
ECOLOGICAL RISK
ASSESSMENT
MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

Lesson Learning Goals

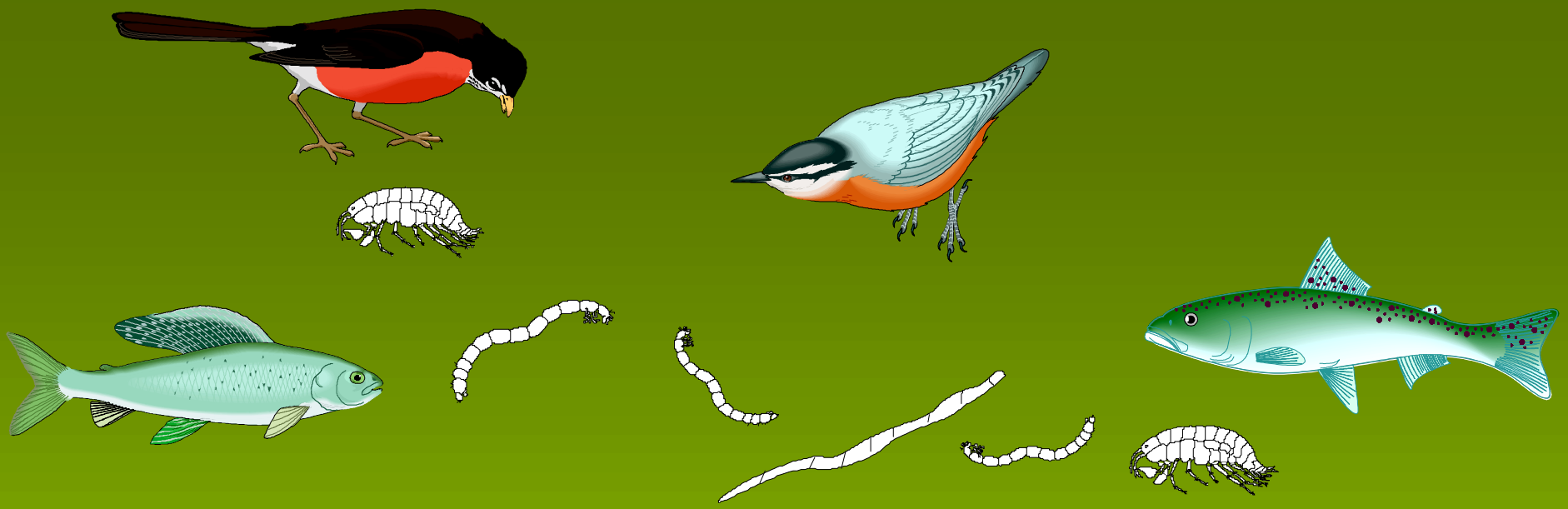
At the end of this lesson you should be able to:

- Define terminology and list the steps in an ecological risk assessment (ERA)
- Sketch a simple conceptual model for an example ecosystem indicating potential stressors, receptors and exposure pathways
- Describe the potential application of ERA in environmental impact assessment (EIA)

What is Ecological Risk Assessment?

Definition:

A tool that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors



RISK = Magnitude of Adverse Ecological Effects X Probability of Adverse Ecological Effects

Temperature Change

Cu

PCBs

Hg

Habitat Loss

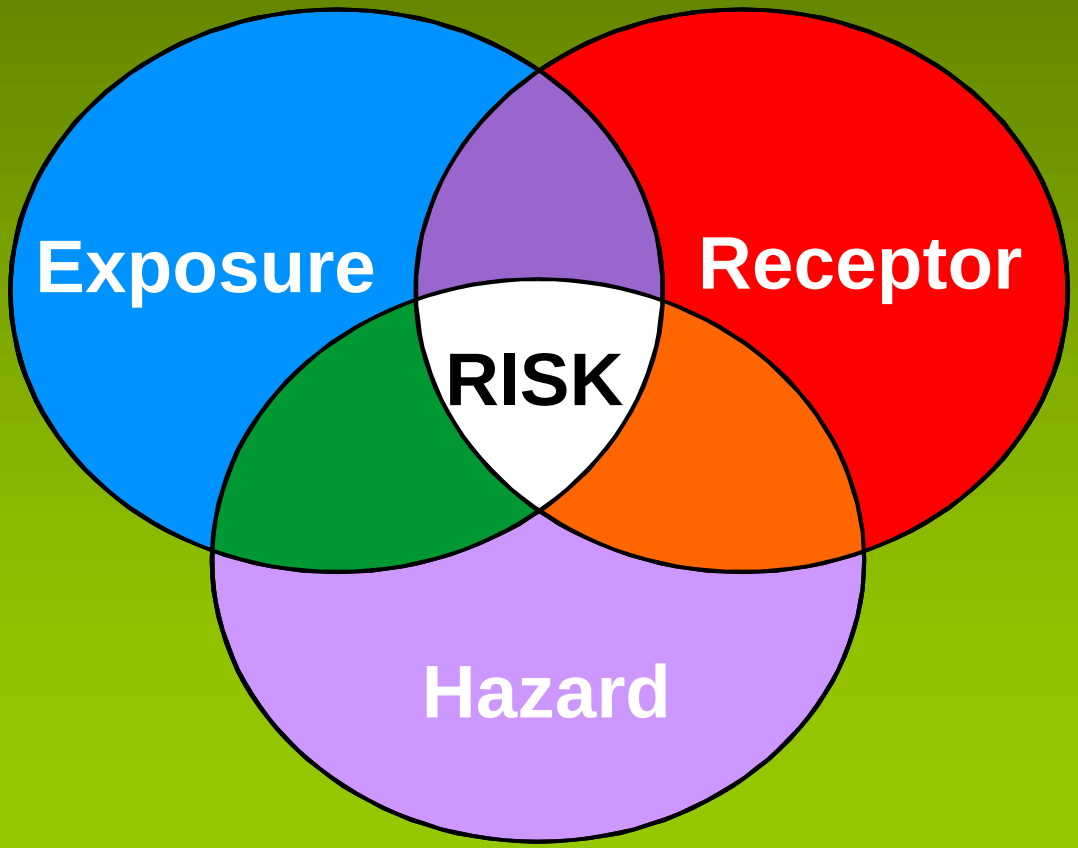
DDT

What Constitutes Risk?

A risk does not exist unless two conditions are satisfied:

1. The stressor has the inherent ability to cause one or more adverse effects
2. The stressor co-occurs with or contacts an ecological component long enough and at sufficient intensity to elicit the identified adverse effect

Required Components of Risk



Two General Types of Risk Assessment

- Ecological Risk Assessment (ERA)
- Human Health Risk Assessment (HHRA)

Both HHRA and ERA share the same overall framework but differ in the specific technical tools used in the assessment; ERA is the focus of this lesson; HHRA will not be covered

Risk Terminology

- Risk Assessment: The process of determining risk
- Receptor: The organism(s) or ecological resource(s) of interest that might be adversely affected by contact with or exposure to a stressor

Risk Terminology (Cont'd)

- Stressor:
  - Any physical, chemical or biological entity that can induce an adverse effect
  - Adverse ecological effects encompass a wide range of disturbances ranging from mortality in an individual organisms to a loss of ecosystem function

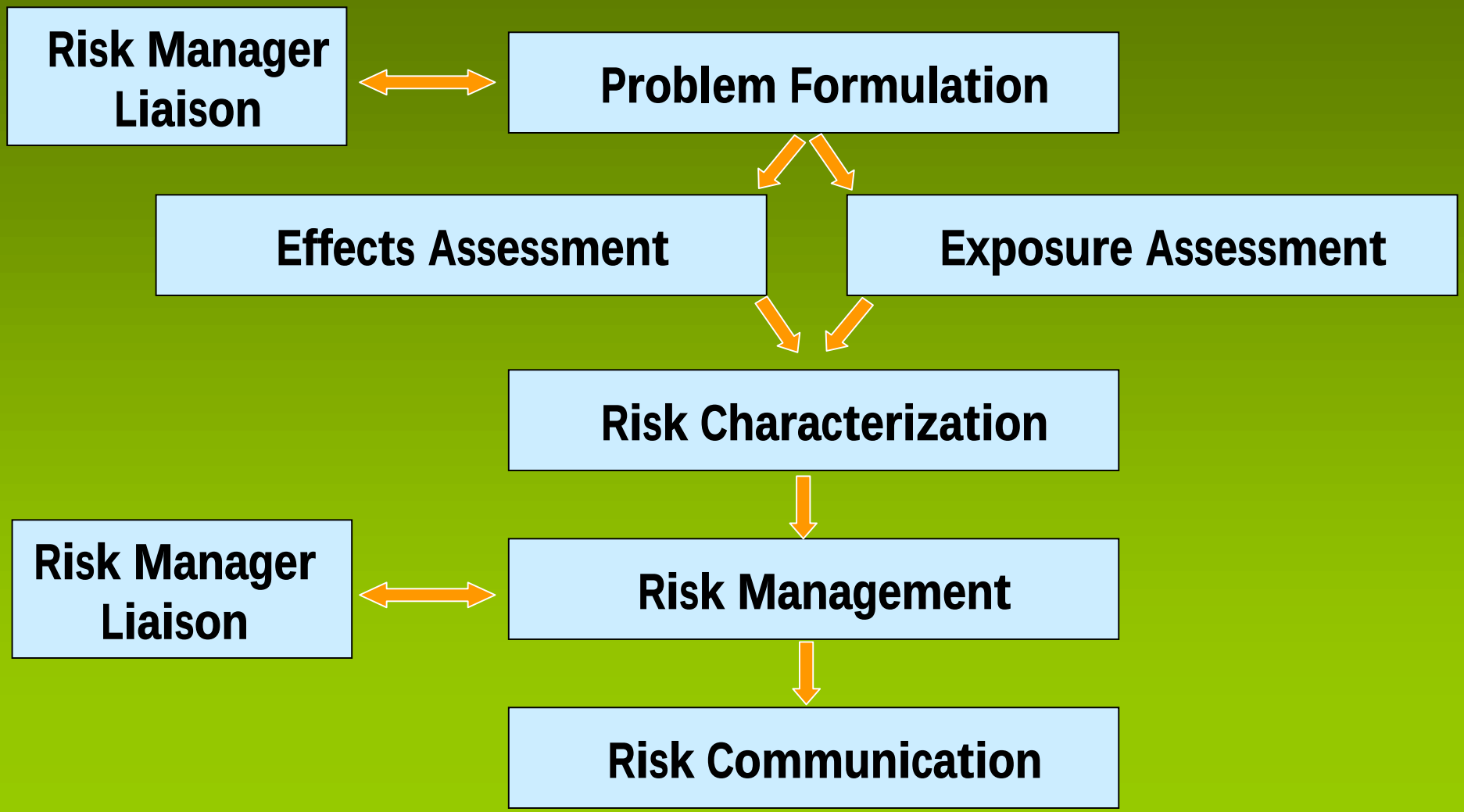
Risk Terminology (Cont'd)

- Exposure:
  - The process by which a stressor is delivered to a receptor
  - Exposure is a result of the magnitude and form of a stressor in the environment, coupled with the presence of the receptor

Risk Terminology (Cont'd)

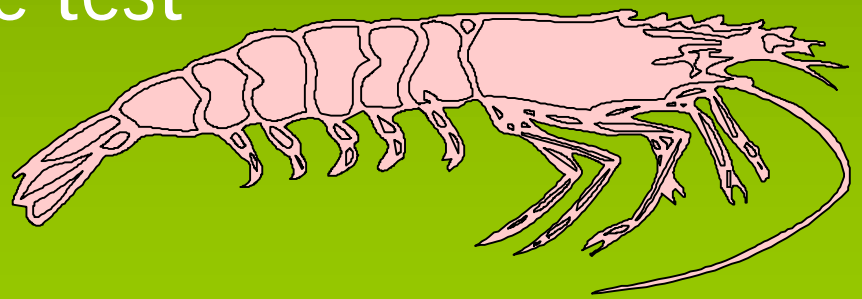
- Risk Management: The process of decision making and action that attempts to minimize risk
- Risk Communication: The expression of the measured or predicted risk (e.g., public meetings)

ERA Framework



ERA – Is It or Isn't It?

1. The 96-h LC50 for juvenile penaeid shrimp exposed to cadmium is 960 g/L Cd. In other words, this concentration of Cd has been shown to kill 50% of the test organisms.



ERA – Is It or Isn't It? (Cont'd)

2. The water level in a mangrove area is predicted to drop as a result of drainage for reclamation activity. The organisms in the area will not be able to survive without access to aquatic habitat. Without risk management intervention, the biodiversity of the area could be severely reduced.

ERA – Is It or Isn't It? (Cont'd)

3. A study reveals that:
   - » sediments contain elevated levels of a bioaccumulative chemical
   - » birds exhibit body burdens of the chemical above a certain level may fail to reproduce
   - » a food chain model and sampling indicate that chemicals are being transported from the sediments to the birds

   The analysis compared measured and estimated body burdens in the birds to the literature values for toxic effects

ERA – Is It or Isn't It? (Cont'd)

4. Elevated levels of pesticide residues have been detected in subsurface soils in a large plot of land on the outskirts of a large city

ERA – Is It or Isn't It? (Cont'd)

5. A power plant is predicted to draw large numbers of larval fish in with its cooling water. Tests show that the survival of the larvae is low. An analysis is performed to determine if the larval mortality could affect the fish population.

ERA – Is It or Isn't It? (Cont'd)

6. A new chemical processing factory is being proposed:
   - » Atmospheric discharge from the factory will be transported toward an adjacent upland forest
   - » Probabilistic models have been used to estimate the frequency and duration of exposure

ERA – Is It or Isn't It? (Cont'd)

7. A probabilistic effects model converts exposure concentrations profiles into the probability of an effect on local vegetation

   The outcomes are summarized as a series of statistics

Components of ERA

1. Problem Formulation
2. Exposure Assessment
3. Effects Assessment
4. Risk Characterization

Problem Formulation

Problem formulation sets the stage for the entire ERA process:

- systematic planning helps identify the major factors that need to be considered
- both risk assessors and risk managers should be involved
- defines protection goals (human values) for the environment
- documents the ERA process

Elements of Problem Formulation

- Interaction between assessor/government agencies
- Site description (identify potential sources)
- Identification and characterization of stressors (e.g., chemicals, physical disturbances)
- Identification of receptors (i.e., ecological components at risk)

Elements of Problem Formulation (Cont'd)

- Identification of potential ecological effects
- Selection of assessment and measurement endpoints
- Development of a conceptual model and risk hypotheses
- Determination of the approach for conducting the assessment

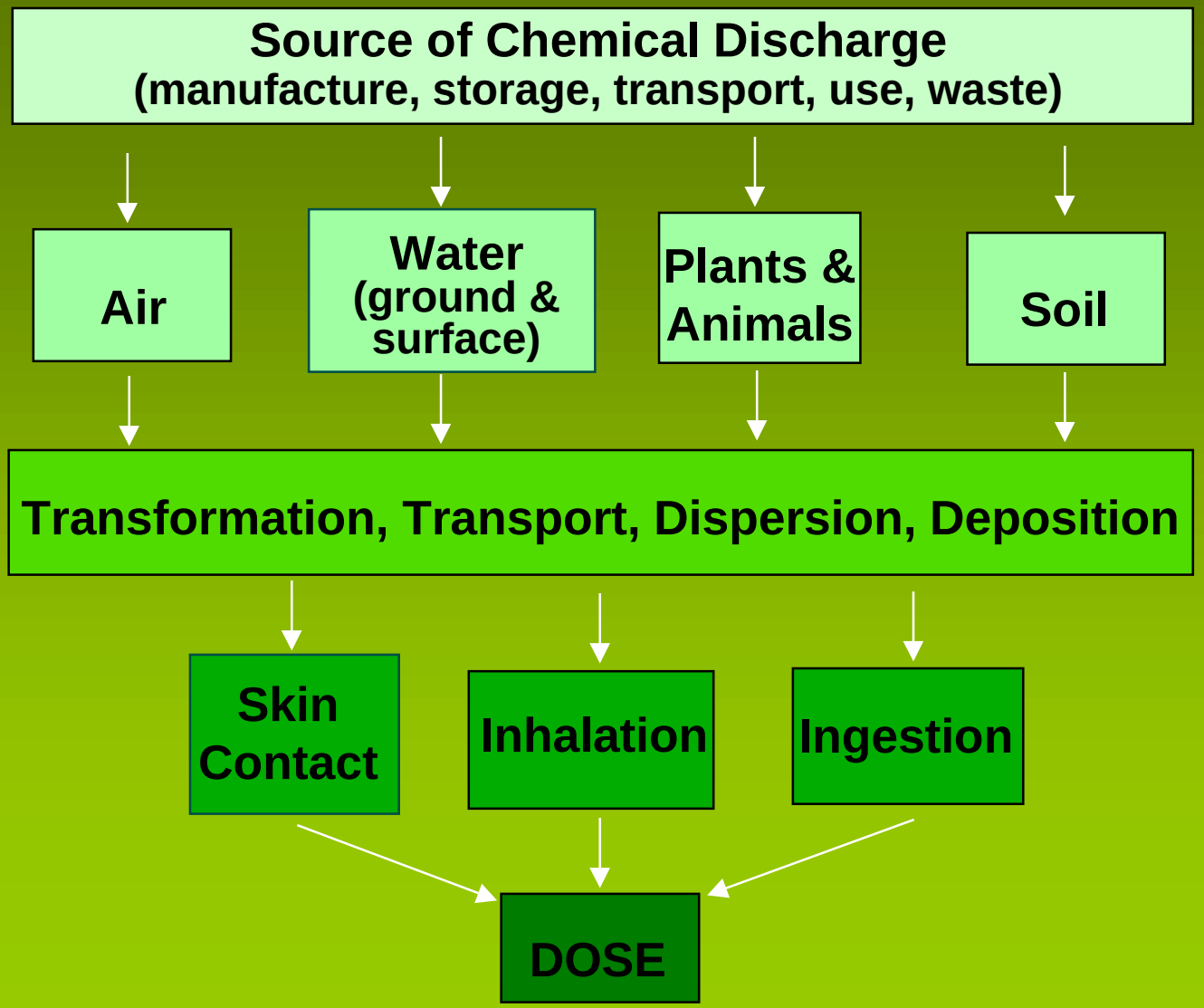
Benefits of a Good Problem Formulation in ERA

- ERA better connected to management goals
- ERA more scientifically defensible
- ERA better accepted by stakeholders
- ERA cost-effective

Identify Stressors of Concern

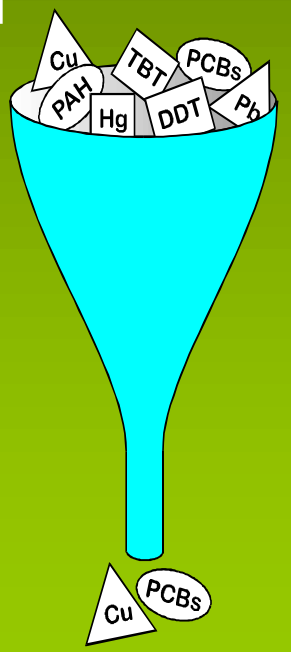
- Stressors:
  - chemical (inorganic or organic substances)
  - physical (extreme conditions or habitat loss)
  - biological (altering biological structure)
- Direct and indirect effects should be considered
- Examine all exposure pathways

Exposure Pathways

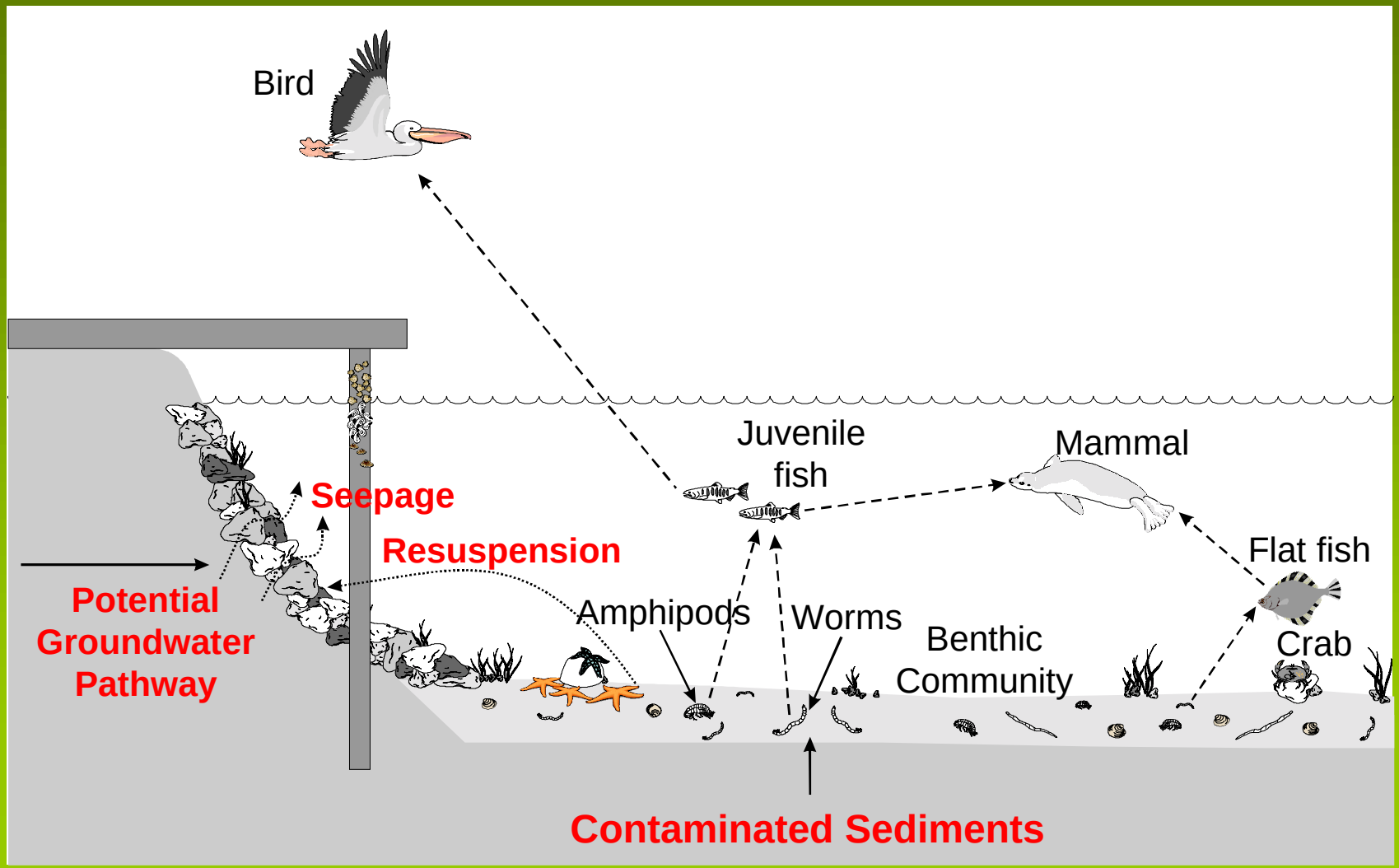


Selection of Key Stressors of Concern

- Objective: Focus on most relevant stressors
- For example, for contaminants screen concentrations against:
  - natural background levels
  - toxicity-based environmental criteria
  - nutritional requirements (mammals and birds)



Conceptual Exposure Diagram for Sediments



Keys to Successful Problem Formulation

- Consensus-based planning process
- Communication between risk assessors and government agencies
- Clear decision criteria
- Community (i.e., stakeholder) involvement
- Concentrates on key contaminants, pathways, and receptors

Components of ERA

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Definition of Exposure

Co-occurrence between a stressor and an ecological component

Key Questions to Address in Exposure Assessment

1. What receptors are exposed to the stressor(s)?
2. What are the significant routes of exposure?
3. What are the exposure concentrations?
4. What is the exposure duration?

Key Questions to Address in Exposure Assessment (Cont'd)

5. What is the frequency of exposure?
6. Are there any seasonal or climatic variations likely to affect exposure?
7. Are there any site-specific geophysical, physical and chemical conditions affecting exposure?

Key Elements of Exposure Assessment

- Stressor source and release
- Stressor transport and fate
- Exposure pathways
- Receptor exposure quantification

Exposure Pathways

- Four elements must be present for an exposure pathway to be complete:
  - source or release of the stressor
  - transport to a point of contact
  - contact
  - absorption

Examples of Exposure Pathways

- Fish or other aquatic receptors - route of exposure may be:
  - water (ingestion and dermal)
  - food (ingestion)
  - sediment (ingestion and dermal)

Examples of Exposure Pathways (Cont'd)

- Mammals and birds - route of exposure may be:
  - water (ingestion and dermal)
  - food (ingestion)
  - sediment (incidental ingestion)

Exposure Estimates

- Measured: on site water, sediment, biota concentrations
- Modeled: on concentrations, degradation rates, mass balance; uses physical/chemical properties of stressors to predict

Exposure Assessment Results

The end product of the exposure assessment is an estimation of the environmental concentration of each contaminant of concern to which each receptor of concern is exposed

Components of ERA

1. Problem Formulation
2. Exposure Assessment
3. Effects Assessment
4. Risk Characterization

What are Effects?

- Increased enzyme activity
- 20% reduction in fish population
- Accumulation of a contaminant in tissues
- Statistically significant decrease in fecundity
- 50% fish mortality in an acute toxicity test

Which ones are important?

Effects (Hazard) Assessment

- Describes the relationship between the stressor(s) and the receptor(s)
- Is used to link a contaminant to a biological response
- Information sources about effects:
  - Literature
  - Laboratory studies
  - Field studies

Levels of Stress Response

- Physiological responses (e.g., enzyme induction)
- Individual integrators (e.g., survival, growth)
- Population and community level (e.g., abundance or community structure)

Principles of Ecotoxicology

- Causality: the effect is clearly a result of the exposure
- Concentration-Response Relationship: the response should increase as concentration or exposure increase
- Quantification of Effects: observed adverse effects can be measured in a reproducible way

Effects Assessment Results

The endpoint of the effects assessment is the highest exposure concentration for each stressor that does not result in unacceptable ecological effects to each receptor

Components of ERA

1. Problem Formulation
2. Exposure Assessment
3. Effects Assessment
4. Risk Characterization

Risk Characterization

- The final phase of the ecological risk assessment
- Estimates the magnitude and probability of effects
- Integrates other risk assessment components (i.e., exposure and effects assessments)

Risk Characterization (Cont'd)

- Risk characterization involves three steps:
  1. Calculation of risk estimate
  2. Description of uncertainty associated with the estimate
  3. Interpretation of the ecological significance of the risk estimate
- Risk characterization can be done on a qualitative or quantitative basis

Calculation of Risk Estimate

- There are a number of different ways to calculate the risk estimate
- One of the simplest and most straightforward way is to use a hazard quotient

Hazard Quotient

HQ = EEC/BC

HQ = Hazard or Risk Quotient

EEC = expected environmental concentration (exposure)

BC = benchmark concentration (effect)

➔ HQs may be calculated for whole sites, or may be spatially distinct

Uncertainty Analysis

- Uncertainty analysis identifies and quantifies uncertainty
- Major sources of uncertainty:
  - Definition of scope
  - Information and data
  - Natural variability
  - Error

Uncertainty Analysis (Cont'd)

- Identifies and quantifies uncertainty in problem formulation, analysis, and risk characterization
  - sensitivity analysis
  - probabilistic modeling (e.g., Monte Carlo)
  - professional judgement

Uncertainty Analysis (Cont'd)

The output of the uncertainty analysis is an evaluation of the impact of the uncertainties on the overall assessment

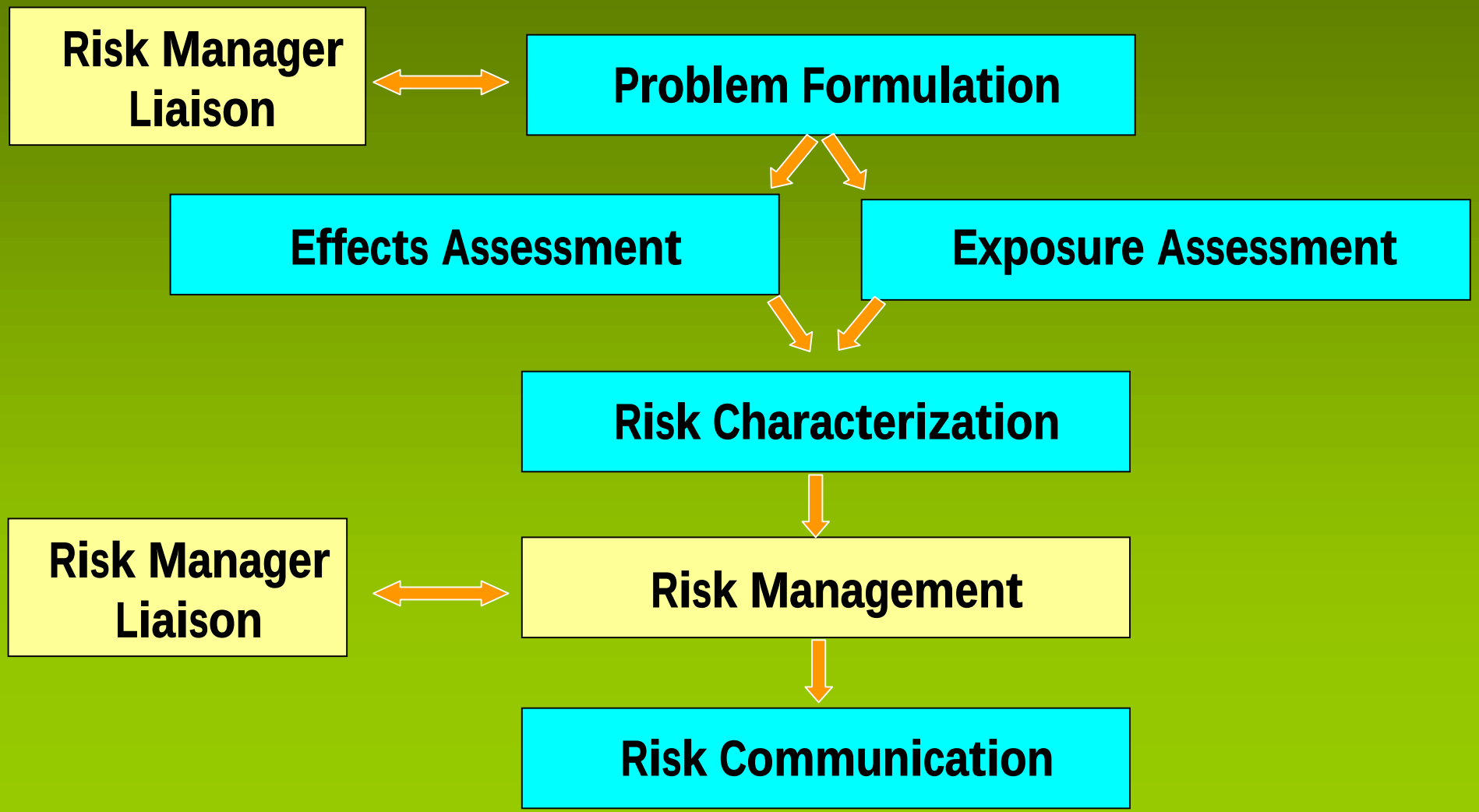
Risk Description

- Ecological risk summary:
  - summarizes results from the risk estimation and discusses uncertainties
  - risk estimate confidence expressed through weight-of-evidence discussion
  - identify additional analyses or data that might reduce uncertainty of risk estimates

Risk Description (Cont'd)

- Interpretation of ecological significance:
  - places risk estimates in context of anticipated effects
  - critical link between risks and communication of results
  - relies on professional judgement
  - considers the nature of effects, spatial and temporal patterns of effects, and potential for recovery

Review of ERA Framework



Risk Management

Involves two components:

- Liaison with risk assessors to ensure that the assessment is comprehensive (e.g., all potential receptors)
- Determination of what to do with the risk assessment results - what course of action should be or not be taken

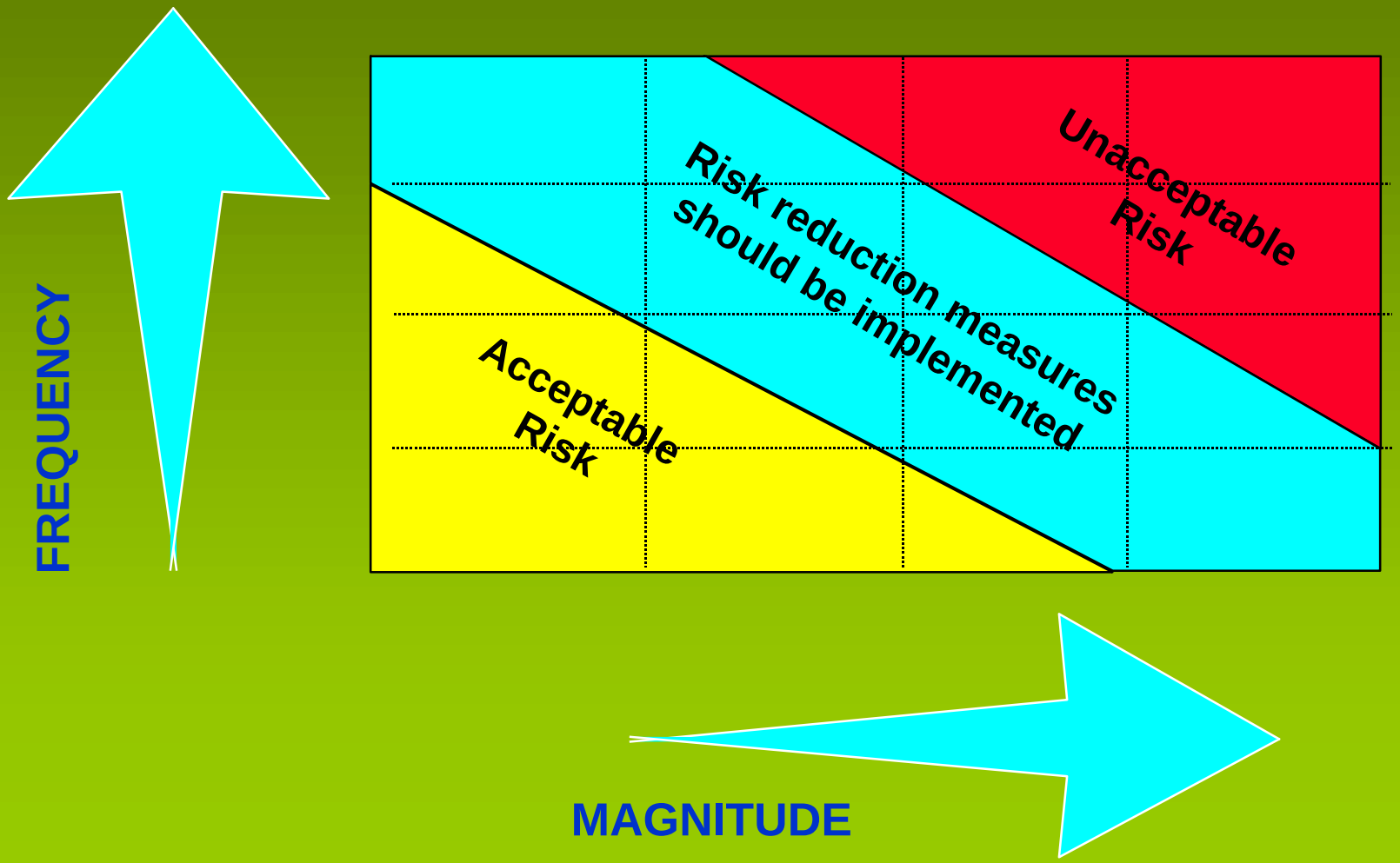
Communication

- Risk assessor presents results to risk manager (e.g., government agency)
- Liaison reduces chance of results misinterpretation
- Risk assessor works with risk manager to develop mitigative measures

The Decision-Making Process

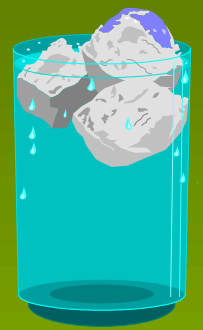
- Start with scientific information from the risk assessment
- Integrate other relevant information
  - economic constraints
  - societal concerns
- Evaluate risk management options
- Identify most appropriate course of action

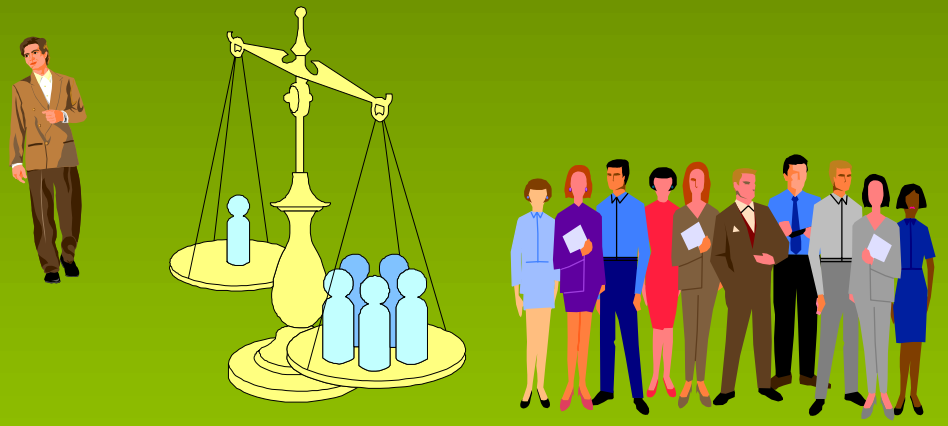
Risk Management



Selecting Alternatives

Risk of small amounts of halomethanes being produced from drinking water chlorination OR





Public health risk from pathogenic organisms in non-chlorinated drinking water

Benefits of Using Risk Assessment in Decision Making

- ➔ It provides the quantitative basis for comparing and prioritizing risks
- ➔ It provides a systematic means of improving the understanding of risks
- ➔ It acknowledges inherent uncertainty, making the assessment more credible

Benefits (Cont'd)

- It estimates clear and consistent endpoints
- It provides a means for the parties making environmental decisions to compare the implications of their assumptions and data
- Risk assessment separates the scientific process of estimating the magnitude and probability of effects (risk analysis) from the process of choosing among alternatives and determining acceptability of risks (risk management)

Applications of ERA

ERA can be applied at different scales and in different processes such as:

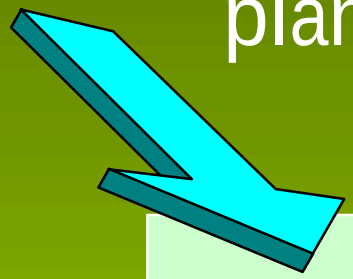
- to support regional planning, or
- to support the EIA process

Regional ERA

- Establishes broad-scale protection goals and ecological criteria
- Addresses multiple stressors, complex endpoints and cumulative effects
- Develops a framework for prioritizing areas and/or issues (e.g., cumulative impacts) within the region

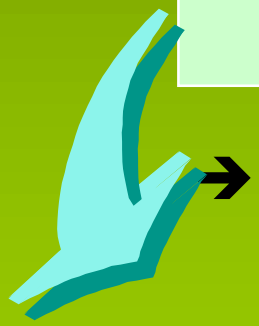
Integrating ERA with EIA

- Regional ERA facilitates environmental planning and management on a regional scale

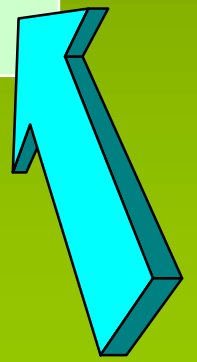


Environmental Impact Assessment

Goal: To determine impact and analyze alternative options



- ERA quantitatively evaluates risks of EIA related stressors to humans or valued ecological resources



Benefits of Using ERA in EIA

- Provide more focused methods for exploring EIA issues
- Allows evaluation of different mitigation option to manage risks (i.e., risk reduction)
- Explicitly addresses uncertainty
- Regional ERAs can focus the scope of EIA towards sensitive issues (e.g., cumulative impacts)

Concluding Thoughts

Important points to remember are:

- ERA can make an important contribution to EIA by quantifying potential risks to humans and/or valued ecological resources
- Uncertainty is explicitly expressed for purposes of decision making and identifying additional scientific study needs
- Using a risk-based approach to EIA evaluation can guide selection of mitigation measures which will result in the most risk reduction per unit expenditure