OPTIMAL HARVEST STRATEGIES FOR PINK SALMON IN THE SKEENA RIVER: A COMPRESSED ANALYSIS

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In The Skeena River: A Compressed Analysis

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In an earlier report,[1] I described a methodology for determining optimal harvest strategies in relation to uncertainty about stock production parameters. This note demonstrates the application of that procedure to pink salmon (odd year cycle) of the Skeena River. The procedure involves four basic steps:

(1) A simple dynamic model is chosen to give a reasonable empirical representation of population changes in relation to harvest rate (e.g. Ricker Curve);

(2) Stock recruitment data are used to derive an empirical probability distribution for the key production parameter of the dynamic model, and this empirical distribution is used to derive judgmental probability distributions for future production rates;

(3) Stochastic dynamic programming is used to solve optimal relationships between exploitation rate and stock size (recruitment), for a series of objective functions which reflect increasing interest in mean catch as opposed to stability of catches over time;

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[1] Walters, C.J. Optimal Harvest Strategies For Salmon In Relation to Environmental Variability And Uncertainty About Production Parameters. January 1975.

(4) By examining the optimal strategy curves for different objectives, a simplified strategy curve is derived and compared to best possible results from the exact strategies.

Figures 1-7 show the results of the analysis using pink salmon data kindly provided by FEA Wood, Environment Canada. Assumptions of the analysis are indicated in the figure captions.

The key recommendations from the analysis are that

(1) Stocks less than 1.0 million should not be exploited.

(2) Stocks above 1.5 million should recieve a fixed exploitation rate of around 0.4.

This strategy should result in a mean catch of close to 0.9 million (only 3% less than can be obtained by the current fixed escapement policy), with only about one-half of the variability that is likely to result from the fixed escapement policy. The frequency of zero catch years using the simplified strategy should be around 4%, while the fixed escapement policy is likely to result in zero catches more than 10% of the time.

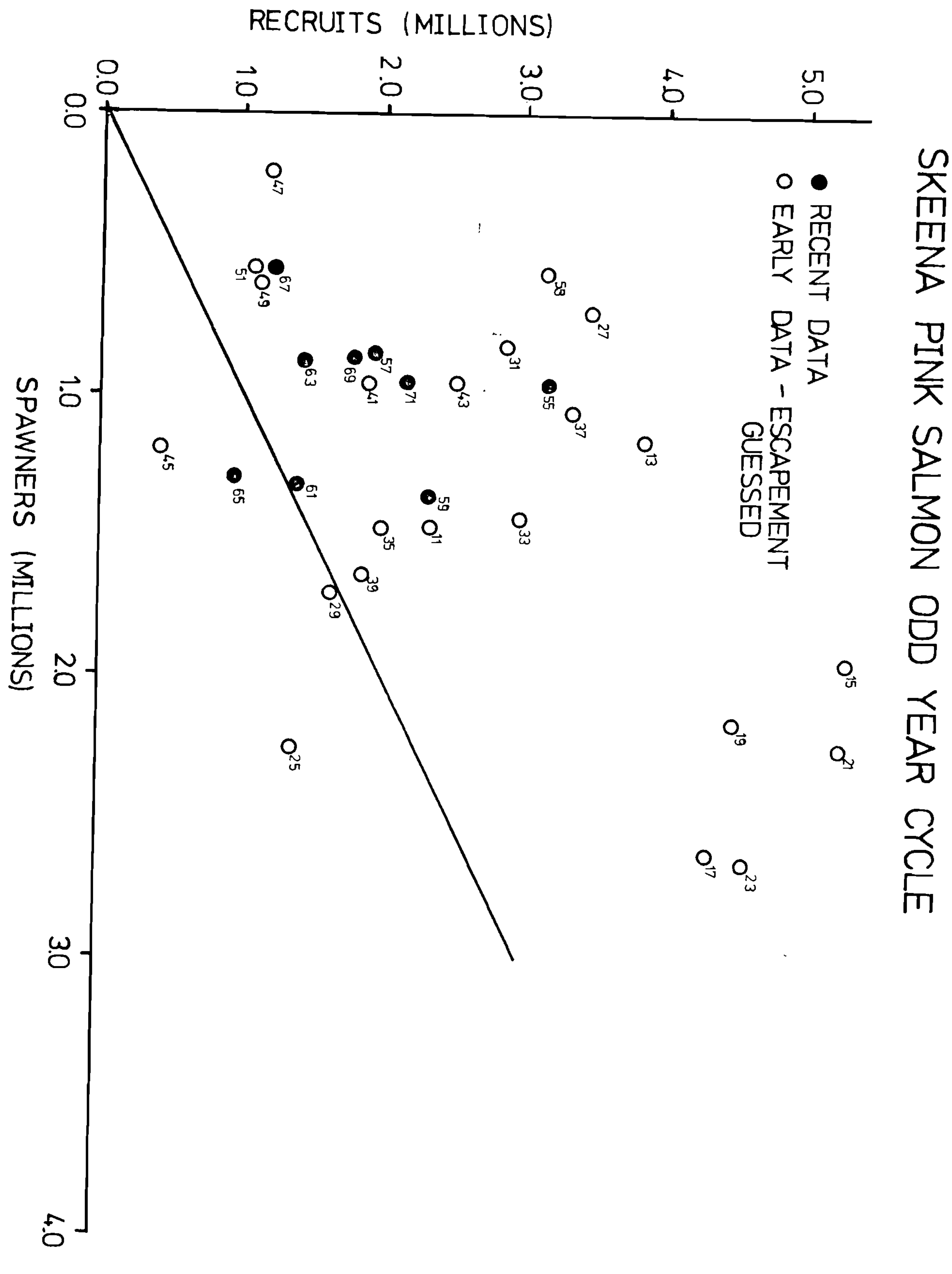


Figure 1. Stock-recruitment relationship for Skeena River pink salmon, odd year cycle. Dates next to points indicate spawning years. Spawners for years before 1955 guessed at 1/2 of total stock. This is probably too low for the early years; the equilibrium (unfished) stock was assumed for the analysis to be about 3.0 million fish.

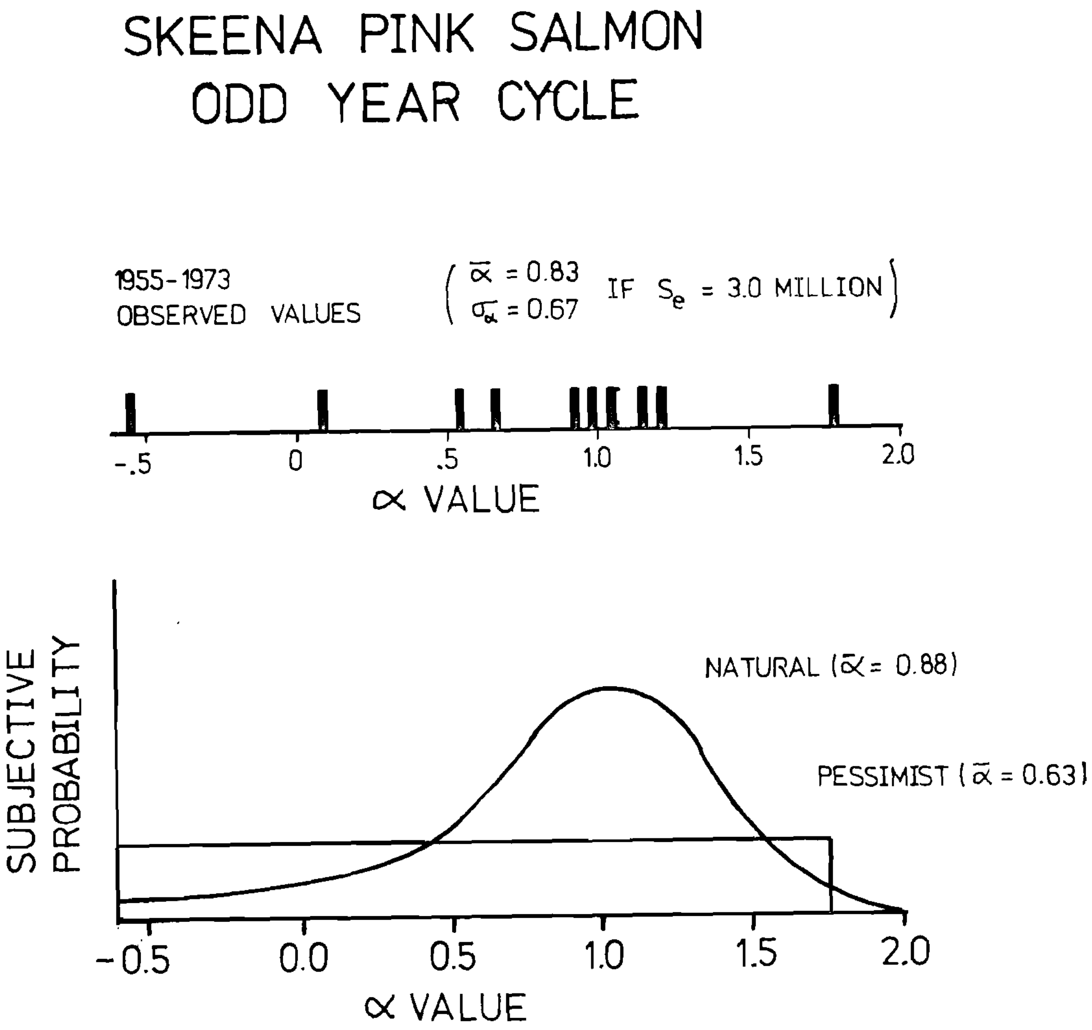


Figure 2. Empirical and judgemental probability distributions for the Ricker Production Parameter α, using data from figure 1 and assuming an unfished equilibrium stock of 3.0 million. α defined by the model $N_{t+1} = S_t e^{\alpha(1-S_t)}$ where N_{t+1} = recruits/3 million, S_t = spawners/3 million, t = 2 year generations. Note the observed and assumed (judgemental) high probability of very poor production values. The "natural" probability distribution assumes less than replacement production ($\alpha < 0$) in about one out of every 20 years.

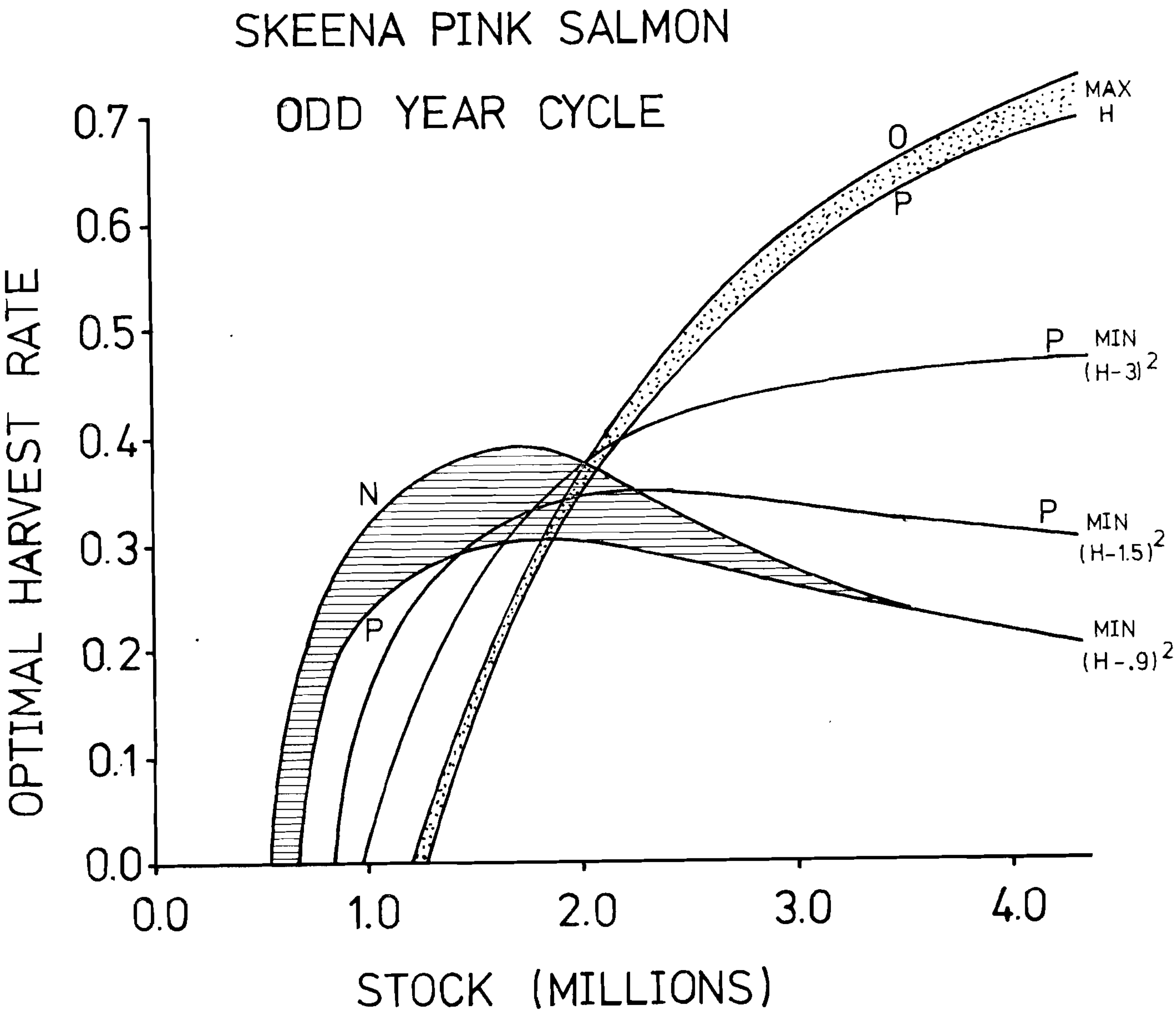
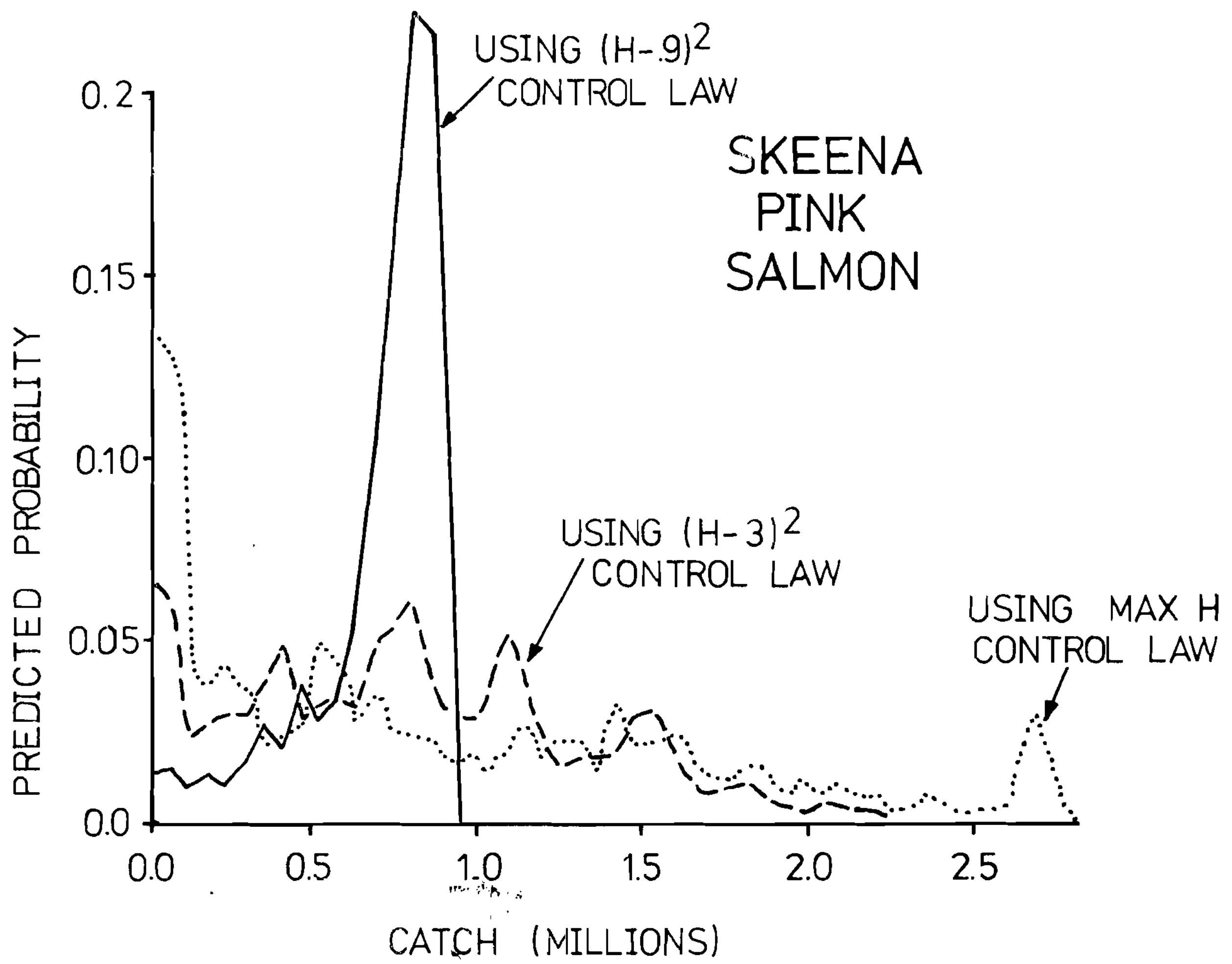
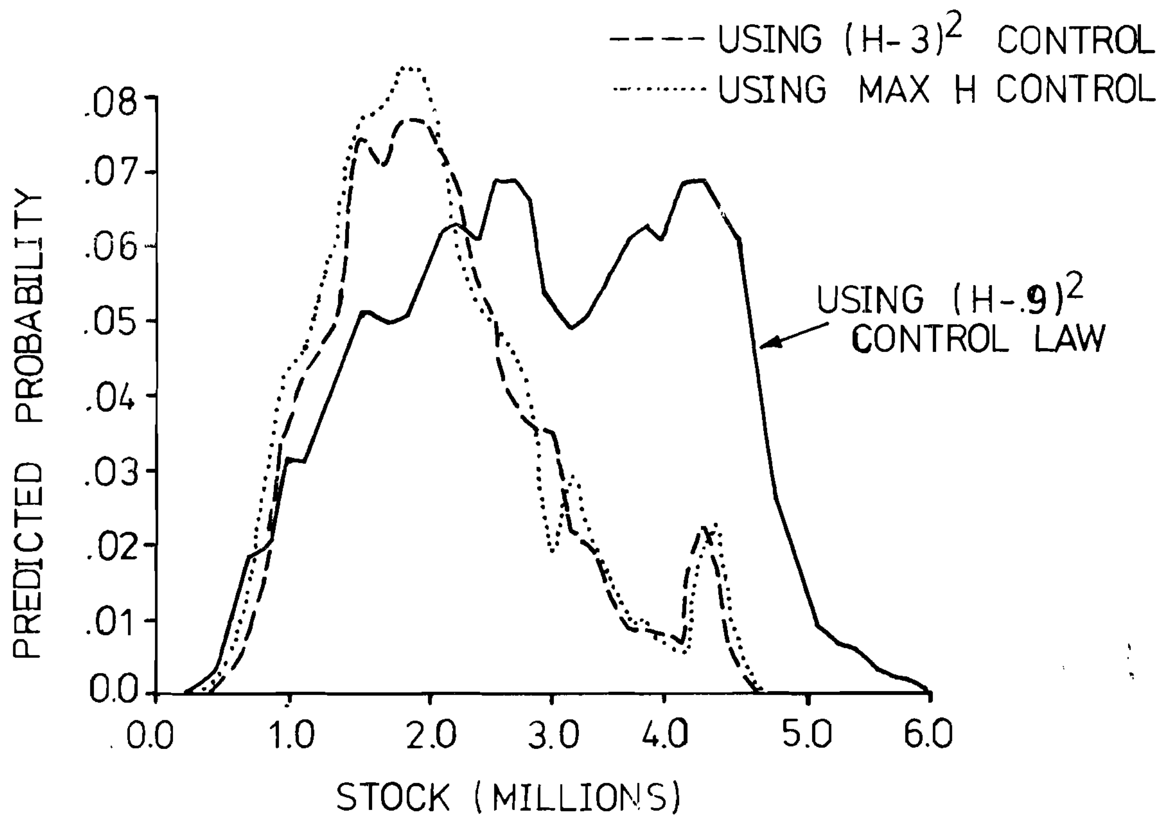


Figure 3. Optimal strategy curves derived by stochastic dynamic programming for different objective functions and judgemental probability distributions for α. N = natural α distributions of figure 2, P = pessimistic α distributions of figure 2. Objective functions as indicated; $(H - \mu)^2$ curves are optimal for minimizing variance around mean catch of μ.



USING $(H-.9)^2$ CONTROL LAW
SKEENA PINK SALMON
USING $(H-3)^2$ CONTROL LAW
USING MAX H CONTROL LAW
PREDICTED PROBABILITY
0.2
0.15
0.10
0.05
0.0
0.0
0.5
1.0
1.5
2.0
2.5
CATCH (MILLIONS)



USING $(H-3)^2$ CONTROL
USING MAX H CONTROL
USING $(H-.9)^2$ CONTROL LAW
PREDICTED PROBABILITY
.08
.07
.06
.05
.04
.03
.02
.01
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
STOCK (MILLIONS)

Figure 4. Probability distributions of catches and stocks likely to result from application of the optimal strategies in figure 3. Based on 5,000 year simulations using α normally distributed with mean 0.8 and standard deviation 0.67 (see figure 2). Note that the $(H - .9)^2$ variance minimizing strategy results in a bimodal distribution of stock sizes, indicating the existance of two near-equilibrium levels; historical data shows a similar pattern, with high stocks mostly prior to 1930. The simulation would not have resulted in this prediction if the exact optimal harvest curve for α normally distributed ($\mu = 0.8, \sigma = 0.67$) had been computed and used.

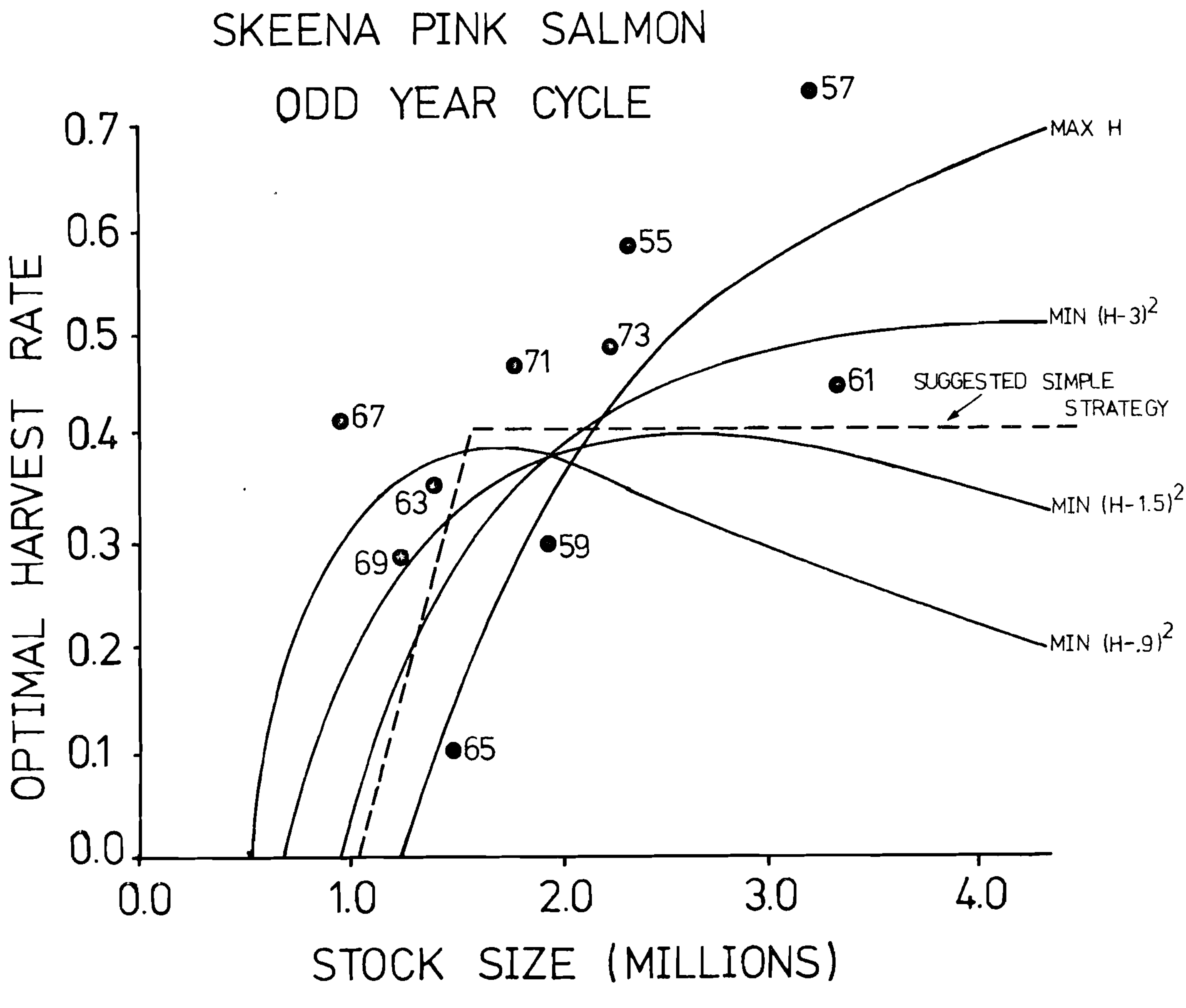
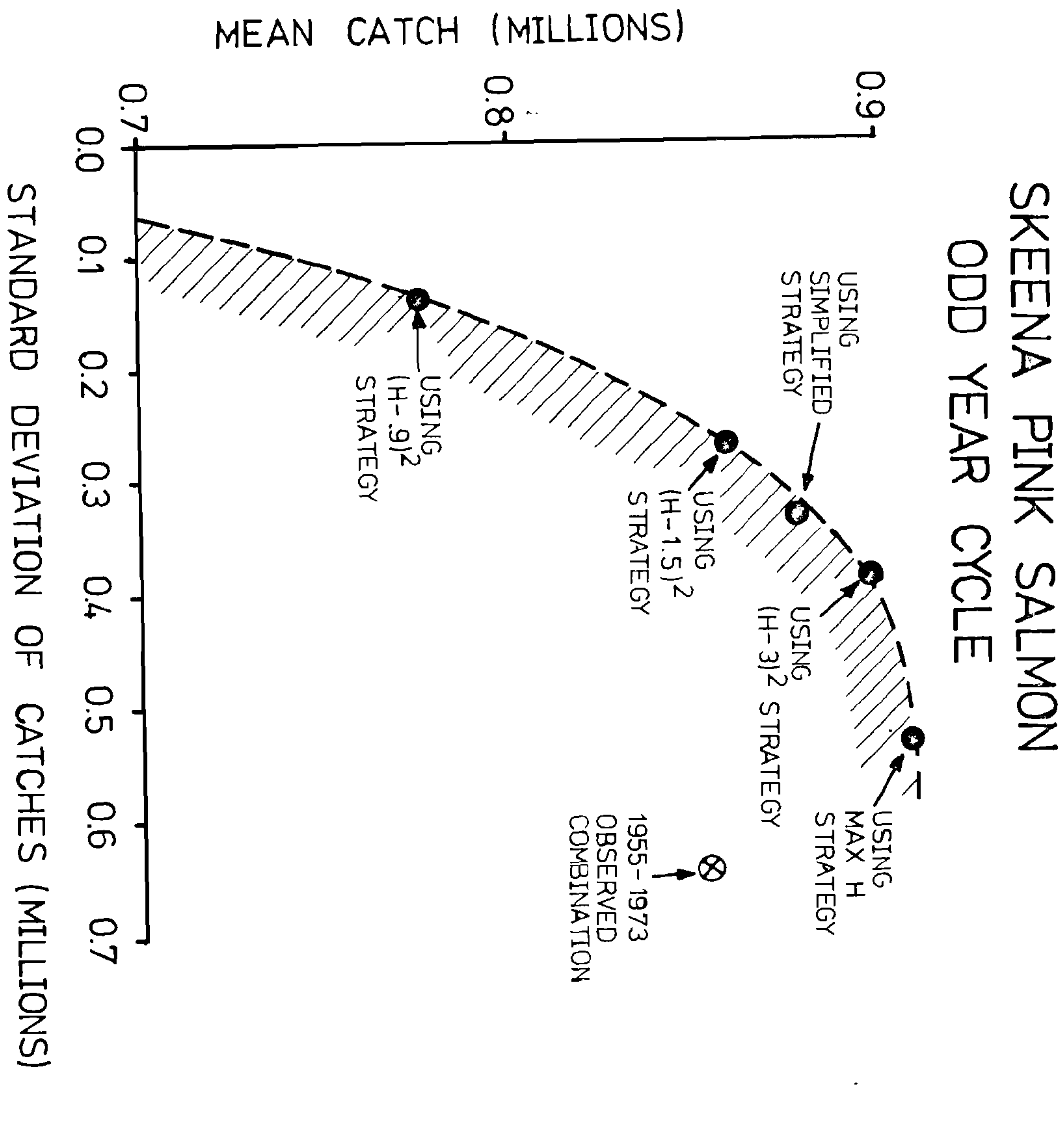


Figure 5. Optimal harvest curves compared to actual management practice, and a suggested simple strategy. Optimal curves derived by assuming the "natural" α distribution of figure 2. It is not clear what the actual strategy has been, but management actions have been complicated by the joint exploitation of sockeye salmon.



<u>Figure 6.</u> Pareto frontier of best strategies for trading off between mean and variability of catches. It is almost impossible to find a strategy which completely eliminates variability since very poor production years are common (see figure 2).

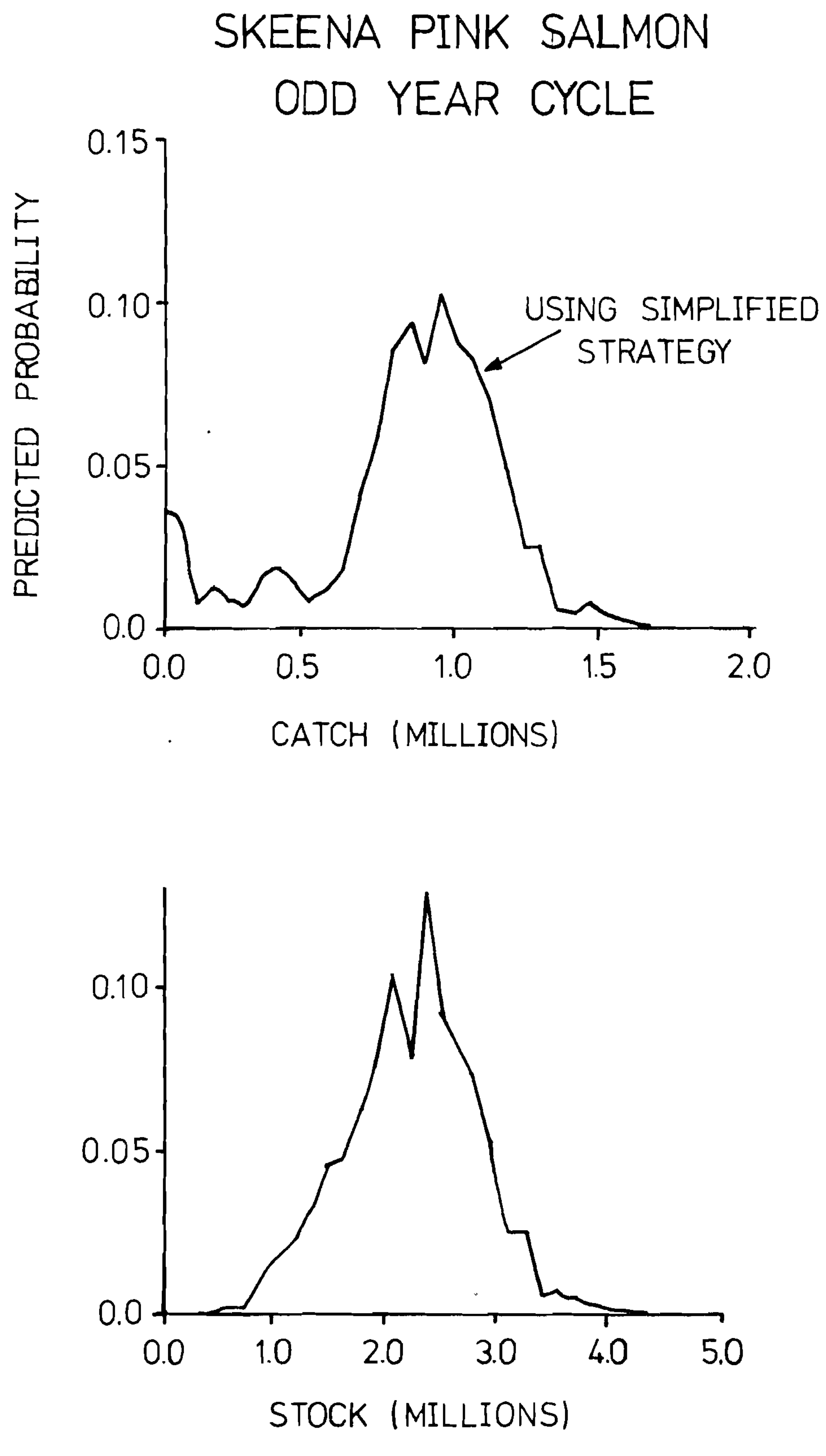


Figure 7. Predicted distributions of catch and stock size using the simplified strategy shown in figure 5.