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Forecasted status of Cultus and Sakinaw sockeye salmon in 2004

Prévisions de l'état des populations de saumon rouge des lacs Cultus et Sakinaw en 2004

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Abstract

The sockeye salmon populations originating in Cultus and Sakinaw lakes (hereafter called Cultus sockeye and Sakinaw sockeye) were both designated "endangered wildlife species" by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) following an emergency assessment in November 2002 that was confirmed in May 2003. In 2003, the number of mature individuals (spawners) has continued to decline to 1,485 in Cultus and 3 or fewer in Sakinaw. Even so there are reasons to be optimistic about recovery: Pre-spawn mortality in Cultus sockeye, considered by COSEWIC to be one of the principal threats, was less severe during the past two years, and as a result, the number of spawners in 2002 and 2003 has increased relative to the brood (parental) years in 1998 and 1999 when pre-spawn mortality was much higher. For Sakinaw sockeye, two years of intensive supplementation with hatchery-reared fry is expected to significantly increase adult returns in 2004 and 2005. However, it must be emphasized that little or no supplementation has occurred in subsequent years when few (2002) and no (2003) broodstock were available; thus, prospects for survival and recovery depend almost entirely on the number of spawners achieved in 2004 and 2005.

Adult returns in 2004 were forecasted with a new conditional Bayesian forecast model that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003. The prior distributions of age-4 adult returns used in the Bayesian model were generated by multiplying estimated smolt abundance in 2002 by "smolt-to-adult survival", considered as a log-normally distributed random variable whose parameters were estimated from recent data (1990-1998) for Chilko sockeye. The Bayesian model is conditional on the assumption that the age-3 proportion (by brood year) is known exactly. Sensitivity of forecasts to errors in the age-3 index assumption was evaluated for both Cultus and Sakinaw populations. An alternative, higher estimate of the age-3 index for Sakinaw sockeye (0.025) was also estimated from age composition data available from a single brood year (1971). The conditional Bayesian forecasts performed better in 3 out of 4 performance measures than the corresponding (prior distribution) forecasts based on smolt abundance alone in retrospective analyses using historical data for Cultus sockeye. As expected, the median posterior estimates were unbiased (over-forecasting in 50% of retrospective comparisons) compared with the prior distribution (which over-forecast in 67% of comparisons).

The recommended median forecast for total returns (before any fishing or pre-spawn mortality) of Cultus sockeye in 2004 is 281 individuals based on the Bayesian model using Chilko smolt survival parameters. The odds are 9 in 10 (90% probability) that total returns will exceed 150, and 3 in 4 (75% probability) that the return will exceed 203 individuals. The recommended median forecast for total returns of Sakinaw sockeye in 2004 is 390 individuals with odds of 9 in 10 (90% probability) that returns will exceed 215, and 3 in 4 (75% probability) that returns will exceed 286 individuals. The Sakinaw forecast is considered highly uncertain, and potentially very optimistic, because the underlying assumptions of smolt-to-adult survival and age-3 proportions are based on speculation that Sakinaw sockeye smolts will survive and mature precociously ("jack") like Cultus sockeye. Alternatively it seems plausible that Sakinaw sockeye smolts are experiencing unusually poor marine survival which could account for the current status of the population. The Sakinaw forecast procedure could not be evaluated in retrospective analyses because no historical data are available.

In conclusion, the recommended median forecasts of adult returns to both populations in 2004 are below the criteria for population viability used by COSEWIC (IUCN criteria) and the respective SARA recovery teams; in this sense, both populations are likely to remain at imminent threat of extinction even with no incidental fishing mortality in 2004. However, fishing restrictions could significantly improve the status of both populations and hasten recovery. Probabilities for achieving the minimum viable population size threshold of 500 spawners in 2004 were computed under alternative assumptions about exploitation rate and pre-spawn mortality, and for Sakinaw sockeye, for opening dates in a plausible but hypothetical fishery.

Résumé

Les populations de saumon rouge des lacs Cultus et Sakinaw (ci-après appelées la population Cultus et la population Sakinaw) ont été désignées d'urgence comme étant en voie de disparition par le Comité sur la situation des espèces en péril au Canada (COSEPAC) en novembre 2002; ce statut a été confirmé en mai 2003. Mais le nombre d'individus matures (reproducteurs) a continué à décliner en 2003, pour ne plus atteindre que 1 485 dans le lac Cultus et 3 ou moins dans le lac Sakinaw. Il y a tout de même lieu de croire qu'elles se rétabliront : la mortalité pré-fraie chez la première, que le COSEPAC considère comme l'une des principales menaces, était moins forte durant les deux dernières années, de sorte que le nombre de reproducteurs en 2002 et en 2003 a augmenté par rapport aux années de génération de 1998 et 1999, lorsque cette mortalité était beaucoup plus élevée. Dans le cas de la population Sakinaw, on s'attend à ce que les déversements de grands volumes d'alevins d'écloserie effectués deux années consécutives résultent en une forte augmentation du nombre d'adultes qui reviendront frayer en 2004 et en 2005. Il faut toutefois souligner que peu ou pas d'empoissonnement a été effectué par après, peu (2002) et pas (2003) de reproducteurs ayant été récoltés. La survie et le rétablissement de cette population dépendent donc presque entièrement du nombre de reproducteurs en 2004 et en 2005.

Nous avons utilisé un nouveau modèle bayesien conditionnel de prévision, tenant compte de l'abondance estimative des smolts en 2002 et des remontes estimatives en 2003 d'unibermarins d'âge 3 de la même année de génération, pour faire des prévisions des remontes en 2004. Nous avons établi les distributions antérieures des remontes de saumons d'âge 4 utilisées dans le modèle bayesien en multipliant l'abondance estimative des smolts en 2002 par le taux de survie du stade smolt au stade adulte, considéré comme une variable aléatoire ayant une distribution logarithmique normale dont nous avons estimé les paramètres à l'aide de données récentes (1990-1998) pour le saumon rouge du lac Chilko. Le modèle bayesien est conditionnel; il repose sur l'hypothèse à l'effet que l'on sait exactement quelle est la proportion de saumons d'âge 3 (selon l'année de génération). Nous avons évalué la sensibilité des prévisions aux erreurs dans l'hypothèse relative à la proportion d'âge 3 pour les populations Cultus et Sakinaw. Nous avons aussi estimé une autre proportion d'âge 3, plus élevée, pour la population Sakinaw (0,025) en nous servant des données sur la composition par âge disponibles pour une seule année de génération (1971). À trois des quatre niveaux de rendement, les prévisions bayésiennes conditionnelles se sont avérées meilleures que les prévisions correspondantes (distribution antérieure) reposant uniquement sur l'abondance des smolts dans des analyses rétrospectives des données historiques pour la population Cultus. Comme prévu, les estimations médianes a posteriori n'étaient pas biaisées (surestimation dans le cas de 50 % des comparaisons rétrospectives) en comparaison de la distribution antérieure (surestimation dans le cas de 67 % des comparaisons).

La prévision médiane recommandée pour les remontes totales (avant la mortalité par pêche et la mortalité pré-fraie) du saumon rouge Cultus en 2004 est l'estimation de 281 individus obtenue par le modèle bayesien reposant sur les paramètres de survie des smolts du lac Chilko. Les chances sont de 9 sur 10 (probabilité de 90 %) qu'elles dépasseront 150 saumons, et de 3 sur 4 (probabilité de 75 %) qu'elles dépasseront 203 saumons. La prévision médiane recommandée pour les remontes totales du saumon rouge Sakinaw en 2004 est l'estimation de 390 saumons. Les chances sont de 9 sur 10 (probabilité de 90 %) qu'elles dépasseront 215 saumons, et de 3 sur

4 (probabilité de 75 %) qu’elles dépasseront 286 saumons. La prévision pour le saumon Sakinaw est considérée comme étant très incertaine, et peut-être très optimiste, parce que les hypothèses sous-jacentes relatives à la survie du stade smolt au stade adulte et aux proportions d’âge 3 reposent sur la conjecture à l’effet que les smolts de la population Sakinaw survivront et atteindront précocement la maturité (madeleineaux) comme le saumon Cultus. D’un autre côté, il semble plausible que les smolts de la population Sakinaw connaissent un taux de survie en mer exceptionnellement faible, ce qui pourrait expliquer l’état actuel de cette population. Il nous a été impossible d’évaluer la prévision pour le saumon Sakinaw en regard des analyses rétrospective parce qu’aucune donnée historique n’est disponible.

En conclusion, les prévisions médianes recommandées des remontes pour les deux populations en 2004 se situent au-dessous des critères de viabilité des populations utilisés par le COSEPAC (critères de l’UICN) et les équipes LEP de rétablissement respectives; dans ce sens, il est probable que les deux populations demeureront exposées à une extinction imminente même en l’absence d’une mortalité accidentelle par pêche en 2004. Des restrictions sur la pêche pourraient toutefois permettre d’améliorer sensiblement l’état des deux populations et de hâter leur rétablissement. Nous avons établi quelles étaient les probabilités d’atteindre la taille de population viable minimale de 500 reproducteurs en 2004 en utilisant d’autres hypothèses en ce qui a trait au taux d’exploitation et à la mortalité pré-fraie, et dans le cas de la population Sakinaw, aux dates d’ouverture d’une pêche plausible mais hypothétique.

Introduction

Fisheries Management, DFO has requested Science Branch advice on the levels of fishing mortality in 2004 that would pose an imminent threat to the survival and recovery of Cultus and Sakinaw sockeye salmon populations. This working paper was prepared as a partial response and includes forecasts of status under alternative hypothetical fishery scenarios.

The Cultus and Sakinaw sockeye populations (hereafter called Cultus sockeye and Sakinaw sockeye) were assessed on an emergency basis by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) in fall 2002; both were found to be *Endangered* "wildlife species" that warrant protection under SARA (if legally listed). The designation was confirmed by COSEWIC in May 2003 and completed status reports were posted on the Public Registry (COSEWIC 2003a, b).

COSEWIC's definition of *Endangered* is "facing imminent extirpation or extinction". The designation for Cultus and Sakinaw sockeye was based largely on IUCN criterion A (over 50% decline in abundance over 3 generations) and criterion C (single population with fewer than 2,500 mature individuals and a continuing decline). Sakinaw sockeye also triggered criterion D (fewer than 250 mature individuals).

IUCN criteria (IUCN 2001) were not designed for setting recovery objectives but they are based on theoretical studies of extinction risk (Mace and Lande 1991). The same theory must be considered in determining minimum requirements for population viability in Pacific salmon (e.g., McElhany et al. 2000) and in setting recovery objectives. For example, recent work by the Willamette-Lower Columbia River Technical Recovery Team has led them to specify default *minimum* viable population sizes (MVP) of 1,000 (for chum salmon) and 1,200 (for chinook salmon) mature individuals annually, calculated as a running average across one-generation (P. McElhany, NMFS, pers. comm.; http://www.nwfsc.noaa.gov/trt/viability_report.htm). Similarly, Allendorf et al. (1997) concluded that, in general, isolated Pacific salmon populations should be considered at high risk of extinction when their genetically-effective population size (N_e) falls below 500 per generation. More recent theoretical studies suggest that N_e must exceed 1,000 to maintain genetic variation in the longer term, especially for alleles associated with disease resistance (Lynch and Lande 1998). For sockeye that mature primarily at age 4, this number is considered equivalent to about 1000 spawners annually where all years contribute equally; however, the overall genetically effective number can be greatly reduced by annual fluctuations in returns. Waples (2002) recommends calculating N_e as the harmonic mean of the individual cycle lines, which weights low abundance years more heavily than high abundance years.

Recovery teams for Cultus and Sakinaw sockeye have now been appointed, pending legal listing under SARA, and significant effort has been directed towards increased monitoring of status, restoration of freshwater habitat, and artificial propagation including captive breeding. Sockeye from both populations are killed incidentally in traditional mixed-stock fisheries directed at other (mostly Fraser) sockeye populations. If legally listed, there would be an automatic prohibition against killing Cultus and Sakinaw sockeye, although exemption may be possible through an

Incidental Harm Permit. Such exemption requires, among other things, that the incidental harm does not jeopardize the survival and recovery of the species.

The Cultus and Sakinaw recovery teams have developed draft goals and objectives for recovery[1]. The Sakinaw Sockeye Recovery Team seeks to "increase the annual number of spawners (here including those removed for hatchery broodstock) to no fewer than 500 from 2004 to 2007" (objective 3) and to "ensure that by 2017, the mean population abundance in any four year period exceeds 1,000 naturally produced spawners, with no fewer than 500 naturally produced spawners in a year" (objective 5) (SSRT 2004). The interim objective 3 is intended as a milestone towards achieving the MVP of at least 1,000 spawners each year (calculated as an average over four years). Note that at least 3,800 spawners would be needed in 2004 to achieve the MVP requirement immediately. The recovery team recognized that this is not biologically feasible, implying that the Sakinaw population will remain at imminent threat for the foreseeable future. The Cultus Sockeye Recovery Team has drafted similar objectives aiming to "ensure the genetic integrity of the population by exceeding a 4-yr arithmetic mean of 1,000 successful adult spawners with no fewer than 500 successful adult spawners on any one cycle" (objective 1) (CSRT 2004). In this case, the average annual abundance of spawners for years 2001-2004 already exceeds 1,000 even if no fish survived to spawn in 2004, so only 500 successful spawners are required to meet the objective in 2004.

In this working paper we review current status and provide probabilistic forecasts for Cultus and Sakinaw returns in 2004. We develop a new Bayesian forecast model that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003. We evaluate the performance of the Bayesian forecasts in retrospective analyses using historical data for Cultus sockeye. We also compute tail probabilities for achieving 500 spawners in 2004 under alternative assumptions about exploitation rate and pre-spawn mortality (for Cultus) and fishery opening dates (for Sakinaw).

Methods

Data sources

Comprehensive reports on the status of Cultus and Sakinaw sockeye were recently reviewed by PSARC (Schubert et al. 2002; Murray and Wood 2002). Consequently, data on spawning escapements, total adult returns, age composition and smolt abundance were readily available for these forecasts. These data were updated with additional new information from the Cultus and Sakinaw sockeye recovery teams, and are included in Appendix Tables 1 through 6. Chilko age-1 smolt-to-adult survival rates were calculated from smolt and total return databases maintained by DFO and the Pacific Salmon Commission (Appendix Table 5).

[1] Bradford and Wood (2004) recently reviewed the scientific basis for these objectives, so for brevity, we have omitted the explanation of these issues presented in our original working paper.

Forecast models

Forecast models for Cultus sockeye have been reviewed extensively by PSARC in previous years (e.g., Cass 2001). Folkes and Cass (2003) recently forecasted returns in 2004 using fence counts of naturally-produced smolts multiplied by the arithmetic mean smolt-to-adult survival observed historically for Cultus sockeye. They concluded that other models used in previous forecasts were inappropriate for the 2004 forecast because pre-spawn mortality (PSM) has varied significantly in recent years and the smolt count for the 2000 brood year (mainly returning in 2004) was a record low. Since their report, smolt abundance estimates have been revised to include the release of hatchery-reared smolts, and removals of naturally-produced smolts needed to augment a captive breeding program. The revised estimates are used in this report.

Three forecasting models were examined to forecast total returns of Cultus sockeye:

Four-year mean model

The 4-yr mean model is a moving average calculated from log-transformed estimates of total returns (R) in the four previous years (one generation) so that

(1) $$Z_t = \ln(R_t)$$

and

(2) $$\hat{Z}_{t+1} = \frac{\sum_{k=t-3,t} Z_k}{4} + e \ .$$

In this case the 4-yr mean model is conceptually equivalent to the 5-year mean model that performed as well as more complicated models under typical conditions for sockeye populations in northern and central British Columbia where biological data are often limited (Wood et al. 1997). The 5-year model was also conceived as a running average across one generation since most sockeye in northern populations mature at age 5.

Smolt model

The smolt model uses an estimate of smolt abundance to forecast total returns from a given brood year by applying an historical smolt-to-adult survival rate. Conceptually, our smolt model is similar to the point estimate forecast provided by Folkes and Cass (2003), but we compute a probabilistic forecast based on an estimated probability distribution for age-1 smolt-to-adult survival. Few recent estimates of smolt survival are available for Cultus sockeye (Appendix Table 1) and there is some evidence that smolt survival has been declining for other Fraser sockeye. We used Chilko age-1 smolt-to-adult survival data for the most recent decade (1990-1998 brood years, Appendix Table 3) as a surrogate because historical survival rates will cause over-forecasting errors if Cultus survival has declined, consistent with the overall decline in adult returns.

The smolt model forecasts adult returns in year *t+1* from the number of age-1 and age-2 smolts (*N*) emigrating Cultus Lake in year *t-1* multiplied by smolt survival (*S*), modelled as a log-normally distributed random variable whose distribution was estimated from age-1 smolt-to-adult survivals in Chilko sockeye for the nine most recent brood years (*BY*) *t-13* to *t-5*. Thus,

(3) $$\ln(\hat{\mathrm{R}}_{t+1}) = \ln(\mathrm{N}_{t-1}) + \ln(\hat{\mathrm{S}}) + e$$

where $\ln(S)$ has a normal distribution $N(m, s^2)$ with parameters estimated from the sample mean and variance of the series $\ln S_{BY=t-13} ... \ln S_{BY=t-5}$. Some additional error will be incurred applying age-1 smolt-to-adult survival to larger age-2 smolts, and from variations in age at return, but we assume these errors are multiplicative, log-normally distributed, and independent of time ($e \sim N(0, s^2)$). Age-2 smolts accounted for about 1% of all smolts emigrating from Cultus Lake from 1927 to 2003. About 3% of Cultus sockeye return at age 5 and 3% at age 3, and these rates appear to vary among brood years.

Bayesian model

The Bayesian model uses Bayes Theorem to estimate the probability of different return sizes given the recent geometric mean age-3 index, the number of age 3 fish ("jacks") observed in the escapement in the previous year, and the probability of a specified return size in the smolt model (used as the prior distribution). Bayes' Theorem can be expressed as,

(4) $$\Pr\{H_i | data\} = \frac{L\{data|H_i\} Prior\{H_i\}}{\sum_{i=1}^{j} L\{data|H_i\} Prior\{H_i\}}$$

where $\Pr\{H_i | data\}$ is the probability of hypothesis *i* given the data (posterior probability), $L\{data|H_i\}$ is the likelihood of the data given the hypothesis, $Prior\{H_i\}$ is the prior probability of the hypothesis before the data are considered, and $\sum_{i=1}^{j} L\{data|H_i\} Prior\{H_i\}$ is the total likelihood of getting the data over all *j* hypotheses admitted as possibly having produced the data (Hilborn and Mangel 1997). The prior probability was estimated from the probability distribution (log-normal) from the smolt model and assumed independent of the likelihood of the data because it was developed from smolts and Chilko survival and independent of age-3 returns and the age-3 index. The prior probability density was estimated as the difference between the cumulative probability at hypothesis *i* and *i-1* because the log-normal distribution is continuous. The likelihood of the age-3 escapement data ($E_{3,t-1}$) given the hypothesis of return size hypothesis *i* was assumed to follow a binomial distribution ($B(E_{3,t-1}, p)$), where the probability density was calculated at the hypothesis of return size *i* because the binomial probability density function is discrete.

For year t, the age-3 index was estimated from the age-3 escapement in year *t-1* and the total age 4 and age 5 returns in year *t*,

(5) $$p_t = \frac{E_{3,t-1}}{E_{3,t-1} + R_{4,t} + R_{5,t}} \times e^{e} .$$

This index ignores fishing mortality on age-3 fish, likely a plausible approximation because jacks are small and considered to be much less vulnerable to fishing gear than age-4 sockeye (although some fishing mortality must occur). The Cultus age-3 index from brood years 1949 to 1998 appeared to follow a log-normal distribution (Kolmogorov-Smirnov 1-sample test, p = 0.14; $e \sim N(0, s^2)$); brood year 1997 was excluded because the age-3 escapement was zero). Errors in the age-3 index were assumed independent of time but may be influenced by errors in jack escapement estimates if counting errors are proportional to the escapement abundance. Forecasts for year *t+1* relied on the geometric mean age-3 index for years *t-13* to *t-5*.

At first we tried a variant of this model that computed the age-3 proportion by including the age-5 return from the same brood year ($R_{5,t+1}$ rather than $R_{5,t}$ in equation 4). Although biologically more plausible, the requirement for consecutive years of data reduced the numbers of years that could be evaluated in retrospective analyses, and the benefits were considered dubious because of the small proportion returning at age 5. We also computed age-3 proportions using the Pacific Salmon Commission's estimates of the total return of age-3 fish (including estimates of catch), but found these estimates to be much more variable over the time series (CV = 0.37) than the age-3 index based only on escapement data (CV = 0.28). Errors in estimating catch of age-3 Cultus fish may have caused the overall estimates of age-3 proportions to be misleading.

Application to Sakinaw sockeye

No reliable estimates of total returns or smolt-to-adult survival are available for Sakinaw sockeye. Total return data are available only for 1975 when it was estimated that 14,000 were caught in Johnstone and Georgia strait fisheries (based on scale analysis) and 16,000 passed the fishway into Sakinaw Lake (Murray and Wood 2002). To apply the 4-yr mean model, total returns for the last four years (2000 to 2003) were estimated by dividing the escapement estimates (122, 87, 78 and 3) by 0.5. We acknowledge that these estimates (and hence the 4-yr mean forecast) are likely biased high because it seems unlikely that recent exploitation rates have been as high as 50%.

A complete count of Sakinaw smolts was obtained in 2003; these smolts will return primarily in 2005, and almost all were from the 2001 brood year. The total count was 14,792 including 9,998 hatchery smolts (recognized by adipose-clips) and 4,794 wild smolts. Some died following a regrettable incident with the smolt trap, but 12,414 survived to migrate seaward. This smolt enumeration program has provided the first estimates of freshwater survival for Sakinaw sockeye. Fry-to-smolt survival of the 30,000 hatchery-reared fry released as fed-fry in June 2002 was 33%, higher than expected. Egg-to smolt survival of naturally-spawning sockeye was also higher than expected, estimated at about 7% as follows. The visual diver survey estimate was 87 spawners and we assumed that half were female; 15 females were captured and removed to be used as broodstock, leaving an estimated 29 females to spawn naturally. These wild females produced a total of 4,794 smolts, at an average of 168 smolts per wild female. We refer to this statistic as the wild smolt-per-female *index*, acknowledging that the number of wild females is not known exactly. Fecundity has been estimated at 2,500 eggs per female (Murray and Wood 2002).

No smolt enumeration program was conducted in 2002 but we can estimate smolt abundance for the 2000 brood year using information about freshwater survival obtained the following year. The release of 15,000 fed-fry in June 2001 would have produced 4,999 hatchery smolts assuming 33% of the fed-fry survived. Ten females were removed as broodstock in 2000, leaving an estimated 51 females to spawn naturally, if half of the 122 fish observed by divers were female. Our estimate of wild smolt abundance is then 8,579 (51 females x 168 smolts per female), for a total smolt migration of 13,578 in 2004. The same chain of calculations suggests that less than 3,600 and 350 smolts will migrate seaward in 2004 and 2005, respectively.

Because there is no reliable information on smolt-to-adult survival for Sakinaw sockeye, we again used Chilko age-1 smolt-to-adult survival estimates as a surrogate. However, we caution that these values may over-estimate Sakinaw smolt survival. Sakinaw smolt abundance was estimated by mark-recapture over four consecutive years and these estimates (15,880 in 1994, 12,760 in 1995, 2,500 in 1996, and 5,200 in 1997, Bates and August 1997) follow the declining trend in spawning abundance. However, the very low escapements reported in 1996 to 1999 (range 1 to 122) suggest that either marine survival was very low (much less than 4%), or that smolt abundance was over-estimated, or that fishing mortality was high, or that the visual estimates of escapement were biased low, or various combinations of these effects (COSEWIC 2003a). Chilko smolt-to-adult survival for the same years ranged from 3.1 to 14.5%.

Age composition data were available from relatively small samples (range 104-144 fish) in only three consecutive years (1974, 1975, and 1976; Appendix Table 4). The age-3 proportion in the 1971 brood year was computed by multiplying the sample proportions at age by the corresponding estimated escapements (range 6,000-16,000 Appendix Table 3), yielding an estimate of 5.0% of escaping fish; this is equivalent to an age-3 index of 2.5% assuming a 50% exploitation on age-4 and age-5 fish in 1975 and 1976, respectively, and no exploitation on age-3 fish (consistent with assumptions for the Cultus sockeye age-3 index). An automatic video enumeration system installed in the Sakinaw fishway in 2003 provided a complete count as well as images of all fish that passed through the fishway; none of the three sockeye returning in 2003 were jacks.

Two Bayesian forecasts were developed for Sakinaw sockeye; both take into account that no age-3 sockeye were observed in the 2003 escapement. The Bayesian 1 forecast uses the age-3 index estimated for the 1971 Sakinaw brood year (2.5%) whereas the Bayesian 2 forecast uses the recent age-3 index for Cultus sockeye (0.5%). If the age-3 index for Sakinaw was reliable and that rate has not changed since 1971, then the Bayesian 1 forecast can be expected to perform well. However, the Sakinaw age-3 index may be unreliable because relatively small samples were used to estimate age composition so that the expansion factors were large and based on indices of escapement rather than complete counts; moreover, the abundance of Sakinaw sockeye has declined dramatically since 1971. If the age-3 index for Cultus sockeye is a good surrogate for Sakinaw sockeye, and conditions have changed since 1971, the Bayesian 2 forecast may be more reliable. The surrogate option seems reasonable given that the age-3 indices for Sakinaw and Cultus were similar in 1971, and the populations are generally similar in smolt size, life history and status.

Model performance

Model performance was evaluated retrospectively by comparing forecasts to estimated (observed) returns for Cultus sockeye. Retrospective forecasts were based only on the time series available at the time of forecasting, i.e., to the year preceding the year of prediction. The analysis was limited to 18 years because smolt emigration data were lacking for some years, and smolt-to-adult survival or age-3 index data were incomplete for years prior to 1963. These years included 1963-1965, 1969-1976, 1978-1980, 1992-1994, and 2003.

Forecast errors were quantified with the mean absolute percent error (MAPE, equation 6) and root mean square error (RMSE, equation 7) criteria. Forecast errors were estimated from the predicted ($\hat{R}_t$) and observed returns (R_t). These calculations were performed in the variable space and not in the transformed space (equation 1).

(6) $$MAPE = \frac{\sum_{t=1963}^{n} \frac{\left|(\hat{R}_t - R_t)\right|}{R_t}}{n}$$

(7) $$RMSE_i = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(R_t - \hat{R}_t)^2}$$

We also compared bias, expressed as the percentage of trials that over-forecasted returns, and the squared Pearson correlation coefficients (r^2) between forecasted and observed returns for the candidate models. Retrospective forecast model performance could not be assessed for Sakinaw sockeye because of insufficient smolt and total return data.

Forecasts for 2004

A cumulative probability distribution for the predicted 2004 return was plotted for each forecast model. For the recommended forecast model, total returns were computed corresponding to the standard PSARC reference probabilities indicating a 95%, 90%, 75%, 50%, 25%, and 10% chance of a greater return. We also computed the probability that returns would exceed thresholds of 250, 500 and 1,000 individuals for the recommended forecast.

Fishery managers requested advice on the probability of achieving the spawning abundance thresholds under various conditions of pre-spawn mortality and exploitation. The probability of achieving these targets was calculated for each forecast model for several scenarios. The return needed to achieve the target was estimated by dividing the spawning abundance threshold by the expected survival, i.e., the product of the percentage surviving the fishery (1- exploitation rate) and the percentage successfully spawning after they migrate past the counting fence (1- pre-spawn mortality).

For Sakinaw sockeye, we modelled an hypothetical fishery that killed sockeye two weeks prior to their expected arrival time at the fishway into Sakinaw Lake. Migration timing past the fishway is relatively well known from observations between 1957 and 1990 (Fig. 11, Appendix Table 6). However, much less is known about the migration timing (or route) of Sakinaw sockeye through Johnstone Strait. The only direct evidence comes from a single fish tagged in Deepwater Bay (Statistical Area 13) on 10 August 1925 which made the trip to Sakinaw Creek in 8 days (Williamson 1927). Tagging data indicate that Fraser sockeye typically migrate from Johnstone Strait to the Fraser River mouth at 40 to 56 km/day (Verhoeven and Davidoff 1962), so that most make the trip in 1-2 weeks. Sakinaw sockeye need travel only about 2/3 of that distance. This suggests that our hypothetical fishery scenarios may be useful (but idealized) representations of the actual Johnstone Strait fishery. However, it should be recognized that the run timing distribution of the escapement is sculptured by fishing; because exploitation rate has typically been higher during August than June-July, the latter part of the run may be under-represented, and the overall timing biased early. On the other hand, there is uncertainty about the extent to which Sakinaw sockeye delay in the terminal marine area before moving upstream, and a 2-week lag time may not be realistic.

In fishery management Scenario A, all sockeye that have not yet (by the date indicated) passed a fishing boundary 2-weeks "upstream" of the Sakinaw fishway are exploited at the indicated rates (0-70%). In Scenario B, sockeye are exposed to the same fishery for a 1, 2 or 3-week window starting on the indicated date. The hypothetical fishery has no spatial dimension along the migration corridor; all fish are killed at a boundary. Increasing the spatial extent of this fishery will decrease the probability of achieving the spawning requirement depending on the duration of the fishery and the time required for fish to migrate through the expanded fishing area. Increasing the migration lag by one week (from 2 to 3 weeks) would be equivalent to opening the fishery one week later. Pre-spawn (migration and in-lake) mortality was assumed constant at 10%.

The number of spawners (S) was computed as a random variable using the formula

(8) $$S = R\left[\,1-(1-p_{ne,day})u\,\right](1-m_{PSM})$$

where R is the forecasted return, a log-normally distributed random variable, $p_{ne,\,day}$ is the proportion of the return that is not exposed to fishing mortality after a specified day of the year, u is the exploitation rate on exposed fish, and m_{PSM} is the rate of pre-spawn mortality after escaping the fishery. Counts of sockeye passing the fishway in Sakinaw Creek are available for most years from 1957-1990 (Appendix Table 6). Counts were not recorded every day, so daily escapements must be estimated by interpolating between records for observation days. To reduce bias, qualification criteria were used to select informative years; nine years (1957, 1963, 1965, 1976, 1980, 1981, 1983, 1984, 1990) were excluded either because there were fewer than 20 days of observation or because the observation period terminated before 20 August even though fish migration was incomplete. Cumulative probability distributions of escapement were computed from daily estimated escapements (the interpolated "counts") in each qualifying year.

The cumulative proportion of the escapement past the hypothetical fishery ($p_{ne,\ day}$) for a specified day (25 July, 1 August, etc.) was defined as the cumulative proportion of the escapement past the fishway two weeks later. Year-to-year variability was included by randomly selecting (with replacement) one of the 25 qualifying years of historical data in each of 5000 trials. Within each trial, all exploitation rate scenarios were computed from the same cumulative probability table (i.e., a single column of Appendix Table 6). Pre-spawn mortality was fixed at 10%, as the best estimate of mortality in or near the outlet to Sakinaw Lake, and during the extended residence (~ 3 months) within Sakinaw Lake before spawning. This value was suggested by the Sakinaw Sockeye Recovery Team as a reasonable minimum estimate based on discrepancies between spawner counts and fishway counts. For example, the visual estimate (from divers) of spawners on beaches was only 86% and 56% of the fishway estimate in 1979 and 2002, respectively. We acknowledge that these discrepancies may have arisen from observation error as well as mortality. The probability distribution for *S* was computed over 5000 trials for each hypothetical fishery scenario; we then determined the tail probability for *S* equal to or greater than 500 spawners.

Sensitivity Analysis

The Bayesian model is sensitive to error in the age-3 index. To illustrate this sensitivity, we varied the age-3 index by degrees under the plausible scenario of 10% exploitation rate and 10% pre-spawn mortality. We calculated the probability of achieving 500 spawners with an age-3 index at the 10^{th}, 20^{th}, 30^{th}, … percentiles of the log-normal distribution for the Cultus time series (1949-1998, excluding a zero value in 1997).

Results and Discussion

Recent Trends In Status

Spawning abundance, averaged across one generation, declined steadily after 1960 in the Cultus sockeye population (Fig. 1) and after the late 1980s in the Sakinaw population (Fig. 2). This trend has continued in both populations since the COSEWIC assessment of May 2003, with spawning abundance falling to 1,485 and 3 mature individuals in Cultus and Sakinaw, respectively, in 2003. Because these populations are still declining, the appropriate reference points for the IUCN categories *Endangered* and *Vulnerable (*equivalent to COSEWIC's *Threatened*) are 2,500 and 10,000, respectively, under criterion C. If the decline had ceased, the appropriate reference points would be 250 and 1,000 under criterion D.

Chilko Survival

Smolt-to-adult survival for Chilko sockeye appears to be declining (Fig. 3) although the median survival for the last decade (5.8%) is not statistically different from that over the long-term (7.9% for brood years 1949-1998, Appendix Table 5). To guard against over-forecasting the 2004 returns, the smolt and Bayesian (smolt + age-3) forecast models were based on Chilko smolt-to-adult survival for the recent period, represented as the log-normal distribution in Figure

4 (upper frame, parameters in Table 1). Had we used the log-normal distribution fitted to all years (Fig. 4, lower frame), the smolt model forecasts for 2004 would be slightly higher.

Age-3 Index

The Bayesian forecast model requires a parameter that specifies the age-3 ("jack") proportion by brood year. The age-3 index is an approximate estimate of this parameter based on age-3 returns in the escapement only (i.e., any fishing mortality on jacks is ignored). Performance in the retrospective analysis was better when we used the age-3 index approximation for Cultus sockeye than when we included Pacific Salmon Commission estimates of the age-3 catch. Age-3 proportions calculated by including catch estimates were highly variable and exceeded 25% in two years. We consider these to be too unreliable for our purpose.

The age-3 index for Cultus sockeye has not exceeded 11% and has no obvious trend since 1950 (Fig. 5). The median age-3 index for the last decade (0.5%) is not statistically different from that over the long-term (0.7% for brood years 1949-1998, Appendix Table 2). To guard against over-correcting the prior distribution based on the 2004 smolt model forecast, and thus under-estimating returns, we calculated likelihoods in the Bayesian model using an age-3 index distribution from the recent period only, as represented in Figure 6 (upper frame). Had we used the log-normal distribution fitted to all years (Fig. 6, lower frame), the Bayesian forecasts for 2004 would be slightly lower.

Model Performance

In the retrospective analyses, the Bayesian model gave unbiased forecasts, and of the models considered, was least likely to over-estimate total returns. In contrast, the smolt model frequently over-estimated returns (2 times out of 3), an undesirable property in forecasting returns for endangered populations (Table 2, Figure 7). The Bayesian model also performed best under the r^2 criterion, and better than the smolt model under the MAPE criterion. The smolt model performed better than the Bayesian model under the RMSE criterion, unless two years (1970 and 1978) following escapements with very high age-3 index values (ranked 1 and 5) were excluded, in which case the Bayesian model scored better. The Bayesian and smolt models both incorporated information on smolt abundance, so these forecasts are not influenced by uncertainty about pre-spawn mortality rates (unlike brood-year escapement-based models).

The 4-yr mean model is considered inappropriate for forecasting returns to Cultus and Sakinaw in 2004 because it does not take into account new information about changes in pre-spawn mortality or smolt production as evident in the reduced smolt abundance for the 2000 brood year (Folkes and Cass 2003). Pre-spawn mortality increased dramatically in 1999 through 2001, although it has since moderated (Appendix Table 1). Even so, the 4-yr mean model performed better retrospectively than the Bayesian or smolt models under both the MAPE and RMSE criteria, although it too tended to over-estimate returns (56% of cases). Such over-forecasting is inevitable for any recent mean model during periods of continuing decline because of the explicit time lag.

We suspect that the smolt model tends to over-forecast Cultus returns because on average, age-1 smolt-to-adult survival has been higher for Chilko sockeye than Cultus sockeye (Figure 8). By taking into account age-3 abundance observed in the previous calendar year (same brood year), the Bayesian model is able to correct the over-forecasting tendency of the smolt model.

Although the Bayesian model provided acceptable forecasts in most years, it produced large positive errors in two years (1971 and 1979) following very high estimates of age-3 abundance in the escapement. These years contributed disproportionately to the poor RMSE score, suggesting that the Bayesian forecast model should be used cautiously in years where the age-3 estimate is atypically high.

Forecasted Total Returns in 2004

Comparison of forecasts

Total returns in 2004 forecasted by the alternative forecast methods are illustrated as cumulative probability plots in Figures 9 (Cultus) and 10 (Sakinaw). Note that the cumulative probability specifies the probability that the return will be less than a specified total return.

Cultus sockeye: For Cultus sockeye, the 4-yr mean model forecasts larger returns than the other models, giving odds of only 2 times in 5 (40%) that the return will not exceed 2,000 sockeye. Although this simple model actually performed best in the retrospective analyses under the MAPE and RMSE criteria, it is not recommended for 2004 in view of the poor smolt production that resulted from atypical conditions of pre-spawn mortality (see Folkes and Cass 2003). The smolt model forecasts a slightly larger return than the Bayesian model, consistent with its tendency to over-forecast historical returns in the retrospective analysis. Primarily for this reason, we recommend the Bayesian model forecast for the Cultus population.

Sakinaw sockeye: For Sakinaw sockeye, the 4-yr mean model forecasts much smaller returns than the other models, giving better than equal odds (>50%) that the return would not exceed 100 sockeye. Again this model is not recommended for 2004 because we know that conditions have changed; supplementation by hatchery fry gives a reasonable expectation that smolt abundance was much higher for the 2000 brood year than for the previous four years. However, it should be noted that the 4-yr mean model is the only model for the Sakinaw population based entirely on empirical data.

Although the smolt model takes into account the expected increase in smolt production for the 2000 brood year, it also includes speculation that subsequent smolt-to-adult survival will be as high as observed for Chilko smolts. This assumption seems reasonable because Sakinaw smolts are larger than Chilko smolts, but it has never been tested; it seems equally plausible that the Sakinaw population has declined over the last decade because its overall productivity has been reduced by poor marine survival, perhaps because Sakinaw smolts have different migratory behaviour than Chilko smolts. The smolt model predicts a 1 chance in 5 (20%) that the total return will be less than 500 sockeye.

The Bayesian models both take into account that no age-3 sockeye were observed in the 2003 escapement (based on a complete count at the Sakinaw fishway). The Bayesian 1 model uses the age-3 index estimated for the 1971 Sakinaw brood year (2.5%) whereas the Bayesian model 2 uses the recent age-3 index for Cultus sockeye (0.5%). If the age-3 index for Sakinaw is reliable and the rate has not changed since 1971, then the Bayesian 1 model is the best choice. However, the Sakinaw age-3 index may be unreliable because relatively small samples were used to estimate age composition so that the expansion factors were large and based on indices of escapement rather than complete counts; moreover, the abundance of Sakinaw sockeye has declined dramatically since 1971. If, on the other hand, the age-3 index for Cultus sockeye is a good proxy for Sakinaw sockeye, and conditions have changed since 1971, the Bayesian 2 model is the correct choice. We recommend the Bayesian 2 forecast given the similarity of age-3 indices for Sakinaw and Cultus in 1971, and the general similarity of these populations in smolt size, life history and status.

Recommended forecasts

Recommended forecasts for 2004 give equal odds (50%) that total returns will be less than 281 individuals for Cultus and 390 individuals for Sakinaw (Table 3). The odds that the total return will exceed 500 individuals are slightly over 1 in 10 (10.5%) for Cultus and 1 in 4 (28.7%) for Sakinaw.

If the conditional Bayesian forecast for Cultus sockeye is based on historical Cultus smolt-to-adult survival rather than Chilko survival, the median forecast for Cultus is slightly lower, with equal odds of total returns less than 246 individuals. This forecast is included only for the sake of comparison, as requested by the PSARC Subcommittee, but is not recommended.

Probability of Achieving Escapement Targets

The future viability of these populations depends on the number of spawners achieved in 2004, not the total return *per se*. Some of these maturing fish will be killed incidentally in fisheries and some will die before having an opportunity to spawn. Accordingly, we calculated the probability of achieving a threshold spawning abundance for a range of exploitation rates and pre-spawn mortality rates (at Cultus) or fishery opening dates (at Sakinaw) for all forecast models.

For Cultus sockeye, the odds of achieving 500 spawners given the recommended forecast are less than 1 in 20 (about 4%) if the overall exploitation rate reaches 20% even in the absence of pre-spawn mortality, or if pre-spawn mortality reaches 20% even in the absence of fishing, or if exploitation rate exceeds 10% when pre-spawn mortality is 10% (Table 4). For Sakinaw sockeye, the odds of achieving 500 spawners under corresponding regimes of about 20% mortality are 1 in 7 (about 14%).

For Sakinaw sockeye, the fishery opening dates apply to a hypothetical fishery that is two weeks “upstream” of the fishway into Sakinaw Lake. Annual variation in run timing past the fishway was taken into account (see Fig. 11). In Scenario A, all sockeye that have not yet (by the date indicated) passed a fishing boundary 2-weeks upstream of the Sakinaw fishway are exploited at the indicated rates (0-70%). In Scenario B, sockeye are exposed to the same (barrier-type) fishery for a 1, 2 or 3-week window starting on the indicated date. Increasing the spatial extent of the fishery would decrease the probability of achieving the spawning requirement. Increasing the migration lag by one week (from 2 to 3 weeks) is equivalent to opening the fishery one week later. Pre-spawn (migration and in-lake) mortality was assumed constant at 10%.

Under the recommended Bayesian 2 forecast, the odds of achieving 500 spawners was only slightly better than 1 in 5 (22%) with no incidental fishing mortality (Fig. 12). These odds dropped to 3 in 20 (15%) for a fishery opening 1 August that exerts an exploitation rate of 50% on exposed fish (i.e., those that had not already passed beyond the fishing boundary). Closing this hypothetical fishery after 2 weeks (the "2wkAug1" case of Scenario B, Table 5B) did not improve the odds appreciably, because few Sakinaw population would remain upstream of the boundary after 15 August. Conversely, delaying the fishery opening to 15 August maintained the odds at 1 in 5 (20.5%) even for exploitation rates as high as 40% (Table 5A).

Sensitivity of Forecasts to Key Parameters

The Bayesian model is sensitive to error in the age-3 index. When the age-3 index is under-estimated, the forecasts are overly optimistic, and the probability of achieving a threshold spawning abundance is over-estimated. To illustrate this sensitivity, we varied the age-3 index by degrees under the plausible scenario of 10% exploitation rate and 10% pre-spawn mortality (Figure 13). Forecasted returns for 2004 were computed for the recent median (or geometric mean) index of 0.005, which corresponds to the 43rd percentile of the Cultus sockeye data over all years (1949-1998).

For Sakinaw, the single historical age-3 index estimate (2.5% from brood year 1971) corresponded to the 83rd percentile for Cultus sockeye over all years (1949 to 1998). However, the age-3 index for Cultus in 1971 was similarly high (1.7%, 75th percentile), which suggests both that conditions have changed, and that Cultus may be a good proxy for Sakinaw (see Fig. 5). From this perspective, the Bayesian 1 model forecasts are likely to under-estimate the odds of achieving 500 spawners.

Conclusions

1) The recommended median forecast for Cultus sockeye in 2004 is 281 individuals with odds of 9 in 10 (90% probability) that the return will exceed 150, and 3 in 4 (75% probability) that the return will exceed 203 individuals. This forecast is based on a Bayesian model that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003. The model performed well in retrospective analyses using historical data for Cultus sockeye.

2) The recommended median forecast for Sakinaw sockeye in 2004 is 390 individuals with odds of 9 in 10 (90% probability) that the return will exceed 215, and 3 in 4 (75% probability) that the return will exceed 286 individuals. This forecast is based on the Bayesian 2 model that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003, but uses an expected age-3 index for Cultus sockeye. The model has not

been evaluated in retrospective analyses for Sakinaw sockeye because no historical data are available.

3) If our 2004 forecasts are correct, it is almost certain that both populations will continue to warrant the *Endangered* designation under criterion C, implying they face ”imminent extinction” (COSEWIC definition) or “very high risk of extinction in the wild” (IUCN definition). Spawning abundance has declined since 1960 for Cultus sockeye and since the late 1980s for Sakinaw sockeye. These trends have continued in both populations since the COSEWIC assessment of May 2003, with abundance falling to 1,485 in Cultus Lake and 3 (or fewer) spawners in Sakinaw Lake in 2003. Because these populations are still declining, both trigger the IUCN under criterion C (fewer than 2,500 mature individuals and decline continuing); Sakinaw sockeye also triggers the *Endangered* designation under criterion D (fewer than 250 mature individuals).

4) The odds of achieving 500 spawners in Cultus Lake in 2004 are only about 1 in 15 (6.8%) assuming no fishing mortality and 10% pre-spawn mortality. Any fishing mortality (or higher pre-spawn mortality) will decrease these odds.

5) The odds of achieving 500 spawners in Sakinaw Lake in 2004 are about 1 in 5 (21.0%) assuming no fishing mortality and 10% pre-spawn mortality. Any fishing mortality (or higher pre-spawn mortality) will decrease these odds. Incidental fishing mortality on Sakinaw sockeye from mixed-stock fishing in Johnstone Strait is expected to be negligible for opening dates on or after 15 August.

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Table 1. Summary of key parameter values used to develop forecasts for 2004.

Cultus	Forecast model		
	smolt	Bayesian	4-yr mean
smolt emigration	7,558	7,558	n/a
median smolt survival	6%	6%	n/a
parameters: E[ln(survival)]	-2.774	-2.774	n/a
SD[ln(survival)]	0.584	0.584	n/a
age-3 index	n/a	0.005	n/a
age-3 count in 2003	n/a	0	n/a
forecast distribution			
parameters: E[ln(returns)]	6.156	5.633	7.828
SD[ln(returns)]	0.584	0.470	0.898

Sakinaw	Forecast model			
	smolt	Bayesian1	Bayesian2	4-yr mean
smolt emigration	13,578	13,578	13,578	n/a
median smolt survival	6%	6%	6%	n/a
parameters: E[ln(survival)]	-2.774	-2.774	-2.774	n/a
SD[ln(survival)]	0.584	0.584	0.584	n/a
age-3 index	n/a	0.025	0.005	n/a
age-3 count in 2003	n/a	0	0	n/a
forecast distribution				
parameters: E[ln(returns)]	6.678	5.133	5.960	4.374
SD[ln(returns)]	0.584	0.364	0.442	1.732

Table 2. Summary statistics for retrospective comparison of forecast models for Cultus sockeye. Best performance statistics are indicated by bold font.

Summary Statistic	Smolt	Bayesian	4-yr mean
MAPE	142%	123%	**107%**
RMSE	38,495	49,753	**29,112**
Percentage over-forecast errors	67%	**50%**	56%
Proportion of variation explained (r^2)	53%	**68%**	10%

Includes return years 1963-65, 1969-1976, 1978-1980, 1992-1994, and 2003.

Table 3. Summary of forecasts for 2004. Recommended forecasts (in bold font) are based on Bayesian model using smolt production and age-3 returns in 2003; the second Bayesian model was used for Sakinaw sockeye.

Table 3a. Total returns by probability level for conditions of no exploitation or pre-spawn mortality.

		Probability (odds) of exceeding specified total returns					
		95%	90%	75%	50%	25%	10%
Population	Model	(19 in 20)	(9 in 10)	(3 in 4)	(1 in 2)	(1 in 4)	(1 in 10)
CULTUS	smolt	180	223	318	472	699	997
	cond. Bayesian	**124**	**150**	**203**	**281**	**386**	**507**
	4-yr mean	574	795	1371	2511	4600	7932
SAKINAW	smolt	304	376	536	795	1179	1680
	cond. Bayesian2	**180**	**215**	**286**	**390**	**525**	**678**
	4-yr mean	5	9	25	79	254	728

Table 3b. Probability of achieving spawning abundance thresholds of 250, 500, and 1,000.

		NO EXPLOITATION + NO PRE-SPAWN MORTALITY			10% EXPLOITATION + 10% PRE-SPAWN MORTALITY		
Population	Model	250	500	1000	250	500	1000
CULTUS	smolt	86.1%	46.0%	9.9%	76.5%	32.3%	5.0%
	cond. Bayesian	**59.6%**	**10.5%**	**<0.1%**	**42.1%**	**4.1%**	**<<0.1%**
	4-yr mean	99.5%	96.4%	84.8%	99.0%	94.1%	78.5%
SAKINAW	smolt	97.6%	78.6%	34.7%	94.7%	66.8%	22.5%
	cond. Bayesian2	**83.2%**	**28.7%**	**1.2%**	**69.8%**	**14.6%**	**0.2%**
	4-yr mean	25.3%	14.3%	7.1%	21.6%	11.8%	5.6%

Table 4. Probability of achieving 500 spawners in 2004 under hypothetical scenarios for pre-spawn mortality and fishery exploitation.

Scenario		Probability of …		
Pre-spawn mortality (%)	Exploitation rate (%)	surviving to spawn	achieving 500 spawners	
			Cultus	Sakinaw
0	0	1.000	0.105	0.287
0	5	0.950	0.086	0.248
0	10	0.900	0.068	0.210
0	15	0.850	0.052	0.173
0	20	0.800	0.039	0.139
0	25	0.750	0.028	0.108
0	30	0.700	0.019	0.079
10	0	0.900	0.068	0.210
10	5	0.855	0.054	0.177
10	10	0.810	0.041	0.145
10	15	0.765	0.031	0.117
10	20	0.720	0.022	0.090
10	25	0.675	0.015	0.067
10	30	0.630	0.010	0.048
20	0	0.800	0.039	0.139
20	5	0.760	0.030	0.114
20	10	0.720	0.022	0.090
20	15	0.680	0.016	0.069
20	20	0.640	0.011	0.052
20	25	0.600	0.007	0.037
20	30	0.560	0.004	0.025
30	0	0.700	0.019	0.079
30	5	0.665	0.014	0.063
30	10	0.630	0.010	0.048
30	15	0.595	0.007	0.035
30	20	0.560	0.004	0.025
30	25	0.525	0.003	0.017
30	30	0.490	0.002	0.010
40	0	0.600	0.007	0.037
40	5	0.570	0.005	0.027
40	10	0.540	0.003	0.020
40	15	0.510	0.002	0.014
40	20	0.480	0.001	0.009
40	25	0.450	0.001	0.006
40	30	0.420	0.000	0.003
50	0	0.500	0.002	0.012
50	5	0.475	0.001	0.008
50	10	0.450	0.001	0.006
50	15	0.425	0.000	0.004
50	20	0.400	0.000	0.002
50	25	0.375	0.000	0.001
50	30	0.350	0.000	0.001

Table 5. Probability that the number of SAKINAW SOCKEYE spawners in 2004 will exceed a threshold of 500 under hypothetical scenarios for fishery opening data and exploitation rate on exposed fish. Results are presented for four alternative forecast models, but the Bayesian 2 forecast is recommended.

Table 5A.. In Scenario A, all sockeye that have not yet (by the date indicated) passed a fishing boundary 2-weeks "upstream" of the Sakinaw fishway are exploited at the indicated rates (0-70%). Note that assuming a migration lag of three weeks is equivalent to opening the fishery one week later.

FISHERY OPEN	EXPLOITATION OF EXPOSED FISH	PROBABILITY OF ACHIEVING 500 SPAWNERS			
		SMOLT	BAYESIAN_1	**BAYESIAN_2**	4-YR MEAN
JUL25	0%	0.711	0.001	**0.221**	0.073
AUG1	0%	0.711	0.001	**0.221**	0.073
AUG8	0%	0.711	0.001	**0.221**	0.073
AUG15	0%	0.711	0.001	**0.221**	0.073
JUL25	10%	0.690	0.001	**0.192**	0.123
AUG1	10%	0.697	0.001	**0.203**	0.125
AUG8	10%	0.704	0.001	**0.213**	0.126
AUG15	10%	0.706	0.001	**0.216**	0.127
JUL25	20%	0.674	0.001	**0.172**	0.118
AUG1	20%	0.693	0.001	**0.194**	0.123
AUG8	20%	0.708	0.002	**0.208**	0.127
AUG15	20%	0.714	0.002	**0.215**	0.128
JUL25	30%	0.639	0.000	**0.143**	0.113
AUG1	30%	0.665	0.001	**0.168**	0.119
AUG8	30%	0.685	0.001	**0.190**	0.125
AUG15	30%	0.694	0.001	**0.201**	0.127
JUL25	40%	0.622	0.000	**0.126**	0.109
AUG1	40%	0.665	0.000	**0.160**	0.119
AUG8	40%	0.696	0.000	**0.188**	0.126
AUG15	40%	0.708	0.001	**0.205**	0.129
JUL25	50%	0.584	0.001	**0.110**	0.106
AUG1	50%	0.643	0.001	**0.150**	0.115
AUG8	50%	0.677	0.001	**0.179**	0.124
AUG15	50%	0.693	0.001	**0.195**	0.127
JUL25	60%	0.566	0.001	**0.095**	0.101
AUG1	60%	0.636	0.001	**0.137**	0.110
AUG8	60%	0.682	0.001	**0.176**	0.121
AUG15	60%	0.701	0.001	**0.196**	0.125
JUL25	70%	0.514	0.000	**0.078**	0.095
AUG1	70%	0.599	0.001	**0.124**	0.106
AUG8	70%	0.658	0.001	**0.166**	0.118
AUG15	70%	0.686	0.001	**0.186**	0.122

Table 5. (continued).

Table 5B. In Scenario B, sockeye are exposed to the same (point-source) fishery as in A but only for a 1, 2 or 3-week window starting on the indicated date. Increasing the spatial extent of the fishery would decrease the probability of achieving the spawning requirement. In this analysis, increasing the migration lag by one week (from 2 to 3 weeks) is equivalent to opening the fishery one week later.

FISHERY OPENS	EXPLOITATION OF EXPOSED FISH	PROBABILITY OF ACHIEVING 500 SPAWNERS			
		SMOLT	BAYESIAN_1	**BAYESIAN_2**	4-YR MEAN
2wkJul25	10%	0.696	0.001	**0.199**	0.127
3wkJul25	10%	0.693	0.000	**0.196**	0.126
1wkAug1	10%	0.704	0.001	**0.208**	0.130
2wkAug1	10%	0.701	0.001	**0.205**	0.129
2wkJul25	20%	0.688	0.000	**0.197**	0.121
3wkJul25	20%	0.680	0.000	**0.188**	0.120
1wkAug1	20%	0.707	0.001	**0.216**	0.126
2wkAug1	20%	0.701	0.001	**0.209**	0.125
2wkJul25	30%	0.665	0.000	**0.167**	0.119
3wkJul25	30%	0.657	0.000	**0.158**	0.115
1wkAug1	30%	0.692	0.001	**0.192**	0.126
2wkAug1	30%	0.683	0.001	**0.184**	0.123
2wkJul25	40%	0.657	0.000	**0.149**	0.113
3wkJul25	40%	0.643	0.000	**0.138**	0.109
1wkAug1	40%	0.696	0.000	**0.184**	0.122
2wkAug1	40%	0.682	0.000	**0.171**	0.118
2wkJul25	50%	0.628	0.001	**0.134**	0.111
3wkJul25	50%	0.606	0.000	**0.121**	0.108
1wkAug1	50%	0.678	0.001	**0.179**	0.123
2wkAug1	50%	0.661	0.001	**0.164**	0.117
2wkJul25	60%	0.612	0.000	**0.121**	0.110
3wkJul25	60%	0.588	0.000	**0.107**	0.106
1wkAug1	60%	0.675	0.000	**0.176**	0.120
2wkAug1	60%	0.654	0.000	**0.155**	0.117
2wkJul25	70%	0.585	0.000	**0.114**	0.107
3wkJul25	70%	0.551	0.000	**0.096**	0.103
1wkAug1	70%	0.662	0.001	**0.162**	0.118
2wkAug1	70%	0.635	0.000	**0.144**	0.114

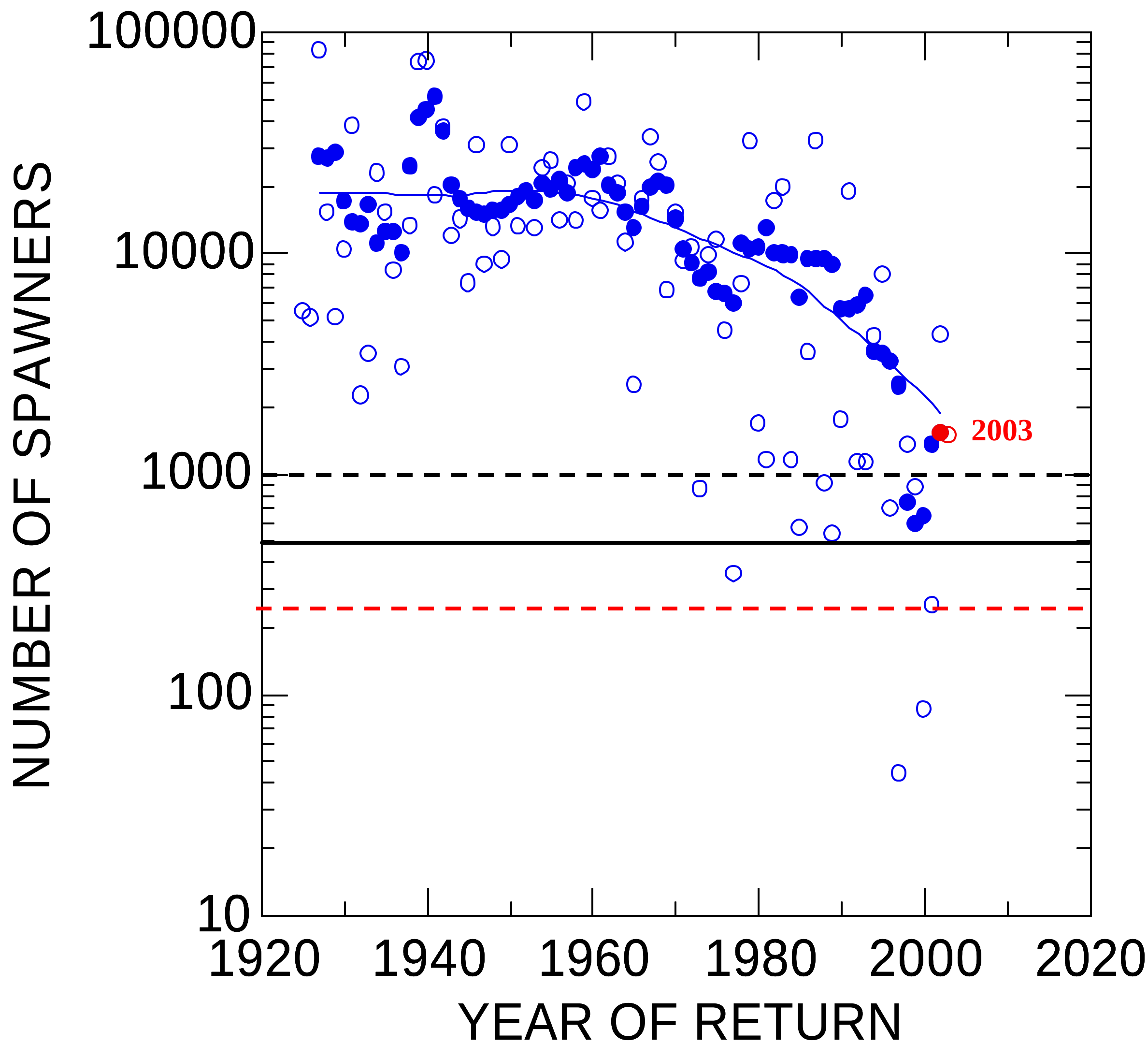

Figure 1. Trend in number of mature individuals in the CULTUS SOCKEYE salmon population. Open circles are annual estimates of spawning escapement; filled circles are the corresponding estimates smoothed over one-generation (4 yr); line is fitted to smoothed data by LOWESS. Red symbols are updated since COSEWIC assessment of status. Horizontal lines correspond to thresholds of 250 (COSEWIC *Endangered* status under Criterion D, red dash), 500 (possible Recovery Team objective for 2004, black solid), and 1000 (COSEWIC *Threatened* status under Criterion D, black dash).

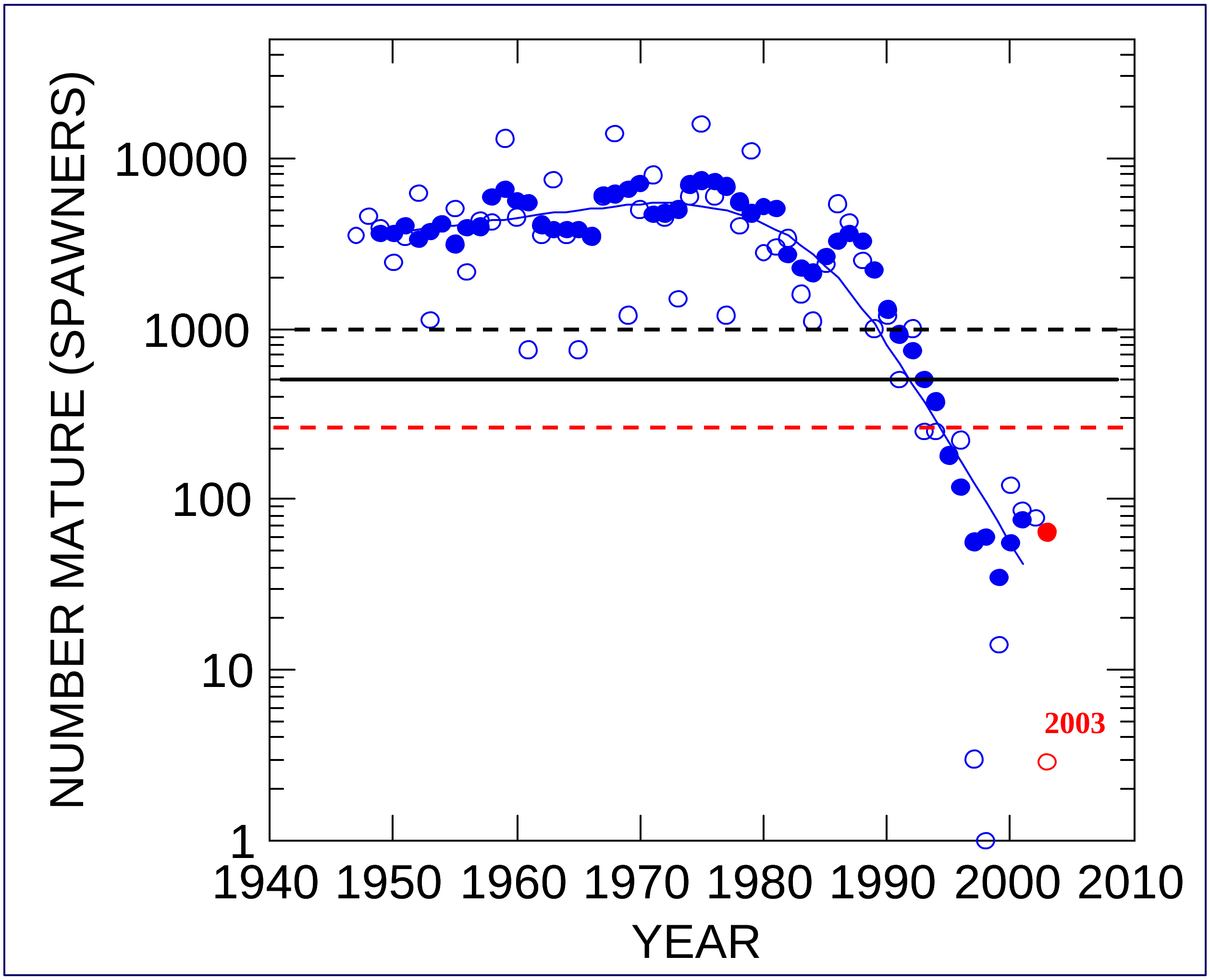

Figure 2. Trend in number of mature individuals in the SAKINAW SOCKEYE salmon population. Open circles are annual estimates of spawning escapement; filled circles are the corresponding estimates smoothed over one-generation (4 yr); line is fitted to smoothed data by LOWESS. Red symbols are updated since COSEWIC assessment of status. Horizontal lines correspond to thresholds of 250 (COSEWIC *Endangered* status under Criterion D, red dash), 500 (Recovery Team interim objective for 2004, black solid), and 1000 (COSEWIC *Threatened* status under Criterion D, black dash).

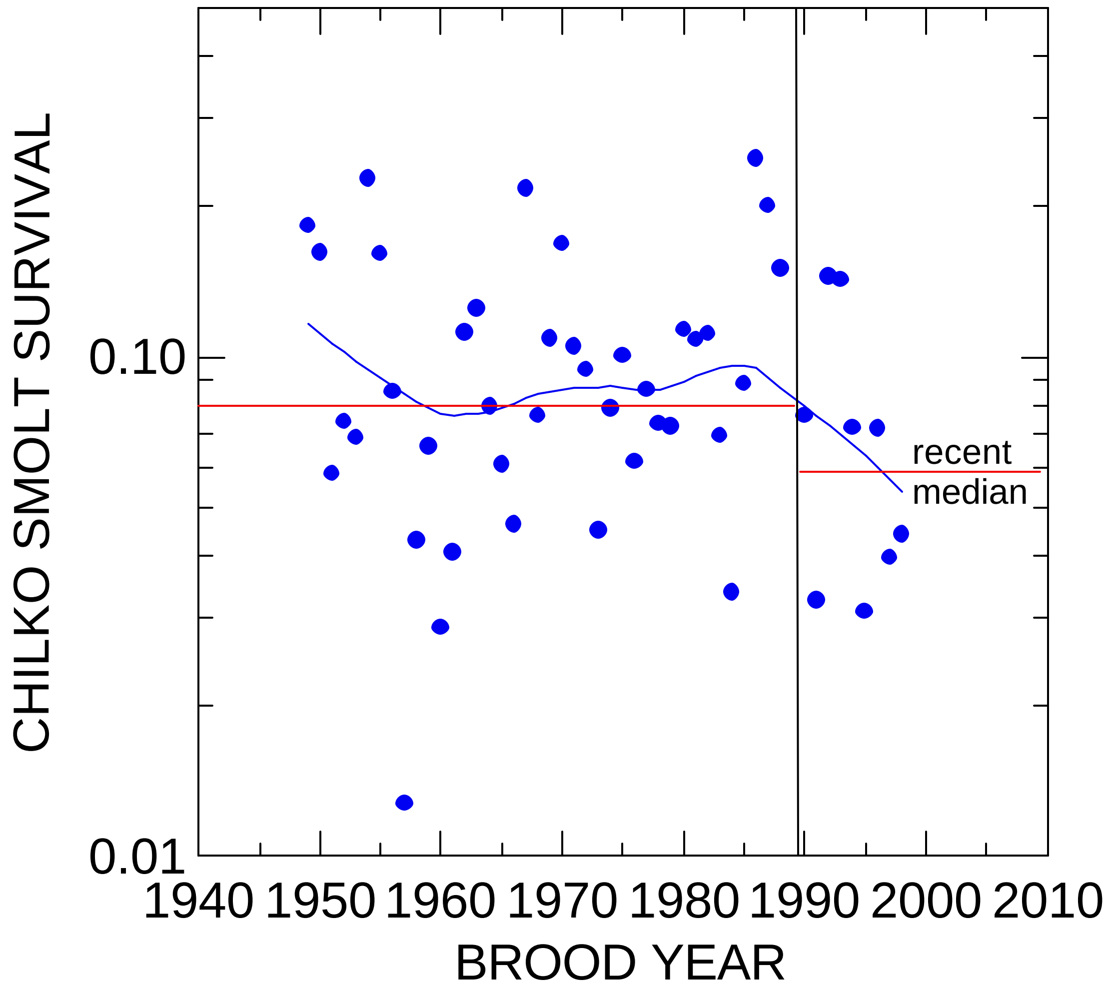

Figure 3. Trend in survival of age-1 Chilko sockeye smolts. Horizontal red lines show medians for all years (1949-1998) and recent years (1990-1998). The difference is not statistically significant (p>0.10).

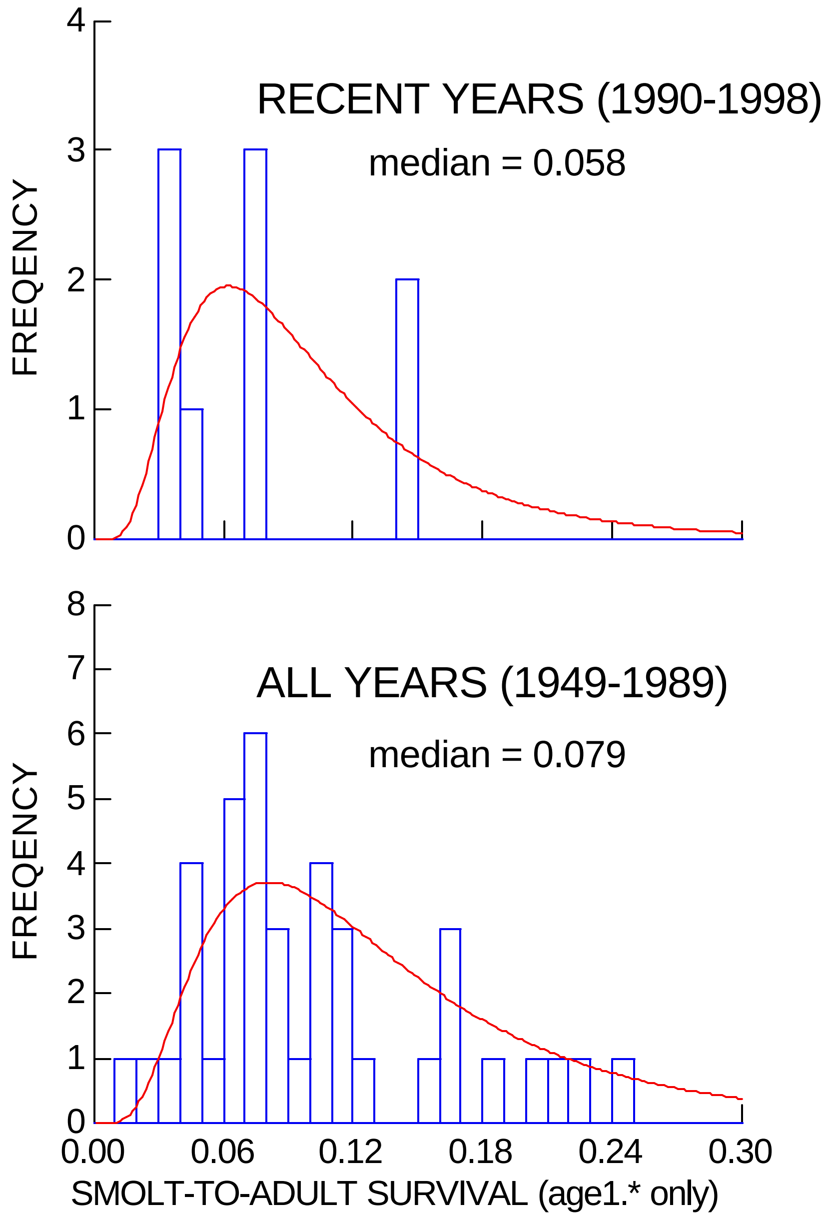

Figure 4. Distribution of age-1 smolt survival for Chilko sockeye for recent (1990-1998) and all (1949-1998) brood years. Red lines show corresponding log-normal distributions (but not to scale).

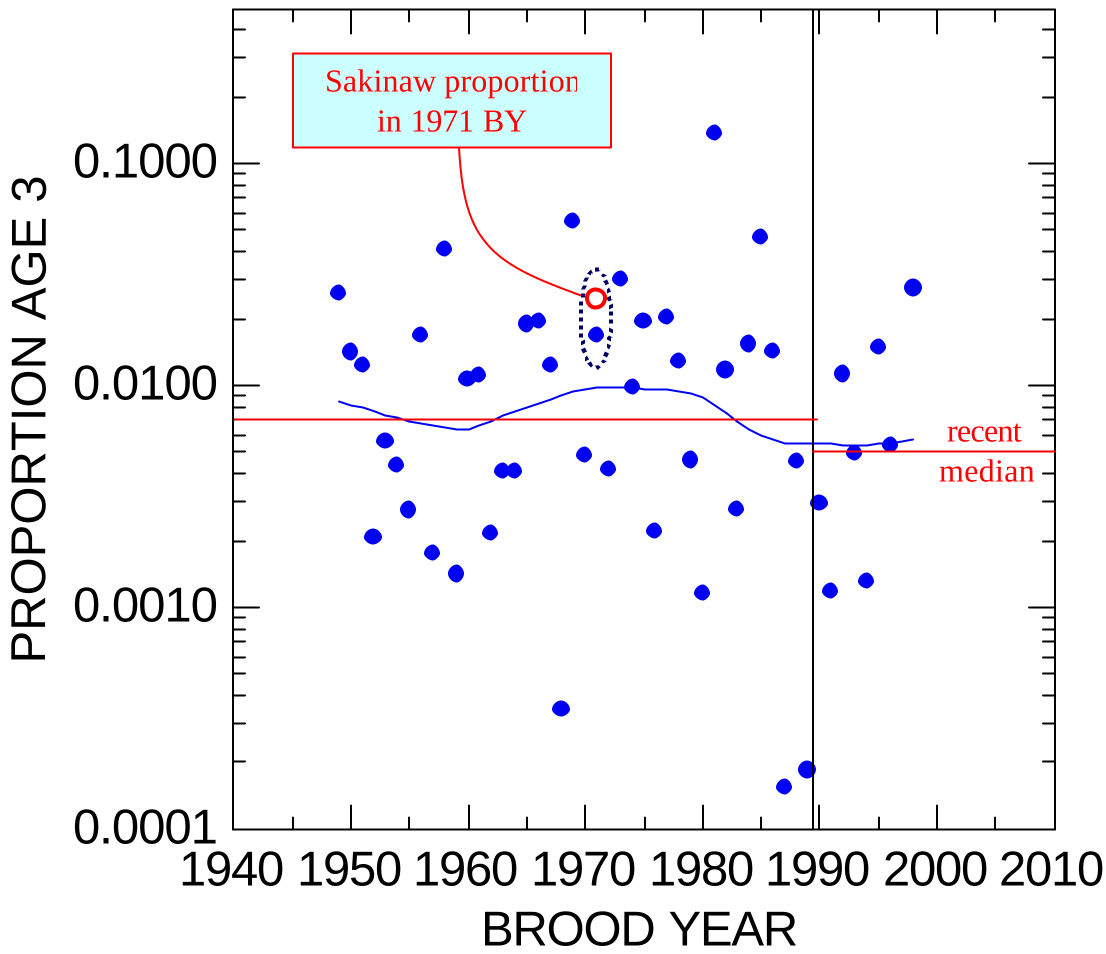

Figure 5. Trend in brood-year proportions of Cultus sockeye returning at age 3 ("jacks"). Horizontal red lines show medians for all years (1949-1998) and recent years (1990-1998). The difference is not statistically significant (p>0.53). Open red symbol is the estimated age-3 proportion in the 1971 brood year of Sakinaw sockeye (2.5% versus 1.7% for Cultus sockeye).

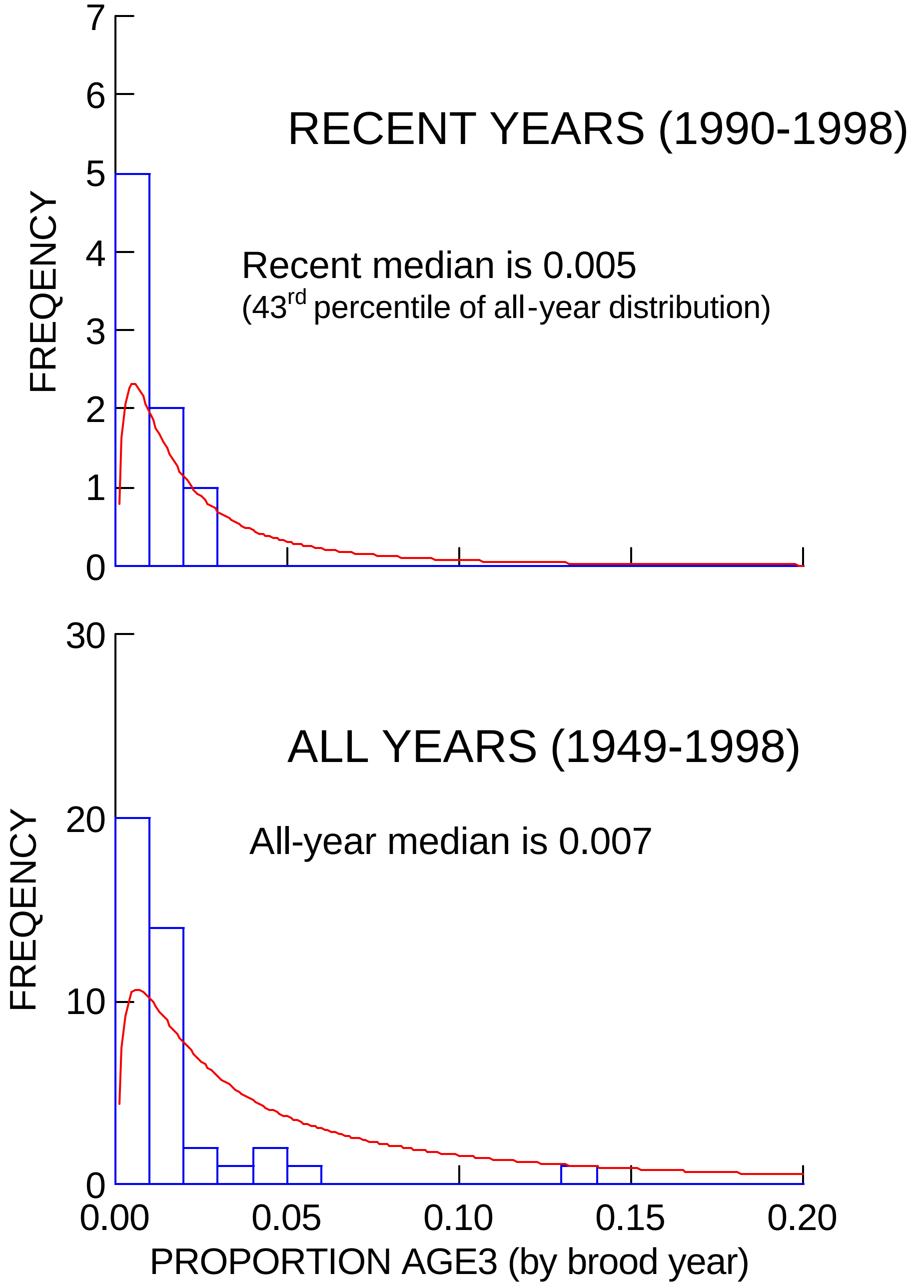

Figure 6. Distribution of brood-year proportions of Cultus sockeye returning at age 3 ("jacks"). Red lines show corresponding log-normal distributions (but not to scale).

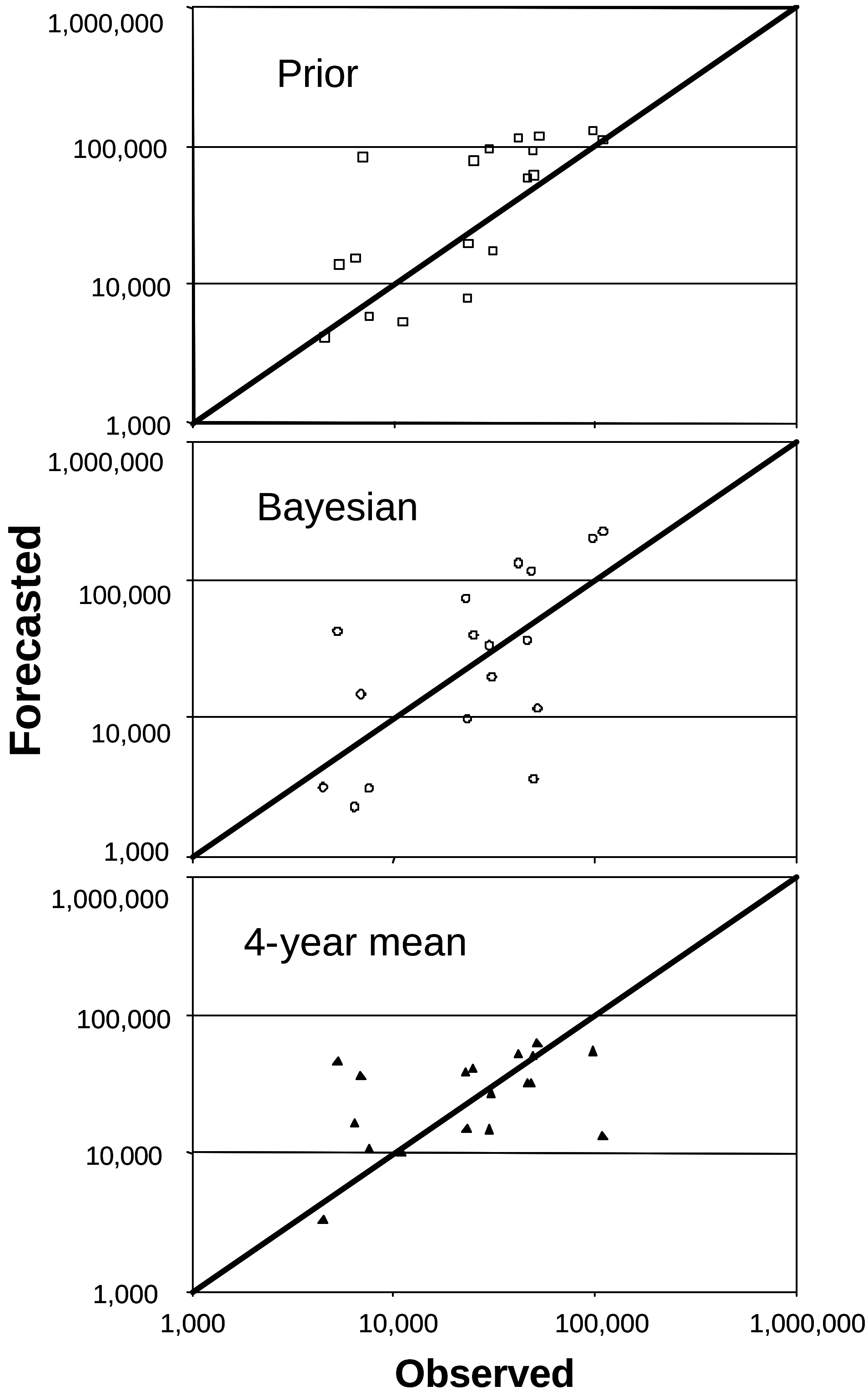

Figure 7. Performance of three alternative forecast models in historical retrospective comparisons for Cultus sockeye. Diagonal line indicates forecasts with no error. The prior model is the smolt model.

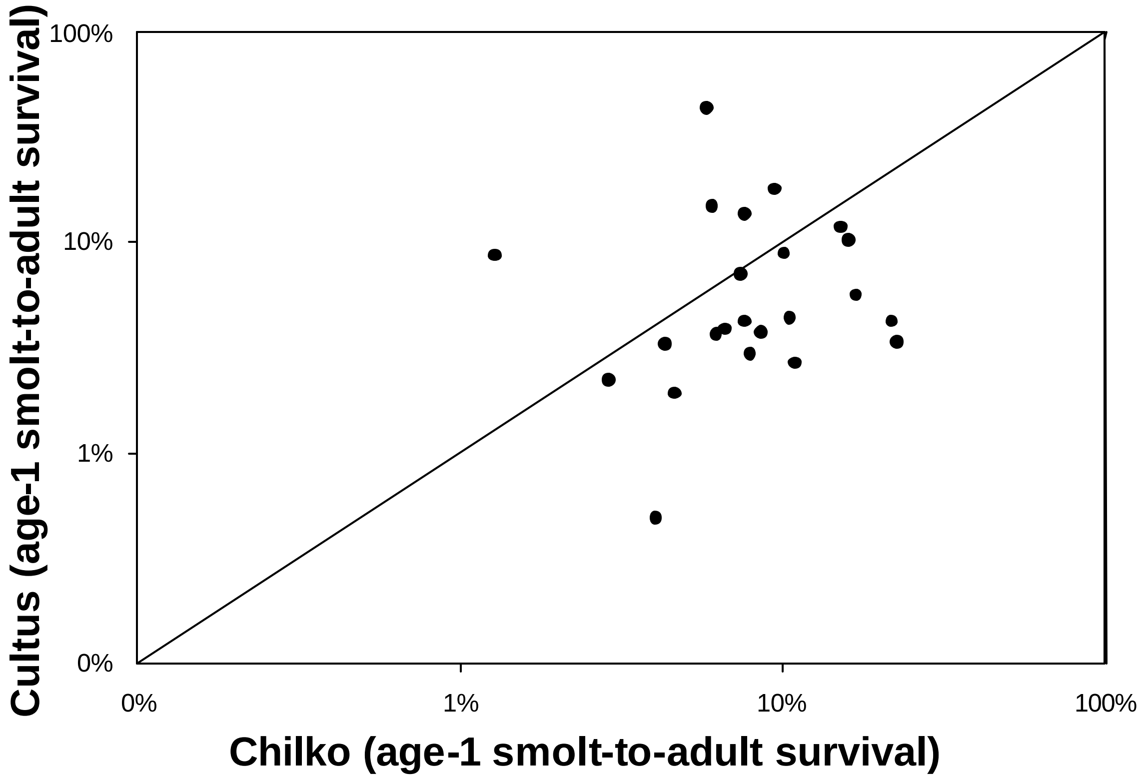

Figure 8. Comparison of age-1 smolt-to-adult survival for Cultus and Chilko sockeye. Diagonal line indicates equal survival (r^2 =0.02).

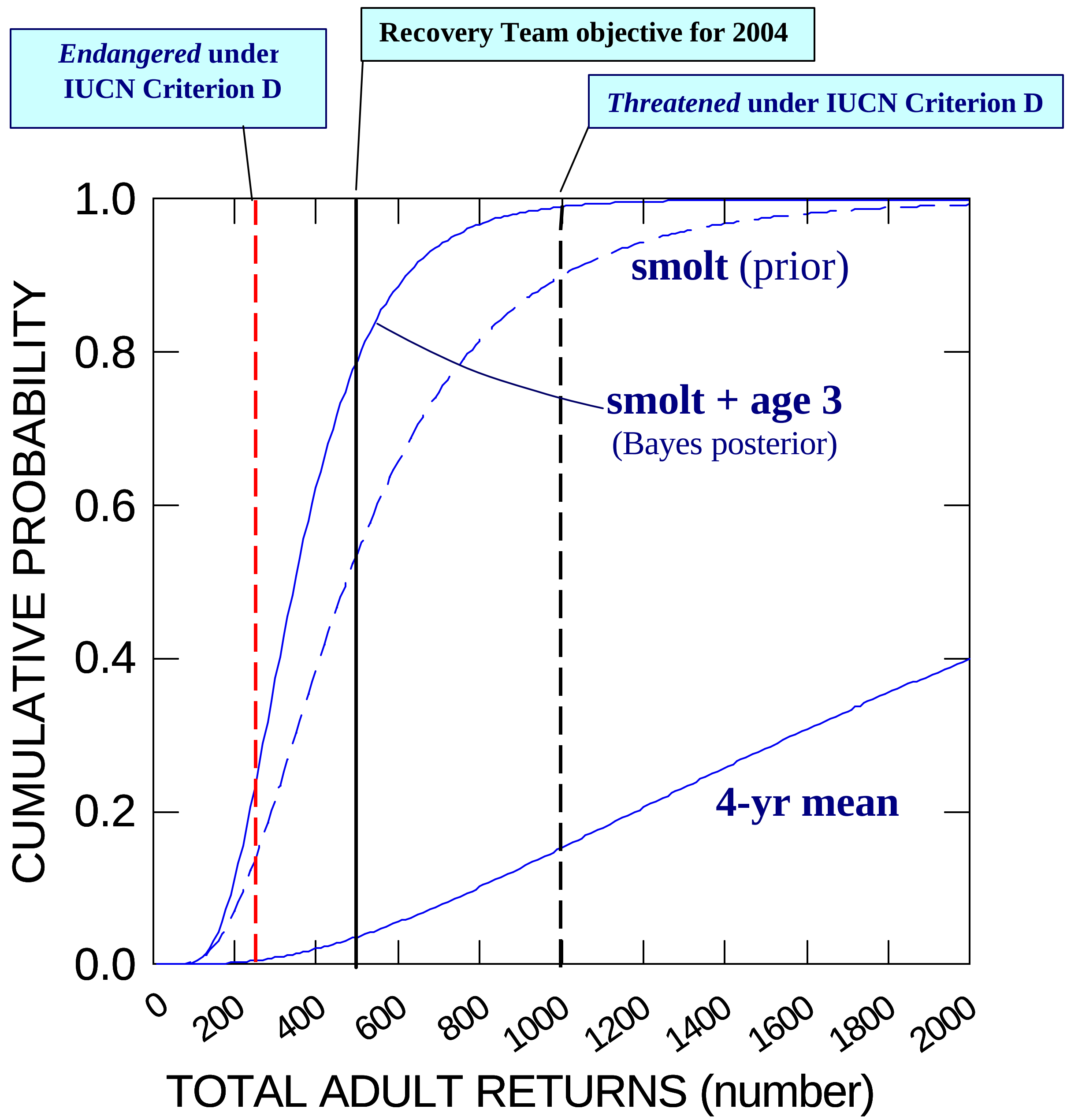

Figure 9. Cumulative probability plots for total adult returns of CULTUS SOCKEYE in 2004 based on three alternative forecast methods. Note that the cumulative probability specifies the probability that the return will be less than a specified total return.

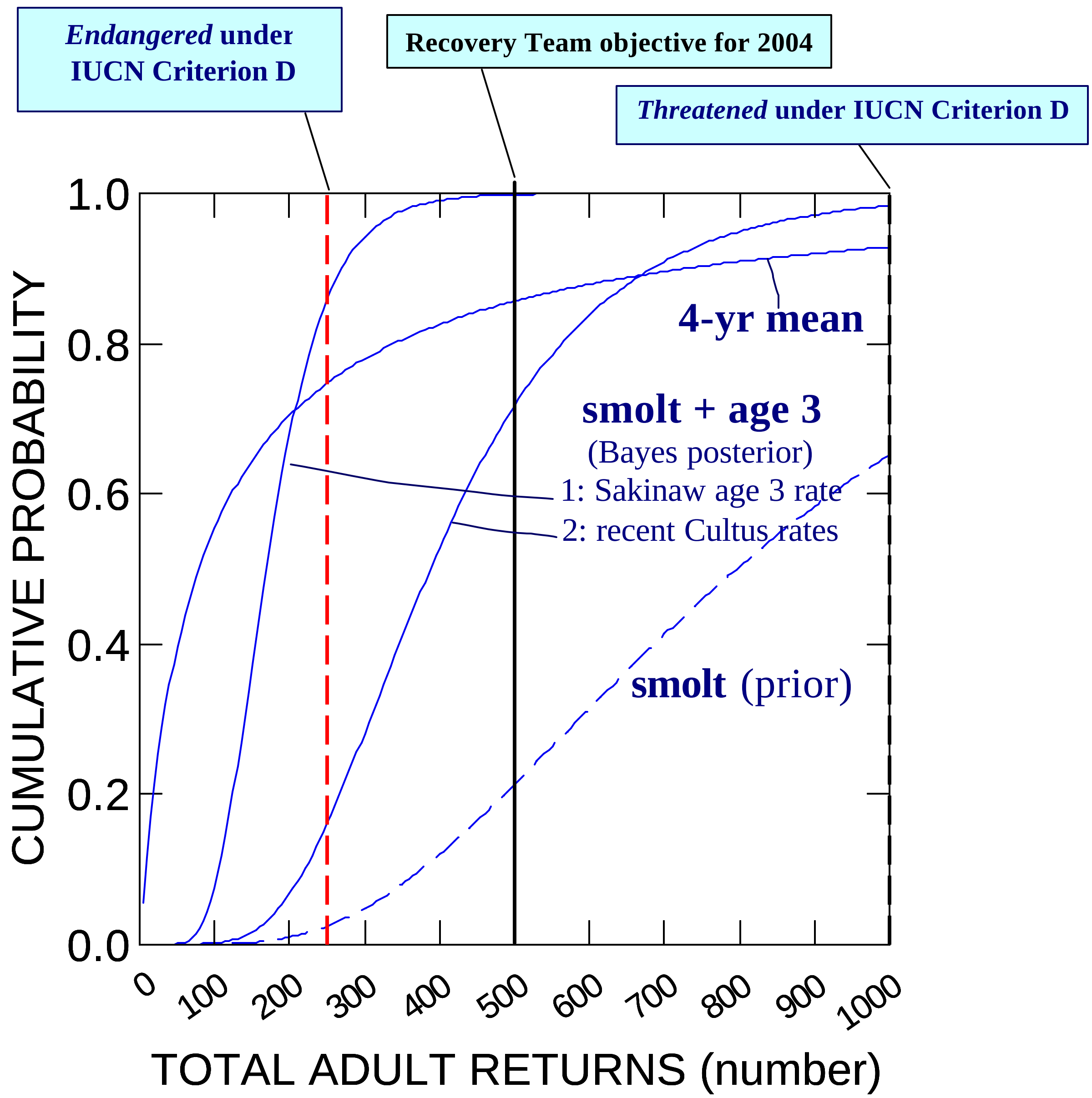

Figure 10. Cumulative probability plots for total adult returns of SAKINAW SOCKEYE in 2004 based on four alternative forecast methods. Note that the cumulative probability specifies the probability that the return will be less than a specified total return.

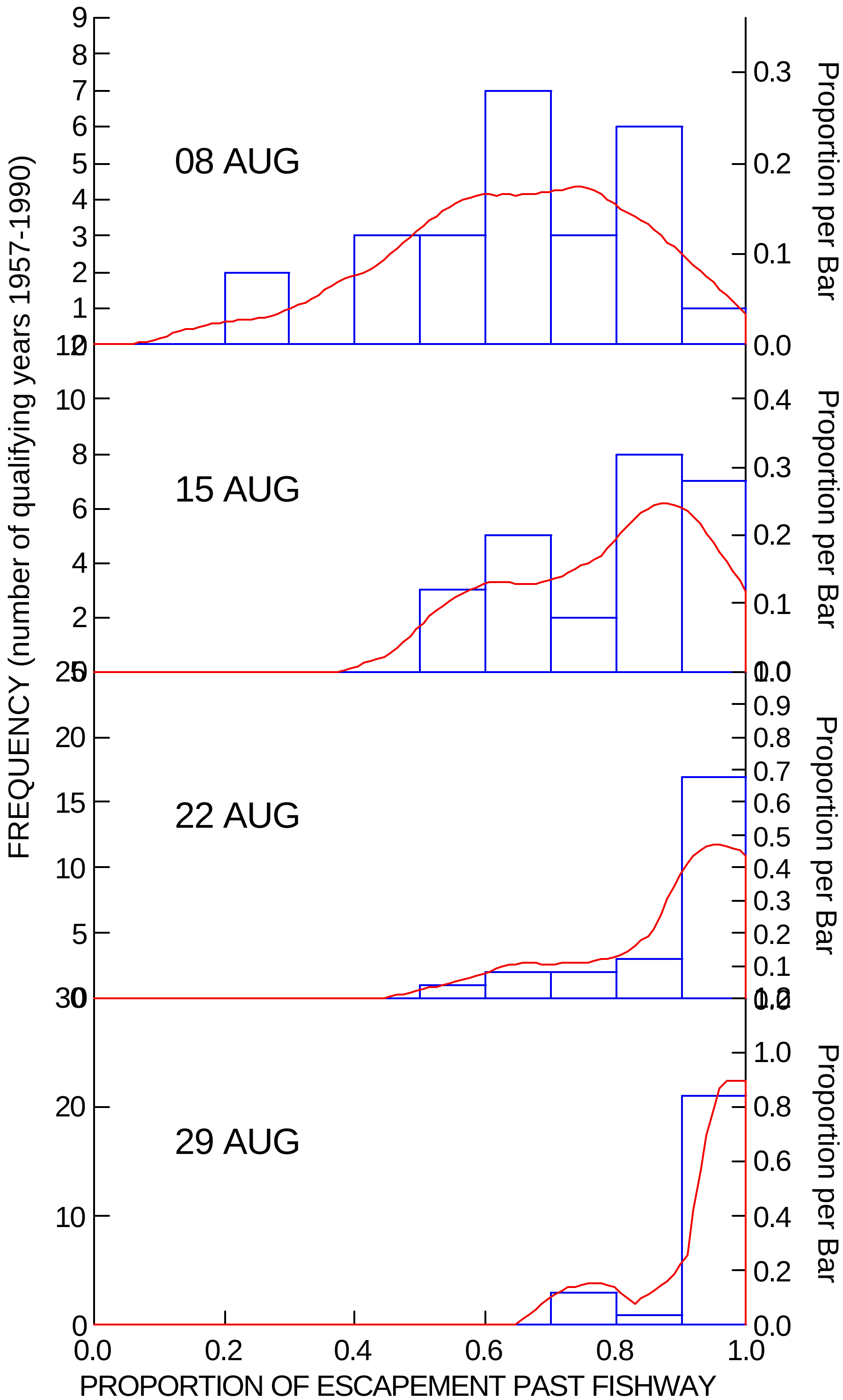

Figure 11. Annual variation in run timing of the SAKINAW SOCKEYE escapement. Cumulative proportions of escapement past the Sakinaw Creek fishway by specified dates were computed by interpolation from historical observations in 25 qualifying years between 1958-1989. Red lines are kernel density functions fitted to the histograms.

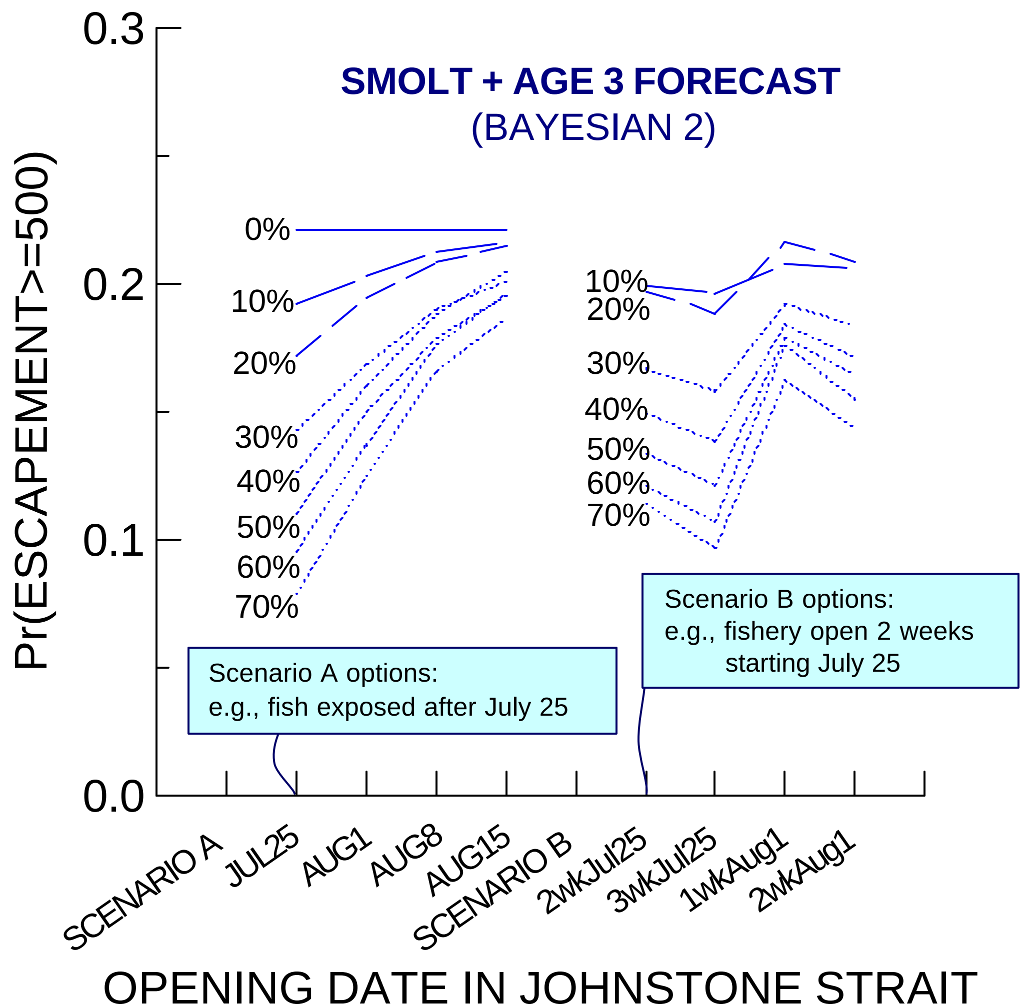

Figure 12. Sensitivity of the Bayesian 2 posterior probability that the number of SAKINAW SOCKEYE spawners in 2004 will exceed 500, to hypothetical fishery management scenarios. Lines show probabilities for alternative exploitation rates on exposed fish under two scenarios. In Scenario A, all sockeye that have not yet (by the date indicated) passed a fishing boundary 2-weeks "upstream" of the Sakinaw fishway are exploited at the indicated rates (0-70%). In Scenario B, sockeye are exposed to the same (point-source) fishery for a 1, 2 or 3-week window starting on the indicated date; increasing the spatial extent of the fishery would decrease the probability of achieving the spawning requirement. In this analysis, increasing the migration lag by one week (from 2 to 3 weeks) is equivalent to opening the fishery one week later.

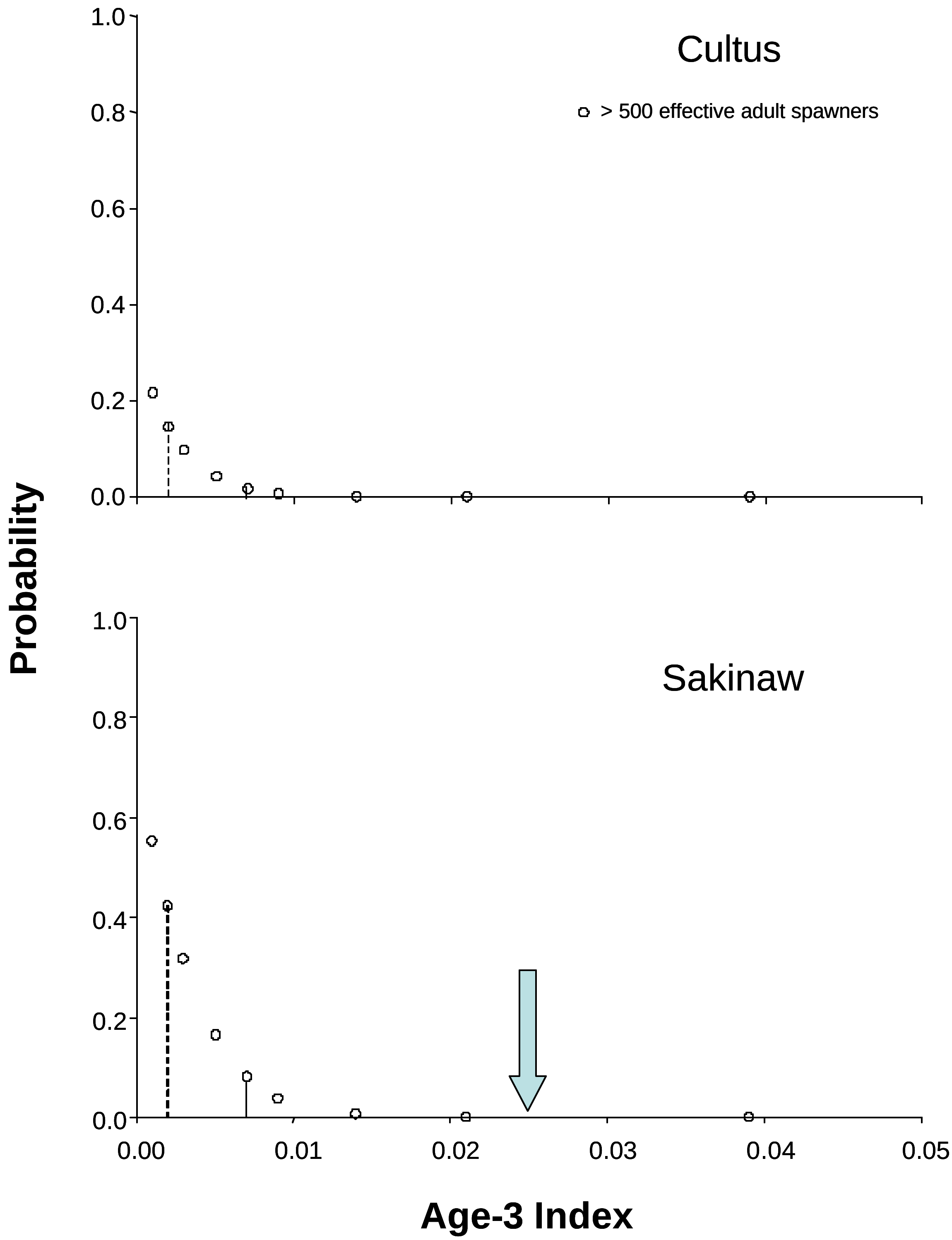

Figure 13. Sensitivity of the Bayesian posterior probability that the number of spawners in 2004 will exceed reference threshold of 500 to the expected proportion at age 3 (the "age-3 index" parameter). The vertical lines indicate the 20th percentile (dashed) and median (solid) values for a log-normal distribution fitted to all historical for Cultus sockeye. The arrow indicates the single historical estimate (1971) for Sakinaw sockeye (83rd percentile). The recommended forecasts are based on an age-3 index of 0.005 (43rd percentile).

Appendix Table 1. Annual escapement of adults by sex and jacks, female spawning success, and smolt production of Cultus sockeye salmon, 1925 to 2003. ("na" indicates data are unavailable) (updated from Schubert et al. 2002).

	Escapement									Smolt Production		
			Adults									
Year	Total population	Jacks	Total	Males	Females	Female carcasses recovered	Female spawning success	Estimated prespawn mortality [c]	Estimated effective spawners	Estimated smolts at age Age-1	Age-2	Total Smolts
1925	5,423	0	5,423	1,540	3,883	-	-	-	5,423	-	-	-
1926	5,071 [a]	2,449	2,622	1,122	1,500	-	-	-	5,071	1,398,000	na	1,398,000
1927	82,426	0	82,426	26,050	56,376	-	-	-	82,426	183,400	66,500	249,900
1928	15,339 [b]	678	14,661	3,700	10,961	-	-	-	15,339	336,200	1,700	337,900
1929	5,084 [a]	0	5,084	1,645	3,439	-	-	-	5,084	2,426,200	8,300	2,434,500
1930	10,395	2,449	7,946	2,404	5,542	-	-	-	10,395	38,600	66,600	105,200
1931	37,473	0	37,473	10,368	27,105	-	-	-	37,473	349,000	5,200	354,200
1932	2,259 [a]	28	2,231	713	1,518	-	-	-	2,259	788,400	200	788,600
1933	3,471 [b]	607	2,864	1,027	1,837	-	-	-	3,471	1,571,000	0	1,571,000
1934	23,026	86	22,940	3,966	18,974	-	-	-	23,026	121,200	63,300	184,500
1935	15,339	na	15,339	5,412	9,927	-	-	-	15,339	242,500	14,200	256,700
1936	8,378	56	8,322	3,261	5,061	-	-	-	8,378	501,600	1,400	503,000
1937	3,061	1,834	1,227	513	714	-	-	-	3,061	3,101,000	23,000	3,124,000
1938	13,342	3,908	9,434	1,603	7,831	-	-	-	13,342	1,627,000	20,000	1,647,000
1939	73,189	2,400	70,789	19,224	51,565	-	-	-	73,189	196,255	20,415	216,803
1940	74,121	585	73,536	16,089	57,447	-	-	-	74,121	1,374,800	138	1,376,736
1941	18,164	4,214	13,950	5,413	8,537	-	-	-	18,164	3,955,502	953	3,965,434
1942	37,305	346	36,959	12,396	24,563	-	-	-	37,305	1,752,551	20,705	1,777,964
1943	11,875	53	11,822	3,881	7,941	-	-	-	11,875	702,980	12,879	715,859
1944	14,200	198	14,002	4,701	9,301	-	-	-	14,200	2,009,186	2,730	2,015,179
1945	9,227	4,197	5,030	1,780	3,250	75	79.0%	21.0%	7,289	390,064	9,698	400,421
1946	33,284	216	33,068	11,911	21,157	434	91.9%	8.1%	30,581	-	-	-
1947	8,898	199	8,699	2,869	5,830	-	-	-	8,898	-	-	-
1948	13,086	340	12,746	5,601	7,145	-	-	-	13,086	-	-	-
1949	9,301	246	9,055	3,039	6,016	-	-	-	9,301	-	-	-
1950	30,595	667	29,928	10,027	19,901	-	-	-	30,595	-	-	-
1951	13,143	466	12,677	3,002	9,675	-	-	-	13,143	-	-	-
1952	18,910	1,077	17,833	5,698	12,135	-	-	-	18,910	-	-	-
1953	13,000	1,457	11,543	6,253	5,290	-	-	-	13,000	392,801	<1%	392,801
1954	24,150	2,114	22,036	10,795	11,241	-	-	-	24,150	626,478	<1%	626,478
1955	26,000	78	25,922	7,990	17,932	-	-	-	26,000	-	-	-
1956	14,133	415	13,718	4,630	9,088	-	-	-	14,133	1,903,296	4,759	1,908,055
1957	20,647	272	20,375	7,245	13,130	-	-	-	20,647	2,688,063	23,589	2,711,652
1958	14,097	773	13,324	5,794	7,530	-	-	-	14,097	976,120	64,512	1,040,632
1959	48,461	682	47,779	15,753	32,026	-	-	-	48,461	319,495	184	319,679
1960	17,689	49	17,640	7,520	10,120	-	-	-	17,689	1,427,228	1,480	1,432,008
1961	15,428	2,032	13,396	6,363	7,033	-	-	-	15,428	1,327,842	2,215	1,330,057
1962	27,070	73	26,997	9,450	17,547	-	-	-	27,070	1,025,404	4,438	1,029,842
1963	20,571	268	20,303	9,032	11,271	-	-	-	20,571	1,200,498	24,859	1,225,357
1964	11,143	76	11,067	4,857	6,210	-	-	-	11,143	-	-	-
1965	2,532	77	2,455	832	1,623	-	-	-	2,532	-	-	-
1966	17,464	545	16,919	7,676	9,243	-	-	-	17,464	-	-	-
1967	33,492	294	33,198	14,767	18,431	-	-	-	33,492	131,106	4,682	135,788
1968	25,736	422	25,314	10,439	14,875	-	-	-	25,736	2,101,506	822	2,102,328
1969	6,739	797	5,942	2,761	3,181	-	-	-	6,739	2,441,694	17,446	2,459,140
1970	15,149	1,208	13,941	5,778	8,163	-	-	-	15,149	1,005,291	17,582	1,022,873
1971	9,145	17	9,128	4,161	4,967	-	-	-	9,145	186,787	7,652	194,439
1972	10,660	294	10,366	4,572	5,794	-	-	-	10,660	na	na	808,014
1973	858	217	641	318	323	-	-	-	858	1,086,016	17,335	1,103,351
1974	9,814	830	8,984	3,630	5,354	-	-	-	9,814	167,111	6,505	175,788
1975	11,478	129	11,349	4,006	7,343	-	-	-	11,478	-	-	-
1976	4,450	15	4,435	1,551	2,884	-	-	-	4,450	na	na	996,263
1977	353	271	82	41	41	-	-	-	353	na	na	1,231,526

Continued

Appendix Table 1 (continued).

	Escapement									Smolt Production		
			Adults			Female	Female	Estimated	Estimated	Estimated smolts at age		
Year	Total population	Jacks	Total	Males	Females	carcasses recovered	spawning success	prespawn mortality [c]	effective spawners	Age-1	Age-2	Total Smolts
1978	7,265	2,189	5,076	1,920	3,156	-	-	-	7,265	na	na	169,679
1979	32,045	14	32,031	11,736	20,295	-	-	-	32,045	-	-	-
1980	1,687	30	1,657	693	964	-	-	-	1,687	-	-	-
1981	1,159	903	256	112	144	-	-	-	1,159	-	-	-
1982	17,222	497	16,725	6,445	10,280	-	-	-	17,222	-	-	-
1983	19,952	8	19,944	8,454	11,490	35	100.0%	0.0%	19,952	-	-	-
1984	1,147	153	994	449	545	-	-	-	1,147	-	-	-
1985	571	147	424	215	209	-	-	-	571	-	-	-
1986	3,533	277	3,256	1,062	2,194	-	-	-	3,533	-	-	-
1987	32,336	152	32,184	14,800	17,384	-	-	-	32,336	-	-	-
1988	964	103	861	374	487	-	-	6.6% [d]	900	-	-	-
1989	568	150	418	182	236	-	-	6.6% [d]	530	-	-	-
1990	1,870	10	1,860	849	1,011	-	-	6.6% [d]	1,746	65,184	459	65,643
1991	20,191	34	20,157	9,690	10,467	246	94.1%	5.9%	19,001	52,865	372	53,237
1992	1,205	2	1,203	455	748	-	-	6.6% [d]	1,125	178,357	2,716	181,073
1993	1,131	68	1,063	492	571	71	100.0%	0.0%	1,131	-	-	-
1994	4,422	23	4,399	1,749	2,650	115	95.2%	4.8%	4,212	-	-	-
1995	10,349	33	10,316	4,744	5,572	28	76.5%	23.5%	7,921	-	-	-
1996	2,030	8	2,022	908	1,114	10	34.4%	65.6%	698	-	-	-
1997	91	3	88	45	43	0	-	51.6% [e]	44	-	-	-
1998	2,166	207	1,959	928	1,031	9	62.5%	37.5%	1,353	-	-	-
1999	12,403	11	12,392	5,576	6,816	0	-	93.0% [f]	868	-	-	-
2000	1,227	0	1,227	613	614	0	-	93.0% [f]	86	-	-	-
2001	675	160	515	257	258	1	0.0%	62.5% [g]	253	62,564	70	62,634
2002	4,882	9	4,873	2,155	2,718	275	86.9%	13.1%	4,242	5,654	27	7,558 [h]
2003	1,939	0	1,939	1,075	864	74	76.6%	23.4%	1,485	11,201	59	11,260

a. No natural spawning; all eggs stripped from females for hatchery incubation and subsequent fry liberation into lake.
b. No natural spawning; all eggs stripped from females for egg plants in tributaries to Cultus Lake.
c. Directly estimated from female carcass recovery, unless otherwise noted.
d. Direct estimate unavailable; 1925-1994 average used for three generation projection.
e. Direct estimate unavailable; 1996 and 1998 average used for three generation projection.
f. Direct estimate unavailable; estimated from ratio of smolts/adult for brood with 1925-1994 (pre-early migration) average.
g. Direct estimate unavailable; 1995, 1996, 1998, 1999 and 2000 average used for three generation projection.
h. Includes hatchery smolt releases (age-1) and natural smolt removals.

Appendix Table 2. Brood year escapement, subsequent return by age in the catch and escapement, and returns per spawner for Cultus sockeye adults, 1948-1999 brood years. (updated from Schubert et al. 2002).

Brood Year	Adult Escapement	Jack Escapement	Jack return 3_2	Adult return (catch plus escapement) 4_3	4_2	5_2	5_3	Total	Age-3 Index
1948	12,746		-	0	37,820	1,256	1,827	40,903	
1949	9,055	1,077	1,662	16	37,489	0	0	37,505	0.026
1950	29,928	1,457	3,623	0	101,664	0	3,074	104,738	0.014
1951	12,677	2,114	3,498	0	166,043	4,527	0	170,569	0.012
1952	17,833	78	159	0	32,999	11,266	0	44,265	0.002
1953	11,543	415	497	0	62,317	855	0	63,172	0.006
1954	22,036	272	1,631	44	61,631	1,933	6,056	69,665	0.004
1955	25,922	773	1,610	204	274,490	1,184	3,596	279,474	0.003
1956	13,718	682	1,273	0	35,165	1,067	0	36,232	0.017
1957	20,375	49	95	0	26,724	1,264	0	27,988	0.002
1958	13,324	2,032	3,547	0	46,269	1,097	117	47,482	0.041
1959	47,779	73	114	94	50,631	1,449	735	52,908	0.001
1960	17,640	268	483	0	22,606	414	436	23,456	0.011
1961	13,396	76	194	0	5,954	0	0	5,954	0.011
1962	26,997	77	524	201	35,483	0	534	36,218	0.002
1963	20,303	545	3,825	0	131,466	3,157	0	134,623	0.004
1964	11,067	294	1,357	0	67,696	1,550	797	70,043	0.004
1965	2,455	422	1,380	34	19,606	0	0	19,640	0.019
1966	16,919	797	4,551	0	40,079	435	0	40,514	0.019
1967	33,198	1,208	7,716	0	96,671	6,114	473	103,258	0.012
1968	25,314	17	36	0	42,418	0	0	42,418	0.000
1969	5,942	294	1,446	0	5,031	0	0	5,031	0.055
1970	13,941	217	910	56	44,797	150	219	45,222	0.005
1971	9,128	830	2,673	58	47,715	313	512	48,598	0.017
1972	10,366	129	337	3	30,020	3	0	30,026	0.004
1973	641	15	44	0	480	189	0	669	0.030
1974	8,984	271	636	0	27,251	1,831	0	29,082	0.010
1975	11,349	2,189	7,700	0	107,820	267	0	108,087	0.020
1976	4,435	14	20	0	6,109	0	0	6,109	0.002
1977	82	30	114	0	1,457	0	0	1,457	0.020
1978	5,076	903	4,837	18	69,111	0	1,279	70,408	0.013
1979	32,031	497	1,662	0	106,617	1,627	610	108,854	0.005
1980	1,657	8	186	0	4,639	0	0	4,639	0.001
1981	256	153	579	0	965	0	0	965	0.137
1982	16,725	147	883	8	12,419	5,529	0	17,956	0.012
1983	19,944	277	423	0	95,192	711	0	95,903	0.003
1984	994	152	215	0	9,074	32	85	9,191	0.015
1985	424	103	329	0	1,980	122	0	2,102	0.047
1986	3,256	150	210	0	10,278	0	0	10,278	0.014
1987	32,184	10	19	0	64,919	917	0	65,836	0.000
1988	861	34	99	0	6,584	1,142	0	7,726	0.005
1989	418	2	4	0	9,729	1,012	0	10,741	0.000
1990	1,860	68	236	0	22,231	2,300	320	24,851	0.003
1991	20,157	23	23	0	16,722	733	24	17,479	0.001
1992	1,203	33	67	0	2,150	0	0	2,150	0.011
1993	1,063	8	11	0	1,600	0	0	1,600	0.005
1994	4,399	3	7	0	2,297	138	0	2,435	0.001
1995	10,316	207	240	0	13,690	510	17	14,217	0.015
1996	2,022	11	12	0	1,497	0	0	1,497	0.005
1997	88	0	0	0	617	17	0	634	0.000
1998	1,959	160	160	0	5,657	90	0	5,747	0.027
1999	12,392	9	9	na	na	na	na	na	na
2000	1,939	0	0	na	na	na	na	na	na

Appendix Table 3. Annual records of spawning escapements to Sakinaw Lake (updated from Murray and Wood 2002).

Return year	Fishway counts	Visual surveys diver	Visual surveys surface
1940			
1941			
1942			
1943			
1944			
1945			
1946			
1947	3500		
1948	4600		
1949	3931		
1950	2473		
1951	3450		
1952	6222		
1953	1131		
1954	4143		
1955	5079		
1956	2150		
1957	4300		
1958	4250		
1959	13000		
1960	4500		
1961	750		
1962	3500		
1963	7500		
1964	3500		
1965	750		
1966	3500		
1967	6000		
1968	14000		
1969	1200		
1970	5000		
1971	8000		
1972	4500		
1973	1500		
1974	6000		
1975	16000		
1976	6000		
1977	1200		
1978	4000		
1979	11000	9482	

Return year	Fishway counts	Visual surveys diver	Visual surveys surface
1980	2800		
1981	3000		
1982	3400		
1983	1600		
1984	1115		
1985	2400		
1986	5400		
1987	4200		
1988	2500		
1989	1000		
1990	1200		
1991			500
1992			1000
1993			250
1994			250
1995			
1996			222
1997			3
1998			1
1999		14[a]	
2000		122	
2001		87	
2002	78	44	
2003	3	1[a]	

[a] *minimum estimate based on partial survey*

Appendix Table 4. Age composition (in European format) of Sakinaw sockeye sampled from the fishway (1972-1980) and off the spawning grounds (2001) (from Murray and Wood 2002).

Year	Age 1.1		Age 1.2		Age 1.3		Age 2.1		Age 2.2		Total	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
1972	0	0.00	121	82.88	19	13.01	0	0.00	6	4.11	146	27.65
1974	14	13.46	84	80.77	6	5.77	0	0.00	0	0.00	104	19.70
1975	0	0.00	110	99.10	0	0.00	1	0.90	0	0.00	111	21.02
1976	0	0.00	131	90.97	7	4.86	0	0.00	6	4.17	144	27.27
1980	0	0.00	10	83.33	2	16.67	0	0.00	0	0.00	12	2.27
2001	0	0.00	3	25.00	8	66.67	0	0.00	0	0.00	11	2.08
Overall	14	2.65	459	86.93	42	7.95	1	0.19	12	2.27	528	

Appendix Table 5. Chilko Lake sockeye smolt abundance and survival by brood year.

brood year	number of age 1+ smolts (millions)	smolt survival
pre-1990		
1949	3.147	0.183
1950	1.170	0.162
1951	11.505	0.058
1952	24.491	0.074
1953	7.690	0.069
1954	2.853	0.227
1955	9.159	0.161
1956	28.242	0.085
1957	9.458	0.013
1958	6.895	0.043
1959	32.165	0.066
1960	33.780	0.029
1961	1.592	0.041
1962	8.813	0.112
1963	9.270	0.125
1964	23.665	0.080
1965	2.346	0.061
1966	17.355	0.046
1967	9.148	0.217
1968	31.542	0.076
1969	3.586	0.109
1970	3.833	0.168
1971	5.672	0.105
1972	20.270	0.094
1973	4.300	0.045
1974	7.246	0.079
1975	14.145	0.100
1976	26.011	0.062
1977	2.268	0.086
1978	16.490	0.073
1979	21.152	0.072
1980	35.038	0.114
1981	1.697	0.108
1982	13.326	0.111
1983	19.715	0.069
1984	9.843	0.034
1985	5.588	0.088
1986	18.885	0.250
1987	21.695	0.201
1988	20.901	0.150
1989	n/a	n/a

brood year	number of age 1+ smolts (millions)	smolt survival
recent		
1990	34.168	0.076
1991	39.722	0.032
1992	12.866	0.145
1993	27.258	0.143
1994	16.977	0.072
1995	39.826	0.031
1996	18.700	0.072
1997	21.838	0.040
1998	11.078	0.044
medians		
all years	13.326	0.079
pre-1990	9.651	0.086
recent	20.269	0.058

Appendix Table 6. Annual records of adult sockeye timing through the Sakinaw Lake fishway. Counts are from Murray and Wood (2002); cumulative probabilities (cumprob) are interpolated for days without counts.

	1957		1958		1959		1960	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000		0.000		0.000
Jul 3		0.000		0.000		0.000		0.000
Jul 4		0.000		0.000		0.000		0.000
Jul 5		0.000		0.000		0.000	6	0.001
Jul 6	46	0.011		0.000		0.000	42	0.012
Jul 7	11	0.014	1	0.000		0.000	100	0.036
Jul 8		0.028		0.001		0.000	96	0.060
Jul 9	100	0.052		0.002		0.000	71	0.078
Jul 10	85	0.073		0.002	59	0.005	111	0.105
Jul 11	235	0.130		0.003	113	0.014	141	0.140
Jul 12	235	0.188		0.005	26	0.016	118	0.169
Jul 13	196	0.236		0.006	110	0.024	165	0.210
Jul 14	259	0.299		0.008	103	0.033	96	0.233
Jul 15	190	0.346		0.010	122	0.042	6	0.235
Jul 16	75	0.364		0.011	298	0.066	158	0.274
Jul 17	51	0.377		0.014	135	0.077	40	0.284
Jul 18	198	0.425		0.016	102	0.085	50	0.296
Jul 19	46	0.437		0.019	149	0.097	98	0.320
Jul 20	295	0.509		0.021	120	0.106	125	0.351
Jul 21	119	0.538		0.024	83	0.113	181	0.396
Jul 22	278	0.606		0.027	407	0.145	295	0.468
Jul 23	191	0.653		0.030	192	0.161	210	0.520
Jul 24	222	0.707		0.034	651	0.212	149	0.557
Jul 25	34	0.715	11	0.037	757	0.273	100	0.582
Jul 26	63	0.731	4	0.039	465	0.310	117	0.610
Jul 27	92	0.753	81	0.065	960	0.386	182	0.655
Jul 28	116	0.782	43	0.079	694	0.441	152	0.693
Jul 29	155	0.820	0	0.079	584	0.488	76	0.711
Jul 30	192	0.867	483	0.238	376	0.517	101	0.736
Jul 31	118	0.896	74	0.262	187	0.532	67	0.753
Aug 1	1	0.896	137	0.307	129	0.543	235	0.811
Aug 2	96	0.919	47	0.323	260	0.563	81	0.831
Aug 3	22	0.925	140	0.369	542	0.606	62	0.846
Aug 4	111	0.952	132	0.412	376	0.636	133	0.879
Aug 5	81	0.972	15	0.417	552	0.680	75	0.897
Aug 6	56	0.986	71	0.440	623	0.730	10	0.900
Aug 7	20	0.990	91	0.470	651	0.782	15	0.904
Aug 8	26	0.997	32	0.481	314	0.806	6	0.905
Aug 9	13	1.000		0.489	168	0.820	12	0.908
Aug 10		1.000	21	0.496	145	0.831	9	0.910
Aug 11		1.000		0.508	172	0.845	78	0.929
Aug 12		1.000		0.524	188	0.860	30	0.937
Aug 13		1.000	62	0.544	219	0.877	76	0.956
Aug 14		1.000	4	0.545	288	0.900	13	0.959
Aug 15		1.000		0.547	302	0.924	19	0.964
Aug 16		1.000		0.550	254	0.945	33	0.972
Aug 17		1.000		0.553	96	0.952	20	0.977

Appendix Table 6 (continued)

	1957		1958		1959		1960	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18		1.000	12	0.557	266	0.973	22	0.982
Aug 19		1.000		0.560	152	0.985	20	0.987
Aug 20		1.000	5	0.562	65	0.991	6	0.988
Aug 21		1.000		0.566	34	0.993		0.990
Aug 22		1.000	22	0.573	25	0.995		0.992
Aug 23		1.000		0.584	37	0.998	7	0.993
Aug 24		1.000	45	0.599	22	1.000		0.995
Aug 25		1.000		0.623		1.000		0.998
Aug 26		1.000	103	0.657		1.000	10	1.000
Aug 27		1.000	105	0.692		1.000		1.000
Aug 28		1.000		0.729		1.000		1.000
Aug 29		1.000	120	0.768		1.000		1.000
Aug 30		1.000	154	0.819		1.000		1.000
Aug 31		1.000	46	0.834		1.000		1.000
Sep 1		1.000		0.857		1.000		1.000
Sep 2		1.000		0.889		1.000		1.000
Sep 3		1.000	122	0.929		1.000		1.000
Sep 4		1.000		0.955		1.000		1.000
Sep 5		1.000	39	0.968		1.000		1.000
Sep 6		1.000		0.980		1.000		1.000
Sep 7		1.000		0.990		1.000		1.000
Sep 8		1.000	29	1.000		1.000		1.000
Sep 9		1.000		1.000		1.000		1.000
Sep 10		1.000		1.000		1.000		1.000
Sep 11		1.000		1.000		1.000		1.000
Sep 12		1.000		1.000		1.000		1.000
Sep 13		1.000		1.000		1.000		1.000
Sep 14		1.000		1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	4028		2251		12573		4025	
total days	34		31		46		49	

Appendix Table 6 (continued)

	1961		1962		1963		1964	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000		0.000		0.000
Jul 3		0.000		0.000		0.000		0.000
Jul 4		0.000		0.000	0	0.000		0.000
Jul 5		0.000		0.000		0.000		0.000
Jul 6		0.000		0.000		0.000		0.000
Jul 7		0.000		0.000		0.000		0.000
Jul 8		0.000		0.000	0	0.000		0.000
Jul 9		0.000		0.000		0.000		0.000
Jul 10	2	0.003		0.000		0.000		0.000
Jul 11		0.005		0.000	4	0.001		0.000
Jul 12		0.008		0.000	18	0.003		0.000
Jul 13		0.010		0.000	4	0.003		0.000
Jul 14		0.011		0.000	20	0.006		0.000
Jul 15	1	0.013		0.000		0.010		0.000
Jul 16	1	0.014		0.000	44	0.016		0.000
Jul 17	5	0.021		0.000	32	0.020		0.000
Jul 18	48	0.088		0.000	38	0.026		0.000
Jul 19	8	0.099		0.000	216	0.054		0.000
Jul 20	5	0.106		0.000	197	0.080		0.000
Jul 21	5	0.113		0.000	50	0.087	2	0.001
Jul 22		0.122		0.000	248	0.120		0.002
Jul 23	7	0.132		0.000	83	0.131		0.004
Jul 24	9	0.144		0.000	235	0.162		0.005
Jul 25		0.159	20	0.010	200	0.189		0.007
Jul 26	12	0.176	31	0.025	292	0.228		0.009
Jul 27		0.209	35	0.042	178	0.251		0.011
Jul 28		0.260	46	0.064	159	0.272	4	0.013
Jul 29		0.327		0.091	151	0.292	28	0.028
Jul 30		0.411	62	0.121	147	0.312	44	0.052
Jul 31	72	0.512	72	0.156		0.341	63	0.086
Aug 1	8	0.523	94	0.202		0.378	94	0.137
Aug 2	14	0.543	84	0.243		0.425	114	0.199
Aug 3	12	0.560	103	0.294	419	0.480	246	0.332
Aug 4		0.582	106	0.345	526	0.550	88	0.380
Aug 5		0.610	114	0.401		0.605	95	0.432
Aug 6		0.644	108	0.454	300	0.645	81	0.476
Aug 7	28	0.683	164	0.534		0.687	84	0.521
Aug 8		0.717	208	0.635	330	0.731	148	0.601
Aug 9		0.745	143	0.705		0.771	61	0.634
Aug 10		0.768		0.769		0.807	26	0.649
Aug 11		0.786	120	0.828		0.840	84	0.694
Aug 12		0.798	84	0.869	218	0.869	7	0.698
Aug 13	5	0.805	63	0.900		0.898	38	0.719
Aug 14	33	0.852	45	0.922		0.928	73	0.758
Aug 15	14	0.871	10	0.927	225	0.958	118	0.822
Aug 16	11	0.887		0.932	112	0.972	53	0.851
Aug 17		0.918		0.939	125	0.989	111	0.911

Appendix Table 6 (continued)

	1961		1962		1963		1964	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18	34	0.966		0.946	70	0.998	36	0.931
Aug 19	8	0.977		0.954	12	1.000	10	0.936
Aug 20	3	0.981	18	0.963		1.000	78	0.978
Aug 21	4	0.987	22	0.974		1.000	28	0.993
Aug 22		0.993	37	0.992		1.000	3	0.995
Aug 23	5	1.000	10	0.997		1.000	7	0.999
Aug 24		1.000	7	1.000		1.000	2	1.000
Aug 25		1.000		1.000		1.000		1.000
Aug 26		1.000		1.000		1.000		1.000
Aug 27		1.000		1.000	0	1.000		1.000
Aug 28		1.000		1.000		1.000		1.000
Aug 29		1.000		1.000		1.000		1.000
Aug 30		1.000		1.000		1.000		1.000
Aug 31		1.000		1.000		1.000		1.000
Sep 1		1.000		1.000		1.000		1.000
Sep 2		1.000		1.000		1.000		1.000
Sep 3		1.000		1.000	0	1.000		1.000
Sep 4		1.000		1.000		1.000		1.000
Sep 5		1.000		1.000		1.000		1.000
Sep 6		1.000		1.000		1.000		1.000
Sep 7		1.000		1.000		1.000		1.000
Sep 8		1.000		1.000		1.000		1.000
Sep 9		1.000		1.000		1.000		1.000
Sep 10		1.000		1.000		1.000		1.000
Sep 11		1.000		1.000		1.000		1.000
Sep 12		1.000		1.000		1.000		1.000
Sep 13		1.000		1.000		1.000		1.000
Sep 14		1.000		1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	354		1806		4653		1826	
total days	25		25		33		29	

Appendix Table 6 (continued)

	1965		1966		1967		1968	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000		0.000		0.000
Jul 3		0.000		0.000		0.000		0.000
Jul 4		0.000		0.000		0.000		0.000
Jul 5		0.000		0.000		0.000		0.000
Jul 6		0.000		0.000		0.000		0.000
Jul 7		0.000		0.000		0.000		0.000
Jul 8		0.000		0.000		0.000		0.000
Jul 9		0.000		0.000		0.000		0.000
Jul 10	10	0.021	0	0.000	11	0.003		0.000
Jul 11		0.044	3	0.001	71	0.022		0.000
Jul 12		0.067	0	0.001	52	0.035		0.000
Jul 13		0.093	4	0.002	16	0.039	325	0.029
Jul 14		0.119	0	0.002	161	0.082	380	0.063
Jul 15		0.147	5	0.004	31	0.090	765	0.131
Jul 16		0.176		0.008	22	0.096	366	0.163
Jul 17		0.207		0.015	20	0.101	429	0.201
Jul 18		0.239		0.025	152	0.141	214	0.220
Jul 19		0.272		0.038	0	0.141	200	0.238
Jul 20		0.307	47	0.053	148	0.180	198	0.256
Jul 21	17	0.342	101	0.086	109	0.209	341	0.286
Jul 22	4	0.351	67	0.108	100	0.235	108	0.295
Jul 23		0.363		0.131	180	0.283	185	0.312
Jul 24	7	0.377		0.156	100	0.309	137	0.324
Jul 25		0.389	83	0.183	81	0.330	187	0.341
Jul 26		0.396	89	0.212	63	0.347	173	0.356
Jul 27	2	0.401	96	0.243	105	0.374	133	0.368
Jul 28	9	0.420	76	0.268	126	0.408	122	0.379
Jul 29		0.439	80	0.294	228	0.468	146	0.392
Jul 30		0.458	80	0.320	163	0.511	157	0.406
Jul 31		0.477	70	0.343	172	0.556	345	0.436
Aug 1	9	0.496	57	0.361	150	0.595	606	0.490
Aug 2	1	0.498	41	0.375	100	0.622	500	0.534
Aug 3	17	0.534	5	0.376	40	0.632	526	0.581
Aug 4	14	0.563	37	0.388	50	0.645	709	0.644
Aug 5	8	0.580		0.402	594	0.802	643	0.701
Aug 6		0.601	44	0.416	102	0.829	571	0.752
Aug 7		0.627	45	0.430	68	0.847	531	0.799
Aug 8		0.656	19	0.437	93	0.871	489	0.842
Aug 9		0.690	34	0.448	80	0.892	200	0.860
Aug 10		0.728	37	0.460	62	0.908	165	0.875
Aug 11		0.771	67	0.481	100	0.935	227	0.895
Aug 12	22	0.817		0.507	118	0.966	218	0.914
Aug 13	5	0.828	89	0.536	12	0.969	92	0.923
Aug 14		0.858	123	0.576		0.972	40	0.926
Aug 15	24	0.909	85	0.603		0.975	78	0.933
Aug 16	31	0.975	55	0.621		0.978	45	0.937
Aug 17	12	1.000	26	0.630		0.980	107	0.947

Appendix Table 6 (continued)

	1965		1966		1967		1968	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18		1.000	65	0.651		0.983	125	0.958
Aug 19		1.000	50	0.667		0.985	94	0.966
Aug 20		1.000	14	0.672	8	0.987	87	0.974
Aug 21		1.000	107	0.706		0.989	74	0.980
Aug 22		1.000	102	0.740		0.991	50	0.985
Aug 23		1.000	83	0.766		0.992	56	0.990
Aug 24		1.000	90	0.796	5	0.993	48	0.994
Aug 25		1.000	63	0.816		0.995	30	0.997
Aug 26		1.000		0.839		0.997		0.999
Aug 27		1.000	78	0.864	10	1.000		1.000
Aug 28		1.000	51	0.881		1.000	4	1.000
Aug 29		1.000	110	0.917		1.000		1.000
Aug 30		1.000	63	0.937		1.000		1.000
Aug 31		1.000	83	0.964		1.000		1.000
Sep 1		1.000		0.964		1.000		1.000
Sep 2		1.000		0.964		1.000		1.000
Sep 3		1.000		0.964		1.000		1.000
Sep 4		1.000	50	0.981		1.000		1.000
Sep 5		1.000	28	0.990		1.000		1.000
Sep 6		1.000	30	0.999		1.000		1.000
Sep 7		1.000		0.999		1.000		1.000
Sep 8		1.000		0.999		1.000		1.000
Sep 9		1.000	2	1.000		1.000		1.000
Sep 10		1.000		1.000		1.000		1.000
Sep 11		1.000		1.000		1.000		1.000
Sep 12		1.000		1.000		1.000		1.000
Sep 13		1.000		1.000		1.000		1.000
Sep 14		1.000		1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	192		2634		3703		11226	
total days	16		48		38		45	

Appendix Table 6 (continued)

	1969		1970		1971		1972	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000		0.000		0.000
Jul 3		0.000		0.000		0.000	6	0.001
Jul 4		0.000		0.000		0.000	10	0.003
Jul 5		0.000		0.000		0.000		0.012
Jul 6		0.000		0.000	250	0.028		0.027
Jul 7		0.000		0.000	120	0.042	120	0.050
Jul 8		0.000		0.000	80	0.051	80	0.064
Jul 9		0.000		0.000	300	0.084		0.077
Jul 10		0.000		0.000	150	0.101	50	0.086
Jul 11		0.000		0.000	100	0.112		0.093
Jul 12		0.000	7	0.002	20	0.115	30	0.099
Jul 13	23	0.055	1	0.002	250	0.143		0.105
Jul 14	3	0.063	0	0.002	100	0.154		0.111
Jul 15	5	0.075	0	0.002	100	0.165		0.118
Jul 16	0	0.075	7	0.004	1	0.165		0.125
Jul 17	0	0.075	0	0.004	180	0.185	40	0.132
Jul 18	4	0.084	0	0.004	36	0.189		0.151
Jul 19	6	0.099	72	0.024	120	0.203	160	0.181
Jul 20	0	0.099	0	0.024	100	0.214	100	0.200
Jul 21	0	0.099	0	0.024	80	0.223	400	0.274
Jul 22	2	0.103	58	0.040	50	0.229	400	0.349
Jul 23	2	0.108	42	0.051	60	0.235	400	0.423
Jul 24	2	0.113	126	0.086	200	0.258	203	0.461
Jul 25	0	0.113	93	0.111	60	0.265	200	0.498
Jul 26	0	0.113	123	0.145	30	0.268	40	0.506
Jul 27	0	0.113	127	0.180	120	0.281		0.516
Jul 28	0	0.113	37	0.190	100	0.293		0.528
Jul 29	0	0.113	80	0.212	100	0.304	80	0.543
Jul 30	0	0.113	72	0.232	120	0.317		0.553
Jul 31		0.116	60	0.248	140	0.333	25	0.557
Aug 1		0.123	140	0.286	150	0.350	80	0.572
Aug 2		0.133	245	0.354	250	0.378	31	0.578
Aug 3		0.147	162	0.398	200	0.401	28	0.583
Aug 4	7	0.164	147	0.438	200	0.423	120	0.606
Aug 5	6	0.178	31	0.447	80	0.432		0.630
Aug 6		0.203	110	0.477	140	0.448	140	0.656
Aug 7		0.238	83	0.500	60	0.454	60	0.667
Aug 8		0.283	67	0.518	50	0.460		0.683
Aug 9	23	0.338	64	0.535	0	0.460	110	0.703
Aug 10	11	0.365	21	0.541	50	0.466		0.725
Aug 11	73	0.540	87	0.565	50	0.471	120	0.747
Aug 12	10	0.564	43	0.577	2	0.471		0.767
Aug 13	27	0.629	33	0.586	175	0.491		0.784
Aug 14	1	0.632	35	0.596	152	0.508		0.799
Aug 15	1	0.634	0	0.596	150	0.525		0.811
Aug 16	29	0.704	68	0.614	30	0.528	50	0.820
Aug 17	37	0.793	62	0.631	50	0.534	200	0.857

Appendix Table 6 (continued)

	1969		1970		1971		1972	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18	18	0.836	60	0.648	50	0.540		0.888
Aug 19	20	0.884	40	0.659	160	0.558		0.912
Aug 20	16	0.923	79	0.680	200	0.580		0.930
Aug 21	15	0.959	75	0.701	240	0.607	60	0.941
Aug 22	6	0.974	73	0.721	150	0.624		0.950
Aug 23	0	0.974	98	0.748	250	0.652		0.956
Aug 24	0	0.974	40	0.759	200	0.674	20	0.960
Aug 25	0	0.974	12	0.762	160	0.692		0.962
Aug 26		0.976	50	0.776	100	0.704	10	0.964
Aug 27		0.981	127	0.810	60	0.710		0.967
Aug 28		0.988	60	0.827	120	0.724		0.969
Aug 29	4	0.998	43	0.839	120	0.737		0.972
Aug 30	0	0.998	28	0.846	80	0.746		0.975
Aug 31	0	0.998	84	0.869	80	0.755		0.979
Sep 1	1	1.000	116	0.901	50	0.761	21	0.983
Sep 2	0	1.000	31	0.910	120	0.774		0.986
Sep 3		1.000	30	0.918	120	0.788		0.989
Sep 4		1.000		0.926	180	0.808		0.991
Sep 5		1.000		0.934	350	0.847		0.993
Sep 6		1.000		0.942		0.884		0.994
Sep 7		1.000		0.949		0.917		0.994
Sep 8		1.000		0.957		0.948	0	0.994
Sep 9		1.000		0.964		0.975	30	1.000
Sep 10		1.000		0.972	220	1.000		1.000
Sep 11		1.000		0.979		1.000		1.000
Sep 12		1.000		0.986		1.000		1.000
Sep 13		1.000		0.993		1.000		1.000
Sep 14		1.000	25	1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	352		3374		7766		3424	
total days	42		55		63		33	

Appendix Table 6 (continued)

	1973		1974		1975		1976	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1							50	
Jul 2		0.000		0.000	100	0.006	100	0.005
Jul 3		0.000		0.000		0.013		0.015
Jul 4		0.000		0.000	100	0.019	300	0.030
Jul 5		0.000		0.000		0.025		0.045
Jul 6		0.000		0.000		0.032		0.060
Jul 7		0.000	150	0.024	100	0.038		0.076
Jul 8		0.000	12	0.026		0.044	300	0.091
Jul 9		0.000		0.028		0.049		0.104
Jul 10	5	0.008	12	0.030		0.053		0.115
Jul 11	2	0.012	200	0.062		0.057		0.124
Jul 12	3	0.017	15	0.064	50	0.060		0.131
Jul 13	6	0.027	12	0.066	20	0.061	100	0.136
Jul 14	9	0.042	5	0.067		0.065	400	0.156
Jul 15	12	0.062	88	0.081	100	0.071	600	0.186
Jul 16	18	0.092		0.101		0.076		0.204
Jul 17	20	0.125		0.127		0.080	106	0.209
Jul 18	25	0.167	200	0.158		0.083		0.214
Jul 19	15	0.192		0.182	20	0.084		0.219
Jul 20	50	0.276	100	0.198		0.088		0.223
Jul 21	50	0.360		0.217		0.095		0.227
Jul 22	30	0.410		0.240		0.105		0.231
Jul 23	10	0.426		0.265	200	0.118		0.234
Jul 24	20	0.460		0.294	300	0.137		0.237
Jul 25	35	0.518	200	0.326	50	0.140		0.239
Jul 26		0.518		0.354	6	0.140		0.241
Jul 27		0.518		0.378		0.142		0.243
Jul 28		0.518		0.397	50	0.145		0.244
Jul 29	30	0.569	100	0.413	30	0.147	20	0.245
Jul 30	52	0.656		0.440		0.150		0.279
Jul 31		0.656		0.477		0.154		0.347
Aug 1		0.656	300	0.525		0.160	2000	0.448
Aug 2	15	0.681		0.557		0.166		0.539
Aug 3		0.681	100	0.573		0.174		0.622
Aug 4	50	0.764	50	0.581		0.183		0.695
Aug 5	3	0.769	100	0.597		0.194		0.760
Aug 6		0.769		0.609		0.205		0.815
Aug 7		0.769	50	0.617	200	0.218		0.861
Aug 8		0.769		0.630		0.243		0.899
Aug 9		0.769		0.650		0.281		0.927
Aug 10		0.769		0.675		0.332		0.946
Aug 11		0.769		0.705	1000	0.395	200	0.956
Aug 12		0.769		0.742	1200	0.471		0.965
Aug 13		0.769		0.784		0.531		0.973
Aug 14	20	0.803	300	0.832		0.577		0.980
Aug 15		0.803		0.865		0.608		0.985
Aug 16		0.803		0.884	250	0.624		0.990
Aug 17		0.803	30	0.889		0.638		0.993

Appendix Table 6 (continued)

	1973		1974		1975		1976	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18		0.803		0.892		0.650		0.996
Aug 19	50	0.886	2	0.892		0.660		0.997
Aug 20		0.886		0.895		0.668	5	0.997
Aug 21		0.886		0.900	100	0.674		0.997
Aug 22	35	0.945		0.907	100	0.681		0.997
Aug 23		0.945	60	0.916		0.687		0.997
Aug 24		0.945		0.925		0.695		0.997
Aug 25	20	0.978		0.934		0.702		0.997
Aug 26		0.978		0.943		0.710		0.997
Aug 27		0.978		0.951		0.718		0.997
Aug 28		0.978		0.958		0.727		0.997
Aug 29		0.978		0.965		0.736		0.997
Aug 30		0.978		0.972		0.746		0.997
Aug 31	10	0.995		0.978		0.755		0.997
Sep 1		0.995		0.984		0.766		0.997
Sep 2		0.995		0.990		0.776		0.997
Sep 3		0.995		0.995		0.787		0.997
Sep 4		0.995	30	1.000		0.799		0.997
Sep 5		0.995		1.000		0.811		0.997
Sep 6		0.995		1.000		0.823		0.997
Sep 7		0.995		1.000	200	0.836		0.997
Sep 8		0.995		1.000		0.848		0.997
Sep 9		0.995		1.000		0.859		0.997
Sep 10		0.995		1.000		0.870		0.997
Sep 11		0.995		1.000		0.881		0.997
Sep 12		0.995		1.000		0.891		0.997
Sep 13		0.995		1.000		0.900		0.997
Sep 14		0.995		1.000		0.909		0.997
Sep 15		0.995		1.000		0.918		0.997
Sep 16	3	1.000		1.000		0.926		0.997
Sep 17		1.000		1.000		0.933		0.997
Sep 18		1.000		1.000		0.940		0.997
Sep 19		1.000		1.000		0.946		0.997
Sep 20		1.000		1.000		0.952		0.997
Sep 21		1.000		1.000		0.957		0.997
Sep 22		1.000		1.000	75	0.962		0.997
Sep 23		1.000		1.000		0.967		0.997
Sep 24		1.000		1.000		0.972		0.997
Sep 25		1.000		1.000		0.976		0.997
Sep 26		1.000		1.000		0.981		0.997
Sep 27		1.000		1.000		0.986		0.997
Sep 28		1.000		1.000		0.991		0.997
Sep 29		1.000		1.000		0.995		0.997
Sep 30		1.000		1.000	75	1.000		0.997
total fish	598		2116		4326		4181	
total days	27		22		20		12	

Appendix Table 6 (continued)

	1977		1978		1979		1980	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000	20	0.002		0.000
Jul 3		0.000	10	0.002		0.004		0.000
Jul 4	75	0.055		0.007		0.006		0.000
Jul 5	36	0.081		0.016		0.008		0.000
Jul 6	3	0.083		0.028	30	0.011	6	0.002
Jul 7	8	0.089	100	0.044	15	0.012	15	0.009
Jul 8	57	0.130	180	0.073	125	0.023		0.017
Jul 9		0.164		0.103	150	0.036		0.027
Jul 10		0.189		0.134	300	0.062		0.039
Jul 11	24	0.206	200	0.166		0.086		0.053
Jul 12	30	0.228	150	0.190		0.109	40	0.070
Jul 13	21	0.243		0.214	250	0.131	100	0.110
Jul 14	13	0.253	150	0.238	100	0.140	50	0.131
Jul 15	36	0.279		0.257	40	0.143	50	0.151
Jul 16	5	0.283		0.271	60	0.148	60	0.175
Jul 17		0.292		0.279	50	0.153	25	0.186
Jul 18	21	0.307	20	0.282	250	0.174	30	0.198
Jul 19	14	0.318		0.287		0.189	50	0.218
Jul 20	16	0.329		0.294	100	0.198	75	0.249
Jul 21	24	0.347	50	0.302	300	0.224	24	0.258
Jul 22	81	0.406		0.309	400	0.259	25	0.269
Jul 23	12	0.414	45	0.316	550	0.306	50	0.289
Jul 24	38	0.442	60	0.326	200	0.323	50	0.309
Jul 25		0.471	50	0.334	200	0.341		0.325
Jul 26		0.502	210	0.368	250	0.362	25	0.335
Jul 27		0.535		0.392	400	0.397	2	0.336
Jul 28		0.570	90	0.406	450	0.436	50	0.356
Jul 29	50	0.606	60	0.416	450	0.475	73	0.386
Jul 30		0.635		0.425	450	0.514	50	0.406
Jul 31		0.657		0.433	50	0.518	50	0.426
Aug 1	20	0.672	50	0.441	100	0.527	30	0.438
Aug 2		0.683	150	0.466	30	0.529	100	0.479
Aug 3		0.692		0.484	70	0.535	60	0.504
Aug 4		0.699		0.498	85	0.543	50	0.524
Aug 5	5	0.702	50	0.506	1000	0.629	20	0.532
Aug 6	12	0.711	20	0.509	1100	0.724	0	0.532
Aug 7	25	0.729	10	0.510	800	0.793	50	0.552
Aug 8	10	0.737	0	0.510	900	0.871	75	0.583
Aug 9		0.747		0.516	400	0.906	100	0.624
Aug 10		0.760		0.529	100	0.914	200	0.705
Aug 11		0.776		0.547	10	0.915	125	0.756
Aug 12		0.795	150	0.571		0.917	300	0.878
Aug 13		0.816		0.596		0.918	150	0.939
Aug 14		0.841		0.623		0.921	20	0.947
Aug 15		0.869		0.651		0.923	30	0.959
Aug 16		0.899		0.680		0.926	50	0.980
Aug 17		0.933		0.711		0.930	20	0.988

Appendix Table 6 (continued)

	1977		1978		1979		1980	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18	50	0.969	200	0.743		0.934	30	1.000
Aug 19		0.989		0.779		0.939		1.000
Aug 20	5	0.993	250	0.819		0.944		1.000
Aug 21		0.996		0.855		0.949		1.000
Aug 22	5	1.000		0.887		0.955		1.000
Aug 23		1.000		0.915		0.961		1.000
Aug 24		1.000		0.940		0.968		1.000
Aug 25		1.000		0.960		0.975		1.000
Aug 26		1.000	100	0.976		0.983		1.000
Aug 27		1.000		0.987		0.991		1.000
Aug 28		1.000	36	0.992	100	1.000		1.000
Aug 29		1.000		0.997		1.000		1.000
Aug 30		1.000	20	1.000		1.000		1.000
Aug 31		1.000		1.000		1.000		1.000
Sep 1		1.000		1.000		1.000		1.000
Sep 2		1.000		1.000		1.000		1.000
Sep 3		1.000		1.000		1.000		1.000
Sep 4		1.000		1.000		1.000		1.000
Sep 5		1.000		1.000		1.000		1.000
Sep 6		1.000		1.000		1.000		1.000
Sep 7		1.000		1.000		1.000		1.000
Sep 8		1.000		1.000		1.000		1.000
Sep 9		1.000		1.000		1.000		1.000
Sep 10		1.000		1.000		1.000		1.000
Sep 11		1.000		1.000		1.000		1.000
Sep 12		1.000		1.000		1.000		1.000
Sep 13		1.000		1.000		1.000		1.000
Sep 14		1.000		1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	696		2411		9885		2310	
total days	27		26		36		39	

Appendix Table 6 (continued)

	1981		1982		1983		1984	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1	0							
Jul 2		0.000		0.000		0.000		0.000
Jul 3		0.000		0.000		0.000		0.000
Jul 4		0.000		0.000		0.000		0.000
Jul 5		0.000		0.000		0.000	1	0.001
Jul 6	0	0.000		0.000		0.000		0.004
Jul 7	0	0.000		0.000		0.000		0.011
Jul 8		0.000		0.000	3	0.002		0.020
Jul 9		0.000		0.000		0.007	15	0.032
Jul 10	21	0.012		0.000		0.015		0.042
Jul 11	73	0.055		0.000		0.027	10	0.049
Jul 12		0.089	110	0.033		0.042		0.059
Jul 13		0.114		0.070		0.061	14	0.070
Jul 14		0.130	140	0.112		0.083		0.083
Jul 15	12	0.137		0.174		0.108		0.099
Jul 16		0.145	280	0.257	50	0.137		0.116
Jul 17		0.155		0.317		0.171		0.136
Jul 18		0.166	120	0.353	70	0.211		0.157
Jul 19		0.177		0.417		0.274	30	0.181
Jul 20		0.191	310	0.509	150	0.360		0.218
Jul 21		0.205		0.564		0.417		0.268
Jul 22		0.220	60	0.582	50	0.446	80	0.331
Jul 23		0.237		0.594		0.487		0.387
Jul 24		0.255	20	0.600	95	0.542	60	0.434
Jul 25		0.274		0.604		0.598		0.479
Jul 26		0.295	10	0.607	100	0.655		0.521
Jul 27		0.316		0.612		0.727	50	0.561
Jul 28		0.339	25	0.620	150	0.812		0.589
Jul 29		0.363		0.646		0.861	20	0.605
Jul 30		0.388	150	0.690	20	0.873		0.618
Jul 31	45	0.415		0.724		0.893	15	0.630
Aug 1		0.458	75	0.746	50	0.921		0.652
Aug 2		0.519		0.766		0.943	41	0.685
Aug 3		0.598	60	0.784	25	0.957		0.720
Aug 4	163	0.693		0.799		0.970		0.756
Aug 5	157	0.786	40	0.811	20	0.981		0.796
Aug 6		0.848		0.821		0.991		0.837
Aug 7		0.880	25	0.828	15	1.000	55	0.880
Aug 8	3	0.881		0.836		1.000		0.903
Aug 9		0.885	25	0.843		1.000	1	0.903
Aug 10		0.891		0.854		1.000		0.906
Aug 11		0.899	50	0.869		1.000		0.912
Aug 12		0.909		0.885		1.000		0.919
Aug 13		0.920	60	0.903		1.000		0.929
Aug 14		0.934		0.923		1.000	15	0.941
Aug 15	27	0.950	75	0.946		1.000		0.952
Aug 16	32	0.969		0.964		1.000	15	0.964
Aug 17		0.982	50	0.979		1.000		0.975

Appendix Table 6 (continued)

	1981		1982		1983		1984	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18	14	0.991		0.989		1.000		0.983
Aug 19		0.996	15	0.993		1.000		0.990
Aug 20	6	1.000		0.997		1.000		0.996
Aug 21		1.000	10	1.000		1.000	5	1.000
Aug 22		1.000		1.000		1.000		1.000
Aug 23		1.000		1.000		1.000		1.000
Aug 24		1.000		1.000		1.000		1.000
Aug 25		1.000		1.000		1.000		1.000
Aug 26		1.000		1.000		1.000		1.000
Aug 27		1.000		1.000		1.000		1.000
Aug 28		1.000		1.000		1.000		1.000
Aug 29		1.000		1.000		1.000		1.000
Aug 30		1.000		1.000		1.000		1.000
Aug 31		1.000		1.000		1.000		1.000
Sep 1		1.000		1.000		1.000		1.000
Sep 2		1.000		1.000		1.000		1.000
Sep 3		1.000		1.000		1.000		1.000
Sep 4		1.000		1.000		1.000		1.000
Sep 5		1.000		1.000		1.000		1.000
Sep 6		1.000		1.000		1.000		1.000
Sep 7		1.000		1.000		1.000		1.000
Sep 8		1.000		1.000		1.000		1.000
Sep 9		1.000		1.000		1.000		1.000
Sep 10		1.000		1.000		1.000		1.000
Sep 11		1.000		1.000		1.000		1.000
Sep 12		1.000		1.000		1.000		1.000
Sep 13		1.000		1.000		1.000		1.000
Sep 14		1.000		1.000		1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	553		1710		798		427	
total days	14		21		13		16	

Appendix Table 6 (continued)

	1985		1986		1987		1988	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Jul 1								
Jul 2		0.000		0.000	5	0.001		0.000
Jul 3		0.000		0.000		0.003		0.000
Jul 4		0.000		0.000		0.006		0.000
Jul 5		0.000		0.000		0.010		0.000
Jul 6		0.000	64	0.011		0.015		0.000
Jul 7		0.000		0.020		0.021		0.000
Jul 8		0.000	45	0.028	32	0.028		0.000
Jul 9		0.000		0.035	3	0.029		0.000
Jul 10		0.000	35	0.041	25	0.035	12	0.005
Jul 11		0.000	45	0.048	25	0.040		0.012
Jul 12		0.000		0.055	25	0.046		0.021
Jul 13		0.000	30	0.060	31	0.052		0.031
Jul 14	2	0.001		0.067	28	0.059	31	0.044
Jul 15		0.010		0.078	35	0.066	50	0.065
Jul 16	36	0.026	75	0.090	14	0.069	49	0.085
Jul 17	51	0.049		0.103	14	0.072	55	0.107
Jul 18	42	0.068		0.116	59	0.085	46	0.126
Jul 19	32	0.082	75	0.129	36	0.093	36	0.141
Jul 20		0.097		0.152	76	0.110	64	0.167
Jul 21	34	0.113	200	0.186	110	0.134	34	0.181
Jul 22		0.137	350	0.246	76	0.151	21	0.190
Jul 23	74	0.171	300	0.297	152	0.184	42	0.207
Jul 24		0.191	250	0.339	130	0.213	62	0.233
Jul 25	14	0.197		0.373	129	0.241	83	0.267
Jul 26		0.205	150	0.399	134	0.271	70	0.296
Jul 27		0.214		0.424	88	0.290	25	0.306
Jul 28	23	0.224	150	0.450	180	0.330	37	0.321
Jul 29	38	0.241		0.472	100	0.352	58	0.345
Jul 30	115	0.293		0.492	84	0.370	77	0.377
Jul 31	130	0.352	100	0.509	144	0.402	31	0.389
Aug 1	100	0.397	50	0.518	136	0.432	67	0.417
Aug 2	89	0.438		0.530	75	0.448	65	0.444
Aug 3		0.471		0.547	33	0.456	59	0.468
Aug 4	60	0.499	120	0.567	67	0.470	51	0.489
Aug 5	76	0.533		0.582	35	0.478	35	0.503
Aug 6		0.581		0.591	64	0.492	60	0.528
Aug 7	138	0.644	20	0.594	97	0.513	93	0.566
Aug 8		0.691		0.600	97	0.535	132	0.620
Aug 9	69	0.722	50	0.609	81	0.553		0.667
Aug 10	101	0.768		0.619	86	0.571		0.707
Aug 11		0.793		0.631	163	0.607		0.739
Aug 12	12	0.799		0.645	80	0.625		0.763
Aug 13		0.812		0.661	254	0.681		0.781
Aug 14	47	0.833		0.678	160	0.716		0.790
Aug 15		0.857		0.698	105	0.739	6	0.793
Aug 16		0.882		0.719	91	0.759	13	0.798
Aug 17		0.909	135	0.742	85	0.778	37	0.813

Appendi x Table 6 (continued)

	1985		1986		1987		1988	
Date	count	cumprob	count	cumprob	count	cumprob	count	cumprob
Aug 18	64	0.938		0.763	66	0.792	35	0.828
Aug 19		0.961		0.783	44	0.802	39	0.844
Aug 20		0.978		0.802	36	0.810	118	0.892
Aug 21	24	0.988	100	0.819	20	0.814	74	0.923
Aug 22		0.996		0.835	103	0.837	34	0.937
Aug 23	9	1.000		0.850	20	0.841	25	0.947
Aug 24		1.000		0.865	96	0.862	14	0.953
Aug 25		1.000		0.879	72	0.878	18	0.960
Aug 26		1.000		0.892	55	0.890	11	0.965
Aug 27		1.000		0.904	37	0.899	16	0.971
Aug 28		1.000		0.915	55	0.911		0.979
Aug 29		1.000		0.926	36	0.919		0.989
Aug 30		1.000		0.936	43	0.928	27	1.000
Aug 31		1.000		0.945	39	0.937		1.000
Sep 1		1.000		0.953	43	0.946		1.000
Sep 2		1.000		0.961	6	0.947		1.000
Sep 3		1.000		0.967	0	0.947		1.000
Sep 4		1.000		0.973	1	0.948		1.000
Sep 5		1.000		0.978	6	0.949		1.000
Sep 6		1.000		0.982	32	0.956		1.000
Sep 7		1.000	20	0.986		0.964		1.000
Sep 8		1.000		0.991		0.972		1.000
Sep 9		1.000	50	1.000		0.981		1.000
Sep 10		1.000		1.000	45	0.991		1.000
Sep 11		1.000		1.000	12	0.994		1.000
Sep 12		1.000		1.000	10	0.996		1.000
Sep 13		1.000		1.000	5	0.997		1.000
Sep 14		1.000		1.000	13	1.000		1.000
Sep 15		1.000		1.000		1.000		1.000
Sep 16		1.000		1.000		1.000		1.000
Sep 17		1.000		1.000		1.000		1.000
Sep 18		1.000		1.000		1.000		1.000
Sep 19		1.000		1.000		1.000		1.000
Sep 20		1.000		1.000		1.000		1.000
Sep 21		1.000		1.000		1.000		1.000
Sep 22		1.000		1.000		1.000		1.000
Sep 23		1.000		1.000		1.000		1.000
Sep 24		1.000		1.000		1.000		1.000
Sep 25		1.000		1.000		1.000		1.000
Sep 26		1.000		1.000		1.000		1.000
Sep 27		1.000		1.000		1.000		1.000
Sep 28		1.000		1.000		1.000		1.000
Sep 29		1.000		1.000		1.000		1.000
Sep 30		1.000		1.000		1.000		1.000
total fish	1380		2414		4339		1912	
total days	24		22		67		41	

Appendix Table 6 (continued)

	1989		1990	
Date	count	cumprob	count	cumprob
Jul 1				
Jul 2		0.000		0.000
Jul 3		0.000		0.000
Jul 4		0.000		0.000
Jul 5		0.000		0.000
Jul 6		0.000		0.000
Jul 7		0.000		0.000
Jul 8	18	0.012		0.000
Jul 9		0.024		0.000
Jul 10		0.038		0.000
Jul 11		0.052		0.000
Jul 12		0.066		0.000
Jul 13		0.081		0.000
Jul 14	24	0.097		0.000
Jul 15		0.117		0.000
Jul 16		0.140		0.000
Jul 17		0.166		0.000
Jul 18		0.197		0.000
Jul 19	51	0.230		0.000
Jul 20	26	0.248		0.000
Jul 21		0.279		0.000
Jul 22		0.326		0.000
Jul 23	92	0.386		0.000
Jul 24	68	0.432		0.000
Jul 25	72	0.479		0.000
Jul 26		0.522		0.000
Jul 27		0.561		0.000
Jul 28		0.595		0.000
Jul 29	45	0.625		0.000
Jul 30	44	0.654		0.000
Jul 31		0.676		0.000
Aug 1	22	0.691		0.000
Aug 2	41	0.718		0.000
Aug 3	26	0.735		0.000
Aug 4		0.751		0.000
Aug 5		0.765		0.000
Aug 6		0.778	19	0.088
Aug 7		0.790		0.174
Aug 8		0.800		0.256
Aug 9		0.809		0.336
Aug 10		0.817		0.414
Aug 11		0.823		0.488
Aug 12		0.828		0.560
Aug 13		0.831		0.630
Aug 14		0.833		0.696
Aug 15	1	0.834		0.760
Aug 16	19	0.846		0.821
Aug 17	15	0.856		0.879

Appendix Table 6 (continued)

	1989		1990	
Date	count	cumprob	count	cumprob
Aug 18	6	0.860	12	0.935
Aug 19	35	0.884	14	1.000
Aug 20	26	0.901		1.000
Aug 21		0.916		1.000
Aug 22		0.929		1.000
Aug 23		0.940		1.000
Aug 24		0.950		1.000
Aug 25	11	0.957		1.000
Aug 26	16	0.968		1.000
Aug 27	22	0.982		1.000
Aug 28	27	1.000		1.000
Aug 29		1.000		1.000
Aug 30		1.000		1.000
Aug 31		1.000		1.000
Sep 1		1.000		1.000
Sep 2		1.000		1.000
Sep 3		1.000		1.000
Sep 4		1.000		1.000
Sep 5		1.000		1.000
Sep 6		1.000		1.000
Sep 7		1.000		1.000
Sep 8		1.000		1.000
Sep 9		1.000		1.000
Sep 10		1.000		1.000
Sep 11		1.000		1.000
Sep 12		1.000		1.000
Sep 13		1.000		1.000
Sep 14		1.000		1.000
Sep 15		1.000		1.000
Sep 16		1.000		1.000
Sep 17		1.000		1.000
Sep 18		1.000		1.000
Sep 19		1.000		1.000
Sep 20		1.000		1.000
Sep 21		1.000		1.000
Sep 22		1.000		1.000
Sep 23		1.000		1.000
Sep 24		1.000		1.000
Sep 25		1.000		1.000
Sep 26		1.000		1.000
Sep 27		1.000		1.000
Sep 28		1.000		1.000
Sep 29		1.000		1.000
Sep 30		1.000		1.000
total fish	707		45	
total days	22		3	