Bayesian decision support to improve flexibility and reduce uncertainty in ecological forecasting of coho salmon survival

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Image by Ernest Keeley

Background

Most coho harvested in the Oregon Production Index (OPI) area originate from stocks produced in rivers within the OPI area (Leadbetter Point, Washington to the US/Mexico border).

Stocks include hatchery and natural production from the Columbia River, Oregon Coast, and Northern California.

Recognized components are public hatchery (OPIH), Oregon coastal natural (OCN), Lower Columbia natural (LCN), and natural and hatchery stocks south of Cape Blanco, Oregon.

The Pacific Fisheries Management Council (PFMC) has authority and responsibility for proposing final ocean salmon fishery management recommendations. To accomplish this, the Salmon Technical Team (STT) of the PFMC provides an assessment of salmon stock abundance projections and analysis of the impacts of year t-1 regulations on projected year t abundances. Population trends of concern are noted.

A more-or-less constant proportion of juvenile coho salmon return to rivers as jack salmon (precocious males) to spawn one year earlier than adults.

Stock assessment scientists (Salmon Technical Team of the PFMC) use the jack counts as a pre-season estimator of adult returns one year later.

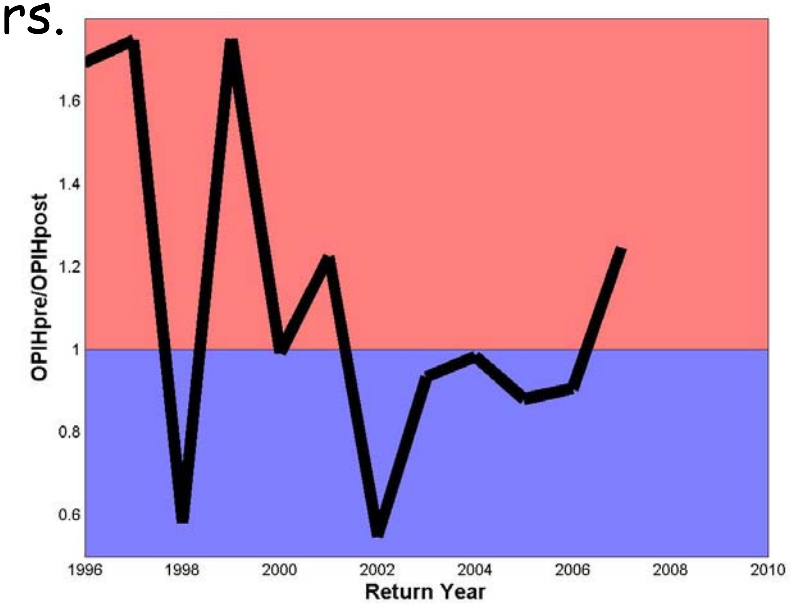
Two problems with this:

(1) the estimates can be very wrong in some years, and

(2) knowledge of jacks provides zero explanatory power for why returns are highly variable among years.

Jack Index: 1996-2008 Predictor performance ➔ usually within a factor of 2.

Can we do better? Do we need to do better?



Decision Making

Decision making activities require choosing a course of action from multiple alternatives and committing resources, using information that is

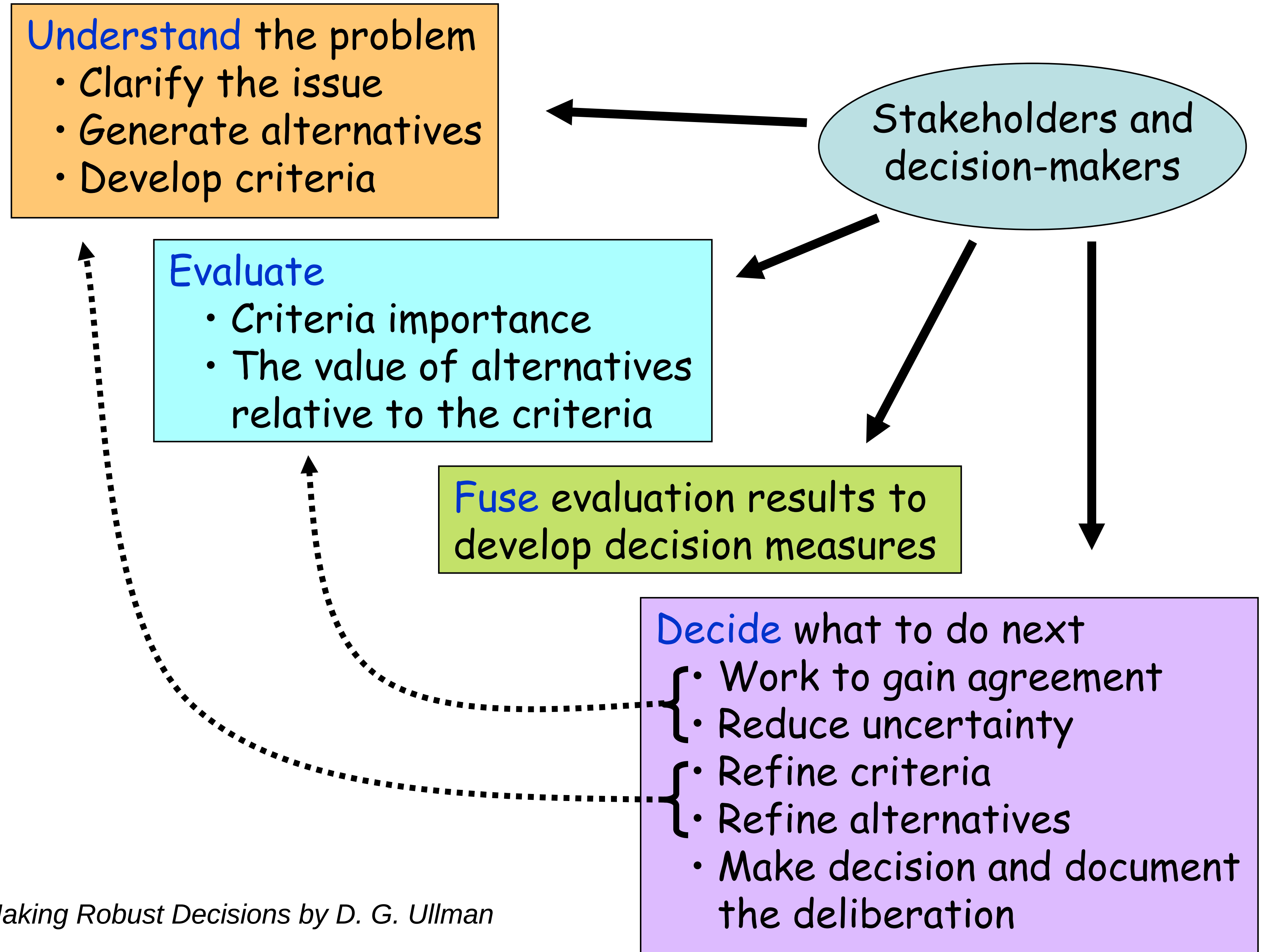
- Uncertain
- Incomplete
- Inconsistent
- Evolving

And based on input from stakeholders who

- Represent many different viewpoints, areas of expertise, and organizational functions
- Know only some of the relevant information
- May be distributed.

From Making Robust Decisions by D. G. Ullman

Steps to Decisions



From Making Robust Decisions by D. G. Ullman

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
PDO (December-March)	10	4	1	7	3	11	6	9	8	5	2
PDO (May-September)	8	2	3	4	5	10	9	11	7	6	1
MEI Jan-June	11	2	3	5	7	9	6	10	4	8	1
SST at 46050 (May-Sept)	9	2	4	5	1	7	11	8	6	10	2
SST at NH 05 (May-Sept)	8	2	1	4	7	6	11	10	5	9	3
SST winter before going to sea	11	6	4	5	3	7	10	9	8	2	1
Physical Spring Trans (Logerwe	9	5	2	1	4	7	6	10	7	3	***
Upwelling (Apr-May)	6	1	10	3	5	9	8	11	6	2	4
Deep Temperature (NH 05)	11	4	6	2	2	7	8	10	9	5	1
Deep Salinity (NH 05)	11	3	3	5	8	9	10	7	6	1	1
Length of upwelling season	11	3	5	3	2	7	9	10	7	6	1
Copepod richness	11	2	1	5	3	8	7	10	9	6	4
Northern Copepod Anomaly	11	7	3	5	2	9	6	10	8	4	1
Biological Transition	11	6	3	2	5	9	7	10	8	4	1
June-Chinook Catches	10	2	3	8	5	7	9	11	6	4	1
Sept-Coho Catches	8	2	1	4	3	5	10	9	6	7	***
Baitfish abundance	9	10	4	1	3	2	5	6	8	7	***
Coho salmon returns	9	6	1	4	2	3	8	7	5	***	***
Mean of Ranks	9.9	3.4	3.5	4.3	4.1	8.1	8.2	9.7	6.9	5.0	1.7
RANK of the mean rank	11	2	3	5	4	8	9	10	7	6	1

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SST at 46050 (May-Sept)											2
SST at NH 05 (May-Sept)											3
SST winter before going to sea	1										1
Physical Spring Trans (Logerwe											***
Upwelling (Apr-May)											4
Deep Temperature (NH 05)	1										1
Deep Salinity (NH 05)	1										1
Length of upwelling season	1										1
Copepod richness	1										4
Northern Copepod Anomaly	1										1
Biological Transition	1										1
June-Chinook Catches	1										1
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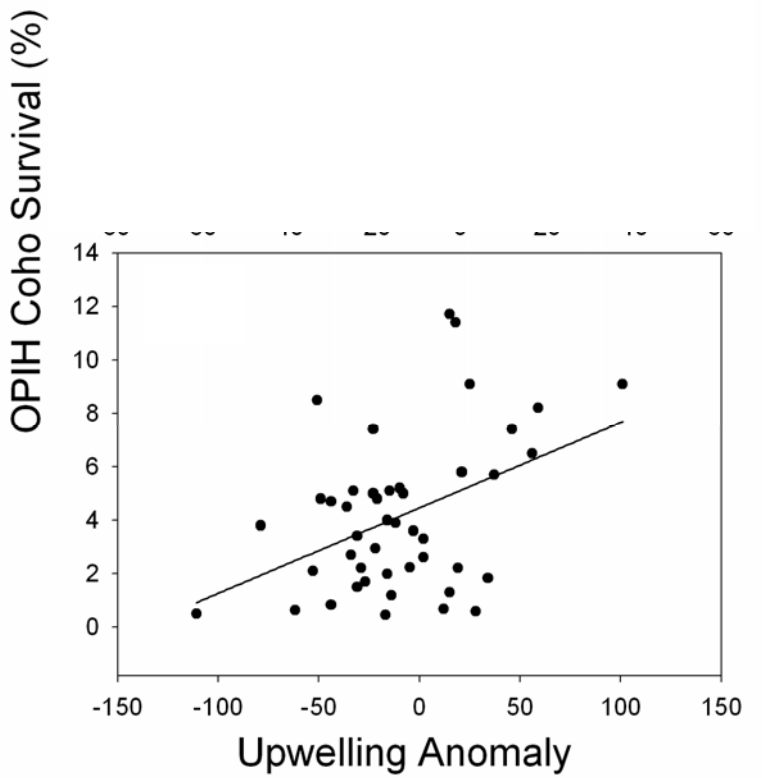
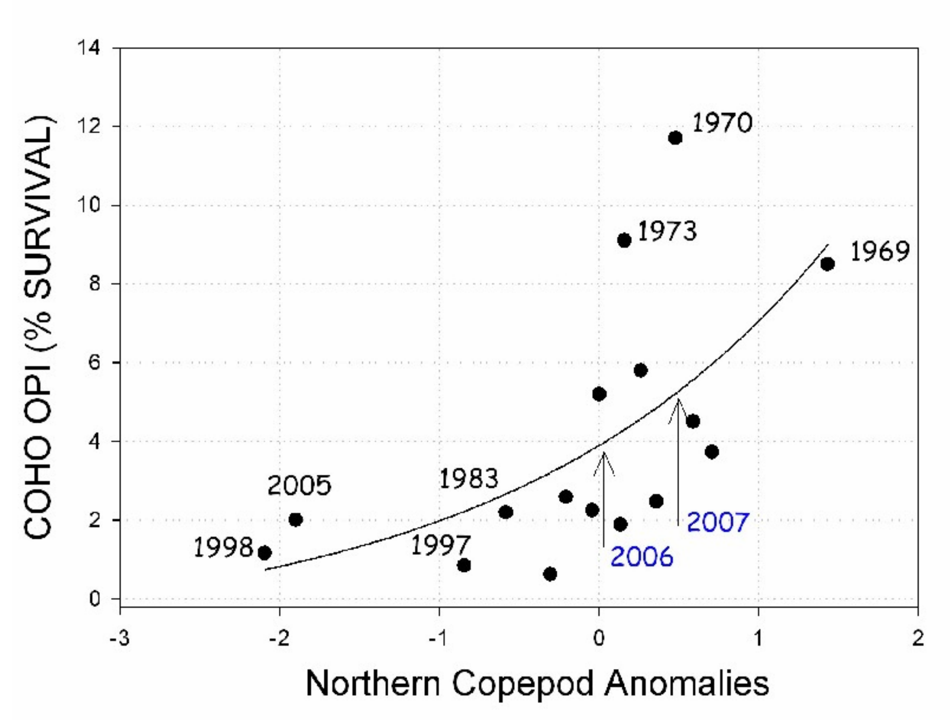
17 indicators, but many of them provide similar information; e.g., three global indices, three SST indices. This information is being used in an ad-hoc fashion now; each value is given a green (good), red (bad) or yellow (intermediate) light, where green is presumed to lead to high juvenile coho salmon survival, and red is presumed to lead to low survival.



Scattergram of coho survival vs. April-May CUI anomaly for 45°N, 1960–2004.



Regression of OPIH coho survival on the northern copepod biomass anomalies. Values for copepod anomalies in 2006-2007 are indicated by arrows.

http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/g-forecast.cfm

Forecast of Adult Returns for Coho in 2009 and Chinook in 2010

(NWFSC Web site: www.nwfsc.noaa.gov/research/divisions/fed/oeip/g-forecast.cfm)

Large-scale Ocean & Atmosphere Indicators

- PDO, MEI

Local/Regional Physical Indicators

- SSTa, UpAnom, PhysSprTrans, BottomT&S

Local Biological Indicators

- CopBiodiversity, NoCopAnom, BiolSprTrans, JunSprChin, SeptCohoCatch, ZooSpeciesComp

Indicators in Development

- BasinMode2SST
- PhytoBiomNewport
- EuphEggAbund, EuphAdultBiomass
- HabitatArea (based on Chl and copepod biomass)
- ForageFishAbund

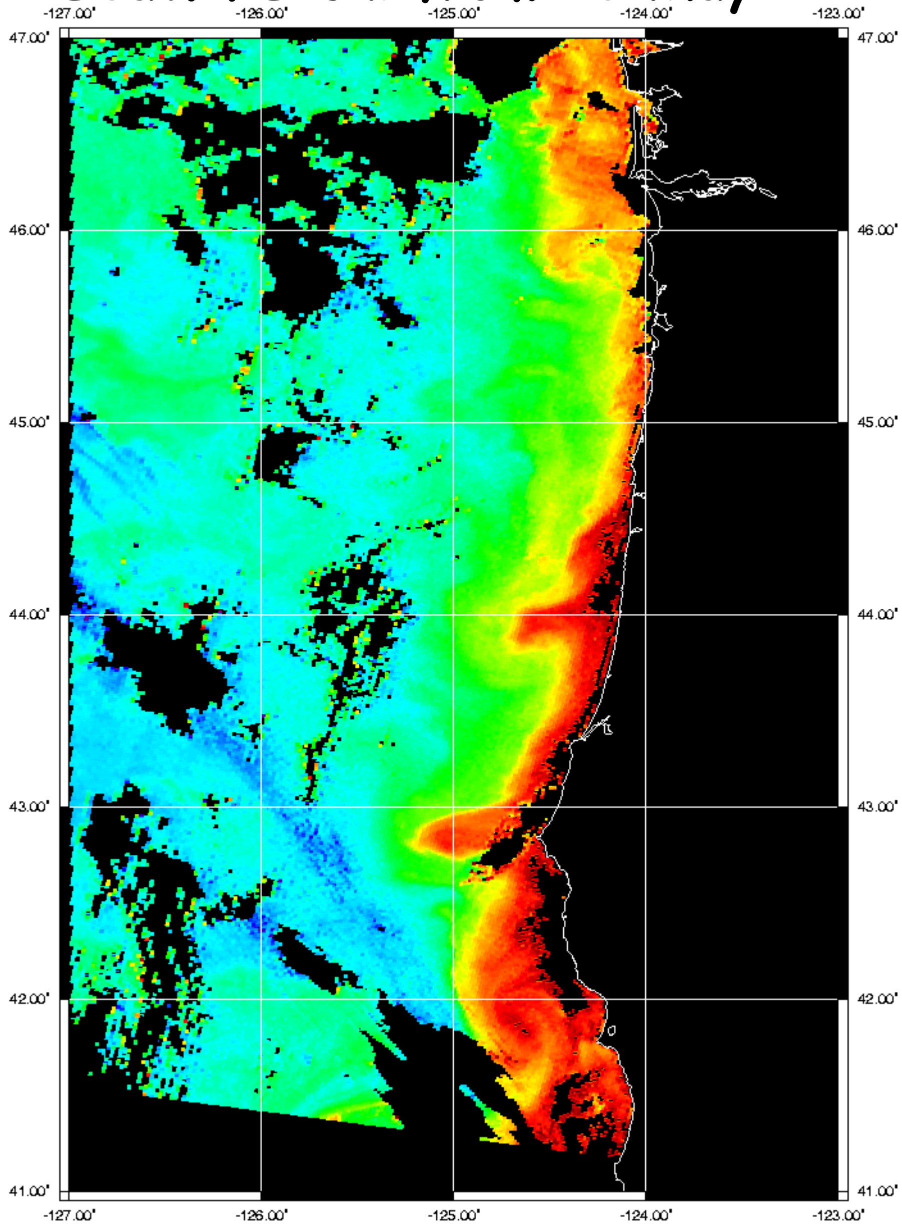
Potential Indices

- CRFlow, CohoJackPred, SalmonHealth (disease/parasite based), additional satellite- and model-based indices

"red light-green light" approach

Satellite Observations

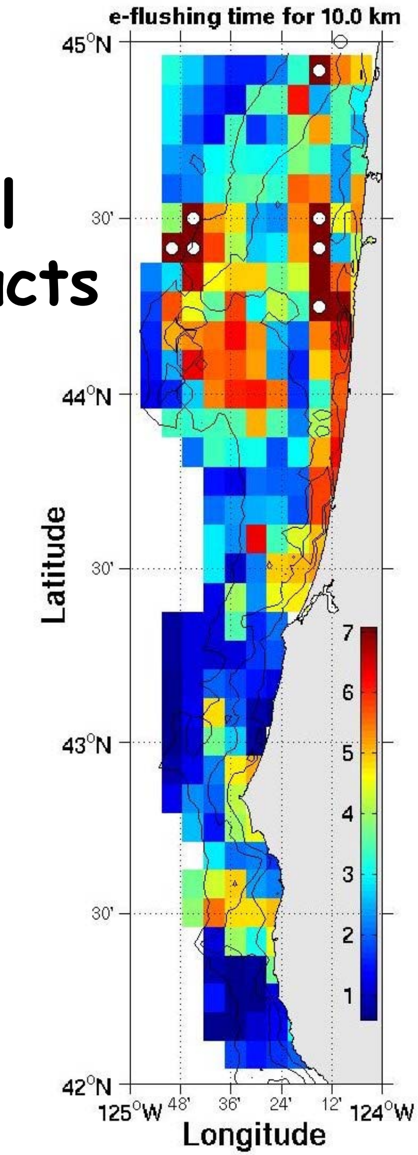
SeaWiFS chl from 23 May 2002



Retention Time

RCCS – 1 km
23 May 2002

Model Products



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A diverse menu of choices, many with overlapping information (e.g., CopBiodiversity, NoCopAnom) and with conflicts and uncertainty, and for which stakeholder beliefs (values) vary widely.

What to do?

Criteria for evaluating ocean environment conditions for juvenile coho salmon

Measured Feature	Type	Units	Delighted Level	Disgusted Level
PDO-Dec-Mar	less-is-better	index	-2.5	2.5
Upwelling Anomaly April-May	more-is-better	index	0	-20
Northern Copepod Anomaly	more-is-better	log_biomass	0.5	-0.7
September Coho catch	more-is-better	fish per km	1.0	0.2
Date of Biological Spring	FIVE-POINT SCALE	Satisfactory (Mar), Mostly Satisfactory (Apr), Average (early-May), Mostly Unsatisfactory (late-May), Unsatisfactory (Jun or later)		

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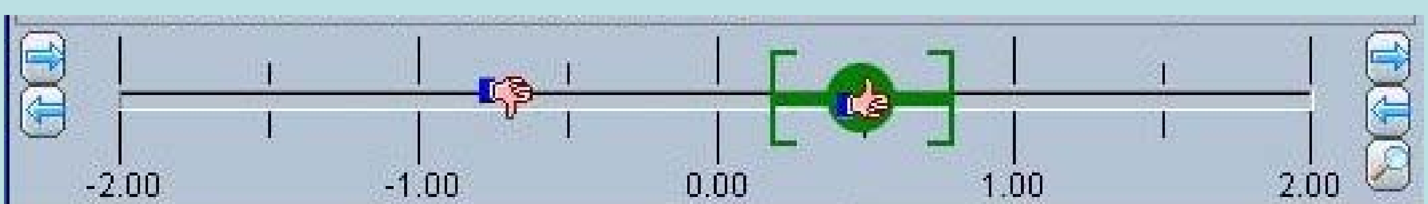
S C				
D B S				

Input: Value and uncertainty estimate for NCA for 2007.



Members and Criteria Importance Weighting

Weights based on Rank Order Centroid Method

Ranking (k)	W_k Proportion	HPB	Top-down bias	Bottom-up bias
1st	0.46	Northern Copepod Anomaly	September Coho catch	PDO-Dec-Mar
2nd	0.26	Date of Biological Spring	Northern Copepod Anomaly	Upwelling Anomaly April-May
3rd	0.16	Upwelling Anomaly April-May	Date of Biological Spring	Date of Biological Spring
4th	0.09	PDO-Dec-Mar	Upwelling Anomaly April-May	Northern Copepod Anomaly
5th	0.04	September Coho catch	PDO-Dec-Mar	September Coho catch

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HPB's beliefs/bias is that trophic quality/biomass (NoCopAnom) and timing of spring are "really important" to salmon survival. Other stakeholders might feel differently.

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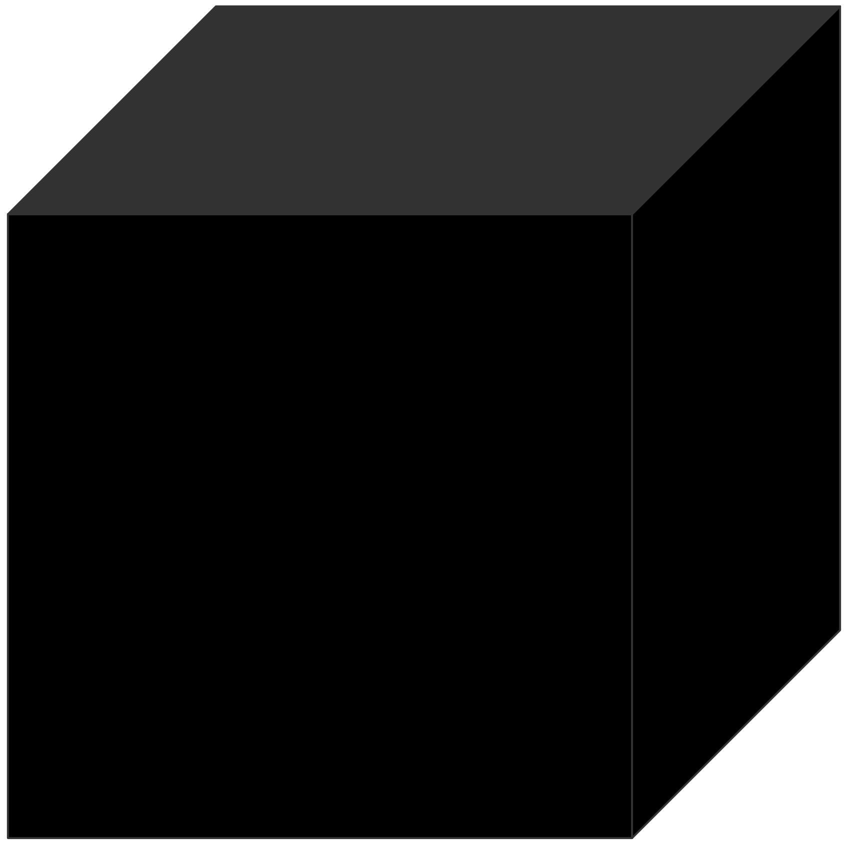
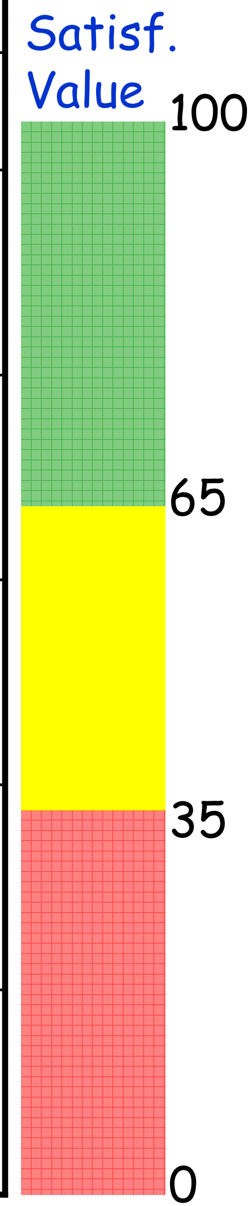
The Bayesian Team Support number-cruncher

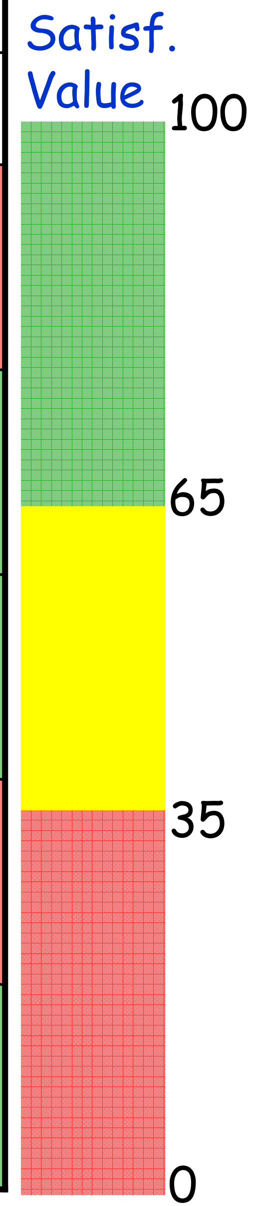


Output is satisfaction scores [that year XXXX will have good salmon survival (e.g., high returns)] for each stakeholder weighted by their beliefs of what is important.

Year	HPB Satisfaction	Top-down bias Satisfaction	Bottom-up bias Satisfaction
	value / (within row rank) {within column rank}	value / (within row rank) {within column rank}	value / (within row rank) {within column rank}
1998	5 / (2) {5}	3 / (3) {5}	8 / (1) {5}
2000	82 / (2) {1}	89 / (1) {1}	73 / (3) {1}
2002	76 / (2) {3}	83 / (1) {2}	69 / (3) {2}
2004	35 / (1) {4}	20 / (2) {4}	14 / (3) {4}
2007	78 / (1) {2}	44 / (3) {3}	66 / (2) {3}



Year	HPB Satisfaction	Top-down bias Satisfaction	Bottom-up bias Satisfaction
	value	value	value
1998	5	3	8
2000	82	89	73
2002	76	83	69
2004	35	20	14
2007	78	44	66



Social Complexity & Fragmentation

Forces of Fragmentation: forces that challenge collective intelligence and make collaboration difficult or impossible.

Collective Intelligence: the creativity and resourcefulness that a group or team can bring to a collaborative problem.

Ecological forecasting of salmon (and fisheries management) is a collaborative problem.

Fragmentation = ⇑f(wickedness, social complexity)

Social Complexity: the number and diversity of stakeholders who are involved in a project.

Wicked Problems: best described by their characteristics…

You don't understand the problem until you have developed a solution.
Stakeholders have radically different world views and different views about what the problem is and what constitutes an acceptable solution.
Constraints and resources to solve the problem change over time.
There is no stopping rule; the problem is never solved.
Solutions are not right or wrong—only good enough or not good enough.

Ideas from Conklin (2005), *Dialog Mapping: Building Shared Understanding of Wicked Problems*

Stakeholders need to understand each other's positions well enough to have intelligent dialogue about the different interpretations of the problem, and to exercise collective intelligence about how to cope with it (Note: not "solve it").

Formal Decision Support Systems provide a framework to achieve effective stakeholder collaboration.

Summary & Concluding Thoughts

- Social complexity makes it difficult to achieve consensus decisions. Salmon forecasting and fisheries management, in general, is a socially complex problem.
- Formal Decision Support Strategies (DSS) provide ways to include bias, data trustworthiness, criteria importance, and world beliefs of diverse stakeholders.
- DSS may not achieve consensus, but through the process you have qualitatively or quantitatively accounted for uncertainty, bias & beliefs and can document why dissenting opinions persist.
- DSS applied to salmon forecasting has potential societal benefits:
    - broader stakeholder participation
    - improved management of threatened/endangered wild stocks
    - greater certainty of returns for managers, fishers and in-stream flow managers
    - better targeting of salmon mitigation/restoration efforts
    - reduced costs of salmon management