Environmental risks of biodiversity

ZA210 (Z5, 19.2. 2025, Wednesday 15.00-16.50)

DEPARTMENT OF GEOGRAPHY
FACULTY OF SCIENCE MASARYK UNIVERSITY

Karel Brabec, Ph.D.

brabec@sci.muni.cz

1. Introduction – risk analysis

picture generated by chatGPT

COURSE AND FINISHING

- **individual study** of the presentations and other materials provided
- **lectures and discussion exercises**: explanation of linkages among topics and practice of practical application of acquired knowledge
- **3 tests**: to test knowledge and understanding of topics
- **oral exam** (taking into account the results of tests, activity in lectures)

RISKS TO BIODIVERSITY
Overview

- risk analysis
- biodiversity
- pressure typology and thier impacts
- stress ecology
- effects of complex pressures (climate, land use)
- management and protection of ecosystems

SYLABUS

1) Introduction (Ecological Risk Assessment)
2) Ecosystem structure, biological diversity, ecological processes
3) Biodiversity – concepts, attributes, drivers
4) Biodiversity – spatio-temporal patterns
5) Environmental risks (typology); DPSIR scheme (Driving forces, Pressures, States, Impacts, Responses)
6) Stress ecology
7) Biodiversity and ecosystem processes
8) Climate-biodiversity relationships
9) Scenarios of land use change
10) Habitat changes (Natura 2000 sites, Habitat Directive, Nature Conservation)

INTRODUCTION

ENVIRONMENTAL RISKS OF BIODIVERSITY

Risk analysis

The starting point can be a territory, type of stressor, target species, habitat, ecological process

Risk related to a planned action or a shift in priorities in an existing environment (e.g. thanks to scientific knowledge, species, habitats, processes will move to the forefront of environmental protection)

Biodiversity

- Diversity of biological components of ecosystems (genetic, species, functional, processes)
- habitats/ecosystems

PROTECTING BIODIVERSITY

WHY IS BIODIVERSITY IMPORTANT?

- reduction of biodiversity → decline in natural capital and threat to the provision of ecosystem services
- bacteria and fungi involved in the decomposition of organic matter (soil fertility)
- insects – pollination of crops
- active substances from natural sources
- by losing biodiversity, we not only lose the beauty and richness of nature, but also destabilize ecological processes
- man is connected to the biosphere, which he also disrupts with his activity

veronica
EKOLOGICKÝ INSTITUT

https://www.veronica.cz/co-to-je-biodiverzita-a-proc-ji-chranit

PROTECTING BIODIVERSITY

https://www.veronica.cz/co-to-je-biodiverzita-a-proc-ji-chranit

WHAT THREATENS BIODIVERSITY?

- degradation and loss of **habitats**
- the **introduction of non-native species** is a serious cause of endangerment of the local ones - in the Czech Republic it is mainly a problem with balsam, knotweed, acacia, American crayfish, etc.
- **depletion of natural resources** and ecosystems - extraction, fishing, hunting, etc. In the Czech Republic, it is mainly poor forest management.
- **environmental pollution** and diseases. In the Czech Republic, it is mainly air pollution.
- **climate change** - changes in the migratory behaviour of species, species distribution changes (range)

PROTECTING BIODIVERSITY

WHAT NEEDS TO BE DONE TO PRESERVE BIODIVERSITY?

- species and ecosystems need space to recover and develop. At least 10% of all ecosystems should be protected
- without biodiversity, there will be no agriculture. Agriculture often threatens ecosystems and non-productive species - lower use of pesticides and artificial fertilizers is key to preserving biodiversity. The principles of organic farming can serve as a good example.
- 75% of all fishing grounds are depleted, and many species of fish (such as cod and plaice) are already endangered. So we need to use them in moderation and more sustainably.

veronica
EKOLOGICKÝ INSTITUT

https://www.veronica.cz/co-to-je-biodiverzita-a-proc-ji-chranit

PROTECTING BIODIVERSITY

WHAT NEEDS TO BE DONE TO PRESERVE BIODIVERSITY?

- the construction of roads, factories and residential houses destroys the habitats of plants and animals. If urban and rural development does not take into account the needs of nature, our surroundings will soon be dominated by concrete. For example, 24% of the area of the Netherlands is built-up.
- ecosystems and habitats of animals and plants will also change as conditions change. We must combat the causes of climate change and adapt the conditions for species to migrate or adapt to new environments.

veronica
EKOLOGICKÝ INSTITUT

https://www.veronica.cz/co-to-je-biodiverzita-a-proc-ji-chranit

PROTECTING BIODIVERSITY

WHAT NEEDS TO BE DONE TO PRESERVE BIODIVERSITY?

- an introduced species can become an invasive species and threaten local flora and fauna. Since we never know how it will behave in the new conditions, preventing these invasions is crucial.
- biodiversity is the basis of sustainable development. Ecosystem services provide the basis for all economic activities. The protection of biodiversity must therefore be integrated into all areas of political decision-making.

veronica
EKOLOGICKÝ INSTITUT

https://www.veronica.cz/co-to-je-biodiverzita-a-proc-ji-chranit

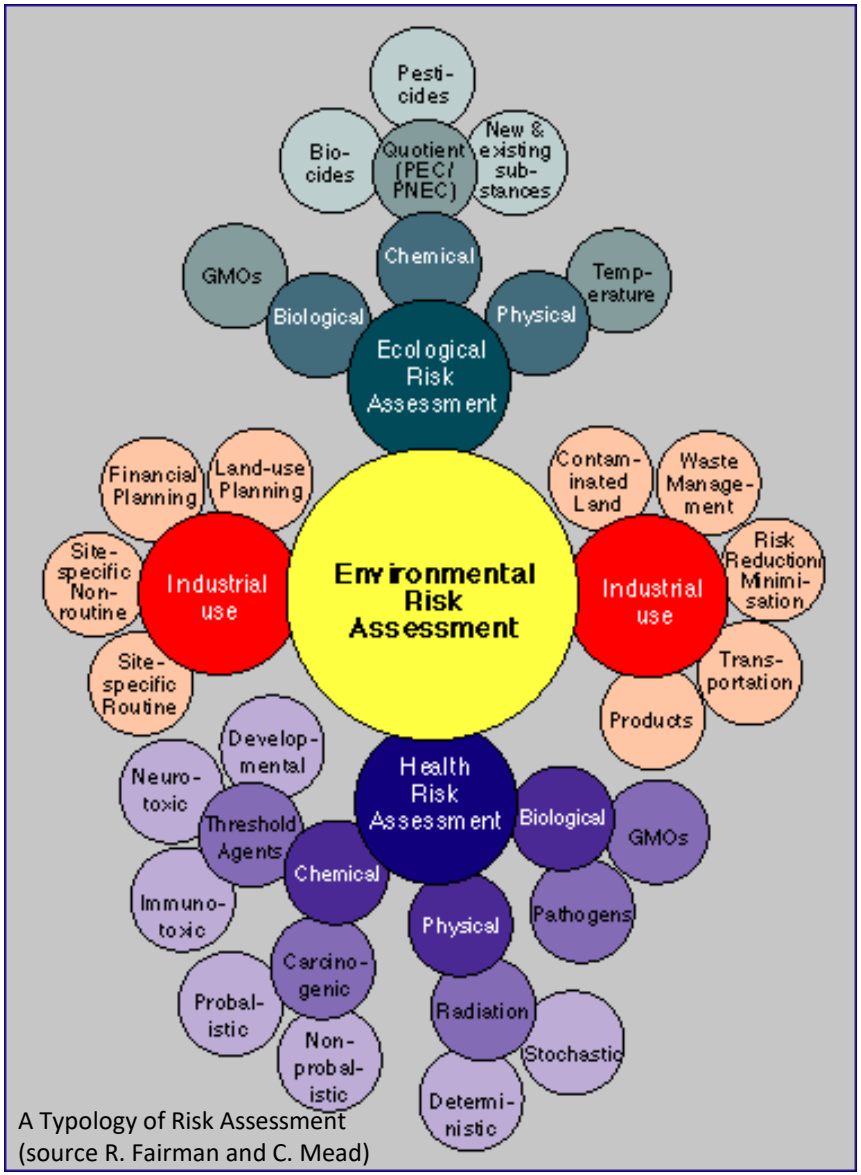
ECOLOGICAL RISK ASSESSMENT

Ecological risk assessments can be used to predict the likelihood of future effects (**prospective**) or evaluate the likelihood that effects are caused by past exposure to stressors (**retrospective**).

RISKS TO BIODIVERSITY

Risk classification

Environmental Risk Analysis (EcoRA): genetically modified organisms (GMOs), chemicals, ionizing radiation and specific industrial installations



A Typology of Risk Assessment
(source R. Fairman and C. Mead)

RISK ANALYSIS

European Environment Agency

https://www.eea.europa.eu/publications/GH-07-97-595-EN-C2/chapter6h.html

Environmental Risk Assessment (ERA)

- an analysis of threats to ecosystems, animals and people related to technology.
- This includes the analysis of health risks, ecological or ecotoxicological risks, and industry-specific hazard analysis applications focusing on people, biota and ecosystems as **endpoints**.

RISK ANALYSIS

European Environment Agency

www.eea.europa.eu

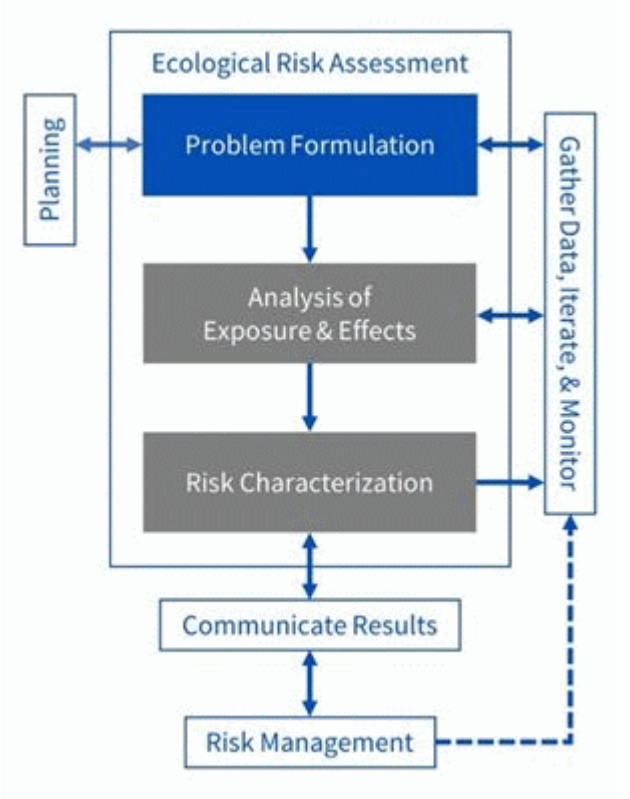
In general, we distinguish between two basic types of risk analysis:

- **Health Risk Assessment** – human health
- **Ecological Risk Assessment** - ecosystems

ECOLOGICAL RISK ASSESSMENT (US EPA)

United States Environmental Protection Agency

Ecological risk analysis is the process of assessing the likelihood that the environment will be affected by exposure to one or more stressors (chemicals, landscape changes, diseases, invasive species, climate change).



https://www.epa.gov/ecobox

https://www.epa.gov/risk/conducting-ecological-risk-assessment

ECOLOGICAL RISK ASSESSMENT (ERA - US EPA)

United States Environmental Protection Agency

An ERA includes **three primary phases**: problem formulation, analysis, and risk characterization.

phase 1 – Planning and Problem Formulation

The information is collected to identify an ecological element (animals and plants) that is endangered and should be protected

phase 2 – Analysis

It determines which plants and animals are exposed to the stressor (and to what extent) and whether this level has the potential to cause environmentally adverse effects.

phase 3 – Risk Characterization

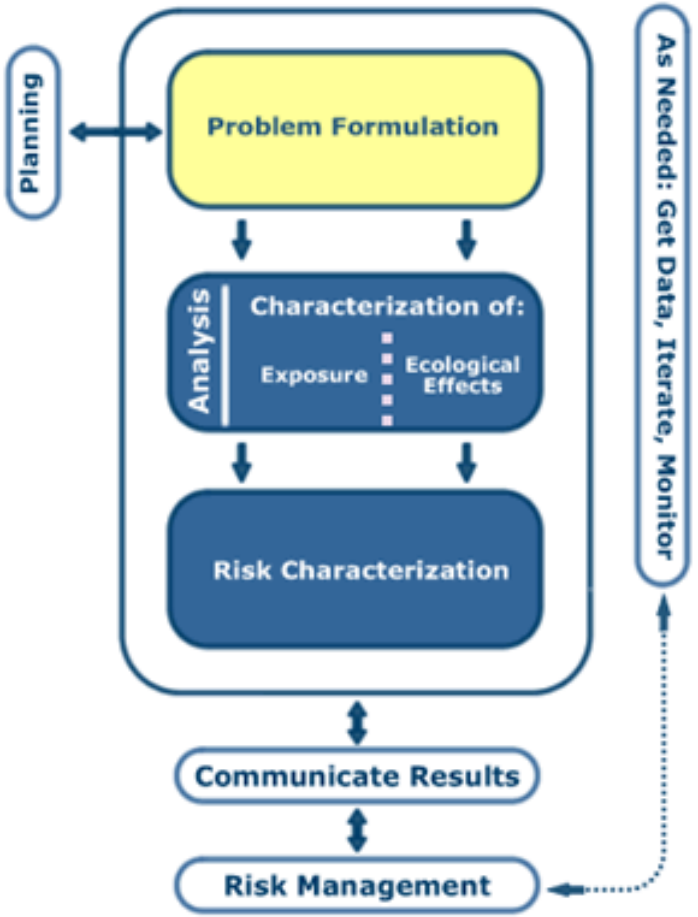
It includes two main components: a risk estimation and a risk description.

Risk estimation: estimate ecological risks through integration of **exposure** and **stressor-response profiles**.

Risk description: provides information relevant to the **interpretation** of risk effects and determines the levels of stressors causing adverse effects on plants and animals of interest.

ECOLOGICAL RISK ASSESSMENT (US EPA)

- planning and research
- problem formulation
- analysis
- risk characterization



ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

Purpose, framework and technical methods/approaches

Who/What/Where is at risk?

- Individual
- Entire population
- Life stages (juvenile stages, adults)
- Subpopulations – highly endangered (e.g. due to genetic characteristics) or highly exposed (e.g. within a geographically defined area)
- Different species – e.g. mink – sensitive to PCBs

ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

What are the risks about?

- Chemicals (individually or in a mixture – cumulative risk)
- Radiation Physical (habitat/habitat changes)
- Microbiological and biological risks (diseases or invasive species)
- Nutritional (e.g. condition, metabolic status)

ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

Where do the risks come from?

- Point sources (e.g. smoke or wastewater from a factory)
- Diffuse/diffuse pollution (e.g. emissions from transport; run-off from farmed areas)
- Natural resources

ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

How does exposure to a risk factor occur?

Pathways (individually or a combination of more)

- Air
- Surface water
- Groundwater
- Soil
- Solid waste
- Food

Routes (and related human activities that result in exposure)

- Food intake (food and water)
- Skin contact
- Inhalation
- Non-dietary ingestion – e.g. behaviour related to grooming (preening/grooming behavior)

ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

What happens to the risk factor in the bodies of organisms and how are these processes affected by factors such as developmental stage, genetic predisposition, differences between species?

- Absorption – the risk factor is taken into the body
- Distribution – is there a transfer of the risk factor within the body?
- Metabolism – are there transformations of the risk factor in the bodies of organisms?
- Excretion – how do organisms get rid of the hazardous substance?

ECOLOGICAL RISK ASSESSMENT (US EPA)
planning

What is the ecological effect?

- For example, changes in the rate of reproduction, the incidence of tumors, effects on the nervous system and mortality.

ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 1: PROBLEM FORMULATION

How long does it take for an environmental hazard to manifest itself in a toxic effect? Does the phase of exposure time matter?

How long?

- Acute – immediate or within hours (max. 1 day)
- Subchronic – weeks or months (generally less than 10% of life expectancy for humans)
- Chronic – a significant proportion of life expectancy or all life expectancy (at least 7 years for a person)
- Occasional

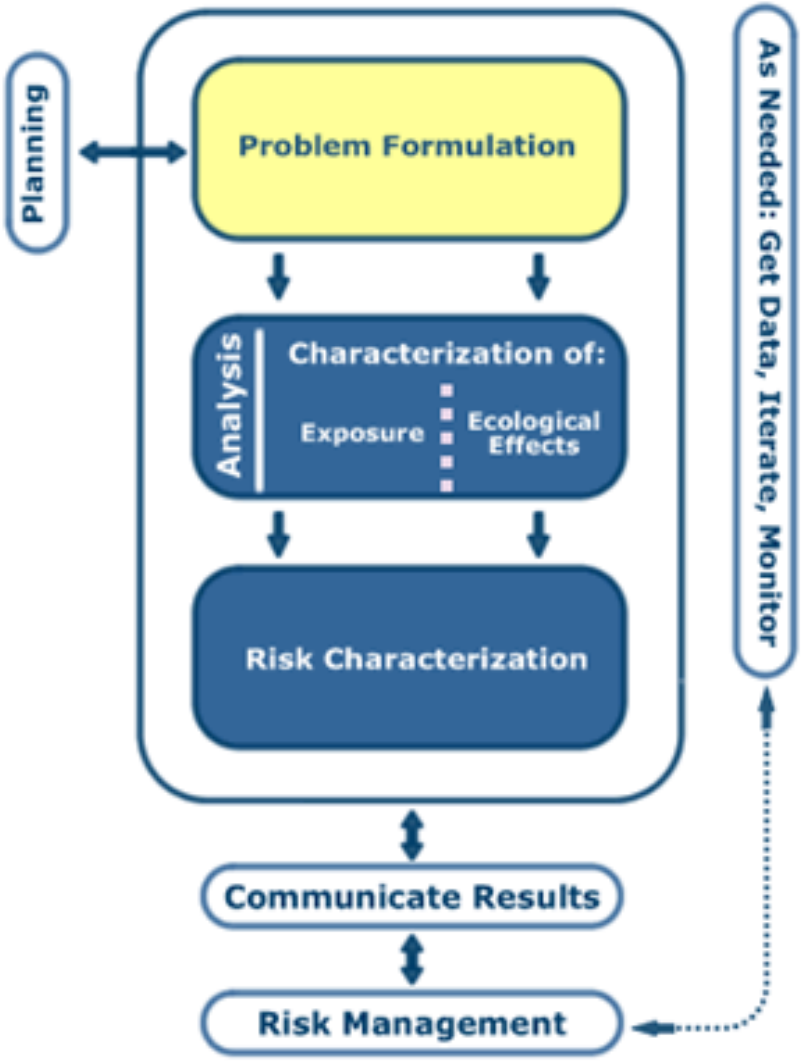
Timing

- Is there a time period in an organism's life cycle when a chemical is most toxic (e.g., embryonic development, juvenile stages, adulthood)?

ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 1: PROBLEM FORMULATION

The aim of the problem formulation process is to determine the **target object** of the evaluation, to determine the ecological element that is important to protect. An ecological element can be:

- Species Functional group of species (e.g., fish-eating species)
- Community (e.g., benthic invertebrates)
- Ecosystem (e.g.: lake)
- Particularly valuable habitat (e.g., waterlogged meadows)



Ecological significance is related to:

Nature and intensity of effects
Spatial and temporal scales of effects
Potential of revitalization
Potential impact on the organizational level
The role of the element in the ecosystem

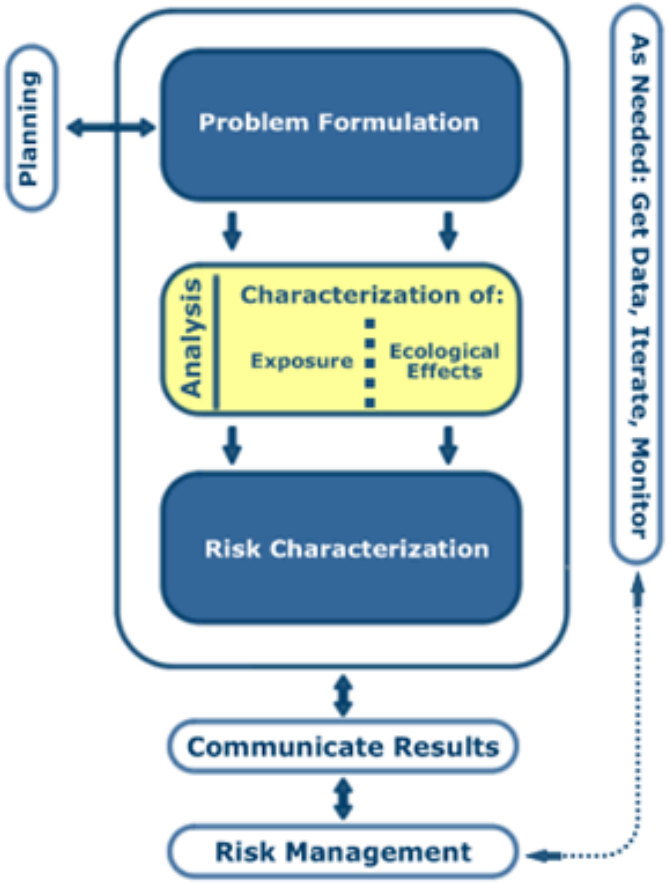
ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 1: PROBLEM FORMULATION

- Endangered species or ecosystems
- Commercially or recreationally important species
- Ecosystem functions or services (food sources, flood protection, nutrient cycling)
- Aesthetic values (clean air in national parks)
- Existence of attractive species such as eagles or whales

- sources
- stressors
- receptors
- potential exposure
- predicted effect on the ecological element (assessment endpoint)

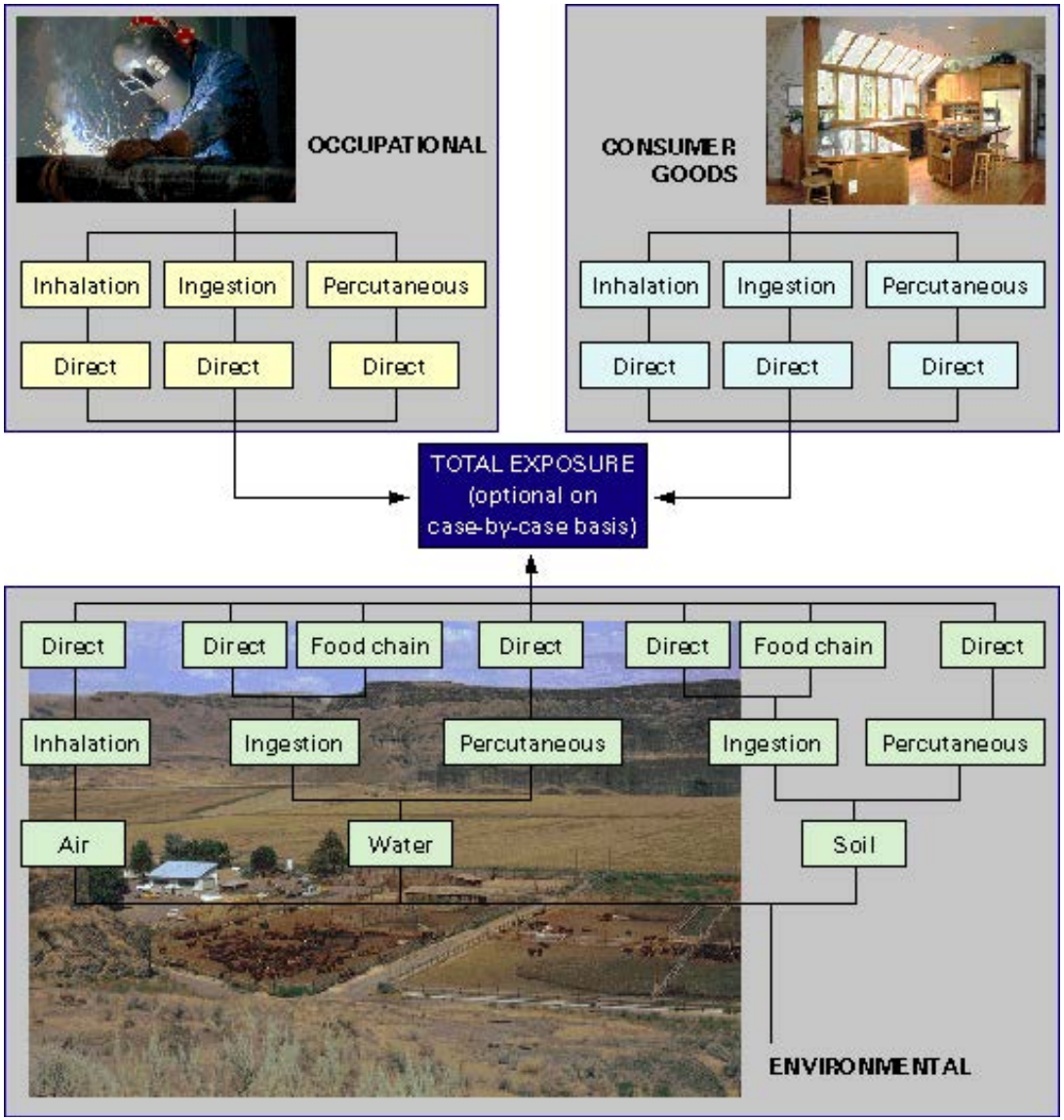
ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 2: ANALYSIS

- provides the components needed to determine or predict the ecological response to stressors within the exposure of interest
- determines which organisms are under stress, to what extent and whether the level of exposure causes adverse ecological effects



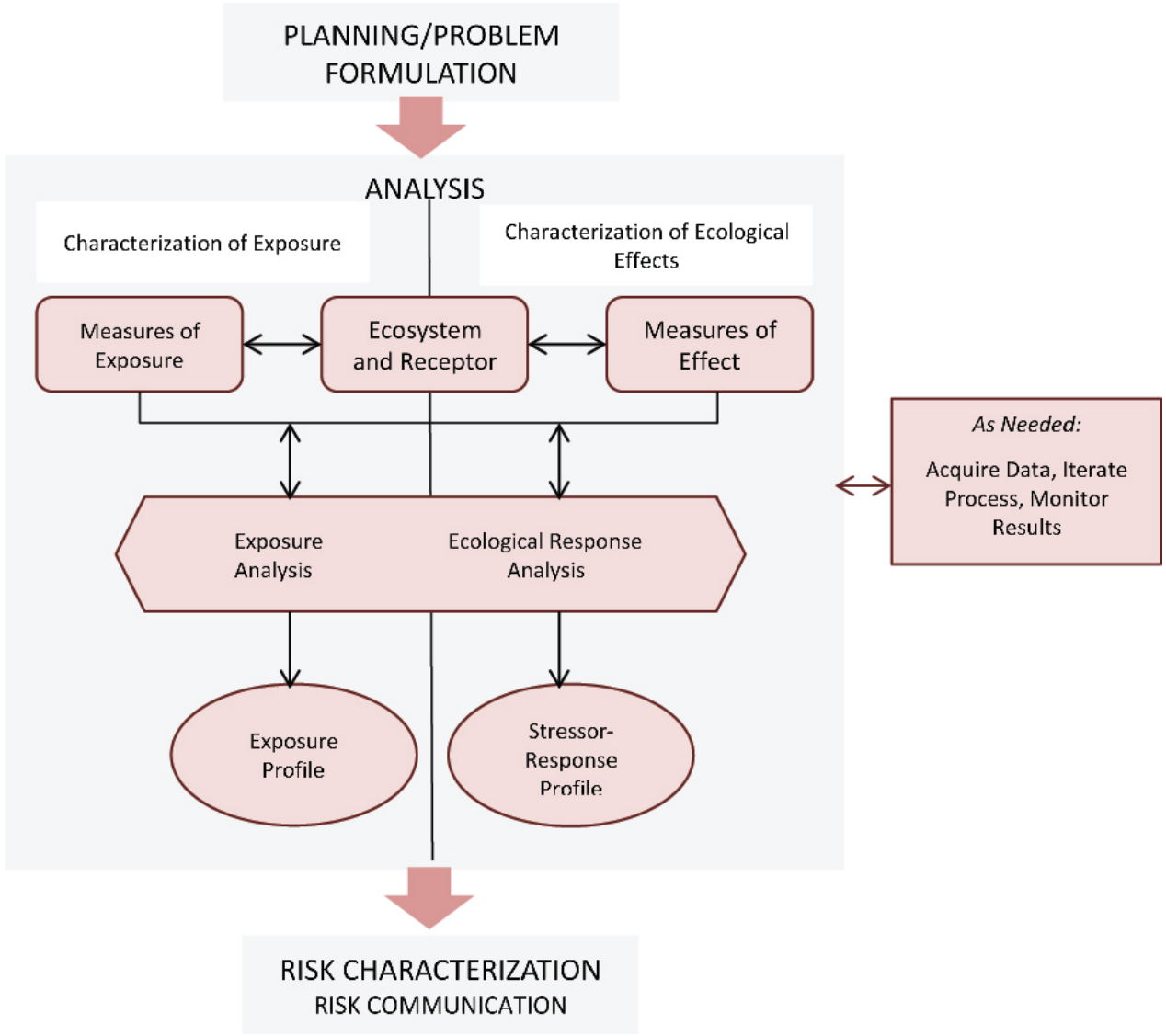
ECOLOGICAL RISK ASSESSMENT (US EPA)

PHASE 2: ANALYSIS - EXPOSURE



ECOLOGICAL RISK ASSESSMENT (US EPA)

PHASE 2: ANALYSIS



ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 2: ANALYSIS

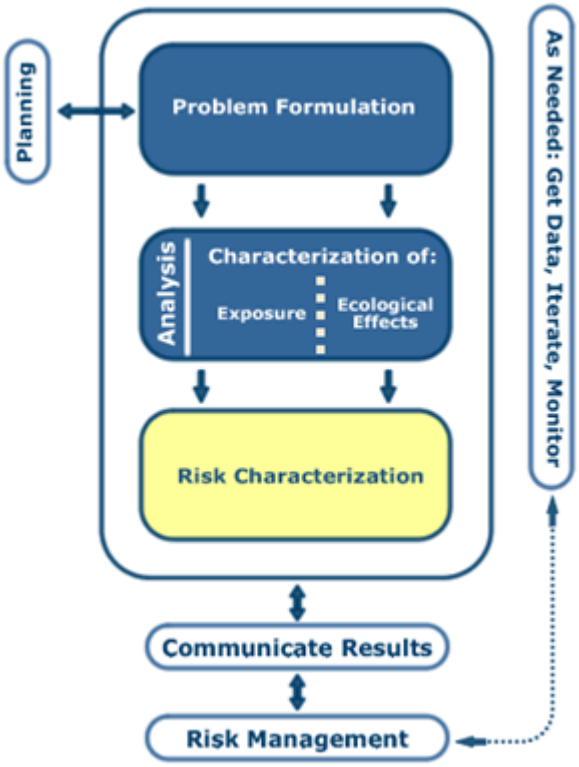
Examples of analyses:

- ***risk quotients*** *– quantification of risks (e.g. ratio of chemical contaminant concentration to background benchmark values)*
- ***various parameters used to determine the level of exposure to a stressor*** *(e.g. chemical contaminant) for selected plant or animal species (receptor):*

  - **Area use**: the proportion of the area under study that is commonly used by the species (home range); or the proportion of the distribution area of the species found in the monitored area
  - **Food ingestion rate**: how much food is eaten by the animal during a certain period of time (usually within one day)
  - **Bioaccumulation rates**: a process in which chemicals are taken up by plants or animals either directly through exposure to a contaminated medium (soil, sediment, water) or through the intake of contaminated food
  - **Bioavailability**: how easily a contaminant can be taken up by an organism from the environment
  - **(Life stage**: juvenile, adult, etc.

ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 3: RISK CHARACTERIZATION

- The aim is to use the results of the analyses to estimate the risks for ecological elements.
- Description of the risk, reliability of its determination, interpretation of ecological impacts



The following factors are taken into account when estimating environmental risks:

Is the risk acute or chronic?
What is the severity of the effects?
How long do the risks exist?
Is one or more species at risk?
How many individuals are at risk?

ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 3: RISK CHARACTERIZATION

Procedures to answer these questions:

- field surveys
- categorical rankings
- process models that partially or fully correspond to theoretical knowledge of exposures and effects
- comparison of exposure and effect data

ECOLOGICAL RISK ASSESSMENT (US EPA)
PHASE 3: RISK CHARACTERIZATION

Principles

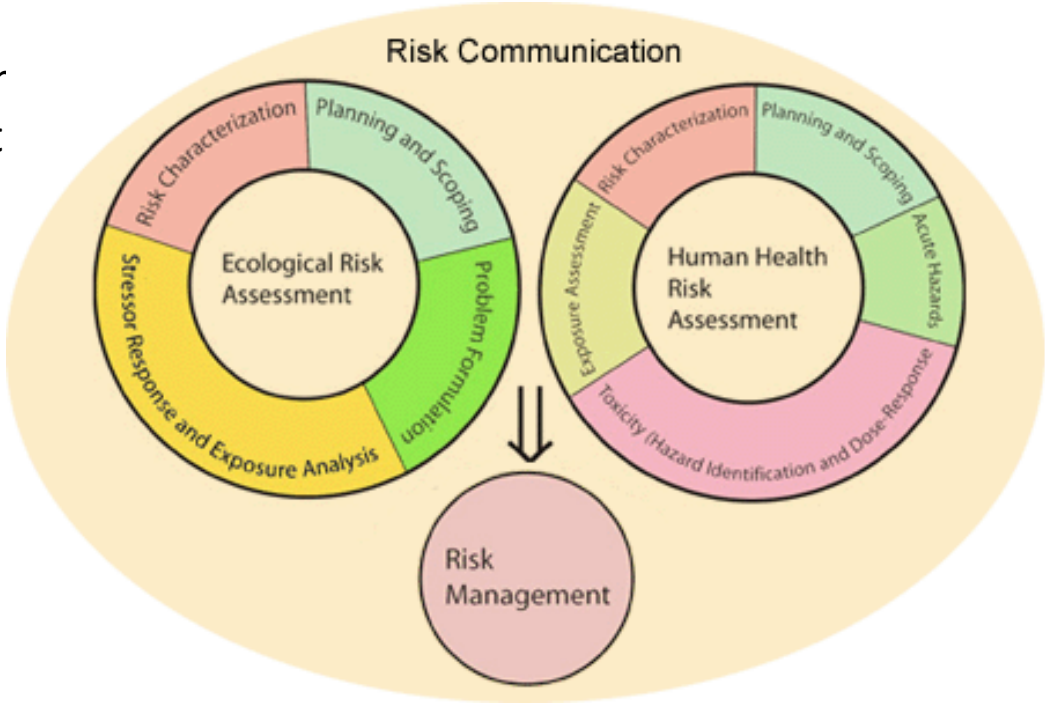
- reiterate the focus of the evaluation
- clearly presenting the results
- formulating the main assumptions and uncertainties
- articulate meaningful alternative interpretations
- separate scientific conclusions from policy decisions

- Transparency
- Clarity
- Consistency
- Prudence

ECOLOGICAL RISK ASSESSMENT (US EPA) COMMUNICATION RESULTS

Risk communication is to inform the public about potential risks to persons, property and society
A science-based procedure for effective information in situations of intense stress, worry or dispute.

- purpose is to enable an understandir of the risk analysis and management process for the affected populations
- to create a scientifically proven perception of hazards and to enable participation in decision-making on their management
- written, verbal, visual



ECOLOGICAL RISK ASSESSMENT (US EPA)
RISK MANAGEMENT

Risk management aims to determine the risks that occur in the target area and to determine how to deal with them to protect human health and the environment as much as possible

Examples of risk management activities:

- deciding **how much** of contaminants a factory can discharge into the river
- deciding which substances can be deposited in a hazardous **waste repository**
- decision on the extent of the **clean-up of hazardous waste** repositories (residual concentrations and their distribution in space and matrices)
- definition of permissible **limits** for flow, storage or transport
- developing national air quality **standards**
- determination of **permissible levels** of drinking water pollution

ECOLOGICAL RISK ASSESSMENT
RISK MANAGEMENT

Risks can be managed in different ways:

- eliminated
- relocated
- stabilized
- reduced

https://moravskoslezsky.denik.cz/galerie/laguny-v-ostrave201801.html?photo=1&back=1025876705-2514-57

Reducing risks to an acceptable level determined by factors such as government policy, industry regulations, economic, social and cultural factors.

ECOLOGICAL RISK ASSESSMENT (US EPA)
RISK MANAGEMENT

Environmental risk management determines which environmental risks exist and at the same time determines how to work with these risks to achieve the best possible protection of human health and the environment.

Risk assessment provides information on potential health or ecological risks, and risk management is the action taken based on consideration of that and other information, as follows:

Scientific factors provide the basis for the risk assessment, including information drawn from toxicology, chemistry, epidemiology, ecology, and statistics - to name a few.

Economic factors inform the manager on the cost of risks and the benefits of reducing them, the costs of risk mitigation or remediation options and the distributional effects.

Laws and legal decisions are factors that define the basis for the Agency's risk assessments, management decisions, and, in some instances, the schedule, level or methods for risk reduction.

Social factors, such as income level, ethnic background, community values, land use, zoning, availability of health care, life style, and psychological condition of the affected populations, may affect the susceptibility of an individual or a definable group to risks from a particular stressor.

Technological factors include the feasibility, impacts, and range of risk management options.

Political factors are based on the interactions among branches of the Federal government, with other Federal, state, and local government entities, and even with foreign governments; these may range from practices defined by Agency policy and political administrations through inquiries from members of Congress, special interest groups, or concerned citizens.

Public values reflect the broad attitudes of society about environmental risks and risk management.