Ecological System (Ecosystem)

System Description

Abstract

The system-of-interest for this System Description is the Ecological System (Ecosystem). The Ecological System (Ecosystem) is a living system that draws on both abiotic and biotic elements that interact to maintain a habitat for numerous species to live.

This Ecological System (Ecosystem) System Description provides a link to the natural systems of the earth and a basis for establishing communities of species (including humans). The effects of human activity are shown in the society and economy layers of the embedded economy model.

PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

PDF: System Description: Earth (Gaia) as a System of Systems, Version 0.20, 07-January-2023 (working)

Author and Version

Bruce McNaughton Version 0.4, 06-November-2023

Contents

Revision History

V0.4 06-November-2023 Added initial systemic problems and solutions (e.g. CO_2 concentrations).
V0.3 28-October-2023 Add Mathematical foundations; Respiration; and Human Activity Habitat and Type.
V0.2 09-October-2023 Revised Ecosystem model based upon Evolution Earth, Grasslands.

V0.1 15-November-2022 add the "Human Activity Habitat" and link to "Human Activity Infrastructure Services" to link to Human Activity System (HAS)

V0.0 26-November-2021 Initial draft as full SD.

System Description: Ecological System (Ecosystem)

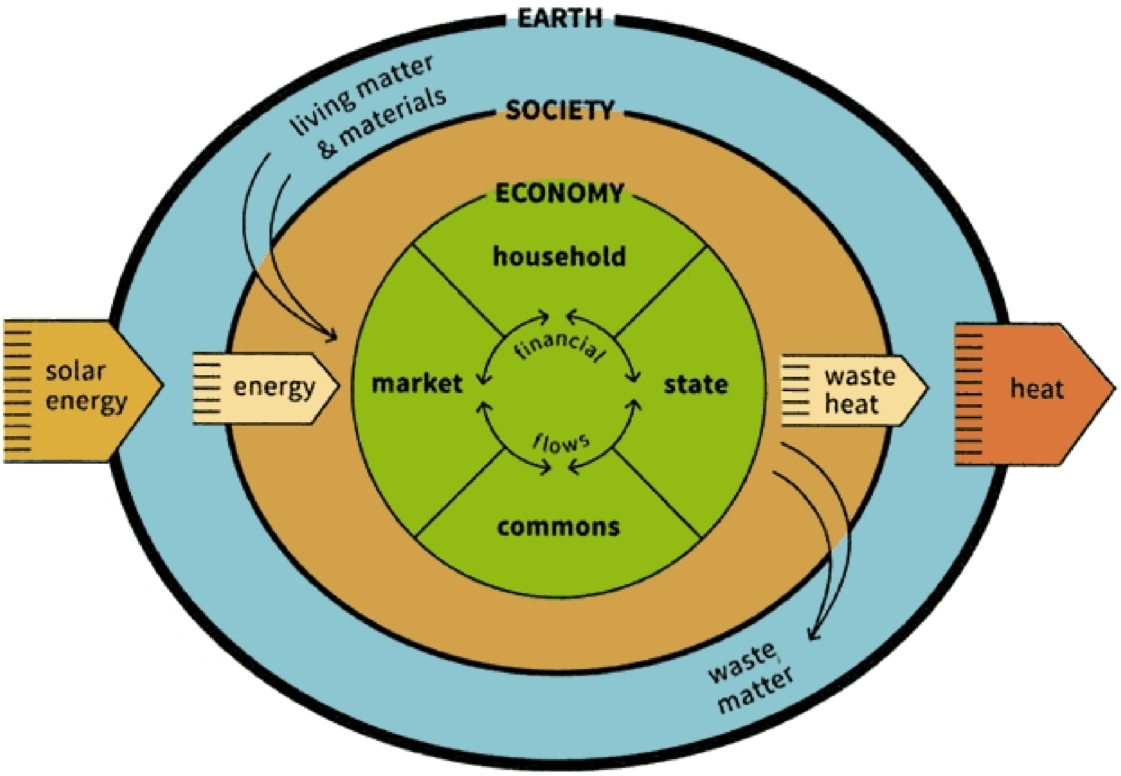
The system-of-interest for this System Description is the Ecological System (Ecosystem). The Ecological System (Ecosystem) is a living system that draws on both abiotic and biotic elements that interact to maintain a habitat for numerous species to live.

This Ecological System (Ecosystem) System Description provides a link to the natural systems of the earth and a basis for establishing communities of species (including humans). The effects of human activity are shown in the society and economy layers of the embedded economy model.

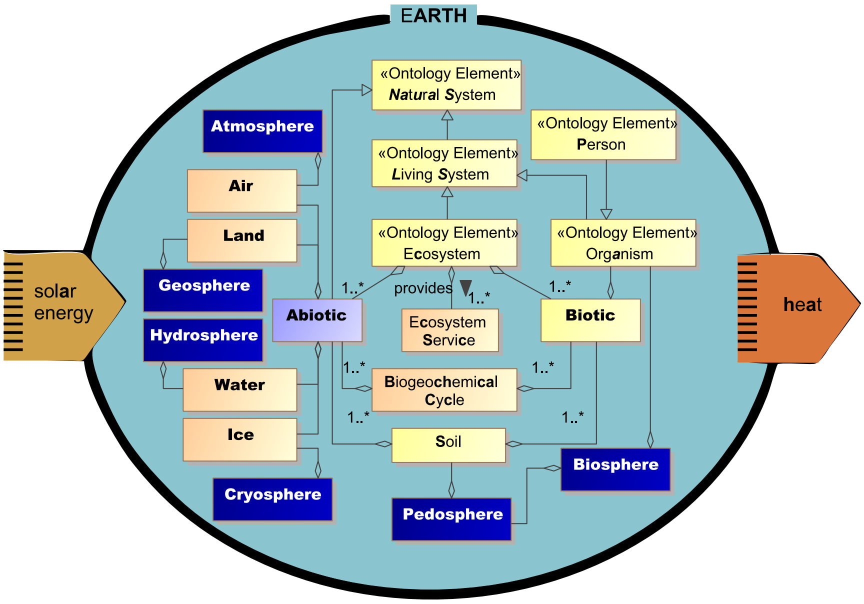
PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

PDF: System Description: Earth (Gaia) as a System of Systems, Version 0.20, 07-January-2023 (working)

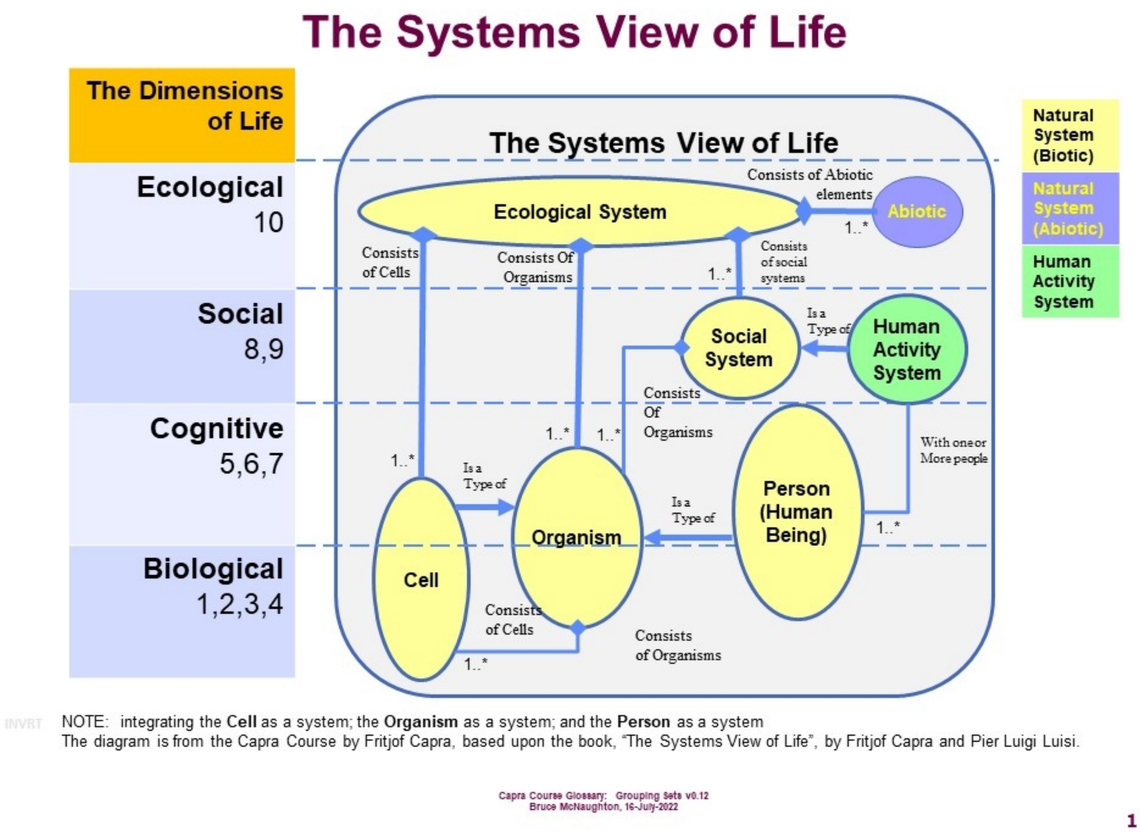
The embedded economy model is shown below:



The following picture highlights the position of the Ecological System (Ecosystem) within the earth layer in the embedded economy model.



This System Description uses the definitions from the glossary for the book, ["The Systems View of Life", Fritjof Capra and Pier Luigi Luisi] as the basis for the description of the ecosystem as a living system. The following diagram from the Capra Course based upon the book shows the relationship of the ecosystem to the other living systems.

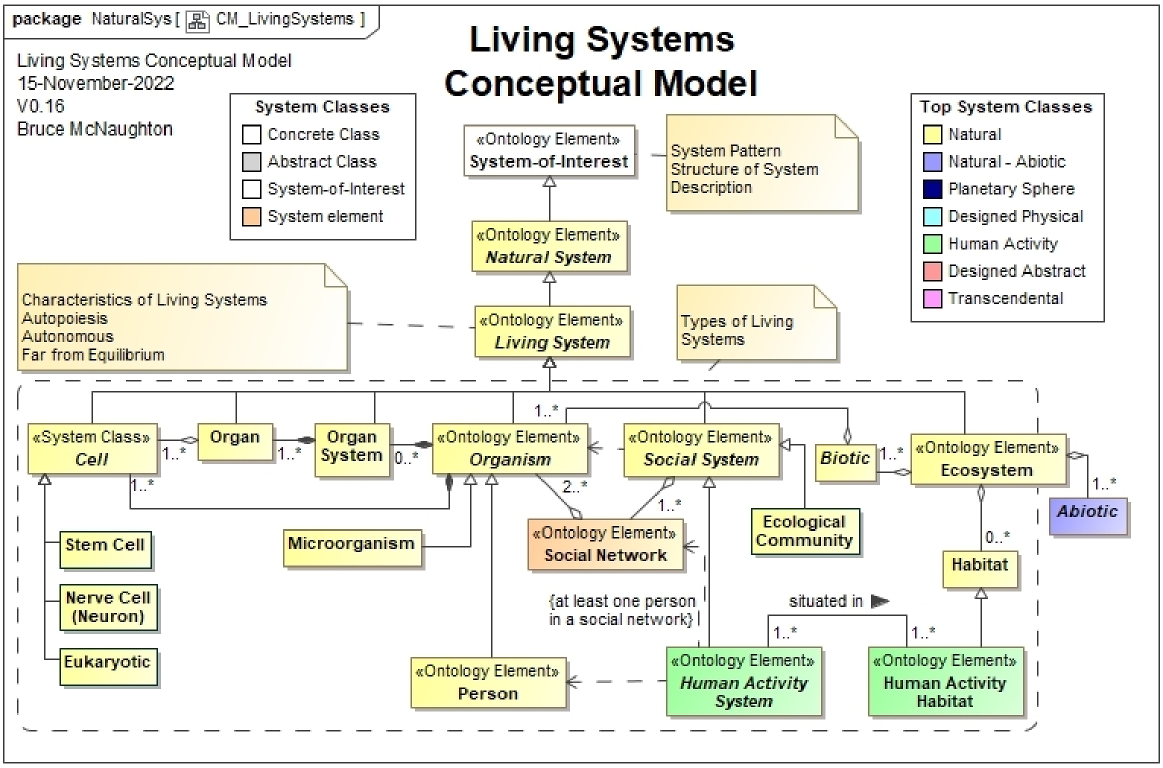


View: System Name and Class

This section identifies the system of interest for this system description

Name: Ecosystem

Based on: Living System



System Level Foundations

- Systems Ecology - Wikipedia
- Ecological Community - Wikipedia
- Systems Biology - Wikipedia

Ecosystem: An ecosystem (or ecological system) consists of all the organisms and the physical environment with which they interact.[2]: 458 These biotic and abiotic components are linked together through nutrient cycles and energy flows.

Abiotic Component: In biology and ecology, abiotic components or abiotic factors are non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems. Abiotic factors and the phenomena associated with them underpin biology as a whole.

Biotic Component (see Ecosystem):

Habitat: In ecology, the term habitat summarises the array of resources, physical and biotic factors that are present in an area, such as to support the survival and reproduction of a particular species. A species habitat can be seen as the physical manifestation of its ecological niche. For terrestrial ecosystems, soil may be a key element of a habitat.

Habitat Type: Habitat types are environmental categorizations of different environments based on the characteristics of a given geographical area, particularly vegetation and climate.[2] Thus habitat types do not refer to a single species but to multiple species living in the same area. For example, terrestrial habitat types include forest, steppe, grassland, semi-arid or desert.

Species: In biology, a species is the basic unit of classification and a taxonomic rank of an organism, as well as a unit of biodiversity.

Respiration (physiology): In physiology, respiration is the movement of oxygen from the outside environment to the cells within tissues, and the removal of carbon dioxide in the opposite direction that's to the environment.[1]

Respiration (Cellular): Cellular respiration is the process by which biological fuels are oxidized in the presence of an inorganic electron acceptor, such as oxygen, to drive the bulk production of adenosine triphosphate (ATP), which contains energy. Cellular respiration may be described as a set of metabolic reactions and processes that take place in the cells of organisms to convert chemical energy from nutrients into ATP, and then release waste products.[1]

Photosynthesis: Photosynthesis (/ˌfoʊtəˈsɪnθəsɪs/ FOH-tə-SINTH-ə-sis)[1] is a biological process used by many cellular organisms to convert light energy into chemical energy, which is stored in organic compounds that can later be metabolized through cellular respiration to fuel the organism's activities.

Ecological Community: In ecology, a community is a group or association of populations of two or more different species occupying the same geographical area at the same time, also known as a biocoenosis, biotic community, biological community, ecological community, or life assemblage.

Carrying Capacity: The carrying capacity of an environment is the maximum population size of a biological species that can be sustained by that specific environment, given the food, habitat, water, and other resources available. The carrying capacity is defined as the environment's maximal load, which in population ecology corresponds to the population equilibrium, when the number of deaths in a population equals the number of births (as well as immigration and emigration). The effect of carrying capacity on population dynamics is modelled with a logistic function. Carrying capacity is applied to the maximum population an environment can support in ecology, agriculture and fisheries.

Food Web: A food web is the natural interconnection of food chains and a graphical representation of what-eats-what in an ecological community. Another name for food web is consumer-resource system.: Also called Trophic Network.

Biome: A biome /ˈbaɪoʊm/ is a large collection of flora and fauna occupying a major habitat.[1]

Ecotone: a region of transition between two biological communities

Sphere:

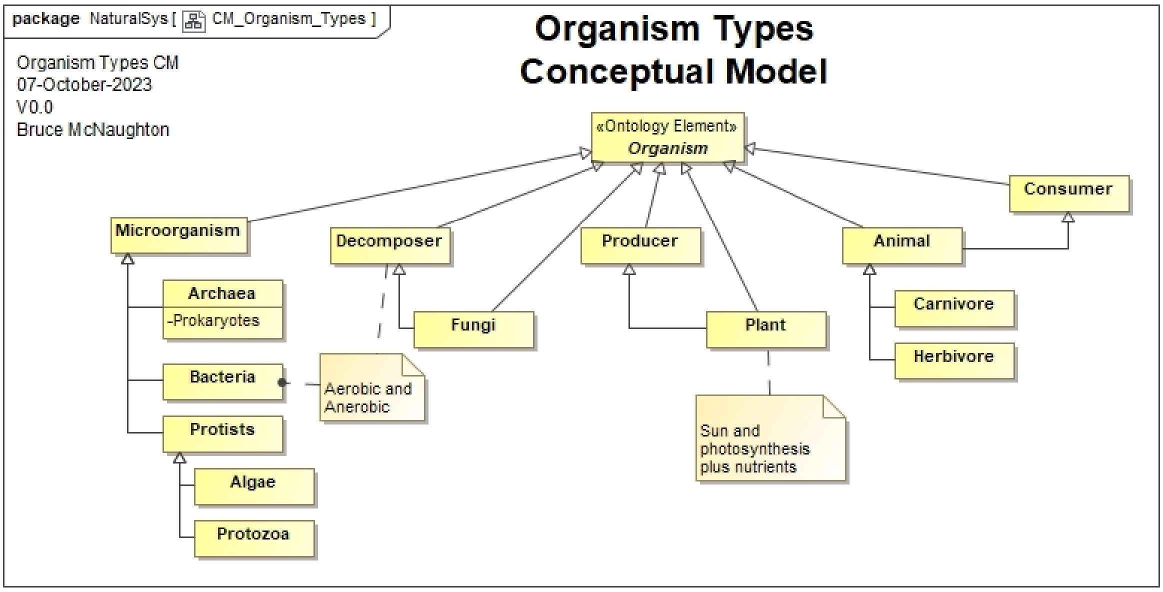
Ecological Niche: The fit within an ecosystem among all of the ecosystem species.

Ecological Boundary: a boundary around the ecosystem of interest or a boundary around a subset of the ecosystem.

NOTE:.The Ecological Boundary can be wide or narrow depending upon the boundary. In all cases, the structural model remains the same. The behaviour varies depending on the configuration (type) of ecosystem within the boundary. Here are some examples:

- The Planet (Whole Earth) is the Boundary. The whole planet is included.
- Biome is the boundary. The characteristics of the Biome determine the behaviours.
- Nation is the boundary: The characteristics of the Nation may vary from regions to towns - however, the overall nation can be understood
- City or neighbourhood is the boundary: Specific issues or problems can be identified locally and plans taken to address the issues.
- Other ecosystem types with a boundary or ecosystem boundaries: These provide a narrow view in a wider context.

Types of organisms in an Ecosystem



Water Terminology

Key terms for water in Ecosystems and the Water and Sanitation Infrastructure Service.

Groundwater.

Aquifer

both confined and unconfined

the underground soil or rock through which groundwater travels.

Saturated zone and unsaturated zone .. relates to water table.

Water Table

the level below which the ground is saturated with water

Watershed

the land area that drains to a point of concern. e.g. lakes and rivers have watersheds. Drainage is done through gravity (e.g. natural).

This allows the ridges to provide boundaries.

Catchment Area

Surface Water.

Occurs on freshwater and seawater in streams, rivers, reservoirs, wetlands, bays, estuaries and oceans. Also appears in solid forms such as snow and ice.

Terms related to water quality

BOD - Biochemical Oxygen Demand

- Nitrogen Loading
- Phosphorus
- Organic Matter

DO - Dissolved Oxygen

Dissolved oxygen is required to maintain a balanced community of organisms in lakes, rivers and the oceans.

OD - Oxygen Deficit

Difference between the demand / use of oxygen and the rate that oxygen can be resupplied to the water.

Thermal stratification of lakes and reservoirs.

NOM - Naturally Occurring Organic Matter

Groundwater Reclamation or Re-mediation

Use of trees to absorb ground water and store water.

Untreated Water.

Treated Water.

Ecological System (Ecosystem) Conceptual Model

Hydraulic Conductivity and Porosity

Intentional or unintentional inputs (additions to water).

Soil Terminology

Key terms for Soil in Ecosystems and for the Food Infrastructure Service (The Farm).

Soil: Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. Earth's body of soil, called the pedosphere, has four important functions:

- as a medium for plant growth
- as a means of water storage, supply and purification
- as a modifier of Earth's atmosphere
- as a habitat for organisms

All of these functions, in their turn, modify the soil and its properties.

Soil can be seen as a type of Ecosystem at a microbiological level.

Soil Science: is the study of soil as a natural resource on the surface of the Earth including soil formation, classification and mapping; physical, chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils.

Pedosphere: Soil occupies the pedosphere, one of Earth's spheres that the geosciences use to organize the Earth conceptually. This is the conceptual perspective of pedology and edaphology, the two main branches of soil science. Pedology is the study of soil in its natural setting. Edaphology is the study of soil in relation to soil-dependent uses. Both branches apply a combination of soil physics, soil chemistry, and soil biology.

Soil Classification: deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use.

- USDA Soil Taxonomy
- World Reference Base for Soil Resources

Soil Formation: also known as pedogenesis, is the process of soil genesis as regulated by the effects of place, environment, and history. Biogeochemical processes act to both create and destroy order (anisotropy) within soils. These alterations lead to the development of layers, termed soil horizons, distinguished by differences in color, structure, texture, and chemistry. These features occur in patterns of soil type distribution, forming in response to differences in soil forming factors.

Soil Fertility: refers to the ability of soil to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality.[3] It also refers to the soil's ability to supply plant / crop nutrients in the right quantities and qualities over a sustained period of time. A fertile soil has the following properties: [4]

- The ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction; and
- The absence of toxic substances which may inhibit plant growth e.g Fe^{2+} which leads to nutrient toxicity.

Soil retrogression and degradation: are two regressive evolution processes associated with the loss of equilibrium of a stable soil. Retrogression is primarily due to soil erosion and corresponds to a phenomenon where succession reverts the land to its natural physical state. Degradation is an evolution, different from natural evolution, related to the local climate and vegetation.

Respiration (Soil): Soil respiration refers to the production of carbon dioxide when soil organisms respire. This includes respiration of plant roots, the rhizosphere, microbes and fauna.

Soil respiration is a key ecosystem process that releases carbon from the soil in the form of CO_2. CO_2 is acquired by plants from the atmosphere and converted into organic compounds in the process of photosynthesis.

Microorganism: A microorganism, or microbe,[a] is an organism of microscopic size, which may exist in its single-celled form or as a colony of cells.

Detritus: In biology, detritus (/dɪˈtraɪtəs/) is dead particulate organic material, as distinguished from dissolved organic material. Detritus typically includes the bodies or fragments of bodies of dead organisms, and fecal material. Detritus typically hosts communities of microorganisms that colonize and decompose (i.e. remineralize) it.

Feces, Fecal Matter, Faeces: are the solid or semi-solid remains of food that was not digested in the small intestine, and has been broken down by bacteria in the large intestine.[1][2] Feces contain a relatively small amount of metabolic waste products such as bacterially altered bilirubin, and dead epithelial cells from the lining of the gut. [1]

Fungus: A fungus (plural: fungi[2] or funguses[3]) is any member of the group of eukaryotic organisms that includes microorganisms such as yeasts and molds, as well as the more familiar mushrooms. (Fungi).

Humus: humus is the dark organic matter that forms in soil when dead plant and animal matter (including aerobic compost) breaks down further, specifically through the action of anaerobic organisms. Humus has many nutrients that improve the health of soil, nitrogen being the most important.

Nutrient Cycle

Nutrients are a necessary part of soil and result from the decomposition process or other biogeochemical processes (see *).

Types of Nutrients

Nutrient (primary)

- Nitrogen *
- Phosphorous *
- Potassium

MicroNutrient

- Boron
- Chloride
- Copper
- Iron
- Magnesium
- Molybdenum
- Zinc

Beneficial

- Aluminium
- Cobalt
- Iodine
- Nickel
- Selenium
- Sodium

Biogeochemical Cycle Terminology

Key terms for Biogeochemical Cycles in Ecosystems.

Biogeochemistry: Biogeochemistry is the scientific discipline that involves the study of the chemical, physical, geological, and biological processes and reactions that govern the composition of the natural environment (including the biosphere, the cryosphere, the hydrosphere, the pedosphere, the atmosphere, and the lithosphere). In particular, biogeochemistry is the study of biogeochemical cycles, the cycles of chemical elements such as carbon and nitrogen, and their interactions with and incorporation into living things transported through earth scale biological systems in space and time..

Biogeochemical Cycle: A biogeochemical cycle is the pathway by which a chemical substance cycles (is turned over or moves through) the biotic and the abiotic compartments of Earth. The biotic compartment is the biosphere and the abiotic compartments are the atmosphere, hydrosphere and lithosphere. There are biogeochemical cycles for chemical elements, such as for calcium, carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, selenium, iron and sulfur, as well as molecular cycles, such as for water and silica.

Biogeochemical Cycles are considered part of the behaviour of an ecosystem or the planetary processes. These biogeochemical cycles are interdependent where one cycle changing can influence the other cycles. For example, The water cycle changing due to temperature change can cause other cycles to change (e.g. extreme weather events).

Note: The Nutrient Cycle is described in the Soil Terminology section.

View: System Purpose

This section includes the stated or implied purposes of the system-of-interest

- Provide habitats for communities of species living in an Ecosystem
- To enable energy and matter to flow and transform in a sustainable way to sustain life.

Principles of Sustainability, Donella Meadows

Five Principles of Sustainability have been identified by Donella Meadows.

1. Renewable resources shall not be used faster than they can regenerate.
2. Pollution and wastes shall not be put into the environment faster than the environment can recycle them or render them harmless.
3. Non-renewable resources shall not be used faster than renewable substitutes (used sustainably) can be developed.
4. The human population and the physical capital plant have to be kept at levels low enough to allow the first 3 conditions to be met.
5. The previous 4 conditions have to be met through processes that are democratic and equitable enough that people will stand for them.

NOTE: Based upon the work of Herman Daly.

Principles of Ecology

The following Principles of Ecology come from the book Hidden Connections by Fritjof Capra, Page 231.

Networks

At all scales of nature, we find living systems nesting within other living systems -- networks within networks. Their boundaries are not boundaries of separation but boundaries of identity. All living systems communicate with one another and share resources across their boundaries.

Cycles

All living organisms must feed on continual flows of matter and energy from their environment to stay alive, and all living organisms continually produce waste. However, an ecosystem generates no net waste, one species waste being another species' food. Thus matter cycles continually through the web of life.

Solar Energy

Solar energy, transformed into chemical energy by the photosynthesis of green plants, drives the ecological cycles.

Partnership

The exchanges of energy and resources in an ecosystem are sustained by pervasive cooperation. Life did not take over the planet by combat but by cooperation, partnership and networking.

Diversity

Ecosystems achieve stability and resilience through the richness and complexity of their ecological webs. The greater their biodiversity, the more resilient they will be.

Dynamic Balance

An ecosystem is a flexible, ever-fluctuating network. Its flexibility is a consequence of multiple feedback loops that keep the system in a state of dynamic balance. No single variable is maximized, all variables fluctuate around their optimal values.

Indigenous Values

Indigenous: originating or occurring naturally in a particular place; native:

Indigenous people were one of many species inhabiting an Ecological Boundary.

A healthy ecosystem that provided ecosystem services provided their habitat.

The humans (People) today have created expectations for Human Activity Habitats within Ecosystems. These expectations and associated values are creating an imbalance between what we take and the ability of the eco-system to regenerate.

See Donella Meadows principles of sustainability..

Indigenous values to be included.

Goal 6. Ensure availability and sustainable management of water and sanitation for all

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

---

6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

6.b Support and strengthen the participation of local communities in improving water and sanitation management

---

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation

14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

---

14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

14.b Provide access for small-scale artisanal fishers to marine resources and markets

14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed

15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation

15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities

View: System Properties

System properties Overview

The properties identified in this section are created through the interaction of the parts.

Systemic Measurable Variables

The key variables are:

- Carrying capacity of the Ecosystem
- Temperature
- Humidity
- Rainfall per time period and aggregate.
- Concentration of Gasses in the Atmosphere See: EcoSysP_001, GHG Concentration in Atmosphere
    - CO_2
    - NO_2
    - Other GHG
- Soil Health Variables for agriculture
    - Soil pH
    - Bulk density
    - Porosity
    - Soil Moisture
    - Number of organisms (microbes, worms, fungi, etc) per area.
    - Amount of bacteria (microbes) for nitrogen fixation.

Systemic Capabilities or Functions

These capabilities are properties of the whole Ecosystem not any of the individual parts.

Ecosystem Services

System States

- Alive
    - Normal seasonal changes
    - Normal ecosystem service provision.
- Distressed
    - Fires, floods, storms
    - Meteor
    - Volcano eruptions
    - Pollution

Systemic Quality Properties

- Health
- Biodiversity

System Quantity Properties

- Weight
- Height
- Volume
- Boundary of the area of the ecosystem
    - **Ecological Boundary**: a boundary around the ecosystem of interest or a boundary around a sub-set of the ecosystem.

      NOTE:.The Ecological Boundary can be wide or narrow depending upon the boundary. In all cases, the structural model remains the same. The behaviour varies depending on the configuration (type) of ecosystem within the boundary. Here are some examples:
        - The Planet (Whole Earth) is the Boundary. The whole planet is included.
        - Biome is the boundary. The characteristics of the Biome determine the behaviours.

- Nation is the boundary: The characteristics of the Nation may vary from regions to towns - however, the overall nation can be understood
- City or neighbourhood is the boundary: Specific issues or problems can be identified locally and plans taken to address the issues.
- Other ecosystem types with a boundary or ecosystem boundaries: These provide a narrow view in a wider context.

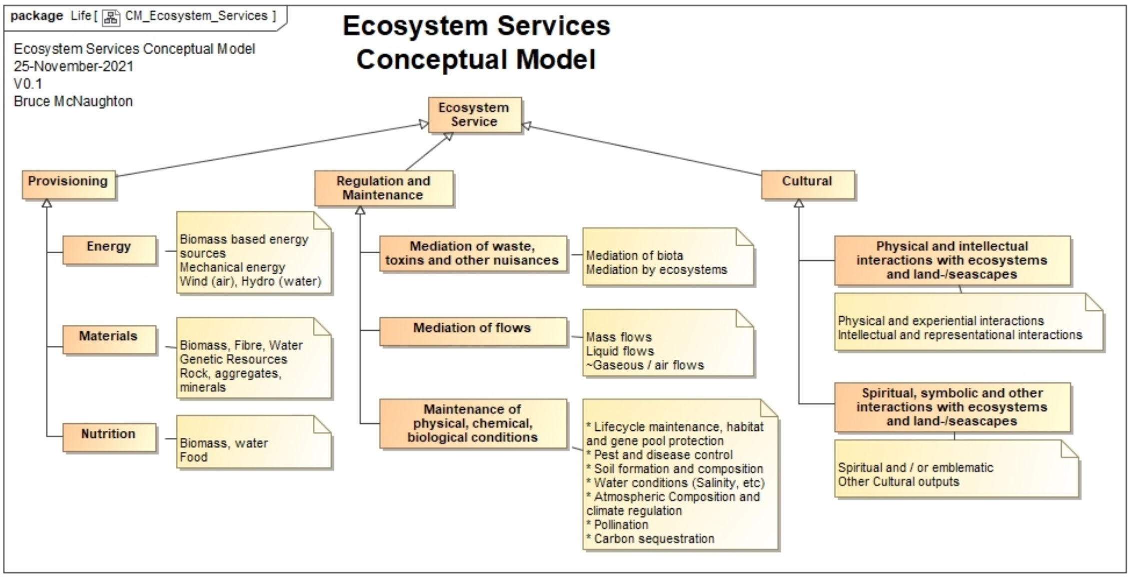
Ecosystem Services

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provides definitions and forecasts for the Ecosystem Services.

Ecosystem services are those ecosystem elements that provide value to humans or can be transformed into useable designed physical systems.

These ecosystem services are part of the natural systems capability. The ecosystem services are classified into the following types (from Table 2.2 High level classification page 19 Ecosystem Services):

Also see EEA ES Classification



Ecological Footprint

The Ecological Footprint is an initiative from the Global Footprint Network to establish measures for the state of the biosphere.

Ecological footprint analysis measures the human impact on Earth's ecosystems. Our ecological footprint is calculated in terms of the amount of land and sea that would be needed to sustainably yield the energy and materials we consume. According to the Global Footprint Network, at our current numbers and current rate of consumption we humans would need 1.5 Earths' worth of resources to sustainably supply our current appetites.

The stated purpose is to:

> "Ecological Footprint accounting measures the demand on and supply of nature."

The sources for the information come from: countries, local leaders, individuals.

Underneath the outputs is a large database of information collected over a number of years.

This helps both at an Earth level and at an ecosystem level.

View: System Stakeholders and Concerns

The Stakeholders and their concerns or interests in this system-of-interest are described in this section.

Stakeholders (typical)

- Organisms living within the ecosystem (Including Humans)
- See Ecosystem related Stakeholder Links

Earth

The following stakeholders from the following disciplines have interest and concerns about the system-of-interest:

Earth Science

Geology, Meteorology (Climatology), Oceanography, Astronomy, Earth System Science

Systems Science

Complex systems, cybernetics, dynamical systems theory, Information Theory, Linguistics, Systems Theory

Life Science

Biology, Zoology, Botany, Genetics, Molecular Biology, Biochemistry, Cytology, Ecology, Systems Ecology, Deep Ecology

Environmental Engineering

Physical Science

Chemistry, Materials Science, Physics, Astrophysics

Mathematical Science

Computer Science, Computational Science, Data Science, Population Genetics, Operations Research, Control Theory, Fluid Mechanics, Theoretical Physics

These stakeholders all are asking questions related to their areas of interest in terms of:

- how do the Earth systems work?
- how was the planet created?
- Is there a core set of subjects that all of the above must understand?

Ecological System (Ecosystem): Stakeholder Links

This section contains a number of stakeholder links who already have an interest or concerns about ecosystems.

Soil

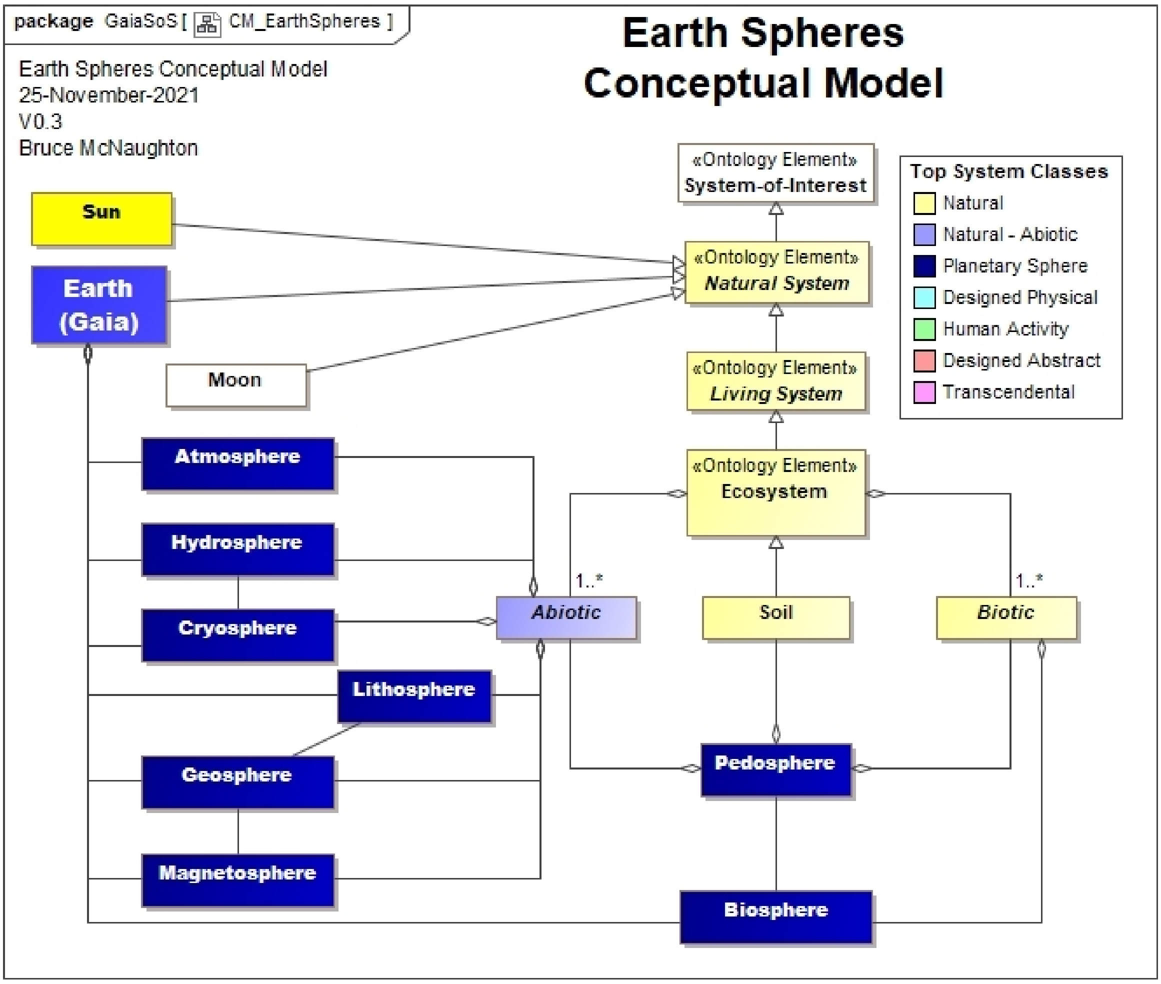
- **Prep Soil.EU**

Ecosystem

- Environmental Change Institute, University of Oxford, UK
- Nature Based Solutions Initiative
- Review: biological engineering for nature-based climate solutions

View: System Environment (Context)

The Ecological System (Ecosystem) fits into the various earth spheres.



In addition, the physical environment provides the context for:

- Human Activity Systems
- Human Activity Infrastructure Services
- Designed Systems (physical and abstract)

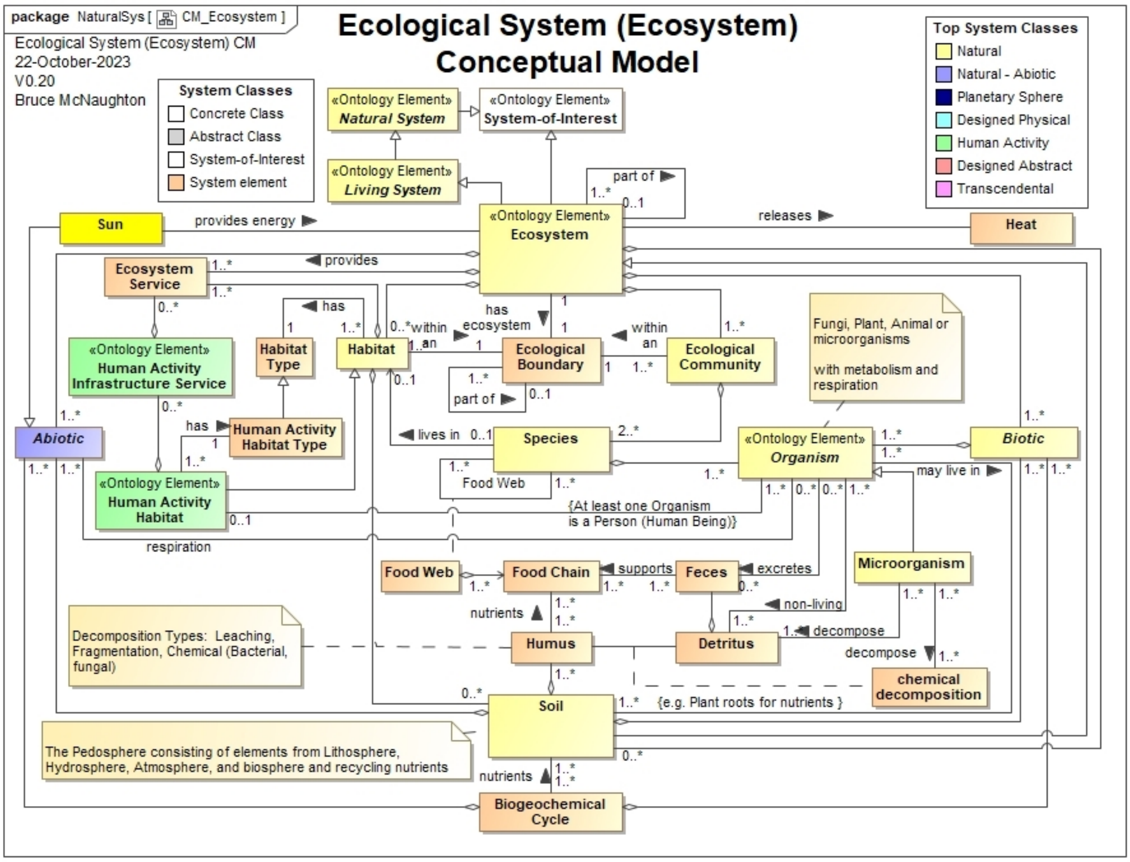
The ecosystem boundary (Ecological Boundary) is defined by the geographic area (spatial) identified in the system-of-interest. The ecological boundary can range from the whole earth to a smaller region. The environment also includes the human activity systems and infrastructure services defined as other types of systems.

View: System Structure (Pattern of Organization)

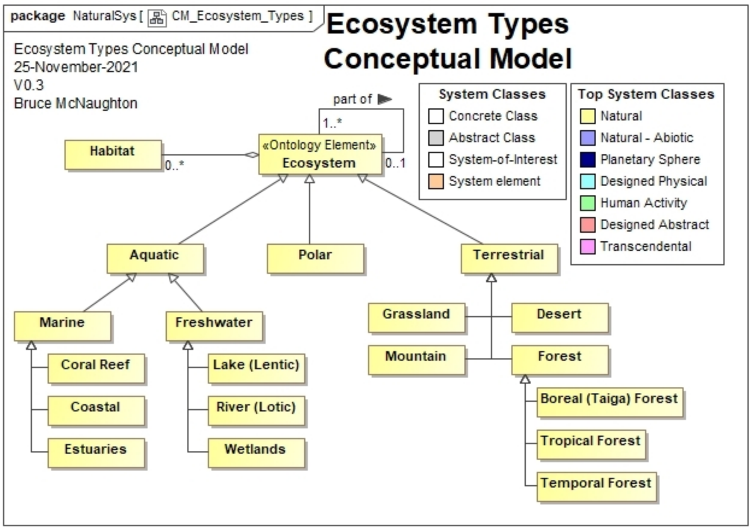
The system structure or pattern of organization represents a logical model of the system elements and their relationships for the system-of-interest. This logical model is independent of any specific physical realization of any of the systems. This logical model may also be called a conceptual model of the system-of-interest. Some system elements may also be holons (a system element that is also a system).

System Element: Identification and Relationships

The Ecological System (Ecosystem) has the following structure and relationships.



The following are some examples of Ecosystem types.



AgroEcosystem is the name of a terrestrial ecosystem for a farm.

View: System Behavior (Structural Changes)

In order to establish the behavior of the system-of-interest, some understanding of the physical configuration of the system is necessary. This allows us to understand the behavior of the system at various points in time.

This physical configuration relates to the type of ecosystem that is of particular interest. This ensures that the correct system elements are considered in each of the areas of behaviour triggered in the system.

Configuration / Scenario: for the option or system-of-interest

Describes any configuration / scenario attributes for a specific system-of-interest. This may not be appropriate for all system descriptions (e.g. patterns or abstract systems).

The key configuration elements for an ecosystem relate to the following:

- Ecosystem Type
- Ecological Boundary
- Identified Species and the population size within the various habitats
- Current state of the environment / external driving pressures.

These elements provide the context for the behaviour of the ecosystem at particular points in time based upon the system elements in the structural view.

There may be multiple configurations with associated cyclical and developmental behaviour descriptions.

NOTE: An Architecture Description Framework based upon this system description may be the best approach to describe specific types of ecosystems. This would allow creation of reference architecture descriptions and specific ecosystem type descriptions. See the Link to prototype Enterprise (SoS) Architecture Description Framework as an example.

Mathematical Methods:

The system behavior (structural changes) uses various mathematical methods to understand the dynamics and interactions of the system elements over time and at specific trigger points.

System Level Foundations

- Systems Ecology - Wikipedia
- Ecological Community - Wikipedia
- Systems Biology - Wikipedia

Mathematics Foundations

- Theoretical ecology - Wikipedia
- Mathematical and theoretical biology - Wikipedia

Mathematical methods and techniques

- Random Walk - Wikipedia
- Energy and Entropy
  - Exergy
  - Negative Entropy (living sysems and some structures)
  - Gibbs Free Energy
- Graph Theory
- Category Theory
- Control Theory (Feedback, Regulation and Adaptive Control)

Typical modelling approaches:

- Causal Loop Diagrams
- *Sequence Diagrams
- *Activity Diagrams
- *State Diagrams and State Machine Diagrams

* items are UML diagrams which can also be used to model the interaction of any types of systems

Many of these modelling approaches have associated tools to create diagrams and manage model elements and realise mathematical methods for simulation purposes.

Mathematical Methods: Systems Biology

This topic focuses on references for Systems Biology

- Institute for Systems Biology (ISB)
- Systems Biology Markup Language (SBML) based upon XML
  - SBML Specifications
- Cell Markup Language (CellML) based upon XML
  - CellML Specifications
- Systems Biology Modeling Software

Cyclical (Repeating / Regular) Processes

These cyclical processes relate to the behavior taken in the various processes. The identified trigger initiates a process that may result in internal changes (structural changes).

This section generally has a specific Trigger event (internal or external) and a process (set of steps / activities / actions that are triggered).

The basic processes in this area relate to the following:

- Biogeochemical Cycle
  - Cycling concentrations of chemicals and nutrients
  - Water cycle is key to fresh water.
- Feeding Webs and Food chains
  - Population density, energy transformation and nutrient cycling (detritus)
- Spread of Disease within a Species (Trigger: disease spread event)
  - R rates and conditions of spreading
- Growing cycles based upon weather and time of year
  - effect of temperature (climate change), and soil quality
- Birth and death of species
  - Natural health of species and fit within ecosystem.
- Normal decomposition / recycle of materials
  - health of the microorganisms in the soil and ecosystem.
- Changes / triggers due to seasonal changes (sunlight / infrared intensity, weather events, time to trigger new growth or alternative processes).
  - Fires, floods, cold, hot, and impacts on cyclical processes.
- Ecological community functioning (single or multi-species)
  - Cooperation and collaboration

This is still work in progress..

Disease Spread within a single species.

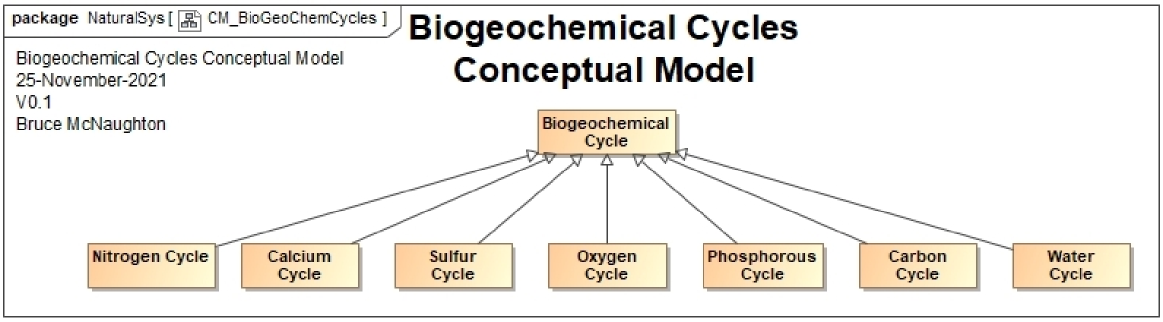
The following notes are from a presentation at the Oxford Martin School, Oxford:

- Link to Oxford Martin School presentation Preventing Pandemics at Source.

The cyclical process works within a host species. Normally this spreading from one host to another host within the same species is contained within a biophysical location / place. This establishes a reservoir ol potential virus to spread. Immunity protects the organisms in this area. If there is a disruption to the species, (E.g. due to climate change) which causes stress on the population, a movement may occur.

Trigger: Reduction in food source due to climate change effects; **Process**: Movement to a different biophysical area and initial spreading of potential disease. **result**: deposit of potential virus in another area previously not having this problem. This may not effect the original hosts but may infect Bridging Organisms

Biogeochemical Cycle Types



See Biogeochemical Cycle

Each cycle has particular steps that are ongoing and continuous. Impacts to any of these cycles may damage the ecosystem.

- Nitrogen Cycle
- Calcium Cycle
- Sulfur Cycle
- Oxygen Cycle
- Phosphorous Cycle
- Carbon Cycle
- Water Cycle

See also Soil Terminology for the Nutrient Cycle and Nutrient Types.

Other Biogeochemical Cycles

- Rock Cycle
- Marine Cycles
- Methane Cycles

Food Web

Food web: A food web is the natural interconnection of food chains and a graphical representation of what-eats-what in an ecological community. Another name for food web is consumer-resource system.

Food Chain: A food chain is a linear network of links in a food web starting from producer organisms (such as grass or trees which use radiation from the Sun to make their food) and ending at an apex predator species (like grizzly bears or killer whales), detritivores (like earthworms or woodlice), or decomposer species (such as fungi or bacteria). A food chain also shows how organisms are related to each other by the food they eat.

Examples to be provided for specific ecosystems.

Development Life Cycle Processes

Development relates to changes occurring through the life cycle of the Ecosystem

The development of ecosystems relates to the following areas:

- Environmental factors and influences: Temperature, Atmosphere, water levels, weather events (storms), physical events (earthquakes, fires, etc).
- Human Activity: Development of human activity habitats and their purpose. Waste from human activity habitats may also have developmental influences.
- Population growth of species within their habitats impacting the carrying capacity of the Ecosystem

other aspects?

Disease transmission across species within an Ecosystem

Disease spread across species may involve bridging hosts (different species) to eventual species being infected.

The process for this transmission is from the Oxford Martin School presentation:

- **Infect**: Infection Infection is circulating in a reservoir for potential spread (normal cyclical process); however, builds up volume

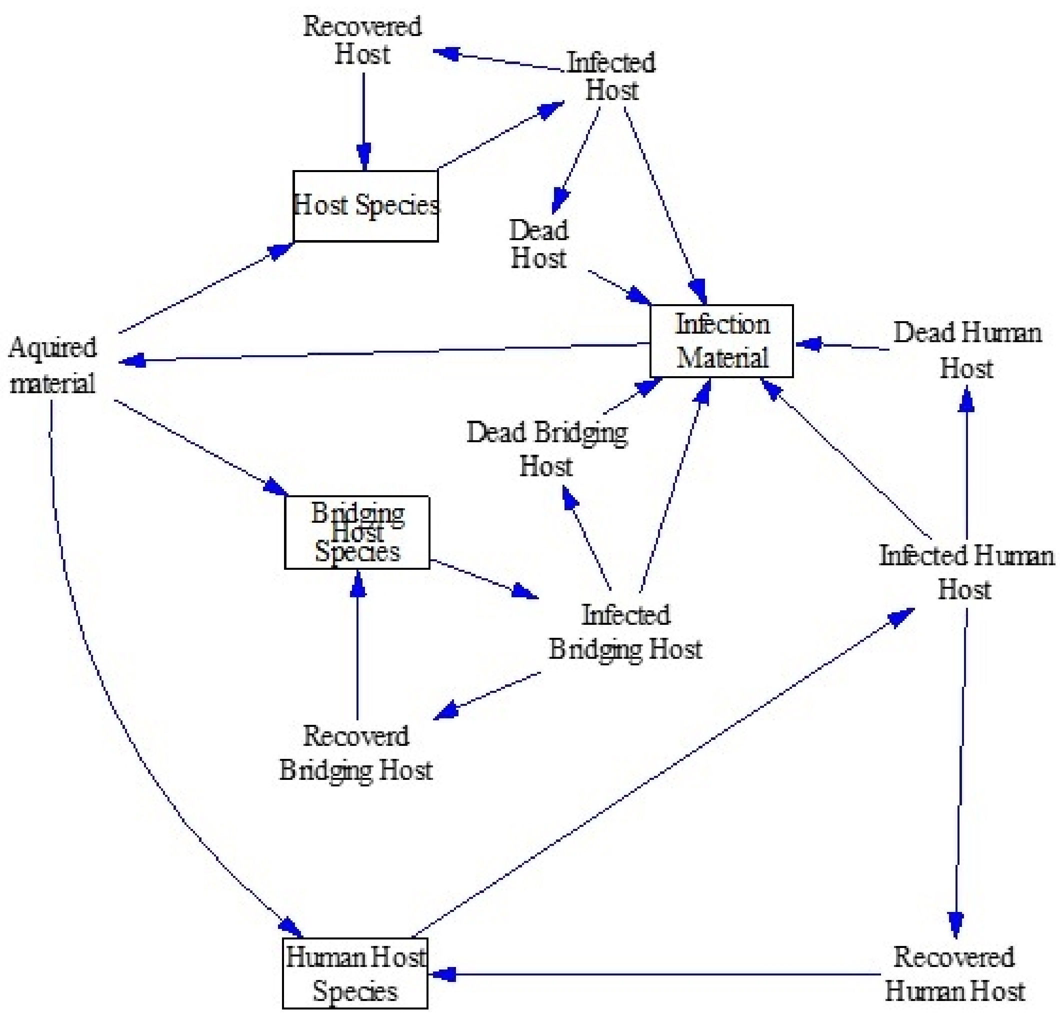
- **Shed**: Infection may be shed (air, water, touch, etc) and spread to same or another species. The other species are a bridging host that may have close proximity to humans.
- **Spill**: Spill is infecting another species and causing an initial outbreak in new species. (this is developmental emergence)
- **Spread**: Epidemic to Pandemic (uncontrollable if rate of infection is too high).

Trigger: Cross-species event; Process: New species starts transmission of new virus.

- Link to Oxford Martin School presentation Preventing Pandemics at Source.

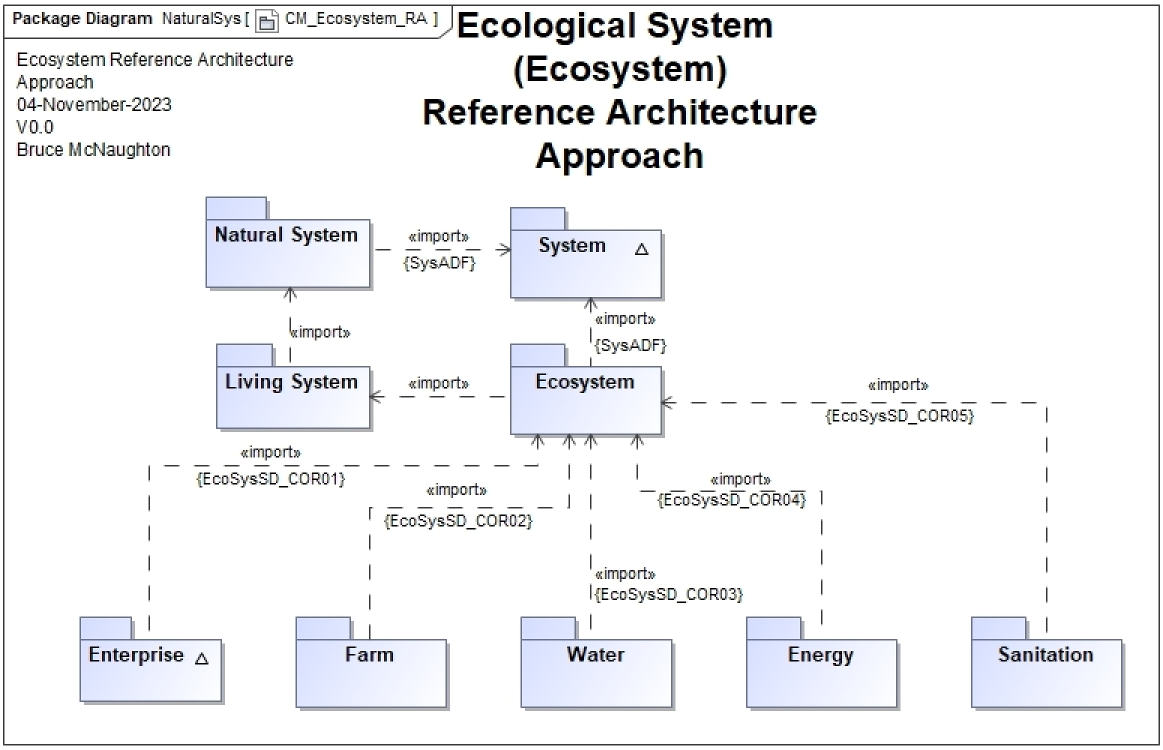
NOTE: This development life cycle event causes structural changes within the ecosystem. The species that are now infected will proceed using the cyclical processes for transmission within a species if the rate of infection within the species if the number of organisms within the species becomes sufficient to maintain transmission. Additional developmental infections may continue until this rate is achieved or transmission stops.

Initial Model of the transmission from species to species in ecosystems



Correspondences

The following diagram shows the correspondences that have been created to extend identified system elements from the Ecosystem to other systems.



Currently, these correspondences are held on the System ADF website as the Ecosystem ADF has not been created.

These correspondences can be seen in this correspondence section

EcoSysSD_COR01: Shared Human Activity Habitat and Habitat Type with the Enterprise

ID and Title

EcoSysSD_COR01: Shared Human Activity Habitat and Habitat Type with the Enterprise

Description

The concept of a Human Activity Habitat and Habitat Type are being shared with the Enterprise to allow for connections from the organizations to the ecosystem. The label of "Human Activity" is used only when there are one or more people carrying out activities within the Human Activity Habitat.

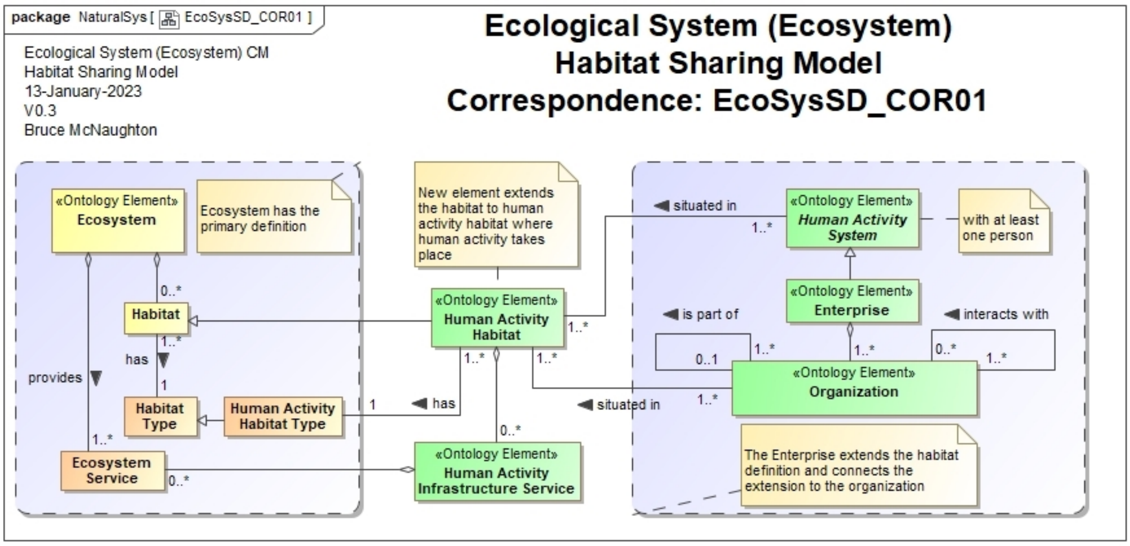
Habitat Type: Habitat types are environmental categorizations of different environments based on the characteristics of a given geographical area, particularly vegetation and climate.[2] Thus habitat types do not refer to a single species but to multiple species living in the same area. For example, terrestrial habitat types include forest, steppe, grassland, semi-arid or desert.

Methods Used

SysADF_CM01: Shared Ontology Elements

Correspondence Results

The following model shows the ontology elements and their relationships to link the Human Activity Habitat and Habitat Type in the Ecosystem.



EcoSysSD_COR02: Ecosystem Concepts and Classes extended for use in Farm

ID and Title

EcoSysSD_COR02: Ecosystem Concepts and Classes extended for use in Farm

Description

The farm includes a number of species that live in ecosystem habitats and habitat types. This correspondence creates sub-classes of ontology elements for use in a Farm as an Enterprise situated in an Ecosystem.

The model being extended is based upon the conceptual model in the Ecosystem System Description (an AD Element).

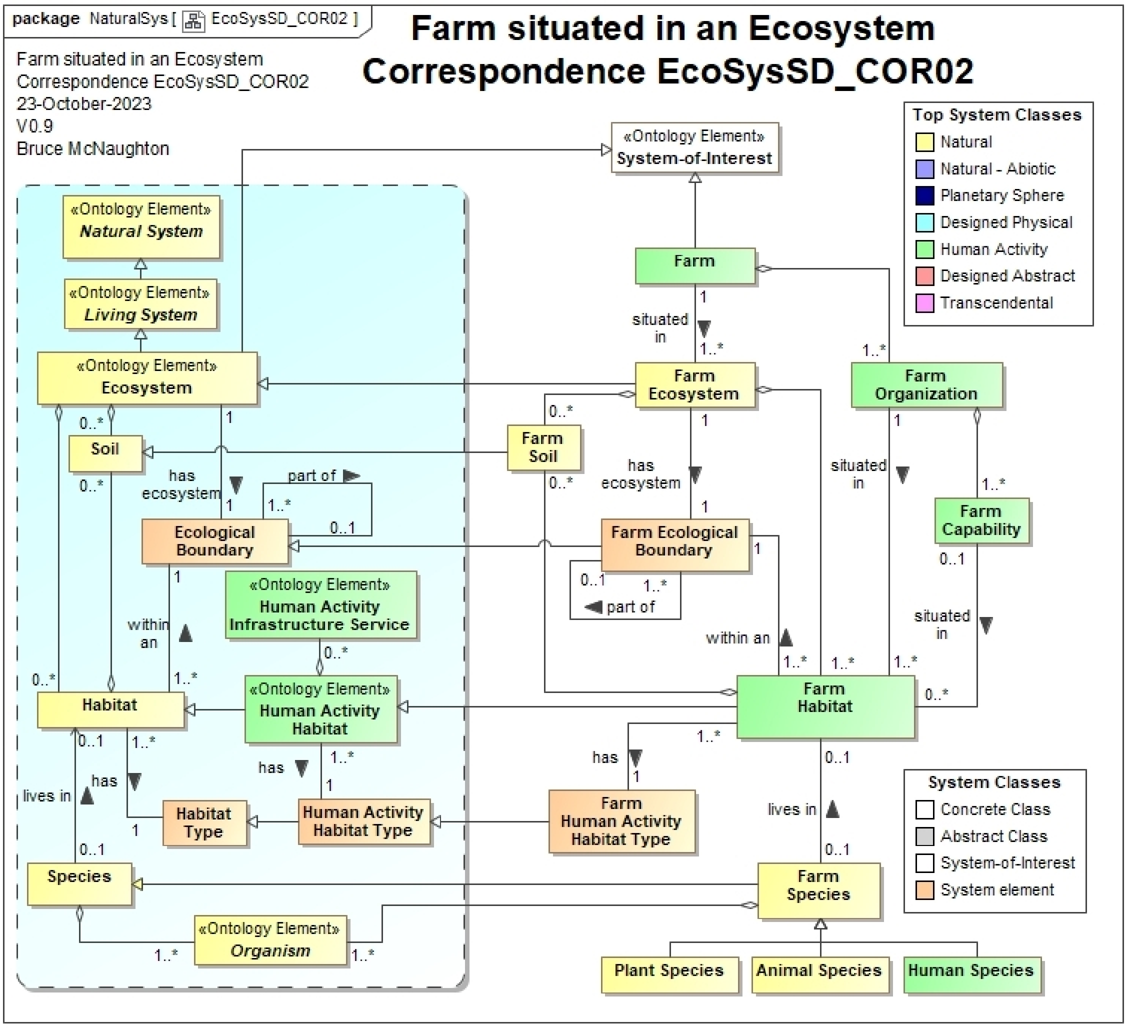
PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

Methods Used

SysADF_CM02: Extend Ontology Elements for new System Type

Correspondence Results

The following model shows the new elements created for use in the Farm situated in an Ecosystem



EcoSysSD_COR03: Ecosystem Concepts / Classes extended for use in Water Infrastructure Service

ID and Title

EcoSysSD_COR03: Ecosystem Concepts / Classes extended for use in Water Infrastructure Service

Description

The Water and Sanitation Infrastructure Service has a number of connection points to a wider ecosystem. This correspondence creates sub-classes of ontology elements for use in a Water Infrastructure Service as an Enterprise situated in an Ecosystem. See EcoSysSD_COR05 for the Sanitation Infrastructure Service.

The model being extended is based upon the conceptual model in the Ecosystem System Description (an AD Element).

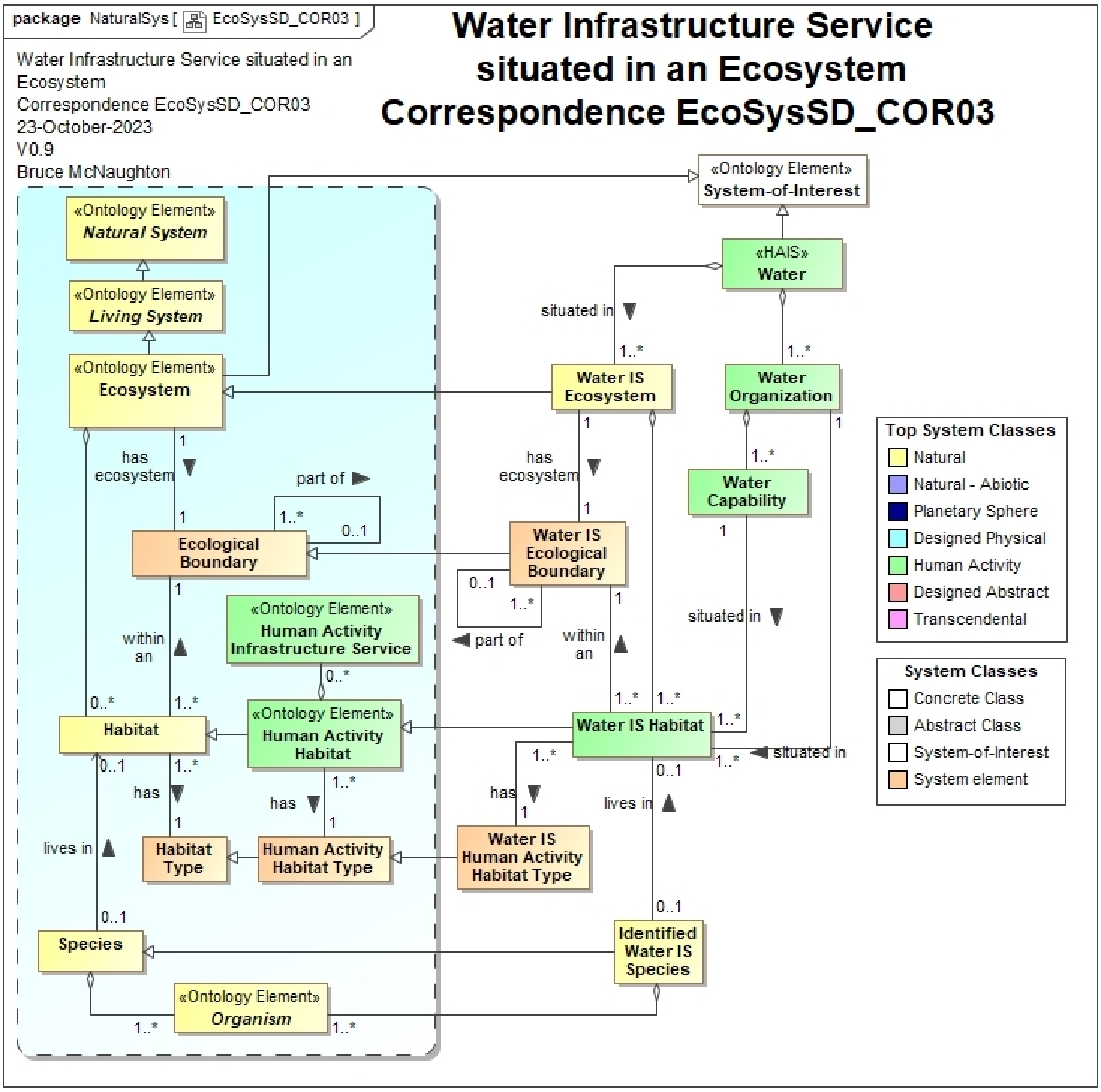
PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

Methods Used

SysADF_CM02: Extend Ontology Elements for new System Type

Correspondence Results

The following model shows the new elements created for use in the Water and Sanitation Infrastructure Service situated in an Ecosystem



EcoSysSD_COR04: Ecosystem Habitat and Ecosystem Service extended for use in Energy Infrastructure Service

ID and Title

EcoSysSD_COR04: Ecosystem Habitat and Ecosystem Service extended for use in Energy Infrastructure Service

Description

The Energy Infrastructure Service has a number of connection points to a wider ecosystem. This correspondence creates sub-classes of ontology elements for use in a Energy Infrastructure Service as an Enterprise situated in an Ecosystem.

The model being extended is based upon the conceptual model in the Ecosystem System Description (an AD Element).

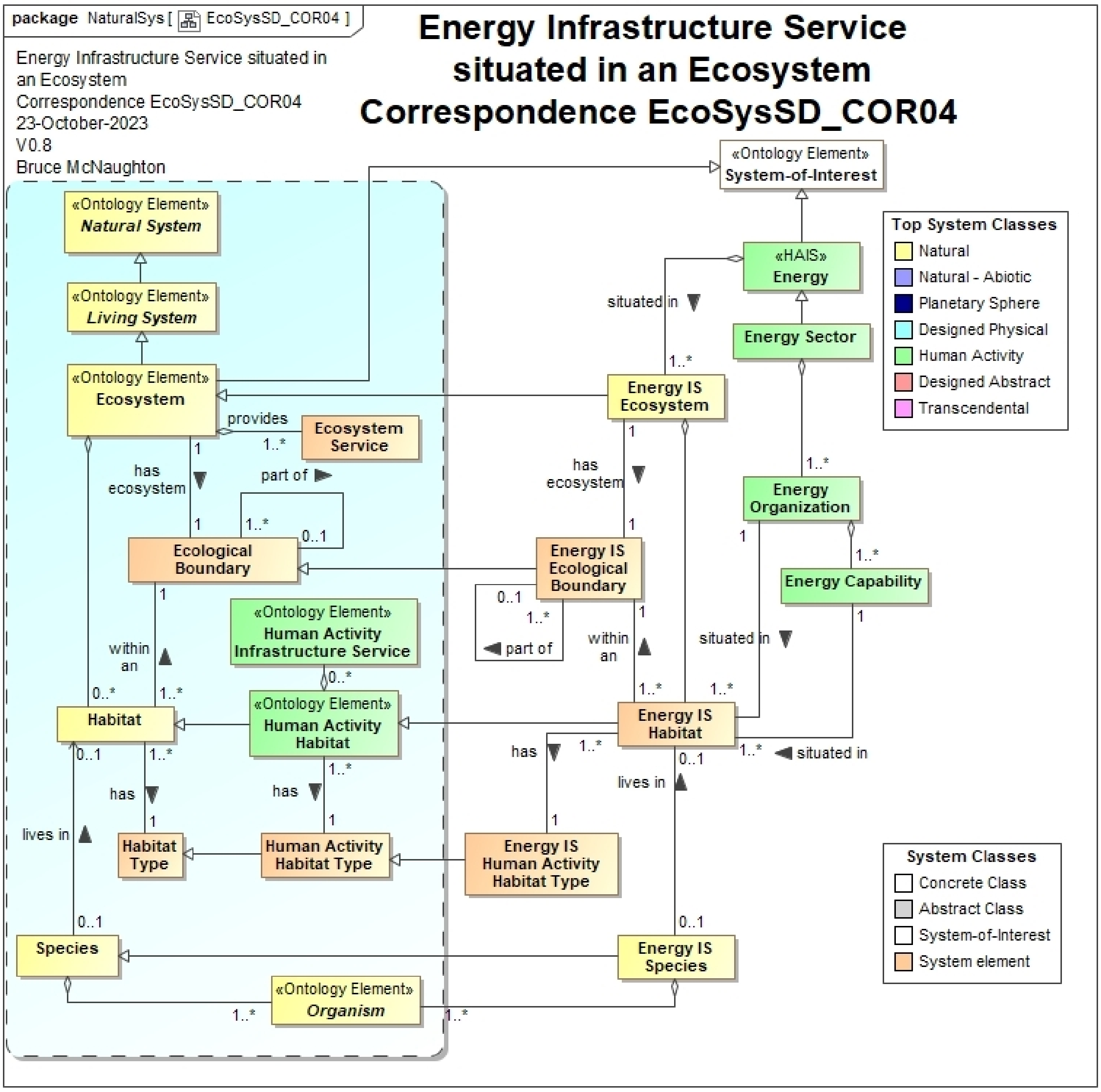
PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

Methods Used

SysADF_CM02: Extend Ontology Elements for new System Type

Correspondence Results

The following model shows the new elements created for use in the Energy Infrastructure Service situated in an Ecosystem



EcoSysSD_COR05: Ecosystem Concepts / Classes extended for use in Sanitation Infrastructure Service

ID and Title

EcoSysSD_COR05: Ecosystem Concepts / Classes extended for use in Sanitation Infrastructure Service

Description

The Water and Sanitation Infrastructure Service has a number of connection points to a wider ecosystem. This correspondence creates sub-classes of ontology elements for use in a Sanitation Infrastructure Service as an Enterprise situated in an Ecosystem.

The model being extended is based upon the conceptual model in the Ecosystem System Description (an AD Element).

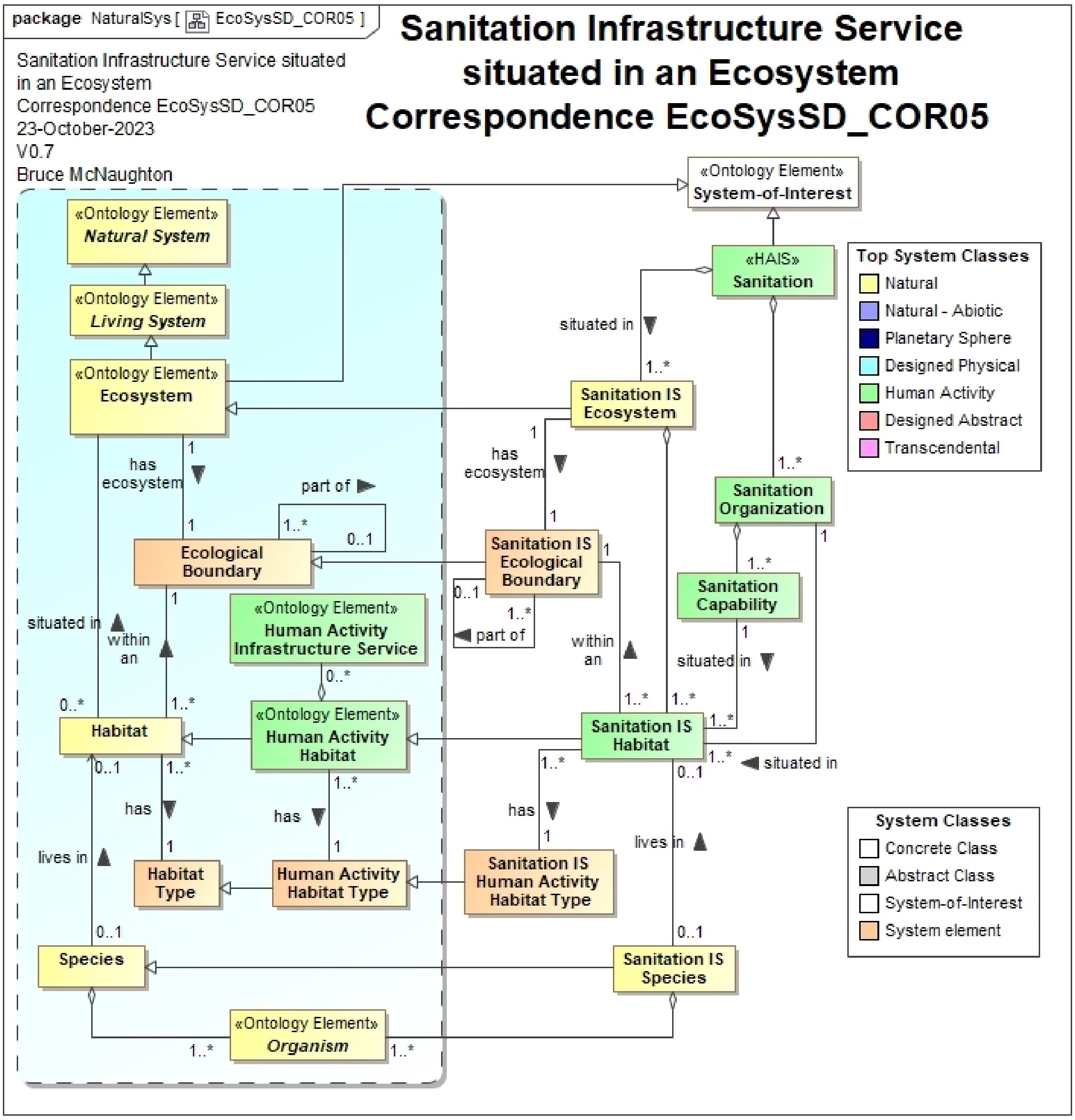
PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023

Methods Used

SysADF_CM02: Extend Ontology Elements for new System Type

Correspondence Results

The following model shows the new elements created for use in the Water and Sanitation Infrastructure Service situated in an Ecosystem


package NaturalSys [EcoSysSD_COR05]
Sanitation Infrastructure Service situated in an Ecosystem
Correspondence EcoSysSD_COR05
23-October-2023
V0.7
Bruce McNaughton
Sanitation Infrastructure Service situated in an Ecosystem Correspondence EcoSysSD_COR05
«Ontology Element» System-of-Interest
«Ontology Element» Natural System
«Ontology Element» Living System
«Ontology Element» Ecosystem
«HAIS» Sanitation
Sanitation IS Ecosystem
Sanitation Organization
Sanitation Capability
Ecological Boundary
Sanitation IS Ecological Boundary
«Ontology Element» Human Activity Infrastructure Service
«Ontology Element» Human Activity Habitat
Habitat
Sanitation IS Habitat
Habitat Type
Human Activity Habitat Type
Sanitation IS Human Activity Habitat Type
Species
Sanitation IS Species
«Ontology Element» Organism
situated in
has ecosystem
part of
within an
lives in
has
Top System Classes
Natural
Natural - Abiotic
Planetary Sphere
Designed Physical
Human Activity
Designed Abstract
Transcendental
System Classes
Concrete Class
Abstract Class
System-of-Interest
System element

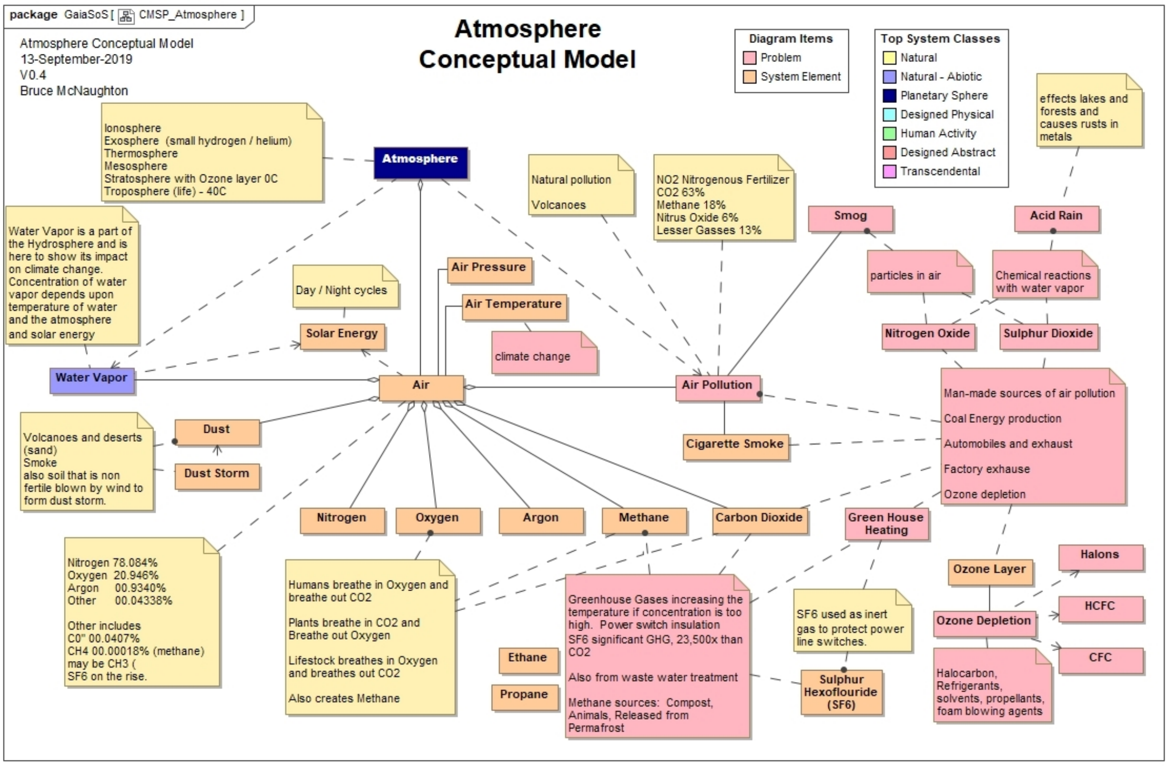
Earth Spheres

The following are some of the earth spheres:

- Atmosphere
- Biosphere
- Geosphere
- Hydrosphere

Earth Sphere: Atmosphere

The following diagram highlights elements of the Atmosphere:

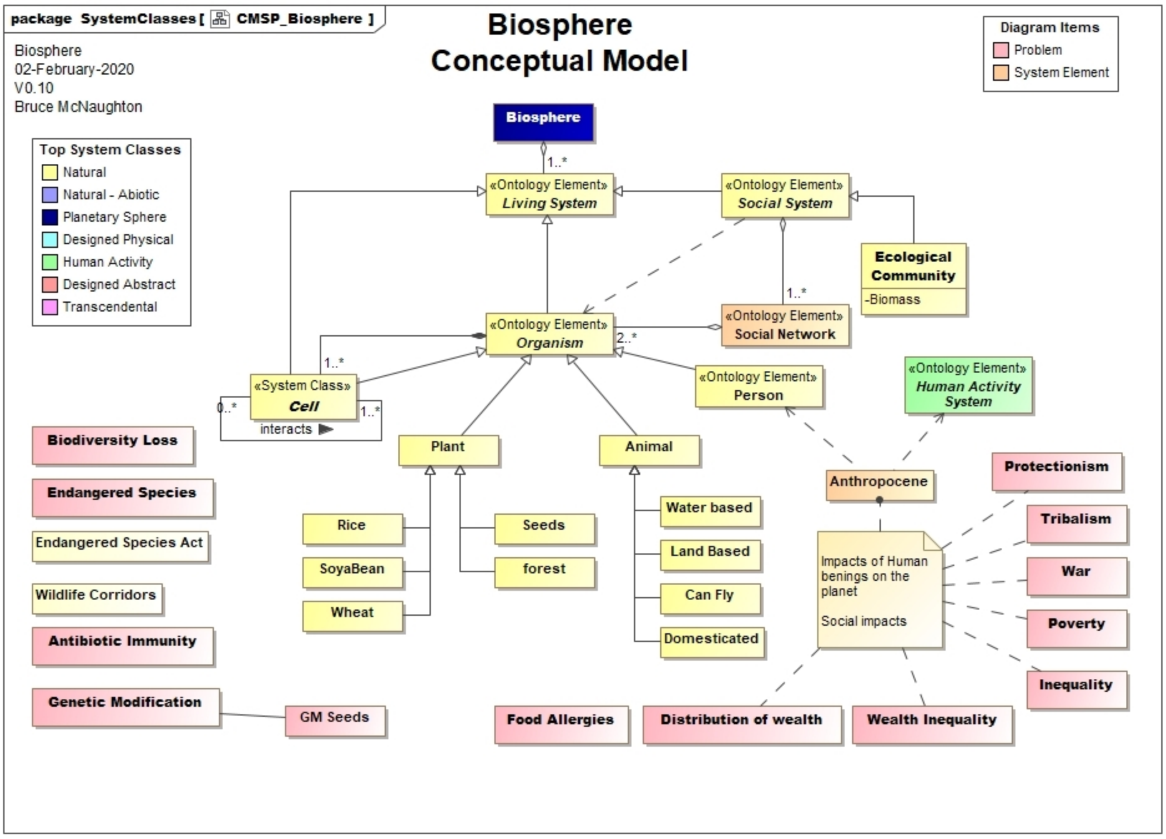


Some of the problems related to the atmosphere are:

- CO_2
- Other GHG
- Temperature Rise

Earth Sphere: Biosphere

The following diagram highlights the Biosphere:

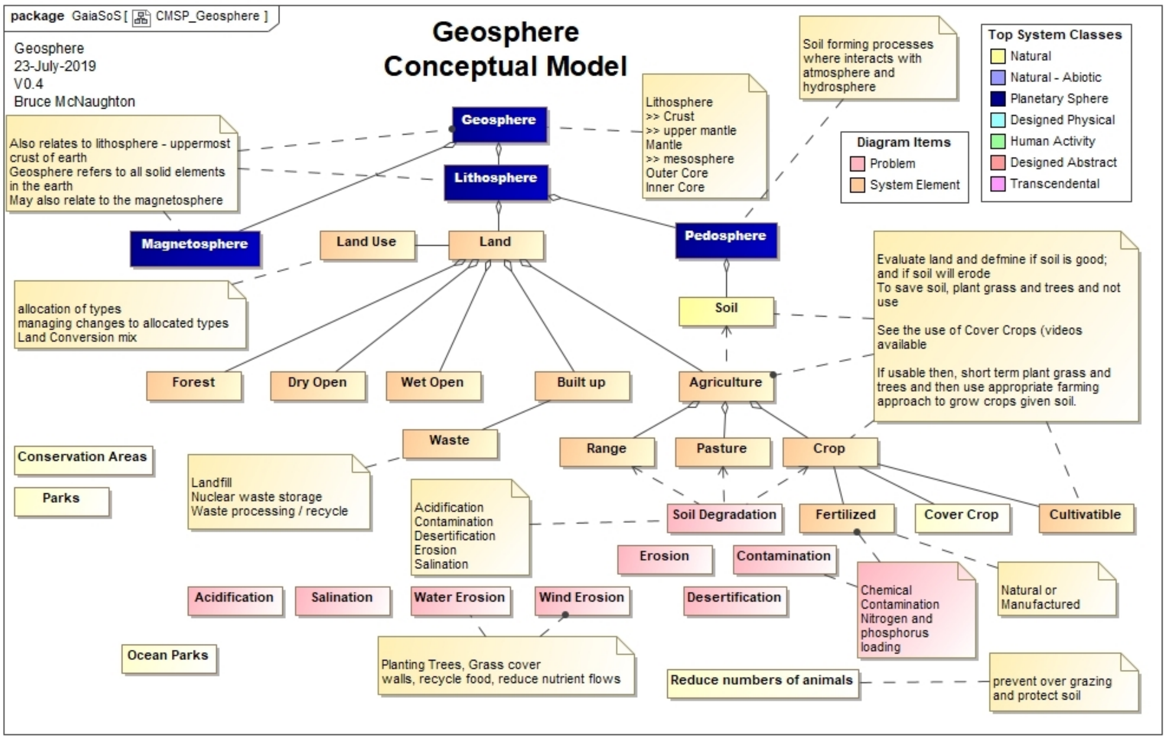


The following are some of the problems with the Biosphere:

- Pandemic / Health Care
- Population

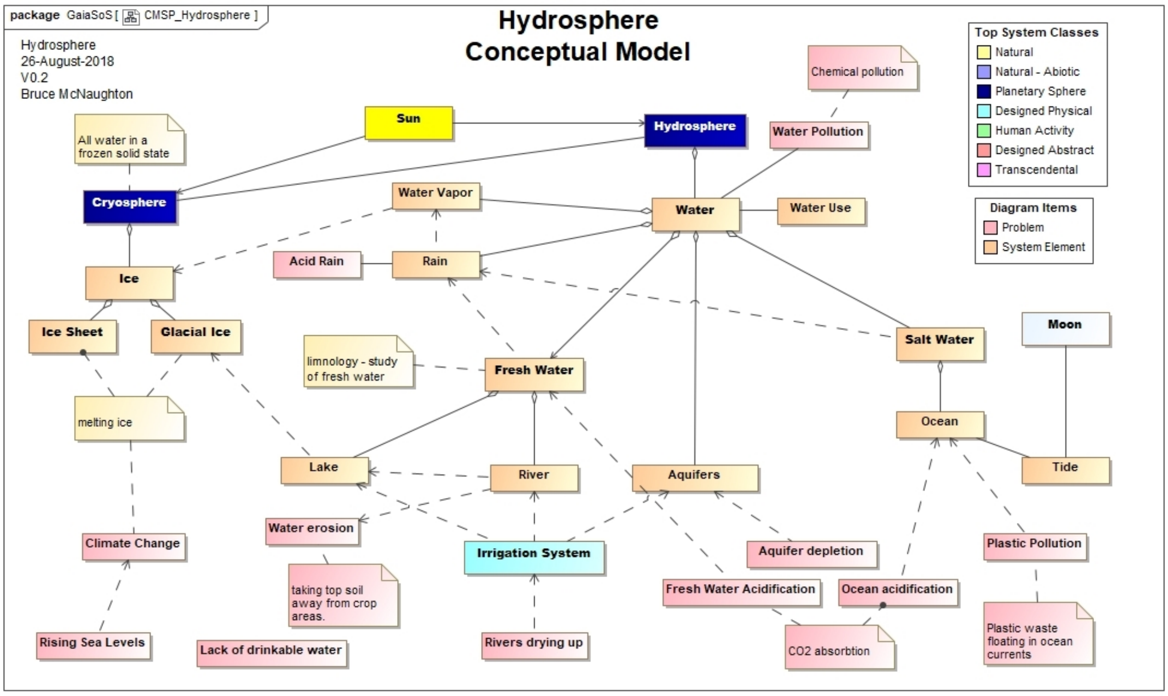
Earth Sphere: Geosphere

The Geosphere relates to soil and the earth. The following highlights the key elements of the Geosphere and some of the problems.



Earth Sphere: Hydrosphere

The hydrosphere and cryosphere relate to water. Here is a diagram of some key elements of the Hydrosphere:



Some of the key issues related to the hydrosphere are:

- pollution
- Plastic Pollution

Systemic Problems

Latest Planetary Boundary Updates from the Stockholm Resielence Centre

The following are descriptions of the systemic problems identified in the Ecosystem.

- EcoSysP_001, GHG Concentration in Atmosphere
- EcoSysP_002, Biodiversity Integrity
- EcoSysP_003, Land System Change
- EcoSysP_004, Freshwater Change
- EcoSysP_005, Nitrogen and Phosphorus Loading
- EcoSysP_006, Chemical Pollution
- EcoSysP_007, Air Pollution

EcoSysP_001, GHG Concentration in Atmosphere

The Greenhouse Gas concentration in the atmosphere is creating a Greenhouse effect which is causing the atmosphere to warm.

Certain Greenhouse Gasses such as CO2 absorb infrared radiation and retain heat in the atmosphere. As the concentration rises, the temperatore will continue to rise.

See chart of CO2 and Temperature rise since the industrial age started. The primary cause of this increase is the buring of Fossil Fuel to support our energy infrastructure.

This Rise in GHG Concentration has been known since the 1970s and the Club of Rome reports.

Greenhouse Gas

Climate Change

EcoSysP_002, Biodiversity Integrity

T.B.D.

Systemic Solutions

This section includes the description of possible solution options.

EcoSysS_001, Net Zero

Achieving Net Zero CO2 emilssions by 2050 is a goal that has been formulated to keep the global temperature rise at or under 1.5 degree centigrade.

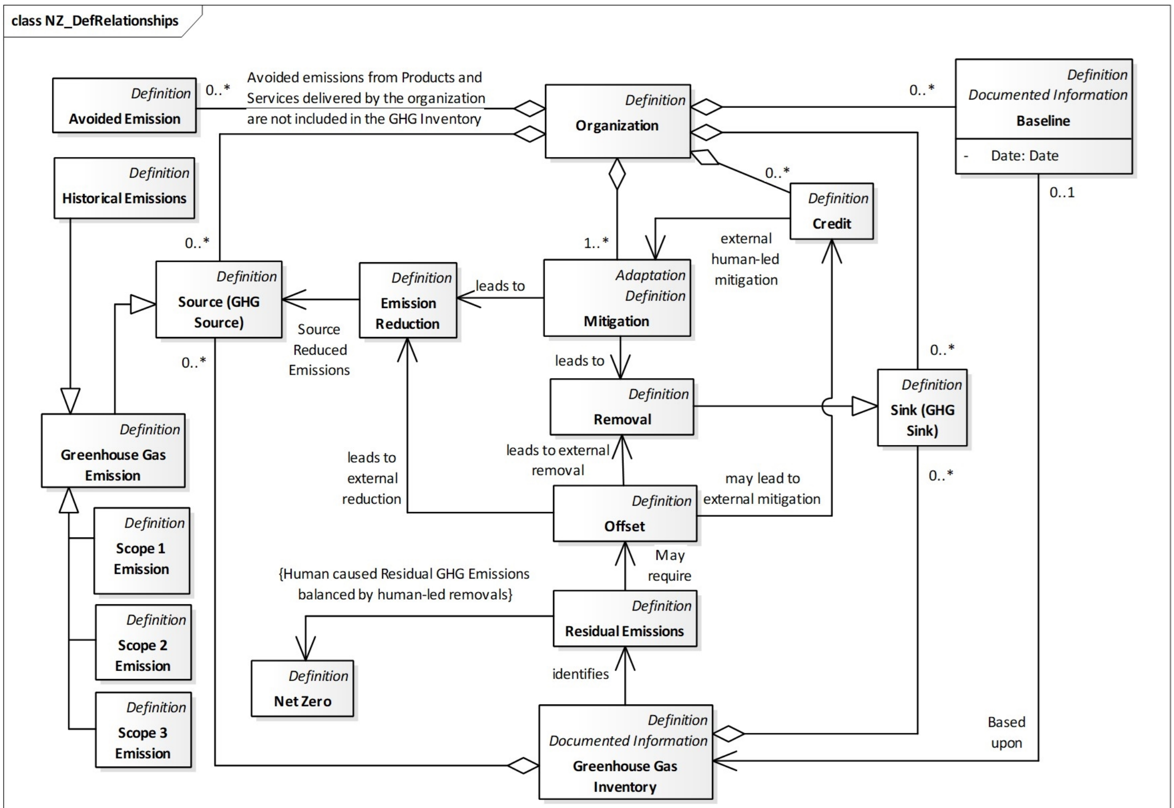
Organizations can plan to achieve these goals by using the following guidelines:

IWA 42:2022 Net Zero Guidelines

Self Assessment is also available

The following highlights the importance of the definitions in the document. The residual GHG amount should only be offset when all other mitigations of current emissions have been taken / planned. The offsets should be creating new sinks (removals) of GHG or Reductions of GHG from new initiatives. The current initiatives have already been factored into the various models.

Here is a diagram of the key definitions found in the Guidelines:



Definitions from "IWA 42:2022 Net Zero Guidelines", available from British Standards Institute (BSI), Bruce McNaughton, 19-October-2023.

References

References: Earth

Please see the following Links for the System Description: Ecosystem

- PDF:: System Description: Ecological System (Ecosystem), Version 0.4, 06-November-2023
- Website:: sysdesc.info: Ecological System (Ecosystem)

The Physics of Living Systems, Fabrizio Cleri

The Physics of Living Systems
Basic textbook providing an understanding of the physics of living systems.

Ecosystem Services, Mark Everard

Ecosystem Services

Animate Earth, Stephan Harding

Animate Earth

Earth System Science, Tim Lenton

Earth System Science, A Very Short Introduction
Pages 14 to 17 Defining the Earth system

Gaia, James Lovelock

Gaia
A new look at life on Earth.

Environmental Engineering, James R. Hihelcic, Julie Beth Zimmerman

Environmental Engineering
Fundamentals, Sustainability, Design

Living Systems

The Systems View of Life, Fritjof Capra and Pier Luigi Luisi

The Systems View of Life
This book is supported by the Capra Course which provides a 12 week course covering the four dimensions of life: Biological, Cognitive, Social, and Ecological.
A Capra Course Glossary is available in the Capra Course Alumni Network - A global Community of Practice related to the book.
See chapter 14 for information on social systems.

The Hidden Connections, Fritjof Capra

The Hidden Connections: Integrating the Biological, Cognitive, and Social Dimensions of Life Into a Science of Sustainability
Some additional information related to social systems.: See page 70 to page 128.
Principles of Ecology: See page 231.

The Turning Point, Fritjof Capra

The Turning Point: Science, Society, and the Rising Culture

The Embodied Mind, Francisco J. Varela, Evan Thompson, Eleanor Rosch

The Embodied Mind
Cognitive Science and Human Experience

Ecological Economics and Ecological Worldview

Doughnut Economics, Kate Raworth

Doughnut Economics
Two models in the book are being used heavily in the development of the Human Activity Ecosystem models: The **Doughnut** and the **Embedded Economy**. The Doughnut is like a balanced scorecard for the planet and the Embedded Economy model is a good starting point to explore the systems that are creating the doughnut problems and the changes that are needed to bring the world into the doughnut safe and just place.
Kate Raworth and Herman Daly Video
Doughnut Economics pictures used with permission, Kate Raworth, 2017

Beyond Growth, Herman E. Daly

Beyond Growth
Kate Raworth and Herman Daly Video

Stockholm Resilience Centre

Stockholm Resilience Centre
Two major areas of interest:

- Planetary Boundaries
- Reconnecting to the Biosphere

Drawdown, Paul Hawken

Drawdown
The Most Comprehensive Plan Ever Proposed to Reverse Global Warming
Project Drawdown

Small is Beautiful, E. F. Schumacher

Small is Beautiful
A Study of Economics as if People Mattered

Governing the Commons, Elinor Ostrom

Governing the Commons, Elinor Ostrom
Approaches to collectively governing the Commons in society.

Kenneth Boulding

This topic contains a number of links to articles on various websites:

- Wikipedia: Kenneth Boulding
- General Systems Theory
- Spaceship Earth

Natural Capital, Dieter Helm

Natural Capital
Valuing the Planet, Restoring the Ecosystems
What would a Sustainable Economy look like.. Dieter Helm at the Oxford Martin School

---

Designing Regenerative Cultures, Daniel Christian Wahl

Designing Regenerative Cultures
Focuses on Whole Systems thinking for society, economy and the environment.

The Great Transition: Using the Seven Disciplines of Enterprise Engineering, James Martin

Great Transition: Using the Seven Disciplines of Enterprise Engineering
Extending Enterprise (SoS) Capabilities to the Planet in the 21st Century
His work continues at the Oxford Martin School

Ellen MacArthur Foundation

Ellen MacArthur Foundation

- Circular Economy
- Publications
- A new Dynamic 2

Transformative Ecological Economics, Ove Jakobsen

Transformative Ecological Economics
Supports the paper by Fritjof Capra on framework for Ecological Economics.

System Thinking Core

Please see the following Links for the System Description: *System (Abstract)*.

- PDF: System Description: System (Abstract), Version 0.30, 27-December-2023 (working draft)
- Link to the System Description Architecture Description Framework
- Link to the System (Abstract) Architecture Viewpoint Definition
- PDF: Structuring Formalism: System Description (SDSF), Version 0.4, 07-February-2023
- Website: sysdesc.info: System

The System Description includes the following sections representing views of the system-of-interest:

- System Name and Class
- System Purpose
- System Properties
- System Stakeholders and their concerns
- System Environment (Context)
- System Structure (Pattern of Organization)
- System Behavior (Structural Changes)
- Correspondences
- Decisions and Rationale
- References

The following links help create a System Description

- Link to the System Description Template
- Link to the System Description Validation Template

The following are links to the COMPASS Project and the CAFF:

- Link to D21.5b Compass Architectural Framework Framework (Local): CAFF Viewpoint Definitions

General System Theory, Ludwig von Bertalanffy

General System theory

Fundamental thinking about a system pattern that applies across many disciplines. Chapter 3 Some System Concepts in Elementary Mathematical Consideration: Pages 54 - 56: provides some key concepts.

Fifth Discipline, Peter M. Senge

The Fifth Discipline: The art and practice of the learning organization: Second edition

The Five Disciplines described in the book are important to seeing systems and understanding the interaction of the parts.

The Five Disciplines are similar to the System of Profound Knowledge described by Deming.

Key elements of this book:

- An understanding of mental models and the impact they can have on decisions
- An understanding of the importance of personal visions both for individual motivation and later for building a shared vision.
- An understanding of the dynamics of systems thinking both in time and place.
- An understanding of the importance of practice in a safe environment.

Re-Creating the Corporation, Russell Ackoff

Re-Creating the Corporation: A Design of Organizations for the 21st Century

Definition of a System and 5 Conditions; Multi-Dimentional Organization Design; Interactive Planning; and more.

System of System Concepts

Systems Thinking, Systems Practice, Peter Checkland

Systems Thinking, Systems Practice: Includes a 30 Year Retrospective

This book contains a good description of Human Activity Systems (HAS) based on a root definition to describe a human activity system (CATWOE). These are both used in the Soft Systems Methodology (SSM).

The concept of the Root Definition has been extended to the System Description that is produced using the System Description Architecture Description Framework. The Human Activity System has also been extended from living social systems.

The book also contains a simple system classification scheme that is being used to define a Earth (Gaia) as a System of Systems model. The system classification system is described in the book from page 102 to page 122. Figure 4, page 112 highlights the 5 system classes. This book also has a good glossary of terms.

This system classification scheme is also being used as the System Classification Framework for the System Description Architecture Description Framework. This framework captures the identified systems and their type.

Thinking in Systems, Donella H. Meadows

Thinking in Systems: A Primer

Donnella Meadows Project

On Dialogue, David Bohm

On Dialogue

A very useful book about conversations that become collective thinking.

On Purposeful Systems, Russell L. Ackoff and Fred E. Emery

On Purposeful Systems: An Interdisciplinary Analysis of Individual and Social Behavior as a System of Purposeful Events

---

Principles of Systems Science, George E. Mobus, Michael C. Kalton

Principles of Systems Science
Excellent visuals, principles and concepts about systems and system science.

Essential Architecture and Principles of Systems Engineering, C. E. Dickerson, Siyuan Ji

Essential Architecture and Principles of Systems Engineering
Explores the mathematical basis of architecture and MBSE
