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D6.2.1
Textual description of the Danube Delta Biosphere Reserve case study focusing on basic biological, physical, and chemical processes related to the environment:

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Abstract

This deliverable presents a detailed textual description of Danube Delta Biosphere Reserve as one of the case studies defined in the NaturNet–Redime project.
The paper follows the structure of two deliverables from project: D.6.1 Framework for conceptual QR description of case studies[2], and D6.8 Guidelines for Sustainable Development Curriculum[3].
The detailed textual description refers to all relevant aspects concerning the basic physical, physical-chemical and biological processes related to the Danube Delta Biosphere Reserve (DDBR) aquatic ecosystems, focussed on water pollution negative effects on aquatic biota (especially on fish) and human health.
In order to assist the DDBR Sustainable Development Strategy, the Qualitative Reasoning concept[4] is to be implemented. This answers the one of the main goals of NaturNet-Redime project: the implementation of new education and decision support model for active behaviour in Sustainable Development based on Qualitative Reasoning.
Qualitative Reasoning (QR) is of great importance for developing, strengthening and further improving education and training on topics dealing with systems and their behaviours (Bert Bredeweg, 2005).
To construct the DDBR Qualitative Reasoning Model, the DDBR system components and the relationships among them are described. QR model fragments are focused on DDBR water pollution rate and its negative effects and the ways they are transmitted from water to aquatic abiotic components - to the biotic ones (flora and fauna species: primary producers and consumers) - to humans. This approach is imposed by the interdependency relations in the framework of the functional feeding groups, governed mainly by the Danube River water quantity and quality.
The Qualitative Reasoning model fragments will emphasize the causality conditions which have been generating loss of DDBR biodiversity, decline of some flora and fauna species, modification of communities' structure, etc, in order to delimit those objectives for a sustainable use of natural resources, and a sustainable development strategy addressed to aquatic ecosystems.
Within the DDBR three functional zones are distinguished: strictly protected areas, their buffer zones, and economic zones. Within the last ones human settlements are located. The most important functional role is given by the "biosphere reserve" status. Economic activities are integrated with this environment. All social and economic actions fall in line with biodiversity conservation and protection measures. Thus, the most appropriate and global concept of sustainable development for Danube Delta Biosphere Reserve can be expressed by **sustainability through biodiversity**. This incorporates biodiversity conservation and protection measures, including all flora and fauna species and their habitats, both as natural resources for social and economic interest and as conservative concern - protected by international conventions.

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[2] Organisation name of lead contractor for deliverable D6.1: University of Amsterdam, Authors: Bert Bredeweg, Paulo Salles, Anders Bouwer and Jochem Liem.

[3] Organisation name of lead contractor for deliverable D6.8: University of Jena, Authors: Tim Nuttle, University of Jena; Paulo Salles, University of Brasilia; Bert Bredeweg, University of Amsterdam

[4] Bert Bredeweg, http://hcs.science.uva.nl/QRM/

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Contents

1 Introduction

The Danube Delta Biosphere Reserve (DDBR) is one of Europe's most extensive wetlands. It forms a unique series of interrelated ecosystems of very large compact surfaces of reed beds, maze of tributaries, the white willow and the poplar, big canals /channels connecting lakes rich in aquatic plants and animals (fish, birds, mammals), and fluvial-maritime sandy dunes with a mosaic of forests and semi-arid grasslands. Human population living inside DDBR counts 12,000 inhabitants.

DDBR exhibits a classic Delta triangular formation with branching tributaries of the Danube River extending out from an apex to nearly 100km in length and width before discharging into the Black Sea.

It plays an important role as a chemical and physical filtering system for Western Black Sea coastal waters, especially for flood waters flowing over the Danube's arms and inner canal banks. DDBR fulfils this role by means of its large and compact surfaces of reed beds.

DDBR is an integrated system at every level: ecological, hydrological, economic and cultural, that must be respected and managed as such for long-term sustainability of the natural resources it provides and the local people who depend on it. Despite production pressures, compared to other wetland ecosystems in the region, DDBR remains largely in natural state.

Within the Danube Delta Biosphere Reserve (DDBR), aquatic ecosystems represent the most important and extended environment for natural resources developed in this area. Therefore, a great concern is focussed on water quality, as "responsible" for DDBR biodiversity including human health. The Danube River water pollution increases, as recorded within the last decades, especially due to the heavy metals increase concentration in water. It has been inducing the most significant negative effect on aquatic ecosystem biodiversity from DDBR.

Conservation and protection of DDBR biodiversity (both as natural resource use and as conservative concern) is one of the main objectives in achieving the Sustainable Development Strategy for this area. These must be based on the best current understanding of the phenomena which occur within and beyond the delta, including the whole basin of the Danube River and the Black Sea.

Knowledge about the state of aquatic ecosystems within DDBR serves for making decisions for sustainable use of resources and protection of the natural heritage as well and this is a requirement in achieving an environmental and socio-economic sustainable development in DDBR. The sustainable development within DDBR directly relies on biodiversity conservation and protection actions. In that respect, the Danube Delta Biosphere Reserve strategy for sustainable development, related to biodiversity preservation and sustainable use, includes action proposals, such as:

1. Implementation of biodiversity preservation and protection measures for endangered, rare or in decline species of conservative concern or of high ecological and economic value and their habitats;
2. Protection, rehabilitation, and sustainable use measures of sturgeon population migrating from Black Sea to the Danube River.
3. Assessment of effects of water pollution on biotic component.
4. Sustainable use of fish stocks.
5. Vegetal resource management improvement.
6. Diversification and reorientation of tourism offer.
7. Mitigation of anthropogenic impacts on the deltaic biome.

2 Documentation

Danube Delta Biosphere Reserve (DDBR) represents one of the main elements of the Danube River – Danube Delta – Black Sea Geosystem. Its present-day morphohydrography expresses the interaction between Danube River (water and sediment discharges) and Black Sea (waves, littoral currents, sea level changes, continental shelf areas etc.).
Danube River is the main water source for DDBR aquatic ecosystems. The river collects and transports huge quantities of water and sediments (each of them being loaded with nutrients, heavy metals, and various other chemicals) from its drainage basin to Danube Delta and Black Sea.
The Danube's drainage basin (500 m mean elevation and 3,798 m maximum in the Alps) covers partly or totally a number of 18 European states (Figure 1. The Danube River hydrographic basin).
The main Danube River water **pollutants** introduced by the largest cities on its banks (Vienna, Bratislava, Budapest and Belgrade) and all its tributaries are ammonia, **nitrogen and phosphorus components, and heavy metals**.

Figure 1. The Danube River hydrographic basin.

2.1 The Danube Delta Biosphere Reserve biodiversity

DDBR is declared as world heritage site and wetland of international importance, since 1990 (according to The Convention on Wetlands, signed in Ramsar, Iran, in 1971). Its area of 5,800 sq. km, making it one of the greatest wetlands in the world, contains 30 types of ecosystems both terrestrial and aquatic, out of which 23 are natural or artificially modified and 7 are man-made ecosystems (including human settlements) (Figure 2. The Danube Delta Biosphere Reserve ecosystems).

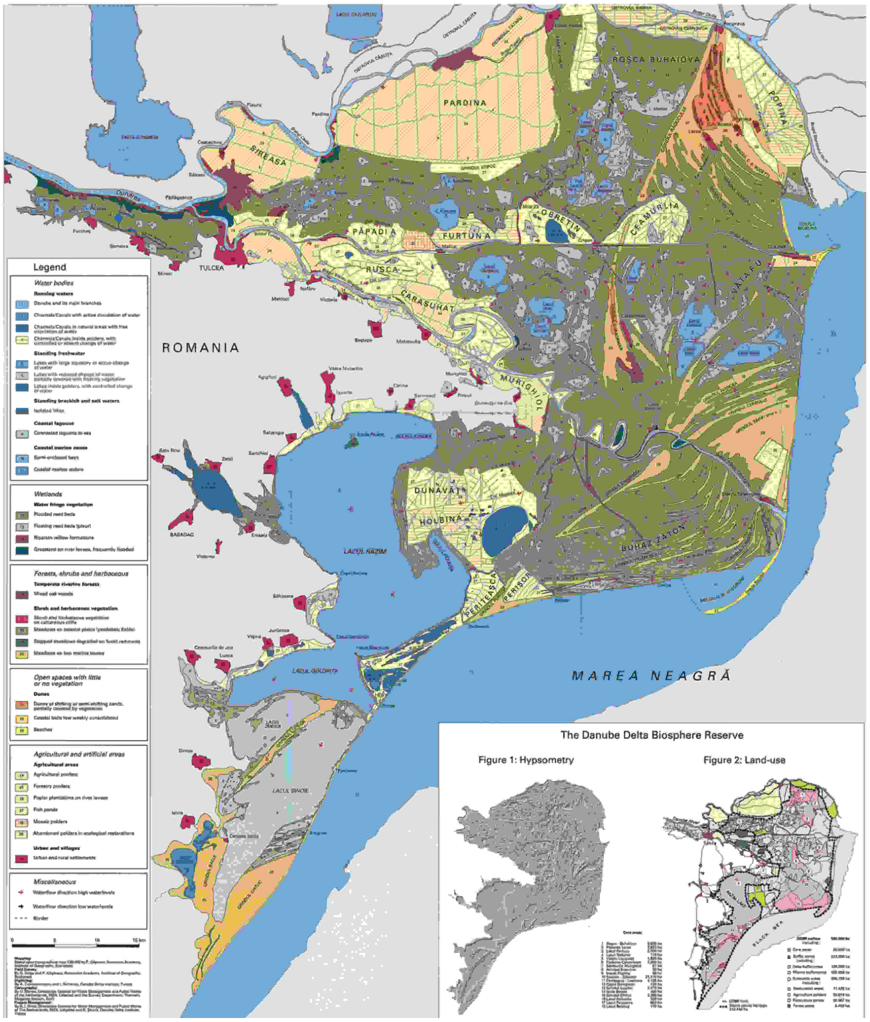

Figure 2. The Danube Delta Biosphere Reserve ecosystems.

DDBR biodiversity – as natural resource ***consists of*** a valuable gene bank for the world natural heritage of flora and fauna species. Inside the DD ecosystems, there has been identified (Otel at all, 1991-1995, Red List of the Danube Delta Biosphere Reserve plants and animal species) a number of 5364 species, from which 823 inferior flora species, 1016 vascular flora species, 3061 invertebrate species, 464 vertebrate species, organised in 34 types of habitats. A great number of new species has been discovered. The large number of fish species (85) is significant both for their high economic and ecological value.

The **biodiversity decline** was reflected by missing an important number of species within last decades, which appeared in some publications as existing in previous period (1960s), such as: 481 spp of planktonic algae, 36 spp vascular plants, 59 spp molluscs, 19 spp fish, 5 spp birds, 2 spp mammals (Otel at all, 2002).

Among species recorded within 1991-1995 (Otel at all, 1991-1995), the following were identified as critically endangered, vulnerable and rare, as follows: 156 spp vascular plants, 8 spp molluscs, 3 spp insects, 18 spp fish, 7 spp reptiles, 128 spp birds, 18 spp mammals. All these, along with a number of 35 recorder endemic species from this territory, are actually nominated within the European Union directives (Habitat Directive/ Nature 2000, and Bird Directive) as species of community concern, which need special protection zones or strict protection regimes.

2.2 Socio-economic aspects

The population of the Danube Delta declined from 21,000 (in the 1970s) to 15,000 (in the year 2000), being strongly influenced by the development of Tulcea town where lately people immigrated, for better life conditions.
Fishing has been the main occupation of the Danube Delta inhabitants, since ancient times, and although nowadays the supply of fish has diminished and changed in quality, it continues to be basic trade. A second major occupation has been (and still is) sheep and cattle breeding. Traditional agriculture has been practiced successfully by the inhabitants of the settlements situated on the river banks at low risk from flooding. After 1960, these traditional occupations were drastically modified by the extension of reed exploitation (later abandoned), fish ponds, large agricultural polders (also partly abandoned) and forest plantations.
Human health is most affected by the water quality degradation, from last decades by pollution, especially with heavy metals due to the fact some people drink water directly from DD canals and also their main food source is the fish (also affected through bioaccumulation of heavy metals in muscle tissue).
During the last decades, the number of inhabitants decreased due to natural negative birth rate, ageing people, or migration to the other regions with better life conditions.
The people's quality of life is relatively low. Their health status is not good, being determined by the habitat conditions and lack of medical assistance too.
The population living in the towns and villages around the Danube Delta's borders is over 145,000. Tourism adds annually about 70,000 people.

Tourism
The Danube Delta is an area with a high reputation in Europe and elsewhere in the world. This is famous for its natural deltaic landscapes made of large canals or marshes and reed-bed surfaces, large colonies of birds.
There is a great potential for developing environmental tourism, but actually, this needs to be provided with sufficient investment for renovating and bringing existing facilities up to modern standards.
The tourism induces a negative effect on the wild nature species (both of flora and fauna) if it is not well organised and the tourists, the tourism vessels have an aggressive behaviour on this very fragile environment.

Navigation
The Danube Delta and its mouths have been used for navigation since the ancient times. Intensified modern system of navigation has been created by hydraulic engineering works, such as deepening and meander cutting-off in Sulina arm. These works had been constructed within 1862 -1902 in order to allow oceanic ships to enter the Danube Delta Sulina arm and navigate the Danube River up to Braila harbour (170 km).
The traffic on the Sulina branch near the Danube harbours of Sulina, Galati, Braila (Romania) and Reni (Ukraine) rose to 8.5 million tons/year in the last decade of the 20th century (Gastescu, 2002). Besides the transport of goods, the transport of passengers also plays an important role inside the Danube Delta.

2.2.1 Issues and stakeholders

The stakeholders involved in the DDBR management are: nature conservation and protection bodies (DDBRA, NGOs), the fishery and fishing companies, tourism companies, fluvial and marine transport companies, recreational hunting groups.
The main impacts induced on the DDBR are:

- loss of wetlands through embankment works for different types of land use (agricultural polders, fish ponds, and forest plantations), summing 15% of the whole DDBR surface
- the Danube River waters have increasingly become impure due to the large amounts of pollutants. These include:
  - high-medium concentration of ***nutrients*** in water. These cause pollution, respectively water eutrophication state. It results in an overgrowth of green alga (toxic phytoplankton fraction, inedible for zooplankton) which reduces water transparency and the quantity of dissolved oxygen in the deep water layer. The submerged vegetation (macrophytes) is thoroughly destroyed and indirectly some fish species (the pike and the tench – species of high economic value), at the same time the development of other species is stimulated (the bream, the crucian, the roach and the pike perch - species of low economic value, easily adaptable to water eutrophication condition).
  - high concentration of ***heavy metals*** in water which are transferred to any aquatic organisms and bioaccumulated in their bodies (either plants or animals). Within the last years in DDBR, especially Cadmium and Lead high values are recorded in water, bottom sediment and fish/molluscs muscle tissue.
- a decrease of fish species diversity and fish population size, as result of water eutrophication high rate recorded within 70's-early 90's, and high heavy metals concentration in water, over fishing (even poaching) recorded especially within last decades.
- navigation along arms and canals, enhances erosion through the waves raised by fast vessels, the sediment transport increases turbidity, all of which, imbalance the nesting or feeding zones
- industrial activity in the neighbouring towns (Tulcea – Romania; Izmail, Kiliya, Vilkovo – Ukraine) releases a series of noxious substances, dusts into the air and the water (CO, CO2, sulphur oxides, nitrogen oxides, aldhehydes, ammonium, ash, no burnt coal dust, soot, tars, hydrocarbons, fluorides, chlorines, sulphates)
- agricultural farming practiced before 1989 has affected the area by the excessive chemical fertilizers and pesticides used in the neighbourhood of the delta and carried downstream by the Danube waters. Although these substances have been significantly reduced, they have accumulated in the higher trophic chain causing physiological changes in plants and animals, up to the total disappearance of some species.
- riverside human settlements, or those located inside the delta, are damaging the ecosystems by discharging waste waters, untreated solid wastes dumped in the water and soil.

2.3 The Danube Delta Biosphere Reserve Concept map

The Danube Delta Biosphere Reserve concept map (Figure 3. Concept map for Danube Delta Biosphere Reserve water pollution – the negative effect on DDBR biodiversity) describes the actual status of this system, based on the dominant processes governing its behaviour.

As DDBR main components are aquatic ecosystems, and their behaviour depend on water quality, the concept maps stresses on water pollution process affecting the aquatic biological components status and human health for people living inside or around the DDBR.

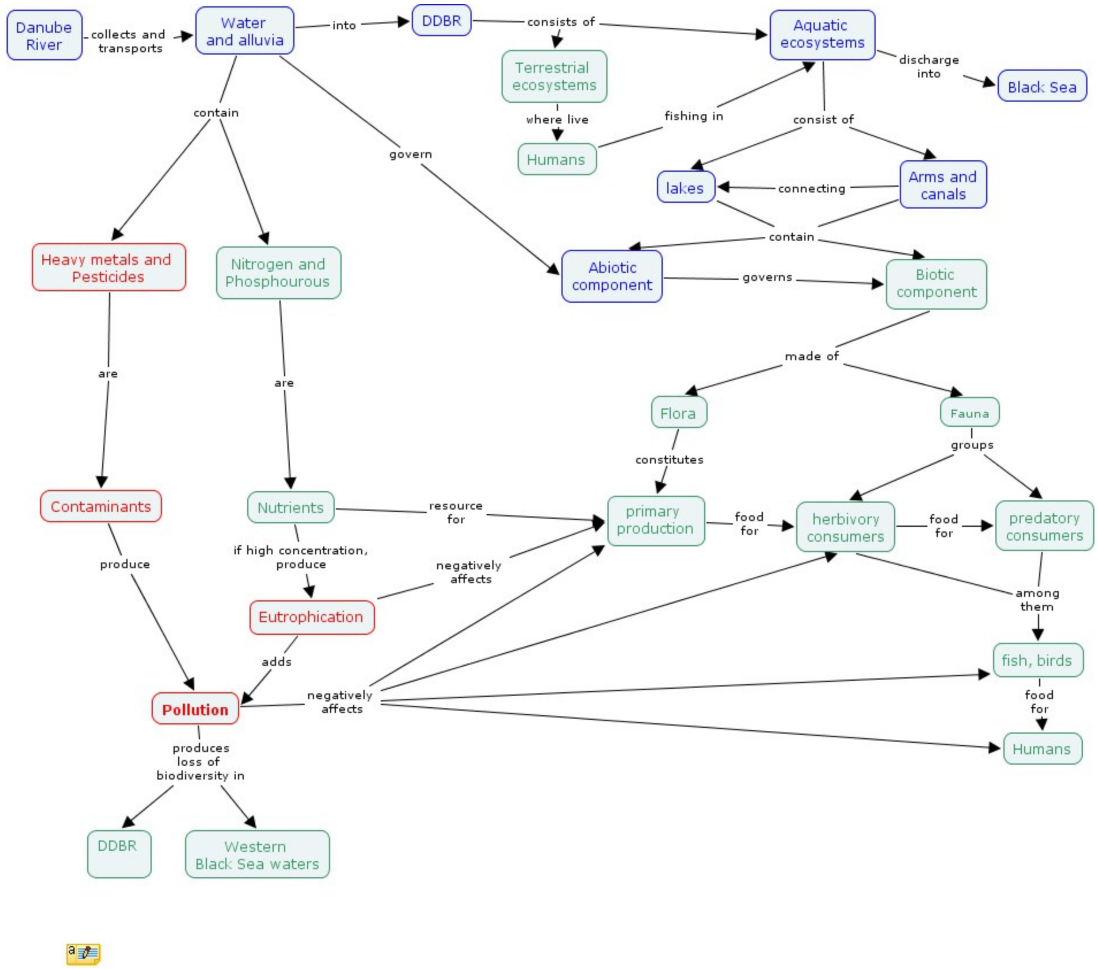

Figure 1. Concept map for Danube Delta Biosphere Reserve water pollution – the negative effect on DDBR biodiversity and human health.

2.4 Main model goals

The Danube Delta Biosphere Reserve model will be concentrated to emphasize the main cause that hampers this system to get a sustainable development. For DDBR aquatic ecosystems the water pollution is identified to be this main cause.

Thus, the DDBR model will describe the aquatic ecosystems behaviour governed by water pollution and the ways it propagates to aquatic organisms and to humans living in or around the DDBR.

The main DDBR model goals are as follows:

1. Understand and emphasize connections between water pollution in the Danube River catchment basin and health of human population living in and around the DDBR.
2. The model will be used to explain and educate the environment agency representatives, decision makers and stakeholders about the working of processes within the Danube River and their influence on these processes.
3. The model will be used for argumentation purposes to convince decision makers what kind of actions they should take in order to improve (or stop) the Danube River water pollution process.

These must be based on the best current understanding of the phenomena which occur within and beyond the Danube Delta, including the whole Danube River basin and the Western Black Sea costal waters.

3 System selection and structural model

In order to build the structural model of a system, the following elements are to be included: the system structure, the system environment and external influences, and assumptions concerning the structure.
For the Danube Delta Biosphere Reserve system, the structural model is based both on aquatic ecosystem physical, physical-chemical and biological components, and on humans living in human settlements which belong to terrestrial ecosystem.

3.1 Danube Delta Biosphere Reserve system structure

System structure refers to those objects which are represented in the model and how they are interrelated.
The content of this subsection includes:
- ¤ The system's entities
- ¤ Structural relationships among entities
- ¤ Decomposition of entities

3.1.1 System entities

The main DDBR system entities are: *Water* and *Humans*.

Water *contains* two types of components: abiotic and biotic.
- · The water abiotic component is made of not living elements.
- · The water biotic component is made of biological elements (living).

Humans
Human population living inside the Danube Delta is about 12,000 inhabitants. For about 70% of them, their life quality is directly dependent on water quality (as they drink water they take it directly from Danube Delta canals), and for most of them, on fish production and quality. Unfortunately, there is a high level of Danube Delta water pollution, especially due to high heavy metals concentration in water and their bioaccumulation in fish muscle tissue. Therefore, a high water pollution rate direct effect on all aquatic *flora* and *fauna* species and *humans* drinking this water occurs, and indirectly on *humans* eating ***fish*** and *birds* from this polluted water. So, the higher water pollution, the higher concentration of *pollutants* in flora and fauna organisms, and the reducer DDBR *biodiversity* and *human health*.

3.1.2 Structural relationships among entities components

1. Functional *feeding* groups:
   - o Primary producers: phytoplankton and aquatic macrophytes flora species ***feed on*** nutrients (Nitrogen, Phosphorous and Silica components) and need the presence of dissolved oxygen and solar energy (light and heat).
   - o Primary consumer fauna species: zooplankton, macroinvertebrates, fish, birds, mammals as herbivore species ***graze*** phytoplankton and aquatic macrophytes.
   - o Secondary consumer fauna species: zooplankton, macroinvertebrates, fish, birds, mammals as predatory species ***prey on*** herbivore species of zooplankton, macroinvertebrates, fish, birds, mammals, or even other carnivore species smaller in size.

2. ***Competition***:
   - phytoplankton and macrophytes *compete* for light and dissolved oxygen;
   - fish-eating birds and humans *compete* for fish.
3. ***Pollution***:
   - pollutant *pollutes* water and aquatic biotic organisms;
   - pollutant *pollutes* human organism (of those humans drinking water from DDBR canals);
   - aquatic fish/bird organism *pollutes* human organism (of those humans eating fish/ birds from polluted water).

3.1.3 Decomposition of entities

W*ater* *contains* the entire range of abiotic and biotic components.

- Among abiotic elements, chemicals (salts, nutrients, heavy metals, pesticides, various other chemicals) are contained in water column, in suspended and bottom sediment and in flora and fauna organisms. This project is focussed on water pollution elements. Water ***pollutants*** are chemical elements which reach the rivers by run-off from industrial zones or agricultural lands. The highest pollution effect on biota species is given mainly by: ***heavy metals, pesticides and nutrients*** (as Nitrogen and Phosphorous compounds). The last ones – nutrients – get pollutant effect only when their concentration in water is so high than reaches and produces the water **eutrophication** (indicated through phytoplankton bloom to water surface). When nutrients are in small concentration in water, they constitute *food source for* phytoplankton and aquatic macrophytes (as ***primary producers*** within the food web).
- Biotic component is made of aquatic ***flora*** and ***fauna*** species**.** Among these species there is a strong structural relationship, in the framework of the functional feeding groups: flora species (phytoplankton and macrophytes) are *food for herbivore fauna* species. The later are *food for predatory consumer* species. Among the *fauna* species, ***fish*** and birds, either herbivore or predatory, constitute *food for* **humans**.

3.2 System environment and external influences

The *system environment* consists of DDBR terrestrial and aquatic ecosystems.

The terrestrial ones shelter human settlements where about 12,000 people live. The aquatic ecosystems are made of Danube's main arms connecting big canals which connect small canals and lakes.

The main ***external influences*** on DDBR aquatic ecosystem water quality are produced both inside and outside the DDBR territory. These are:

¤ Tourism inside DDBR.

¤ Industry: source of *heavy metals* running-off into Danube River.

¤ Agriculture: source of *pesticides* and *nutrients* (nitrogen and phosphorous compounds) running-off from agricultural lands to groundwater, lakes and rivers.

The Danube River experiences substantial annual and interannual variations in water and sediment load and concentration of the various chemical compounds transported. Organic matter ranges from dissolved molecules to particulate aggregates and can be present as living and dead material.

In river, natural levels of organic matter are related to in-river production and allochtonous input from river watershed.

Human activities alter organic matter natural levels in rivers mainly by:

(i) modifications of river watershed by urban and agricultural land use;

(ii) direct organic matter releases into river water: domestic and industrial wastewater, livestock and fish farming.

The Danube River exerts the main external influences on DDBR ecosystems as it is the main water source for DDBR aquatic ecosystems. The river water quantity and quality depend on the water and sediment the river collects from its hydrographic basin (see Figure 1. The Danube River hydrographic basin). This way the Danube River is the main DDBR water pollution *source*. The higher the river *water and sediment* discharge the higher the *pollutant* content, the higher the DDBR *water pollution, the higher the negative effect* on DDBR and Western Black Sea coastal water biodiversity.

3.3 Assumption concerning structure

- Among the water chemical components, only the water pollution elements have been considered in constructing the DDBR water QR models. These are *heavy metals*, *and nutrients* as "the guiltiest" pollutants within the water pollution process.
- *Silica,* as desirable nutrient for diatom (algae) species development, has low influence on water pollution rate. It is ignored.

4 Global behaviour

This section describes the global behaviour of Danube Delta Biosphere Reserve system, as next step in capturing knowledge concerning its behaviour related to basic physical, chemical and biological processes from aquatic ecosystems. It details the inner system main processes and external influences for delimiting the main causes and effects they induce on system changes, necessary in building Qualitative Reasoning models of the system.
The specification of DDBR global behaviour is developed here by:

- textual description of the main processes within aquatic ecosystems
- external influences and deliberate actions
- overall causal model
- typical scenario and behaviour graph
- assumptions concerning the global behaviour of the DDBR

In order to get the DDBR global behaviour specification, the choice of the typical scenario and its behaviour graph was identified and presented here. The typical scenario means initial behavioural situation of the system. Starting the initial situation triggers processes and deliberate actions inducing changes to system.

4.1 Main processes

This subsection presents the main physical, physical-chemical and biological processes inside the DDBR aquatic ecosystems, strictly related to the *water pollution process* and its effects on aquatic organisms (especially on *fish*) and on *humans* (those people who *drink* water they take it directly from DDBR canals, or *eat* fish from polluted water).

4.1.1 Physical processes

4.1.1.1 Water flow process

Water flow process takes place due to the river / channel water column hydraulic energy, and the river flowing slope created by the river / channel bed elevation difference between two sections of the river / channel. For Danube River, the water stream maximum elevation is 1,241 m (the river spring in Kandel Peak, Schwarzwald Mountains in Germany), and decreases to 0 m when it meets the Black Sea waters.
Inside the 11 types of aquatic ecosystems of the DDBR, water flow process assures their supply with water and sediment discharges collected and transported by the Danube River from its drainage basin.

The **entities** structurally related in this process are:

- *Object:*
  - *Danube's aquatic ecosystems:*
    - *Channel*
    - *Lake*
- *Material:*
  - *Water*
  - *Sediment*

Quantities involved:

-*Water discharge*

-*Sediment discharge*

-*Dissolved oxygen*

-*Nutrients concentration*

-*Heavy metals concentration*

-*Water pollution*: is given by high concentrations of **nutrients***, heavy metals and pesticides*, and toxic substances released by some algae and aquatic vegetation species.

Start conditions:

Mostly, the water flow is a permanent process.

The seasonal variation of Danube River water discharge shows a wintertime minimum (with a small range in amplitude) followed by a significant maximum in spring-summer, a medium in summer, and another minimum in autumn. The spring-summer maximum represents 33% of the Danube annual water discharge while the autumn minimum (which corresponds to the highest level of *water pollution*) represents only 17-18% of the annual water discharge.

Due to the very high Danube's water discharge amplitude, from maximum value (reached during the river spring-summer flood pulse) to minimum value (from droughty season), there are created three flow conditions:

1. High flow takes place at maximum discharges of Danube River. The Danube Delta inner aquatic ecosystems are supplied to their high levels of *water and sediment*. Both water and sediment contain high concentrations of inorganic (*nutrients, heavy metals*) and organic (*pesticides*, other chemicals) pollutants. The spring floods bring an overflow of *nutrients*, exceeding the normal inflow of nutrients necessary as food resource for primary producers: phytoplankton and aquatic vegetation. This generates the spring *phytoplankton blooms* of diatoms.
2. Medium flow takes place for Danube medium discharges. This hydrologic regime frequently occurs in early summer time.
3. At very low Danube water level, there is no inner delta's canal and lake supply with water. This happens in very dry seasons, especially in those DDBR zones further from the Danube main branches and big canals.

Effects:

-A high flow process has as effect an increase of the:

¤ water discharge, sediment amount, water turbidity, water flowing velocity, dissolved oxygen, *nutrients, heavy metals, and pesticides*;

¤ wash-out of phytoplankton;

¤ aquatic vegetation.

-A low flow process causes:

¤ an increase of *water pollution*, produced by phytoplankton toxicity, and by high concentration of pollutants (*heavy metals, nitrogen, phosphorous*) due to high water evaporation and release of pollutants with the decay of aquatic vegetation and phytoplankton;

¤ very low content of dissolved oxygen

¤ much reduced zooplankton

- ¤ no aquatic vegetation
- ¤ no fish, and no birds.

Stop conditions:
When the Danube's water levels are low, and when inside the DDBR small canal water circulation gets very slow, and inside the connected lakes no water circulation at all.
In running water ecosystems (Danube's arms and big canals) stop conditions can hardly occur. Perhaps in extreme droughty years, like 1921.

4.1.1.2 Water oxygenation process

The **entities** structurally related in this process are:
Entities: *Water*
Quantities involved:
- *Water discharge*
- *Dissolved oxygen*
- *Water flow velocity*.

Start conditions:
The process is always active in Danube's arms and big canals and is assured by the water active flow process, and a medium, high water flow velocity, necessary to mix water layer with air.
In small canals and shallow lakes, in phytoplankton bloom condition, the water layers oxygenation is much reduced.
Effects:
An increase of water oxygenation process in water column assures:
- ¤ good life condition for all aquatic organisms;
- ¤ necessary oxygen content for organic matter decomposition process, at the bottom sediment level.

Stop conditions:
Within standing shallow lakes, located further of Danube's arms and big canals, in low flow conditions and high phytoplankton bloom, there almost is no water oxygenation process.

4.1.1.3 Bottom sediment resuspension process
The **entities** structurally related in this process are:
Water, Phytoplankton, Macrophytes, Macroinvertebrates, ***Fish***
Quantities involved:
- *Bottom sediment*
- *Water velocity*
- *Phytoplankton biomass*
- *Macrophytes biomass*
- *Macroinvertebrates biomass*
- *Fish biomass.*

Start conditions:
When the water waves or small and large animal scraping, searching for food make the bottom sediment content to be resuspended (reintroduced in water column).
Effects:
The bottom sediment resuspension process has as effect:
- ¤ an increase of *water pollution rate* as result of reintroduction of *nutrients, heavy metals,* organic matter decomposed by bacteria, and all other *toxins* deposited in bottom substrate, in water column.

Stop conditions:
When there is not water layer movement or animal scraping for food.

4.1.2 Physical - chemical processes

4.1.2.1 Water eutrophication

The **entities** structurally related in this process are: *Water*.

Quantities involved:

-*Water discharge*
-*Nutrient (Nitrogen, Phosphorous) concentration*
-*Phytoplankton biomass*
-*Aquatic vegetation (macrophytes) biomass*
-*Water pollution rate*

Start conditions:

When Total Nitrogen concentration in water is higher than 1.00 mg/l, and Total Phosphorous is higher than 0.1 mg/l.
Eutrophication has as start condition a nutrient enrichment, typically in the form of nitrates and phosphates, often from human sources such as agriculture, sewage, and urban runoff.

The enrichment of water by *nutrients*, especially compounds of nitrogen and/or phosphorus, causes an accelerated growth of algae and higher forms of plants to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.

Effects:

An excess enrichment in water inorganic *nutrients* can have the following effects:

- ¤ an accelerated growth of phytoplankton and higher forms of plants
- ¤ reduction of dissolved oxygen;
- ¤ an increase of organic matter when these organisms die;
- ¤ an increase of *water pollution* due to phytoplankton *toxicity* (toxic substances like nitrite and ammonia can form which in high concentrations are lethal to fish and invertebrates).

Stop conditions:

When the concentration of nutrients decreases both in water column and in sediments, as follows:

- ¤ Nitrogen concentration less than 1 mg/l
- ¤ Phosphorous concentration less than 0.1 mg/l

4.1.2.2 Water pollution process

The water pollution is the process which takes place as result of an increase of any pollutant concentration over certain limits. The main pollutants occurred within DDBR aquatic ecosystem water are: *heavy metals, nutrients.* Nutrients in high concentration in water produce water eutrophication process which contributes to the water pollution process due to high concentration of toxins released as result of phytoplankton bloom process (triggered as result of water eutrophication process).
The ***entities*** structurally related in this water pollution process are: *Water*.

Quantities involved:

-*Water discharge*
-*Sediment discharge*
-*Heavy metal concentration*
-*Nutrient concentration*
-*Phytoplankton biomass*
-*Aquatic vegetation biomass*

-*Detritus biomass*
-*Fish (Birds, Mammals) biomass*

Start conditions: when one of the following conditions occurs:
-High concentrations of *heavy metals and pesticides* in water column and/or in bottom sediment;
-High concentration of *nutrients* in water column and/or in bottom sediment;
-High amount of *Phytoplankton* (toxic algae species);
-High amount of vegetation (toxic species);
-High amount of detritus;
-Bottom sediment resuspension.

Effects:

An increase of *water pollution rate* has negative influence both on any aquatic organism growth and on human health (those people who drink polluted water, or eat fish from polluted water).

Heavy metals are dangerous because they tend to **bioaccumulate** in aquatic organisms. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment.
A major role in terms of danger to the ecosystem is played by heavy metals, which stand out by their persistence and bioaccumulation.
The fish organs - in particular the muscles - show a very wide spread of heavy metals concentration.
The presence of higher concentrations of several metals (lead, cadmium) in water channels and lakes of Danube Delta Biosphere Reserve led to their absorption in fish muscle to an amount several times higher than expected for the individual heavy metals.
Based on the results of study carried out within 2003 – 2005, fin Danube Delta aquatic ecosystems, cadmium and lead concentration were found out in high values, in whole fish body.
Pb and Cd are much higher *accumulated in fish muscle tissue* than maximum limit admitted as established by the Romanian Council of Ministers of the Environment (Guideline No. 356/2001). This limit is:

- 0.2mg/kg for Lead (Pb);
- 0.05 mg/kg for Cadmium (Cd).

The highest values of Cd in fish muscle tissue were found out in *Carassius auratus gibelio* = gibel carp (of 0.19mg/kg-0.06 mg/kg)*, Perca fluviatilis* = perch (0.20 mg/kg-0.08 mg/kg). These values are higher than the limit recommended for human consumption (0.05 mg/kg).
The metals Cu, Zn in water and fish are within permitted limits.
At present, there is not a Law (Romanian or European) entered into force to interdict the fishing and fish consumption by people, also the fish contamination with *heavy metals* is demonstrated with data.

Stop conditions:
-Low concentration of water and sediment (both suspended and bottom) in *heavy metals and pesticides.*
-Medium-high concentrations of *nutrients*.

4.1.2.3 Phytoplankton bloom process

The **entity**: *Water.*
Quantities involved:

- *Water discharge*
- *Nutrient concentration*
- *Phytoplankton biomass*

Start conditions:
When ***nutrients*** are in high concentration, the water gets eutrophic state and a high development of phytoplankton algae and aquatic vegetation is generated. In this condition phytoplankton bloom occurs, which is an indicator of water eutrophication phenomenon. The term phytoplankton (algal) bloom means that phytoplankton strongly increases in numbers in a limited period of time (of few days). This phenomenon could take place every season.
Effects:

-increase of water turbidity by phytoplankton high biomass;
-decrease of water transparency, dissolved oxygen content;
-collapses the aquatic vegetation;
-increase of detritus after phytoplankton death and is decomposed by bacteria;
-increase of *water pollution* due to some phytoplankton species (large blue-green algae) toxicity they release in water and from detritus by bottom sediment resuspension process;

- the occurrence both of Danube River nutrient-rich, heavy metals and pesticide inflows and the in-stream recycling processes, change the water colour due to the excessive growths of phytoplankton, this being the most visible symptom of eutrophication. The increase incidence of algal blooms gets out of order the macrophytes, zooplankton, ***fish***, and bird assemblages. It has as effect the reduction of favourable habitats and ***diversity for fish communities*** of clear water (a decline of some economic valuable species such as predatory species), and a dominance of placid species (species of low economic value).

Stop conditions: when nutrients and phytoplankton biomass decrease at a low concentration.

-

4.1.3 Biological processes

4.1.3.1 Fish growth process

The **entities**: *Water, Fish.*
Quantities involved:

-*Fish population size*
-*Fish species diversity*
-*Aquatic vegetation biomass*
-*Water discharge*
-*Dissolved oxygen content*
-*Nutrient concentration*
-*Heavy metals and pesticides concentration*
-*Phytoplankton biomass*
-*Zooplankton biomass*
-*Macroinvertebrates biomass*
-*Number of birds*
-*Number of mammals*
-*Detritus biomass.*

Start conditions:
The fish growth process needs very different conditions as function of fish species which are grouped by their preference for flowing or stagnant water conditions, feeding type, food preference, reproductive/spawning substrate requirements.

¤ As function of the water flow conditions, **start conditions** for fish growth process occur depending on the fish preference for water level fluctuation, and water current velocity, as follows (Schiemer and Waidbacher, 1992):
- rheophilic- riverine species are dependent on the connectivity to the river and its tributaries as they require water flow for spawning and during their early life stages;
- eurytopic- as "habitat generalists" are found both in the river and various types of stagnant water bodies;
- limnophilic species are confined to various microhabitats of disconnected former river branches with a strong development of submerged vegetation;
- migratory species travel from Black Sea to Danube River for spawning. Damming hydrotechnic works built on river (such as: Iron Gate I, and Iron Gate II) are true barriers for these species. Their ways of migration for spawning have been much disturbed by these huge constructions.

¤ As function of fish food preference, **start conditions** occur when the food resource is assured, and can it be one of the following: algae; benthos; detritus; fish; invertebrates; omnivore; phytoplankton; plankton; plants (superior plants: aquatic macrophytes); zoobenthos; zooplankton.

¤ As function of the *water quality*, **start conditions** occur when low-medium concentration of *nutrients* and low concentration of *heavy metals* are found in water.

Effects:
An increase of *fish species diversity* has as effect the assurance of the fish population growth stability due to the fact that some predatory fish species prey on other fish species (either herbivore or predatory).
An increase of *fish population size* has as effects:

- an increase of the:
  - · fish-eating bird number;
  - · fish-eating mammal number;
  - · detritus biomass: after fish dies and decays the organic matter resulted is decomposed by bacteria, and the detritus is enriched;
  - · phytoplankton bloom by grazing (and so decreasing) the zooplankton which is the main grazers on phytoplankton;
  - · *Human employment*: as most people living inside the DDBR are fishermen.
- a decrease of the:
  - · zooplankton – main food resource for fish planktivorous species;
  - · aquatic vegetation – food resource for fish herbivore species;
  - · some fish species – food resource for predatory fish species;
  - · dissolved oxygen content;
  - · phytoplankton – food resource for fish at its larvae and juvenile age.

Stop conditions:
When one of the following conditions occurs:

¤ high water pollution degree: high *nutrients and heavy metals* concentration in water;
¤ high phytoplankton bloom rate;
¤ low content of dissolved oxygen;
¤ low food resource;
¤ bad reproduction/spawning substrate conditions;

¤ over fishing doubled by poaching

4.2 External influences and deliberate actions

4.2.1 Fishing

Fishing is deliberate human action to fish.

-The agent: the fisherman
-Entity: ***Fish***
-Quantity involved: fish size population
-Start condition: fish has a normative size for fishing
-Effect: reduces the size of population
-Stop condition: prohibition period

4.2.2 Hunting

Hunting is deliberate action to hunt birds and mammals

-The agent: the hunter
-Entities: birds and mammals
-Start condition: the population size allows the extraction of a number of individuals
-Effects: changes in numerical population dynamics.
-Stop condition: reaching an ecological optimal territorial density of the tow populations.

4.3 Global Danube Delta Biosphere Reserve Causal model

There are seven main processes influencing each of aquatic biotic organism group within the DDBR aquatic ecosystems and humans living inside DDBR.

These processes are:

- water flow
- water eutrophication
- phytoplankton bloom
- bottom sediment resuspension
- water pollution
- fish growth
- human disease incidence.

In total, 12 processes are active in the DDBR aquatic environment which influence the quantities that represent the amount of each organism. Changes in these amounts propagate to other quantities, as effect of one organism group to another one.

The causal relations among the DDBR aquatic biotic groups are presented in Figure 4.

From these causal relations, the ones related *strictly to water pollution process* and its direct effect both on aquatic biotic components and on humans, are described below:

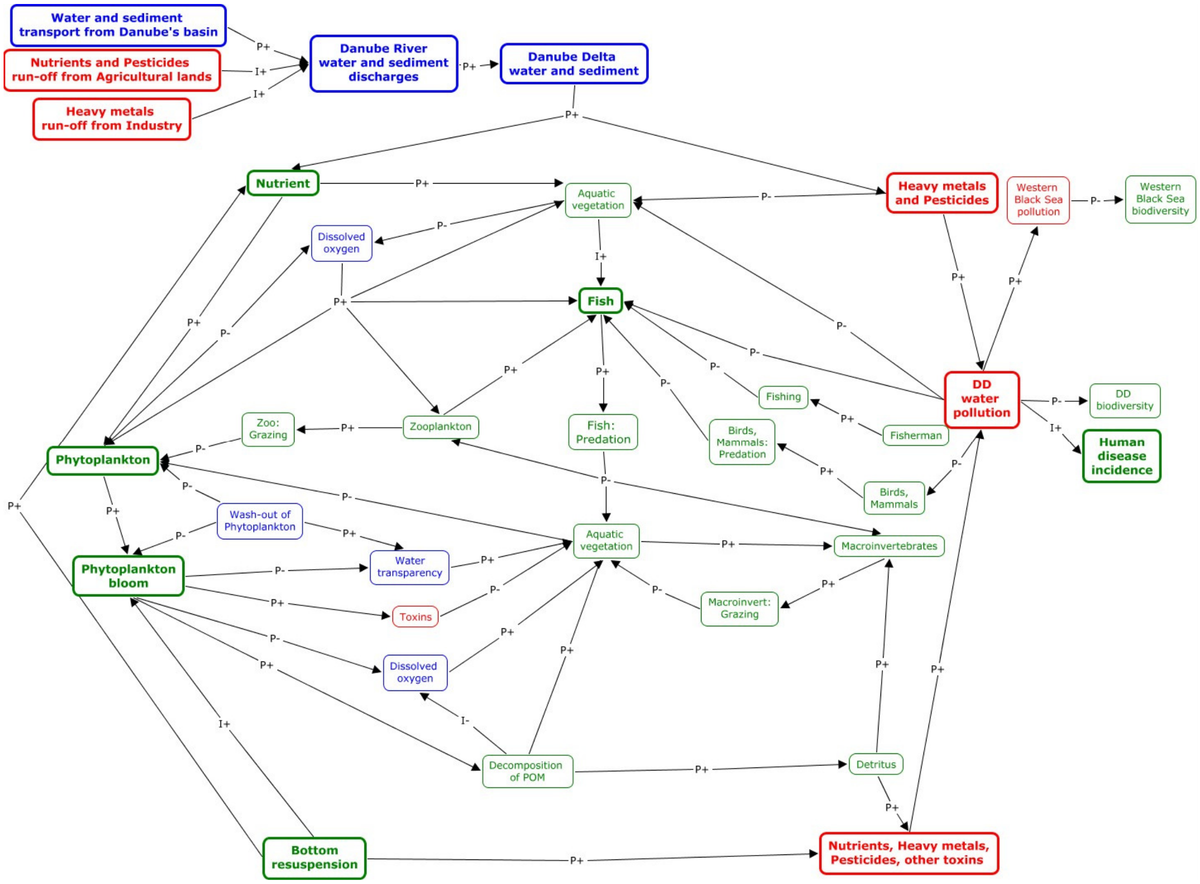

Figure 2. Global Causal model for Danube Delta Biosphere Reserve aquatic ecosystems water pollution.

(Note: The processes strictly related to water pollution process and its effect on Fish and Humans behaviour are represented in bold feature and their causal relations are described below).

- If there is an increase of water and sediment inflow from Danube's basin to Danube River, there will be an increase in river discharges; therefore there is a P+ relation between them.
- If there is an increase of ***Nutrients*** and ***Pesticides*** run-off from Agricultural lands, and ***Heavy metals*** run-off from Industry, into the Danube River, there will be an increase in these ***water pollution*** element concentration in the river water and sediment, too; therefore there is a positive influence I+ relation between them.
- If there is an increase of Danube River water and sediment inflow rate into the DDBR, there will be an increase of water and sediment amount inside the DDBR hydrographic network, too; therefore there is a positive influence I+ relation between them.
- If the DDBR amount of water and sediment increases, the ***nutrient*** concentration will increase; therefore there is a P+ relation between them.
- If the DDBR amount of water and sediment increases, the ***heavy metals and pesticides*** concentration in water will increase; therefore there is a P+ relation between them.
- If there is an increase in nutrient concentration, the phytoplankton biomass will increase too (triggering the phytoplankton bloom process); therefore there is a P+ relation between them.

- If the bottom sediment resuspension occurs, the *nutrients, heavy metals, pesticides and other toxins f*rom bottom sediment will be recycled in water column. So, the concentration of nutrients, heavy metals, pesticides and all other toxins will increase in water. This process will lead to increasing the *water pollution rate*.
- If the DDBR water pollution increases, the *human population living inside DDBR* will be negatively influenced, there will be recorded an *increase of disease incidence*; therefore there is a I- relation between them. If the humans both inside and outside DDBR eat fish in high amount, the *disease incidence can increase due to high heavy metals bioaccumulation in fish muscle tissue* occurs within last years.

4.4 Scenarios and behaviour graphs

Typical scenario and behaviour graph:

4.4.1 Danube Delta Biosphere Reserve water pollution current state

Scenario name: DDBR water pollution current state
Collection of entities (partial system structure) for this scenario: ***Water, Fish,*** and ***Human***.

- Quantities corresponding to selected entities (QS with **current state value in bold**):

Water*:*

- *Water pollution rate* (z**p**) = (zero, plus).
- *Nutrients* (zs**c**h) = (zero, small, **critical level**, high).
- *Heavy metals* (zs**c**h)

Human**:**

- *Number of inhabitants* (z**l**mh)= (zero, **low**, medium, high).
- *Consumption rate of fish* (z**p**)
- *Consumption rate of water* (z**p**)
- *Disease incidence* (z**p,** zsc**h**)
- *Employment rate* (z**p**)
- *Quality of life* (z**l**mh)

Fish*:*

- *Population size* (z**l**mh)
- *Fish species diversity* (z**l**mh)
- *Heavy metals in fish muscle tissue* (zs**c**h) = (zero, small, **critical level**, high).
- *Fish pollution rate* (z**p**)

Agents:

Industry:

- Heavy metal production (zs**c**h) = (zero, small, critical level, high)

Agriculture:

- Nutrients runoff (zs**c**h).

Behaviour graph of DDBR related to water pollution process Table 1.

State	Values and (in)Equalities	Description
1	<u>High degree of water pollution</u>. ***Water***: *Water pollution rate* (z**p**) *Nutrients* (zsc**h**). *Heavy metals* (zsc**h**). ***Human***: *Number of inhabitants* (z**l**mh) *Consumption rate of fish* (z**p**) *Consumption rate of water* (z**p**) *Disease incidence* (z**p**). *Employment* (z**p**). *Quality of life* (z**l**mh). ***Fish***: *Population size* (z**l**mh). *Fish species diversity* (z**l**mh). *Heavy metals in fish muscle tissue* (zsc**h**). *Fish pollution rate* (z**p**).	If there is a **Plus** DDBR *Water pollution rate*, this will lead to a **High** *Human*: *Disease incidence* for those people who either drink water they take it directly from DDBR canals, or eat *Fish* which to this water pollution rate will bioaccumulate a "**High**" concentration of *Heavy metals in fish muscle tissue*. This will induce a **Low** level for *Human*: *Quality of life. Fish population size* can reach a **low** level and so can happen with the *Fish species diversity,* both inducing a **low** level for *Human*: *Employment*. *Number of inhabitants* is at **low** level, too (it depends on all *Water, Human* and *Fish* quantity values). If this DDBR water quality bad state occurs it can trigger a high loss of DDBR biodiversity, leading to "critical" aquatic species size stability.
2	<u>"Critical level" of water pollution.</u> ***Water***: *Water pollution rate* (z**p**) *Nutrients* (zs**c**h). *Heavy metals* (zs**c**h). ***Human***: *Number of inhabitants* (zl**m**h) *Consumption rate of fish* (z**p**) *Consumption rate of water* (z**p**) *Disease incidence* (zs**c**h). *Employment* (zl**m**h). *Quality of life* (zl**m**h). ***Fish***: *Population size* (zl**m**h). *Fish species diversity* (zl**m**h). *Heavy metals in fish muscle tissue* (zs**c**h). *Fish pollution rate* (z**p**)	<u>**This condition is characteristic for the DDBR current state of water pollution.**</u> For a "critical level" of *Heavy metals in fish muscle tissue,* the *Human*: *Disease incidence* is at "critical level" if there is a "**Plus** " *Consumption rate of fish* is. *Human*: *Quality of life* is **medium**. *Fish population size* and *Fish specie Diversity* are **medium** value. This water pollution status is recorded within the last years as result of reduction the Nutrients concentration in Danube River water. In some DDBR lakes, nutrients are still in high concentration due to their accumulation in bottom sediment from where can be recycled. Among Heavy metals, the Cadmium and the Lead record high concentration, both in water and in fish muscle tissue. A loss of DDBR biodiversity still can occur.
3	<u>Small degree of water pollution</u>. ***Water***: *Water pollution rate* (z**p**) *Nutrients* (z**s**ch). *Heavy metals* (z**s**ch). ***Human***: *Number of inhabitants* (zm**h**) *Consumption rate of fish* (z**p**) *Consumption rate of water* (z**p**) *Disease incidence* (z**s**ch).	*Human*: **High** *Quality of life* can occur if there is **a "zero"** DDBR *Water pollution rate.* This leads to **Small** *Heavy metals in fish muscle tissue* and it results in *Human*: **Small** *Disease incidence*. *Human*: *Consumption rate of fish* is **Small**, too **High** *Employment can occur due to* **High** *Fish**:** Population size,* and *Fish species diversity.* High DDBR biodiversity can occur if agricultural lands and industry do not contribute than in a **small**

	Employment (zlm**h**). *Quality of life* (zlm**h**). ***Fish***: *Population size* (zlm**h**). *Fish species diversity* (zlm**h**). *Heavy metals in fish muscle tissue* (z**s**ch). *Fish pollution rate* (z**p**)	quantity with pollutants released in Danube River, and so will be in the DDBR aquatic ecosystems.

Note:
The quantity spaces used in QR model are: (zsch) = (zero, small, critical level, high).
"Critical level" value indicates the "critical" state for an associated quantity, similarly with "warning" situation.

4.5 Assumption concerning behaviour

Within the framework of the global behaviour specification, the following assumptions have been made:
1. Water salt concentration is low, with no changes induced in organism behaviour. Therefore it's ignored.
2. Silica, as one of the eutrophication components, is low in the DDBR aquatic ecosystems, and therefore ignored.
3. Pesticides, as one of the strongest water and biota component pollutants, along with Heavy metals and Nutrients, are low in the DDBR aquatic ecosystems, and therefore ignored.

5 Detailed system structure and behaviour

This section contains a detailed description of the **Danube Delta Biosphere Reserve aquatic ecosystem structure and behaviour** by specification of all the model ingredients using the Qualitative Reasoning (Garp3) vocabulary. This description is developed here in the framework of the following subsections:

- Structural details of the Danube Delta Biosphere reserve ecosystems
- Agents
- Assumptions
- Quantities and quantity spaces
- Detailed description of scenarios
- Detailed description of model fragments

5.1 Structural details of the Danube Delta Biosphere Reserve ecosystems

In order to specify and detail the Danube Delta aquatic and terrestrial ecosystems structure, the following ingredients are specified:

5.1.1 The global entity subtype hierarchy

- Entity:

Ecosystems:

I. Terrestrial ecosystem:
1. Human settlements
◊ Biotic component:
    - ***Human***
2. Others

II. Aquatic ecosystem:
◊ Abiotic component:

- Fluid
  - ***Water***
- Solid: Sediment
  - Mineral particles
  - Particulate organic matter (POM)
- Gas
  - Dissolved oxygen
  - Ammonia gas
  - H_2S
  - Carbon dioxide

◊ Biotic component

- Plants
  - Phytoplankton
  - Aquatic vegetation
- Animals
  - Herbivore and Carnivore: Zooplankton; Macroinvertebrates; ***Fish****;* Birds; Mammals
- Microbes (Decomposers)
  - Bacteria
  - Protozoa

The full structural model of the Danube Delta Biosphere Reserve, for the two types of ecosystems terrestrial and **aquatic,** is shown in Figure 5.

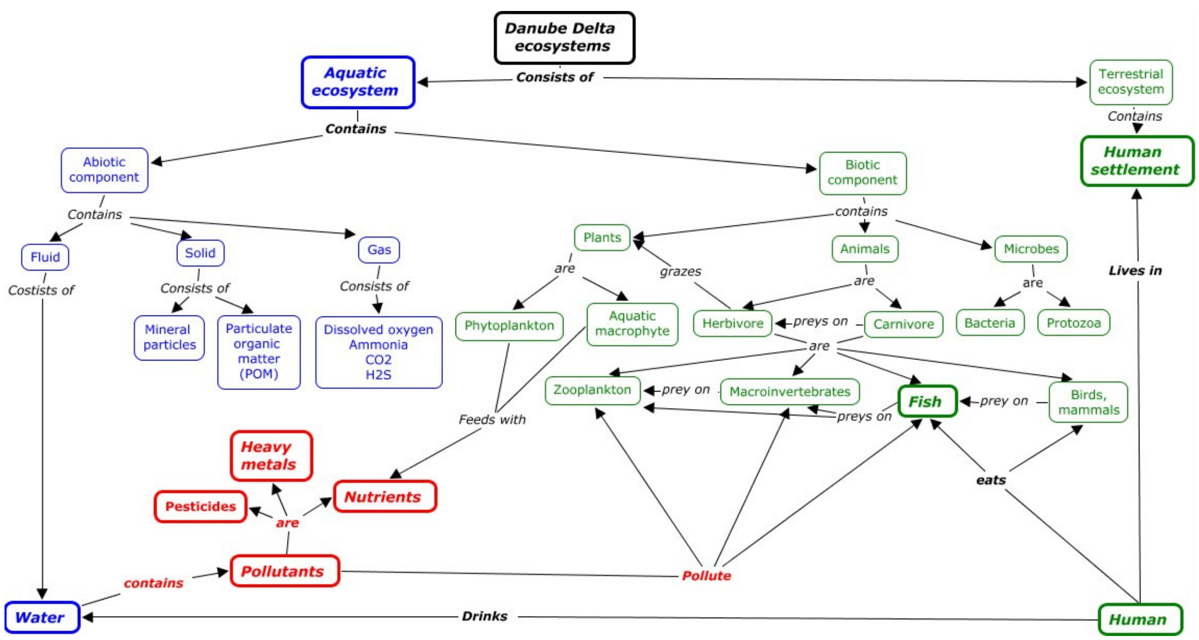

Figure 3. Structural model of the Danube Delta Biosphere Reserve aquatic ecosystems.

Note: The structural entity hierarchy related directly to water pollution is ***selected*** and represented in ***bold*** feature. This selected part is described below.

5.1.2 The entity subtype hierarchy for a selected part of DDBR structural model

The Qualitative Reasoning Model will be constructed for the Danube Delta Biosphere Reserve case study focussing on **water pollution impacts on humans** living in or outside the DDBR. Thus, both "Scenarios" and "Model fragments" (the two components of QRM) will be constructed to describe the ways the humans are negatively impacted by the DDBR water pollution.

With this reasoning, from the DDBR global entity subtype hierarchy described above (subsections 5.1.1 and Figure 5) a "focussed" entity subtype hierarchy is **selected** (in ***bold*** feature in Figure 5) and described below:

- ***Selected entities:***

Ecosystems:
Terrestrial ecosystem:
◊ Biotic component:
  o ***Human***
Aquatic ecosystem:
◊ Abiotic component:
  • Fluid
    ▪ ***Water***
◊ Biotic component
  o Animals
    ¤ ***Fish***

5.1.3 Configurations of selected entity subtype hierarchy

The configurations within the selected entity subtype hierarchy in Danube Delta ecosystems are:
Aquatic ecosystem ***contains*** *Water*.
Water ***contains*** Pollutant
Pollutant ***pollutes*** water and any aquatic organism, even ***humans*** drinking polluted water or eating fish from polluted water
Fish ***lives in*** *Water*
Human ***lives in*** Human settlements.
Human ***eats*** *Fish*.
Human ***drinks*** *Water*.

5.2 Agents

External influences on Danube Delta ecosystems are mainly represented by two types of agents:

1. Agriculture lands which produce run-off of Nutrients and Pesticides.
2. Industry produces run-off of Heavy metals and Nutrients.

1. **Agriculture** releases nutrients (**Nitrogen, Phosphorus and Silica**) to the environment under different forms: emissions of ammonia to air and leaching and runoff of nitrogen and phosphorus that reach the river. Nitrogen and phosphorus are naturally present in streams, through transport of terrestrial organic matter, leaching and runoff of terrestrial inorganic nutrients and decomposition of in-stream biological material. **Pesticides** are chemicals designed to kill or control insects, weeds, diseases and other unwanted organisms. Over 800 active ingredients are sold worldwide in tens of thousands of formulations. Products are widely used in agriculture, public health, domestic and urban areas. Many pesticides have

been found to be harmful to human and animal health or to the environment, and this briefing has proved to be a popular resource for identifying these. Lately, within the Danube Delta Biosphere Reserve pesticides recorded a decrease tendency.

2. **Industry**: All anthropogenic activities that release organic and inorganic matter (**nutrients, heavy metals**) in the environment may cause in-stream enrichment in these elements. They can be grouped into four categories: human life, industry, agriculture and transport/power plants.

5.3 Assumptions

- Silica, as one of the water eutrophication components, is low and therefore ignored.
- Pesticides, as strong pollutant as Nutrients and Heavy metals, have lately recorded low and stable values. So, they are ignored.
- Water salt concentration is low and generally stable, with no changes induced in aquatic organism behaviour. It's ignored.

5.4 Quantities and quantity spaces[5]

5.4.1 Quantities

Quantities are changeable features of the Danube Delta Biosphere Reserve (selected) entities and are specified by means of the following quantities, corresponding to the three entities: *Water, Humans, Fish.*

Quantities:

1. *Water:*
   - *Water pollution rate*
   - *Nutrients concentration*
   - *Heavy metals concentration*
2. *Human:*
   - *Number of inhabitants*
   - *Consumption rate of fish*
   - *Consumption rate of water*
   - *Disease incidence*
   - *Employment*
   - *Quality of life*
3. *Fish:*
   - *Population size*
   - *Fish species diversity*
   - *Heavy metals in fish muscle tissue*
   - *Fish pollution rate*

*5.4.1.1 **Quantities** associated to **Water***

1. *Nutrients* are mainly represented by Nitrogen and Phosphorus compounds. First of all, they are the only food resource for Plants (Phytoplankton, Phytobenthos, and Aquatic macrophytes). But, when they are in high concentration in water, the water eutrophication process occurs. That means there is an excess of Nutrients (mainly Nitrogen and Phosphorous compounds) in water. So, if there is an excess of Nutrients (as food), this

[5] It refers to only the selected entity subtype hierarchy.

excess triggers, first of all, an excess of Phytoplankton growth, named as "Phytoplankton bloom".

2. *Heavy metals* are represented by any metallic chemical element that has a relatively high density and is toxic or poisonous at certain concentrations. These chemicals produce the water pollution. The main heavy metals met in DDBR waters are Cadmium, Mercury, Lead, Nickel, Iron, and Zinc. They cannot be degraded or destroyed. As trace elements, some heavy metals (e.g. cooper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metals are dangerous because they tend to **bioaccumulate**. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment.
3. *Water pollution* within the DDBR aquatic ecosystems takes place due to mainly an increase of Nutrients, and Heavy metals concentration in water. This occurs either as inflow of Danube River water and sediment loaded with high content of these pollutants, collected and transported by river from its hydrographic basin (especially in spring flood periods), or as result of DDBR in-stream physical, physical-chemical and biological processes (such as: high water evaporation, low flow, high number of Phytoplankton blooms a year, organic matter decomposition, bottom sediment resuspension, etc).

*5.4.1.2 **Quantities** associated to **Human***

1. *Number of inhabitants*: the population of the Danube Delta fluctuated between 15,000 inhabitants in 2000 and 21,000 in the 1970s. During last decades, the number of inhabitants decreased due to natural negative birth rate, ageing people, or migration to the other regions with better life conditions. The *Number of inhabitants* increase or decrease depend directly on *Employment* rate increase or decrease within DDBR and on *Quality of life* the DDBR environment can assure.
2. *Consumption rate* (of fish by humans). For most DDBR human population (and not only), the main food source is the fish.
3. *Employment* rate in DDBR is relatively low, mainly due to the decrease of jobs, especially as fisherman. Lately, as result of decrease of *Fish population size*, *Employment* decreased too.
4. *Disease incidence* (of some Humans who *drink* water they it take directly from DDBR canals and eating fish) is dependent on: *Water pollution* degree, *Heavy metals in fish muscle*, and *Consumption rate* (of fish by humans). The problems in health domain for DDBR are complex. Disease causes are cardio-vascular illness, tumours, breath diseases and digestive diseases. The illness rate is 3 times higher than the country average in 2000. Human health is most affected by the water pollution from last decades, especially with heavy metals. Action required: Epidemiological studies for all trophic chain.
5. *Quality of life* for Humans living in DDBR is determined by two factors: the *Employment* rate and the *Disease incidence.* Generally, for many of Humans, the *Quality of life* is relatively low, due to low *Employment* rate, habitat conditions and lack of medical assistance too. As result of poor health shorter live spans is expected. Poor diet and water borne disease are all contributing factors for a low *Quality of life* for some of humans.

*5.4.1.3 **Quantities** associated to **Fish***

1. *Fish population size* has registered a significant decrease in the last decade. Two main causes can be cited: increase of *Water pollution* and over fishing. Due to their complex requirement, fish are sensitive indicators for habitat quality at various spatial scales. As consumers and/or

top predators, they subsume the trophic conditions across the food chain. They also provide detailed information on the respective trophic level. There is a long tradition to link health of the fish population with water quality.

2. *Fish species diversity* is very important to be high, as for any other aquatic species, because it assures a biological equilibrium in the framework of the functional feeding groups. Degradation of habitat by increased water pollution in Danube River and many water bodies in DDBR, is thought to have caused the decline *Fish population species diversity* (Staras & Navodaru, 1995). The relationship between concentration level of phosphorus in water and fish diversity is clearly demonstrated (Ligtvoet & Grimm, 1992), including changes to the trophic web, water transparency and aquatic submerged vegetation. The fish species of high tolerance to low dissolved oxygen content of the marine littoral fisheries have also declined and small species have replaced the larger and more valuable species. Inorganic nutrients do not have a direct impact on fish, except for the worst cases of eutrophication when toxic concentrations of ammonia and very low levels of dissolved oxygen occur. These two situations can lead to the death of sensitive species, affecting the species diversity and the age structure. After the Law of Concession the fishing activity entered into force (in 2000), the over fishing (including the poaching) almost exploded within DDBR. It leads to a significant decrease of both *Fish population size* and *Fish species diversity*. The sensitive species are sometimes in decline. Generally, the species with high economic value are more sensitive to high water pollution degree than species with low economic value.
3. *Heavy metals in fish muscle tissue.* The fish organs - in particular the muscle tissue - show a very wide spread of heavy metals concentration. The presence of higher concentrations of several metals (lead, cadmium) in channels and lakes of Danube Delta Biosphere Reserve leads to their absorption in fish muscle tissue to an amount several times higher than the admitted limits for human consumption. Humans *Disease incidence can occuts*, due to the fact the heavy metals from fish are transferred and bioaccumulated in the human organism.

5.4.2 Quantity spaces

Quantity spaces attached to their correspondent quantities are presented in Table 2.

Entity	Quantity	Quantity space
Water	*1. Water pollution rate*	{zp}
	2. Nutrients concentration	{zsch}
	3. Heavy metals concentration	{zsch}
Humans	*1. Number of inhabitants*	{zlmh}
	2. Consumption rate (of fish/water by people)	{zp}
	3. Disease incidence	{zsch}
	4. Employment rate	{zlmh}
	5. Quality of life	{zlmh}
Fish	*1. Population size*	{zlmh}
	2. Fish species diversity	{zlmh}
	3. Heavy metals concentration in fish muscle tissue. *4. Fish pollution rate*	{zsch} {zp}

{zp} = {zero, plus}
{zsch} = {zero, small, critical level, high}
{zlmh} = {zero, low, medium, high}

5.5 Detailed description of scenarios

The scenarios present initial situations and describe what will happen with some quantities which are influenced by other changeable quantities, and what is the final situation.

There are three main types of Scenarios to describe the ways the Danube Delta Biosphere Reserve aquatic ecosystem *Water pollution rate* propagates and induces directly changes on *Fish population* behaviour and both directly and indirectly on *Human* behaviour.
These types of Scenarios are presented here:

I. The *Water pollution rate* direct impacts on *Fish* behaviour and *Human* health. This type of scenarios relates both to the configuration *Fish* ***lives in*** water, and *Human* ***drinks*** water (they take it directly from the DDBR canals/lakes). These scenarios address the following quantities:
   - ¤ ***Water***: *Water pollution rate*
   - ¤ ***Fish***: *Fish Population size; Fish species diversity; Heavy metals in fish muscle tissue.*
   - ¤ ***Human***: *Disease incidence*.

II. The *Water pollution rate* indirect impact on *Humans* health. This type of scenarios relates to the configuration *Human* **eats** *Fish.* The scenarios address the following quantities:
   - ¤ ***Water***: *Water pollution rate*
   - ¤ ***Fish***: *Heavy metals in fish muscle tissue*.
   - ¤ ***Human***: *Consumption rate* (of fish by humans); *Disease incidence; Quality of life.*

III. The *Water pollution rate* indirect impact on *Human* social behaviour. This type of scenarios relates to the configuration *Human* ***fishes*** *Fish*. The scenarios address the following quantities:
   - ¤ ***Water***: *Water pollution rate*
   - ¤ ***Fish***: *Population size*; *Fish species diversity*.
   - ¤ ***Human***: *Employment, Quality of life, Number of inhabitants*.

These three types of Scenarios are detailed described in the framework of 6 Scenarios in next subsections.

5.5.1 Scenario 1

Name: **Plus** *Water pollution rate* and assume **Low** level of *Fish population size* and *Fish species diversity*.

- Assumption: The value {zero} for quantities *Water pollution rate, Nutrients concentration,* and *Heavy metals concentration* is never reached.
- Agents: Agriculture lands and Industry from where run-offs of Heavy metals and Nutrients (as main pollutants) reach the Danube River.
- Instances of Entities: *Water, Fish, Human.*
- Attributes (and specific values)
- Configurations:
   - ¤ *Fish* ***lives in*** *Water*
   - ¤ ***Human drinks*** *Water* (directly from DDBR canals/lakes)
   - ¤ *Human (not only from DDBR)* ***eats*** *Fish*.
   - ¤ *Human* ***fishes*** *Fish*.
- Quantities and Initial values[6] are:
   - o *Water pollution rate*: **Plus**. This value of *Water pollution rate,* can occur when one of the pollutants (Heavy metals, Pesticides, Nutrients) concentrations in water exceeds the maximum limit (tolerable for aquatic living organisms). Above this limit, the sensitive species can be eliminated.

[6] Value refers to both the magnitude and derivative (the direction of change) of a quantity.

- *Fish population size*: **Low**. This quantity value indicates that the fish species is threatened due to High *Water pollution* degree, warning that special measures of conservation and protection to be immediately applied, in order not to create a collapse of this species population.
- *Fish species diversity*: **Low**. This quantity value can occur due to a High *Water pollution* degree. Those species more sensitive to high *Water pollution* can be eliminated. If any species (not only the fish) diversity reaches the value **Low**, it can induce a biological disequilibrium in the framework of the functional feeding groups relationships, and can produce the elimination of some higher trophic level species, which have as feed resource the eliminated species. For example, predatory fish species prey on the herbivore fish species. If the later are (at least partially) eliminated, the former ones are threatened to be much reduced, and the fish population stability is threatened too.

i. The above quantity value of *Water pollution rate* induces the following quantity values:
   - ***Fish***: *Heavy metals bioaccumulation in fish muscle tissue*: **High**.
   - ***Human***: *Disease incidence*: **High**. This situation can occur for about 75 % of the DDBR *Humans* drinking water they take it directly from DDBR canals/lakes, due to the lake of the Water Purifying Plants in some of DDBR human settlements.

ii. The above quantity value of *Fish population size* and *Fish species diversity* induce the following quantity values:
   - ***Human***: *Employment rate*: **Low**.
   - ***Human***: *Quality of life*: **Low**.
   - ***Human***: *Number of inhabitants*: **Low**.

The derivative for *Water pollution rate* is "Decrease", and "Stable" for *Fish population size,* and *Fish species diversity.*

5.5.2 Scenario 2

Name: **Plus** *Water pollution rate* and assume **high** *Fish population size* and **high** *Fish species diversity.*

- Assumptions: The value {zero} for quantities *Water pollution rate, Nutrients concentration,* and *Heavy metals concentration* is never reached.
- Agents: Industry and Agriculture lands which release Heavy metals and Nutrients, as main pollutants, in Danube River.
- Instances of Entities: *Water, Fish, Human.*
- Attributes (and specific values)
- Configurations:
   - *Fish* ***lives in*** *Water*
   - ***Human drinks*** *Water*
   - *Human (not only from DDBR)* ***eats*** *Fish.*
   - *Human* ***fishes*** *Fish.*
- Quantities and initial values are:
   - *Water pollution rate*: **Plus**
   - Fish population size: **High**
   - Fish species diversity: **High**.

i. The above quantity value of *Water pollution* induces the following quantity values:
   - ***Fish***: *Heavy metals in fish muscle tissue*: **Small**
   - ***Human***: *Disease incidence*: **Small**

ii. The above quantity value of *Fish population size* and *Fish species diversity* induce the following quantity values:
   - ***Human***: *Employment*: **High**

- ¤ ***Human:*** *Quality of life*: **High**
- ¤ ***Human***: *Number of inhabitants*: **High**.

The derivative for *Water pollution* is “Decrease”, and “Stable” for *Fish population size*, and for *Fish species diversity*.

5.5.3 Scenario 3

Name: **Plus** *Water pollution rate* and assume **medium** *Fish population size* and **medium** *Fish species diversity.*

- Assumptions: The value {zero} for quantities *Water pollution rate, Nutrients concentration,* and *Heavy metals concentration* is never reached.
- Agents: Industry and Agriculture lands which release Heavy metals and Nutrients, as main pollutants, in Danube River.
- Instances of Entities: *Water, Fish, Human.*
- Attributes (and specific values)
- Configurations:
  - ¤ *Fish* ***lives in*** *Water*
  - ¤ ***Human drinks*** *Water*
  - ¤ *Human (not only from DDBR)* ***eats*** *Fish.*
  - ¤ *Human* ***fishes*** *Fish.*
- Quantities and Initial values are:
  - o *Water pollution*: **Plus**
  - o *Fish population size*: **Medium**.
  - o *Fish species diversity*: **Medium**.

i. The above quantity value of *Water pollution* induces the following quantity values:
  - ¤ ***Fish***: *Heavy metals in fish muscle tissue*: **Critical level**.
  - ¤ ***Human:*** *Disease incidence*: **Critical level**.

ii. The above quantity value of *Fish population size* and *Fish species diversity* induce the following quantity values:
  - ¤ ***Human*: *Employment:*** **Medium**.
  - ¤ ***Human*:** *Quality of life*: **Low**.
  - ¤ ***Human***: *Number of inhabitants*: **Low**.

The derivative for *Water pollution rate* is “Decrease”, and “Stable” for *Fish population size*, and for *Fish species diversity*.

5.5.4 Scenario 4

Name: **Plus** *consumption rate* of fish by humans and assume **high** *Heavy metal in fish muscle tissue*

- Assumptions:
  - ◊ The value {zero} for quantities *Water pollution rate, Nutrients concentration,* and *Heavy metals concentration* is never reached.
  - ◊ *Consumption rate* > Zero.
- Agents: Industry and Agriculture lands which release Heavy metals and Nutrients, as main pollutants, in Danube River
- Instances of Entities: *Water, Fish, Humans.*
- Attributes (and specific values).
- Configurations:
  - ¤ *Fish* ***lives in*** *Water*
  - ¤ *Human* ***drinks*** *Water*
  - ¤ *Human* ***eats*** *Fish.*

- ¤ *Human **fishes** Fish.*
- Quantities and Initial values are:
  - o *Heavy metal in fish muscle tissue*: **High**
  - o *Consumption rate* (of fish): **Plus**

i. The above quantity values induce the following quantity values:
- ¤ ***Human*: *Disease incidence*: **High**
- ¤ ***Human*: *Quality of life*: **Low**.
- ¤ ***Human***: *Number of inhabitants*: **Low**.

The derivative for *Consumption rate* is "Decrease", and also "Decrease" for *Heavy metal in fish muscle tissue.*

5.5.5 Scenario 5

Name: **Plus** *consumption rate* of fish by humans and assume **critical level** *Heavy metal in fish muscle tissue*

- Assumptions:
  - ◊ *Consumption rate* > Zero.
- Agents: Industry and Agriculture lands which release Heavy metals and Nutrients, as main pollutants, in Danube River
- Instances of Entities: *Water, Fish, Human.*
- Attributes (and specific values).
- Configurations:
  - ¤ *Fish **lives in** Water*
  - ¤ *Human **eats** Fish.*
  - ¤ *Human **fishes** Fish.*
- Quantities and Initial values are:
  - o *Heavy metal in fish muscle tissue*: **Critical level**
  - o *Consumption rate* (of fish): **Critical level**

i. The above quantity values induce the following quantity values:
- ¤ ***Human*: *Disease incidence*: **Critical level**
- ¤ ***Human*: *Quality of life*: **Medium**
- ¤ ***Human***: *Number of inhabitants*: **Medium**.

The derivative for *Consumption rate* is "Decrease", and also "Decrease" for *Heavy metal in fish muscle tissue.*

5.5.6 Scenario 6

Name: **Plus** *consumption rate* of fish by humans and assume **small** *Heavy metal in fish muscle tissue*.

- Assumptions: *Consumption rate* > Zero.
- Agents: Industry and Agriculture lands which release Heavy metals and Nutrients, as main pollutants, in Danube River
- Instances of Entities: *Water, Fish, Human.*
- Attributes (and specific values).
- Configurations:
  - ¤ *Fish **lives in** Water*
  - ¤ *Human **eats** Fish.*
  - ¤ *Human **fishes** Fish.*
- Quantities and Initial values are:
  - o *Heavy metal in fish muscle tissue*: **Small**
  - o *Consumption rate* (of fish): **Small**

i. The above quantity values induce the following quantity values:
   - ***Human*****:** *Disease incidence*: **Small**
   - ***Human*****:** *Quality of life*: **High**
   - ***Human***: *Number of inhabitants*: **High**.

The derivative for *Consumption rate* is "Decrease", and "Decrease" for *Heavy metal in fish muscle tissue.*

5.6 Detailed description of model fragments

The model fragments constructed for the Danube Delta Biosphere Reserve ecosystem are static model fragments and process model fragments. Because the Delta Biosphere Reserve ecosystem model is quite complex in nature, it involves many model fragments. A few of the most typical model fragments are described here.
The following configurations are met among entities:
- *Fish* ***lives in*** *Water;*
- *Human* ***eats*** *Fish*
- *Human* ***drinks*** *Water*
- *Human* ***fishes*** *Fish.*

5.6.1 Static model fragments

The static model fragments will describe the *Water,* the *Fish* and *the Human*.
As consequences the quantities for *Humans*: *Number of inhabitants, Fish population*, and *Water pollution rate* are added.

5.6.1.1 Water

CONDITIONS:
Entity: *Water*
CONSEQUENCE:
Heavy metal concentration
Nutrient concentration
Water pollution rate
For this model fragment, these quantities associated to *Water* (*Heavy metal concentration, Nutrient concentration, and Water pollution rate*) have been considered to indicate the main variables participating in the DDBR water pollution process.

If there is an increase of *Heavy metal concentration* in water, the *Water pollution rate* will increase too. Therefore there is a positive proportionality (P+) relation between these two quantities. The same causal relation will occur if there is an increase of *Nutrient concentration* in water: [P+ (*Water pollution rate, Nutrient concentration*)].

5.6.1.2 DDBR Human population

Human population living inside the DDBR is about 12,000 inhabitants.
CONDITIONS:
Entity: *Human*
CONSEQUENCE:
Number of inhabitants > 0

This model fragment indicates that Human population exists within DDBR.

5.6.1.3 DDBR Fish population

Existing population: Fish population.
CONDITIONS:
Entity: *Fish*
CONSEQUENCE:
Fish population size
Heavy metals bioaccumulated in fish muscle tissue
This model fragment indicates that *Fish population* exists within the DDBR.

If there is an increase of *Heavy metals bioaccumulated in fish muscle tissue*, the *Fish Population size will* decrease. Therefore there is a negative proportionality relation (P-) between these two quantities. This causal relation is written using the qualitative proportionality: [P-(*Fish population size, Heavy metals bioaccumulated in fish muscle tissue*)]

5.6.2 Basic process model fragments

There are model fragments for the basic processes such as *Water pollution* process, *Consumption rate of fish by people*, *Humans population diseases incidence*, *Humans Employment*, presented here.

5.6.2.1 Model fragment "Water pollution process"

The DDBR *Water pollution* process occurs both due to the upstream inflow of pollutants, especially *Heavy metals* and *Nutrients*, at high concentration in Danube's River water (as run-off from the river hydrographic basin Agricultural lands and Industry), and as result of DDBR in-stream physical, physical-chemical and biological processes (such as: high water evaporation, low flow, high number of Phytoplankton blooms a year, organic matter decomposition, bottom sediment resuspension, etc).

CONDITIONS:
Entity: *Water, Human, Fish.*
CONSEQUENCES:
Quantities:

- ***Water***: *Water pollution rate; Heavy metals concentration; Nutrients concentration*
- ***Human***: *Disease incidence*
- ***Fish***: *Fish population size; Fish Species diversity**;** Heavy metals in fish muscle tissue.*

Add dependencies:
Water pollution rate= plus
Water: *Heavy metals concentration* > zero
Water: *Nutrient concentration* > zero
Human: *Disease incidence* > zero
Fish: *Fish population size*> zero
Fish: *Fish Species diversity*> zero
Fish: *Heavy metals in fish muscle tissue*> zero.

If there is positive *Water pollution rate*, the *Fish Population size* and *Fish species diversity* will be negatively influenced (I-). This relation shows the sensitivity of the fish to the *Water pollution.*
If there is positive *Water pollution* rate, the *Heavy metals in fish muscle tissue* will be positively influenced (I+).
If there is positive *Water pollution* rate, the *Human*: *Disease incidence* will be positively influenced (I+).

5.6.2.2 Consumption rate of fish by people

CONDITIONS:
Entities: *Human*; *Water*, *Fish*
CONSEQUENCES:
Configuration:

- ¤ *Fish* ***lives in*** *Water*
- ¤ *Human* ***eats*** *Fish*

Quantities:

- ***Water:*** *Water pollution rate; Heavy metals concentration;*
- ***Human:*** *Consumption rate* (of fish by people); *Disease incidence*
- ***Fish***: *Heavy metals in fish muscle tissue*.

Add dependencies:
Consumption rate of fish by *Humans*= plus
Water pollution = plus
Heavy metals in fish muscle tissue> zero

If there is a positive *Consumption rate* (of fish by Humans), and assume there is an increase of *Heavy metals in fish muscle tissue,* this will result in a positive influence I+ on the *Human*: *Disease incidence.*
If there is a positive rate of *Disease incidence*, the *Quality of life* will be negatively influenced (I-).

5.6.2.3 Human population diseases incidence

This process model fragments describes the ***Human***: *Diseases incidence* in DDBR *Water pollution* conditions for those people drinking water they take it directly from DDBR canals/lakes. There are about 75% from DDBR Humans in this situation.

CONDITIONS:
Entity: *Human*; *Water*.
CONSEQUENCES:
Configurations: *Human* ***drinks*** *Water*
Quantities:

- ***Water***: *Water pollution rate; Heavy metals concentration*
- ***Humans***: *Disease incidence; Quality of life*

Add dependencies:
Water pollution rate = plus
Water pollution rate has a positive influence (I+) on DDBR *Human*: *Disease incidence*.
Disease incidence has a negative influence (I-) on *Quality of life*.

5.6.2.4 Human Employment

This process model fragments describes the ***Human***: *Employment* process in DDBR *Water pollution* conditions and *Fish: Population size*. For many of DDBR Humans their job depends on ***Fish***: *Population size*, as traditionally they are fishermen.

CONDITIONS:
Entity: *Humans*; *Water, Fish.*
CONSEQUENCES:
Configurations: *Human* ***fishes*** *Fish; Fish* ***lives in*** *Water.*
Quantities:

- ***Water***: *Water pollution rate; Heavy metals concentration; Nutrients concentration.*
- ***Human***: *Employment rate; Quality of life.*
- ***Fish***: *Fish population size.*

Add dependencies:
Employment rate > zero
Water pollution rate =plus
Fish Population size> zero

If there is an increase of *Fish Population size,* the *Human*: *Employment rate* will increase (P+) too.
If there is an increase of *Employment rate,* the *Quality of life* will be positively influenced (I+).

Conclusions

This deliverable contains a **detailed textual description** of the Danube Delta Biosphere Reserve case study relevant components and structural relationships among them. It emphasizes the main causes and their effects that hamper the Sustainable Development process from this area. This description refers both to basic physical, physical-chemical and biological processes inside the DDBR aquatic ecosystems and to social-economic aspects of humans living within the DDBR territory.

The Danube Delta Biosphere Reserve Sustainable Development Strategy is mainly based on biodiversity conservation and protection measures. To construct this strategy, there is necessary to know how water pollution (relatively high in the study area, and main cause of "biological disequilibrium") participates in the DDBR biodiversity decline recorded here. Thus, this deliverable describes the main "external causes: agents" and in-stream physical, physical-chemical and biological processes which are involved in water pollution process within the DDBR aquatic ecosystems and the way its negative effect propagates from water to aquatic biota (plants, zooplankton, macoinvertebrates, **fish**, birds) and ultimately to **human**.

The deliverable's content includes the entire DDBR system structure and behaviour description. From this global presentation of physical, physical-chemical and biological processes inside the aquatic ecosystems of DDBR, the ones involving only water pollution process and its negative effects on aquatic biota behaviour till the human health and quality of life, have been selected, and thus much more developed are the sections "Detailed description of scenarios" and "Detailed description of model fragments". This way, the DDBR Qualitative Reasoning Model can be clearly and easy understood.

The future "Qualitative Reasoning Model of the Danube Delta Biosphere Reserve" will be focussed to describe this system components behaviour under different degrees of aquatic ecosystem ***water pollution*** occurred here and the aquatic biota (especially ***fish***) feedback and the way the water pollution affects ***human (health, quality of life)*** depending on water and fish as their life resources.

This QR model can be easily extended both "upstream" including "Agent" scenarios and model fragments (considering the most important external influences on DDBR water quality: Agriculture and Industry) and "downstream", including the propagation of DDBR water pollution effects on Western Black Sea coastal water biodiversity.

In order to prepare the "Implementation" phase of "Qualitative Reasoning Model of Danube Delta Biosphere Reserve", the detailed description of typical scenarios and detailed description of model fragments **selected** are presented in this deliverable. The scenarios show the *Fish* and *Human* quantity values changes as result of changes of the *Water pollution rate* quantity value. Table 1: "Behaviour graph for DDBR water pollution" also shows how the Quantity values for Quantities associated to *Human*: ***Disease incidence; Employment rate,*** and ***Quality of life,*** improve step by step, from "Plus" *Water pollution rate* condition, to "High" *Quality of life* under "Zero" *Water pollution rate* condition.

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