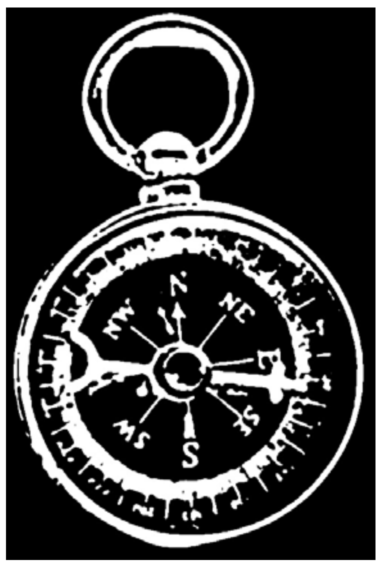
Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and National Marine Fisheries Service
851 SW 6th Avenue, Suite 1100
Portland, Oregon 97204
ISAB@nwcouncil.org

Review of the COMPASS Model



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ISAB Review of the COMPASS Model

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Executive Summary

NOAA Fisheries, along with federal, state, tribal agencies, and the University of Washington, are developing a new comprehensive fish passage model (COMPASS) that is intended to replace the currently used simulated fish passage model (SIMPAS). NOAA Fisheries has indicated that the new COMPASS model will be used extensively in the new Federal Columbia River Power System Biological Opinion (BiOp) and that it should be subjected to thorough and transparent scientific review. On January 12, 2006, NOAA Fisheries requested that the ISAB review the partially completed COMPASS model specifically addressing several questions regarding the model capabilities, complexity, data usage, statistical protocols, documentation, and graphical interface.

On January 27, 2006, following a briefing describing the development and status of the COMPASS model, the ISAB accepted this assignment. A summary of the ISAB's findings and answers to questions posed by NOAA Fisheries are provided in this Executive Summary. Full explanations of the ISAB's findings with technical details intended for the model developers and users are in the main body of the report.

Capabilities of the COMPASS Model

(a) How realistically does COMPASS portray the hydrosystem and variable river conditions?

Since the model uses a daily time step, it should have the potential to portray the downstream movement of fish through the hydrosystem realistically and with sufficient detail to capture the impact of hydrosystem and river variability. It divides the model into individual modules for passage through the individual reservoirs and dams. It accounts for the spread of passage times through reservoirs. It separates the various modes of dam passage (bypass, spill, turbine) and will account for day/night differences. It separately tracks transported fish. These are all critically important functions and all are treated pretty much as one would imagine them being treated.

(b) Does the model allow users to simulate the effects of management actions?

It provides for user input of fish release schedules, dam operation and fish transportation scenarios, and flow and temperature files (scenarios). One should be able to create any reasonable management scenario with these inputs. The real issue is how easy it will be to develop and input new scenarios. Our assessment of that will have to await the final model, examination of a complete manual, and a trial of the user interface.

(c) Does the model accurately reflect available data, particularly PIT-tag data?

The in-river part of the model seems to be in place, but the part of the model that accounts for survival from below Bonneville Dam to the ocean and the return is not completed yet. To deal with a major limitation of two alternative passage models, SIMPAS and CRiSP, that component of COMPASS needs to be completed.

(d) Does the model adequately characterize uncertainty in predictions?

To account for uncertainty in the predictions, a stochastic version of the model will be needed, the lack of which was a major criticism of the SIMPAS model. At the time of writing this review, the stochastic version was not yet available.

(e) Does the model adequately account for hydrosystem effects occurring outside the hydrosystem?

This is a major component of the model that was not completed at time of our review. In the model overview, the authors state that the downstream passage model and post-Bonneville mortality module operate independently and that they "would like" to integrate these into one modeling platform. It is imperative that they link these models into one platform.

Model Complexity

The SIMPAS model is too simplistic, treating all species, life history types, sizes of anadromous juveniles the same. By contrast, the CRiSP model is too complex, with the assumptions based too much on theory, with a lack of empirical evidence. COMPASS is similar to but less complex than CRiSP, providing a reasonable level of complexity, with sufficient detail to capture what is happening, without being overly demanding of knowledge that does not exist. In this vein, the ISAB recommends that a list of the model assumptions should be put together and placed up front in the manual.

Statistical Methods

The ISAB recommends several alternative estimation techniques that should improve the estimates (and thus) the parameters of the model. It is possible to over-fit a regression model to data, and while there are standard criteria for deciding "when to stop", the real issue is that one wants a model that will generally behave well, under a wide variety of circumstances. In that vein, for predictive power and for transportability from one site to another, a model should include only mechanisms that we understand, in mechanistic terms, and the model should be economical of explanation, wherever possible. At the same time one should be very wary of eliminating data sets because of small sample size. Instead data can be weighted to reflect the fact that some data is better than others.

Data Representation, Documentation, and User Interface

These elements of the model are incomplete and in various stages of development. The model is designed to incorporate all the available data (but see pages 9-13, below). The plans for the stochastic model suggest that it will eventually reflect variability in the data and in the hydrosystem. The documentation is reasonable for this stage of development, but is not yet sufficient for complete review, nor is it currently adequate for operation of the model by the many new users who will need it. The graphical user interface has not yet been developed.

Concluding Comment

This new COMPASS model will be heavily used by many people in the Columbia River Basin and should prove to be a welcome addition to the analytical tools available to both scientists and managers alike. Our critique here is voluminous, but is explicitly intended to provide a series of strong but constructive suggestions to facilitate the continuing development of what we feel will be a valuable new modeling tool for the region. The model is still under active development, particularly the components for stochasticity and the Bonneville-to-ocean-Bonneville segment, and will profit from another review when it is complete. We look forward to that review.

ISAB Review of the COMPASS Model

I. Introduction and Background

Background on SIMPAS – the Currently Used Hydrosystem Passage Model

The Simulated Passage (SIMPAS) model is a spreadsheet-based Excel module, produced in the mid-1990's to evaluate the effects of various structural or operational management measures on passage and survival of juvenile salmonids through the mainstem Columbia and Snake River dams. Since its development, SIMPAS has been used extensively for a variety of hydroelectric system operational management decisions and structural fish passage improvements. SIMPAS was also recently used for analyses in development of the 2004 BIOP. Lately, SIMPAS has received a number of regional criticisms, among which are that: (1) it only produces seasonal survival predictions; (2) it is not stochastic; and (3) it does not adequately deal with effects expressed outside the hydrosystem.

Past ISAB and ISRP Comments on SIMPAS

While the ISAB and the ISRP have not done a specific in-depth review of SIMPAS, we have periodically commented on the model's strengths and weaknesses (mostly its weaknesses), as documented below:

(1) The ISRP Reimbursable Review of the Bonneville I. Decision Document (ISRP 2001-11) was the first opportunity to comment on SIMPAS, as follows:

> To develop estimates of relative survival benefits as called for in the BiOp, the Decision Document employs the SIMPAS model. The ISRP referred to Appendix D of the BiOp for description of the SIMPAS model. The SIMPAS model consists of a simple set of deterministic mathematical calculations of by-reach and overall survival estimates of juvenile salmonids as they pass downstream in the Columbia and Snake rivers. Only the Bonneville portion was used in preparing the Decision Document. The model was used for analysis and evaluation of alternative devices intended to improve survival of juvenile salmonids at Bonneville Dam. The model requires explicit specification of fewer assumptions and is more straightforward than the models reviewed by the ISAB in ISAB 2001-1 (www.nwcouncil.org/library/isab/isab2001-1.pdf), but of course the simplicity of this model constitutes a far-reaching implicit (and possibly unexamined) assumption. For example, the SIMPAS model includes no provision for addressing the impacts of fish passage routes on biodiversity of anadromous or resident species. The estimates of survival by size and life cycle stage for multiple resident and anadromous species are well beyond the information available and the capabilities of the model.

(2) From the ISAB Review of Giorgi et al. (ISAB 2002-1, pp 17-18):

> Giorgi et al. (2002) suggest employment of mathematical models, namely computer based models such as CRiSP or SIMPAS to estimate or predict the total mortality experienced by smolts in passing either a series of projects or a single dam. They attempt to identify key issues applying to the use of passage models in spill analysis. They identify a primary concern as being the criteria adopted for selecting the best estimate from a pool of estimates of spill efficiency and survival in spill, among other inputs that will be employed in the model analysis. "There will surely be factions that take exception to the resultant set of estimates." It seems more appropriate for a diverse technical group to develop and apply criteria that would be used for assembling the most representative set of inputs that could be applied as a standard. It is not clear that NMFS employment of the SIMPAS model to evaluate changes in expected smolt survival under four spill scenarios accurately depicted spill related survival, particularly under the extreme low flow conditions experienced in 2001. The only analysis they found that attempts to assess the change in survival for the smolt population subjected to different spill scenarios is the 2001 model analysis conducted by NPPC staff. It may not be totally satisfactory because the SIMPAS model used in the analysis probably needs updating. A number of improved estimates have become available since SIMPAS was constructed. Giorgi et al. (2002) doubt that it would be practical to attempt to design manipulative experiments that could isolate spill effects in the complex Columbia River system.
>
> The ISAB finds that the SIMPAS model is being used in the region for several kinds of applications, some of which are inappropriate or questionable. This model can be an important and useful tool, but it should be the subject of an update and verification, as suggested by Giorgi et al. (2002). In particular, input values for the SIMPAS model are most often *ad hoc* guesses, suffering from a lack of real data. It is important to build regular updates of the necessary parameter values into an ongoing, long-term monitoring and evaluation plan. As above, the effects of speed in passing smolts through the concrete when water is spilled should be factored into modeling.

(3) From the ISAB Flow Update and Clarification Report (ISAB 2003-1):

> Bruce Suzumoto used SIMPAS to estimate changes in survival that might result from the Council's proposed modifications. But then he offers, "SIMPAS is not highly sensitive to changes in flows. Another regional model might be better to estimate the effect of flow changes on total system survival." (Suzumoto, B. 2002. Mainstem juvenile survival: CRiSP modeling results. Memorandum of December 2, 2002 to Council members)

(4) The ISAB Flow Symposium Report (ISAB 2004-2) offered the following comment about the strengths and weaknesses of available (SIMPAS and CRiSP) models:

> No present model is capable of an accurate, precise analysis of the effects of the Montana proposal. The two process models we examined, CRiSP and SIMPAS, contain unrealistic or untested assumptions. The models include an a priori effect of flow on survival based on simplified conditions, which to some extent predetermines the result. Nonetheless, both models suggest that the effect of the Montana System Operations Request will be small. The regression models we saw often contain so much data scatter that model fitting is itself uncertain. Because the regression models use the same data with the same scatter, however, comparisons can be made among flow conditions. The results to date from the Fish Passage Center and NOAA Fisheries regression models suggest the Montana System Operations Request would result only in small changes.

Development of a New Passage Survival Model - COMPASS

In light of the above criticisms of SIMPAS, NOAA Fisheries, along with federal, state, tribal agencies, and the University of Washington, are developing a new comprehensive passage model, COMPASS, that is intended to replace SIMPAS. Prior to initiating model development, NOAA Fisheries reviewed and analyzed all existing passage models to determine if components of one or more of these models could be used in the new model that would address the concerns elaborated above. The results of that review and analysis are described in a NOAA, Northwest Fisheries Science Center Report (NOAA Fisheries Memo, 2005).

The results of that comparative review indicated the CRiSP model (developed by the University of Washington, with funding from BPA) had a number of desirable features that have now been incorporated into the COMPASS model.

Review Request

NOAA Fisheries has indicated that the new COMPASS model will be used extensively in the new Federal Columbia River Power System Biological Opinion (BiOp) and that it should be subjected to thorough and transparent scientific review. On January 12, 2006, NOAA Fisheries requested the ISAB to review the partially completed, new fish passage survival model, COMPASS, specifically addressing the following questions:

(1) *Does the model successfully perform the desired capabilities, as listed below?*

a) realistically portray the hydrosystem and variable river conditions
b) allow users to simulate the effects of management actions
c) accurately reflect available data, particularly PIT-tag data
d) characterize uncertainty in predictions
e) account for hydro-system-related effects that occur outside the hydrosystem

(2) *Is the model too complex or too simple?*

(3) *Does the model realistically represent the data and its variability?*

(4) *Are the statistical methods sound?*

(5) *Is the documentation adequate?*

(6) *Is the graphical user interface easy to understand, intuitive, and transparent?*

On January 27, 2006, following a briefing describing the development and status of the COMPASS model, the ISAB accepted this assignment with no alterations to the above review questions.

II. Review Results

Model Capabilities

(a) How realistically does it portray the hydrosystem and variable river conditions?

Since the model uses a daily time step, it should have the potential to portray the downstream movement of fish through the hydrosystem realistically and with sufficient detail to capture the impact of hydrosystem and river variability. It divides the model into individual modules for passage through the individual reservoirs and dams. It accounts for the spread of passage times through reservoirs. It separates the various modes of dam passage (bypass, spill, turbine) and will account for day/night differences. It separately tracks transported fish. These are all critically important functions and all are treated pretty much as one would imagine them being treated.

(b) Does it allow users to simulate the effects of management actions?

It provides for user input of fish release schedules, dam operation and fish transportation scenarios, and flow and temperature files (scenarios). One should be able to create any reasonable management scenario with these inputs. The real issue is how easy it will be to develop and input new scenarios? Our assessment of that will have to await the final model, examination of a complete manual, and a trial of the user interface.

(c) Does the model accurately reflect available data, particularly PIT-tag data?

The downstream part of the model seems to be in place, but the part of the model that accounts for survival from below Bonneville Dam to the ocean and the return is not completed yet. To deal with a major limitation of the SIMPAS and CRiSP models, that component of the model needs to be completed.

The fish travel time model presented graphically in Figure 13 (from Zabel and Anderson, 1997) indicates that the model systematically underestimates the mode of the actual distribution of the data. This could lead to overestimating the frequency with which long travel times occur, because the right tail of the modeled distribution is overestimated. Furthermore, the travel time models in Zabel and Anderson (1997) exhibited a significant lack of fit ($p < 0.05$) in 22 out of 46 data sets.

The authors state in their Proposal for Final Data Set for Passage Models that they will use the harmonic mean as a measure of travel time, because it behaves more like the median than the arithmetic mean. Why not just use the median travel time directly?

In their Passage Model Design Considerations, Figure 2 shows system survival, plotted against water travel time. It is clear that the 2001 data point is different from the other data, but the statement following the figure, "The relationship indicates that in years of poor flow (high water travel times) fish survive at relatively low levels" seems too strong, inasmuch as it is based on one anomalous observation.

There are some statistical issues for the translation of real data into model inputs (see 4, below) that may have some impact on the accuracy of the chosen model values, but the model is designed to take advantage of the real data, as they come in.

(d) Does the model adequately characterize uncertainty in predictions?

To account for uncertainty in the predictions, a stochastic version of the model will be needed, the lack of which was a major criticism of the SIMPAS model. At time of writing this review, the stochastic version was not yet available. There are not enough details presented to evaluate stochasticity in reservoir survival adequately. For example, it is not clear what statistical distribution is assumed when sampling from an error term with variance based on the error term from the regression equation used to predict $-\ln(S_{g.p})$. Nor is it clear how the assumed distribution will be justified.

There is a distinction to be made between varying the parameters over some range, even if drawing from a distribution, and varying the outcome for individual fish, given a set of fixed parameter values for the model, determined via multiple sampling runs of any particular model. Our sense is that parametric uncertainty will yield a greater degree of outcome variability, and that the dam passage algorithm will be "stochasticized" by the imposition of variability on top of the deterministic models, but exactly how this is to be done is not entirely clear from the write-up of COMPASS. For the travel time parts of the model, it reads as though variability will be imposed on individual fish transit times, but again, the report is unclear on this aspect of the problem.

(e) Does the model adequately account for hydrosystem effects occurring outside the hydrosystem?

There are two major pieces of the model that were not completed at time of review. The stochastic element was one of them. This is the other. In the model overview, the authors state that the downstream passage model and post-Bonneville mortality module operate independently and that they "would like" to integrate these into one modeling platform. It is imperative that they link these models into one platform.

Model Complexity

The SIMPAS model is too simplistic, treating all species, life history types, sizes of anadromous juveniles the same. By contrast, the CRiSP model is too complex, with the assumptions based too much on theory, with a lack of empirical evidence. COMPASS is similar to but less complex than CRiSP, providing a reasonable level of complexity, with sufficient detail to capture what is happening, without being overly demanding of knowledge that does not exist. In this vein, we would recommend that a list of the model assumptions should be put together and placed up front in the manual.

Data-Based Model

The downstream migration model is designed to incorporate the available data (but see below). The plans for the stochastic model suggest that it will eventually reflect variability in the data and in the hydrosystem. The state of development of the model is not yet sufficient, nor is it well enough documented to say more at this time.

A late-breaking missive came in from the COMPASS team, just before submission of this report, describing the progress on the stochastic version of the model. We had insufficient time to evaluate that addition, before submission of our report. We suggest that a careful review of the stochastic aspects of the COMPASS model should be dealt with at the same time as the below-Bonneville portion of the model (see just below), when the work is finally completed and available for another review.

Statistical Methods

The current version of COMPASS incorporates laudable attempts to connect the model parameters with the real data, enabling adjustment of parameters as real world experience accumulates. There are some guiding principles that should govern any effort to estimate parameters for such a complex model, and there are improvements in estimation techniques that should improve the estimates (and thus) the parameters of the model. In the spirit of improving statistical performance, the ISAB would recommend the following:

(a) It is possible to over-fit a regression model to data, and while there are standard criteria (R^2-values, AIC and the more conservative AICC criteria, likelihood ratios) for deciding "when to stop", the real issue is that one wants a model that will generally behave well, under a wide variety of circumstances. In that vein,

For predictive power and for transportability from one site to another, a model should include only mechanisms that we understand, in mechanistic terms. And while we may be able to improve performance ever so slightly at one site by adding another variable, the model should be economical of explanation, wherever possible. It is important to allow testing of more elaborate models, where and when it becomes appropriate, but parsimony of explanation should be the goal, everything else being equal.

(b) Log-linear models facilitate the use of simple statistical families for purposes of fitting. Estimated coefficients can be expected to vary from place to place and year to year, and we need to allow for that, but they should behave coherently. For example, if a variable increases survival in general, we should expect it to yield a variable (but generally positive) β-coefficient, not sometimes positive and sometimes negative.

Higher order interactions that are significant in one reservoir, but not in the next, or that are strongly positive in one reservoir and strongly negative in the next, are an indication that one has over-fit noisy data, and that the effect is not well estimated in general. It is not generally a good idea to turn sampling noise into "signal."

(c) A log-linear regression model (reflecting non-linear survival probabilities) which also employs high order polynomial functions of its predictive *x*-variables is a statement of ignorance about the variables in question, and is not mechanistically credible. It is good to have a model that allows the users to evaluate higher order functions, but for routine use, it is better to use defensible log-linear functions. We suspect that the authors are systematically over-fitting their data (Tables 3 & 4, page 15).

We also note that the log-linear models presented do not (currently) have an intercept term. That creates unnecessary statistical limitations later. For example, R^2- values are presented as indicators of model fit in Tables 3, 4, 5 and 6, as well as in Figures 6, 7, 8 and 9. Unless these R^2-values are adjusted for the lack of intercept terms, they cannot be interpreted in the usual manner. A proper cascade of log-linear models would be the following (using the model in Figure 4 to illustrate):

$$\ln(S_t) = -\beta_0 + \varepsilon \quad \text{(log-intercept model)}$$

$$\ln(S_t) = -\beta_0 - \beta_1 t + \varepsilon \quad \text{(log-linear model)}$$

$$\ln(S_t) = -\beta_0 - \beta_1 t - \beta_2 t^2 + \varepsilon \quad \text{, (log-quadratic model)}$$

with the understanding that even if $t = 0$ (no elapsed time), survival probability may be less than '1', and that one should probably not extend beyond the second (log-linear) version of the model without compelling evidence of cubic effects, in which case, one probably has the wrong mechanistic description, and needs to reconsider the model.

(d) Many of the regression models used in COMPASS are an attempt to predict survival, as functions of some set of predictive variables. Survival is bounded by both '0' and '1', and the authors realize that one cannot model *S* as a linear equation near the boundaries, so they use a set of exponential models of the general form:

$$S(\underline{X}) = \exp\{-fn(\underline{\theta}, \underline{X})\} \qquad \text{or} \qquad \ln S(\underline{X}) = -fn(\underline{\theta}, \underline{X}) \ ,$$

where $fn(\underline{\theta}, \underline{X})$ is some regression function of the measured *x*- (hopefully predictive) variables, and $\underline{\theta}$ is a set of parameters (regression coefficients, to be estimated). We have commented on the choice of those models above.

The authors have recognized that the measured survival estimates from the field are themselves of variable reliability, some having much higher variance than others. To a first approximation, the variance of an observed value of *S* is $S\bullet(1 - S)/N$. Given that small sample sizes yield less reliable data, for any given value of *S*, the authors have chosen to suppress (ignore) data sets for which the sample sizes were "too small", but have chosen to weight the other data points equally. As a matter of standard operating procedure, there is **almost no** justification for eliminating data for any reason other than verifiably mistaken values. To eliminate substantial portions of the project survival estimates because of large standard errors is especially troubling.

We would suggest that all of the data should be used, preferably with inverse variance weighting (see below), and that some compelling justification be provided before data are removed. The data are never perfect, and some data are better than others, but they are all we have that connects the model with the real world!

Standard theory in binomial regression also suggests that one should weight all the data by the inverses of their respective variances. When conducting a binomial regression of *S* on $\underline{X}$, the values near '0' or '1' should receive substantial weight (small variances), and values near ' ½' should receive less weight (large variances), for any given sample size. Weights of $w_i = N_i / S_i\bullet(1 - S_i)$ are appropriate.

The authors are regressing ln*S* on a set of *x*-variables, and the weighting scheme has to change from that described above (see Logit Regression, below). In particular, under that type of analysis, the survival values near ' ½' acquire high weight, and those near '0' or '1' acquire substantially less weight, for any given sample size. In either case, ignoring the profound differences in precision of the *S*-values near ' ½' and those near '0' or '1' is not making good use of (hard to come by) data. Differences in sample size are only part of the estimation strategy. The plots on pages 17 & 18 of the preliminary report indicate what happens when relative precision is ignored. The authors can do much better.

(e) The plots on pages 17 and 18 are revealing in yet another way. We understand that Cormack-Jolly-Seber estimates of survival can occasionally exceed '1', particularly when the parametric value of S is near '1' and the sample size is small. The best interpretation is that the estimates "cannot be distinguished from complete survival", but it makes no sense to fit a regression model that attempts to mimic an S-value of 1.02, simply because that is what we "poorly perceive" in the data. Some of the regression models in the preliminary report provide estimates of S that exceed '1', which requires that $fn(\underline{\theta}, \underline{X}) < 0$, rendering $\exp\{-fn(\underline{\theta}, \underline{X})\} > 1$, some β-coefficients being positive and some negative. The regression has become pathological.

There is an easy (and standard) way to deal with this particular problem. Instead of using $\ln S(\underline{X}) = -fn(\underline{\theta}, \underline{X})$ to represent the relationship, we use a logit regression instead,

$$Y = \ln\left(\frac{S(\underline{X})}{1 - S(\underline{X})}\right) = -fn(\underline{\theta}, \underline{X}) \ ,$$

which is sigmoid, asymptotically approaching both $S \to$ '0' and $S \to$ '1'. It has all the nice features of $\ln S(\underline{X}) = -fn(\underline{\theta}, \underline{X})$, uses data weights of $w_i = N_i \bullet S_i \bullet (1 - S_i)$, and (most importantly) stays bounded between '0' and '1', whether the β-coefficients are positive or negative, and whether $\exp\{-fn(\underline{\theta}, \underline{X})\}$ is > or < '1'. We can also write the model as

$$0 \le S(\underline{X}) = \frac{\exp\{-fn(\underline{\theta}, \underline{X})\}}{1 + \exp\{-fn(\underline{\theta}, \underline{X})\}} \le 1.$$

By virtue of the weighting scheme, most of the weight goes to the S-values near ' ½'. To allow for the fact that we have some "observed" values of $S \ge 1$, we adjust the Y = logit (S) values as follows. If $S_i = s_i \div N_i$, then we set $Y_i = (s_i + 1)/(N_i - s_i + 1)$, which - for the case of observed $S_i \ge 1$ - becomes Y_i = logit $(S_i) = (N_i + 1)/1$. We have simultaneously constrained the predicted survival values between '0' and '1' and have weighted the observations appropriately, with more weight going to the values near ' ½'. In other words, instead of using the cascade of models shown above, we would use

$$Y_t = \ln(S_t) - \ln(1 - S_t) = -\beta_0 + \varepsilon \quad \text{(logit intercept model)}$$

$$Y_t = \ln(S_t) - \ln(1 - S_t) = -\beta_0 - \beta_1 t + \varepsilon \quad \text{(logit-linear model)}$$

$$Y_t = \ln(S_t) - \ln(1 - S_t) = -\beta_0 - \beta_1 t - \beta_2 t^2 + \varepsilon \quad \text{, (logit-quadratic model)}$$

Converting to logit regression models (with an intercept, β_0) will cost the authors very little estimation or programming time, and the modeling results should improve.

(f) The preliminary report also provides estimation procedures for spill, water flow, and travel times. We see mixtures of different types of models, some linear (but with quadratic and cubic terms), some exponential, some logistic, and so on.

Some effort to establish a relatively coherent modeling and estimation philosophy would seem to be in order, based on what the theory tells us, and based on the best of modern statistical practice. Our intent is not so much to fine tune as to recommend “an approach.” The users of the COMPASS model will need something relatively simple, coherent, and well behaved, while retaining the flexibility that is currently being introduced. Our earlier comments on fish travel time distribution modeling are appropriate in this vein.

Documentation

The documentation is reasonable for this stage of development, but is not yet sufficient for complete review, nor is it currently adequate for operation of the model by the many new users who will need it.

Graphical User Interface

Not yet developed.

III. Concluding Comment

This new COMPASS model will be heavily used by many people in the Columbia River Basin and should prove to be a welcome addition to the analytical tools available to both scientists and managers alike. Our critique here is voluminous, but is explicitly intended to provide a series of strong but constructive suggestions to facilitate the continuing development of what we feel will be a valuable new modeling tool for the region. The model is still under active development, particularly the components for stochasticity and the Bonneville-to-ocean-Bonneville segment, and will profit from another review when it is complete. We look forward to that review.

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