

# SEI Science Panel Workshop

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Marriott – Waterfront

Portland, Oregon

Monitoring and Adaptive Management  
in the Context of Risk and Uncertainty

S.M. Bartell

# Purpose

- Briefly review
  - Decision making
  - Risk and uncertainty
  - Monitoring
  - Adaptive Environmental Management
- Address the interrelationships among these components in relation to the proposed project
- Provide a point of departure for discussion

# Components of a decision...

## Alternative actions

- what the decision-maker controls

## States of nature

- factors not controlled by the decision-maker

## Outcomes

- results of alternative actions and states of nature

## Utility

- value of an outcome to the decision-maker

## Objective

- desired result from decisions

# Components of a dredging decision...

## Alternative actions

- To dredge or not; location, amount, timing

## States of nature

- River discharge regime, water quality, food web dynamics, salmonid distribution and abundance

## Outcomes

- Salmonid survival, production, diversity

## Utility

- Comply with ESA, integrity of stocks, biomass

## Objective

- Maintain diversity, minimize extinction probability, reliable production/harvest

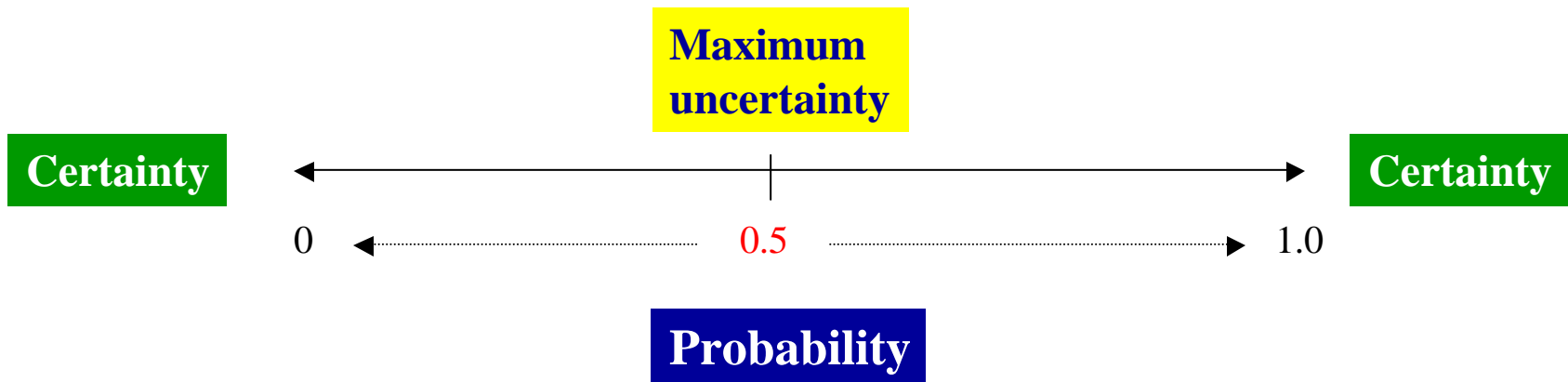
## A simple model of risk (Kaplan and Garrick, 1981)

$$\text{Risk} = f\{x_i, p_i, c_i\}$$

where,

$x_i$	Adverse effect $i$	(What can happen?)
$p_i$	Probability of $x_i$	(How likely is it?)
$c_i$	Consequences of $x_i$	(So what?)

# Risk estimation... in the absence of information...



# Uncertainty

- Nature and sources
  - Variability
  - Observer-dependent
- Characterization
  - Qualitative, quantitative
  - Statistical, intervals, fuzzy sets
- Impacts on decision-making
  - Obscure selection among alternatives

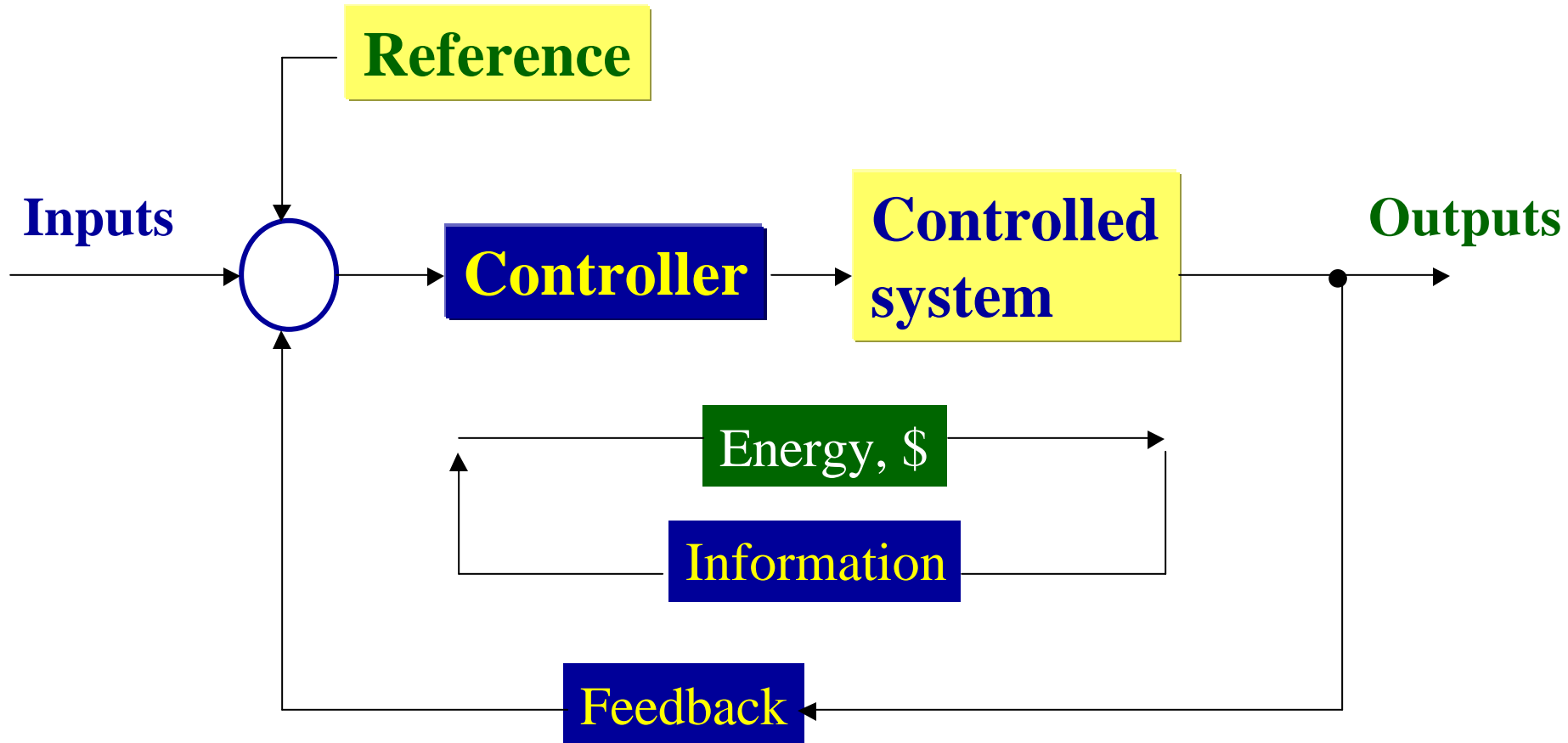
# Monitoring Issues

- Objectives in relation to decision making
  - Compliance
  - Effectiveness
  - Investigation (Validation)
- Design
  - Attributes, factors, indicators
  - Spatial and temporal scales
  - Statistical design
- Value of new information
- Feedback to management (i.e., the adaptive part)

<i>Monitoring program</i>	<i>Acronym</i>	<i>Primary resources</i>	<i>Coverage extent</i>
<b>National Agricultural Statistical Service National Resource Inventory Forest Inventory &amp; Analysis National Forest System Forest Health Monitoring National Wetlands Inventory Status &amp; Trends EMAP Estuaries National Estuary Program NOAA National Status &amp; Trends Section 305(b) Water Quality Assessment EMAP Surface Waters National Stream Quality Accounting Network National Water Quality Assessment Biomonitoring Environmental Status &amp; Trends – Fish North American Breeding Bird Survey</b>	NASS NRI FIA NFS FHM NWI S&T EMAP-E NEP NOAA S&T 305(b) EMAP-SW NASQAN NAWQA BEST Fish BBS	Agricultural lands Land; cropland and rangeland focus Forest Forest Forest Wetlands Estuaries Estuaries Estuaries, coastal waters, Great Lakes Rivers, lakes, estuaries, coastal waters Streams, lakes Rivers Rivers, streams, aquifers Rivers, Great Lakes Birds	Conterminous US Non-federal lands in 50 states, P.Rico, Virgin. I Non-federal lands in 50 states National Forests Non-urban; 14 states, planned for 50 states 50 states Atlantic, Gulf; all planned 21 designated estuaries All coastal waters 50 states, territories Mid-Atlantic streams, Northeast lakes Major US Rivers 60 hydrogeological basins covering 70% US water use Major rivers in conterminous US; Great Lakes Conterminous US, Alaska, portions of Canada and Mexico

Olsen et al.  
1999

# Adaptive Environmental Management: A Dynamic Control System



Rubenstein 1975

# A Dynamic Dredging-Salmonid Control System

**Inputs:**  
Dredging-  
location,  
amount,  
timing

**Desired  
Fishery**

**Agencies**

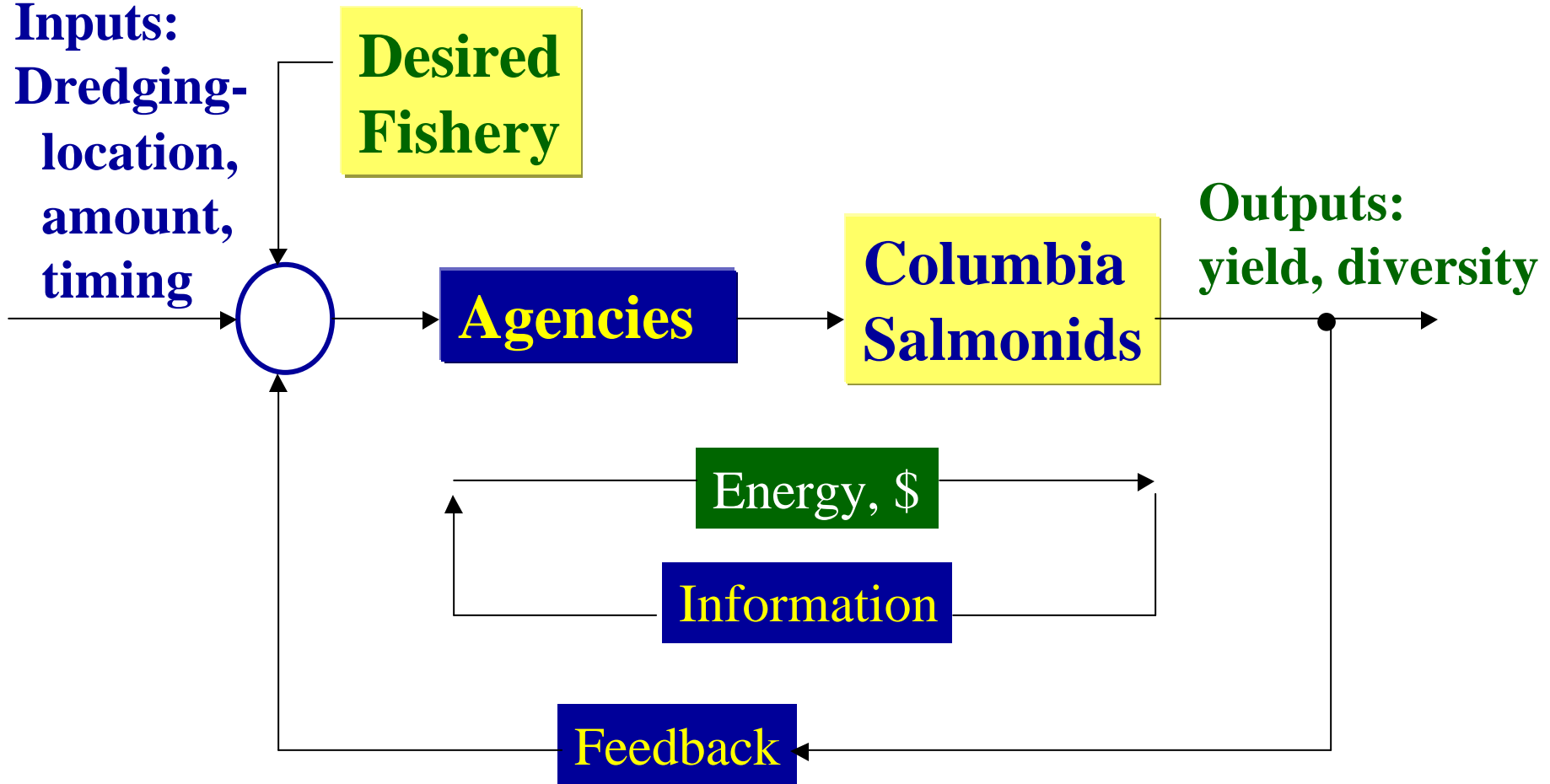
**Columbia  
Salmonids**

**Outputs:**  
yield, diversity

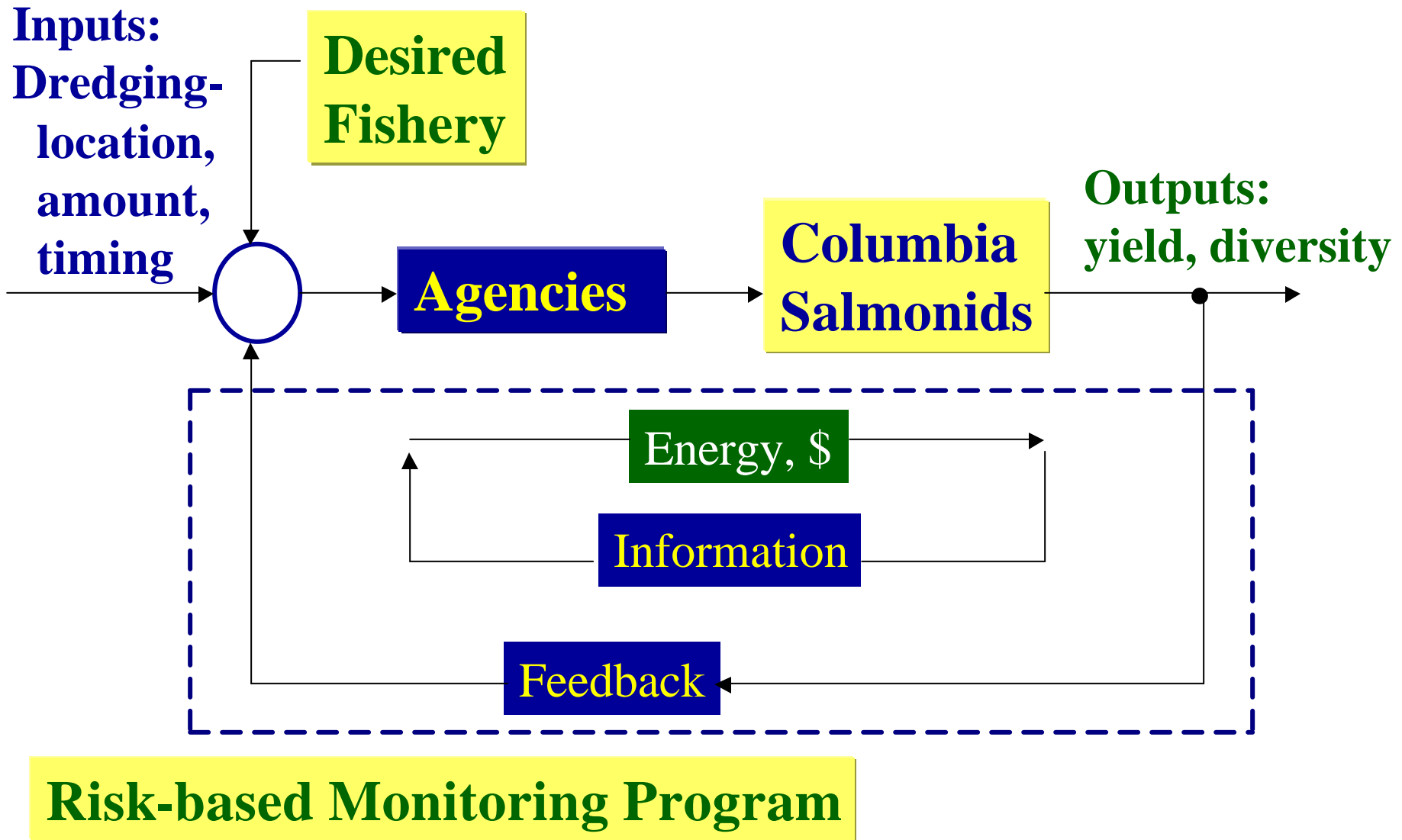
**Energy, \$**

**Information**

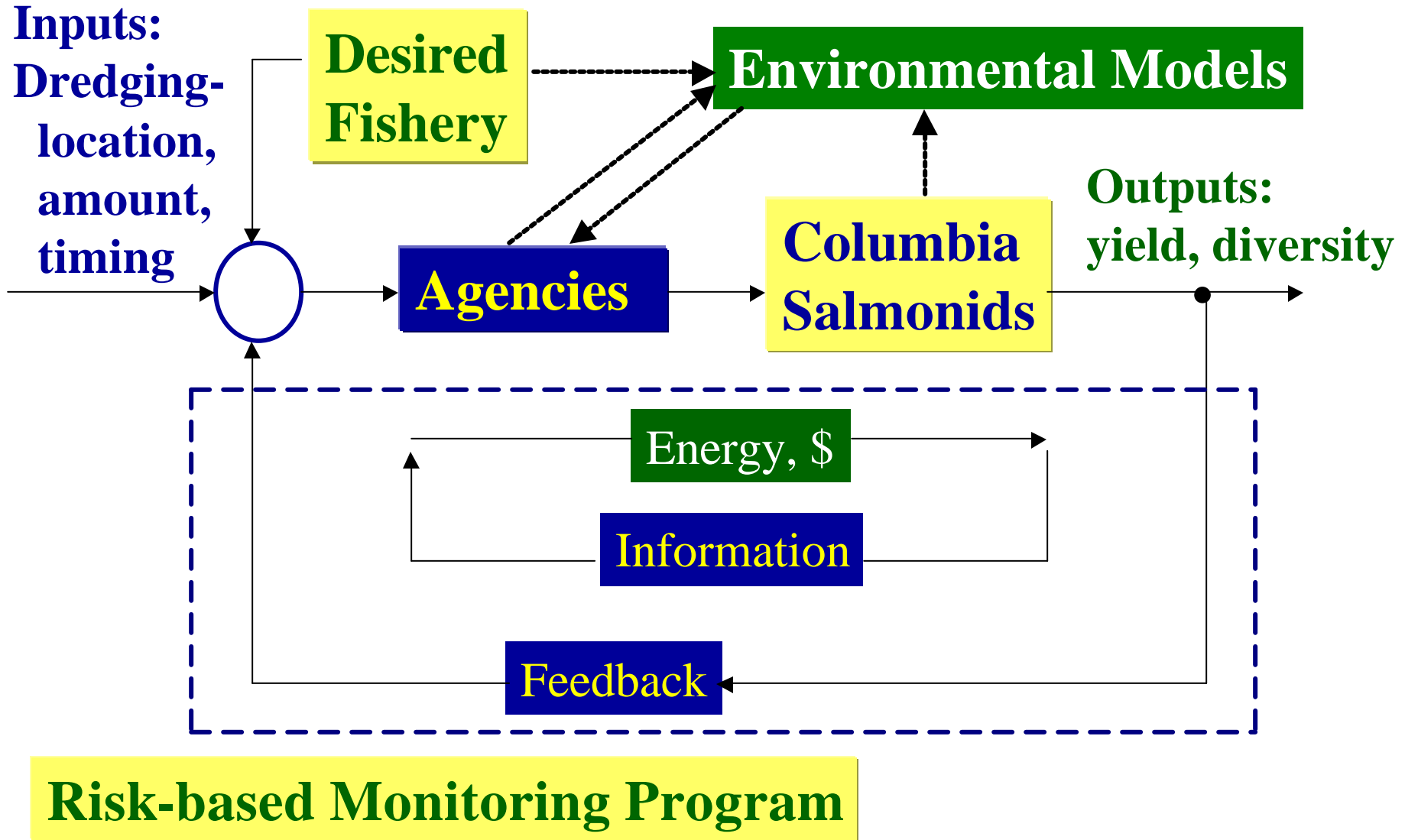
**Feedback**



# A Dynamic Dredging-Salmonid Control System



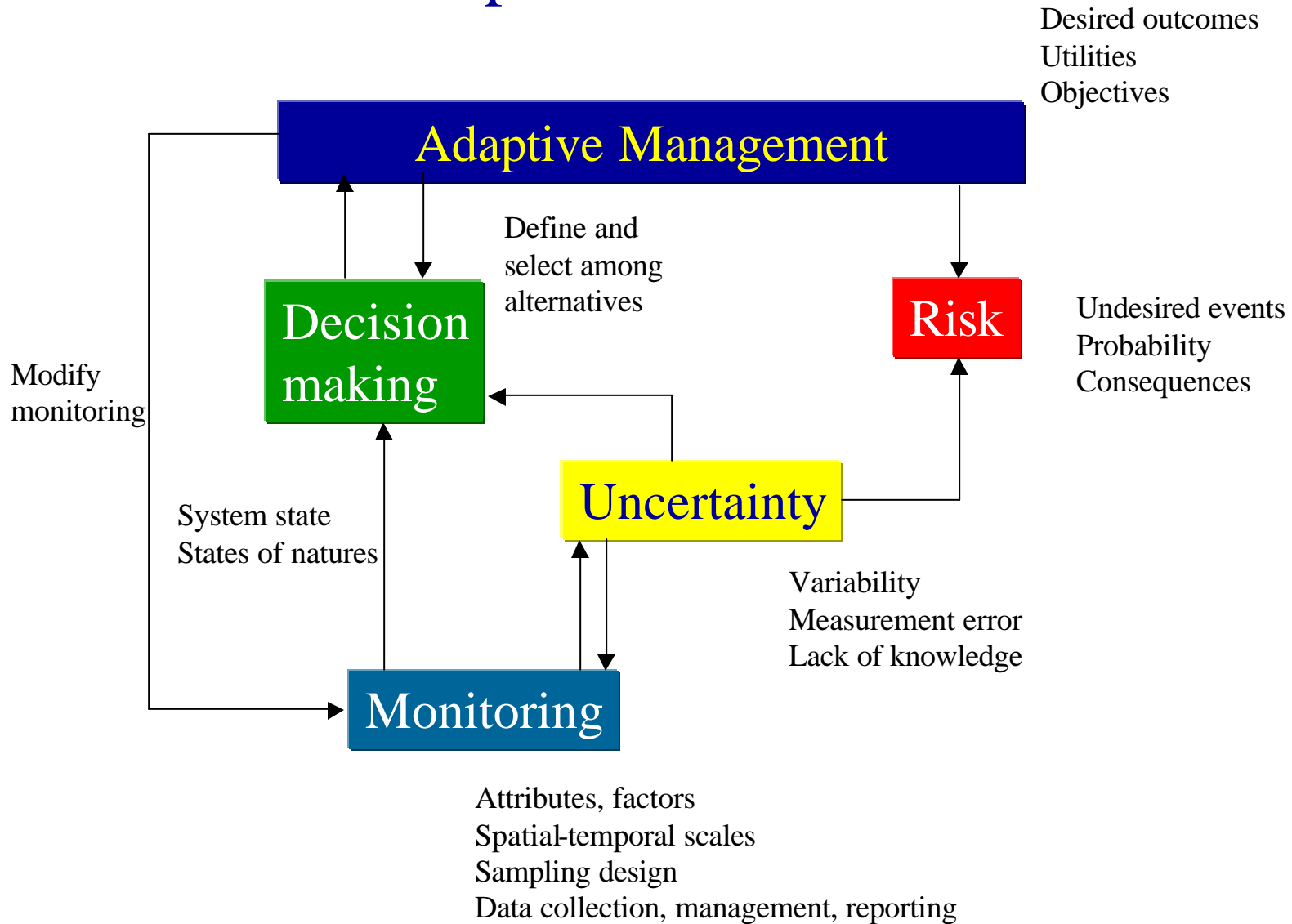
# A Dynamic Dredging-Salmonid Control System



# Environmental models in monitoring...

- Model the underlying chemical, biological, ecological, and environmental structures and processes
- Identify key processes and parameters influencing statistics of monitoring
- Determine critical frequency, scale and extent for monitoring

# Interrelationships...



# Proposed project...

## Desired outcomes:

- ESA and salmonids
- Commercial navigation
- Salmonid fishery

## Objectives:

- Multiobjective optimization
- Avoid “lose-lose”
- Identify “win-win”

## Undesired events:

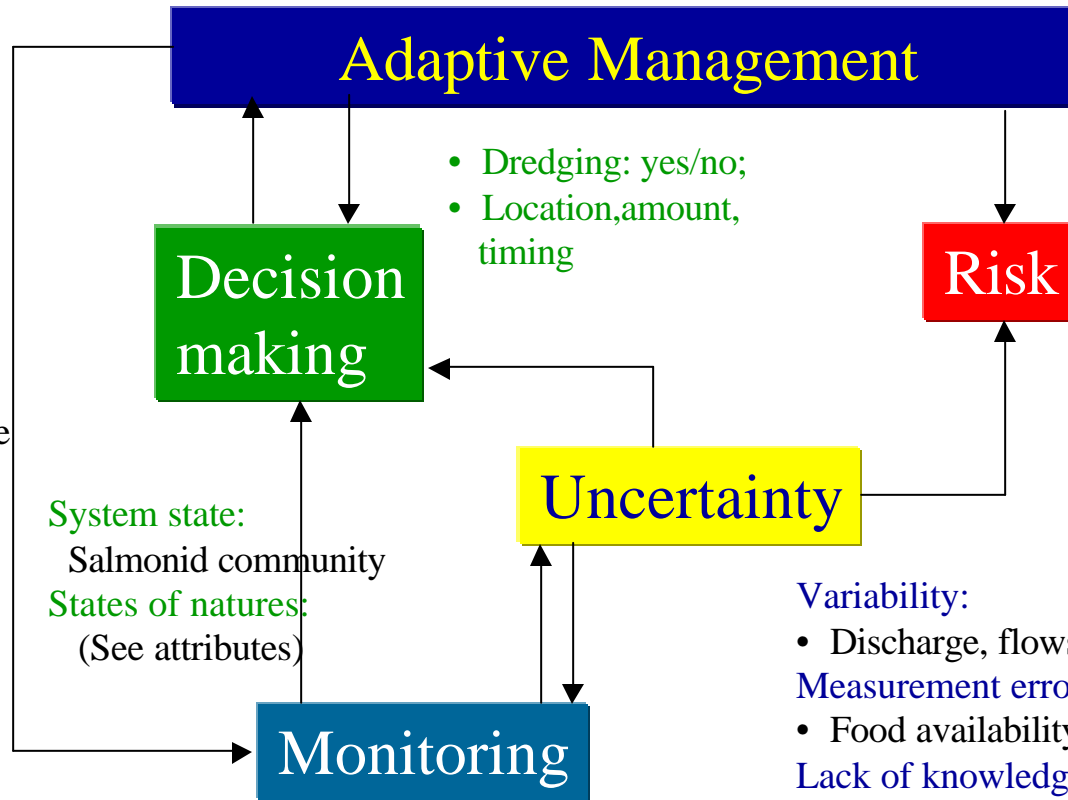
- Extinction
- Losses in production
- Unrealized trade

## Consequences:

- Loss in diversity
- Lost revenues

## Modify Monitoring:

- Add/remove attributes
- Revise sampling



System state:  
Salmonid community  
States of nature:  
(See attributes)

- Dredging: yes/no;
- Location, amount, timing

## Variability:

- Discharge, flows

## Measurement error:

- Food availability

## Lack of knowledge:

- Estuary utilization

## Attributes, factors:

- Salinity, temperature, DO
- Turbidity maximum
- Current velocity
- Salmonid distribution, abundance
- Benthic invertebrates
- Zooplankton

## Spatial-temporal scales:

- Diurnal - local
- Seasonal - estuary
- Annual – Columbia R.
- Interannual

## Sampling design:

- Uniform
- Random, stratified-random

## Data collection, management, reporting

# Challenges in adaptive management...

- **Value conflicts: adaptive towards what?**
- **Authority: who decides?**
- **Modeling and reliable assessment**
- **Costs and risks of large-scale management experiments**
- **Research and management interests**

(i.e., Walters, 1997)