Roland Maw proposals 88-102

Kenai River Salmon Stock Assessment Methodologies

The BOF is charged with using the "Best Available Science" in the development and conservation of salmon resources. Best available science is that which is most accurate and reliable in stock assessment and prediction. In the recent past ADF&G has begun utilizing Bayesian statistical modeling for salmon stock assessments. While Bayesian methodology has value in salmon run modeling, it cannot replace the legitimacy of empirical data. It is not working in Upper Cook Inlet at present.

During the last 20 years, the Kenai River late-run sockeye salmon escapement and in-river goals have been increased with the promise that the higher escapement goals will provide for larger runs. Larger runs to the Kenai would benefit all Alaskans, it is the salmon system that most Alaskans can access. Looking at the past ten years of data, 90% of the time the upper end of the increasingly large escapement goals have been exceeded. Instead of the predicted increased run sizes, we are now experiencing some of the smallest returns in recent history including, in 2018, the smallest sockeye return in over 40 years. The forecast for 2020 isn't looking much better than 2018. If new information about the status of the fry population in the Kenai system is correct, no one will be allowed to harvest Kenai River salmon in a couple of years; no dipnetting, no sportfishing and no commercial fishing.

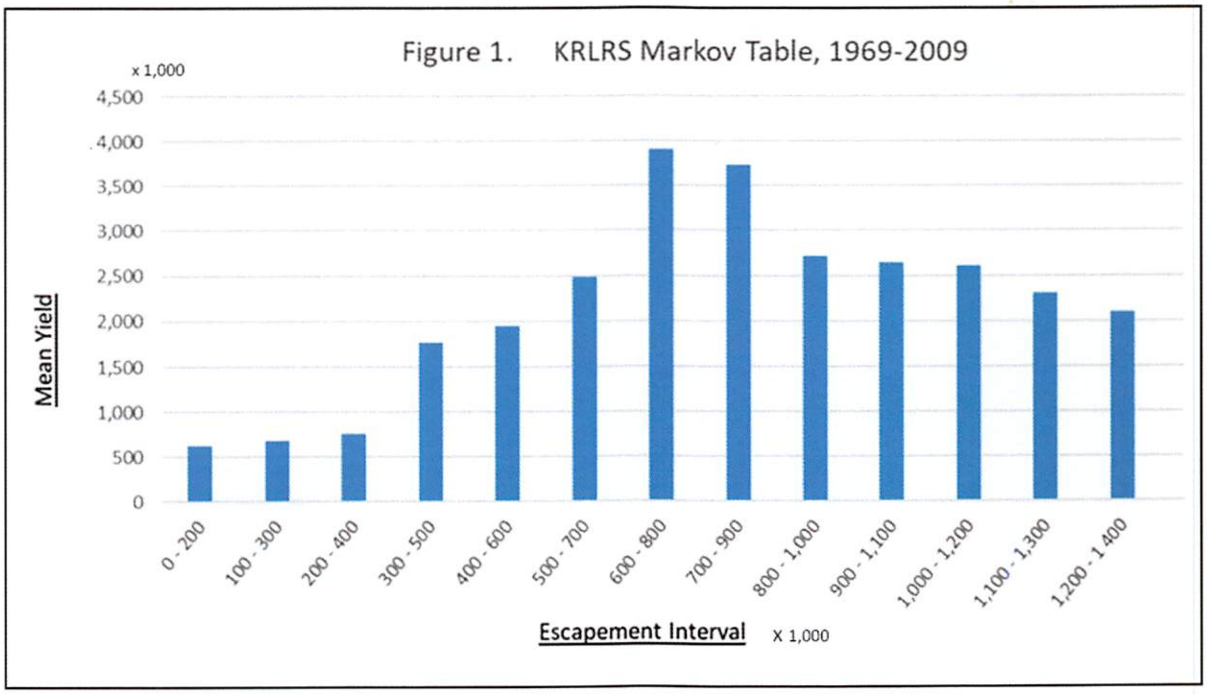
Bayesian modeling persists in suggesting that higher escapements will produce larger runs. Actual data refutes it. Bayesian statistical methods are strictly hypothetical and computer generated. Other methodologies, including the Markov table, are based on empirical field data collected from salmon.

In the publication "Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty," world-renowned scientists Ray Hilborn and Carl J. Walters made the following statement about the Markovian approaches for salmon stock assessment:

> "This type of approach is also called a Markov model in mathematical terms and the table is called a Markov transition probability matrix, but it is simpler to just think of it as a table. **This approach is highly recommended when many years' data are available**, because it can accommodate any possible form of stock-recruitment curve and explicitly incorporates the type of variation seen in the data. (Hilborn and Walters, 1992, p 263-264.)

As there are over 40 years of data available for the Kenai River Late-Run Sockeye Salmon, it makes sense to use the data-based Markov table. A Markov table of Kenai's late-run sockeye clearly supports lower escapement goals for increased returns, as seen in Figure 1.

A spawning escapement of around 750,000 produced all of the largest returns, except for one, over the span of 40 years. This is the science that ADF&G and the BOF should be using for setting escapement goals in the Kenai River.



Data Source: Erickson, Willette and McKinley: 2016 Review of salmon escapement goals in Upper Cook Inlet, Alaska; Fishery Manuscript Series No. 17-03.

Salmon, and their natural, living systems, are dynamic and changing. The Bayesian methods totally ignore the dynamic nature involved with living organisms, depending instead on computer-generated, random data that magnifies outlying data points.

The Bayesian methods may work well in non-living situations, such as quality control, where the breadth and scope of change can be controlled. However, fish are adaptive and interact with hundreds of variables, some of which we do not understand, and are changing annually. Examples where the Bayesian methods may work well include testing metal hardness, and composition in making hardware such as screws and doorknobs.

Bayesian methods failed to anticipate the Chignik sockeye run failure in 2018, the missing 2.3 million Kenai River late-run salmon in 2018, and the general decline in recent Kenai returns.

The Bayesian Statistics Model is named after Thomas Bayes who, in the early 1700s, formulated a probability distribution based upon a prior set of beliefs and data derived from a set of random numbers. He further theorized that these numbers were representative of what goes on in natural systems. Now, with the advent of powerful computers and new algorithms, Bayesian methods have seen increasing use within statistics in the 21st century.

Bayesian methods are theories in fields of statistics based on the interpretations of probability that express **degrees of belief** in an event or a policy. These degrees of **belief** may be based on prior knowledge about the event or policy, such as the results of previous experiments, or on personal **beliefs**. Example: A policy shift from Maximum Sustained Yield (MSY) to Maximum Sustained Return (MSR). Bayesian methods may provide estimates of MSY, MSR, escapement goals or in-river goals. These are all expressions of belief or policy objectives. This differs from the scientific method in which a number of other interpretations that view probability as the limit of the relative frequency of an event after extensive field trials.

Bayesian methods use Bayes' theorem to compute and update probabilities after obtaining new data from tables of random numbers. Bayes' theorem describes the conditional probability of an event based on randomly obtained data as well as prior information or **beliefs** about the event or policies followed.

For Board of Fish member reference, a side-by-side comparison of traditional scientific methodological statistics to the Bayesian methods and experimental techniques is presented in the following table. Much of the information contained in the side-by-side comparison came from the article titled *Objections to Bayesian Statistics,* Andrew Gelman, 2008, in Bayesian Analysis 3, Number 3, pgs. 445-450.

Traditional Statistics	Historical	Bayesian Statistics
• Data comes from fish being		• Data is generated by
studied in real environments		table of random numbers
• Data comes from live organisms		• Data does not come
		from living organisms
	Data Sources	
• Observed data from the fish		• Unobserved data from table of
population(s) measured at		random numbers
specific times and locations		• As a surrogate for actual fish
• No exchangeability to random events		• Relies on random computer 'data'
• Surrogates possible under specific conditions		as an exchange for real fish (field) data
	Applied - Experimental	
• Applied sciences, biology and ecology		• Experimental method(s)
• Descriptive data - from fish		of inferential applications
		based on little applied science
	Randomness	
• Natural systems do have sequences,		• Natural systems operate as a
patterns, cause & effect		series of random events & data
• Spawner/recruit relationships		
	Objective - Subjective	
• Objective, observational understandings		• Subjective attempts at developing an
• Follows scientific methods		understanding that follows beliefs
	Comparable Assessments	
• Assess the management plans		• Assess understandings
through field experiences		with more random data
	Logics	
• Operates in instictual fashion		• Heavy reliance on a logic that natural
• Fish do not care about our beliefs or wants		systems do consider the outcome and
• Truth is independent of our observation		operate within these parameters
	Beliefs	
• Not a **belief** system,		• **Belief** is the basis for
• Hypothesis-scientific		accepting/rejecting an outcome
methods to discover		
	Science-Based Hypothesis Testing	
• Hypothesis testing collects more data		• Weak or uniform prior **belief**
• Tests hypothesis at specified probabilities		• Data is produced by tens of thousands
• Often expensive $$, multi-year		of computer generated operations
field data collection systems		• Assigns probability based on belief(s)
• Scientific methodology used and relied upon		• Inexpensive data creation, generate
• Statistical bias is to be known and avoided		another 10,000 events, keyboard entries
		• Seduced by promise of automatic inference
		• Statistical bias is embraced
		• Statistical **beliefs** are introduced as
		a substitute of scientific methodology

The Bayesian design of experiments includes a concept called 'influence of prior **beliefs**'. This approach uses sequential analysis techniques to include the outcome of earlier experiments in the design of the next experiment. This is achieved by updating **'beliefs'** in events or policies through the use of prior and posterior distribution.

In the same report by Hasbrouck et al., (2020, p 6) referenced above, it states "Each model was run for 100,000 iterations, of which the first 20,000 were discarded (i.e. burn-in). Bayesian Markov Chain Monte Carlo method (MCMC) samples were drawn from the joint posterior probability distribution of all unknowns in each model." Each of the 6 models had the first 20,000 iterations discarded.

In "Susitna River Chinook Salmon Run Reconstruction and Escapement Goal Analysis" by Reimer and DeCovich, (Fishery Manuscript No. 20-01, January 2020, p. 15) it states the following: "MCMC samples were drawn from the joint posterior probability distribution of all unknowns in the model. The model was initiated with 3 chains and 200,000 samples were generated per chain. Initial values were generated randomly although some parameters were generated from a uniform distribution truncated to plausible values within the parameter's support. The first 50,000 samples from each chain were discarded and the remaining samples were thinned by a factor of 200, resulting in 2,250 samples that were used to estimate the marginal posterior means, standard deviations, and percentiles." Three chains of 50,000 per chain were discarded. Then the remaining iterations were further thinned by a factor of 200 resulting in 2,250 Bayesian-derived iterations that were used rather than real, boots-on-ground, empirical data.

These models are clearly mathematically driven. Mathematical models cannot incorporate field observations of run size, age composition, weights (fry, smolt and adults), run timing, health, vigor, climate change effects and spawning success that all come into the stock assessment process. These and other field observations and data provide "ground truthing" of the theoretical. It is through these applied science ground truthing activities that we actually become aware of what is going on in these salmon populations.

It is very difficult for non-statisticians to argue the details of the Bayesian methodology in particular applications. But we can all clearly observe the reduction of the Kenai River late-run sockeye returns as escapement and in-river goals have been increased.