The use of regional scale risk analysis to integrate science, risk, and policy and decision making.

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Introduction to the presentation

First Principals—and a reality check

Regional risk assessment and the relative risk model.

Bayesian Networks applied to regional risk assessment

IEA is a regional risk assessment

Part 1-First Principals

My point of view of the Salish Sea is probably a bit different……

First Principals-1

Societal values are often expressed in normative terms (health, integrity, normal, historical, resilience) that are not part of ecological structures.

To manage an ecological structure values need to be expressed in explicit terms amenable to mathematical expression.

First Principals-2

The mathematical expression has to reflect cause-effect relationships and the probabilistic nature of these interactions.

The expression should be tractable by at least simulation and should be the simplest necessary to make a decision.

Part 2-Regional risk assessment and the relative risk model.

Some Worldwide Examples

Northern Tropical Rivers Australia-Renee Bartolo, Rick van Dam and Peter Bayliss, CSIRO

North Hebei Province and Island systems--Xiaolong Wang, China

Delaware River and Bay-Ralph Stahl, Dupont, USA

Fundamentals of regional risk assessment

Conventional Risk Approach

Regional Risk Assessment using the RRM

Location-Location-Location

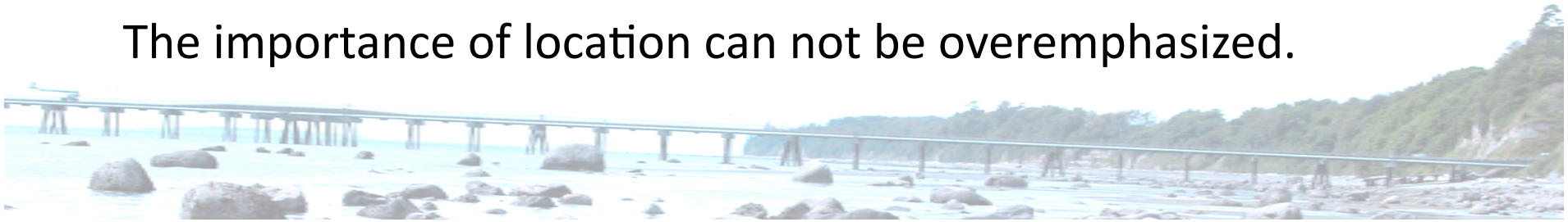
Fundamentals of regional risk assessment

Origin of set of stressors, chemicals, invasive species, temperature change, habitat alteration.

The location or potential location of the organisms for ecological services being managed.

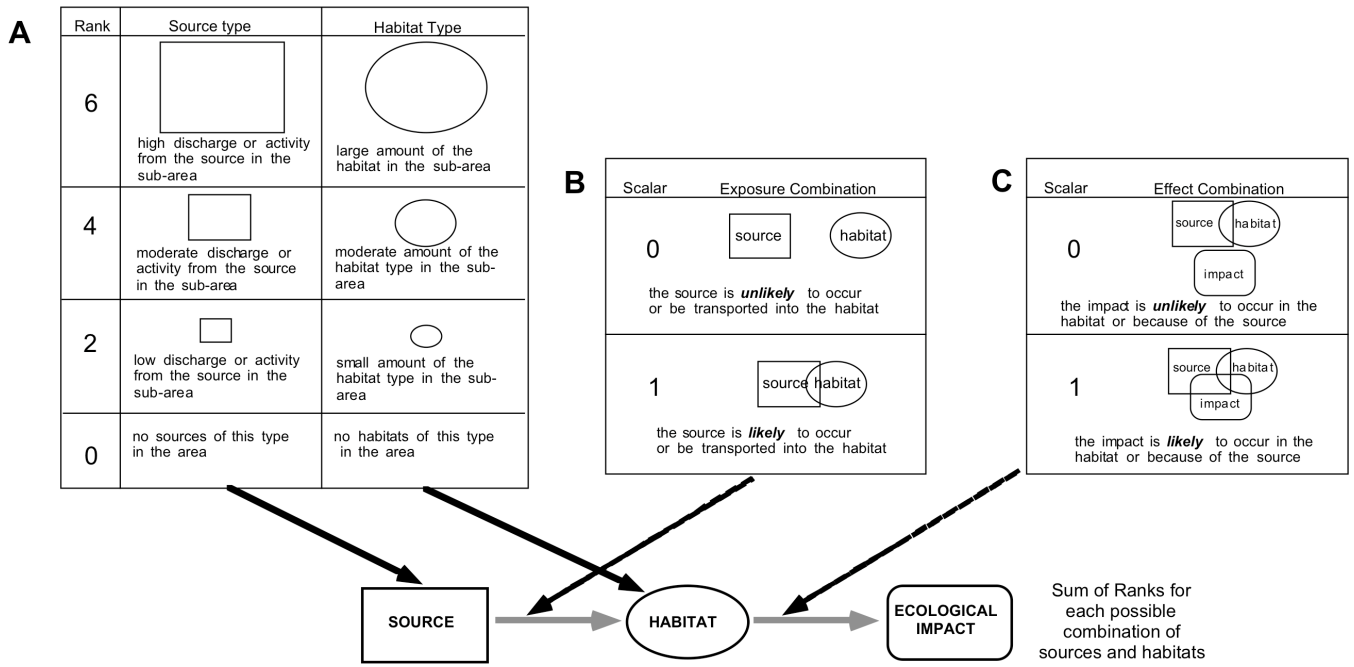
The combination of the effects to the number of assessment endpoints under management consideration.

The importance of location can not be overemphasized.



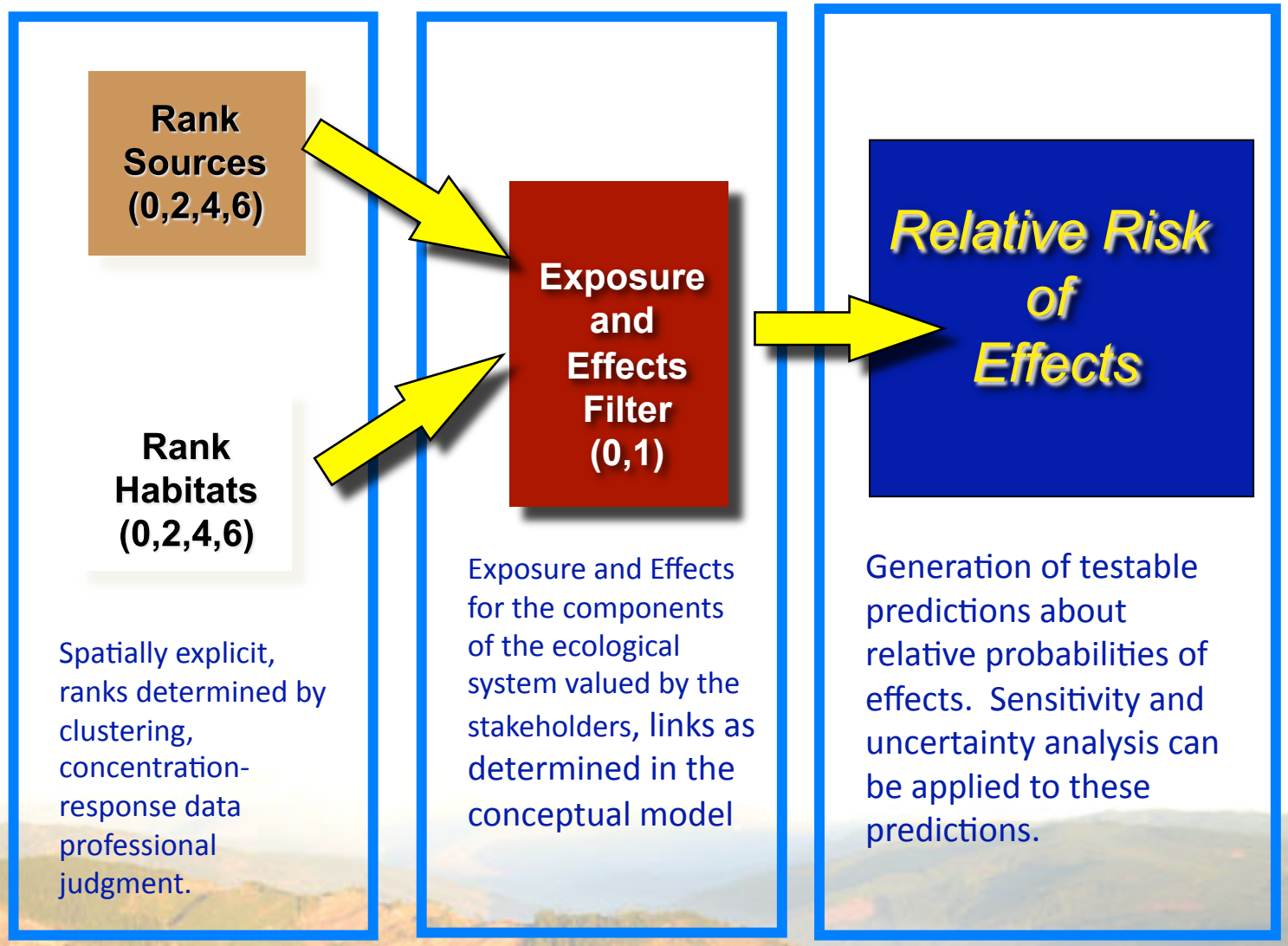
Fundamentals of regional risk assessment

Diagram of the ranking and combining process for the fjord of Valdez, still works with some modification.



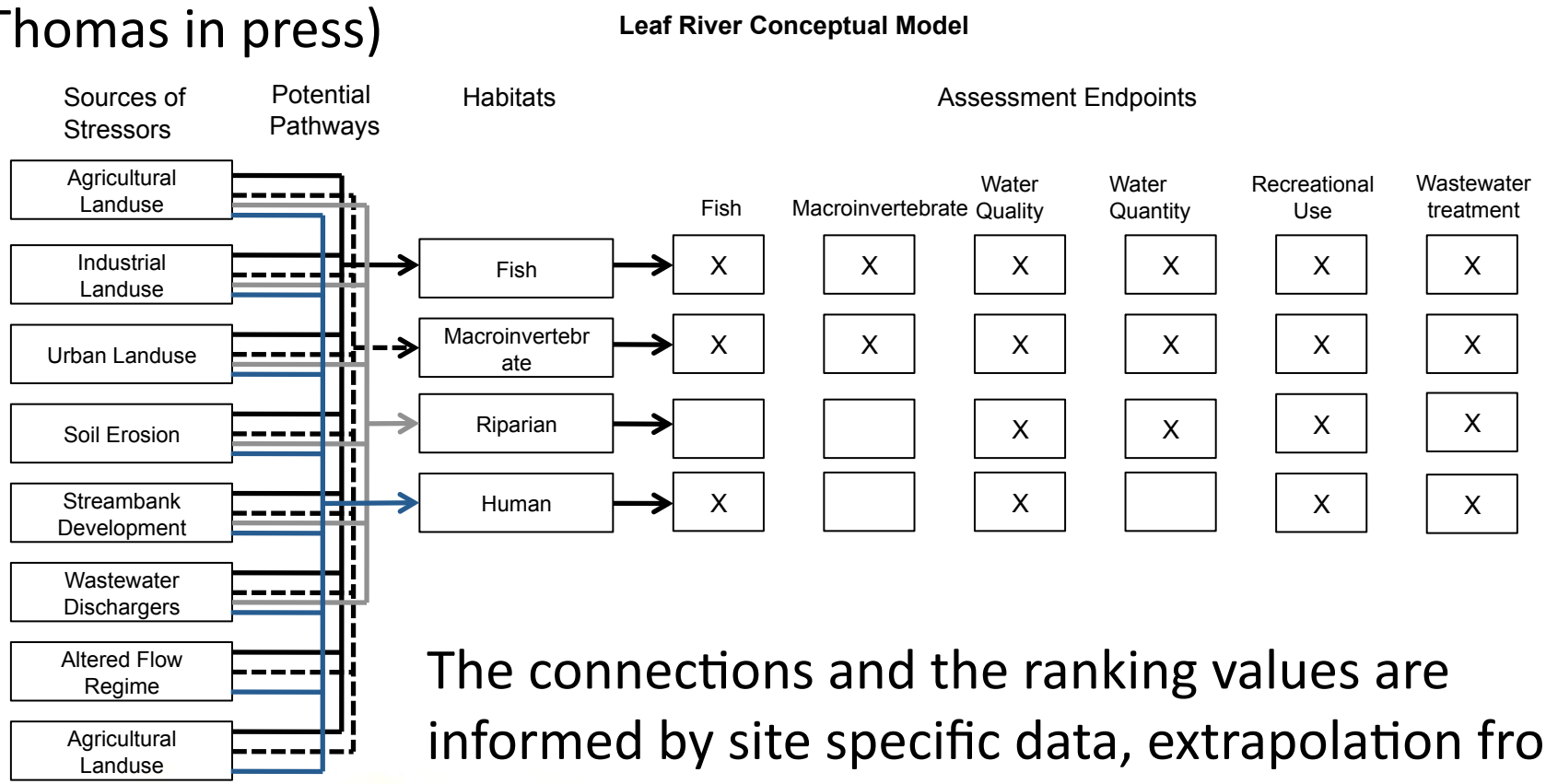
Fundamentals of regional risk assessment

The RRM is based upon combining sources and habitats as mediated by filters.



Fundamentals of regional risk assessment

An example of a real conceptual model-Leaf River (Landis and Thomas in press)

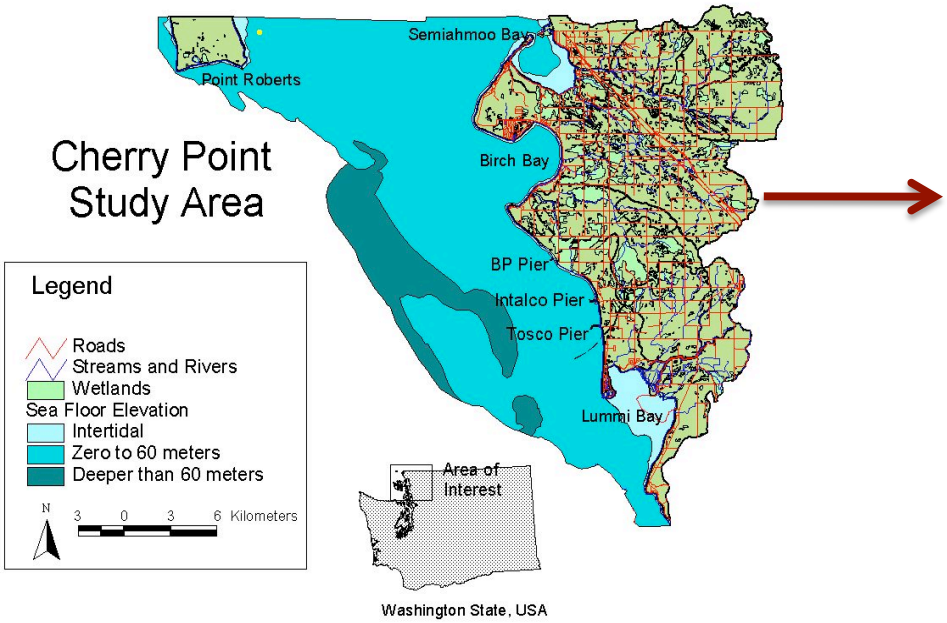


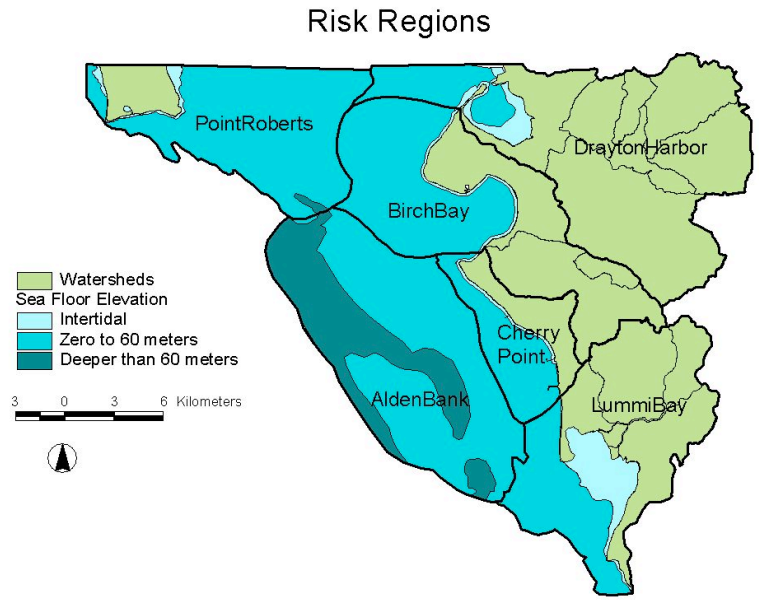
The connections and the ranking values are informed by site specific data, extrapolation from other sites, and a variety of types of models.

Fundamentals of regional risk assessment

Map the relationships of the sources, stressors and the ecological services of concern.

Break the region into risk regions that share grouping of sources etc and also management options.

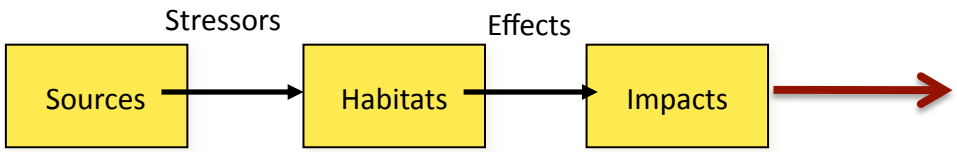




Hart Hayes and Landis 2004, 2005

Fundamentals of regional risk assessment

Map the relationships of the sources, stressors and the ecological services of concern.



Source-Stressor-Habitat Exposure Interactions

Source	Habitat: Gravel-Cobble Intertidal	Sandy Intertidal	Nearshore Soft Bottom Subtidal	Intertidal Mudflats	Inter or Subtidal Eelgrass	Inter or Subtidal Macro-algae	Water Column	Stream	Wetland	Forest
Accidental Spills		C	C	C	C	C		C	C	C
Agricultural Landuse	S	C, S	C, S	C, S	C, S, Sh	C, S, Sh		C, S, T	C, S, T	C, T
Ballast Water	B, E	B, C, E	B, C, E	B, C, E	B, C, E	B, C, E	B, E			
Piers	S	C, S	C, S	C, S	S, Sh	S, Sh				
Point Source Pollution		C	C	C	C	C		C	C	C
Recreational Activities	B, E, S	B, E, S	B, E, S	B, E, S	B, E, S	B, E, S	B, E	B, E	B	B
Urban / Industrial Landuse	S	C, S	C, S	C, S	C, S, Sh	C, S, Sh		B, C, S, T	B, C, S, T	B, C, T
Vessel Traffic		C, E	B, C, E	C, E	B, C,E, Sh	B, C, E, Sh	B, E			

Habitat-Endpoint Exposure & Effects Interactions

Endpoint	Habitat: Gravel-Cobble Intertidal	Sandy Intertidal	Nearshore Soft Bottom Subtidal	Intertidal Mudflats	Inter or Subtidal Eelgrass	Inter or Subtidal Macro-algae	Water Column	Stream	Wetland	Forest
Coho Salmon	Feeding; B, E, S						Feeding; B, S	Spawning; B, C, E, S, T		
Juvenile Dungeness Crab		Feeding; B, C, E, S	Feeding; B, C, E, S	Feeding; B, C, E, S	Feeding; B, C, E, S, Sh	Feeding; B, C, E, S, Sh				
Juvenile English Sole			Feeding; B, C, E, S	Feeding; B, C, E, S						
Great Blue Heron				Feeding; B, C, E, S	Feeding; B, C, E, S, Sh	Feeding; B, C, E, S, Sh		Feeding; B, C, E, S, T	Feeding; B, C, S, T	Nesting; B, C, T
Littleneck Clam	Feeding, Refuge; B, E, S	Feeding, Refuge; B, E, S								
Surf Smelt	Spawning; B, E, S	Spawning; B, C, E, S					Feeding; B, E			

Fundamentals of regional risk assessment

The criteria for the ranks and filters are set and the calculations made (equations after Landis and Wiegers 1997,2005):

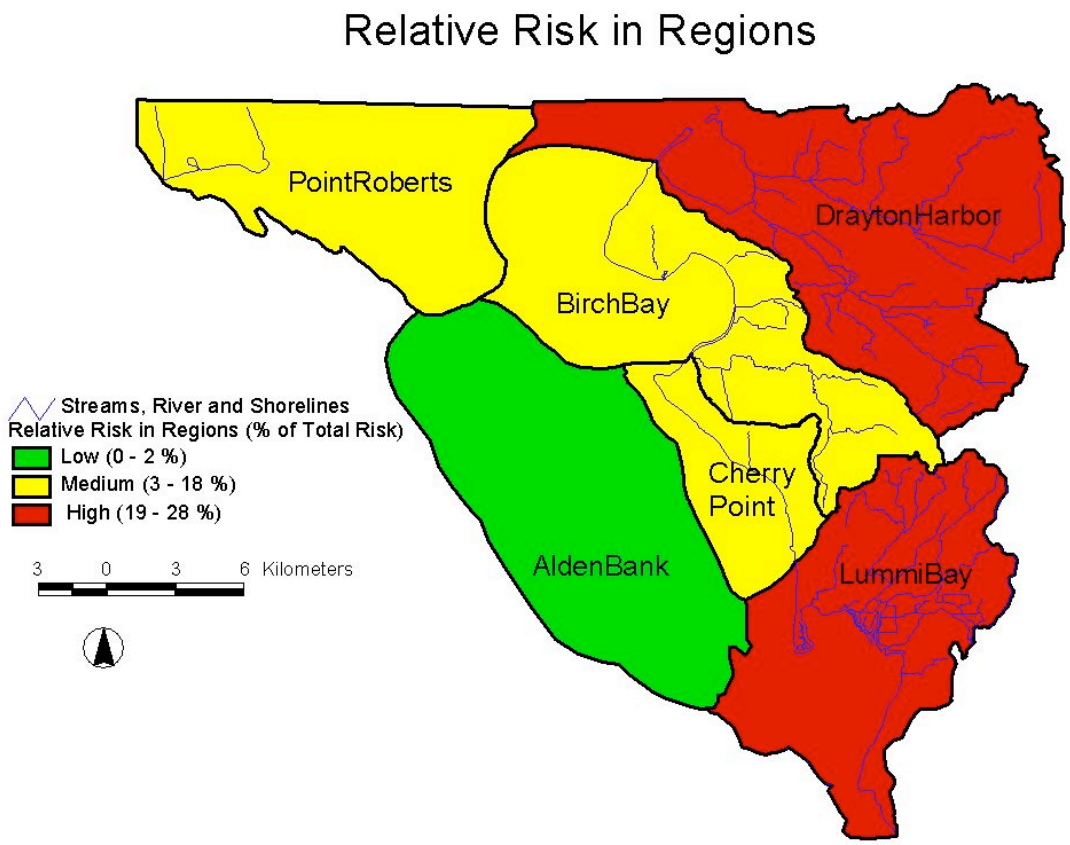
$$RS = S_{ij} \times H_{ik} \times W_{jk} \qquad (1)$$

$$RSsource = \sum(S_{ij} \times H_{ik} \times W_{jk}) \text{ for } j = 1 \text{ to } n, \quad (2)$$
$$RShabitat = \sum(S_{ij} \times H_{ik} \times W_{jk}) \text{ for } k = 1 \text{ to } n. \quad (3)$$

where:
i = the sub-area series (Region 1, 2, 3 etc),
j = the source series (discharge ..., shoreline activity),
k = the habitat series (mudflat ..., stream mouth),
S_{ij} = rank chosen for the sources between sub-areas,
H_{ik} = rank chosen for the habitats between sub-areas,
W_{jk} = weighting factor established by the exposure or effect filter.

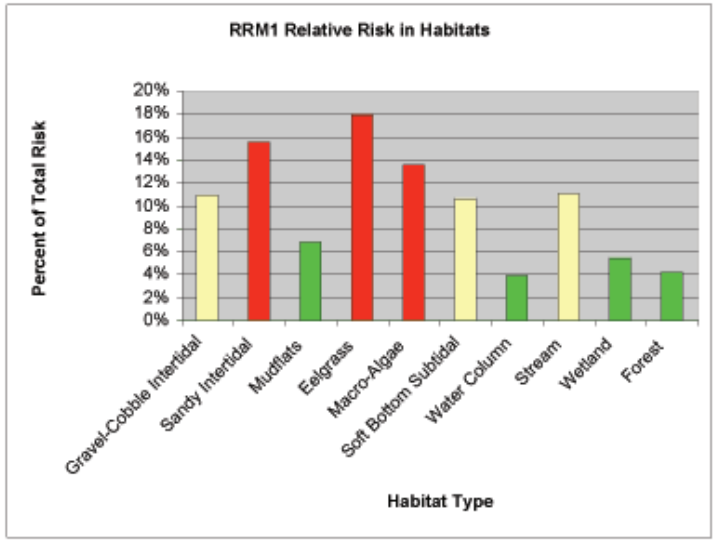
The criteria used for the rankings in the Cherry Point example can be found in Hart Hayes and Landis (2004, 2005)

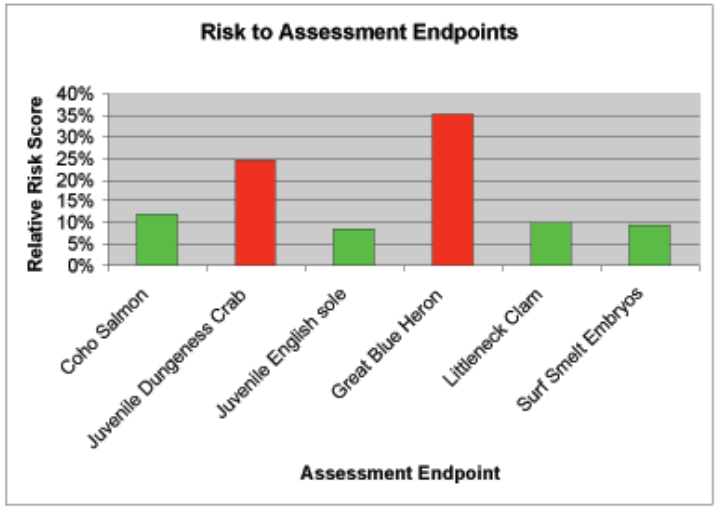
Fundamentals of regional risk assessment



The overall risk is then portrayed as a map of the risk regions coded to indicate relative risk.

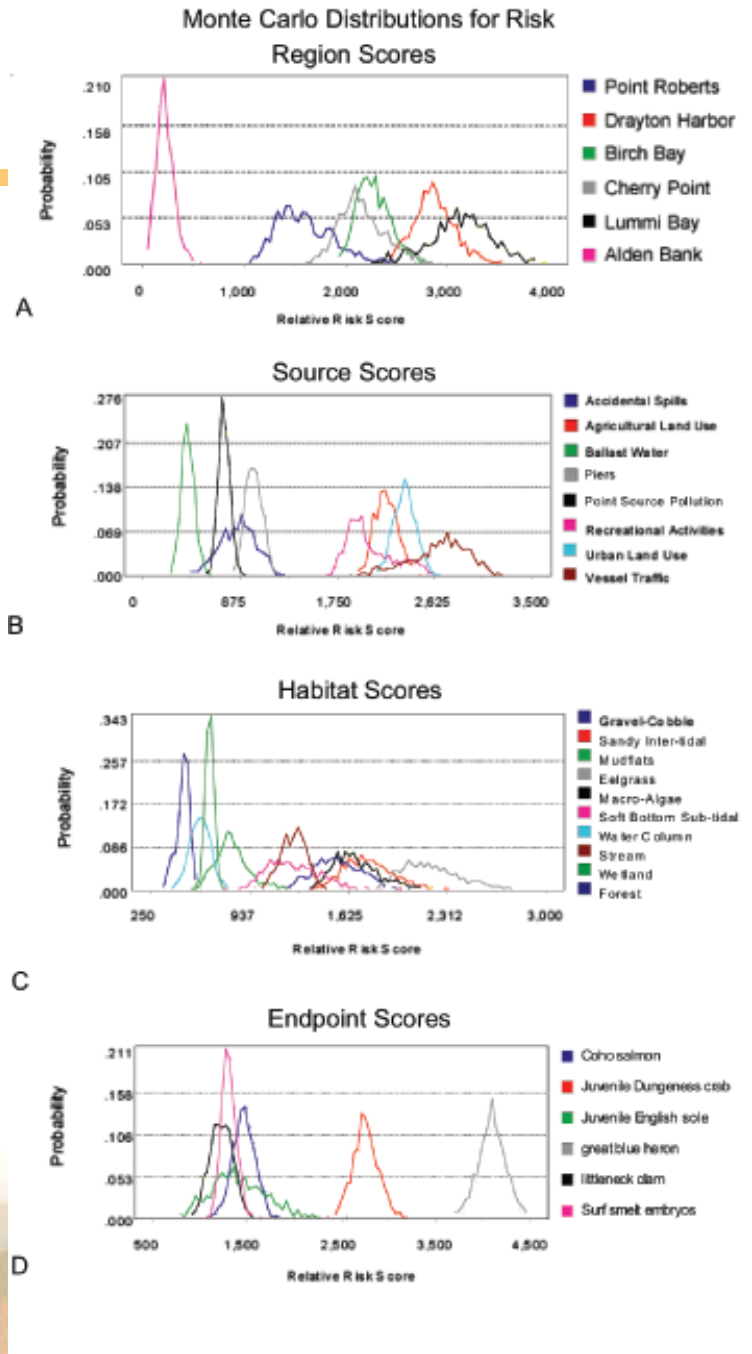
Fundamentals of regional risk assessment





The risks to the different habitats can be graphed as well to each assessment endpoint. The risks due to each source and stressor can also be documented in this fashion.

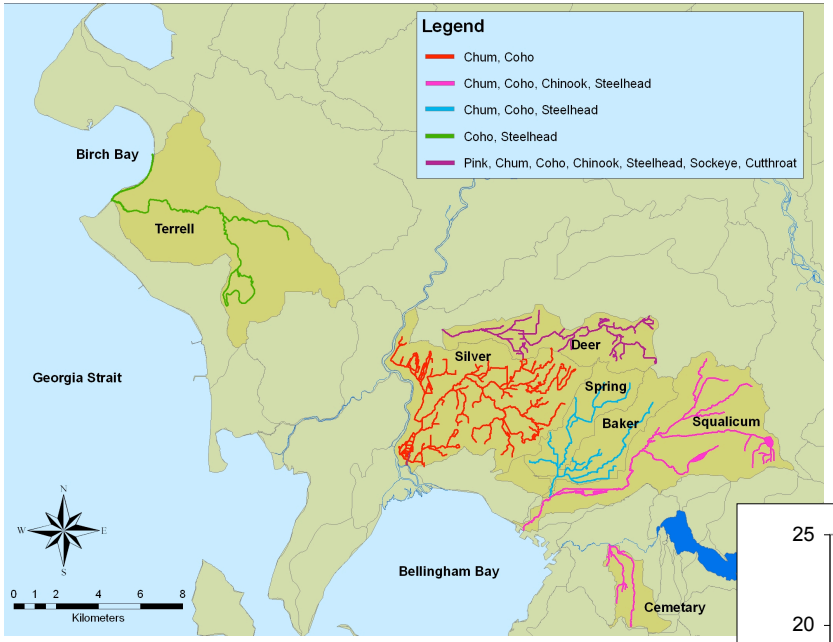
Uncertainty Analysis



The uncertainty with each estimation is now investigated using Monte Carlo analysis for each type of result.

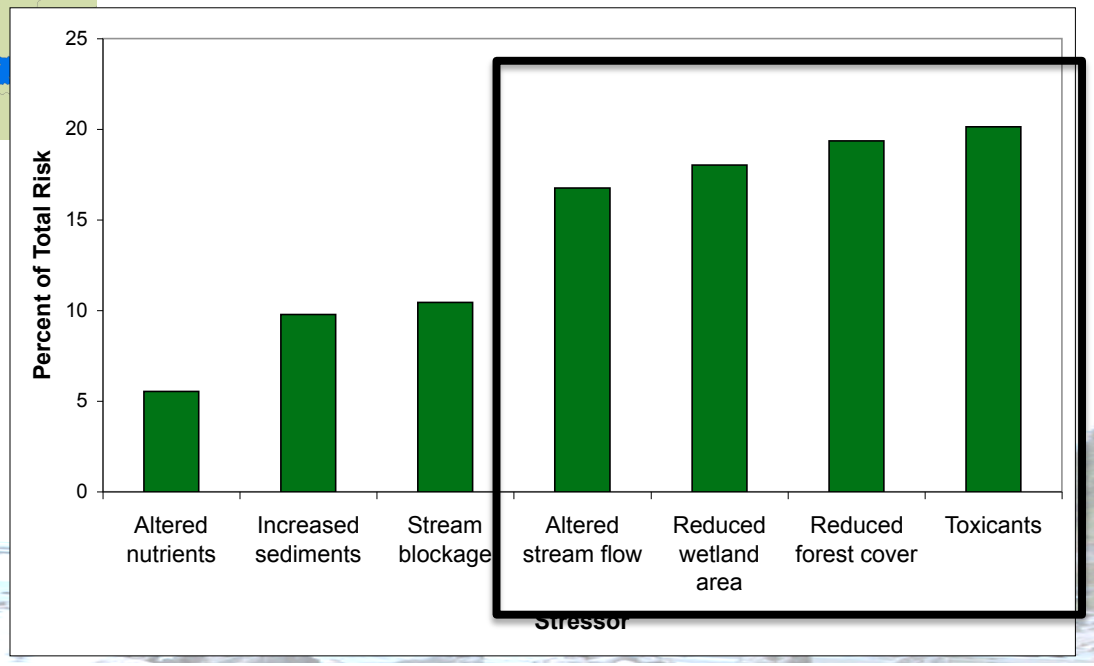
As typical, clusters of risk factors appear in the analysis.

Case Study-USGS GAP, Whatcom County and Salmonids

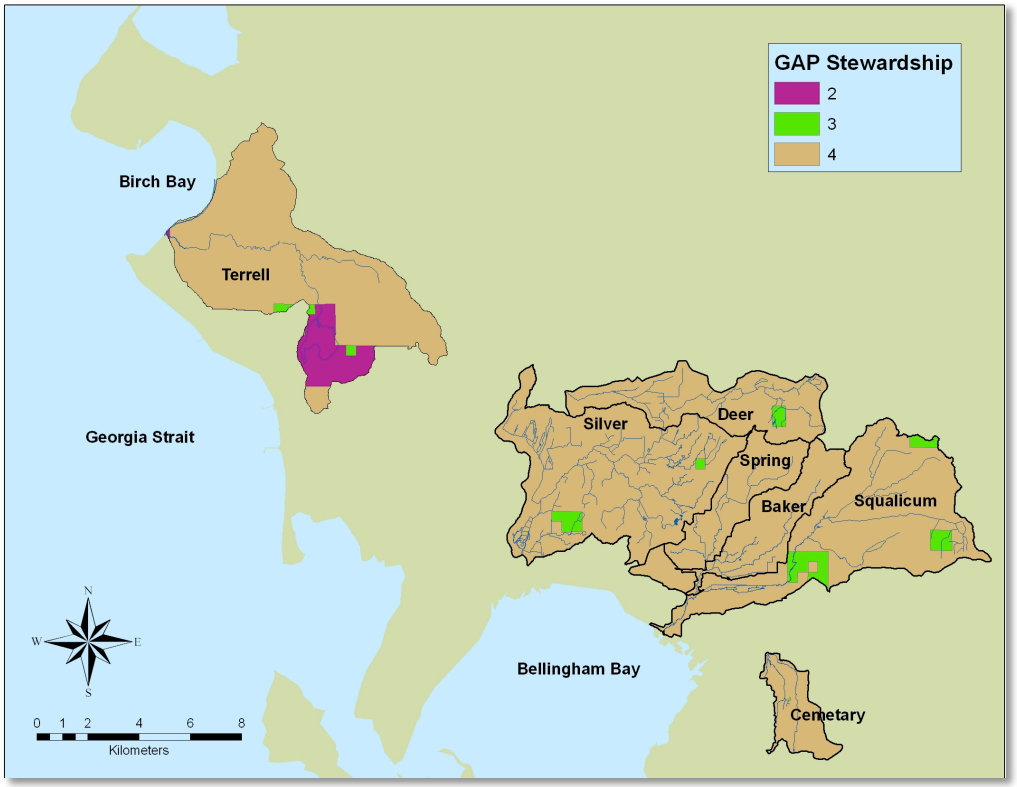


Risk assessment for the smolt production of Chum, Coho, Chinook, Steelhead, Pink, Sockeye and Cutthroat found in these streams.

The top risk factors are varied in type, toxicants, alterations in landscape and altered water flow.



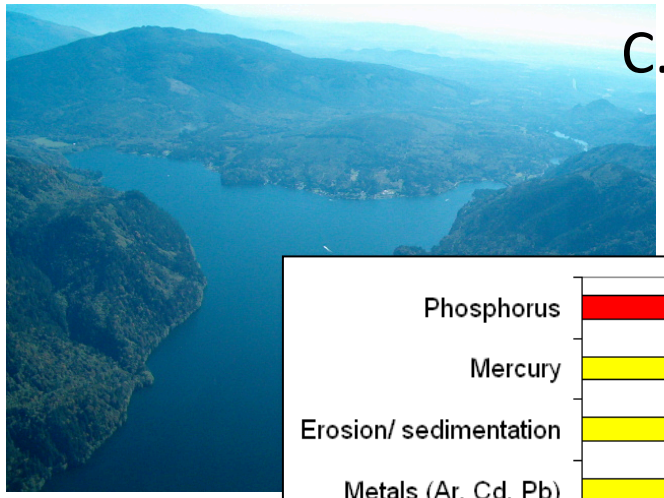
How about GAP management?



Only 18 percent of the risk is in the USGS Stewardship 2 and 3 areas.

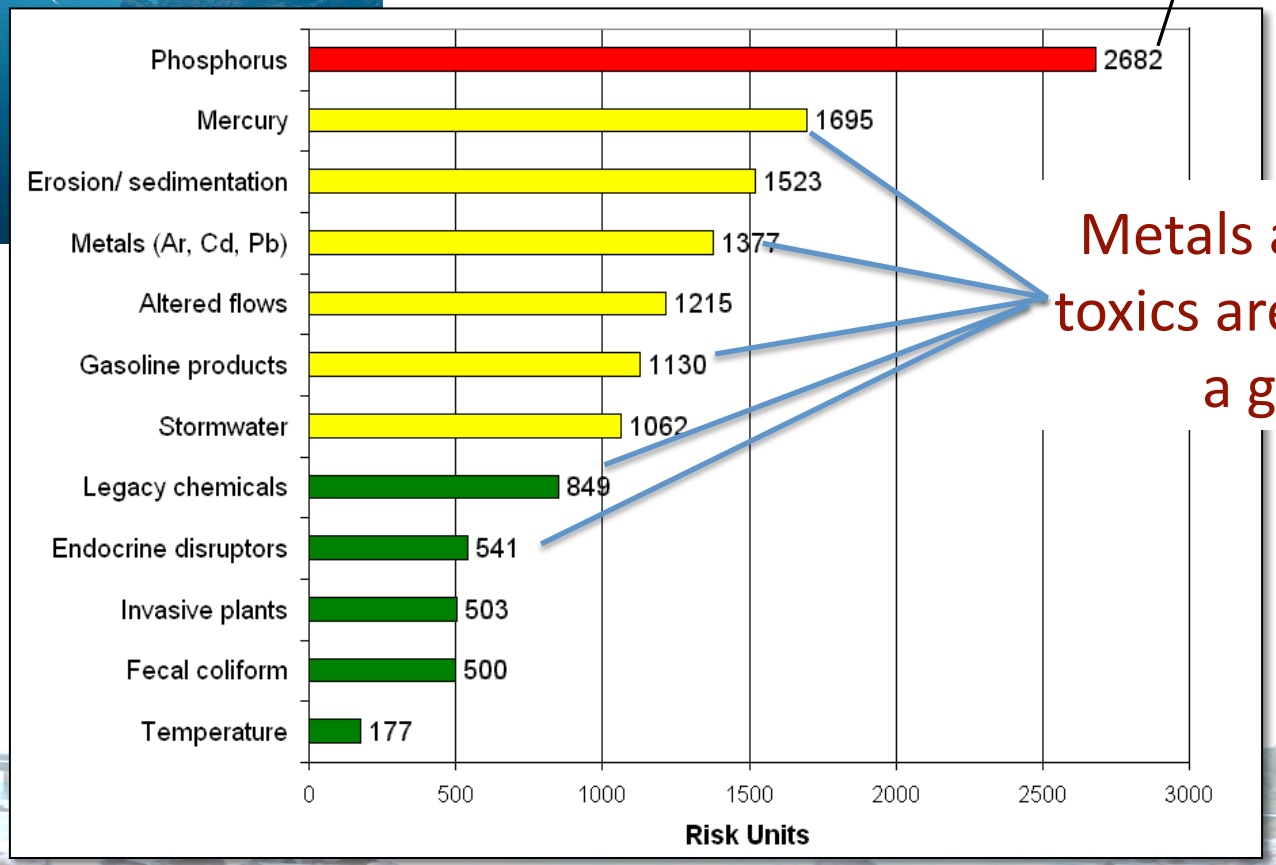
Other types of ecological services are currently a priority in these regions including residential and commercial regions, port facilities, industry and agriculture.

Lake Whatcom Ecological risk assessment-



C. Maginnis MS Thesis

Only 20 percent of the risk is covered by TMDL



Metals and other toxics are higher as a group

Bayesian Networks applied to regional risk assessment

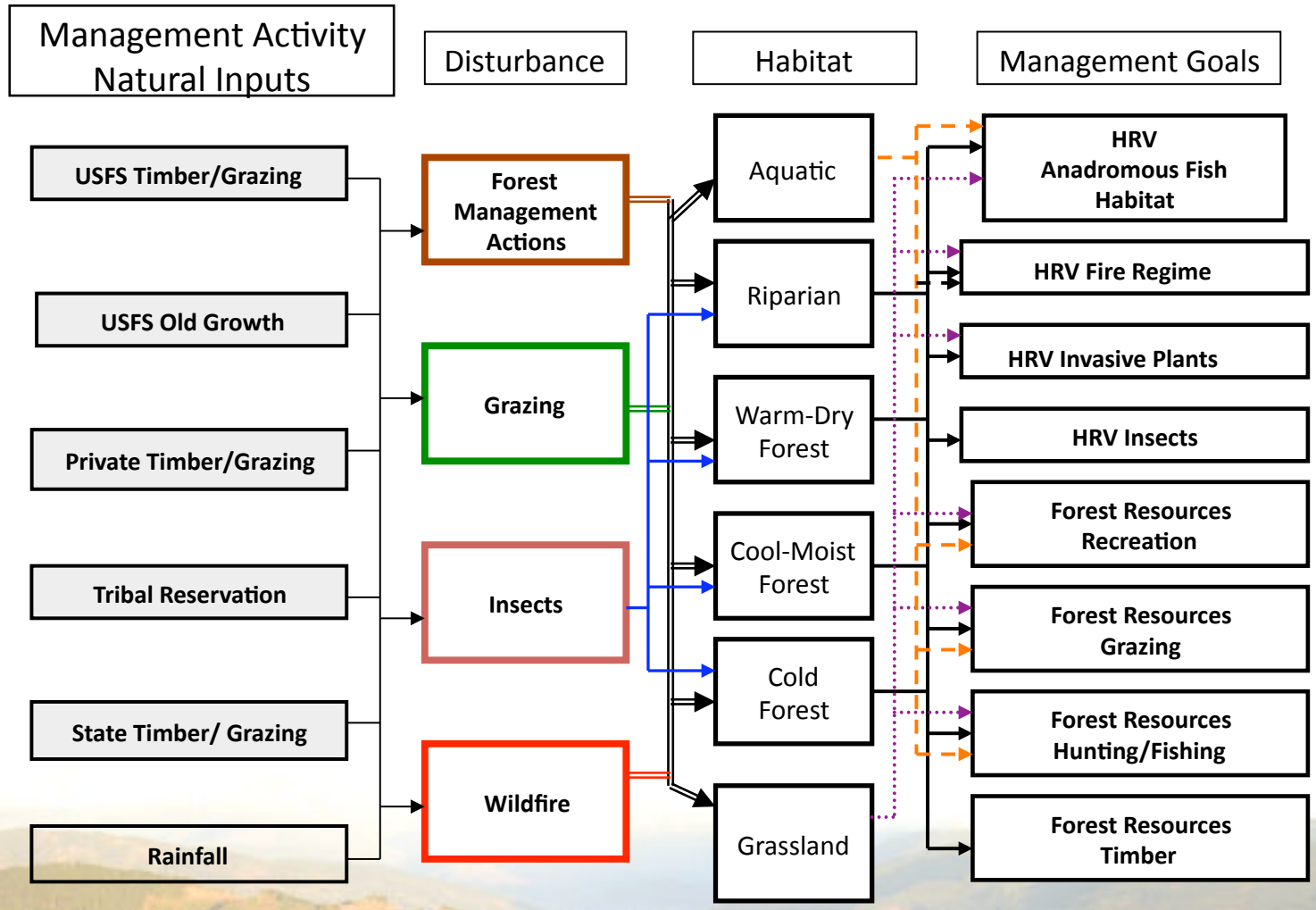
Why use Bayesian Networks?

1. Combine different types of data including model predictions and expert judgment
2. Uncertainty is inherently reflected in the probability distributions
3. Updateable when new information or knowledge comes available
4. Can be used to predict <u>both</u> input and output variable states

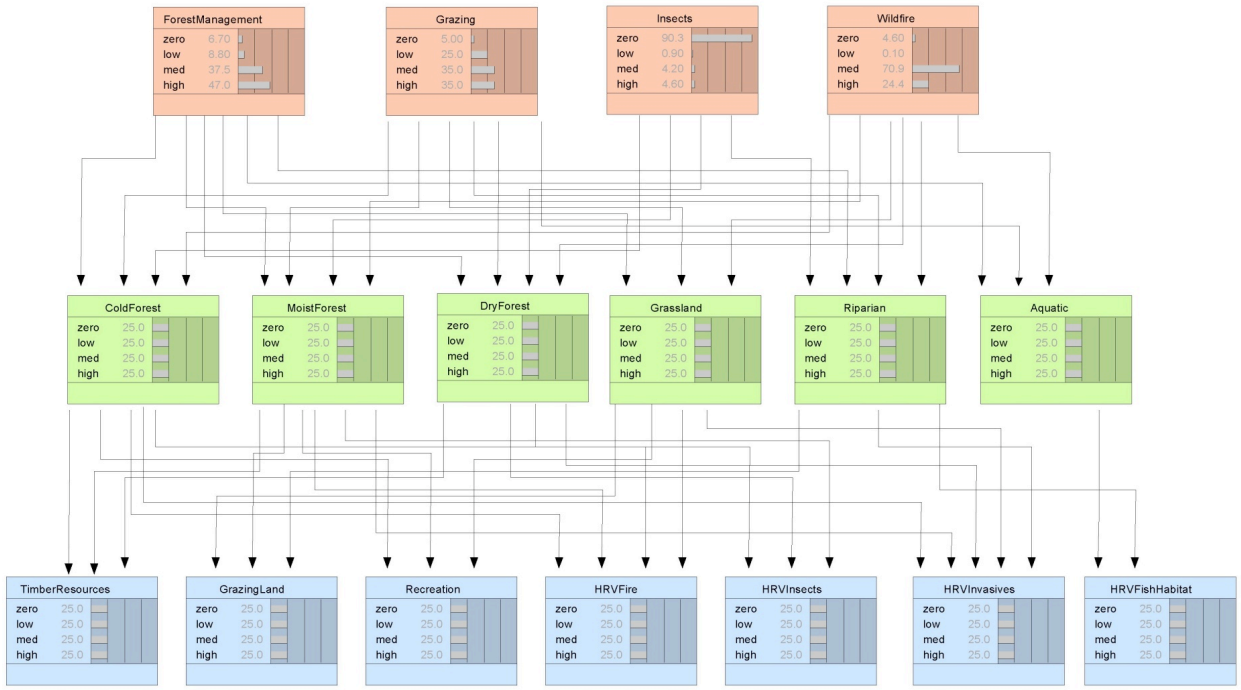
Bayesian Network Structure

- Nodes represent variables
  - Parent node has no input variables
  - Child node has input from other variables
- Variables are assigned states
- Structure reflects causality

INLAS conceptual model



BN Network for INLAS



Disturbances

Habitats

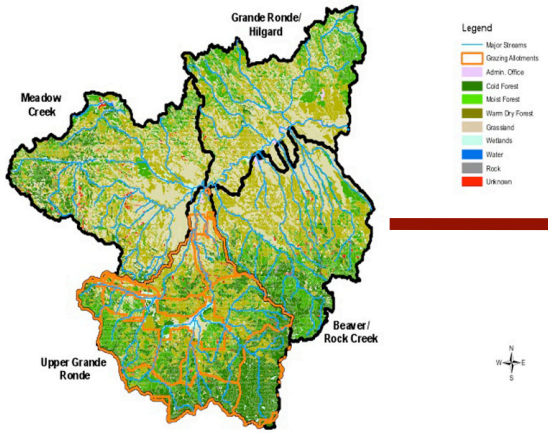
Endpoints

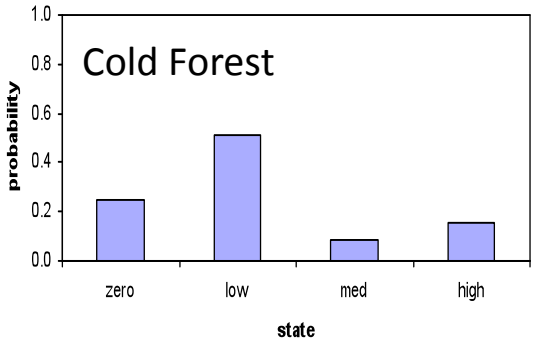
The relationships between nodes are set by conditional probability tables. Setting these CPTs can be informed by simulation, systems or other models, but the best means is from data.

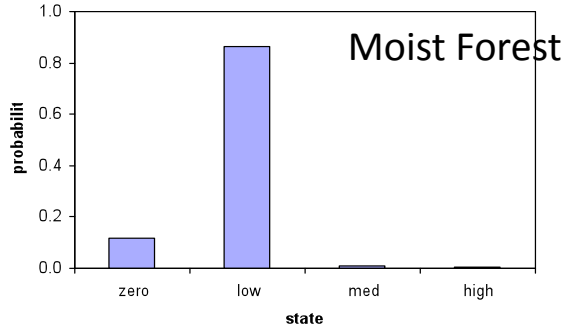
K. Kolb Ayre and W. Landis

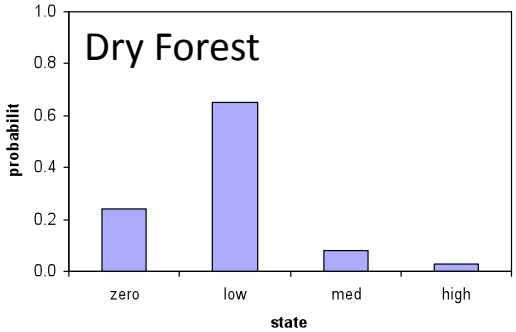
Grazing as a disturbance

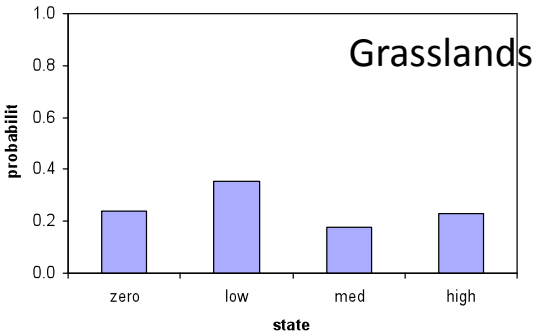
Map of sources



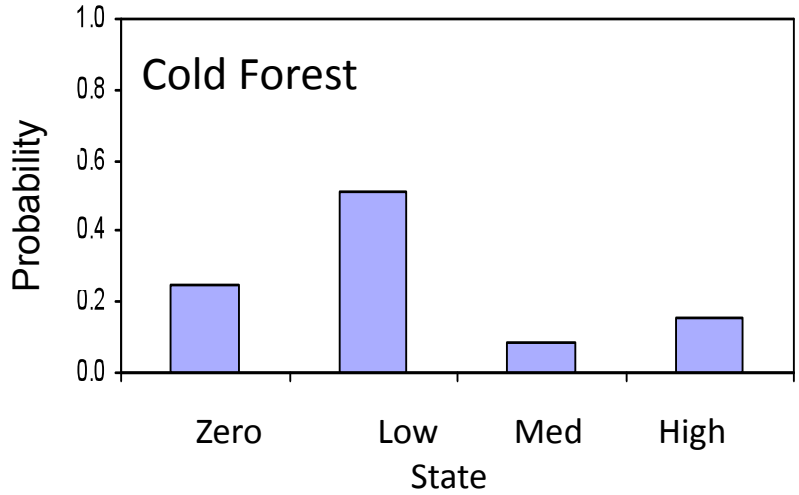


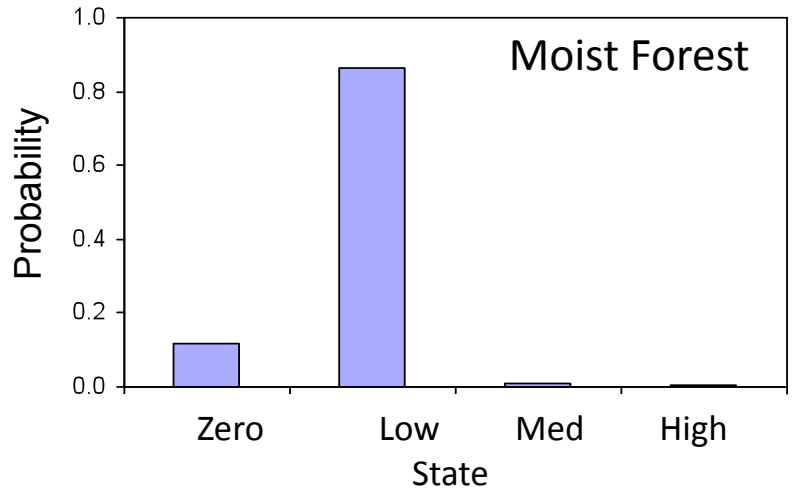


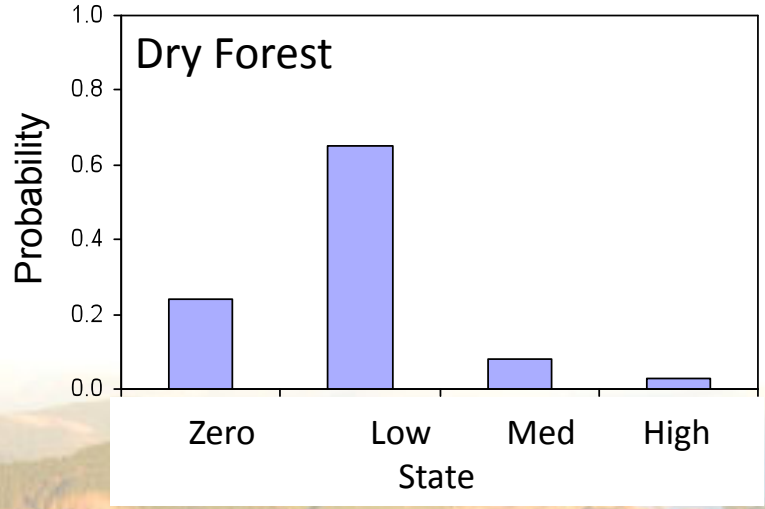


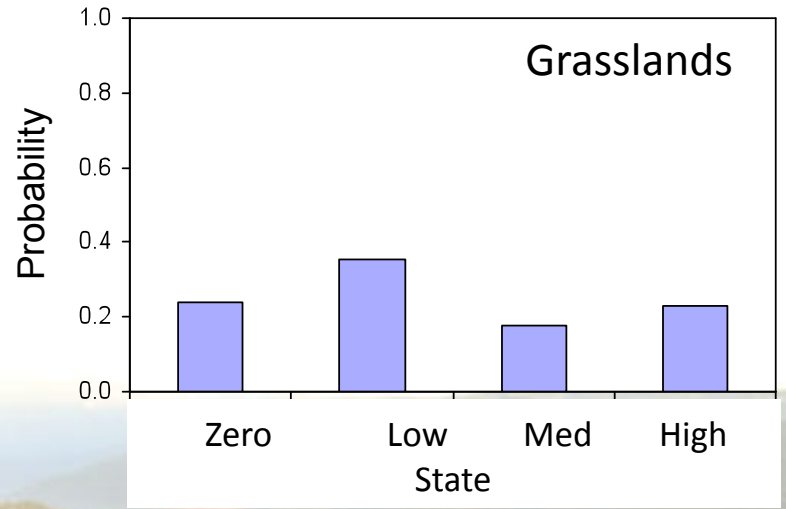


Example: Grazing and interactions with Habitats





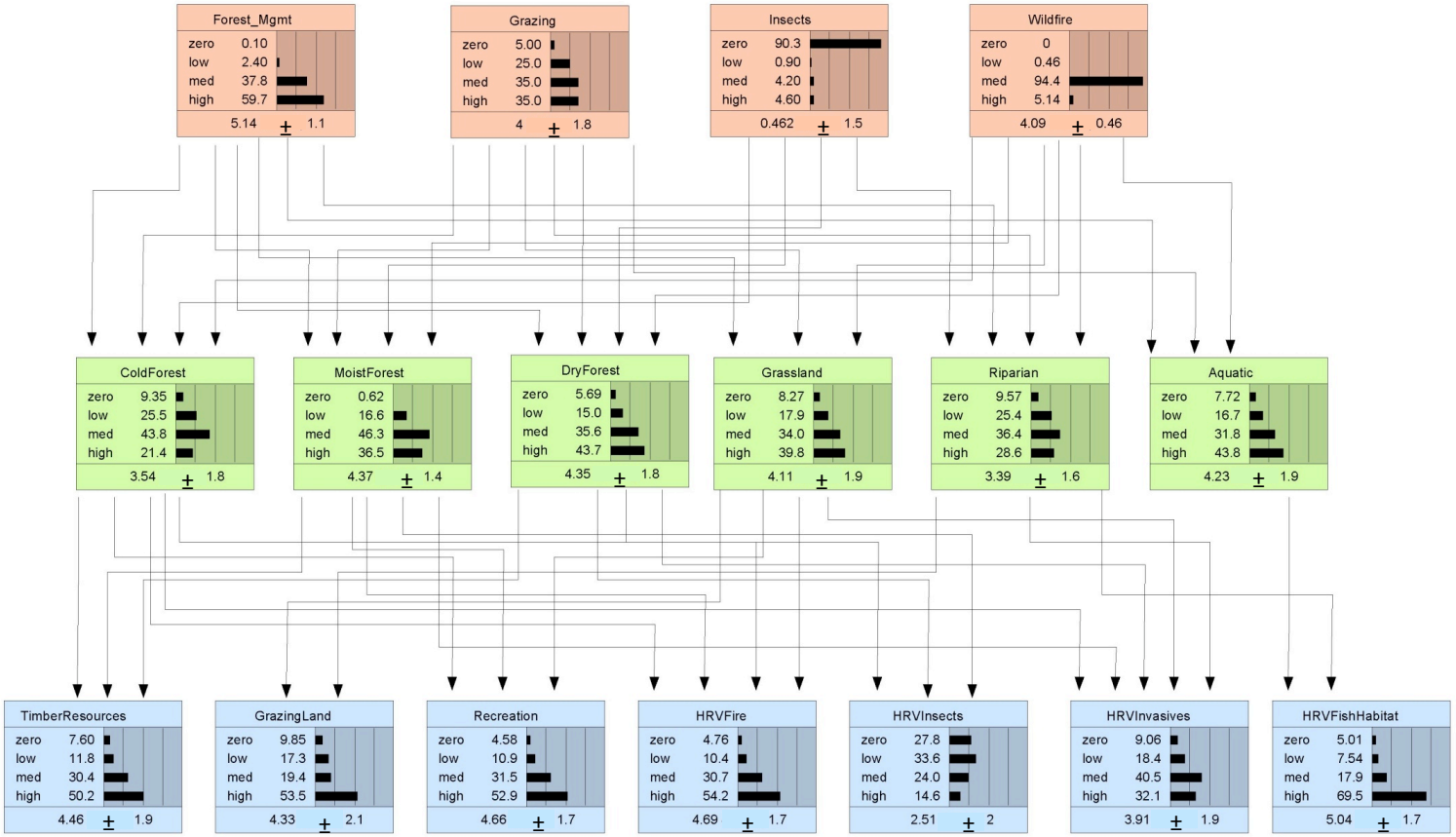




Risk Ranks

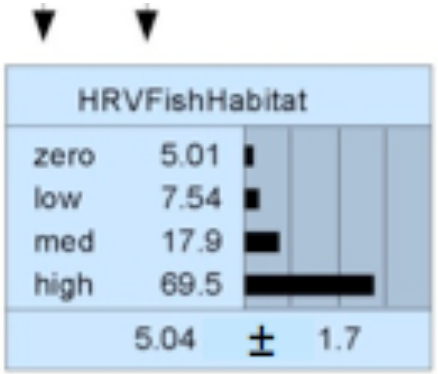
- Risk rankings calculated as the mean state of the probability distribution
- Expressed ± standard deviation for the probability distribution
- Output represents the likely range of risk ranks

Computed BN (Netica)

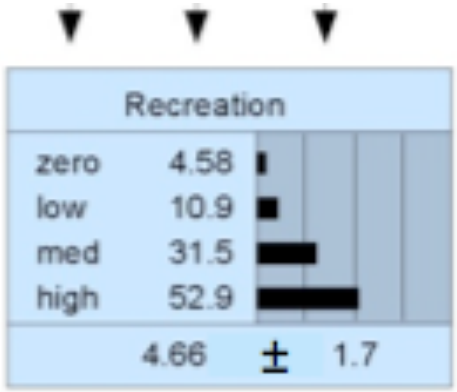


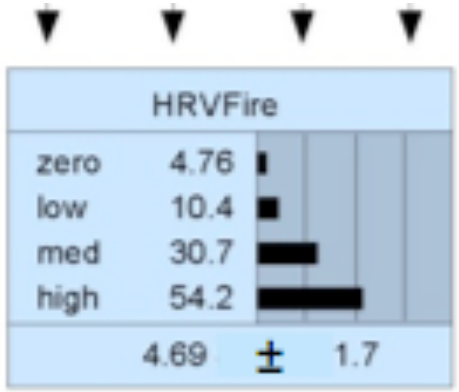
Let us concentrate on a few of the endpoints

Example of Results-Endpoints



Fish Habitat most at risk-HRV difficult to define





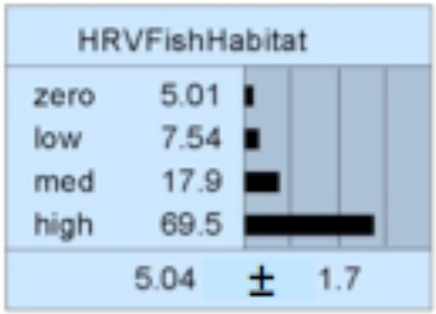
Results very similar to the original regional scale risk assessment.

Solving the Model "Backwards"

- Set endpoint risk values to desired risk level
- Model automatically updates values of parent parameters need to achieve desired risk level
- Now for an example!

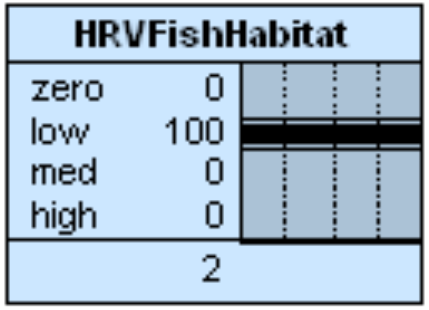
Now to set management goals

Original



Fish Habitat most at risk-HRV difficult to define

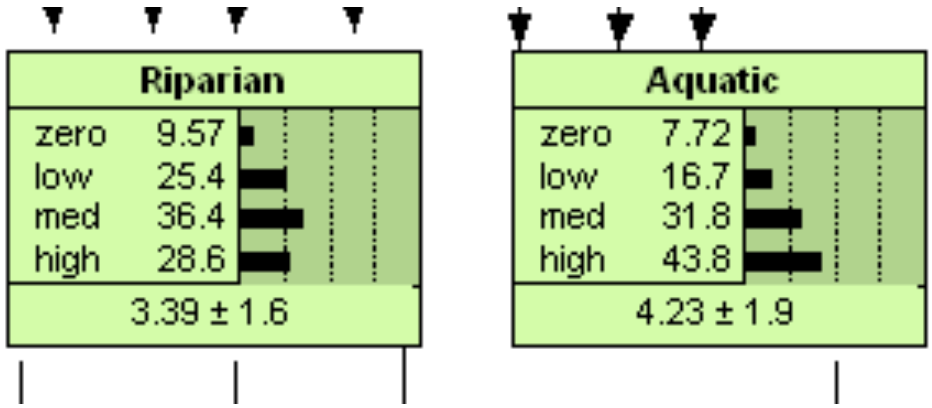
100 percent Low Risk



Now to set HRV fish to low risk

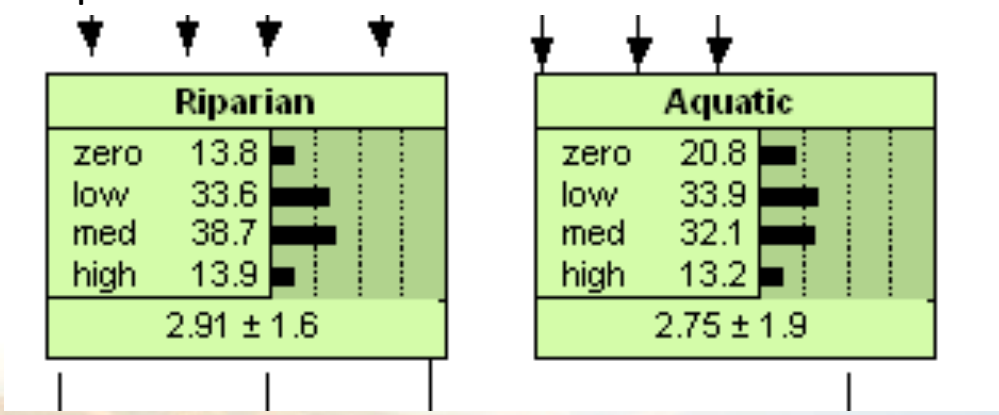
Now to set management targets

Original



Original nodes show medium and high exposure to Riparian and Aquatic habitats

100 percent Low Risk



Low risk means controlling the exposure to habitat, but note not the elimination of exposure

IEA as a subset of the Risk Assessment Process

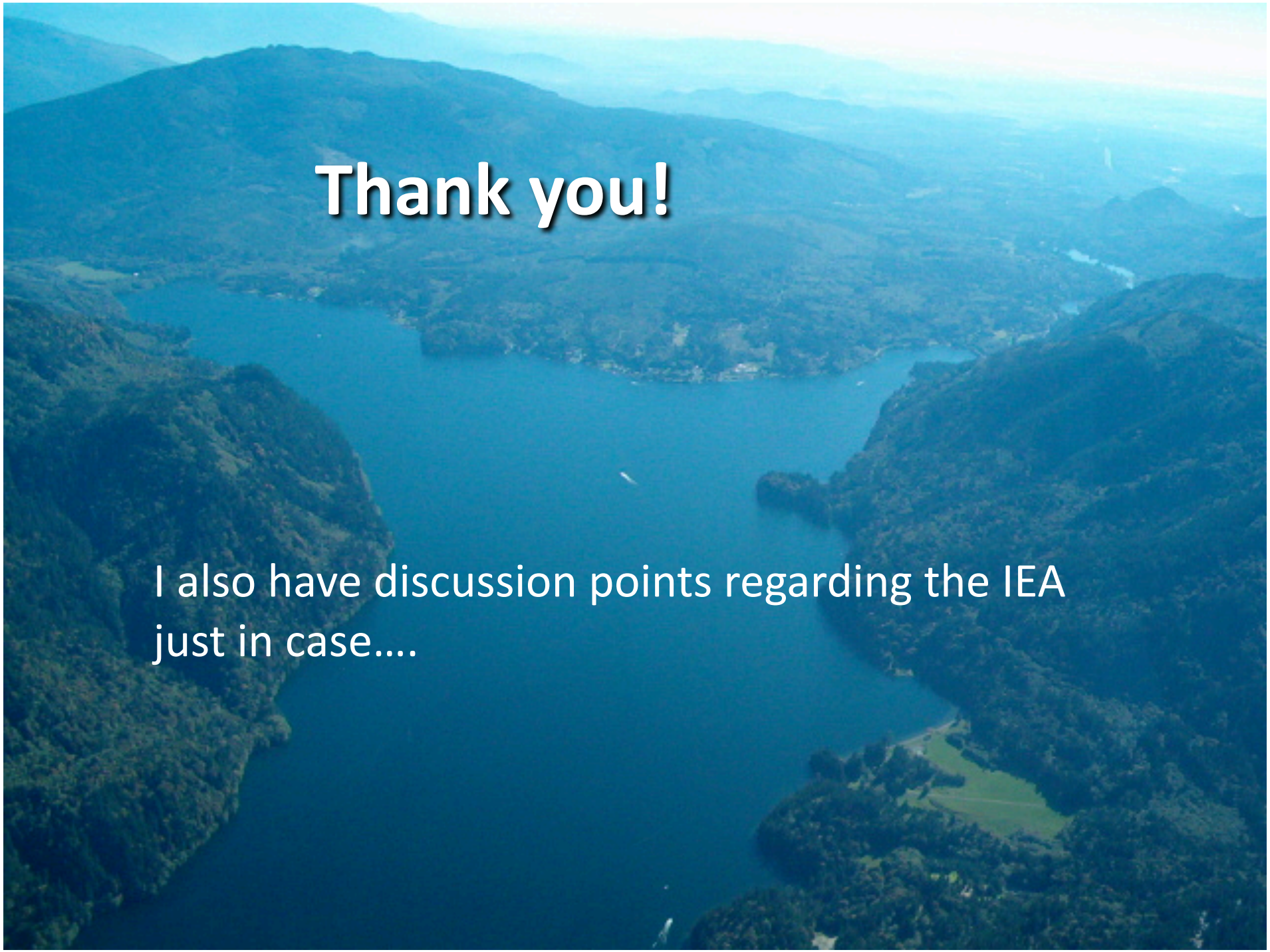
1. **Scoping** - Identify management objectives for ecosystem to be assessed, its attributes of concern/at risk, and stressors
2. **Indicator Development** - develop and test indicators that reflect the ecosystem attributes, stressors, and problems identified in Step 1 that link to decision criteria.
3. **Risk Analysis** – use a hierarchical approach (from qualitative semi-quantitative to a highly focused and fully quantitative approach) to fully explore the susceptibility of each indicator to natural or human threats, and its resiliency after being perturbed.
4. **Overall Ecosystem Assessment** – integrate results to quantify the overall status of the ecosystem relative to historical status and prescribed targets.
5. **Evaluation** - evaluate the potential of different management strategies to influence the status of the ecosystem.

Problem formulation

Analysis and Characterization

EcoRA

Each step is a part of the scope of the Society for Risk Analysis, which includes other vital aspects such as valuation, risk communication and decision analysis.



Thank you!

I also have discussion points regarding the IEA just in case….

Appendix: Discussion Items

Sources

Stressors-Many of the Local Threat categories (i.e., stressors) for each Action Area would be better identified as sources.

Habitat Alteration **(not specific)**
Pollution **(many types not specific)**
Diminished Freshwater Sources (Source)
Invasive Species
Aqua-culture (fish hatcheries, shellfish beds)-can be a source
Harvesting (fishing, logging) and Bycatch
Climate Change (not a stressor but a source)
Human Population Growth (Again, a source because it leads to stressor being introduced to the system.)
Harmful Algal Blooms (The area of the bloom is a source)
Pathogens
Disease

The Action Plan is not specific about sources of stressors Usually controlling the source is the best means of managing the environment.

Threat is a normative term and implies you already know the direction of the effect or impact.

Barriers to migration are also a critical stressor for many migratory species and should be added as a specific item in this category.

Appendix: Discussion Items

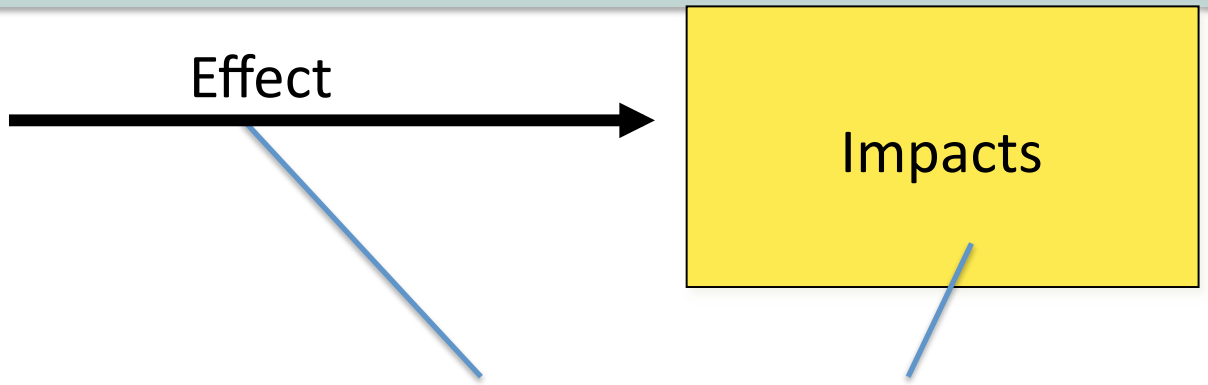
Habitats

This is the best developed list, but not yet specific enough. for many of the endpoints such as Pacific herring or Dungeness crab, where substrates are important.

Uplands – agriculture, rural/urban development, forestry, industrial, park, wilderness area.

The uplands areas also need to be specific as to the variety of habitats that can be included in a classification such as "urban development"

Appendix: Discussion Items



The **Provisional Indicators** (i.e., impact indicators) are a mixture of effects and impacts.

Air Quality Advisories-**Impact**
Shellfish Bed Closures-**Impact**
Biotoxin Alert-**Impact**
Fish/Shellfish Consumption Advisories-**Impact**
Reduced/Increased Water Levels/Flows-**Effect**
Dead Zones in Marine/Fresh Waters-Impact
Waterbody listing as impaired under Section 303(d) of the CWA-**Impact**
Species mortality, absence where once present, present where once absent,**-Effects**
ESA listed-**Impact**
Lower Harvests – fish, logging, shellfish-**Effects and Impacts**

These do not specifically address the ecological services (after Costanza) and measure things that have already crashed.