EVALUATING MANAGEMENT OPTIONS FOR KLAMATH CHINOOK

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ABSTRACT

Present management goals for Klamath chinook include a target harvest rate and a minimum number of natural spawners (escapement floor). I evaluated the effects of changes in management goals for the Klamath River stock of chinook salmon using a simulation model incorporating stochastic variation in recruitment, life-history, growth rate, stock assessments, and fisheries. Alternative management goals evaluated include elimination of the escapement floor, a partial escapement ceiling, and a constant escapement goal. Alternative goals were evaluated over an array of stock-recruitment parameters to examine sensitivity to current assumptions about stock productivity and equilibrium stock size. These strategies were compared to status quo management on the basis of total landings, variability in landings, the frequency with which management goals were met, and the frequency with which restrictions were placed on ocean fisheries to attempt prevention of overfishing.

Simulation results indicate that the constant escapement policy is far more sensitive to equilibrium stock size than is status quo management, and could provide a modest increase in harvest if equilibrium stock size is larger than presently assumed. The partial escapement ceiling could produce slightly increased landings if equilibrium stock size is larger, and the stock more productive than presently assumed. Elimination of the escapement floor would result in increased landings if the stock is more productive and has a smaller equilibrium size, but would lead to reduced landings if the stock is less productive than presently assumed.

INTRODUCTION

Klamath River chinook stocks comprise natural stocks from the Klamath River, Trinity River and a number of major tributaries, and hatchery stocks from two hatcheries. Current management of Klamath River stocks has been called harvest rate management and has two management goals. The first is to allow 33 to 34% of the potential spawners from each brood year to spawn, and the second is to provide a minimum of 35,000 natural spawners each year. The target harvest rate was based on the productivity from the fit of a Ricker stock-recruit relationship to spawner counts from the Shasta River (a Klamath tributary), and the escapement floor was arrived at by consensus of interested parties.

This management policy has been justified by a number of arguments. The rationale is that a constant escapement rate provides an expected harvest that is nearly as large as the MSY policy of a constant escapement goal while providing informative variation in spawning escapements that will help to better define the production of the Klamath basin in the future so the optimal number of spawners can ultimately be determined. At the same time, a constant harvest rate policy provides less variability in landings than a constant escapement policy, thus providing more stable supply to markets. The escapement floor was included as a safeguard to speed up recovery of the stocks if they should ever become depressed.

Two different changes to the current escapement goal have been proposed. In response to very large spawning escapements in 1986, 1987 and 1988, a partial ceiling on spawning escapement was proposed. Under this modified goal, when natural spawning escapement was forecast to be greater than 70,000 adults, 1/2 of the additional spawners would be allocated to harvest. Subsequently, spawning escapement has been below the escapement floor in 1990, 1991, and was projected to be below the floor in 1992. As a result of this, the utility of the escapement floor has been questioned.

The arguments supporting the current escapement goals are based on the assumptions that there is a fixed production function that can describe the Klamath basin, and that fishery managers can know the present status of the stocks and control the mortality inflicted on the stocks by the fisheries. I wanted to examine the performance of different management policies under more realistic conditions, with random variability in production, mortality rates, maturity rates, growth, and vulnerability, and managers have imprecise information about stock status and imperfect control over the fisheries.

METHODS

To evaluate these possible changes to current escapement goals, I constructed a detailed simulation model of the natural component of the Klamath basin chinook stock. The model includes components describing the population, fisheries, assessment and management processes. The population model operates with a monthly time interval using instantaneous rates. Recruitment is described by a Ricker SRR with multiplicative log-normal errors. The growth of each cohort is normally distributed about a modified Von Bertalanffy growth curve that includes seasonal growth (Pauly 1987) fitted by eye to the length distributions of aged spawners from the Sacramento River. In addition, each year there is a random deviation in growth rate. Maturation rate for each year class is drawn from a logit transform (Johnson 1987) of a normal distribution fitted to the variability in maturation rates of coded-wire-tagged (CWT) fish from basin hatcheries. A correlation between deviation in size and maturation rate is included (Hankin 1990), and maturing fish all leave the ocean at the end of August.

The fishery model contains commercial and sport troll fisheries in the ocean and a terminal fishery on the spawning run. The distribution of fishing effort within each year for the ocean fisheries is based on the average distributions of effort from Fort Bragg to Coos Bay, with independent deviations occurring in both fisheries on a monthly basis. Ocean fisheries use California size limits of 66.0 cm total length for the commercial fishery and 50.8 cm for the recreational fishery. Fishery contact rates and shaker mortality rates were taken from the management models presently used for Klamath stocks. River fisheries use average selectivities estimated from CWT fish from river fisheries on the Klamath River from 1983 to 1990 (KRTAT unpublished). Observational errors and sampling errors are included in data generated from the population and fisheries by introducing independent multiplicative lognormal errors to actual catches and spawning escapements and then ageing a random sample of specified size from each data series.

In the assessment model, cohorts are reconstructed from the observed data. This cohort model uses an annual time-step and estimates mortalities as fractions of the population. Because the assessment model is discrete and the population model is continuous, this builds up a distorted picture of the population. The model uses a data series of constant length, so as each new year's data is added to the data set, the oldest year's data is deleted. Harvest rates, selectivities and maturation probabilities are estimated, but no attempt is made to reassess the SRR or recalibrate the escapement goals. Age specific stock forecasts are made from the reconstructed stock abundances and the observed spawning runs.

The management model uses the stock forecasts and past performance of fisheries to set seasons for the ocean fisheries and quotas for the river fisheries. River fisheries are given priority as forecast abundance decreases so that, in order to protect the escapement goals, both ocean and river fisheries are reduced equally until the river fishery reaches a minimum subsistence level. Beyond this, the ocean fisheries are reduced to try to protect escapement goals. After ocean fisheries are eliminated, river fisheries are reduced until they reach a minumum level corresponding to harvest by Indians for ceremonial purposes.

Simulations were run for 1100 years with data from the last 1000 simulated years used to characterize the performance of the management strategy. Management strategies evaluated included: status quo, the partial escapement ceiling, elimination of the escapement floor, and a fixed escapement policy. Each management policy was applied to stocks driven by a variety of SRR parameters that bracketed the parameters for which the policy was intended to evaluate the sensitivity of the policy to errors in the SRR parameters.

RESULTS AND DISCUSSION

The constant escapement policy offers little improvement over status quo (Figure 1). If the current assumptions about stock production are correct, a constant escapement policy would offer about a 2% increase in total landings. In theory, the benefits from a constant escapement policy should be greater, but given the imperfect control over fishing mortalities in the ocean and the errors in river quotas that result from errors in stock forecasts, escapement is still quite variable under a constant escapement policy. If the current

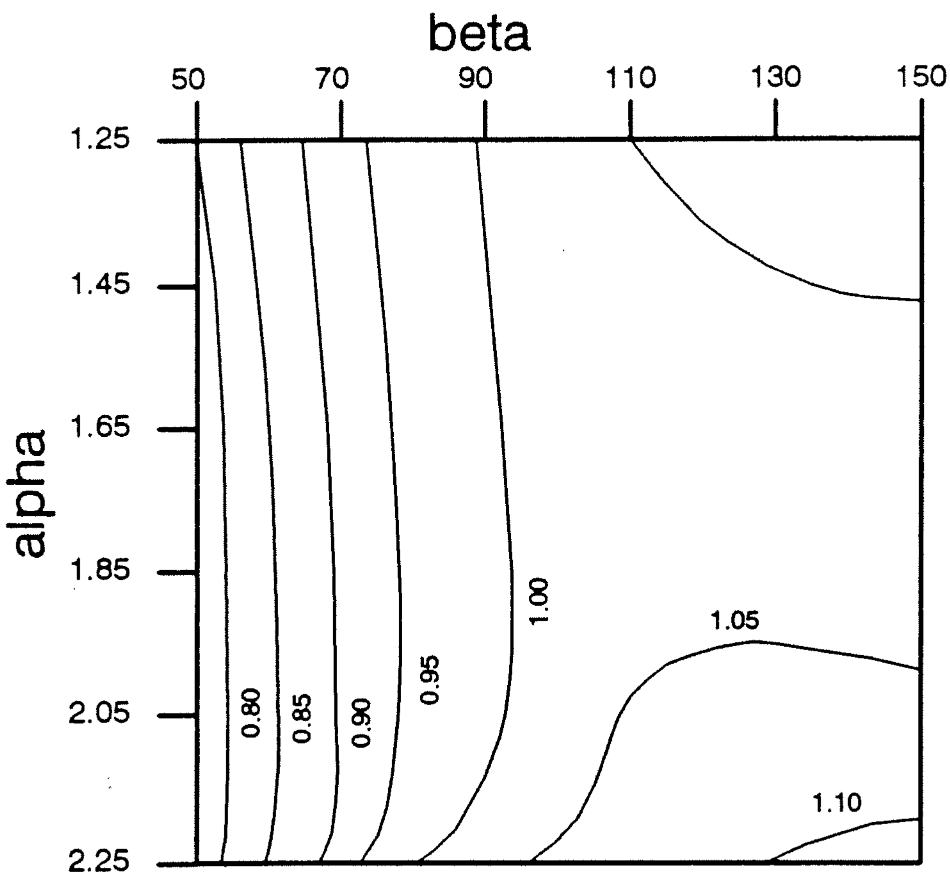

Figure 1. Expected yield from a constant escapement policy relative to status quo management. The escapement goal was chosen to maximize yield under current assumptions of stock productivity (a=1.76) and equilibrium stock size (Beta = 100).

assumptions about stock production are conservative, a constant escapement policy could increase landings by 5 to 10%. If the equilibrium stock size is smaller than presently assumed, a constant escapement policy with an escapement goal chosen as optimal for the current assumptions about stock and recruitment would result in less yield because of more frequently restricted seasons to try to meet an unrealistically high escapement goal.

The partial escapement ceiling has very limited potential to increase yield, and this is only realized if current assumptions underestimate stock productivity and equilibrium size (Figure 2). With current SRR parameters, there is no perceptible benefit from the partial ceiling even though the spawning escapement exceeds the ceiling 17% of the time. The reason that this policy fails to increase landings is that increases in harvest rate are triggered by forecast abundance, but are implemented on actual abundance. Because the correlation between forecast abundance and actual abundance is not very high, forecasts fail to predict most instances of escapement exceeding the ceiling. In the simulations, harvest rate was correctly increased 2.4% of the time. Similarly, most of the time when forecasts predict spawning escapements in excess of the ceiling, these large escapements fail to materialize (Figure 3).

Elimination of the escapement floor would potentially decrease the yield for most combinations of SRR parameters (Figure 4). If productivity is less that currently assumed, the escapement floor dramatically increases yield by preventing overfishing. The only case where this offers the potential to substantially increase yield is if the stock is more productive and with smaller equilibrium size than is presently assumed. Coincidentally, if a Ricker SRR is fitted to Klamath data from recent years, this is exactly where the parameters lie. Record abundances in 1986, 1987, and 1988 resulted from small spawning escapements, and produced the low abundances in 1990 and 1991. These extreme values dominate the fit of the SRR (Figure 5). This apparent SRR must be viewed with caution because parameter estimates are known to be biased in exactly this direction (Walters and Ludwig 1981, Walters 1985), and the situation is further confounded by coincidence of the high production years with favorable environmental conditions and the low production years with drought.

With current assumptions for SRR parameters, elimination of the escapement floor decreased the average yield from ocean fisheries by approximately 4%, inriver fisheries by 10%, and average spawning escapement by 25%. However, under the same scenario, restrictions on the ocean fisheries decreased from 27% of the years to 2.4% and complete closures of the ocean fisheries, which occurred 1.7% of the time under status quo management, were eliminated.

SUMMARY

Placing bounds, like escapement floors and ceilings, on the escapement goals of an otherwise constant harvest rate management strategy can increase the expected yield. This occurs because the hybrid strategy bears more resemblance to a constant escapement policy which theoretically produces MSY

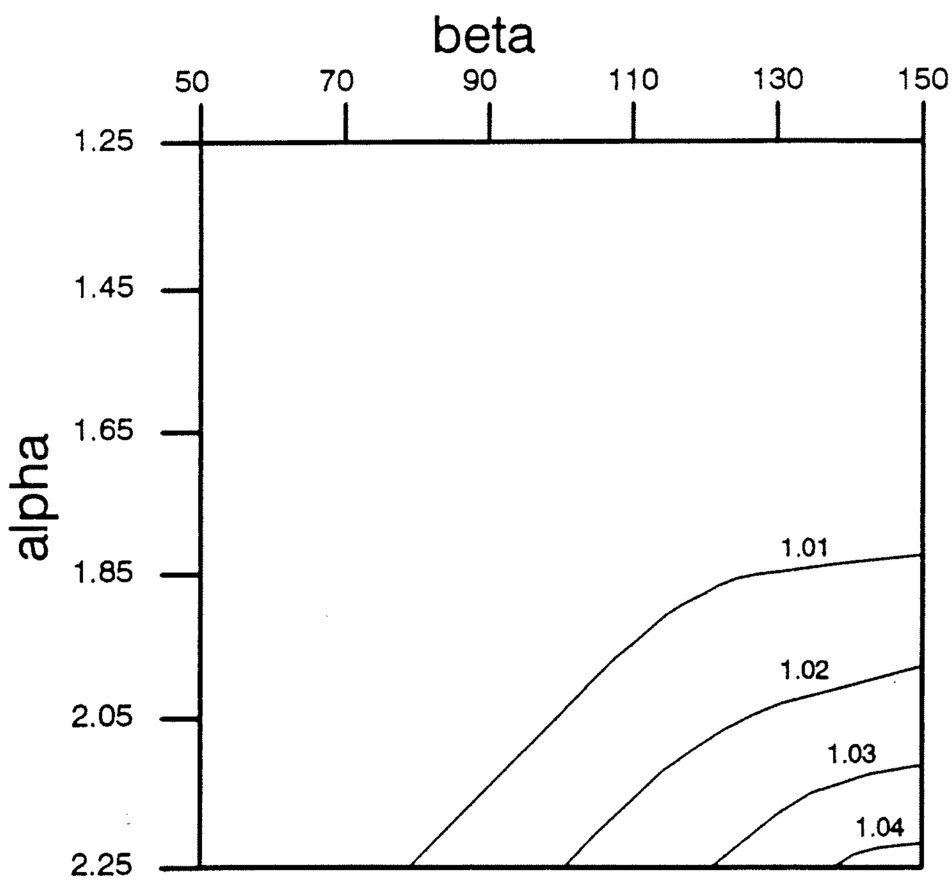

Figure 2. Expected yield resulting from adding a partial ceiling on spawning escapement relative to status quo management.

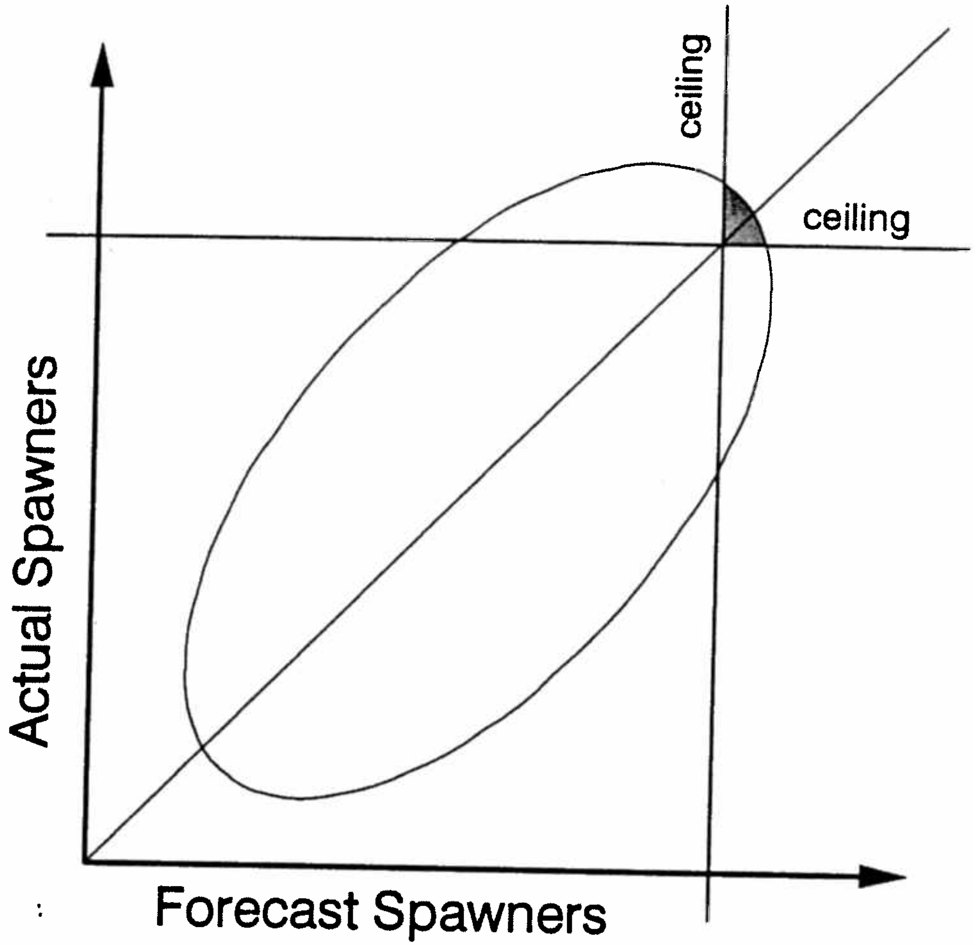

Figure 3. The effect of uncertainty on implementing an escapement ceiling. The goal is to increase harvest rates when actual escapement would be higher than the ceiling (left of the vertical line). Harvest rates are modified in response to forecast escapement (above the horizontal line). The imperfect relationship between forecasts and reality means that the fraction of the time that harvest rates are correctly altered may be very small (shaded region).

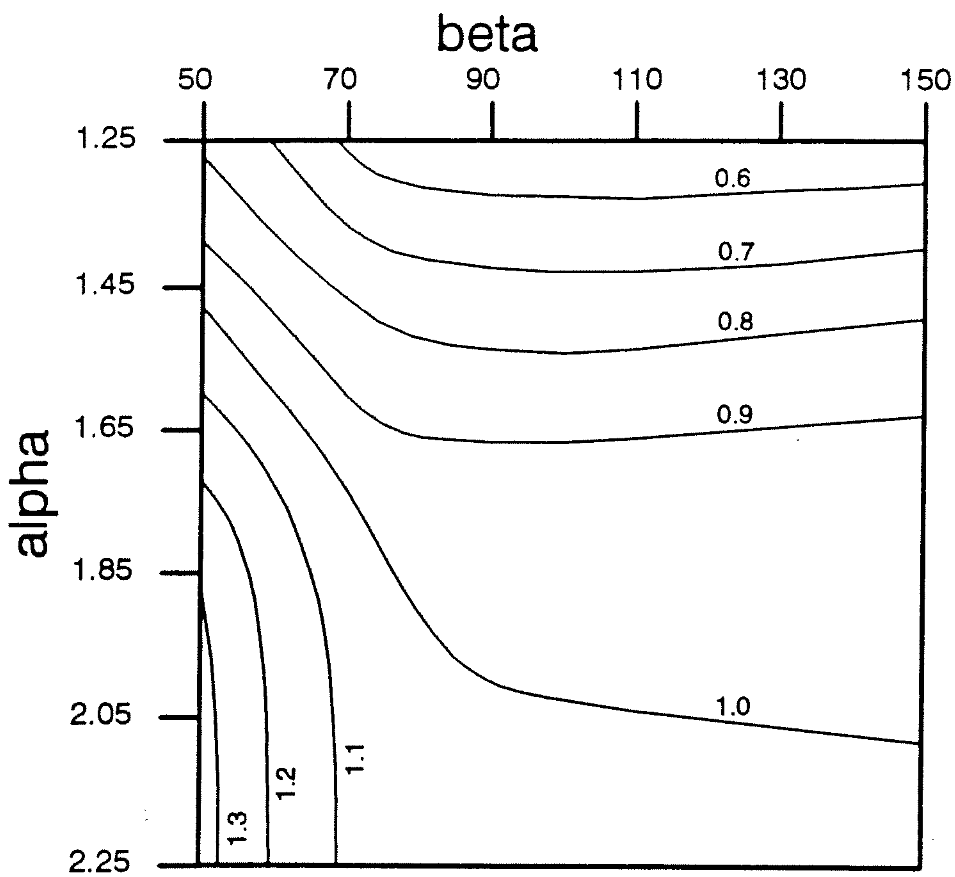

Figure 4. Expected yield resulting from removing the escapement floor relative to status quo management.

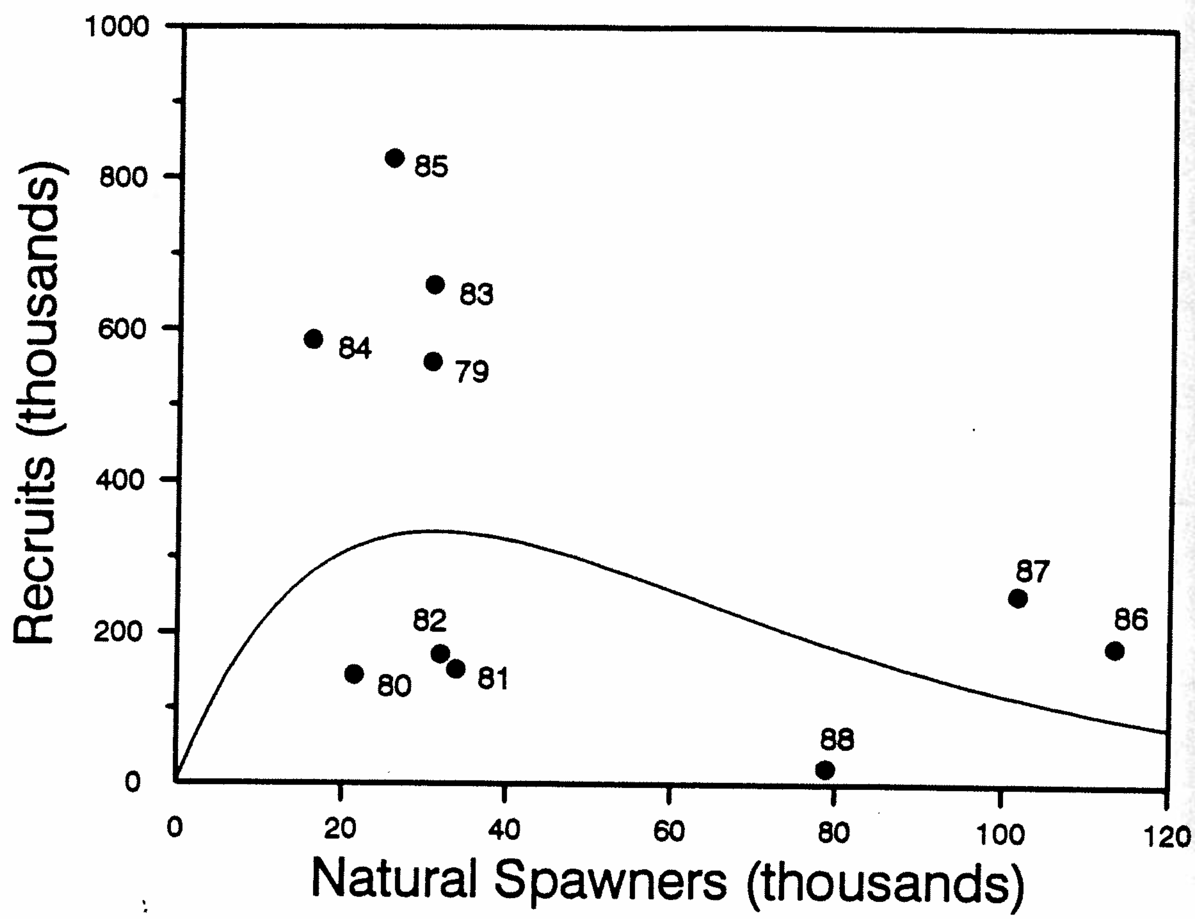

Figure 5. Apparent stock-recruit relationship for the natural component of the Klamath stock of fall-run chinook salmon. Recruits are age-2 ocean abundance of natural fish reconstructed by California Department of Fish and Game and data points are labeled by brood year.

if the goal is set at the correct level. A partial ceiling on escapement could increase landings if current estimates of stock productivity and equilibrium size are conservative, but would otherwise have no demonstrable effect. Eliminating the existing escapement floor would result in decreased landings unless the stock productivity is greater and the spawner capacity of the basin is less than presently assumed.

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