.660         0.6291    BY(6).AREA(4)
[o]    48        0.4431        0.4697    BY(7).AREA(2)
[o]    49        0.8112        0.4392    BY(7).AREA(3)
[o]    50        2.081         0.4746    BY(7).AREA(4)
[o]    51        1.064         0.3321    SEA(2).AREA(2)
[o]    52        3.020         0.6477    SEA(2).AREA(3)
[o]    53        4.088         0.9909    SEA(2).AREA(4)
[o]    54        0.6729        1.289     AGE(2).AREA(2)
[o]    55       -0.2402        1.222     AGE(2).AREA(3)
[o]    56        1.213         1.421     AGE(2).AREA(4)
[o]    57       -0.8406        1.235     AGE(3).AREA(2)
[o]    58       -1.691         1.169     AGE(3).AREA(3)
[o]    59       -0.1930        1.372     AGE(3).AREA(4)
[o]    60       -1.051         1.277     AGE(4).AREA(2)
[o]    61       -1.685         1.193     AGE(4).AREA(3)
[o]    62        0.2691        1.399     AGE(4).AREA(4)
[o]     scale parameter taken as  3.640
```

```
o|
i| ? SC Add BROOD YEW-SEASONAL TIME interactionS
i| ? SFIT -by.seaS
o| deviance = 270.63 (change =  -27.84) at cycle 4
o|     d.f. =  76    (change =    -6   )
o|
i| ? SC Non-significant. Crop the interactionS
i| ? SFIT -by.seaS
o| deviance = 298.47  (change = ●  27.80 at cycle 5
o|     d.f. 3  a2    (change  =  +6  )
o|
i| ? SC End sectionS
i| ? SSTOPS
```

APPENDIX 5. FALL CHINOOK RECOVERIES FOR 5 COLUMBIA RIVER HATCHERIES AS USED WITHIN GLIM. EXAMPLE 2.

COLUMN	VARIABLE	CODING/COMMENTS
1	Code group	
2	Actual code	
3	Number of fish released	
4	Brood year	1=78, 2.79. 3=80, 4=81
5	Year of recapture	1=81, 2=82, 3.83, 4=84, 5=85
6	Age	1=3yr, 2=4yr
7	Area	1=OR, 2=WA, 3=AK, 4=BC
8	Hatchery	1=Abernathy, 2=Bonneville, 3=Priest Rapids, 4=Spring Creek, 5=Cowlitz
9	Tags recovered in sample	
10	Expanded number of tags	
11	Sampling fraction	Tag8 recovered/Expanded number

1	050450	43400	1	1	1	1	1	5.00	15.17	0.25
1	050450	0400	1	1	1	2	1	22.00	sm.91	0.34
1	050450	41400	1	1	1	4	1	27.00	166.31	0.18
1	050450	0400	1	2	2	1	1	0.00	0.00	0.36
1	050450	63400	1	2	2	2	1	0.00		0.34
1	050450	43400	1	2	2	3	1	0.00	0.00 0.00	0.43
1	050450	43400	1	2	2	4	1	4:oo	lb.0	0.22
2	050451	48900	1	1	1	1	1	4.00	25.62	0.25
2	050451	48900	1	1	1	2	1	20.00	49.53	0.34
2	050451	48900	1	1	1	4	1	8.00	62.80	0.18
2	050451	40500	1	2	2	1	1	1.00	3.91	0.36
2	050451	48900	1	2	2	2	1	1.00	3.51	0.34
2	050451	4000	1	2	2	3	1		0.00	0.43
2	050451	48900	1	2	2	4	1	0.00	3.72	0.22
J	050644	15700	2	2	1	1	1	a.00	4.17	0.36
J	050644	35200	2	2	1	2	1	11.00	41.00	0.34
J	350444	15200	2	2	1	3	1	0.00	0.00	0.43
3	050644	35200	2	2	1	4	1		46.18	0.22
3	050644	35200	2	3	2	1	1	10.00	0.00	0.38
3	050644	35200	2	3	2	2	1	1.00	2.11	0.10
3	050644	35200	2	3	2	3	1	0.00	0.00	0.36
3	050644	35200	2	3	2	4	1	1.00	4.66	0.18
4	050446	112500	2	2	1	1	1	10.00	49.38	0.36
4	050646	112500	2	2	1	2	1	60.00	200.10	0.34
4	050444	112500	2	2	1	3	1	0.00	0.00	0.43
4	050445	112500	2	2	1	4	1	28.00	133.85	0.22
4	050646	112500	2	3	2	1	1	0.00	0.00	0.38
4	050646	112500	2	3	2	2	1	0.00	0.00	0.38
4	050444	112500	2	3	2	3	1	0.00	0.00	0.10
4	050646	112500	2	3	2	4	1	2.00	10.45	0.18
5	050744	19100	3	3	1	1	1	11.00	2.28	0.38
5	050744	19100	3	3	1	2	1		30.15	0.10
5	050744	19100	3	3	1	3	1	0.00	0.00	0.36
5	050744	19100	3	3	1	4	1		90.02	0.18
5	050744	19100	3	4	2	1	1	18.00	0.00	0.60
5	050744	19100	3	4	2	2	1	0.00	0.00	0.41
5	050744	19100	3	4	2	3	1	1.00	2.15	0.31
5	050744	19100	3	4	2	4	1	2.00	3.06	0.23
6	050745	63500	3	3	1	1	1	54.00	143.8.90	0.38
4	05074s	63500	3	3	1	2	1			0.38
6	050745	63500	111			3	1	0.00	0.00	0.36
6	050745	63500	3	3	1	4	1	27.00		0.18
6	050745	63500	3		2	1	1	0.00	147.98 0.00	0.60
6	050745	63500	3	:	2	2	1	0.00	0.00	0.41
6	050745	63500	3	4	2	3	1		0.00	0.31
6	050745	41500	3	4	2	4	1	1.00	3.57	0.23
7	051058	90600	4	4	1		11	1.00	1.40	0.60
7	051058	90600	4	4	1	2	1	4.00	9.03	0.41
7	051058	90600	4	4	1	1	1	0.00	0.00	0.31
7	051058	90600	4	4	1	4	1		69.85	0.23
8	051059	20000	4	4	1		1	10.00	0.00	0.60
	051059	29800	4	4	1	:	1	1.00	2.86	0.41
:	051059	29800	4	4	1	3	1	0.00	0.00	0.31
8	051050	29800	4	4	1	4	1	4.00	17.00	0.23
9	071842	287900	1	1	1	1	2	11.00	56.79	0.25
9	071842	287900	1	1	1	2	2	80.00	238.08	0.34
9	071842	287900	1	1	1	4	a	43.00	250.93	0.18
9	071842	287900	1	2	2	1	2	0.00	0.00	0.36
9	071141	287900	1	2	2	2	2	3.00	6.23	0.34

I	071842	287900	1	2	2	3	2	0.00	0.00	0.43
9	071842	287900	1	2	2	4	2	20.00	104.60	0.22
10	071843	15100	1	1	1	1	2	0.00	0 JO	0.25
10	071843	15100	1	1	1	2	2	3.50	0.00	0.34
10	071843	15100	1	1	1	4	2	0.00	0.00	0.18
10	071843	15100	1	2	2	1	2	0.00	0.00	0.16
10	071843	15100	1	2	2	2	2	0 00	0.00	3 34
10	071843	15100	1	2	2	3	2	0.00	0.00	3 . 0
10	071843	15100	1	2	2	4	2	0.30	1.00	0.22
11	072157	121100	2	2	1	1	2	5.00	0.00	0.36
11	072157	121100	2	2	1	2	2	12.00	35.73	0.34
11	072157	121100	2	2	1	3	2	0.00	0.00	0.41
11	072157	121100	2	2	1	4	2	9.00	51.82	9.22
11	072157	121100	2	3	2	1	2	0.00	9.00	0.38
11	072157	121100	2	3	2	2	2	1.00	2.11	0.38
11	072157	121100	2	3	2	3	2	0.00	0.00	0.36
11	072157	121100	2	3	2	4	2	4.00	22.24	0.18
12	072156	130000	3	3	1	1	2	2.30	5.46	0.38
12	072156	110000	3	3	1	2	2	22.00	53.07	0.38
12	072156	130000	3	3	1	3	2	0.00	0.00	0.36
12	072156	110000	3	3	1	4	2	18.00	90.73	0.18
12	072156	1 JO000	3	4	2	1	2	0.00	0.00	0.60
12	072156	110000	3	4	2	2	2	0.00	0.00	0.41
12	072156	1 JO000	3	4	2	3	2	0.00	0.00	0.11
12	072156	130000	3	4	2	4	2	a.00	24.09	0.21
13	072329	75700	3	3	1	1	2	1.00	4.11	0.38
13	072329	75700	3	3	1	2	2	8.00	20.35	0.11
13	072329	75700	3	3	1	3	2	0.00	0.00	0.36
13	072329	75700	3	3	1	4	2	16.00	86.87	0.11
13	072329	75700	3	4	2	1	2	0.00	0.00	0.60
13	072329	75700	3	4	2	2	2	0.00	0.00	0.41
13	072329	75700	3	4	2	3	2	0.00	0.00	0.31
13	072129	75700	3	4	2	4	2	3.00	15.05	0.23
14	072407	105900	4	4	1	1	2	10.00	18.67	0.40
14	072407	105900	4	4	1	2	2	10.00	20.01	0.41
14	072407	105900	4	4	1	3	2	0.00	0.00	0.31
14	073401	105900	4	4	1	4	2	JJ:OO	139.48	0.21
15	072408	96800	4	4	1	1	2	0.00	0.00	0.60
15	072408	96800	4	4	1	2	2	2.00	S.88	0.41
15	072408	96800	4	4	1	3	2	0.00	0.00	0.31
15	072408	96800	4	4	1	4	2	1.00	46.51	0.23
16	072663	102400	4	4	1	1	2	16.00	21.62	0.60
16	072663	102400	4	4	1	2	2	17.00	35.71	0.41
16	072663	102400	4	4	1	3	2	0.00	0.00	0.31
l b	072663	102400	4	4	1	4	2	46.00	172.66	0.23
17	01821	48100	1	1	1	1	3	1.00	3.00	0.24
17	631821	48100	1	1	1	2	3	1.00	7.24	0.14
17	631821	48100	1	1	1	4	3	3.00	14.41	0.18
17	631821	48100	1	2	2	1	3	0.00	0.00	0.36
17	631821	48100	1	2	2	2	3	1.00	2.94	0.34
17	631821	48100	1	2	2	3	3	20.00	48.33	0 . 0
17	631821	48100	1	2	2	4	3	7.00	29.49	0.22
18	02017	82200	1	1	1	1	3	0.00	0.00	0.25
18	632017	82200	1	1	1	2	3	0.00	0.00	0.34
18	01017	82200	1	1	1	4	3	0.00	0.00	0.18
18	632017	82200	1	2	2	1	3	0.00	0.00	0.36
18	632017	82200	1	2	2	2	3	0.00	0.00	0.14
18	632017	82200	1	2	2	3	3	4.00	7.02	0.41
18	632017	82200	1	2	2	4	3	1.00	10.54	0.22
19	631948	110100	2	2	1	1	3	2.00	1.18	0.36
19	631948	110100	2	2	1	2	3	5.00	13.23	0.34
19	631948	110100	2	2	1	3	3	6.00	14.84	0.42
19	631948	110100	2	2	1	4	3	11.00	65.06	0.22
.19	631948	110100	2	3	2	1	3	1.00	1.00	0.38
19	421948	110100	2	3	2	2	3	1.00	2.19	0.38
19	631948	110100	2	3	2	3	3	41.00	112.89	0.36
19	621948	110100	2	3	2	4	3	13.00	57.20	0.18
20	632155	194600	3	3	1	1	3	0.00	0.00	0.38
20	632155	194600	3	3	1	2	3	0.00	0.00	0.38
20	632155	194600	3	3	1	3	3	2.00	6.65	0.36
20	632155	194600	3	3	1	4	3	13.00	72.32	0.18
20	632155	194600	3	4	2	1	3	0.00	0.08	0.60
20	632155	194600	3	4	2	2	3	2.00	7.99	0.41
20	632155	194600	3	4	2	3	3	42.00	131.71	0.31
20	632155	194600	3	4	2	4	3	32.00	175.91	0.23
21	632261	42100	3	3	1	1	3	0.00	0.00	0.38
21	632261	42100	3	3	1	2	3	1.00	2.18	0.38
21	02281	42100	3	3	1	3	3	1.08	3.17	0.36
21	02281	42100	3	3	1	4	3	6.08	34.52	0.18
21	632261	42100	3	4	2	1	3	1.00	1.33	0.60
21	632261	42100	3	4	2	2	3	0.00	0.00	0.41
21	632261	42188	3	4	2	3	3	18.00	69.16	0.31
21	632261	421.8	3	4	2	4	3	18.00	89.49	0.23
22	632252	262200	4	4	1	1	3	1.00	1.00	0.60
12	632252	262200	4	4	1	2	3	1.00	5.07	0.41
22	632252	262200	4	4	1	3	3	6.00	10.38	0.11
a2	632252	262200	4	4	1	4	3	26.00	135.52	0.23
23	632456	48700	4	4	1	1	3	0.00	0.00	0.60
23	632456	48700	4	4	1	2	3	0.00	0.00	0.41
23	632456	48700	4	4	1	3	3	3.00	10.01	0.31
21	632456	48700	4	4	1	4	3	8.00	14.80	0.23
24	050433	140900	1	1	1	1	4	30.00	115.21	0.25
24	050433	140900	1	1	1	2	4	145.00	425.18	0.34
a4	050433	140900	1	1	1	4	4	62.00	332.76	0.18
24	050433	140900	1	2	2	1	4	1.00	6.50	0.36
24	050433	140900	1	2	2	2	4	9.00	29.78	0.34
24	050433	140900	1	2	2	3	4	0.00	0.00	0.43
24	050433	140900	1	2	2	4	4	11.00	52.48	0.22
25	050444	135500	1	1	1	1	4	32.00	136.62	0.25
25	050444	135500	1	1	1	2	4	140.00	708.10	0.34
25	090444	135500	1	1	1	4	4	85.00	460.22	0.18
25	050444	135500	1	2	2	1	4	2.00	5.52	0.36
25	050444	135500	1	2	2	2	4	17.00	44.94	0.34
25	050444	135500	1	2	2	3	4	0.08	0.00	0.43
25	050444	135500	1	2	2	4	4	21.00	93.53	0.22
26	05044s	55600	1	1	1	1	4	0.00	0.88	0.25
26	050445	55600	1	1	1	2	4	1.00	1.89	0.34
26	050445	55600	1	1	1	4	4	0.00	0.00	0.18

26	050445	55600	1	2	2	1	4	0.00	a 00	0.36
26	050445	55600	1	2	2	2	4	0 JO	0 0 0	0.14
26	050445	55600	1	2	2	3	4	0.00	0.00	3 . 0
26	050445	55600	1	2	2	4	4	0.00	0.10	0.22
27	050446	246000	1	1	1	1	4	11.00	55.66	0.24
27	050446	246000	1	1	1	2	4	133.00	10.99	0.14
27	050446	246000	1	1	1	4	4	54.00	322.28	0.11
27	050446	246000	1	2	2	1	4	1.00	2.29	0.16
27	050446	246000	1	2	2	2	4	6.00	15.41	0.34
27	050446	246000	1	2	2	3	4	0.00	0.00	0 . 0
27	050446	246000	1	2	2	4	4	11.00	56.51	0.22
2:	050639	125500	2	2	1	1	4	16.00	40.79	0.36
28	050639	125500	2	2	1	2	4	105.00	125.47	0.14
28	050639	125500	2	2	1	3	4	0.00	0.00	0.41
28	050639	125500	2	2	1	4	4	11.00	210.63	0.22
28	05009	125500	2	3	2	1	4	0.00	0.00	0.1.
28	05009	125500	2	3	2	2	4	a.00	5.22	0.38
28	050639	:a5500	2	3	2	3	4	0.00	0.00	0.36
28	050639	125500	2	3	2	4	4	2.00	11.53	0.18
a9	050440	75200	2	2	1	1	4	a1.00	59.22	0.18
a 9	050640	75200	2	2	1	2	4	120.00	365.03	0.14
a9	050640	75200	2	2	1	3	4	0.00	0.00	0.41
a9	050640	75200	2	2	1	4	4	51.00	225.81	0.22
a9	050640	75200	2	3	2	1	4	0.00	0.00	0.38
a9	050640	75200	2	3	2	2	4	2.00	1.49	0.38
a9	050640	75200	2	3	2	3	4	0.00	0.00	0.36
a 9	050640	75200	2	3	2	4	4	1.00	17.23	0.1.
J0	050641	60500	2	2	1	1	4	16.00	34.71	0.36
30	050641	60500	2	2	1	2	4	112.00	324.88	0.14
10	010441	60500	2	2	1	3	4	0.00	0.00	0.41
IO	050641	60500	2	2	1	4	4	12.00	157.86	0.22
30	050641	60500	2	3	2	1	4	0.00	0.00	0.38
30	050641	60500	2	3	2	2	4	0.00	0.00	0.18
30	050641	60500	2	3	2	3	4	0.00	0.00	0.36
30	050641	60500	2	3	2	4	4	1.00	9.48	0.18
31	050642	23100	2	2	1	1	4	1.00	6.24	0.36
31	050642	23100	2	2	1	2	4	13.00	30.43	0.34
31	050642	23100	2	2	1	3	4	0.00	0.00	0.43
31	050642	23100	2	2	1	4	4	3.00	11.33	0.22
31	050441	23100	2	3	2	1	4	0.00	0.00	0.38
31	050642	23100	2	3	2	2	4	1.00	3.52	0.38
11	050642	23100	2	3	2	3	4	0.00	0.00	0.36
31	050642	23100	2	3	2	4	4	4.00	20.82	0.18
32	050740	104700	3	3	1	1	4	1.00	2.28	0.38
32	050740	104700	3	3	1	2	4	0.00	24.19	0.38
32	050740	104700	3	3	1	3	4	0.00	0.00	0.36
32	050740	104700	3	3	1	4	4	1.00	31.26	0.10
32	050740	104700	3	4	2	1	4	0.00	0.00	0.60
32	050740	104700	3	4	2	2	4	0.00	0.00	0.41
32	050740	104700	3	4	2	3	4	0.00	0.00	0.11
32	050740	104700	3	4	2	4	4	3.00	10.44	0.23
33	050741	76700	3	3	1	1	4	0.00	0.00	0.10
33	050141	76700	3	3	1	2	4	12.00	44.41	0.10
33	050741	79700	3	3	1	3	4	0.00	0.00	0.36
11	OS0741	76700	3	3	1	4	4	7.00	14.51	0.10
33	050741	79700	3	4	2	1	4	0.00	0.00	0.40
33	050741	76700	3	4	2	2	4	0.00	0.00	0.41
33	050741	76700	3	4	2	3	4	0.00	0.00	0.31
JJ	OS0741	76700	3	4	2	4	4	1.00	9.53	0.23
34	050742	63100	3	3	1	1		0.00	0.00	0.38
34	050742	63100	3	3	1	2	:	11.00	26.65	0.10
34	050742	63100	3	3	1	3		0.00	0.00	0.36
34	050742	63100	3	3	1	4	:	11.00	69.93	0.18
34	050742	63100	3	4	a	1	4	0.00	0.00	0.10
34	050742	63100	3	4	2	2	4	0.00	0.00	0.41
34	050742	63100	3	4	2	3	4	0.00	0.00	0.11
34	050742	63100	3	4	2	4	4	2.00	6.67	0.23
35	050743	25700	3	3	1	1	4	1.00	2.79	0.38
35	050743	25700	3	3	1	2	4	17.00	40.40	0.38
35	050743	25700	3	3	1	3	4	0.00	0.00	0.14
35	050743	a5700	3	3	1	4		16.00	93.97	0.10
35	050743	25700	3	4	2	1	:	0.00	0.00	0.60
35	050743	25700	3	4	2	2	4	0.00	0.00	0.41
35	050743	as700	3	4	2	3	4	0.00	0.00	0.31
35	050743	a 5 1 0 0	3	4	2	4	4	2.00	11.11	0.23
36	050746	150500	3	3	1	1	4	9.00	29.37	0.38
36	050746	150500	3	3	1	2	4	90.00	247.86	0.38
36	050746	150500	3	3	1	3	4	0.00	0.00	0.36
36	050746	150500	3	3	1	4	4	82.00	416.99	0.18
36	050746	150500	3	4	2	1	4	2.00	2.70	0.60
36	050746	150500	3	4	2	2	4	2:oo	5.78	0.41
36	050746	150500	:3	4	2	3	4	0.00	0.00	0.11
36	050144	150500	3	4	2	4	4	15.00	63.88	0.23
37	050748	28800	3	3	1	1	4	1.00	4.13	0.10
37	050740	28800	3	3	1	2		0.00	0.00	0.38
37	050748	28800	3	3	1	3	:	0.00	0.00	0.36
37	050140	28800	3	3	1	4	4	1.00	6.31	0.18
J7	050748	28800	3	4	2	1		0.00	0.00	0.60
17	050748	28800	3	4	2	2	:	0.00	0.00	0.41
17	050748	28800	3		2	3		0.00	0.00	0.31
J7	050748	28800	3	:	2	4	:	0.00	0.00	0.23
38	050749	30900	3	3	1	1		0.00	0.00	0.38
38	050749	30900	3	3	1	2	:	5.00	15.60	0.38
J0	050749	30900	3	3	1	3		0.00	0.00	0.36
38	050749	10900	3	3	1	4	:	7.00	40.15	0.18
J0	050749	30900	3	4	2	1	4	0.00	0.00	0.60
38	050749	30900	3	4	2	2		0.00	0.00	0.41
38	050749	30900	3	4	2	3	:	0.00	0.00	0.31
38	050149	JO900	3	4	2	4	4	1.00	3.57	0.23
19	050750	13700	3	3	1	1	4	0.00	0.00	0.38
39	050750	13700	3	3	1	2	4	0.00	0.00	0.38
19	050750	13700	3	3	1	3		0.00	0.00	0.36
19	050750	13700	3	3	1	4	:	0.00	0.00	0.18
39	050750	13700	3	4	2	1		0.00	0.00	0: 60
39	050750	11100	3	4	2	2	:	0.00	0.00	0.41
19	050750	13700	3	4	2	3	4	0.00	0.00	0.31
39	050750	13700	3	4	2	4	4	0.00	0.00	0.23
40	050751	19400	3	3	1	1	4	0.00	0.00	0.38

40	050751	15400	3	3	1	2	4	1. JO	1.51	a 38
40	050751	15400	3	3	1	3	4	0.00	I 30	3 36
40	050751	15400	3	3	1	4	4	1.30	4 90	3 18
40	050751	15400	3	4	2	:	4	[illegible]	[illegible]	3 60
40	050751	15400	3	4	2	2	4	0.00	3 30	1.41
40	150751	15400	3	4	2	3	4	0.00	3.30	3 31
40	050751	15400	3	4	2	4	4	0.00	0.30	3.23
41	350851	44700	4	4	1		4	0.00	11 59	0.40
41	050851	46700	4	4	1	:	4	4.00	11.10	0.41
41	050851	46700	4	4	1	3	4	0.00	3.00	0.31
41	350851	46700	4	4	1	4	4	22.00	88.26	3.23
42	051050	151400	4	4	1		4	8.00	13.87	3 60
42	051050	151400	4	4	1	:	4	10.00	27.34	0.41
42	051050	151400	4	4	1		4	0.00	0.00	0.31
42	051050	151400	4	4	1	:	4	27.00	109.18	0.21
43	151051	18900	4	4	1		4	1.30	2.66	3.60
43	051051	18900	4	4	1	:	4	a.00	4.39	0 41
43	051051	38900	4	4	1	3	4	0.00	0.50	0.31
43	051051	38900	4	4	1	4	4	5.00	15.97	3.23
44	051052	58300	4	4	1	1	4	5.00	10.34	0.60
44	051052	58300	4	4	1	2	4	8.00	15.13	0.41
44	011052	58300	4	4	1		4	0.00	0.00	0.11
44	051052	58300	4	4	1	:	4	39.00	166.94	0.23
45	051057	102300	4	4	1		4	21.00	37.18	0.60
45	051057	102300	4	4	1	:	4	21.00	5b . 0	0.41
45	051057	102300	4	4	1	3	4	0.00	0.00	0.31
45	051057	102300	4	4	1	4	4	55.00	216.63	0.23
46	631942	143600	1	1	1		5	5.00	15.07	0.25
46	01942	143600	1	1	1	:	5	10.00	31.45	0.34
46	631942	143600	1	1	1	4	5	5.00	30.41	0.18
48	01942	143600	1	2	2	1	5	4.00	24.89	0.36
46	631942	143600	1	a	a	2	5	19.00	48.99	0.34
46	01942	143600	1	2	2	3	5	a.00	6.13	0 . 0
46	631942	143600	1	2	2	4	5	10.00	55.25	0.22
47	01941	11100	1	1	1		15	0.00	0.00	0.25
47	631941	11100	1	1	1	2	5	1.00	2.65	0.34
47	01941	11100	1	1	1	4	5	2.00	14.86	0.18
47	431941	11100	1	2	2	1	5	3.00	15.10	0.36
47	01941	11100	1	2	2	2	5	2.00	5.79	0.34
47	01941	11100	1	2	2	3	5	a.00	3.13	0 . 0
47	631941	11100	1	2	2	4	5	10.00	44.53	0.22
48	632154	244300	a	2	I	1	5	3.00	1.57	0.38
48	02154	244300	2	2	1	2	5	34:oo	73.35	0.34
48	02154	a44300	2	2	1	3	5	0.00	0.00	0.43
48	632154	244300	2	2	1	4	5	4.00	14.49	0.22
48	632154	244300	2	3	2	1	5	0.00	0.00	0.38
48	632154	244300	2	3	2	2	5	18.00	38.60	0.38
48	02154	244300	2	3	2	3	5	7.00	20.22	0.36
48	632154	a44300	2	3	2	4	5	8.00	45.46	0.18
49	632137	20700	2	2	1	1	5	4.00	10.45	0.36
49	632137	20700	2	a	I	2	5	28.00	68.91	0.34
49	632137	a0700	2	2	1	3	5	0.00	0.00	0.43
49	632137	20700	2	2	1	4	5	1.00	3.66	0.22
49	632137	20700	2	3	2	1	5	3:oo	5.51	0.18
49	632137	10100	2	3	2	2	5	37.00	88.00	0.38
49	632137	20700	2	3	2	3	5	0.00	0.00	0.36
49	632137	20700	2	3	2	4	5	9.00	58.94	0.18
SO	632156	153200	3	3	1	1	5	8.00	18.16	0.38
SO	632156	153200	3	3	1	2	5	40.00	90.28	0.38
50	632156	153200	3	3	1	3	5	0.00	0.00	0.36
50	632156	153200	3	3	1	4	5	9.00	70.32	0.18
s o	632156	153200	3		2	1	5	9.00	13.30	0.60
so	632156	153200	3	:	2	2	5	6.00	14.40	0.41
s o	632156	153200	3	4	2	3	5	4.00	19.0s	0.31
SO	632156	153200	3	4	2	4	5	39.00	187.64	0.23
51	632255	121300	3	3	1	1	5	1.00	2.00	0.38
51	632255	121300	3	3	1	2	5	4:oo	11.85	0.38
51	632255	121300	3	3	1	3	5	0.00	0.00	0.38
51	632255	121300	331		4		9	9.00	48.32	0.18
51	632255	121300	3	4	2	I	5	2.00	4.38	0.80
51	632255	121300	3	4	2	2	5	1.00	1.35	0.41
51	632255	121300	3	4	2	3	5	5.00	17.09	0.31
51	632255	121300	3	4	2	4	5	11.00	57.72	0.23
52	632032	41300	4	4	1	1	5	0.00	0.00	0.60
52	632032	41300	4	4	1	2	5	0.00	0.00	0.41
52	632032	41300	4	4	1	3	5	0.00	0.00	0.31
52	632032	41300	4	4	1	4	5	1.00	9.41	0.23
53	632462	199200	4	4	1	1	5	2.00	4.06	0.60
53	632462	199200	4	4	1	2	5	3.00	4.84	0.41
53	632462	199200	4	4	1	3	5	0.00	0.00	0.11
53	632462	199200	4	4	1	4	5	6.00	30.17	0.23
54	632603	47500	4	4	1	1	5	0.00	0.00	0.40
54	632603	47500	4	4	1	2	5	0.00	0.00	0.41
54	632603	47500	4	4	1	3	5	0.00	0.00	0.31
54	632603	47500	4	4	1	4	5	1.00	5.69	0.23

APPENDIX 6. TRANSCRIPT OF GLIM ANALYSIS OF DATA IN APPENDIX 5, EXAMPLE 2

(Comments in **Appendix 4** can be used as a guide to the fitting process.)

```
): GLIM 3.77 update 1 (copyright)1985 Royal Statistical Society, London
[i] $units 3605
[i] $data coda ac rel by ab year ● y ago time fish hat counts or fracS
[i] $dinput 21$
[i] File name? fall.dat
[o]
[i] $factor by 4 hat 5 fish 4 year 5 age 2$
[i] $cal off=%log(rel*frac)$
[i] Syvar counts$err p$link l$offset off$scale 3
[o]
[i] ? $fit hat+age+fish+year$
[o] deviance = 4318.0 ● c cycle 6
[o]      d.f. = 348
[o]
[i] ? $dis m$
[o] Current model:
[o]
[o]   corms =  ... + AGE + ...
[o]
[i] ? $fit -hat$
[o] deviance = 4974.8 (change =   -657.) at cycle 6
[o]      d.f. = 352   (change =     +4 )
[o]
[i] ? $fit +hat$
[o] deviance = 4318.0 (change =   -657.1 ac cycle 6
[o]      d.f. = 348   (change =     -4 )
[o]
[i] ? $fit -age$
[o] deviance = 5068.7 (change =   +751. ) ac cycle 5
[o]      d.f. = 349   (change =     +1 )
[o]
[i] ?$fit● agoS
[o] deviance = 4318.0 (change =   -751.) at cycle 6
[o]      d.f. = 348   (change =     -1 )
[o]
[i] ? $fit -fish$
[o] deviance = 6538. (change = ● 2220.1 atcycle5
[o]      d..f.. = 351 (change =     '3 )
[o]
[i] ? $fit +fish$
[o] deviance = 4319.0 (change = -2219.9) at cycle 6
[o]   d.f.  =  348   (change =     -3  )
[o]
[i] ? $fit -years
[o] deviance = 4786.1 (change =   +468. ) ● c cycle 6
[o]      d.f. = 351   (change =     -3 )
[o]
[i] ? $cal %z=468/%ac$
[i] ? $print %z$
[o]    34.32
[o]
[i] ? $fit +year$
[o] deviance = 4318.0 (change =   -468.) at cycle  6
[o]      d.f. = 348   (change =     -3 )
[o]
[i] ? $fit +age.fish$
[o] deviance = 3874.9 (change =   -443.) at cycle  5
[o]      d.f. = 345   (change =     -3 )
[o]
[i] ? $dis m$
[o]
[o]   terms =  1 + HAT + AGE + FISH + YEAR + AGE.FISH
[o]
[i] ? $fit +year.fish$
[o] deviance = 3285.9 (change =  -589.0) at cycle  5
[o]      d.f. = 337   (change =    -8  )
[o]
[i] ? $cal %z=589/%ac$print %z$
[o]    60.41
[i] ? $dis m$
```

```
[o]
[o]   terms =  1 + HAT + AGE + FISH + YEAR + AGE.FISH + FISH.YEAR
[o]
[i] ? $fit [illegible]
[o] deviance = 3252.0 (change =    -34.) at cycle 5
[o]     d.f. =  335   (change =     -2 )
[o]
[i] ? $cal %z=34/%sc$print %z$
[o]    3.502
[i] ? $fit -year.age$
[o] deviance = 3285.9 (change =    +34.) at cycle 5
[o]     d.f. =  337   (change =     +2 )
[o]
[i] ? $dis m$
[o] Current  model:
[o]
[o]   terms =  1 + HAT + [illegible] + FISH + YEAR + AGE.FISH + FISH.YEAR
[o]
[i] ? $fit +hat.fish$
[o] deviance = 2382.0 (change =  -903.9) at cycle 7
[o]     d.f. =  325   (change =    -12 )
[o]
[i] ? $cal %z=903.9/%sc$print %z$
[o]    123.3
[i] ? $dis m$
[o] Current model:
[o]
[o]   terms =  1 + HAT + [illegible] + [illegible] + YEAR + HAT.FISH + AGE.FISH + FISH.YEAR
[o]
[i] ? $fit +hat.age$
[o] deviance = 1730.2 (change = -651.9) at cycle 7
[o]     d.f. =  321   (change =     -4 )
[o]
[i] ? $dis m$
[o] Current  model:
[o]
[o]   terms =  1 + HAT + AGE + FISH + YEAR + HAT.AGE + HAT.FISH + AGE.FISH +
[o]            FISH.YEAR
[o]
[i] ? $fit +hat.year$
[o] deviance = 1475.8 (change = -254.41) at cycle 7
[o]     d.f. =  309   (change =  -12 )
[o]
[i] ? $cal %z=254.41/%sc$print %z$
[o]    53.27
[i] ? $dis m$
[o] Current  model:
[o]
[o]   terms =  1 + HAT + AGE + FISH + YEAR + HAT.AGE + HAT.FISH + AGE.FISH +
[o]            HAT.YEAR + FISH.YEAR
[o]
[i] ?$dis e$
[o]          estimate       s.e.      parameter
[o]     1     -8.006      0.4596      1
[o]     2     -0.6255     0.5767      HAT(2)
[o]     3     -3.404      1.375       HAT(3)
[o]     4      0.5148     0.4530      HAT(4)
[o]     5     -1.413      0.7162      HAT(5)
[o]     6     -3.732      0.7551      AGE(2)
[o]     7      1.360      0.4577      FISH(2)
[o]     8     -3.389      2.296       FISH(3)
[o]     9      1.388      0.4754      FISH(4)
[o]    10     -0.1106     0.4193      YEAR(2)
[o]    11     -0.6307     0.5348      YEAR(3)
[o]    12     -1.657      0.5648      YEAR(4)
[o]    13      0.000      [illegible] YEAR(5)
[o]    14      1.256      0.7104      HAT(2).AGE(2)
[o]    15      3.024      0.6881      HAT(3).AGE(2)
[o]    16      0.6536     0.6258      HAT(4).AGE(2)
[o]    17      3.821      0.6484      HAT(5).AGE(2)
[o]    18      0.07705    0.5769      HAT(2).FISH(2)
[o]    19     -5.352     16.65        HAT(2).FISH(3)
[o]    20      0.1235     0.5741      HAT(2).FISH(4)
[o]    21     -0.5176     1.186       HAT(3).FISH(2)
[o]    22      5.191      2.439       HAT(3).FISH(3)
[o]    23      1.212      1.022       HAT(3).FISH(4)
[o]    24      0.1721     0.4402      HAT(4).FISH(2)
[o]    25     -5.397      9.009       HAT(4).FISH(3)
[o]    26     -0.08505    0.4522      HAT(4).FISH(4)
[o]    27      0.03012    0.5857      HAT(5).FISH(2)
[o]    28      0.6557     2.346       HAT(5).FISH(3)
```

```
[o]   29     -1.204      0.6201    HAT(5).FISH(4)
[o]   30     -0.06013    0.5178    AGE(2).FISH(2)
[o]   31     3.108       0.3041    AGE(2).FISH(3)
[o]   32     1.168       0.5112    AGE(2).FISH(4)
[o]   33     -0.7378     0.4931    HAT(2).YEAR(2)
[o]   35     -0.3337     0.4513    HAT(2).YEAR(3)
[o]   36     0.000 1.124 0.5522    HAT(2).YEAR(4)
[o]                      aliased   HAT(2).YEAR(5)
[o]   37     0.7969      1.115     HAT(3).YEAR(2)
[o]   13     0.2284      1.094     HAT(3).YEAR(3)
      39     1.848       1.134     HAT(3).YEAR(4)
o]    43     0.300       aliased   HAT(3).YEAR(5)
o]    41                 0.3205    HAT(4).YEAR(2)
o]    42     0.09448 -1.407  0.3486    HAT(4).YEAR(3)
o]    43     3.4097      0.5015    HAT(4).YEAR(4)
o]    44     0.000       aliased   HAT(4).YEAR(5)
o]    45     0.3411      0.5884    HAT(5).YEAR(2)
o]    46     -0.06134    0.6020    HAT(5).YEAR(3)
o]    47     1.203       0.7228    HAT(5).YEAR(4)
o]    48     0.000       aliared   HAT(5).YEAR(5)
o]    49                 0.3403    FISH(2).YEAR(2)
o]    50     0.3385 0.9141   0.4746    FISH(2).YEAR(3)
o]    51                 0.4123    FISH(2).YEAR(4)
o]    52     -0.9858 0.000   aliased   FISH(2).YEAR(5)
o]    53     -1.091      0.6930    FISH(3).YEAR(2)
o]    54     0.5222      0.6961    FISH(3).YEAR(3)
o]    55     0.000       aliased   FISH(3).YEAR(4)
o]    56     0.000       aliased   FISH(3).YEAR(5)
o]    57     0.1361      0.3666    FISH(4).YEAR(2)
o]    58     1.524       0.4083    FISH(4).YEAR(3)
o]    59     1.020       0.3768    FISH(4).YEAR(4)
o]    60     0.000       aliased   FISH(4).YEAR(5)
o]      scale parameter taken as 4.776
o]
o]
i] ? SC Pipe the processes below Co a new channel (15), writing co a file$
i] ? SC called resid.dat$
i] ? $output 15$
i] File name? resid.dat
o]
i] ? SC Display observed and fitted value8 and residuals$
i] ? $dis r$
o]   unit  observed    fitted    residual
o]     1          5     5.285     -0.124
o]               22    28.018     -1.137
o]     3         27    15.249      3.009
o]     4          0     0.163     -0.404
o]     5          0     0.794     -0.891
o]     6          0     0.049     -0.222
o]     7          4     1.473      2.083
o]     8          4     4.076     -0.038
o]    10         20    21.610     -0.346
o]    11          8    11.761     -1.097
o]                1     0.126      2.464
o]    13          1     0.612      0.496
o]    14          0     0.038     -0.195
o]                1     1.136     -0.127
o]    15          2     3.783     -0.917
o]    16         21    19.538      0.331
o]    17          0     0.051     -0.226
o]    18         11    10.615      0.118
o]    19          0     0.057     -0.238
o]    20          1     0.521      0.664
o]    21                0.069     -0.262
o]    22          1     1.594     -0.471
o]    23         18    12.090      1.700
o]    24         60    62.442     -0.309
o]    25          0     0.164     -0.405
o]    26         28    33.926     -1.017
o]    27          0     0.182     -0.426
o]    28          0     1.664     -1.290
o]    30          0     0.219     -0.468
o]    31          2     5.095     -1.371
o]    32          1     1.288     -0.254
o]    33         13    12.525      0.134
o]                0     0.049     -0.264
o]    34         18    11.230      2.020
o]    35                0.017     -0.132
o]    36          0     0.016     -0.128
o]                1     0.007     12.036
o]    38          2     0.239      3.603
```

[o]	39	4	4.282	-0.136
[o]	40	51	41.641	1.450
[o]	41	0	0.231	-0.480
[o]	42	27	37.334	-1.591
[o]	43	0	0.058	-0.241
[o]	44	0	0.054	-0.233
[o]	45	0	0.023	-0.150
[o]	46	1	0.794	0.231
[o]	47	1	3.455	-1.321
[o]	48	4	3.434	0.305
[o]	49	0	0.560	-0.245
[o]	50	16	14.715	0.335
[o]	51	0	1.137	-1.966
[o]	52	1	1.130	-0.122
[o]	53	0	0.020	-0.141
[o]	54	4	4.840	-0.382
[o]	55	12	12.840	-0.234
[o]	56	80	73.519	0.756
[o]	57	43	41.913	0.168
[o]	58	0	0.665	-0.816
[o]	59	3	3.496	-0.265
[o]	60	0	0.001	-0.031
[o]	61	20	6.793	5.067
[o]	62	0	0.673	-0.821
[o]	63	0	3.856	-1.964
[o]	64	0	2.198	-1.483
[o]	65	0	0.035	-0.187
[o]	66	0	0.183	-0.428
[o]	67	0	0.000	-0.007
[o]	68	0	0.356	-0.597
[o]	69	0	3.329	-1.825
[o]	70	12	18.572	-1.525
[o]	71	0	0.000	-0.01s
[o]	72	9	10.570	-0.483
[o]	73	0	0.152	-0.390
[o]	74	1	1.501	-0.409
[o]	75	0	0.001	-0.029
[o]	76	4	4.815	-0.371
[o]	77	2	1.938	0.044
[o]	78	22	20.358	0.364
[o]	79	0	0.000	-0.022
[o]	80	18	19.119	-0.256
[o]	81	0	0.686	-0.820
[o]	82	0	0.694	-0.833
[o]	83	0	0.001	-0.036
[o]	84	6	10.630	-1.420
[o]	85	1	1.129	-0.121
[o]	86	8	11.855	-1.120
[o]	87	0	0.000	-0.017
[o]	88	16	11.133	1.459
[o]	89	0	0.400	-0.632
[o]	90	0	0.404	-0.636
[o]	91	0	0.001	-0.027
[o]	92	3	6.190	-1.282
[o]	93	10	6.641	1.300
[o]	94	10	7.137	1.072
[o]	95	0	0.001	-0.023
[o]	96	33	32.031	0.171
[o]	97	0	6.077	-2.465
[o]	98	2	6.524	-1.771
[o]	99	0	0.001	-0.022
[o]	100	8	29.279	-3.932
[o]	101	16	6.428	3.775
[o]	102	17	6.901	3.844
[o]	103	0	0.001	-0.023
[o]	104	46	30.972	2.700
[o]	105	1	0.133	2.375
[o]	106	1	0.421	0.893
[o]	107	3	1.292	1.503
[o]	108	0	0.188	-0.433
[o]	109	1	0.544	0.618
[o]	110	20	10.222	3.058
[o]	111	7	5.694	0.547
[o]	112	0	0.228	-0.477
[o]	113	0	0.719	-0.840
[o]	114	0	2.207	-1.486
[o]	115	0	0.321	-0.567
[o]	116	0	0.930	-0.965
[o]	117	4	17.468	-3.222
[o]	118	3	9.730	-2.15.
[o]	119	2	0.172	1.207

[o]	120	5	2.685	1.413
[o]	121	6	2.122	2.663
[o]	122	11	9.224	0.969
[o]	123	1	0.153	2.167
[o]	124	1	0.834	0.132
[o]	125	41	33.116	1.370
[o]	126	13	14.391	-0.367
[o]	127	0	0.548	-0.740
[o]	128	0	3.175	-1.792
[o]	129	2	5.307	-1.436
[o]	130	13	16.050	-0.761
[o]	131	0	0.771	-3.978
[o]	132	2	0.430	2.393
[o]	133	42	54.083	-1.643
[o]	134	32	35.487	-0.585
[o]	135	0	0.119	-5.344
[o]	135		0.687	0.378
[o]	137	1	1.148	-0.138
[o]	138	6	3.472	1.356
[o]	139	1	0.167	2.039
[o]	140	0	0.093	-3.305
[o]	141	18	11.700	1.342
[o]	142	18	7.677	3.726
[o]	143	1	2.109	-0.763
[o]	144	1	1.249	-0.223
[o]	145	6	6.607	-0.236
[o]	146	26	30.171	-0.759
[o]	147	0	0.392	-3.626
[o]	148	0	0.232	-0.402
		3	1.227	1.600
[o]		8	5.604	1.012
[o]	150	30	19.654	2.334
[o]	152	145	123.766	1.909
[o]	153	62	52.085	1.374
[o]	154	1	1.283	-0.250
[o]	155	9	7.409	0.504
[o]	156	0	0.002	-0.042
[o]	157	11	10.628	0.114
[o]	158	32	18.901	3.013
[o]	159	240	119.022	11.089
[o]	160	85	50.089	4.933
[o]	161	2	1.233	0.690
		17	7.125	3.699
[o]	162	0	0.002	-0.041
[o]	163 164	21	10.221	3.372
[o]	165	0	7.756	-2.705
[o]	167 166	1	48.839	-6.045
		0	20.553	-4.534
[o]		0	0.506	T0.711
[o]	168 169	0	2.924	-1.710
[o]	170	0	0.001	-0.026
[o]	172 171	0	4.194	-2.040
		18	34.315	-2.785
[o]		133	216.085	-5.652
[o]	173 174	56	90.936	-3.664
[o]		1	2.239	-0.828
[o]	175 176	6	12.936	-1.929
[o]		0	0.003	-0.055
[o]	177 178	13	18.556	-1.290
[o]	180 179	16	24.806	-1.768
		105	152.175	-3.824
[o]	181	0	0.002	-0.039
[o]	182	52	63.930	-1.492
[o]	183	0	0.160	-0.400
[o]	184	2	1.737	0.200
[o]	185	0	0.001	-0.030
[o]	186	2	4.111	-1.041
[o]	187	21	14.864	1.592
[o]	188	120	91.184	3.018
[o]		0	0.001	-0.030
[o]	189 190	51	38.307	2.051
[o]		0	0.096	-0.309
[o]	191 192	2	1.041	0.940
[o]		0	0.001	-0.023
[o]	193 194	3	2.464	0.342
[o]	195	16	11.958	1.169
[o]		112	73.359	4.511
[o]	196	0	0.001	-0.027
[o]	198	32	30.819	0.213
[o]	199	0	0.077	-0.277
[o]	200	0	0.837	-0.915

[o]	201	0	0.000	-3.021
[o]	202	1	1.082	-0.698
[o]	203	3	4.566	-0.733
[o]	204	13	28.010	-2.336
[o]	205	0	0.000	-0.017
[o]	206	3	11.767	-2.556
[o]	297	0	0.029	-0.171
[o]	200	1	0.320	1.203
[o]	239	0	0.000	-4.013
[o]	210	4	0.757	3.728
[o]	211	1	2.893	-1.113
[o]	212	8	33.412	-4.396
[o]	213	0	0.001	-0.027
[o]	214	7	23.163	-3.358
[o]	215	0	0.464	-0.601
[o]	216	0	0.515	-0.718
[o]	217	0	0.001	-0.029
[o]	218	3	5.830	-1.172
[o]	219	0	2.119	-1.456
[o]	220	12	24.477	-2.522
[o]	223	0	0.001	-0.023
[o]	222	7	16.969	-2.420
[o]	223	0	0.340	-0.563
[o]	224	0	0.378	-0.614
[o]	225	0	0.001	-0.024
[o]	226	3	4.271	-0.615
[o]	227	0	1.743	-1.320
[o]	228	11	20.137	-2.036
[o]	229	0	0.000	-0.021
[o]	230	11	13.960	-0.792
[o]	231	0	0.279	-0.529
[o]	232	0	0.311	-0.557
[o]	233	0	0.000	-0.022
[o]	234	2	3.514	-0.007
[o]	235	1	0.710	0.344
[o]	236	17	0.202	3.072
[o]	237	0	0.000	-0.013
[o]	238	16	5.686	4.326
[o]	239	0	0.114	-0.337
[o]	240	0	0.127	-0.356
[o]	241	0	0.000	-0.014
[o]	242	2	1.431	0.476
[o]	243	9	4.158	2.374
[o]	244	90	40.020	6.056
[o]	245	0	0.001	-0: 032
[o]	246	82	33.296	0.441
[o]	247	2	0.666	1.634
[o]	248	2	0.741	1.463
[o]	249	0	0.001	-0.034
[o]	250	15	8.380	2.207
[o]	251	1	0.796	0.229
[o]	252	0	9.191	-3.032
[o]	253	0	0.000	-0.014
[o]	254	1	6.372	-2.128
[o]	255	0	0: 121	-0.357
[o]	256	0	0.142	-0.377
[o]	257	0	0.000	-0.01s
[o]	258	0	1.604	-1.266
[o]	259	0	0: 854	-0.924
[o]	260	5	9.861	-1.548
[o]	261	0	0.000	-0.014
[o]	262	7	6.836	0.063
[o]	263	0	0.137	-0.370
[o]	264	0	0.152	-0.390
[o]	265	0	0.000	-0.016
[o]	266	1	1.721	-0.549
[o]	267	0	0: 379	-0.615
[o]	268	0	4.372	-2.091
[o]	269	0	0.000	-0.010
[o]	270	0	3.031	-1.741
[o]	271	0	0.061	-0.246
[o]	272	0	0.067	-0.260
[o]	273	0	0.000	-0.010
[o]	274	0	0.763	-0.873
[o]	275	0	0.425	-0.652
[o]	276	1	4.915	-1.766
[o]	277	0	0.000	-0.010
[o]	278	1	3.407	-1.304
[o]	279	0	0.068	-0.261
[o]	280	0	0.076	-0.275
[o]	281	0	0.000	-0.011

[0]	282	0	0.958	-0.926
[0]	283	8	4.490	1.657
[0]	284	4	5.301	-0.565
[0]	285	0	3.900	-0.019
[0]	286	22	17.561	1.059
[0]	287	9	14.555	-1.719
[0]	288	10	17.185	-1.733
[0]	289	0	0.001	-0.034
[0]	290	27	56.932	-3.967
[0]	291	1	3.740	-1.417
[0]	292	2	4.415	-1.149
[0]	293	0	0.300	-3.017
[0]	294	5	14.629	-2.517
[0]	295	5	5.605	-0.255
[0]	296	9	6.617	0.537
[0]	297	0	0.000	-0.021
[0]	299	39	21.923	3.647
[0]	299	21	9.935	3.560
[0]	300	21	11.612	2.755
[0]	301	0	0.001	-0.028
[0]	302	55	39.469	2.665
[0]	303	5	2.913	1.223
[0]	304	10	15.915	-1.403
[0]	305	5	2.522	1.561
[0]	306	6	5.779	0.092
[0]	307	19	29.963	-1.851
[0]	308	2	3.372	-0.747
[0]	309	10	15.644	-1.427
[0]	310	0	0.225	-0.475
[0]	311	1	1.230	-0.208
[0]	312	2	0.195	4.088
[0]	313	3	0.447	3.820
[0]	314	2	2.239	-0.160
[0]	315	2	0.261	3.407
[0]	316	10	1.209	7.994
[0]	317		8.986	-1.997
[0]	319	3:	47.027	-1.999
[0]	319	0	0.234	-0.484
[0]	320	4	7.566	-1.296
[0]	321	0	4.127	-2.031
[0]	322	18	38.941	-3.356
[0]	323	7	9.588	-0.836
[0]	324	8	34.708	-4.533
[0]	325		0.761	3.712
[0]	326	2:	4.052	11.896
[0]	327	0	0.020	-0.141
[0]	328	1	0.641	0.440
[0]	329	3	0.350	4.482
[0]	330	37	3.300	18.553
[0]	331		0.912	-0.901
[0]	332	8	2.941	3.533
[0]	333	8	2.365	3.664
[0]	334	40	23.703	3.347
[0]	335	0	0.246	-0.496
[0]	336	9	6.187	1.131
[0]	337		5.178	1.690
[0]	338	a	4.995	0.450
[0]	339		3.992	1.068
[0]	340	3:	21.275	3.843
[0]	341	1	1.873	-0.639
[0]	342	4	18.767	-3.409
[0]	343	0	0.194	-0.441
[0]	344	9	4.099	1.853
[0]	345	2	4.100	-1.037
[0]	346	1	3.955	-1.486
[0]	347	5	3.082	1.093
[0]	348	12	16.845	-1.180
[0]	349	0	1.276	-1.130
[0]	350		1.307	-1.143
[0]	351	8	0.043	-0.207
[0]	352	1	1.630	-0.494
[0]	353	2	6.154	-1.674
[0]	354	3	6.304	-1.316
[0]	355	0	0.207	-0.455
[0]	356	6	7.864	-0.665
[0]	357	0	1.467	-1.211
[0]	358		1.503	-1.226
[0]	359	8	0.049	-0.222
[0]	360	1	1.875	-0.639
[0]				

```
[1] ? $C Return the output to the screen (channel 0$
[1] ? $output 6$
[1] ? $stop$
```

DOE/BP-35885-5
November 1993
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