Setting Allowable Catch Levels within a Stock Rebuilding Plan: Preliminary Thoughts on a Probabilistic Approach

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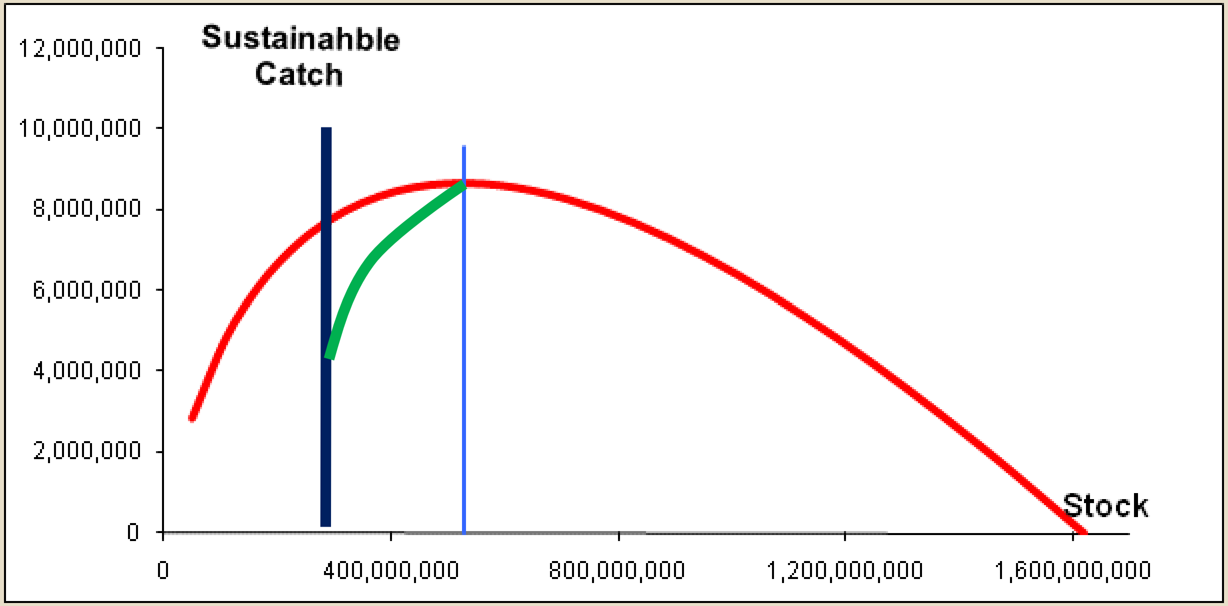
I have set a rather narrow topic. I will assume that we already have a Stock Rebuilding Plan (SRP). This puts aside the question of what the SRP should look like.

This is a big policy problem involving trade-offs between the present and the future and between and among various sectors in the economy.



Policy Choice

My purpose is to develop an analytical probabilistic framework to consider how the control rule harvest level can be modified to address the possible weaknesses in the construction and use of harvest control rules.

In current US law this is the problem of setting Annual Catch Levels (ACLs).

Why is this necessary? Why not just use the harvest level which follows from the control rule?

Because we have Limited Ability to Describe and Predict stock characteristics and conditions.

LADP

LADP

Describe: Stock Characteristics
Current Stock Conditions

Project: Future Stock Conditions under Different Amounts of Fishing.

Some just lump all this together under risk and uncertainty.

Why are the reasons that we have LADP?

Incomplete data.
Inaccurate data due to measurement and sampling error.
Model error.
Estimation error.
Stochastic and environmental variation.

Risk	Randomness with knowable probabilities.
Uncertainty	Randomness with unknowable probabilities.

Frank Knight ***Risk, Uncertainty, and Profit*** Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Co. 1921.

Because of this limited ability it makes sense to consider the benefits of modifying the control rule harvest level during annual specification setting.

Because the goal is to focus on a probabilistic analysis, it will be necessary to focus attention on relatively data rich situations involving risk. There will be no analysis of uncertainty although the procedure may provide some hints as to conceptualize the problem.

I illustrate my discussion with calculations from a quasi-hypothetical stock projection model written in EXCEL with a Chrystal Ball add on to perform Monte Carlo analysis. The model is described in my written paper.

The help of Drs. Clay Porch and Shannon Cass-Calay of the National Marine Fisheries Service in getting into the details of stock assessment reports into the model and computational assistance and helpful comments of Kathryn Semmens is gratefully acknowledged but the author takes full responsibility for data interpretations

Definitions:

X_t stock size at time t.

F_{Ct} The control rule fishing mortality rate at time t.

Y_{Ct} The proposed control rule harvest level in time t

$$Y_{Ct} = F_{Ct} * X_t$$

X_{Ct+1} The estimate of the stock size at time t+1 that follows from implementing the control rule harvest level in time t.

The procedure to modify the control rule harvest can be introduced by inserting a buffer between Y_{Ct} and the harvest level that is actually promulgated in the fishery management process, call it Y_{Pt} .

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Harvest level from control rule.

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Buffer which can be thought of as a variable in our problem. How big should the buffer be?

It will be convenient to consider the buffer as a percentage of the control rule harvest level.

$$0 \leq B/Y_{Ct} \leq 1$$

Note that $B \leq Y_{Ct}$

It would be useful to expand the probability analysis to consider multiple years, even if it is to be performed annually. To simplify the discussion the focus will be on a one year horizon but the concepts should be relatively easy to apply in a more general model.

There are three issues that need to be addressed in order to introduce this probabilistic approach.

First, what is the probability distribution that is of policy relevance?

Second, how can the PDF be generated?

Third, how can the PDF be used to convey useful information about how to set buffers?

Question 1. The control rules provides a basis for specifying the policy relevant probability Distribution Function

Deterministic calculation using mean value of parameters.

Current stock	Control rule	Expected X next year
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X_{Ct+1} becomes an i*nterim* target stock size.

The policy relevant probability distributions will be specified as:

$$P(B) \equiv P(X_{t+1} < X_{Ct+1} \mid B)$$

$$0 \leq B \leq Y_{Ct}$$

Call this the probability of failure.

See also the following which follows the same path but investigates a different probability distribution:

Schertzer, K. W., M. H. Praeger, and E. H. Williams 2008 *A probiblity based approach to setting annual catch limits. Fishery Bulletin. 106(3):225-232.*

There is an interesting subtly here. X_{Ct+1} is a result of the stock projection model, and there are as many questions about its true value as there are about any other number in the whole exercise. However, it is necessary to specify something as the critical stock criterion.

Question 2. How can the PDF be generated?

Using a Monti Carlo analysis, it is possible to estimate $P(X_{t+1} < X_{Ct+1} \mid B)$ for any B using two approaches.

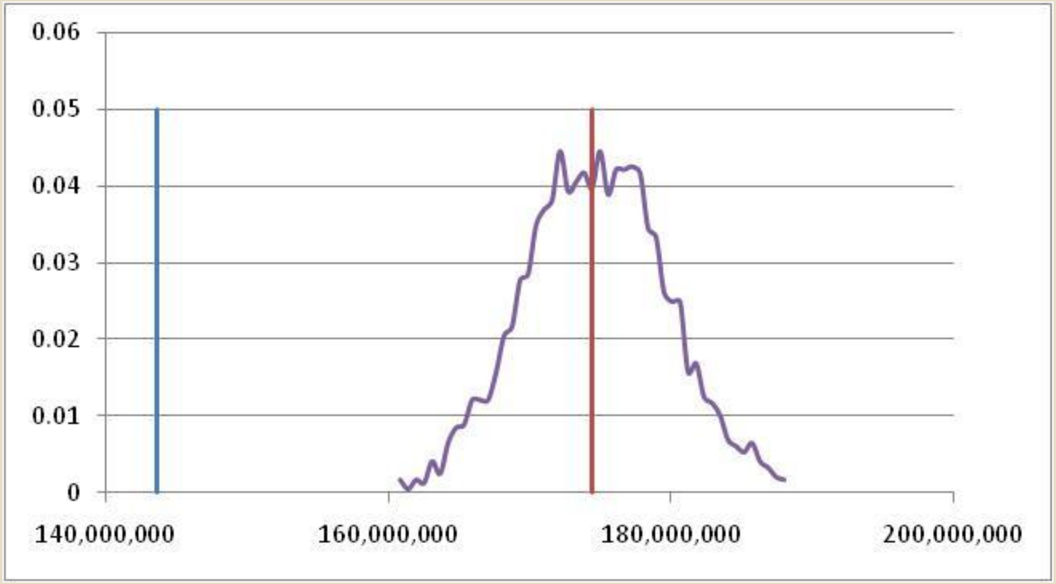
1. Considering endogenous randomness.

    What is distribution of X_{t+1} given a specific harvest level (F rate) and the PDFs of the endogenous parameters of the stock projection model?

2. Considering both endogenous and exogenous randomness .

    What is distribution of X_{t+1} given the PDFs of the endogenous parameters of the stock projection model and the PDF of expected F given existing abilities to implement and enforce regulations.

Endogenous Randomness



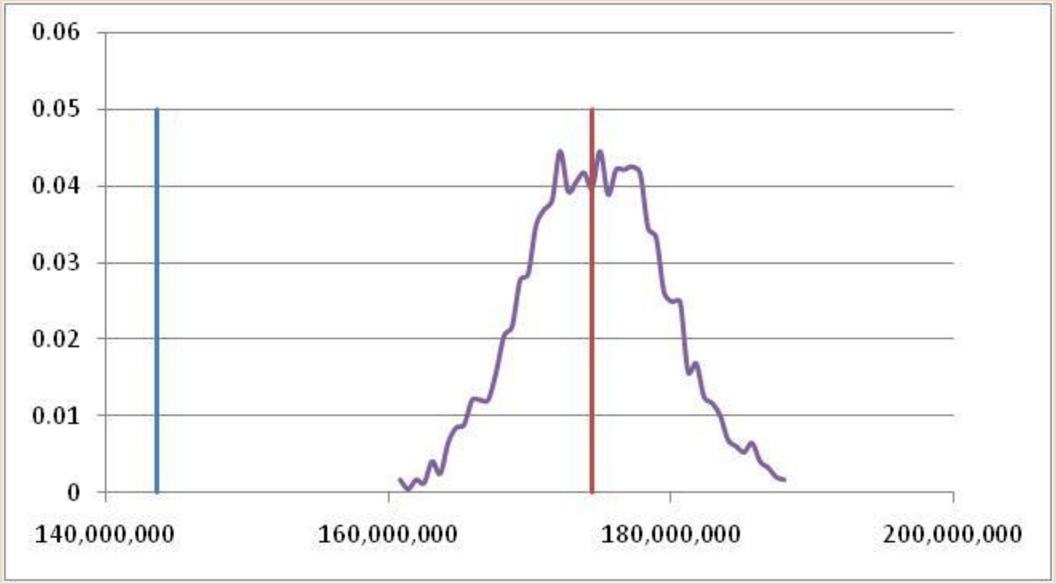
X_t X_{Ct+1}

$$P(X_{t+1} < X_{Ct+1} \mid 0) \approx .5 \quad [49.02]$$

This is an example of the Monte Carlo results of the model assuming PDFs of SPM are normally distributed.

Endogenous Randomness

The fact the distribution looks normal not be a surprise.



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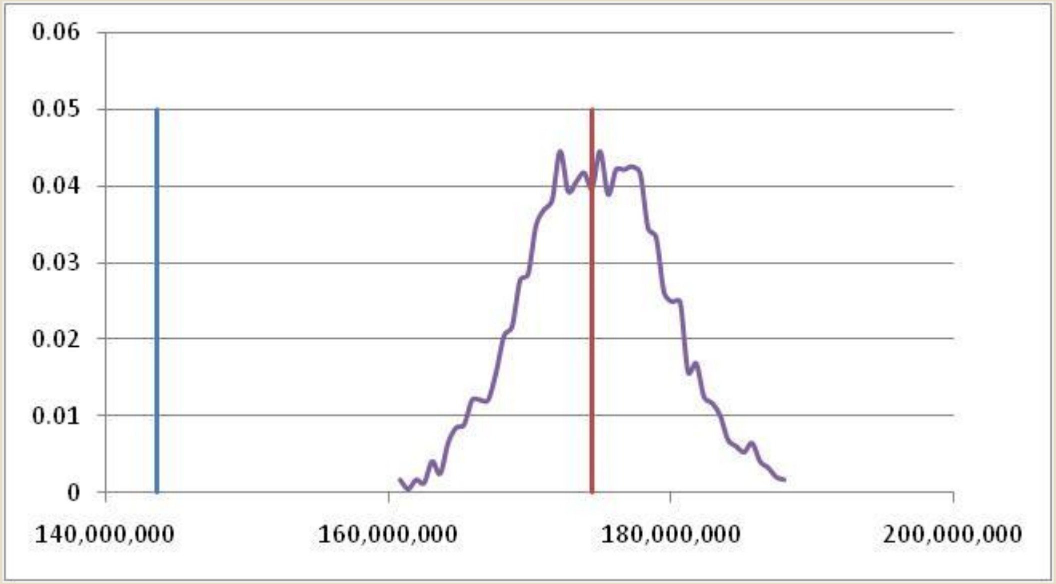
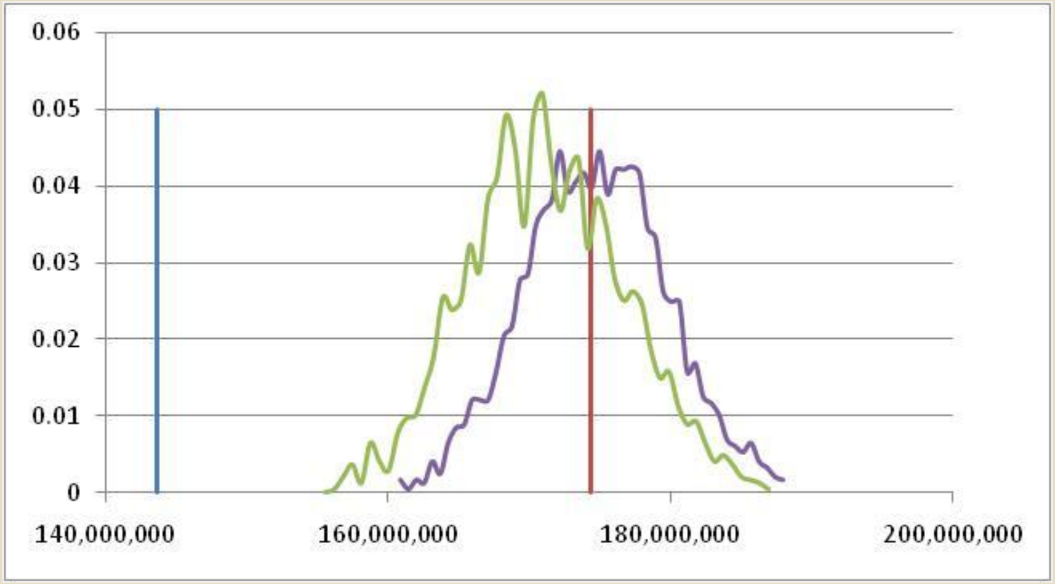


This demonstrates some weakness of the common procedure of providing only point estimates of the expected result of a particular harvest level, which would result in a point estimate of X_{Ct+1}.

Endogenous and Exogenous Randomness

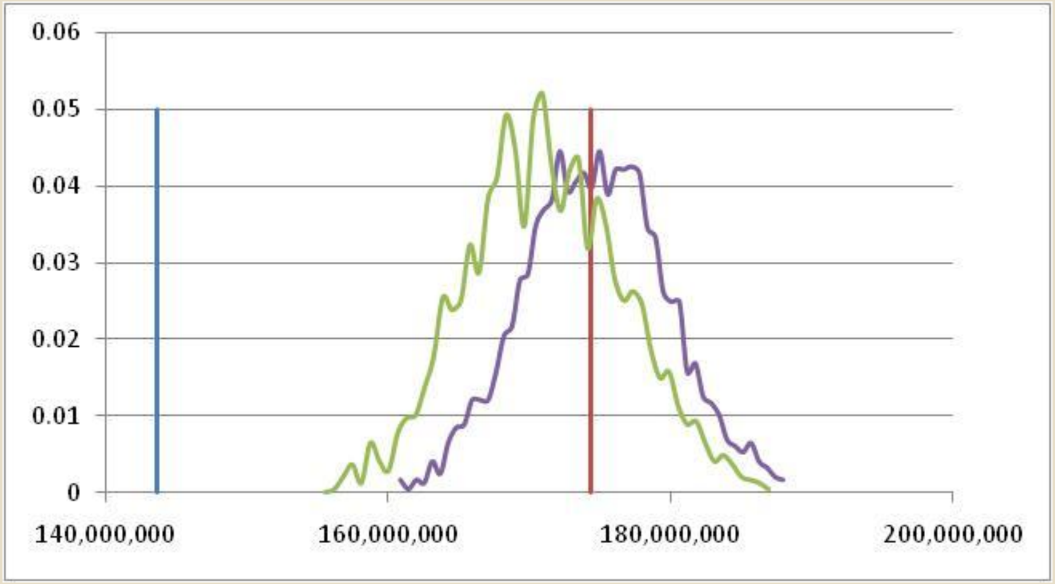


$$P(X_{t+1} < X_{Ct+1} \mid 0) = .69$$

This is directly related what is currently called the need to address both scientific uncertainty and implementation uncertainty.

Endogenous and Exogenous Randomness

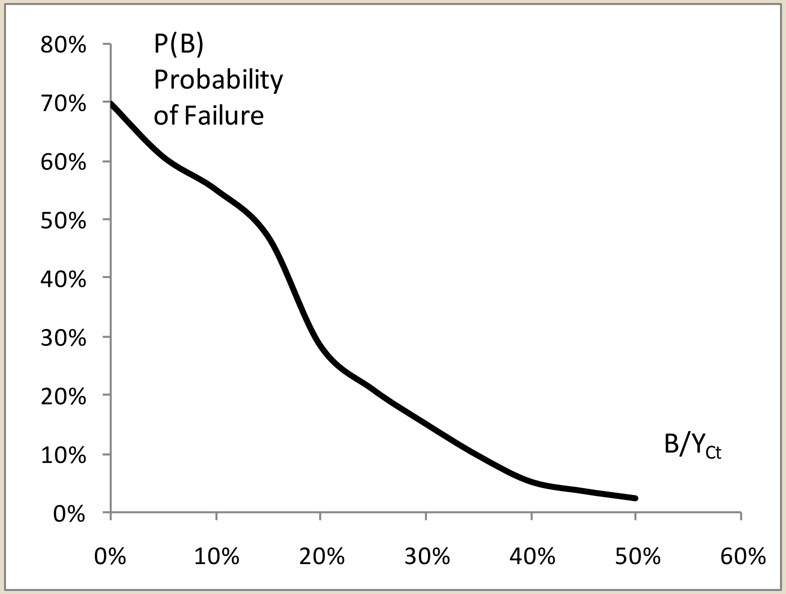
Likely a better picture of the issue. Both types randomness need to be considered simultaneously.



$$P(X_{t+1} < X_{Ct+1} \mid B) = .69$$

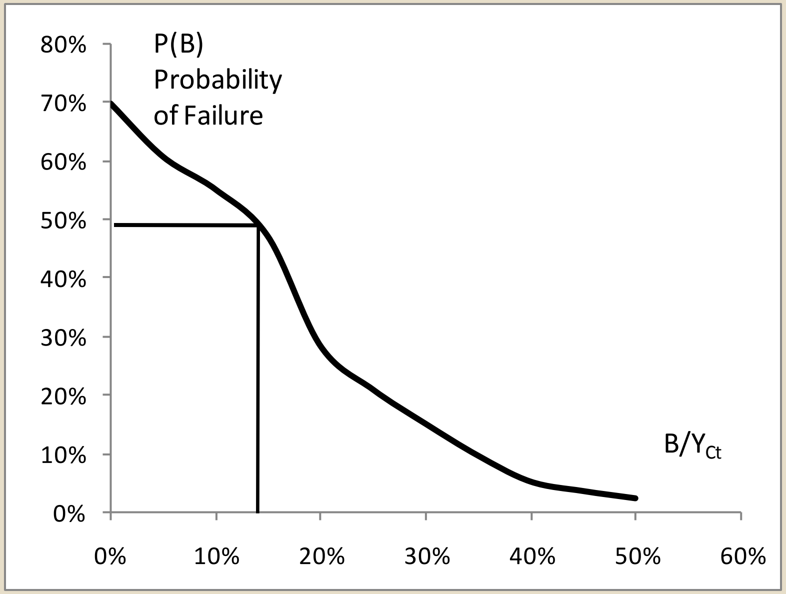
How does $P(X_{t+1} < X_{Ct+1} \mid B)$ change as B is increased from zero.

Calculated using a series of Monte Carlo analysis with 5% reductions in F from $F_{Ct.}$

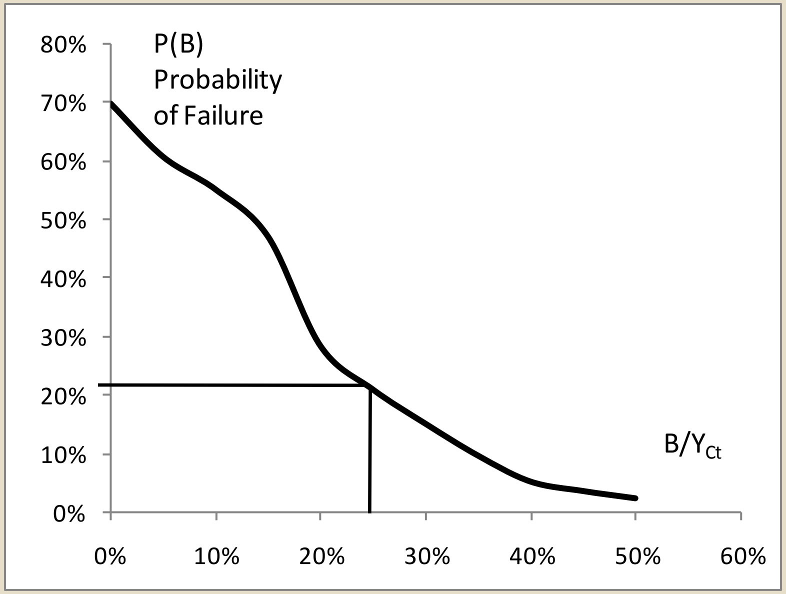


Probability of Failure Reduction Curve

How can this inform Policy?



Set the buffer such that P(B) is the same as would be expected considering only endogenous randomness.



Or set another minimally acceptable level of the probability of failure.

A tentative step toward a more formal cost minimization approach

There is a cost of implementing a buffer.

At minimum it is the forgone value from reducing harvest.

But what is the benefit of a buffer?

Really. Think about it.

Let L be the loss that will occur if the target stock is not achieved. Conceptually there is also a loss (L) for missing the interim target stock size. This is a very hard thing to even conceptualize because of the illusive chain between missed targets in a single year and forgone future benefits. This is especially true if a similar decision is to must be made every year. But even in lieu of firm estimates L, it possible to finesse this and still provide some policy relevance.

Minimization of expected costs using Buffer

$$C = P(B)*L + [B/ Y_{Ct}]*NV \qquad \text{Equation 1}$$

NV is the net value of producing Y_{Ct} units of fish.

As B is increased from zero to Y_{Ct}, the cost in terms of the lost value of production will increase from zero to NV

The first order condition for a minimum is

$$-P'(B)*L = NV/ Y_{Ct} \qquad \text{Equation 2}$$

Note that $-P'(B)$ is positive.

Optimal level of B occurs where the marginal reduction in the value of expected losses is equal marginal cost of increasing the buffer. The term NV/Y_{Ct} is per unit net value of harvest.

Given that it is possible to obtain estimates of -P'(B) and NV/ Y_{Ct}, it is possible to use either Equation (1) or (2) to investigate how the optimal buffer size will change with different values of L.

Reformulating the first order condition obtains the following:

$$L = \{ NV/Y_{Ct}\}*\{1/[-P'(B)]\}$$

This allows for the calculation of the minimum value of L necessary to justify a given buffer.

This value of L is equal to the inverse of the negative of the slope of PFRC at the particular buffer level times the per unit value of harvest.

These are values for the example probability of failure reduction curve.

Buffer	P(B)	"-ΔP(B)"	Inverse
0	69.8%		
5%	60.7%	0.091	11.0
10%	55.1%	0.056	17.9
15%	47.0%	0.081	12.4
20%	28.3%	0.188	5.3
25%	20.8%	0.075	13.4
30%	15.0%	0.059	17.1
35%	9.5%	0.055	18.3
40%	5.0%	0.045	22.5
45%	3.4%	0.016	61.7
50%	2.2%	0.013	80.0

L would have to be 17 times the unit net value of harvest to justify a buffer of 25%.

These are admittedly small first steps but hopefully in the direction of providing information how to “consider” our limited ability to describe and predict stock conditions when setting permissible harvest levels.

Thank you.