Pacific Fishery Management Council
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Mark Cedergreen, Chairman Donald O. McIsaac, Executive Director

January 4, 2011

Mr. Bob Turner
Assistant Regional Administrator, Salmon Management Division
510 Desmond Dr. SE, Ste 103
Lacey, WA 95803

Dear Mr. Turner:

RE: Task G from the 2010 Biological Opinion on Ocean Salmon Fisheries.

This letter provides an update on Pacific Fishery Management Council's progress on tasks regarding the Lower Columbia River Chinook Evolutionarily Significant Unit (ESU) identified in the 2010 Biological Opinion (BO) for the Pacific Coast Salmon Fishery Management Plan. The BO described a set of tasks designed to accelerate the recovery process by completing actions with immediate benefit to tule populations. National Marine Fisheries Service (NMFS) has indicated that total exploitation rate limits on Lower Columbia River natural (LRN) tule Chinook will be contingent on satisfactory progress in completing certain tasks. This report includes progress on Task G, which involves development of options for incorporating abundance-driven management principles into LRN tule Chinook management.

At their June 2010 meeting, the Council established an Ad Hoc Tule Chinook Workgroup (TCW) to explore abundance-based approaches to setting allowable fishing rates in the long term to protect LRN tule Chinook. The TCW includes members from NMFS, Washington and Oregon Departments of Fish and Wildlife, Columbia River treaty Tribes, and the Makah tribe, and is facilitated by Council staff.

The TCW met on September 30, 2010 to identify a process, tasks, schedule and assignments. A draft work plan and schedule was developed from initial TCW discussions (Attachment A). The draft work plan identified four primary tasks involving LRN tule fall Chinook. These included identification and evaluation of: 1) effects of alternative fishing rate strategies, 2) forecasting methods for LRN tule Chinook abundance, 3) alternative abundance-based fishing rate strategies, and 4) effects of alternative fishing rate strategies on escapement and population risks.

The TCW met again on December 9, 2010 to review the draft work plan and results of preliminary work on specific tasks and activities by TCW members. Results of this preliminary work are as follows:

Task 1 – Fishing Effects: Retrospective analyses of 2008-2010 fisheries were conducted using the Fishery Regulation and Assessment Model to identify example changes in fishery-specific exploitation rates that would have resulted from a low status estimate for LRN tule Chinook under implementation of an abundance-based management system (Attachment B). This analysis considered the recent distribution of exploitation in Alaska/Canada, Council, and Columbia River fisheries. In these examples, impacts on the LCN tule stock in the southern U. S. fisheries would have to be reduced by nearly 50 percent in order to remain under an exploitation rate ceiling of 28 percent and by 23 percent to remain under a ceiling of 33 percent, assuming current conditions in northern fisheries.

Task 2 – Forecasting Methods: Data on historical releases and returns of Lower Columbia River hatchery (LRH) tule stock were compiled and analyzed to estimate an annual marine survival index for potential use as an indicator of LRN tule abundance (Attachment C). Initial comparisons of the marine survival index based on LRH stock with estimates of LRN escapement of Washington tule populations were significantly correlated. This suggests that survival of hatchery tules provide at least a partial indicator of natural population status suitable for consideration in an abundance-based fishery strategy. Precision and accuracy of historical forecasts of hatchery tules was documented for use in assessing risks associated with forecast errors (Attachment D). In addition, alternatives for improving forecast precision by incorporating ocean environmental indicators and advanced statistical methods was explored (Attachment E).

Task 3 – Alternative Identification: Examples of abundance-based matrix fishery strategies were identified based on preliminary analyses described above (Attachment F). Matrices might include indicators based on natural index populations or a hatchery aggregate. Abundance-related metrics might ultimately include LRH forecasts, ocean survival indices, environmental correlates, and/or LRN seeding levels. By way of example, a matrix based on LRH forecasts might identify a fishery impact rate of 38 percent at forecasts of 40,000-100,000 (60 percent occurrence), 33 percent at forecasts under 40,000 (20 percent occurrence), and 43 percent at forecasts over 100,000 (20 percent occurrence). Other potential matrices might involve lower rates (28 percent) at low run size tiers, higher rates (48 percent) at high run sizes or differences in the base 38 percent exploitation rate in combination with different tiers. Benefits and risks of these and other alternatives have yet to be evaluated.

Task 4 – Risk Analysis: A conceptual approach was identified for analysis of LRN tule population risks using stochastic stock-recruitment modeling. This approach is consistent with population viability analyses employed in salmon Endangered Species Act (ESA) status assessments and recovery plans (Attachment F). Similar modeling approaches have previously been utilized by the Council in conservation risk analyses for other stocks, including Klamath River fall Chinook. A contractor has been engaged to develop and implement this risk analysis consistent with guidance from the TCW.

The draft work plan developed by the TCW also describes a schedule for integrating this review with the Council's annual salmon methodology review process that produces recommendations in November of each year. By April 2011, a progress report will be provided to the Council, towards a determination if a viable approach is likely to be developed in time to be integrated with the 2011 review process. Another progress report is envisioned for the June Council meeting. By September 2011, a determination will be made if the final report write-up would be ready for review during the October salmon methodology review meeting. Presentation of a final report to the full Scientific and Statistical Committee and Council for approval would then occur at the November Council meeting. If approved by the Council, the final report would be forwarded to NMFS for consideration in ESA consultations and guidance to the Council. In the event a usable approach emerges from this process, the Council may consider a possible Fishery Management Plan amendment process beginning after November 2011.

In summary, the Council has initiated a significant effort to address Task G, identified in the 2010 BO on the Pacific Coast Salmon Fishery Management Plan, regarding development of options for incorporating abundance-driven management principles into Lower Columbia tule Chinook management. An ad hoc Tule Chinook Workgroup has been established by the Council. This workgroup has developed a detailed plan and schedule for completing this work. Work has been initiated and significant progress has been made. It remains to be determined whether an abundance-based approach for LRN tule Chinook is feasible and appropriate, but an evaluation process has been developed and implemented by the Council consistent with the guidance and standards identified in NMFS' 2010 fishery consultation.

If you have any questions or require additional information on this effort, please contact Mr. Chuck Tracy of the Council staff.

Sincerely,

D. O. McIsaac, Ph.D.
Executive Director

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Enclosures:

- Attachment A – draft work plan
- Attachment B – retrospective example of low status exploitation rate
- Attachment C – comparison of hatchery releases and returns
- Attachment D – analysis of forecast error
- Attachment E – preliminary attempt to predict run size from marine conditions
- Attachment F – presentation outlining analytical approach

cc: Council Members
TCW
John Coon
Chuck Tracy

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AD HOC TULE CHINOOK WORK GROUP – WORKING WORK PLAN

Objective: **Assist the Council and NMFS in exploring the development of abundance-based management approaches to allow fishing on abundant salmon stocks while protecting the recovery of Lower Columbia River tule Chinook.**

At their June 2010 meeting, the Council convened an Ad Hoc tule Chinook Work Group to explore abundance-based approaches to setting allowable fishing rates in the long term to protect Lower Columbia River tule Chinook. Work group efforts will ultimately be integrated with the Council's annual salmon methodology review process that produces recommendations in November of each year. The TCW met on September 30, 2010 to review process, schedule, work products and assignments. This work plan reflects the results of that initial meeting and is intended to serve as a checklist and template for tracking and reporting progress.

Abundance-based management typically employs a variable exploitation rate fishing strategy based on stock abundance to achieve a combination of fishery and escapement/risk objectives (Figure 1). Specific tasks were identified by the work group to address each of these essential elements:

1. Describe and evaluate the effects of alternative fishing rate strategies on Council fisheries involving Columbia River tule Fall Chinook.
2. Describe and evaluate current and alternative methods of forecasting Columbia River tule Fall Chinook abundance.
3. Identify alternative abundance-based fishing rate strategies for consideration consistent with forecast abilities.
4. Describe and evaluate the effects of alternative fishing rate strategies on escapement and population risks for tule Fall Chinook.

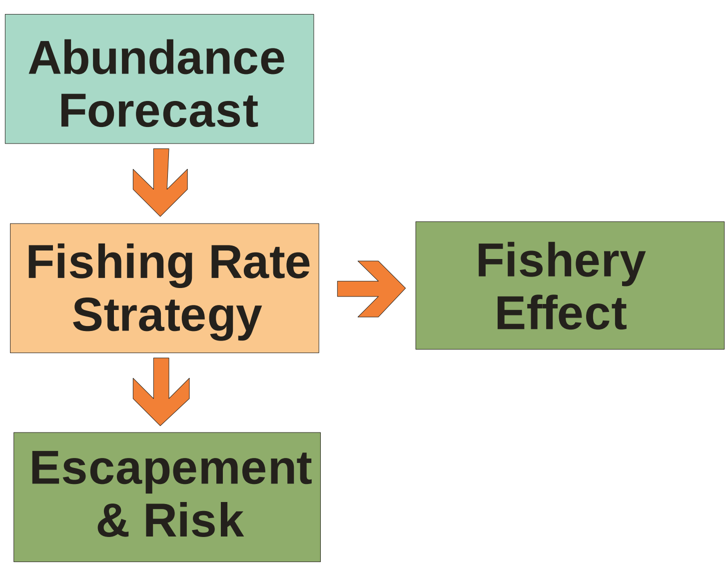


Figure 1. Conceptual depiction of an abundance-based management analysis.

Background

The current approach to tule Chinook fisheries involves a fixed annual impact rate limit. Protection of wild lower Columbia River Fall Chinook has involved a progressive reduction in the impact rate limit over the last decade. Maximum exploitation rates for tule Fall Chinook historically reached levels of 65% or more. More recently, maximum impact rate limits have been reduced to 49% in 2002, 42% in 2007, and 38% in 2009. The need for even greater reductions is currently being contemplated by NMFS as per their 2010 fishery guidance letter.

Management of tule Chinook is complicated by their widespread occurrence in fisheries from Oregon and Alaska. Impacts are distributed among many fisheries and the net impact of all fisheries can be significant. For instance, the 2009 impact of 38% included approximately 20% in Canada and SE Alaska ocean, 5% in ocean Treaty Indian, 5% in ocean sport, 4% in Columbia commercial and 4% in Columbia sport fisheries.

Fishery limits for tule Chinook can be a significant constraint in Council fisheries. Because much of the tule fishery impact currently occurs in areas outside the Council's direct management authority (Canada, Alaska, and treaty fisheries), reduced impact limits have seriously constrained Columbia River fisheries and have the potential to constrain Oregon and Washington ocean fisheries in some years.

In Columbia River fisheries, current limits are being met by a combination of fishery reductions and area restrictions. The recent year strategy has been to limit the Buoy 10 sport fishery and to move other fisheries targeting upriver fall Chinook to areas above the Lewis River. In 2010, impact rates on tule fall Chinook in combined sport and commercial fisheries were limited to just 8%. Further reductions might involve mark-selective regulations in selected fisheries (such as the Columbia River buoy 10 sport fishery).

Management has historically been based on the Coweeman River index population. Recent past rate limits of 42-49% were established based on risk analyses of fishery effects relative to escapement of this index population. However, the Coweeman population is one of the larger and more productive extant tule populations. Current impact rate limits of 38% adopted by NMFS, reflect additional reductions intended to reduce conservation risks of the weaker populations of tule Chinook.

ESA Recovery Plans for lower Columbia River salmon in both Washington and Oregon include specific measures calling for the evaluation of abundance-based management for tule Chinook. Abundance-based management is a variable exploitation rate fishing strategy that is currently employed in a number of fisheries. There are two potential benefits of an abundance-based: it reduces conservation risks in years of low returns and increases fishery flexibility in years of high returns. State fishery representatives on the Council have expressed an interest in pursing abundance-based management of tule Chinook. The Council is also interested due to fishery implications of current NMFS guidance for fishery impact rates and related conditions.

Task 1. Describe and evaluate the effects of alternative fishing rate strategies on Council fisheries involving Columbia River tule Fall Chinook.

Explanation: This task answers the question of "what fishery benefits and tradeoffs are potentially associated with abundance-based management?" Effects analyses are needed to place the potential benefits and tradeoffs of an abundance-based management strategy in context for consideration by Council constituents and policy makers. Potential effects can be evaluated using current fisheries models in prospective analyses of expected future fisheries under various conditions. Retrospective analysis of effects under alternative management strategies by hind-casts of the last few years are also particularly informative.

Activity 1.1. Inventory and document information on target and observed exploitation rate.

Establishes baseline point of reference and also captures fishery implementation uncertainty.

Activity 1.2. Describe in writing how different tule fall Chinook abundance and fishing rates generally affects ocean and Columbia River fisheries.

This is supporting text for fishery effects analysis.

Activity 1.3. Hind-cast (using FRAM) the fishery effects of different ceiling exploitation rates for low run sizes of LCN tule Chinook.

Note that FRAM currently uses an aggregate wild stock number based on 7% of the hatchery forecast.

Activity 1.4. Hind-cast (using FRAM) the fishery effects of different ceiling exploitation rates for high run sizes of LCN tule Chinook.

It is unclear to what extent the current ocean fishery north of Falcon opportunity might benefit from higher rates due to other constraints. South of Falcon fisheries might benefit somewhat in years of high Sacramento abundance.

Activity 1.5. Describe potential effects and schedule of mark-selective fall Chinook fisheries.

Stepwise implementation of mark-selective fisheries might help ease the burden of drastic cuts in fisheries to achieve a lower exploitation rate ceiling. The selective fishery implementation schedule will help identify reasonable exploitation rates, particularly at the bottom end of the range. Implementation of mark-selective fisheries will also require modeling of different hatchery and wild exploitation rates in different fishery scenarios.

Activity 1.6. Evaluate the historical incidence of different tule run sizes to provide some sense on how frequently various abundance-based criteria might be implemented (e.g. how frequently we might be in any specific management cell).

This information will also inform the development of potential abundance-based management matrix alternatives.

Task 2. Describe and evaluate current and alternative methods of forecasting Columbia River tule Fall Chinook abundance.

Explanation: This task answers the question of "how accurately and specifically can we forecast numbers and components of the tule Chinook run?" The feasibility and effectiveness of abundance-based management will ultimately depend on the ability to forecast annual run size. Current forecasts use sibling models based on a stock aggregate consisting of primarily hatchery fish. Conservation-based management objectives would ideally be based on population-specific forecasts of wild fish. However, the feasibility of forecasting aggregate or population-specific, hatchery or wild components is also in question. Preliminary examinations by NMFS (Scheurell 2009) suggest that wild population forecasts may not be feasible due to data limitations, primarily related to inability to distinguish hatchery and wild contributions. In spite of this apparent limitation, abundance-based management might still potentially provide conservation and fishery benefits. A variety of alternative forecast methods and indicators might be considered. Forecast errors associated with each alternative will also need to be explicitly incorporated into the risk analysis.

Activity 2.1. Inventory and document aggregate and population-specific information on run size and escapement, wild and hatchery composition, and age-composition.

Activity 2.2. Describe current forecast methodology, accuracy and age-specific errors based on pre and post-season comparisons of forecast vs. actual numbers. (Note forecast comparison for LRH is in the pre-I document).

Activity 2.3. Evaluate relationships between aggregate versus Coweeman, and wild versus hatchery numbers.

Analyses of correlations among hatchery and wild, and population and aggregate abundance patterns are needed to evaluate the potential effectiveness of various indicators related to wild population abundance. Analyses might also include hind casting to examine what escapement would have looked like under an aggregate forecast for wild populations such as Coweeman.

Activity 2.4. Document marine survival estimates.

Forecasts based strictly on hatchery numbers may be confounded by effects of changes in hatchery release levels. Indices based on survival rather than numbers would avoid this effect.

Activity 2.5. Evaluate prospects for improving tule abundance predictions using ocean indicators.

Ocean data is available from Scheurell (2009) and from OCN coho analyses. Analyses to include pair wise and stepwise correlation analyses. For use in forecasting, ocean indicator data would need to be available pre-season (some ocean data considered in the Scheuerell analysis are only available post-season).

Activity 1.6. *Evaluate management implications of forecast errors (e.g. frequency with which errors result in ending up in a different management cell or stratum than predicted).*

Forecast errors are problematic only if they translate into significant changes in management or escapement.

Task 3. Identify alternative abundance-based fishing rate strategies for consideration consistent with forecast abilities.

Explanation: This task identities appropriate indicators or triggers for determining annual fishing rate and corresponding ranges of exploitation rates. Different combination of abundance indicators, stock or population units, and rates warrant consideration.

While population-specific indicators for fall Chinook do not appear to be adequate to implement a population-specific abundance-based strategy, variable fishing rates in years of low aggregate ocean survival might reduce the effective average annual rate with corresponding risk reduction benefits. The greater the reduction in impacts in the low return years, the greater the flexibility to absorb higher impacts in the large return years.

Activity 3.1. *Review abundance-based approaches employed in other fisheries to provide examples for potential application to tule Fall Chinook.*

- Puget Sound coho: preseason abundance sets exploitation rate but at no point does the rate go to zero.
- Klamath Fall Chinook: exploitation rate cap, exploitation reduced based on abundance and limited to *de minimis* rates at low numbers.
- Oregon Coast Natural and Columbia River coho: exploitation rates based on seeding level of parent spawners and a marine survival index based on hatchery jack returns.
- Pacific Salmon Commission: aggregate abundance based management
- Col R upriver approach for Snake River Wild and Upriver Bright fall Chinook

Activity 3.2. *Indentify and evaluate potential indicators of abundance of wild fish.*

A variety of abundance-based estimators or indicators that mean something to natural fish might be considered. These include abundance forecasts, brood year spawner numbers, marine survival, and ocean conditions related to marine survival. Indicators might be based on wild or hatchery fish at an aggregate or indicator population level. Indices might also consider recent escapements (e.g. lower fishing rates in years following poor wild escapements).

Potential indicators include populations where data on the status of the wild component is currently available (e.g. Coweeman, East Fork Lewis, Washougal). Where "strong" population indicators are used, implications to other weaker stocks need to be considered.

Activity 3.3. *Indentify range of exploitation rates for consideration.*

This activity identifies what changes in exploitation rate can be realistically considered. The intent would be to set some reasonable bounds on the consideration of different rates. In part, this will be based on the fishery implications of different rates and what fishery steps might be taken. This exercise is complicated by fisheries not in US jurisdiction.

Alternatives will include a fixed 38% exploitation rate strategy and the current 38% with higher or lower rates based on abundance indicators. Analyses should also examine the sensitivity of results to different base rates. It will also be instructive to explore other alternatives including going to 0% in some years even if this is not a realistic fishery option given fisheries outside of US jurisdiction.

Activity 3.4. *Indentify appropriate combinations of exploitation rates and indicator-based implementation thresholds (i.e. harvest matrices).*

Many different combinations of rates and thresholds might be contemplated. Single year alternatives would might be based on annual run size expectations. Multi-year alternatives might also include extra conditions on adoption of higher or lower rates (for instance, limits if coming off successive low run years.)

Simple examples based on the LRH aggregate stock might use 40,000 and 100,000 trigger points (equivalent to 20% of time at high, 20% of time at low, 60% in the middle). Example exploitation rates might be based on the current rate ±5% (33%, 38%, 43%), current rate ±10% (28%, 38%, 48%), or variations where the current rate represents the maximum allowed (e.g. 33%, 38%, 38%).

Exploitation rate strategies must also be grounded with consideration of other tule Chinook objectives (e.g. hatchery escapement goals – note these goals might change with expected changes with weirs and hatchery practices).

Task 4. Describe and evaluate the effects of alternative fishing rate strategies on escapement and population risks for tule Fall Chinook.

This task answers the question of how we assess benefits of different fishing rates to evaluate whether one strategy is better than another with respect to fish status.

Effects of fishing on tule Fall Chinook status can be estimated based on escapement numbers and viability risks. Simple escapement numbers relative to goals are the traditional approach to fishery management. More recently, risk analyses are increasingly being used to consider the combined effects of fishing, fishery uncertainty, and variable production and survival on escapement levels that may threaten the long term persistence or viability of a population or group of populations. Current recovery plans for Columbia River salmon listed under the ESA typically define status in terms of risk.

Population Viability Analyses (PVA) have been used by NMFS, ODFW and WDFW to estimate the risk status of Columbia River tule Fall Chinook based on stochastic stock-recruitment models and current population data. A similar analytical framework and modeling tools can be also be used to evaluate the effects of fishing on population and status in an ESA context.

This approach is particularly well-suited for evaluating fishing effects on populations of different productivity including weak populations that are most at risk of falling to critical low level where they are no longer capable of sustaining themselves. This approach allows for recognition that the weaker populations can't withstand the same exploitation levels as the stronger populations. This framework also allows for weighing the benefits of low exploitation rates on weak populations where poor habitat conditions limit status regardless of fishery impacts.

Effective analysis will also consider the tradeoffs in fishery reductions of wild fish spawning escapement and fishery benefits to wild fish status by reducing the incidence of hatchery fish in natural production areas.

Risk analyses for other stocks have demonstrated that a variety of fixed and variable annual rate strategies may produce equivalent risks. For instance, risk effects of higher fishing rates in large return years could be offset by reduced fishing rates in low return years. It is typically the poor ocean survival years that pose the greatest risk of critical low escapements. This is the basis for the abundance-based fishery strategy that this Plan proposes for consideration.

Analysis should also consider near-term and longer-term alternatives that take advantage of future improvements in data. There may be increased opportunity in the future to develop more specific wild population indicators based on results of full hatchery marking and increased wild status monitoring. Changes in hatchery programs also warrant consideration in longer term analyses. Changes in other factors including habitat conditions over the long term will also have a substantial influence on fishery effects. It may be appropriate to include a recommendation for a new look at these questions in 5-10 years.

Activity 4.1. Identify model components essential to the questions of interest.

These include conceptual and mathematical descriptions of model inputs, functions, and outputs. Of particular interest will be the metrics by which fishery effects will be evaluated (e.g. wild and hatchery escapement, low-run size risk, proportion hatchery origin spawners).

Activity 4.2. Compile and analyze fish status data required to simulate fishery effects.

Data on wild population status and productivity is currently available for the Coweeman and East Fork Lewis populations which are among the more productive remaining (hence, not necessarily representative of the full spectrum for the stock or ESU). Some information is also available for the Grays and Clatskanie. Status of other populations has been inferred in recovery plan analyses based on habitat availability and condition. While these inferred estimates are uncertain, they do appear to provide a realistic range of expectations for lower Columbia River tule Chinook.

Risk analyses will also need to consider the effects of fishery implementation uncertainty which results in differences between planned and actual exploitation rates. Fishery uncertainty is estimated with comparisons of pre and post-season values.

Activity 4.3. Adapt population viability analysis models from salmon recovery planning for use in analysis of alternative fishing strategies on fish status.

Adaptation of an existing model will ease the task of model development and also provide results consistent with salmon conservation needs driving current salmon management and associated consultations. Recovery planning by NMFS and the States have developed effective population viability analysis frameworks for evaluating tule Chinook population status in terms of low escapement risks.

Both the PopCycle model employed by Washington and the SLAM model employed by NMFS have been utilized to evaluate effects of fixed exploitation rates. The PopCycle model has previously been utilized to evaluate abundance-based fishing strategies for Columbia River coho. Both models are stochastic life cycle models built around the salmon stock-recruitment function and both models can be expected to produce similar results if parameterized with equivalent inputs. Models differ primarily in the detail by which stages of the salmon life cycle are represented.

The analysis of abundance-based fishery alternatives will initially be based on the PopCycle model which can be more readily-adapted by the project implementer. Analyses will be qualified with differences in model inputs for the productivity of specific populations that drove difference in results of previous SLAM and PopCycle analyses for tule Fall Chinook. Additional analysis using multiple models might be contemplated in the future depending on resource availability.

Activity 4.4. Conduct simulations of alternative combinations of exploitation rates and indicator-based implementation thresholds .

There are at least two ways to approach design of abundance-based fishery scenarios. One is to maximize catch at an equivalent fixed rate. The other is to reduce escapement risk at an equivalent catch. Simulations of various alternatives will identify these tradeoffs. Simulations will compare effects of abundance-based and fixed harvest strategies. A fundamental question is what abundance-based strategies produce an equivalent level of risk to any given fixed rate strategy. Simulations will consider population-specific and ESU-aggregate risks associated with different fishery strategies. (Aggregate risks reflect the net benefit of reduced risk for the stronger populations due to protection of the weaker populations).

Activity 4.5. Document methods and results.

This activity will be iterative involving technical review of interim products and refinements based on input received. Initial reviews and input will be guided by the TWC.

Schedule

Jun 2010	Council convened an Ad Hoc tule Chinook Workgroup (TCW) to explore abundance-based approaches to setting allowable fishing rates in the long term to protect Lower Columbia River tule Chinook.
Sep 2010	First meeting of the TCW to identify work plan for consideration of alternatives.
Nov 2010	Brief progress report for the Council meeting.
Dec 2010	Second meeting of the TCW and development of a progress report for the Recovery Board and for NMFS consideration in developing guidance on 2011 Council and Columbia Basin fisheries.
Apr 2011	Determination if a viable approach was likely to be developed in time to be integrated with the Council's 2011 salmon methodology review process.
Jun 2011	Possible brief progress report for the Council meeting.
Sep 2011	Determination if the final report write-up would be ready for review during the October salmon methodology review meeting, and if possible, including the final report in the September briefing book (deadline of August 23).
Oct 2011	Presentation of final report at the SSC Salmon Subcommittee and Salmon Technical Team review of proposed salmon methodology changes.
Nov 2011	Presentation of final report to the full SSC and Council for approval. If approved by the Council, the final report would be forwarded to NMFS for consideration in ESA consultations and guidance to the Council.

Attachment B

12/6/10

TO: Ad Hoc Tule Chinook Workgroup

FROM: Larrie La Voy

SUBJECT: Additional work on retrospective look at an example "low" status exploitation rate for Lower Columbia Natural (LCN) tule Chinook.

I have added an additional comparison using a LCN ER ceiling of 0.33 to the table that I had previously produced. I also added a row for the Treaty troll fishery.

As before, to obtain some perspective on the effect to preseason fisheries shaping of a "low" status under an abundance based management system for Lower Columbia natural tule Chinook; I looked at the 2008-2010 FRAM preseason run estimates of total ER for LCNs. For this exercise, I used a "low" status abundance forecast of 40, 000 Lower River Hatchery (LRH) Chinook and an exploitation rate ceiling of 0.28 and 0.33 for LCN, a reduction of 0.10 or 0.05, respectively, from the 2010 ER ceiling of 0.38. All fishery catches/inputs and stock abundances (including mark rates) were unchanged from the preseason runs except that the LRH abundances were lowered to achieve a terminal run of about 40,000 adults.

Table 1 contains LCN total exploitation rates under preseason and "low" abundance LRH stock using the FRAM and in-river harvest model system currently employed during Council preseason management. My summary comments include:

- LCN exploitation rates in Alaska and Canada are approximately 15% and do not vary year to year by the same degree as ERs in Council fisheries partly because they are modeled with scalar values rather than quotas. ERs in 2009-2010 include reductions in southeast Alaska and Vancouver Island fisheries from 2008 PST Agreement.
- Without reductions, exploitation rates in Council fisheries can approach 15% depending on overall Columbia River stock abundances and extent of fishing South of Cape Falcon (primarily Oregon troll) that can be add 1-3%.
- Exploitation rates in the mainstem Columbia net and sport fisheries are about 8% when using the preseason in-river harvest rates of about 11%.
- Approximately, two thirds of the ER in Council fisheries is in the nontreaty troll and sport fisheries (Treaty troll averages about 5% in these runs).
- In these examples, impacts on LCN stock in the southern U.S. would have to be reduced by nearly 50% in order to remain under an ER ceiling of 0.28 and by 23% to remain under a ceiling of 0.33, assuming current conditions in northern fisheries.

I have added an additional table that shows the effect on the LCN Tule ERs from additional mark selective fisheries using 2010 fisheries and low LRH run size as base case. Table 2 shows the effect on LCN ER from implementation of mark selective fisheries in the river fisheries and in nontreaty fisheries north of Cape Falcon. Cindy LeFleur (WDFW) and John North (ODFW) developed placeholder river harvest rates on unmarked LRH Tule Chinook at four incremental steps of MSFs from the 2010 preseason value: 1) Buoy 10, 2) Buoy 10 plus mainstem sport, 3) all sport plus gill net, and 4) all sport plus full alternative commercial gear MSF.

Implementation of MSF regulations in all nontreaty fisheries north of Cape Falcon reduced the Council fishery ER for LCN Tules by about 40% (0.167 to 0.101). Implementation of MSF regulations in river fisheries reduced the LCN Tule ER by about 35% (0.079 to 0.051) for Buoy 10 and mainstem sport as MSF, by about 50% (0.079 to 0.038) for sport and gill net, and by about 65% (0.079 to 0.028) under full implementation (max case) MSF.

Table 1. Exploitation rates for Lower Columbia natural (LCN) tule Chinook from FRAM and in-river harvest models.

	2008		2009		2010			'08-'10 Average	
Fishery	**Preseason a/**	**LRH at 40K**	**Preseason**	**LRH at 40K**	**Preseason**	**LRH at 40K**		**Preseason**	**LRH at 40K**
AK-BC	0.138	0.173	0.156	0.156	0.140	0.142		0.145	0.157
Council Total	**0.098**	**0.104**	**0.14**	**0.176**	**0.151**	**0.167**		**0.130**	**0.149**
No. of Falcon	0.097	0.103	0.140	0.176	0.136	0.152		0.124	0.144
(treaty troll only)	0.043	0.045	0.068	0.084	0.045	0.048		0.052	0.059
So. of Falcon	0.001	0.001	0.000	0.000	0.015	0.015		0.005	0.005
Other So. U.S. marine	0.002	0.002	0.003	0.004	0.003	0.003		0.003	0.003
River	0.076	0.072	0.081	0.076	0.081	0.079		0.079	0.076
So. U.S subtotal	0.176	0.178	0.224	0.256	0.235	0.249		0.212	0.228
LCN Total ER	**0.314**	**0.351**	**0.380**	**0.412**	**0.375**	**0.391**		**0.356**	**0.385**
% Reduction in So. U.S. to achieve 0.28	19%	40%	45%	52%	40%	45%		35%	45%
% Reduction in So. U.S. to achieve 0.33	--	12%	22%	32%	19%	24%		21%	23%
% Reduction in Nontreaty So. U.S. to achieve 0.33	--	16%	32%	48%	24%	30%		28%	31%

a/ Council preseason ER was 0.358 based on fishing year assessment; this brood year method ER for LCN began in 2009.

Table 2. Exploitation rate on LCN tule w LRH at 40K and different river MSFs using 2010 as base.

Fishery	2010 w LRH at 40K, River MSF: Preseason	B10	B10+mstem Spt	All spt+Net	All spt+alt gear	2010 w/ NT NoF MSF same effort; LRH at 40K	2010 w/ NT NoF MSF same quota; LRH at 40K	
AK-BC	0.142	0.142	0.142	0.142	0.142	0.146	0.145	
Council Total	**0.167**	**0.167**	**0.167**	**0.167**	**0.167**	**0.101**	**0.122**	
No. of Falcon	0.152	0.152	0.152	0.152	0.152	0.086	0.107	
(treaty troll only)	0.048	0.048	0.048	0.048	0.048	0.050	0.050	
So. of Falcon	0.015	0.015	0.015	0.015	0.015	0.015	0.0145	
Other So. U.S. marine	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
River	**0.079**	**0.059**	**0.051**	**0.038**	**0.028**	**0.086**	**0.084**	(@ 2010 HR)
So. U.S subtotal	0.249	0.229	0.221	0.208	0.198	0.190	0.207	
LCN Total ER	**0.391**	**0.370**	**0.363**	**0.349**	**0.340**	**0.336**	**0.353**	
% Reduction in So. U.S. to achieve 0.28	45%	39%	37%	33%	30%	29%	35%	
% Reduction in So. U.S. to achieve 0.33	24%	18%	15%	9%	5%	3%	11%	
% Reduction in Nontreaty So. U.S. to achieve 0.33	30%	22%	19%	12%	6%	4%	15%	

12/1/10

TO: Ad Hoc Tule Chinook Workgroup

FROM: Larrie La Voy

SUBJECT: A quick look at comparison of tule releases from lower river hatcheries to Lower River Hatchery (LRH) returns to river.

The table below shows tule releases in millions from lower river facilities compared to adult returns to derive a survival index that could be used to stratify LRH aggregate abundance forecasts into low, medium, and high categories. For this quick-look exercise, I compared the running three-year average smolt releases to the LRH return four years later. Releases were obtained from PSMFC-RMIS data query for fall Chinook released below Bonneville Dam. I excluded fall bright and Cole River (Rogue) releases from the sum. Also included in the table are wild tule escapement estimates that Dan Rawding (WDFW) had compiled for the VRAP-RER work done in 2007.

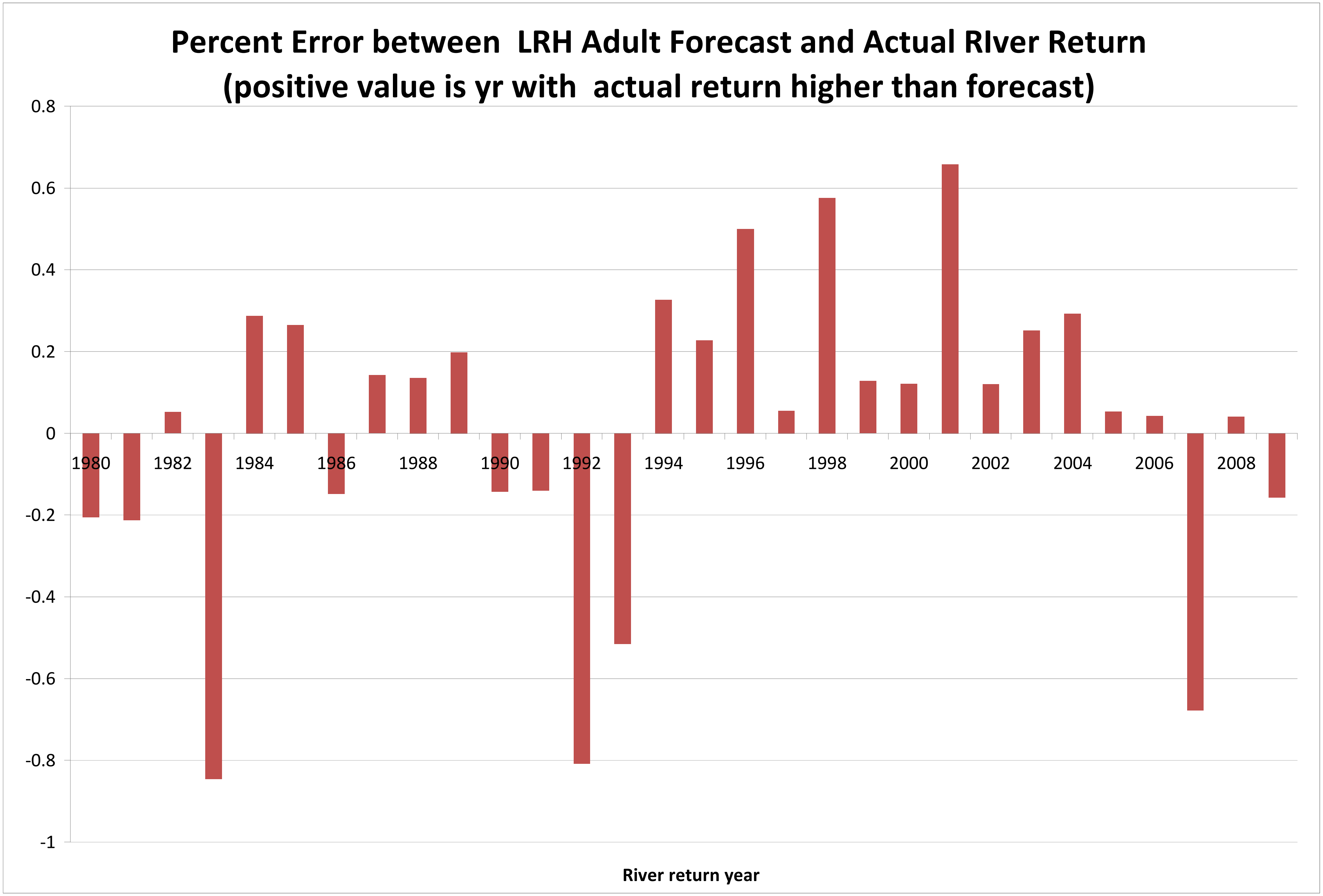
Smolt releases have declined from 45-60M for the late 1980's brood, to 35-40M in the early to mid 1990s, to the recent year levels of about 20M. Not too surprisingly, the return-per-smolt released has increased as total smolts have declined, presumably from reductions in releases from lower survival facilities. The table contains a survival index of adult returns per thousand releases. For 1993 brood onward, this survival index corresponds roughly with the low (red) and high (green) wild escapements to the Washington tributaries. So there appears to be at least some relationship between an LRH aggregate abundance measurement and the corresponding wild escapement for these tributaries. Since 1993 brood (1997 return), the survival index has ranged from about 1 adult per thousand released to nearly 8 adults per thousand released. A low to medium threshold of about 2 adults per thousand and a medium to high of about 4 per thousand may approximate a 20%, 60%, and 20% frequency of low, medium, and high status categories based on the indices over the last 10 years. Years with these indices thresholds also roughly correspond to LRH returns of less than 40K and more than 100K.

Table 1. Releases and adult returns of Lower River Hatchery Tule (LRH) Chinook.

Brood Yr	Total Rel. (M's)	Running 3yr Ave Rel. (M)	Brd Yr+4	LRH Rtn- - Brd Yr+4 (K's)	Surv Index (Rtn per 1K smolts)
1985	52.7				
1986	52.2	56.4	1990	60.0	1.06
1987	64.2	59.3	1991	62.7	1.06
1988	61.5	58.9	1992	62.6	1.06
1989	51.1	55.4	1993	52.3	0.94
1990	53.6	52.3	1994	53.6	1.02
1991	52.2	49.5	1995	46.4	0.94
1992	42.7	44.1	1996	75.5	1.71
1993	37.3	39.6	1997	57.4	1.45
1994	38.8	41.3	1998	45.3	1.10
1995	47.9	40.1	1999	39.9	1.00
1996	33.7	35.8	2000	27.0	0.75
1997	25.9	25.5	2001	94.3	3.71
1998	16.8	21.6	2002	156.4	7.24
1999	22.2	20.0	2003	155.0	7.77
2000	20.9	22.4	2004	109.1	4.87
2001	24.1	23.2	2005	78.3	3.38
2002	24.5	24.0	2006	58.3	2.43
2003	23.3	23.8	2007	32.7	1.38
2004	23.4	21.5	2008	61.6	2.86
2005	17.7	21.2	2009	76.7	3.62
2006	22.4	19.5	2010		
2007	18.3	21.9	2011		
2008	25.0	18.8	2012		

Wild Tule Escapement (Rawding, WDFW)

Rtn Yr	Coweeman	East Fork Lewis	Grays	Washougal
1990	753	328	187	1003
1991	315	230	187	1734
1992	1,157	199	4	1828
1993	826	154	43	2025
1994	1,572	484	47	2737
1995	1,269	204	29	1204
1996	2,138	311	175	485
1997	639	184	9	542
1998	455	55	38	710
1999	277	111	154	2137
2000	269	161	93	1511
2001	744	219	161	1666
2002	813	596	82	2831
2003	1,026	361	279	1333
2004	1,394	262	669	2678
2005	791	607	98	1085
2006	482			
2007	233			
2008	393			


Percent Error between LRH Adult Forecast and Actual RIver Return
(positive value is yr with actual return higher than forecast)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
River return year

	Total Adults Predicted Adults	Actual Adults	Actual minus Predicted	Actual minus Predicted/ Actual
1980	127.3	105.6	-21.7	-21%
1981	115.0	94.9	-20.1	-21%
1982	132.2	139.5	7.3	5%
1983	162.5	88.1	-74.4	-85%
1984	70.4	98.9	28.5	29%
1985	81.5	111.0	29.5	27%
1986	177.6	154.8	-22.8	-15%
1987	294.9	344.1	49.2	14%
1988	267.7	309.9	42.2	14%
1989	104.9	130.9	26.0	20%
1990	68.5	60.0	-8.5	-14%
1991	71.4	62.7	-8.7	-14%
1992	113.2	62.6	-50.6	-81%
1993	79.3	52.3	-27.0	-51%
1994	36.1	53.6	17.5	33%
1995	35.8	46.4	10.6	23%
1996	37.7	75.5	37.8	50%
1997	54.2	57.4	3.2	6%
1998	19.2	45.3	26.1	58%
1999	34.8	39.9	5.1	13%
2000	23.7	27.0	3.3	12%
2001	32.2	94.3	62.1	66%
2002	137.6	156.4	18.8	12%
2003	115.9	155.0	39.1	25%
2004	77.1	109.1	32.0	29%
2005	74.1	78.3	4.2	5%
2006	55.8	58.3	2.5	4%
2007	54.9	32.7	-22.2	-68%
2008	59.0	61.6	2.6	4%
2009	88.8	76.7	-12.1	-16%
Average	93.4	99.4	6.0	2%
Avg over			-26.8	
Avg under			22.4	
Number over			10	
Number under			20	

	Age 3 Predicted Age 3	Actual Age 3	Actual minus Predicted	Actual minus Predicted/ Actual
1984	25.0	49.3	24.3	49%
1985	37.7	62.0	24.3	39%
1986	108.0	96.8	-11.2	-12%
1987	189.0	237.3	48.3	20%
1988	36.5	27.3	-9.2	-33%
1989	32.5	25.5	-7.0	-28%
1990	22.4	16.0	-6.4	-40%
1991	52.1	39.4	-12.7	-32%
1992	65.1	29.6	-35.5	-120%
1993	45.5	20.5	-25.0	-122%
1994	14.1	24.5	10.4	42%
1995	16.8	24.1	7.3	30%
1996	22.0	37.2	15.2	41%
1997	25.3	12.9	-12.4	-96%
1998	7.6	21.2	13.6	64%
1999	12.3	17.8	5.5	31%
2000	5.5	6.4	0.9	14%
2001	23.5	60.5	37.0	61%
2002	60.6	65.6	5.0	8%
2003	21.8	31.1	9.3	30%
2004	13.3	23.8	10.5	44%
2005	19.2	16.3	-2.9	-18%
2006	12.4	12.6	0.2	1%
2007	19.4	16.2	-3.2	-20%
2008	26.6	38.9	12.3	32%
2009	36.8	29.7	-7.1	-24%
Average	36.6	40.1	3.5	-1%
Avg over			-12.1	
Avg under			14.9	
Number over			11	
Number under			15	

	Age 4 Predicted Age 4	Actual Age 4	Actual minus Predicted	Actual minus Predicted/ Actual
1984	41.7	47.9	6.2	13%
1985	38.7	42.7	4.0	9%
1986	65.4	49.3	-16.1	-33%
1987	100.9	98.7	-2.2	-2%
1988	219.1	270.8	51.7	19%
1989	40.6	57.3	16.7	29%
1990	39.1	33.5	-5.6	-17%
1991	15.8	19.7	3.9	20%
1992	47.2	30.4	-16.8	-55%
1993	30.7	28.0	-2.7	-10%
1994	19.1	24.3	5.2	22%
1995	17.7	17.0	-0.7	-4%
1996	15.3	36.3	21.0	58%
1997	26.2	39.6	13.4	34%
1998	8.0	14.9	6.9	46%
1999	20.8	20.7	-0.1	0%
2000	16.2	18.3	2.1	12%
2001	6.7	31.5	24.8	79%
2002	72.7	86.2	13.5	16%
2003	80.1	107.0	26.9	25%
2004	45.8	63.1	17.3	27%
2005	44.6	45.5	0.9	2%
2006	34.8	32.1	-2.7	-8%
2007	29.2	12.5	-16.7	-134%
2008	30.9	20.8	-10.1	-48%
2009	48.7	44.9	-3.8	-8%
Average	44.5	49.7	5.3	3%
Avg over			-7.0	
Avg under			13.4	
Number over			11	
Number under			15	

	Age 5 Predicted Age 5	Actual Age 5	Actual minus Predicted	Actual minus Predicted/ Actual
1984	3.7	1.6	-2.1	-132%
1985	5.1	6.3	1.2	19%
1986	4.2	8.5	4.3	51%
1987	5.0	7.9	2.9	37%
1988	12.1	11.7	-0.4	-3%
1989	31.8	48.1	16.3	34%
1990	7.0	8.6	1.6	19%
1991	3.5	3.5	0.0	1%
1992	0.9	2.6	1.7	65%
1993	3.1	3.8	0.7	18%
1994	2.9	4.8	1.9	39%
1995	1.3	5.2	3.9	75%
1996	0.4	1.9	1.5	79%
1997	2.7	4.9	2.2	45%
1998	3.6	9.1	5.5	60%
1999	1.7	1.4	-0.3	-25%
2000	2.0	2.3	0.3	12%
2001	2.0	2.3	0.3	13%
2002	4.3	4.6	0.3	7%
2003	14.0	16.8	2.8	17%
2004	18.0	21.5	3.5	16%
2005	10.3	16.0	5.7	35%
2006	8.6	13.2	4.6	35%
2007	6.3	3.8	-2.5	-64%
2008	1.5	1.7	0.2	13%
2009	3.3	2.1	-1.2	-55%
Average	6.1	8.2	2.1	16%
Avg over			-1.3	
Avg under			2.9	
Number over			5	
Number under			21	

11/29/10

TO: Ad Hoc Tule Chinook Workgroup
FROM: Matt Falcy, Oregon Department of Fish and Wildlife
SUBJECT: Tule run-size forecast
SUMMARY: A preliminary attempt to predict Tule run size from marine conditions using an autoregressive neural network yielded promising results.

The accuracy of traditional forecasting methods such as multiple regression can be compromised by high colinearity among independent variables. Since metrics of marine conditions are known to be highly correlated with one another, I proposed to predict Tule abundance after removing the colinearity among independent variables with a Principle Components Analysis (PCA). However, after further considering the essence of the Tule prediction problem, I concluded that an autoregressive neural network would have superior performance to the PCA approach. I believe this approach also has the potential to outperform Generalized Additive Models (GAMs), which were employed by Rupp et al. (2010) to predict coastal Coho using similar independent variables.

A neural network is a machine learning method, with origins in the field of artificial intelligence. Neural networks are widely applied in engineering and economic contexts (e.g. missile guidance systems, stock market prediction) but are seldom used in ecological science. Nonetheless, neural networks have properties that make them inherently and demonstrably superior to more traditional methods such as generalized linear models. In particular, neural networks are well suited to problems where multiple interacting factors nonlinearly influence some phenomenon of interest. This is precisely the nature of the Tule forecast problem, with the exception that both Tule abundance and the marine conditions used to predict Tule abundance are time-series. For this reason, I applied a neural network with internal structure that accommodates the time-series nature of these data. It is known as a NARX network (nonlinear autoregressive network with exogenous inputs), and has the form

$$y_t = f(y_{t-1}, y_{t-2}, ...y_{t-4}, x1_{t-1}, x1_{t-2}, ...x1_{t-4}, x2_{t-1}, x2_{t-2}, ...x3_{t-4}, ...xn)$$

where the function f includes complex interactions among the n different predictor variables, x.

The variables I selected to make Tule run size in the LRH aggregate are the number of jacks in the previous two runs, the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), Ocean Nino Index (ONI), and multivariate ENSO Index (MEI). These variables were chosen after reading Rupp et al. (2010). Many other marine index variables are on hand but have not been explored.

Fitting a neural network is unlike traditional methods because the predictions of a complex network are capable of exactly matching observations. Thus, the essence of fitting a neural network is to prevent the network from becoming overfit (i.e. the model not only fits the signal, but also fits the noise. This results in false confidence in the model's prediction of new observations.). This is achieved by withholding data from the model fitting process and using it to evaluate model performance. The original data set includes 40 observations (1962-2001). Since I used a lag-4 autoregressive framework, there are 36 observations that can be predicted. These 36 observations were pseudorandomly broken into three groups: i) 20 observations were used to fit the model, ii) 6 observations were used to determine when the model begins to become overfit, and iii) 6 observations were used as an independent test of model predictions. The partitioning of the 36 observations into these three groups is pseudorandom because I repeated the process of dividing data and fitting the model several times. I stopped when I obtained really good results, as judged by how well the model predicted the data withheld for testing (group iii). The results of this model are displayed in Figure 1.

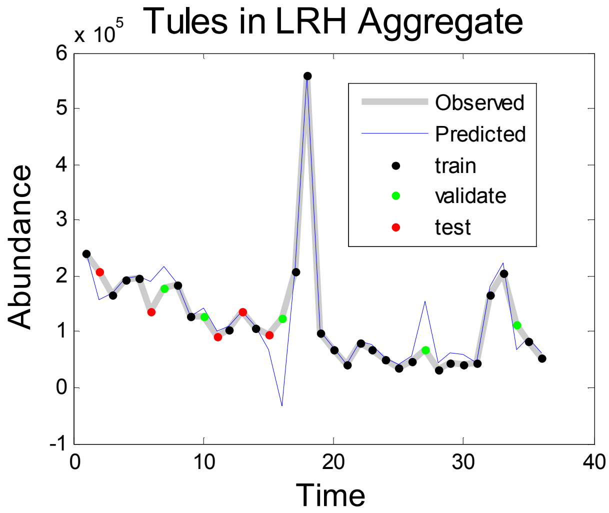


Figure 1. Results of an autoregressive neural network fit to LRH aggregate Tule Chinook abundance. The x-axis is years, beginning with 1966. All points are empirical observations. The black points were pseudorandomly chosen to train/fit the model. Training/fitting stopped when the difference between predictions and the green points began to increase (i.e. the model showed evidence of overfitting). The red points were never used during model development and can therefore be used as an independent test of model performance.

Assessing performance

Rupp et al. (2010) report a statistic called Ordinary Cross-Validation (OCV) that describes the predictive ability of the model. The process begins by: (1) leave out a single point, (2) fit the model, (3) obtain a prediction of the point that was left out, (4) subtract the empirically observed value from the prediction, and (5) square this difference. These steps are repeated until every point has been sequentially left out. Summing all the values obtained on the 5th step yields the numerator in the equation below. The denominator is simply the variance of the entire data set.

$$\text{OCV} = 1 - \frac{\sum_{i=1} (\hat{y}_i - y_i)^2}{\sum_{i=1} (\bar{y} - y_i)^2}$$

Rupp et al. (2010) obtain OCV scores for several different models. Their scores are approximately 0.6 – 0.7.

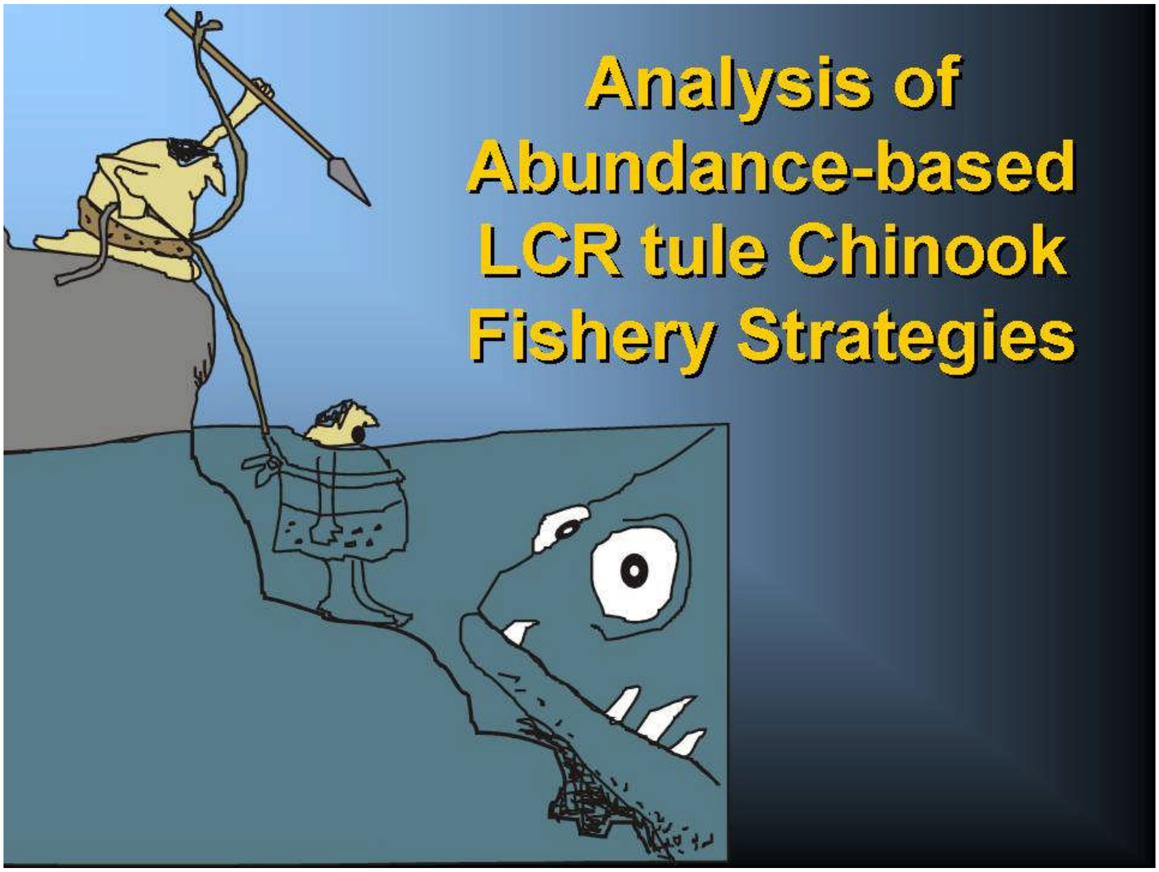
The approach I applied simultaneously leaves out 12 points rather than sequentially leaving out all the points. To compute a statistic that is similar to OCV, I used

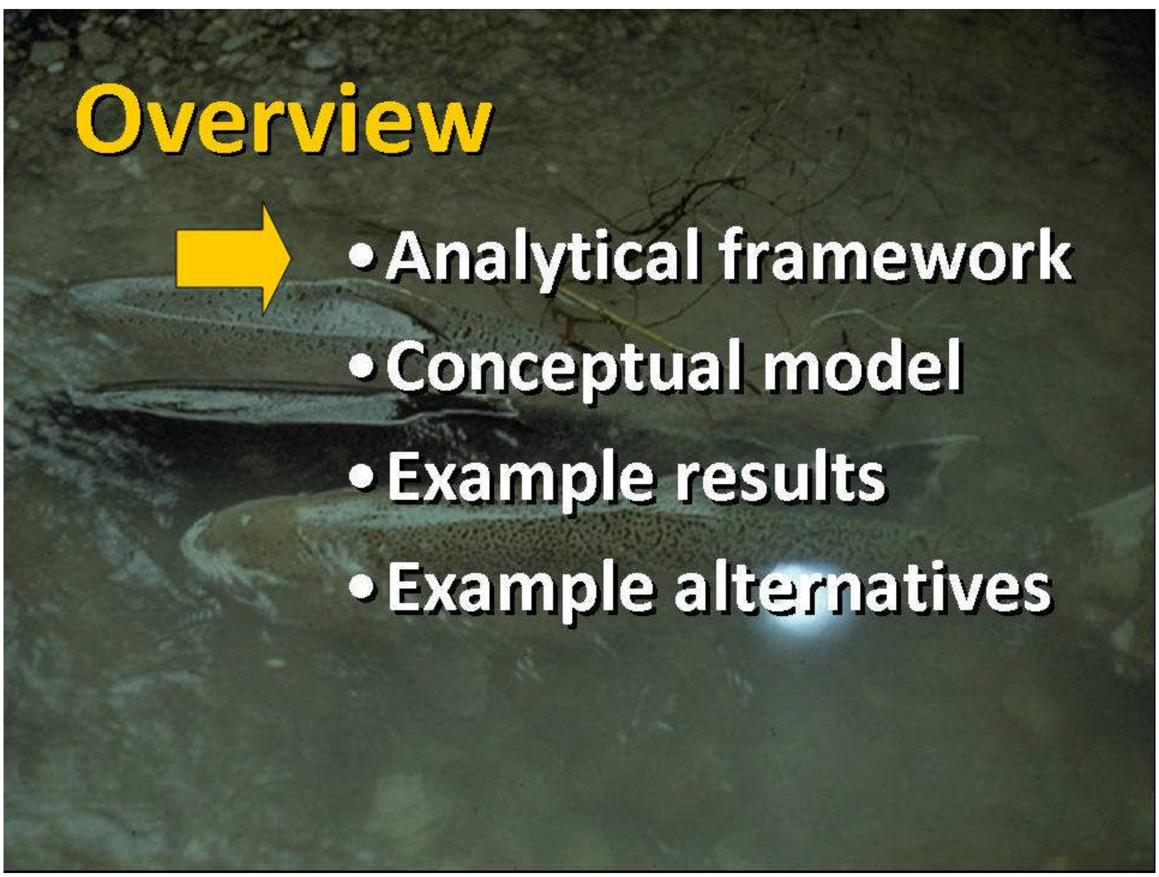
$$1 - \frac{\sum_{i=1}^{j=6} (\hat{y}_i - y_i)^2 / 6}{\sum_{k=1}^{l=36} (\bar{y} - y_k)^2 / 36}$$

Where j=6 are the 6 points used as independent tests (red dots, Figure 1). Using averages in the numerator and denominator rather than the sum, as in OCV, rescales the statistic to a single observation. The value I obtained after this rescaling is 0.86. This should be interpreted cautiously however, because the year of extremely high abundance (Time = 18) contributes to denominator of the equation but does not contribute to the numerator. This would not be true of the OCV value. Furthermore, as with any neural network, concern that this model is overfit is legitimate.

Different marine condition variables are available for the LRH aggregate but have not been evaluated. Since data on the runs in Grays, Coweeman, and EF do not begin as far back in time as the LRH aggregate, there are even more marine condition variables available for predicting these stocks.

Rupp et al. 2010. Forecast Models for Oregon Coast Natural Coho Salmon (Oncorhynchus kisutch) Adult Recruitment. Emailed to the Tule Ad-hoc Workgroup on 9/30/2010.


Analysis of
Abundance-based
LCR tule Chinook
Fishery Strategies


Overview
• Analytical framework
• Conceptual model
• Example results
• Example alternatives

Retrospective Analysis

How would past fisheries & escapements been affected?

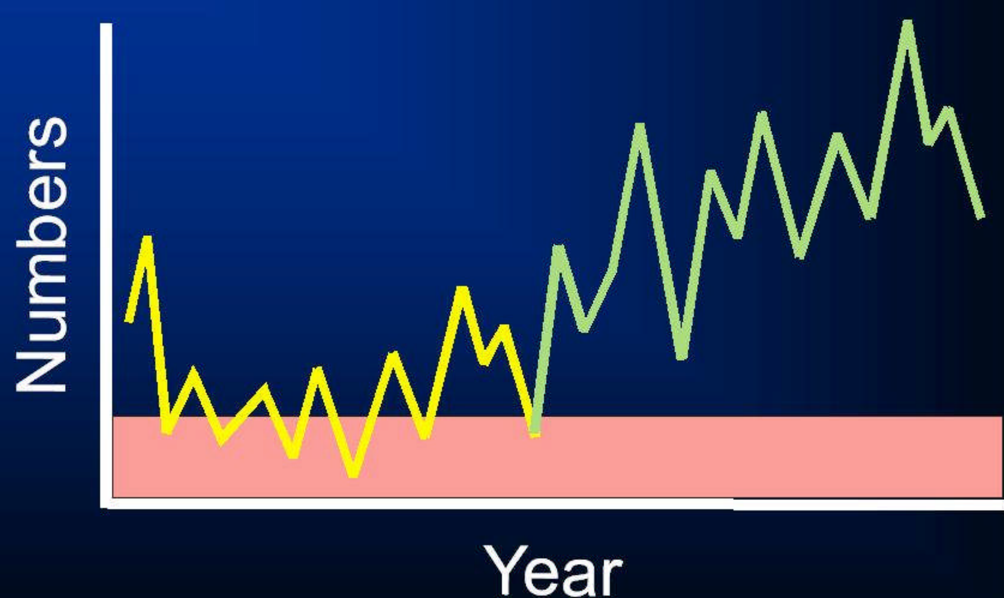
- Specific, grounded examples
- Limited combinations
- Within year effects

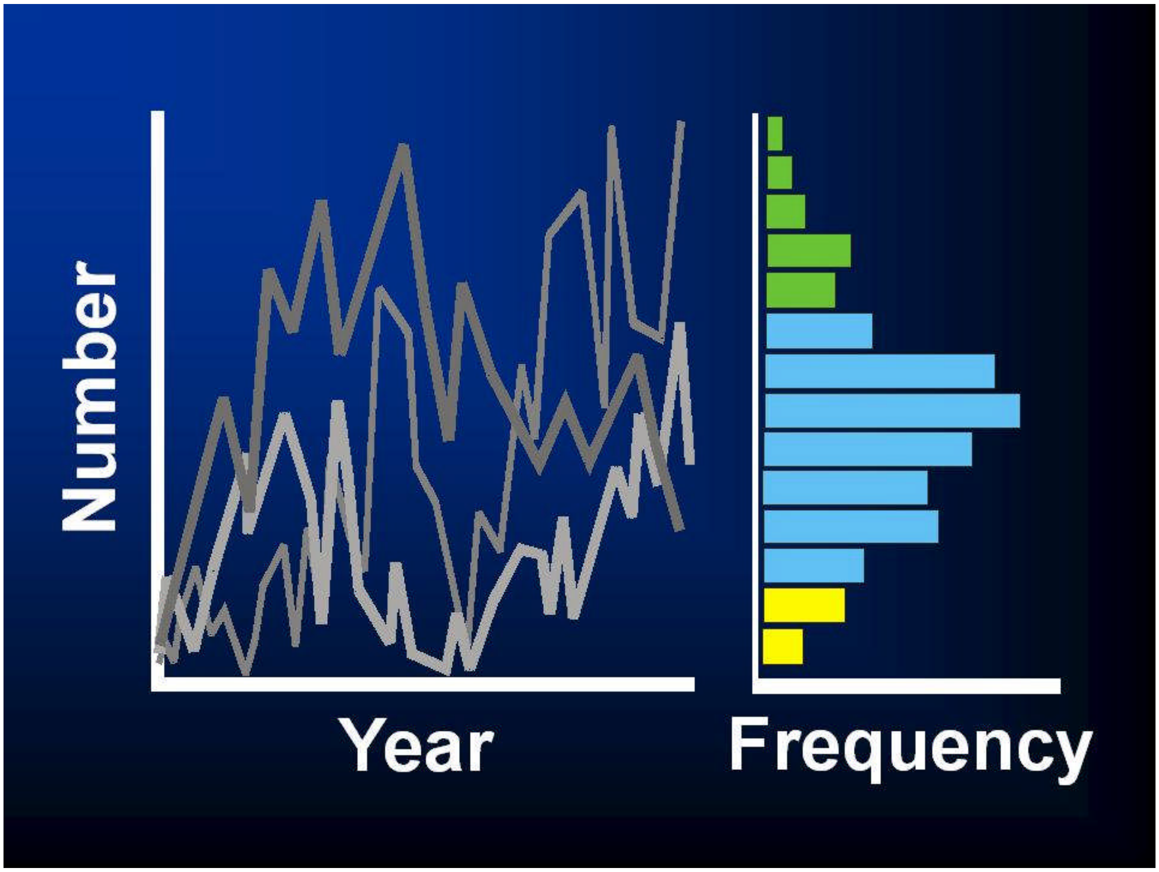
Prospective Analysis

How will future fisheries & escapements be affected?

- Unlimited combinations
- Multi-year effects
- Hypothetical / Assumptions

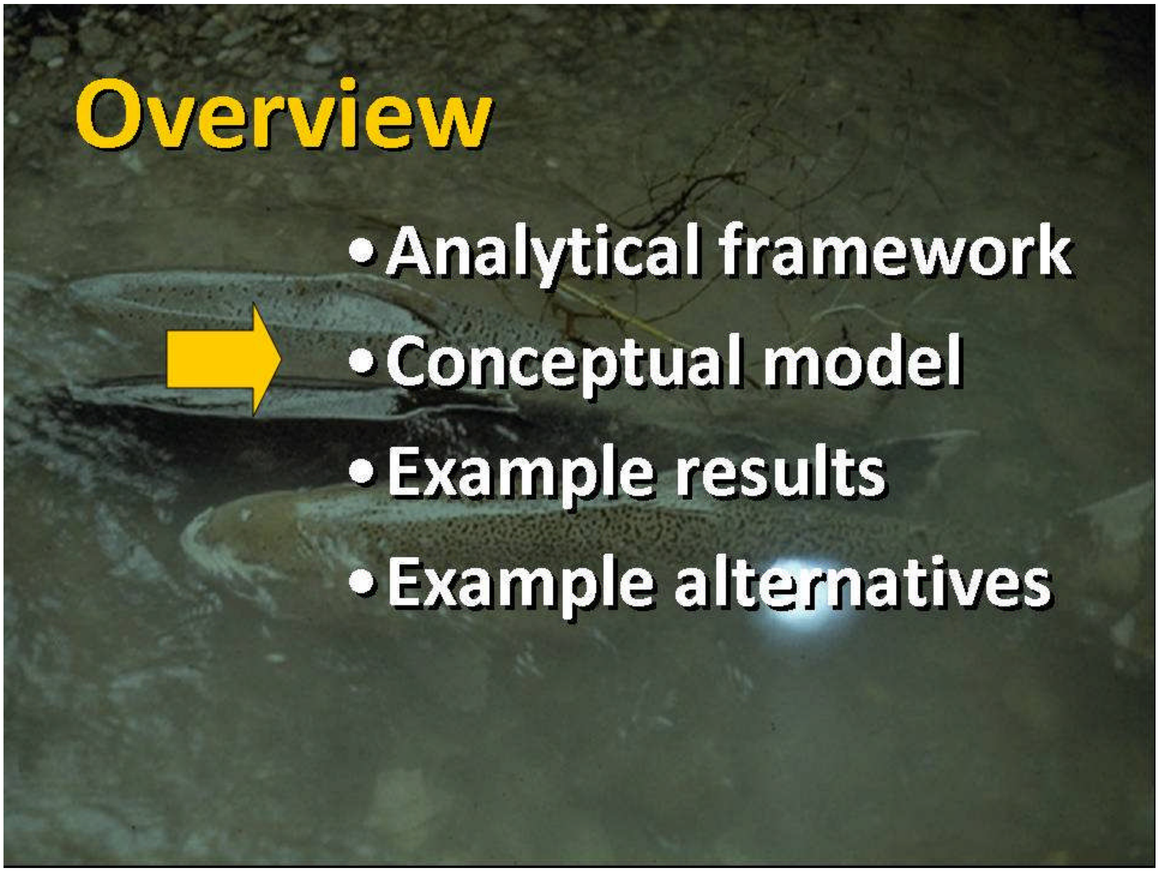
Prospective Risk Analysis





Why Risk Analysis?

- Emphasizes weak stock/pop conservation
- ESA/Recovery Plan Context
- Captures stock & environmental dynamics
- Real world standard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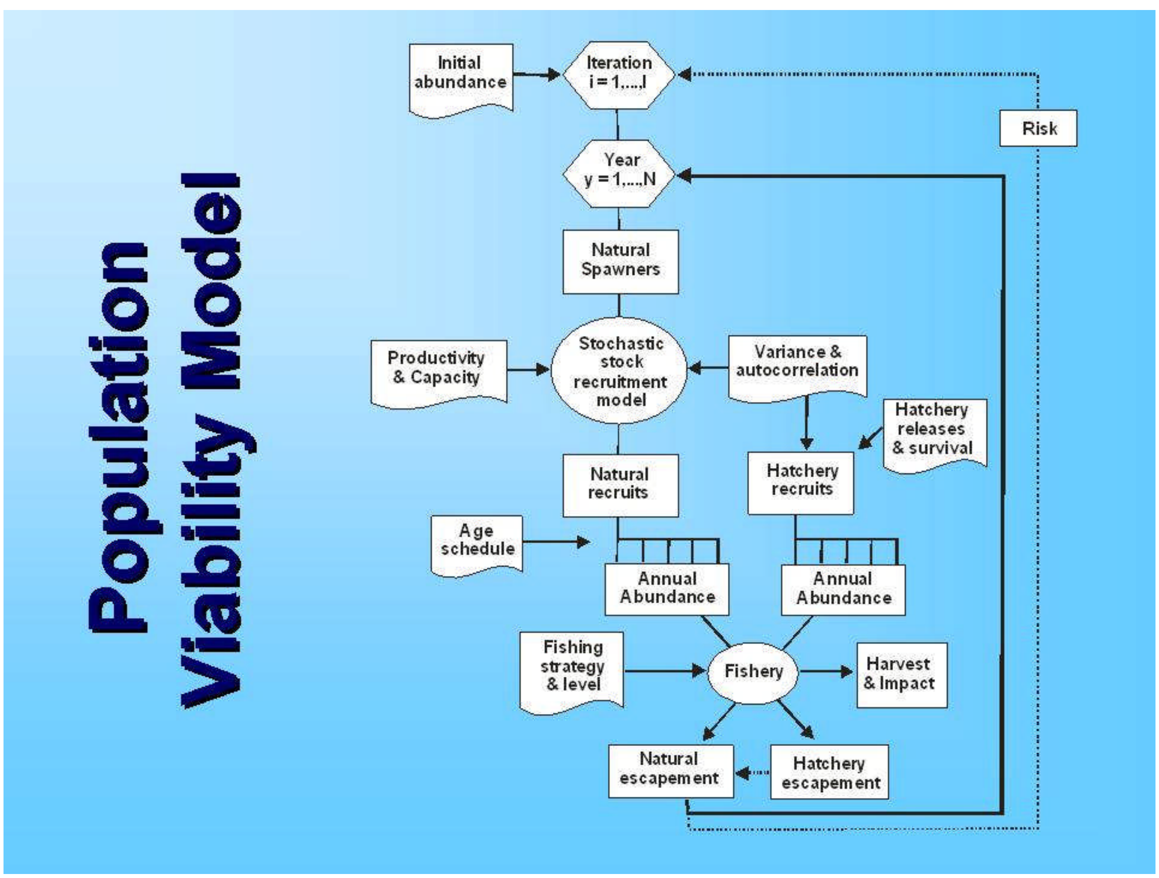
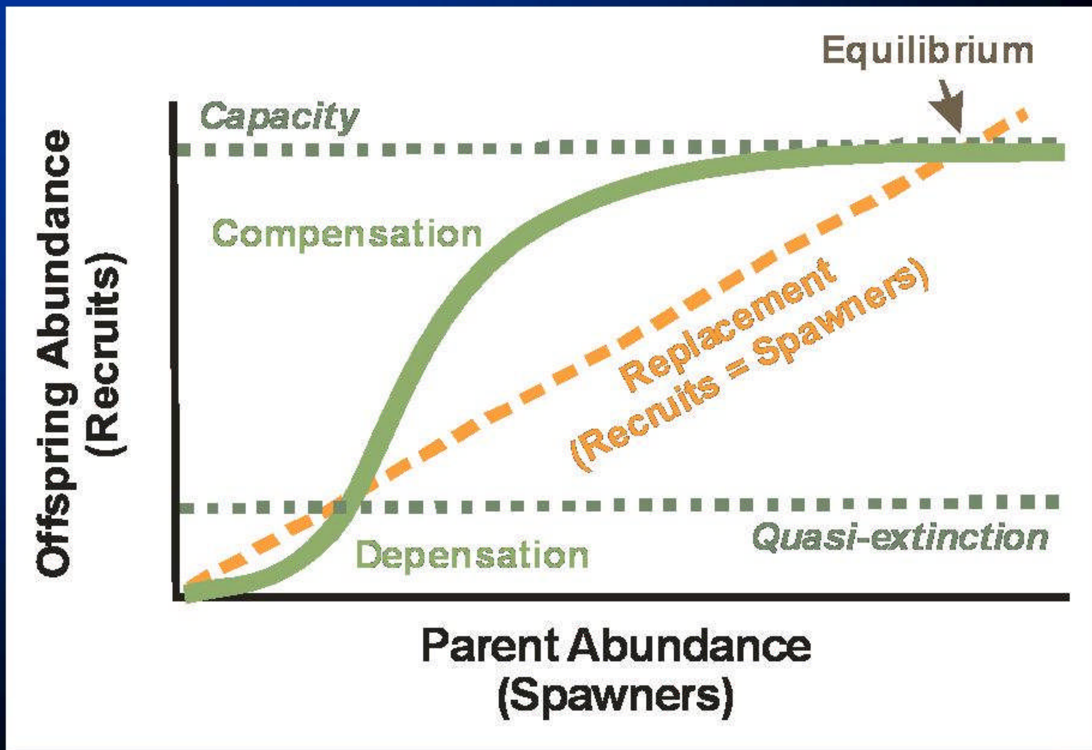
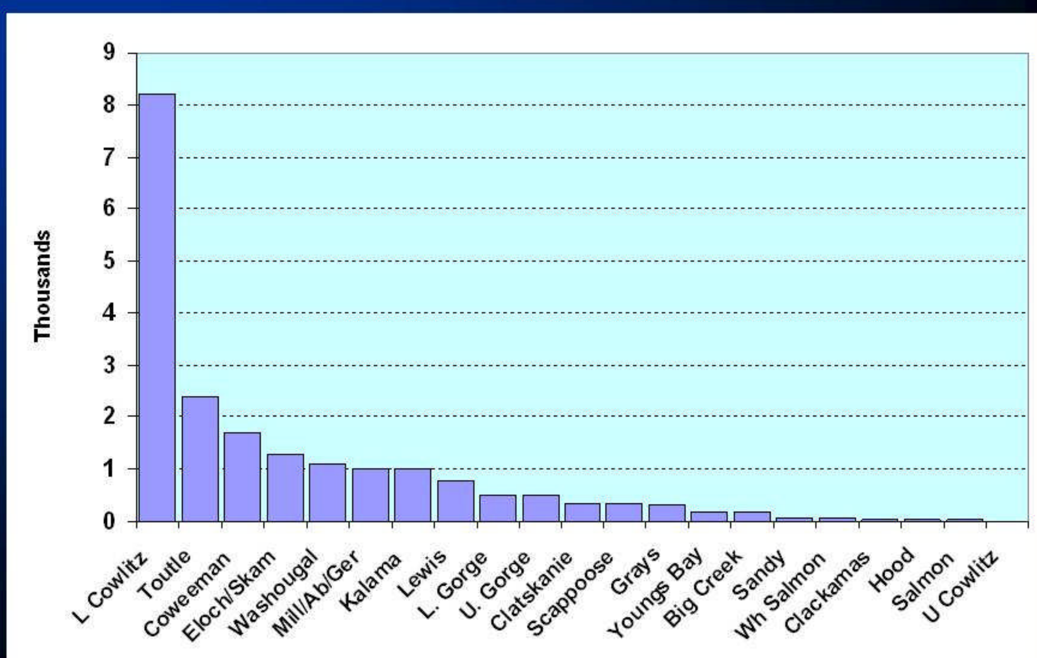
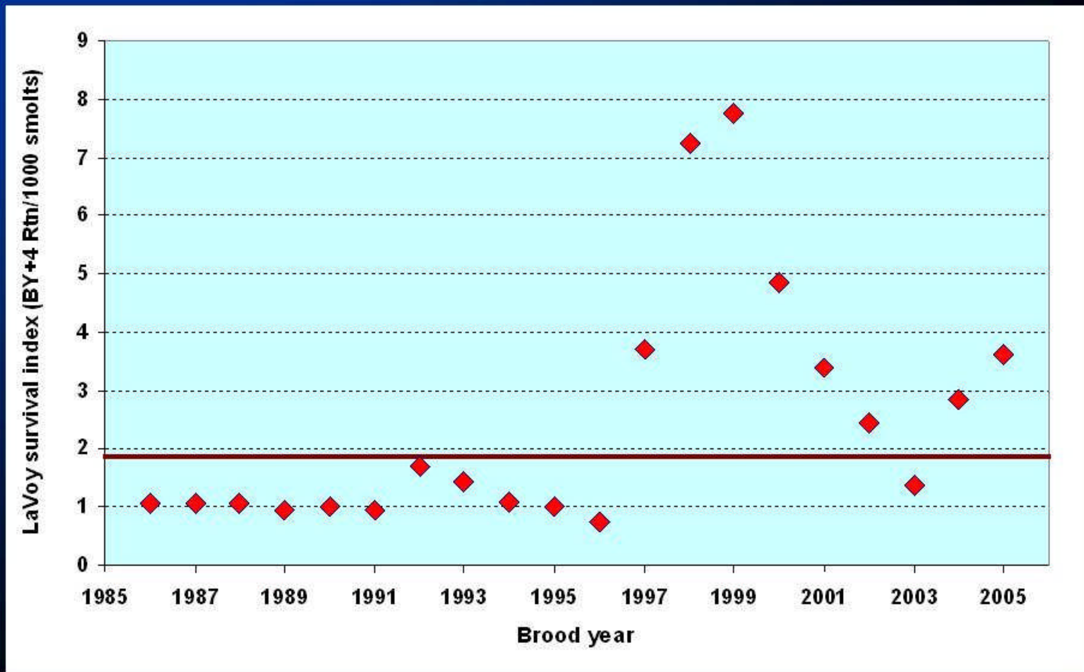

Population Viability Model
Initial abundance
Iteration i = 1,...,I
Risk
Year y = 1,...,N
Natural Spawners
Productivity & Capacity
Stochastic stock recruitment model
Variance & autocorrelation
Hatchery releases & survival
Natural recruits
Hatchery recruits
Age schedule
Annual Abundance
Annual Abundance
Fishing strategy & level
Fishery
Harvest & Impact
Natural escapement
Hatchery escapement



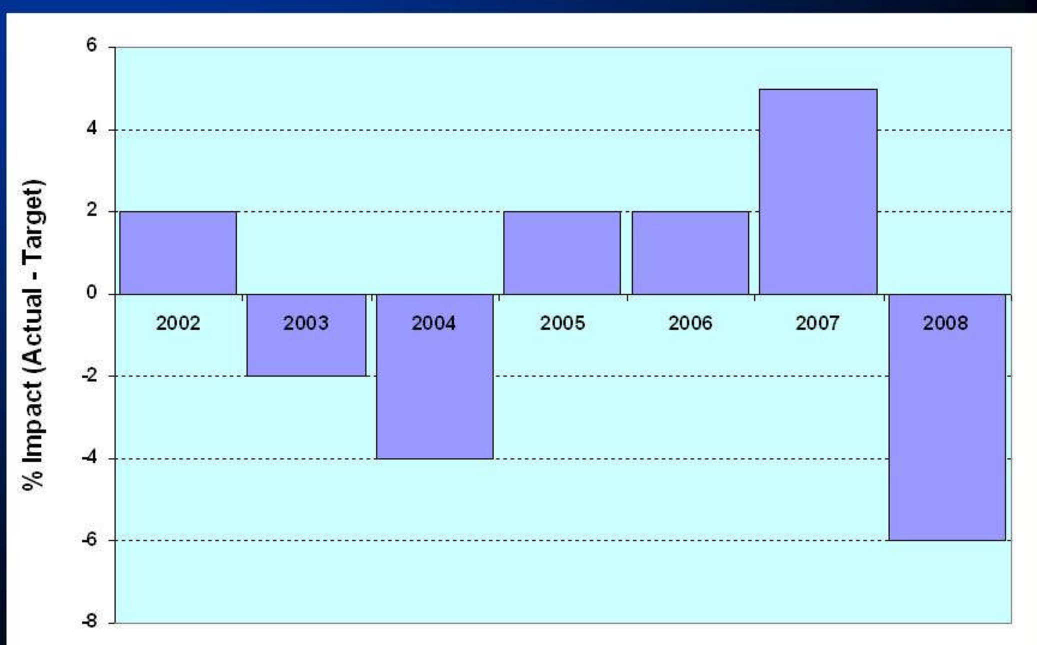
Population parameters

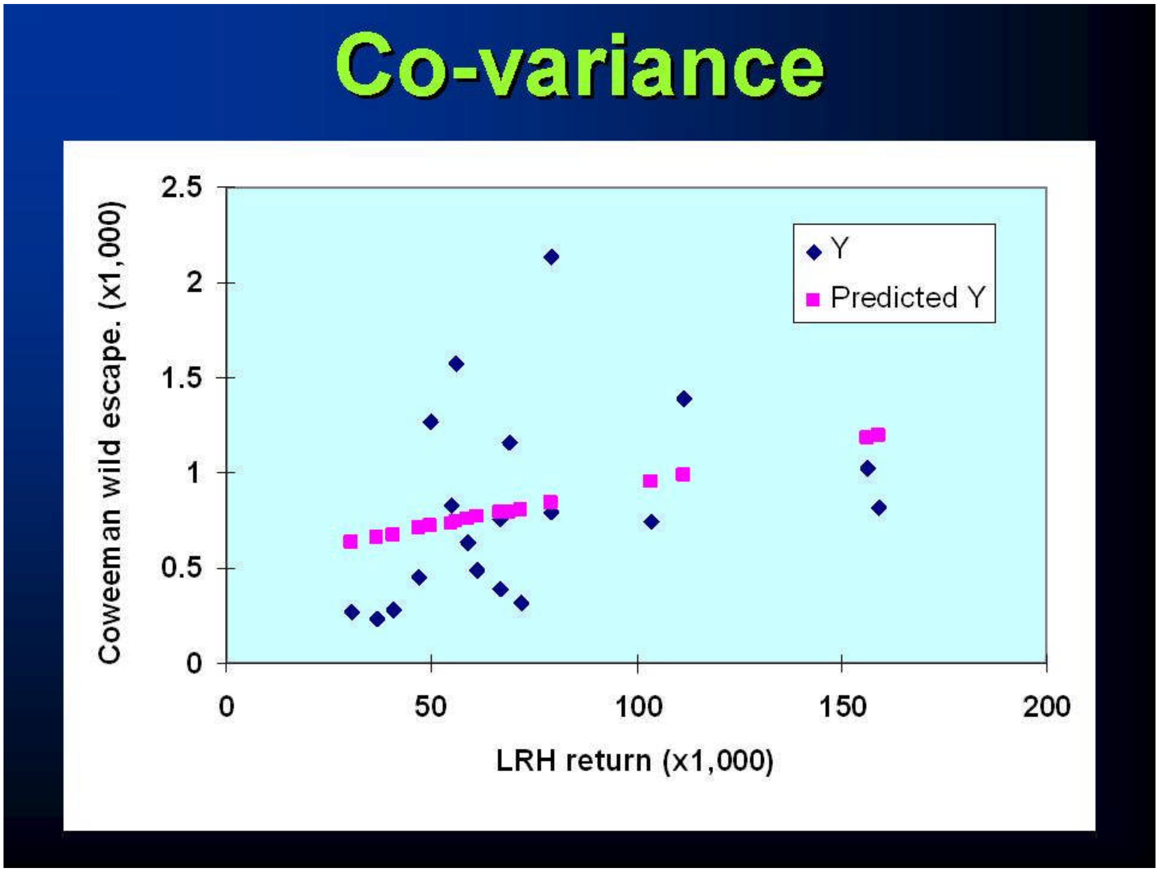


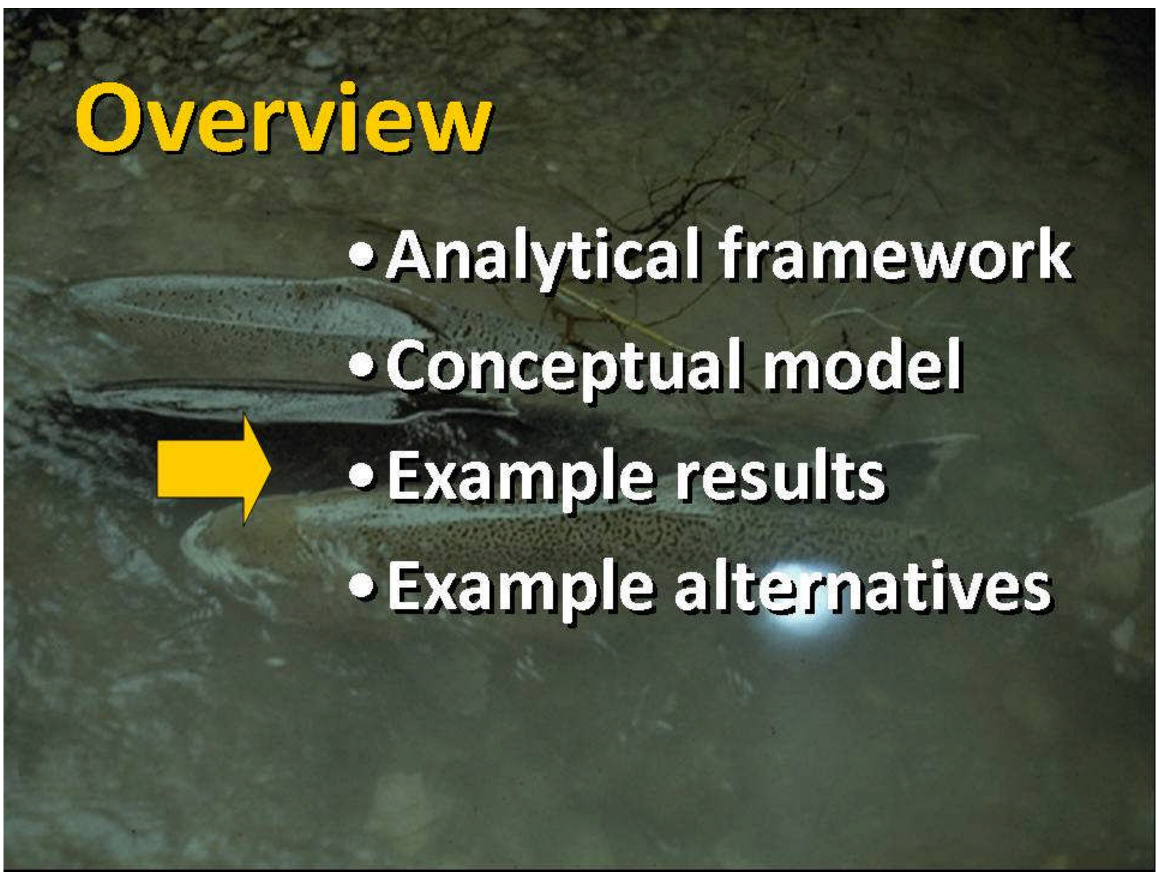
Variability



Implementation "error"




Co-variance
Coweeman wild escape. (x1,000)
LRH return (x1,000)
Y
Predicted Y
2.5
2
1.5
1
0.5
0
0
50
100
150
200


Overview
• Analytical framework
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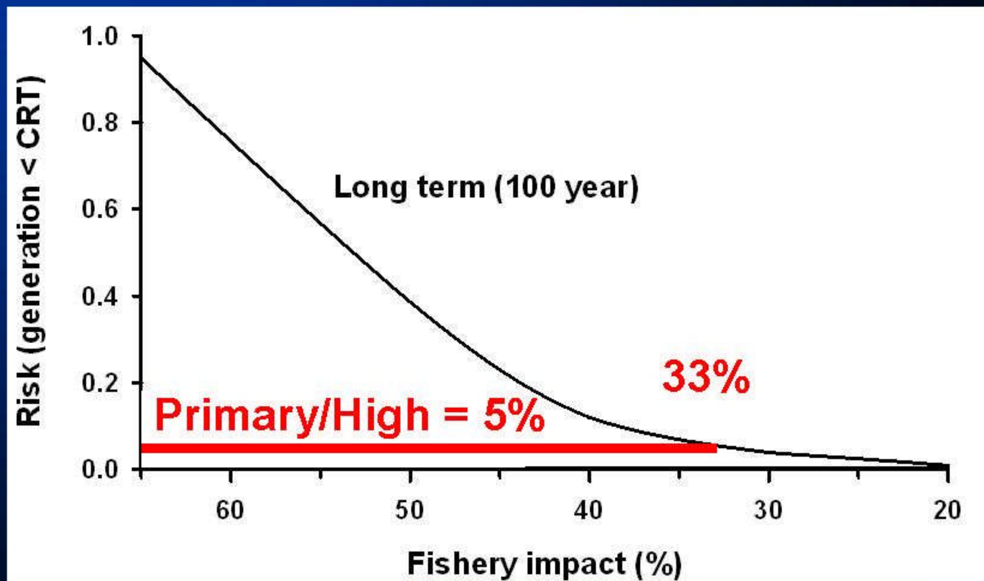
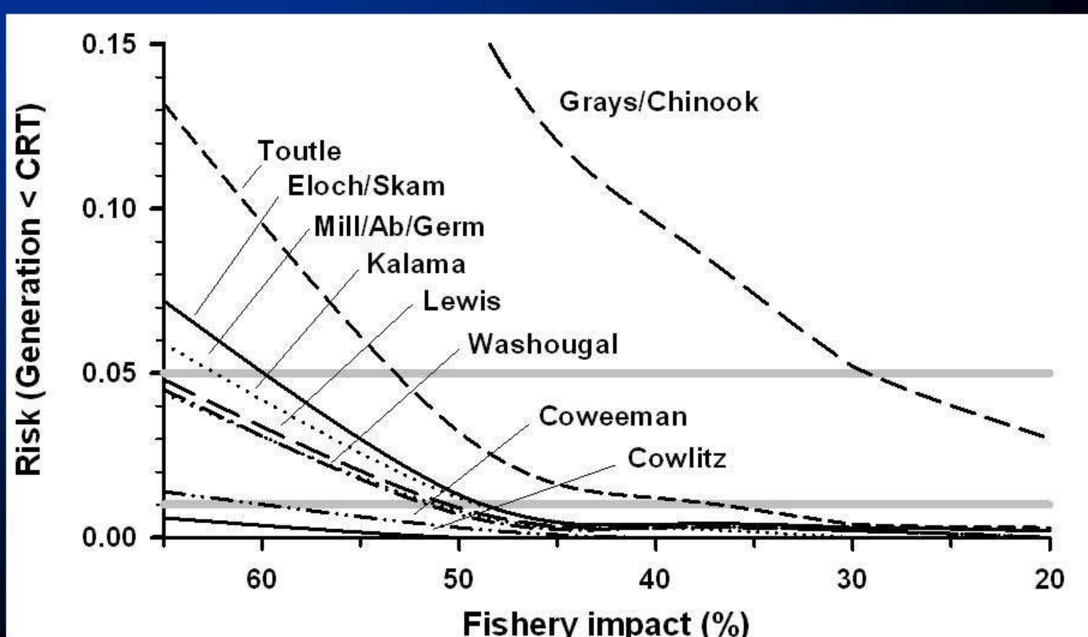
• Example alternatives

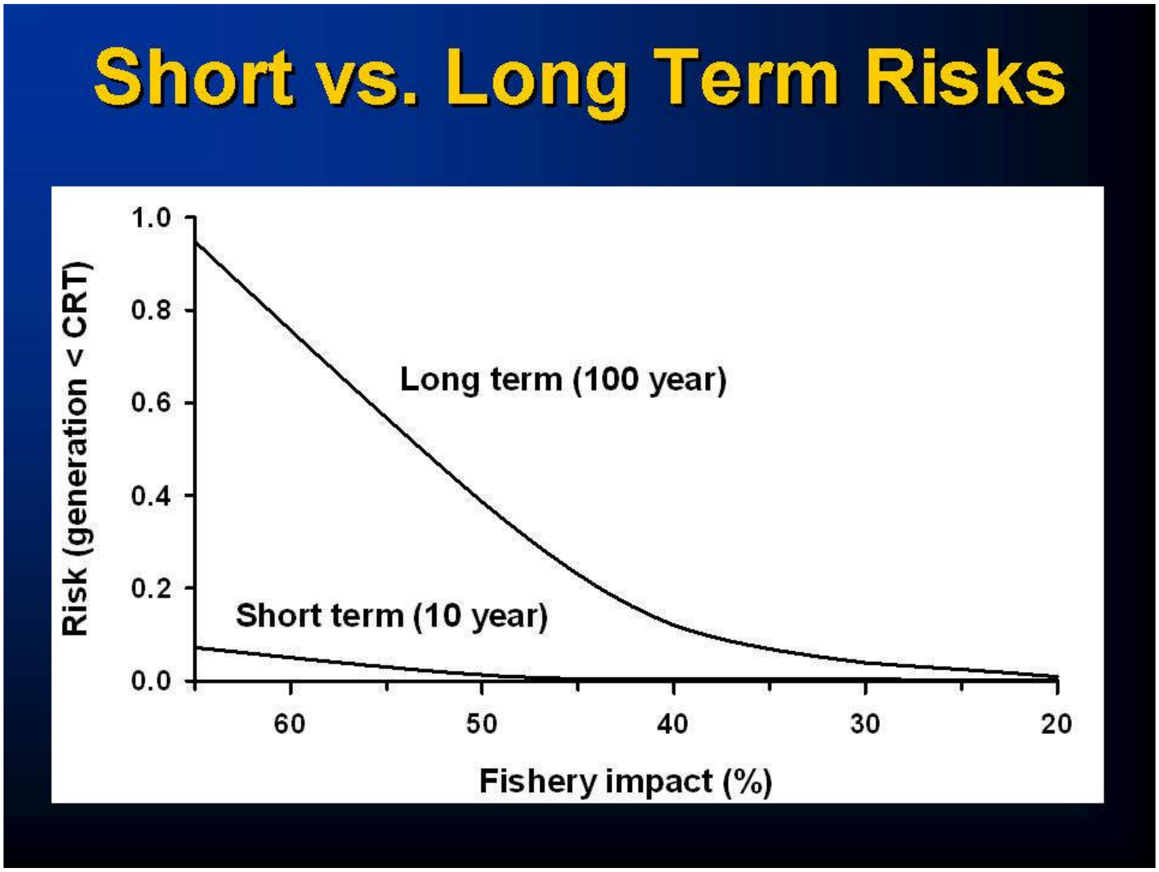
Example Analysis

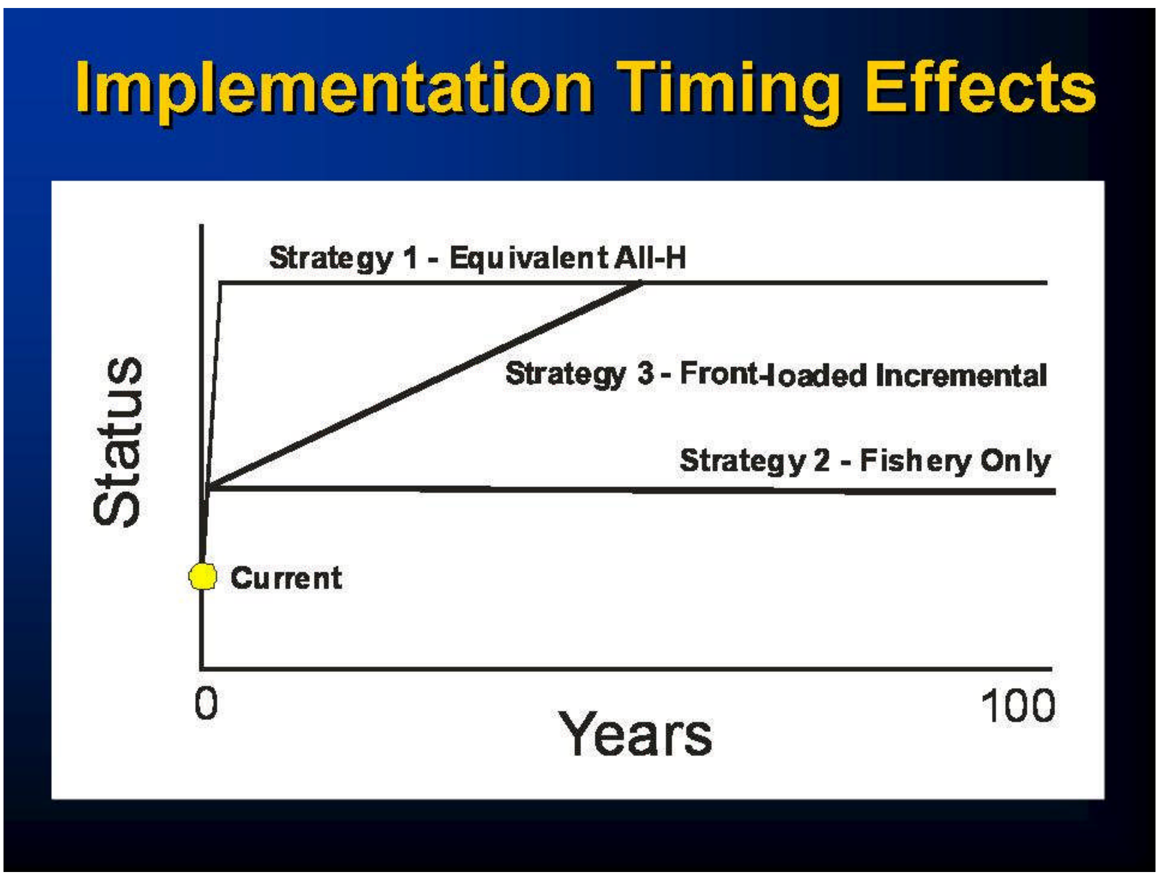


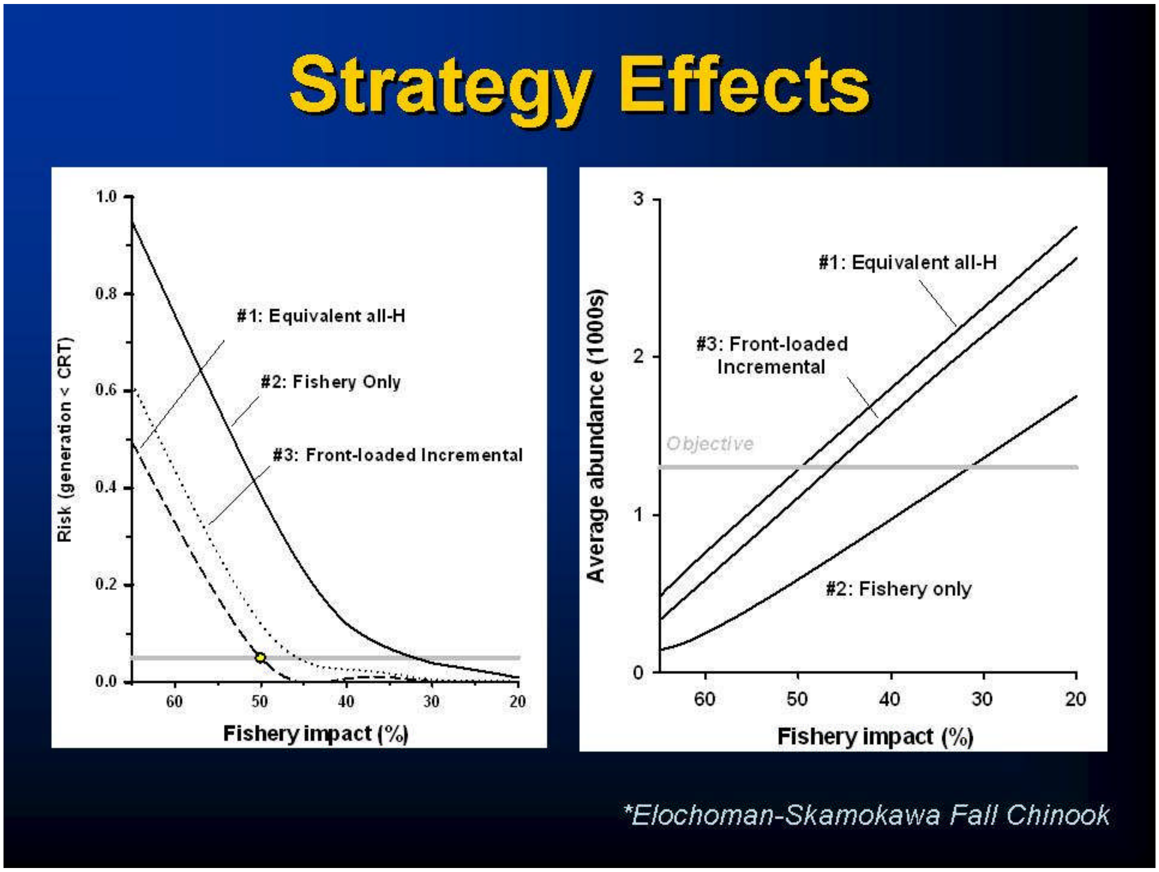
**Elochoman-Skamokawa Fall Chinook*

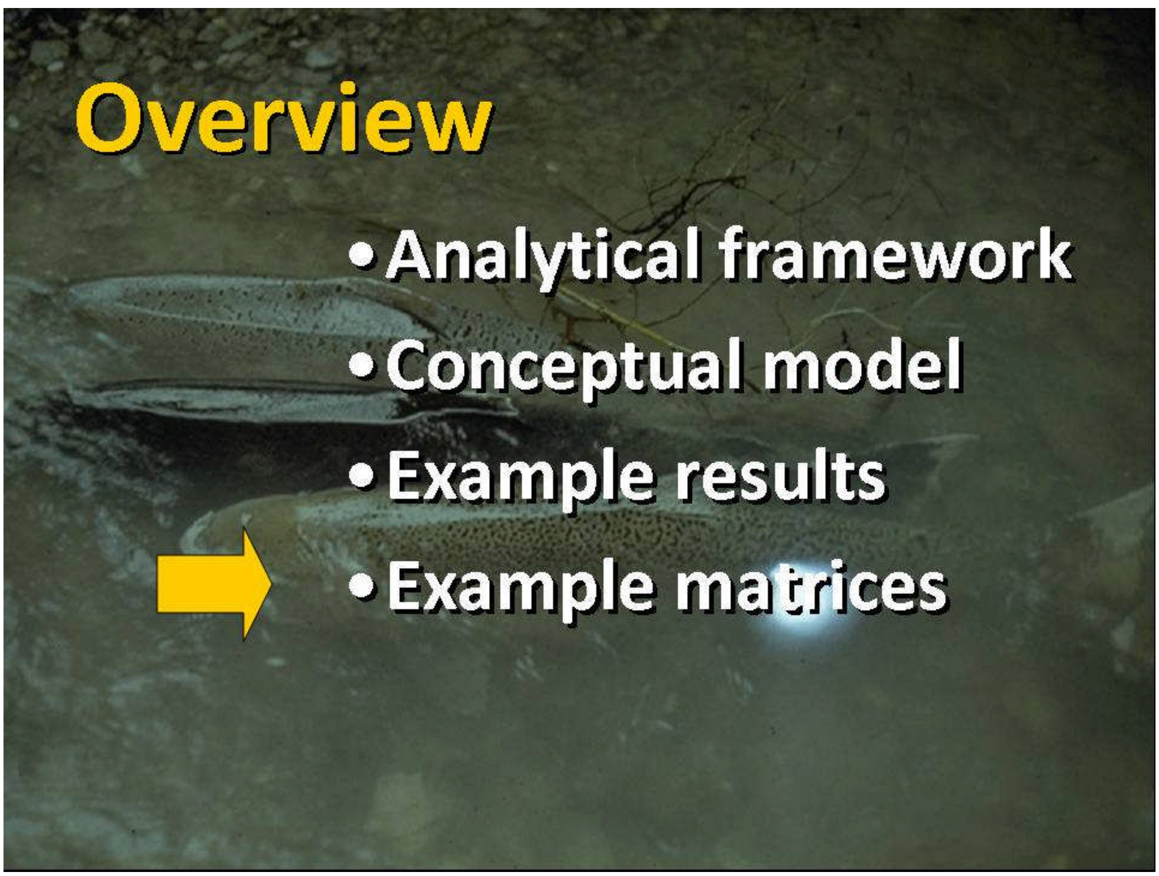
Population Differences




Short vs. Long Term Risks
1.0
0.8
0.6
0.4
0.2
0.0
Risk (generation < CRT)
Long term (100 year)
Short term (10 year)
60
50
40
30
20
Fishery impact (%)


Implementation Timing Effects
Strategy 1 - Equivalent All-H
Strategy 3 - Front-loaded Incremental
Strategy 2 - Fishery Only
Status
Current
0
100
Years


Strategy Effects
1.0
0.8
0.6
0.4
0.2
0.0
Risk (generation < CRT)
#1: Equivalent all-H
#2: Fishery Only
#3: Front-loaded Incremental
60
50
40
30
20
Fishery impact (%)
3
2
1
0
Average abundance (1000s)
#1: Equivalent all-H
#3: Front-loaded Incremental
Objective
#2: Fishery only
60
50
40
30
20
Fishery impact (%)
*Elochoman-Skamokawa Fall Chinook


Overview
• Analytical framework
• Conceptual model
• Example results
• Example matrices

OCN Coho Matrix

	Marine Survival Index			
Seeding	V Low	Low	Med	High
>75%	8%	15%	30%	45%
51-75%	8%	15%	20%	38%
19-50%	8%	15%	15%	25%
<19%	8%	11%	11%	11%
≤ 4 fish/mi	0-8%	0-8%	0-8%	0-8%

Matrix Alternatives

Indicators

- Wild populations
- Wild index pops.
- Hatchery aggregate

Metrics

- Abundance forecast
- Ocean survival index
- Environmental correlates
- Wild seeding level

Example 1a

LRH forecast	Impact
<40,000	33%
40,000 – 100,000	38%
>100,000	43%

*Aggregate / current ± 5%

Example 1b

LRH forecast	Impact
<40,000	28%
40,000 – 100,000	38%
>100,000	48%

*Aggregate / current ± 10%

Example 1c

LRH forecast	Impact
<40,000	33%
40,000 – 100,000	38%
>100,000	38%

*Aggregate / current -5%

Example 1d

LRH forecast	Impact
<40,000	28%
40,000 – 100,000	38%
>100,000	38%

*Aggregate / current -10%

Relative Outcomes

Case	Risk	Benefit
0	Equal	Equal
1	Low	High
2	High	Low
3	Equal	High
4	Low	Equal