RECONCILING EDT AND CRI AS ALTERNATIVE DECISION SUPPORT SYSTEMS: TWO IS BETTER THAN ONE

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A. EDT and CRI as Two Alternative Analytical Tools for Decision-Support

EDT and CRI are alternative analytical frameworks that can guide decision-making regarding endangered and threatened salmonids and other regional goals. The CRI (Cumulative Risk Initiative) is a statistically based system that focuses on populations as the unit of analysis and measures population performance using annual rates of population growth and risks of quasi-extinction. EDT (Ecosystem Diagnosis and Treatment) is a rule-based system that focuses on habitat as the unit of analysis and measures salmon performance by predicted number of fish supported by the habitat over the life history. CRI relies on population dynamics models and explicit statistical relationships between risk factors and demographic rates. In contrast, the EDT is more of an "expert system" that captures the state of existing knowledge including areas of incomplete or missing data.

In this document, for each of these analytical frameworks we describe separately:

(i) their basic steps
(ii) the data they use
(iii) the scale and resolution of their analysis
(iv) their measures of "performance"
(v) their general "philosophy" and aims

Then after discussing each approach separately, we conclude with a final section that compares the approaches, emphasizes their complementarity, and describes how the results of the two approaches can be compared by common performance measures. It is our belief that there is no "universal model" that applies equally to all problems and provides all needed information. Different analytical tools supply different kinds of knowledge and examine problems from different angles. Used in a constructive fashion, different tools such as CRI and EDT can advance scientific knowledge in ways that neither can do separately.

There will likely be instances where CRI and EDT yield different results when applied to particular problems. This is always the case with alternative scientific methods. If EDT and CRI agree with respect to certain conclusions, then our confidence in those conclusions grows. If they disagree, it can point to critical uncertainties and possible solutions. Science works by comparing alternative hypotheses and methods; science does **not** work by "arranging" a contrived consensus or by forcing a single solution. In the case of EDT and CRI, the two methods have different strengths and weaknesses and are aimed at slightly different questions. It is far better to avail ourselves to the strengths of the different approaches than to try to force "one approach" to fit all problems. It is like limiting ourselves to using only a hammer or only a screwdriver when, in fact, each has its own strengths and both may be required to complete a job. The most important requirement of using two alternative methods to support salmon decision-making is that both methods share data, seek common performance measures where possible, and are as explicit and transparent as possible. It is imperative that the decision process understands the strengths and weaknesses of both methods and the synergy of constructive alternatives.

B. CRI: A Population-Based Analysis of How to Mitigate Extinction Risk

B-1. The four key steps to a CRI analysis

1.) Estimate the risk of quasi-extinction for known populations.

2.) Construct demographic projection matrices that depict current demographic performance rates and in turn can be used to calculate annual population growth rates (assuming a"current conditions").

3.) Perform sensitivity analyses to assess where in the life cycles of salmonids there are the greatest opportunities for promoting recovery, as measured by changes in the annual population growth rate. This can be done several different ways. The simplest is to manipulate the values in baseline matrices to represent particular demographic improvements, and calculate the % increase in annual population growth rate that results. This increase in annual population growth can then be converted into an estimated reduction in quasi-extinction risk.

4.) For those demographic improvements that give a noteworthy response in terms of population growth, identify management actions that might accomplish those improvements, and use statistical analyses or experimental studies to determine whether there is evidence that those improvements are actually feasible with the management action being considered.

More details can be found in several other documents available from the CRI website (**http:/www.nwfsc.noaa.gov/cri/).**

B-2. The data used in CRI

The primary data used by CRI are time series of population counts, and recruits per spawner ratios. An example is given below, from fall chinook salmon in the Snake River.

Table 1. Counts for Fall chinook salmon.

year	spawners	Recruits to spawning grounds (total)	Recruits to spawning grounds (minus jacks)
1980	515	2294	1285
1981	878	1555	983
1982	1209	1810	1224
1983	909	1986	1115
1984	717	1764	934
1985	1080	654	541
1986	1403	706	539
1987	1064	373	292
1988	702	747	710
1989	815	656	529
1990	273	284	227
1991	767	300	206
1992	674		
1993	883		
1994	448		
1995	226		
1996	964		

From this, one can calculate an extinction risk, and estimate how much we need to increase annual population growth to mitigate this risk , as shown below (details can be found at the CRI website, in the August workshop document)

Table 2. Quasi-extinction risks for Snake River fall chinook salmon (based on data from 1980-1996).

	Avg. λ	**avg. N over last 5 years**	**p(one spawner within 10 yrs)**	**p(one spawner within 100 yrs)**
Fall Chinook	1.13 (0.89-1.44)	639	<0.0001 (<0.0001-0.16)	0.06 (0.0002-1.0)

Table 3. Quasi-extinction probability for Snake River Fall Chinook associated with particular increases in λ.

% change in λ	**p(one spawner within 100 years) Fall Chinook**
5	0.005
10	0.0003
15	1.3×10^{-5}
20	7.1×10^{-7}

It may also be possible to construct a detailed demographic matrix that can then be used to simulate management experiments such as harvest reductions. Below, as an example is the Snake River fall chinook salmon demographic matrix.

	2	3	4	5	6
Age frequency of females (f_x)	0	0.129	0.652	0.198	0.020
93-96 Ocean harvest rate (h_x)	0.0123	0.0465	0.1368	0.1838	0.1953
Female eggs per female spawner (m_x)		1442.5	1566.5	1625.5	1625.5
Propensity to breed (b_x)	0	0.081	0.648	0.859	1.0

93-96 Mainstem adult harvest rate	0.174
93-96 adult Bon to Basin conversion rate	0.471
s_1	0.0102

These parameters are then substituted into the following matrix where, μ represents the age-specific fraction of ocean dwelling salmon that return to spawn (it combine the probability of returning during that year, with the survival rate swimming upstream, which includes harvest reductions as well as other mortality), s_1 represents survival during the first year of life, s_A is survival as adults living in the ocean, and h_i indicates ocean harvest rates on fish in ageclass i.

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\begin{array}{ccccccc}
 & 1 & 2 & 3 & 4 & 5 & 6 \\
1 & 0 & 0 & (1-\mu)s_1b_3m_3 & (1-\mu)s_1b_4m_4 & (1-\mu)s_1m_5 & (1-\mu)s_1m_6 \\
2 & (1-h_2)s_A & 0 & 0 & 0 & 0 & 0 \\
3 & 0 & (1-h_3)\, s_A & 0 & 0 & 0 & 0 \\
4 & 0 & 0 & (1-b_3)(1-h_4)s_A & 0 & 0 & 0 \\
5 & 0 & 0 & 0 & (1-b_4)(1-h_5)s_A & 0 & 0 \\
6 & 0 & 0 & 0 & 0 & (1-b_5)(1-h_6)s_A & 0
\end{array}
$$

This matrix can be used to simulate the consequences of reduced harvest, and other management actions. Importantly, for many management actions (almost everything other than harvest reductions) it is not certain whether a given action will accomplish the desired demographic improvement. This is where the "feasibility studies" discussed in section B.1 come into play. For a feasibility study, the dependent variable will typically be recruits per spawner, number of spawners, smolts pers spawner, smolt-to-adult returns, or survival during some life stage. Correlations are then sought between these measures of salmonid productivity and variables such as number of hatchery releases, fraction of stream miles failing to meet EPA water quality standards, and so forth. What CRI envisions as feasibility studies also represent evidence that EDT uses in constructing its "rules" relating stream attributes to salmon production.

B-3. <u>The scale and resolution of CRI analyses</u>

CRI is most effective when applied to distinct populations, or collections of populations. This is because it focuses on population growth rate and a population's risk of extinction. The spatial scale at which CRI best operates ranges from subwatershed on up to subbasin or basin. As it is currently developed, CRI is not equipped to deal with an entire province or region comprised of many populations and multiple ESUs. However, there are plans for extending the CRI to this large scale (beginning with a technical workshop in December at NWFSC, which is aimed at multiple populations and ESU-wide priority-setting). CRI would never be used at the fine scale of a particular reach or stream. CRI could never inform us about reach-specific or small-scale management actions. The output of CRI often takes the form of: " ***if this, then the expected response is ___".*** CRI does not deal with individual fish at all, and also does not deal with life history diversity. In the absence of data and statistical relationships, the CRI does not venture very far with its analysis.

B-4. <u>Measures of "performance" for the CRI analysis</u>

The primary measure of performance for CRI is average annual rate of population growth. This core measure is then the basis for two additional measures of performance: risk of extinction over 10 years and 100 years, and the percentage by which annual population growth is expected to increase with some management action. Although it is impossible to validate “risk of extinction” as a performance measure, annual population growth rate and % change in annual population growth can be validated – these are both measurable, and in fact are routinely available from the type of spawner or redd counts typically made for salmonids.

B-5. CRI’s general philosophy and aims

CRI’s three most distinctive features are:

1.) an emphasis on simplicity and simple models, so that others outside NMFS can repeat their own analyses with slight modifications of the assumptions, new data, different time periods, different levels of risk averseness, and so forth

2.) a staunch empiricist’s skepticism, such that a priority is placed on relationships supported by data, and that otherwise must be couched as “*if this, then that*” statements

3.) focusing on population dynamics or demography as the window through which to evaluate management actions

C. EDT as an Expert System that Makes the Best of a Data-poor World

C-1. Steps in the EDT analysis

The basic steps of EDT are captured in its name, Ecosystem Diagnosis and Treatment1:

> Ecosystem: The description of the bio-physical environment of species and populations of concern.
> Diagnosis: Evaluation of the “health” or quality of the environment with respect to specific species or populations.
> Treatment: The analysis of the impact of different strategies in changing the existing environment toward one that is more compatible with the needs of the species or population of interest.

More explicitly, in EDT we:

1) Describe the habitat template in terms of a set of physical attributes of the current terrestrial and aquatic environment at the level of the HUC-6.
2) Assess the habitat template in regard to how it affects biological performance measured as productivity, capacity and life history diversity of salmon and other species – i.e. derive a “survival landscape” based on habitat conditions.
3) Evaluate how regional alternatives might change biological performance by relating strategies to changes in environmental attributes.

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1 Mobrand Biometrics, Inc. 1999. *The EDT method*. Available from the Framework website.

4) Capture our accumulated knowledge about the relationship between salmonids and other aquatic and terrestrial species and their environment in the form of documented "rules" that explain or hypothesize survival responses to their habitat – i.e. organize a repository of knowledge and information.
5) Perform sensitivity analysis to guide refinement and modification of management strategies and or objectives and development of monitoring and evaluation plans.

More details on EDT and the Framework Project can be found at the Framework web site: http:/www.nwframework.com.

C-2. The data used in EDT

There are four major types of data used in EDT. The first data category consists of the 108 strategies that are selected and combined to make up an alternative. In the Framework Project, these are arrayed across 10 ecological provinces to make an alternative focused on a particular vision.

In EDT, we distinguish information that is actually observed from information that is derived from other information. Most of the information that is routinely used in natural resource management is actually derived from a smaller set of real observations. For example, counts of adult salmon at mainstem dams, abundance estimates of spawning fish and the number of fish harvested are all basic fisheries information that is expanded or derived from a much smaller set of actual observations. As you might expect, to describe the habitat of the entire Columbia River, we have to derive a lot of the information. We note where these derivations occur and base them on a set of explicit rules. The description begins by filling in the available information for each of the 7200 HUC-6 units. Where information is missing, the scientific literature and appropriate experts are consulted to derive rules for filling in the gaps.

The next higher level of derived information is the assessment of the habitat with respect to specific fish or wildlife species. Habitat quality is assessed for each life stage in terms of productivity and capacity. For chinook salmon we distinguish habitat quality for each of 16 life stages.

Finally, the productivity and capacity is integrated over the entire life history to derive the overall estimated productivity and capacity. A number of life history pathways are tested to assess the impact on life history diversity as well.

The different data types are related through a set of rules that are the heart of the EDT expert system. They are the basis for describing habitat and relating habitat observations to the higher level environmental attributes and the resulting biological response. The rules capture the region's expertise and are derived from empirical research, the scientific literature and expert opinion.

There are four types of rules that call on different types of expertise. The first links each of the 108 strategies to one or more of 51 types of habitat observations. Those devising the strategies and alternatives intend them to result in some change in the environment. This is formalized by capturing the knowledge of how different types of actions (strategies) affect our 51 descriptors of habitat conditions.

The second type of rule links the observations to 44 Environmental Attributes. These rules describe how the habitat observations are expanded to account for incomplete or missing information. These rules are devised by hydrologists, geomorphologists and other physical scientists to expand the direct habitat observational data to all 7200 HUC-6 units for all time periods.

The third rule category is based on the knowledge of biologists regarding life stage survival response or productivity of specific species to one or more of the Environmental Attributes for each HUC-6. The resulting Biological Metrics can be thought of as 19 graphs showing the relationship between life stage productivity and Environmental Attributes.

The final type of rule is an algorithm that integrates over the entire life history pathway to compute total productivity and capacity. This is done for each successful life history pathway to estimate life history diversity.

C-3. The scale and resolution of the EDT analysis

EDT paints a picture of the biological and physical landscape of the Columbia River. The "pixel" size of this picture is the HUC-6 (hydrologic unit code) of which there are approximately 7200 in the Columbia River basin. These are organized in a spatial hierarchy to describe subbasin, ecological provinces and the Columbia River basin. EDT describes the equilibrium condition of the basin as a result of a set of strategies. Time is not a factor in EDT except in regard to the explicit description of the various life history pathways of target species.

Biological resolution in EDT is limited only by the available data. The present analysis assesses habitat conditions in terms of four species: two aquatic species, chinook salmon and bull trout, and two terrestrial species, black bear and beaver. Data has been assembled to distinguish 107 natural and 50 hatchery populations of chinook salmon as well.

C-4. Measures of "performance" in the EDT analysis

EDT measures biological performance in terms of three population parameters: productivity, abundance potential, and life history diversity. Productivity is the density independent component of survival times the rate of reproduction. Abundance potential is the carrying capacity of the habitat. Productivity and abundance potential are assessed for habitat in each life history stage. They are integrated over the life history to describe performance of a particular life history pathway. The grain and variation of the habitat description means that there can be more than one potentially successful pathway across the "survival landscape." This provides an assessment of the strategies in terms of their positive or negative effect on life history diversity as well as population productivity and abundance. All three parameters reflect the ability of the *environment* to support salmon production *in the long term*.

C-5. General philosophy and aim of the EDT

The general philosophy of EDT is well grounded in establish scientific principles describing the influence of habitat structure on the characteristics of biological communities. Specifically, EDT assumes that habitat characteristics determine biological performance. Hence, changing habitat through natural events or by human action will have a corresponding effect on biological performance.

A second philosophical point is that EDT recognizes that the scientific basis for decisions regarding the future of the Columbia River cannot and will not be limited to statistically "proven" knowledge. While statistically based information is important, scientists are increasingly aware that the complex and dynamic nature of ecological systems is currently, and perhaps always will be, imperfectly captured in statistical relationships. Prudent management must take advantage of all available information. For this reason, EDT uses both statistically-based and heuristic knowledge.

The current application of EDT is to the Multi-Species Framework Project sponsored by the Northwest Power Planning Council and federal and tribal management agencies. The focus of the Framework Project is on the long-term vision for fish and wildlife management in the Columbia River. Development of a vision involves consideration of the types of strategies required and their impacts in terms of human communities and other social and economic factors in addition to their ecological impacts. EDT is being used in this context as a tool to facilitate long-term basin-wide planning. However, it also will provide a basis for development of more detailed and shorter term plans for individual subbasins.

Even as one is unlikely to construct an attractive or enduring house without some vision of its style, purpose and size, the region is unlikely to construct an ultimately satisfying, successful or cost-effective management plan for the Columbia River without a long-term vision of the desired end-state. While near term efforts are important to protect existing genetic resources, we must concurrently initiate long term measures in a scientifically supported way so that populations can better cope with environmental variability and so that national, regional and local goals for fish and wildlife can be met.

D. Contrasting EDT versus CRI, and Finding Some Common Ground for Comparisons of Results.

We conclude that the region is poised before an opportunity to expand the scientific knowledge regarding fish and wildlife in the Columbia Basin. This opportunity is offered by the chance to employ alternative analytical tools in a collaborative and constructive way to aid decision making and to fashion research and experimental management. Both CRI and EDT have unique strengths and weaknesses that can contribute to long and short-term regional planning and evaluation. Used together, they can provide far more than either can provide separately. The alternative is to deteriorate into analytical competition and antagonism about which the region is only too familiar.

The two analytical methods are compared in the following table:

Feature	CRI	EDT
Time focus	Short-term	Long-term
Analytical basis	Statistical population dynamics	Deterministic, habitat-based rules
Internal structure	Statistical correlations	Mechanistic hypotheses
Evaluate extinction risk	Yes	No (not directly)
Evaluate life history diversity	No	Yes
Evaluate specific strategies	No	Yes
Statistical confidence limits	Yes	No
Time-line to future state	Yes	No
Describe habitat	No	Yes
Data limitations	Requires statistical relationships	Large data requirements and maintenance
Data strengths	Empirical observations	Can deal with limited and heuristic information
Spatially explicit	No	Yes
Biological focus	Salmon	Salmon, resident fish and wildlife
Basic analytical unit	Fish populations	HUC-6 habitat units
Geographic scope	ESU habitats	Columbia River basin
Contribute to adaptive management	Yes	Yes

EDT and CRI can work together as an *a priori* experimental system to guide planning and especially to guide research, monitoring and evaluation. EDT provides mechanistic hypotheses concerning biological relationships while CRI provides statistical, non-mechanistic correlations. In effect, EDT can serve as an hypothesis and CRI the empirical test. Where CRI and EDT agree, then EDT provides a plausible hypothesis of the mechanisms leading to the correlations in CRI. Areas where they do not agree indicate the need for further research and refinement leading ultimately to statistically supported mechanistic explanations of fish/wildlife habitat relations.

EDT and CRI can be compared by focusing on two performance measures:

1) Percent improvement from current conditions given a management action
2) Maximum annual rate of population growth.

Both approaches should be able to output these measures and hence be compared with respect to their assessment of alternative management scenarios.

One way that we might frame our common objectives and different roles is illustrated in the following example. For a hypothetical set of fish populations, EDT could describe their biological performance in terms of productivity, capacity and life history diversity. EDT could locate the mean equilibrium location of each population, while CRI could describe the present population abundance, how quickly it will move towards its long term equilibrium , and how much it will vary around that equilibrium. EDT could measure the performance potential of a population with respect to a set of management actions, while CRI could define the “risk boundaries” of these populations, i.e. the isopleths describing the probability of extinction within some time period. . EDT could define the long term trajectories of the populations where, specified production goals will be met, but it cannot estimate the likelihood that a population will persist while waiting for recovery measures to be fully implemented. CRI, on the other hand, could evaluate the route the population takes to arrive at the destination including possible short-term extinction risk.