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Assessing catchment-coast interactions for the Bay of Gdansk

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Abstract

While eutrophication creates impacts on coastal ecosystems and can result in negative impacts on coastal ecosystem services, its source is often located far away from the coast, related to nutrient emissions from river catchments. Within the EU funded EUROCAT project a chain of tools and models were applied to assess these catchment-coast interactions. Aim of the project is to support Integrated River Basin Management (IRBM), as targeted in the Water Framework Directive (WFD), in order to mitigate possible externalities induced in the coastal zone by socio-economic development in the catchment. The DPSIR-approach of the European Environment Agency was selected as the analytical tool to handle this complex man-ecosystem interactions. Scenarios represent possible futures in which environmental risk perception, societal interpretation of environmental risk and (coastal) vulnerability will influence political targets, such as the WFD implementation. Some society drivers and related policies are qualitatively assessed under each scenario and the resulting ecological impact on ecosystem integrity is quantified by applying ecosystem models. The Vistula catchment is one of several case studies within EUROCAT. The presentation will outline the assessment framework of EUROCAT focussing on the link between scenarios, DPSIR-indicators and potential impacts. Modelling ecosystem changes for the Bay of Gdansk using the eco-hydronamic model ProDeMo and related to different scenarios for development within the Vistula catchment will then be presented as a Baltic Sea example to illustrate the approach.

1 Introduction

The coastal zone is under heavy pressure from land-based activities located in the catchment of rivers. Traditionally, both scientific research and the governance framework have treated catchments and coasts as separate entities. However, it is increasingly recognised that they should in fact be treated as an integrated whole, encompassing both environmental and socioeconomic and political systems.

The EUROCAT project was established with an integrated perspective and analytical framework in mind. Across seven regional case studies, local teams of natural and social scientists used a common interdisciplinary strategy to:

- Identify the impacts on the coast
- Interface biophysical catchment and coastal models with socio-economic models
- Develop regional environmental change scenarios (2001-2020)
- Link scenarios with the modelling toolbox to evaluate plausible futures
- Evaluate research outcomes with regional boards consisting of stakeholders and policy makers.

Aim of EUROCAT is to promote and assist Integrated River Basin Management (IRBM), as targeted in the Water Framework Directive 2000/60/EC (WFD), in order to prevent and mitigate possible externalities induced in the coastal zone by socio-economic development in the catchment. Implementation of the WFD can be expected to form a major issue in future debates on local as well as regional level which makes the EUROCAT approach relevant for future discussions concerning sustainable regional development.

In EUROCAT initially five case studies were performed, focussing on the following river catchments and coastal areas:

1. Rhine-Elbe catchment and North Sea (RebCAT);
2. Humber catchment and Humber estuary (HumCAT);
3. Vistula catchment and Bay of Gdansk (VisCAT);
4. Po catchment and North Adriatic Sea (PoCAT);
5. Axios catchment and Bay of Thessaloniki (AxCAT);

In 2002/2003 two additional case studies were added:

6. Idrija catchment and North Adriatic Sea (IdriCAT);
7. Provadijska catchment and Black Sea (ProvaCAT);

The seven systems cover all coastal types (with the exception of fjords) in Europe and different socio-economic settings. The rivers Vistula, Rhine, Elbe Idrija and Axios are transboundary rivers. Eutrophication and in one case pollution (metals) were identified as major issues for the coastal zone.

Figure 1: Case study areas in EUROCAT.

The Vistula River Catchment and the Baltic Sea Coastal Zone Case Study (VisCAT) was undertaken as a part of the EUROCAT project. The Vistula river carries polluted waters from its catchment (over 100 000 square kilometres area) to the Gulf of Gdansk. These riverine waters, rich with nitrogen and phosphorus compounds, have an effect on the coastal waters, particularly on the Gulf of Gdansk. A research of response of marine ecosystem to inflowing contaminates has been undertaken within VisCAT using mathematical modelling.

The ecohydrodynamic model ProDeMo has been applied for investigation of biogeochemical processes at the water environment of the Gulf of Gdansk. Detailed examinations were conducted for period 1994 – 2002. However, forecasts for the gulf ecosystem behavior were evaluated according to three scenarios. These assumed that the riverine loads of nitrogen and phosphorous are reduced according to expected policy targets related to the three scenarios (Kowalewski et al. 2003).

2 The VisCAT case study area

2.1 Vistula Basin

The Vistula Basin covers 54% of Poland and is principally located in this country. It is essentially an agricultural catchment (63% of land use) with an important proportion of forested area located on fluvio-glacial soils less apt to agriculture. The major features of human pressures on the basin are the following (figure 2, Meybeck at al. 2004):

- The Silesia mining district is located in the headwaters of the catchment upstream of the city of Krakow. Until now this region is responsible for major contamination sources (metals) and for marked salinisation of the river.
- Many major cities of Poland are located on the main branch of the river since their origins as Krakow, Warszawa, Woklawek, Torun, Bydgoszcz. The cities of Gdansk and Elblag are located at the edge of the river delta, in the adjacent coastal zone.
- Some of the greatest reservoirs of Poland are located on the main river (Goczalkowichie and Woklawek Reservoirs) or near confluences with major tributaries (Bug R., Debe or Zegrzynskie Reservoir). These reservoirs are extended (30 to 70 km2) but are characterized by low fall height. Their retention capacity of particulates is therefore limited. For the Woklawek reservoir, the sediment transport reduction is estimated to 30-65%. This reservoir is now eutrophic and hypoxic at low flows and may also store total P (10-25%) but total N is barely affected (3.7% only). The Goczalkowichie reservoir is probably retaining some part of the highly contaminated sediments of Silesia, thus protecting the medium and lower course of the Vistula.

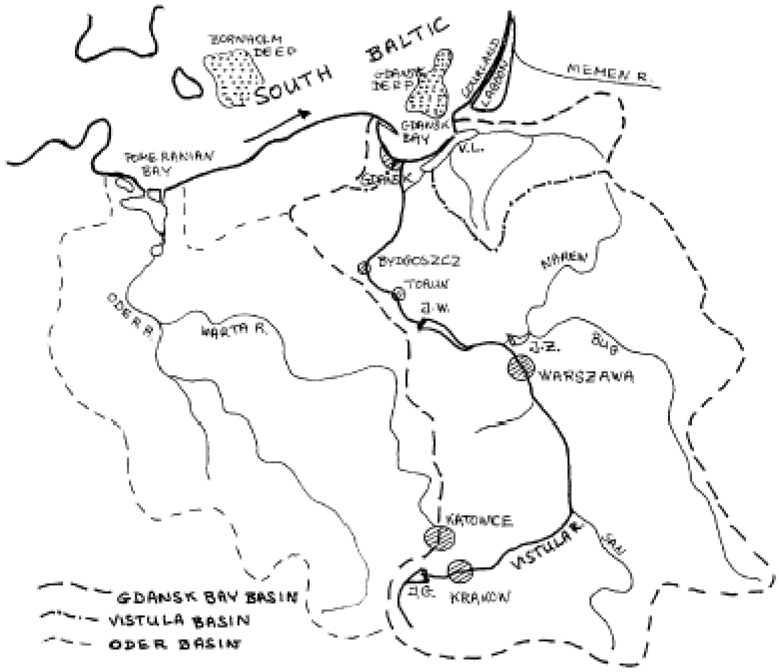

Figure 2: The South Baltic catchment. The Gdansk urban area is located on the west side of the Vistula Delta entering Gdansk Bay. Part of the Gdansk Bay drainage area is actually discharging to the Vistula Lagoon (VL) a nearly enclosed coastal entity (Meybeck et al. 2004).

2.2 Vistula Delta, Gdansk Bay and Vistula Lagoon

The original Vistula Delta extends over about 1000 km^2 of lowland. This area was probably a single wetland system when Gdansk city was founded, a thousand years ago. Both Gdansk and Elblag, the second city of the delta, have been built at the limits of the flood plain on the edges of the Delta. Originally the Vistula river had multiple arms as the Nogat branch that reaches the Vistula Lagoon (Meybeck et al. 2004). Now the Vistula river is channelized to allow navigation up to Wlokawek City and the river mouth is now constrained by dykes. Few km upstream of the mouth a former natural and now channelized branch of the Vistula goes to Gdansk (figure 3, B). The treated effluents of the Gdansk-Sopot-Gdynia conurbation (Tricities, 1 million people) are now injected near the river mouth. Gdansk sewage treatment has begun in 1871, from 1932 onwards at the old Zaspa treatment plant, rebuilt in 1967. This treatment plant will be closed in 2006 and be replaced by the Wschod major treatment plant located between Gdansk and the river mouth that will treat the effluents of the tricities. The Gdansk refinery effluents are discharged directly to the bay near the Vistula mouth.

The Vistula Lagoon is separated from Gdansk Bay by a sand bar more than 20 km long (Mierzeja Wislano). The border between Poland and the Russian enclave of Kaliningrad crosses the sand bar and separates the Vistula Lagoon into two parts. This sand bar has a narrow opening at Baltijsk (Pillau) which allows the Russian fleet of the Baltic to reach Kaliningrad a major navy base. The Paslewa and Pregolia rivers are direct tributaries of the Vistula Lagoon which should be considered as a subset of Gdansk Bay. Direct pollutants inputs to the Vistula Lagoon (Zalew Wislany and Kaliningrad zaliv) include agricultural inputs from the Paslewa and Pregolia basins, smelters and industrial inputs (Cu, Zn and Ni) from Elblag and from Kaliningrad (navy shipyard). Most of these pollutants are likely to stay in the lagoon but their dissolved parts can seep through the sand bar. The management of this coastal lagoon adjacent to the bay of Gdansk and shared between Russia and the European Union - after 2004 - will probably be a difficult one (Meybeck et al. 2004).

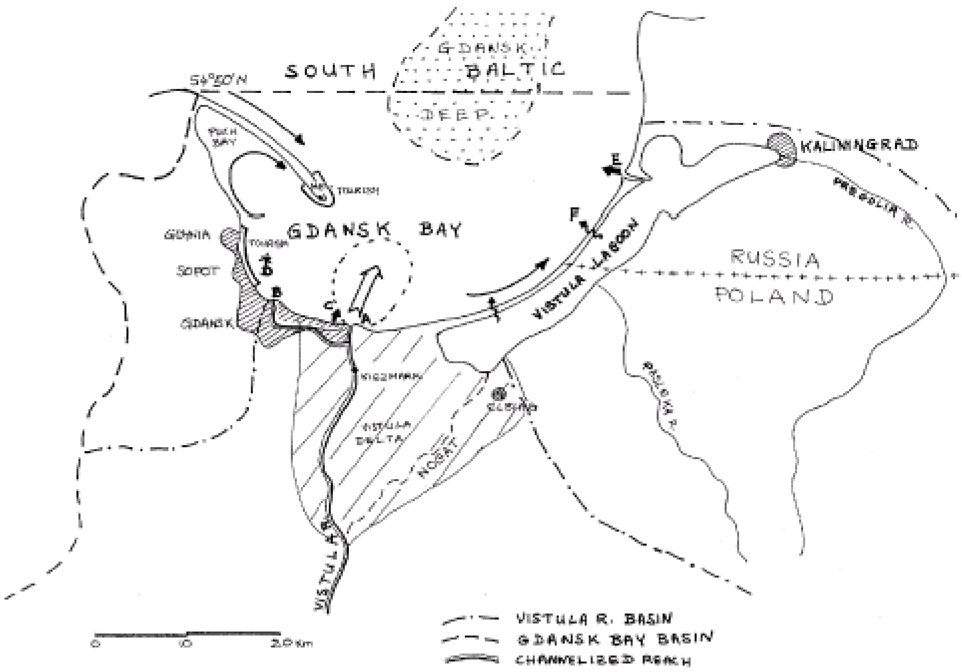

Figure 3: Gdansk Bay coastal area. The Vistula River is connected to the bay through an extended delta in which the river is now channelized for navigation and flood control, and partially drained. The former active Nogat branch is connecting the river to its lagoon, which extends accross the Russia-Poland border (Kaliningrad enclave). Most of the pollutants loads received by the Vistula Lagoon are trapped there: the exchange through the opened channel (E) or across the sand bar (F) are probably limited. The active Vistula mouth (A) corresponds to a river plume extending 10 km sea-wards. An old river branch (B) connecting the Vistula to the Gdansk port and ship yard is regularly maintained. The treated effluents (C) of the Gdansk-Sopot-Gdynia conurbation are now injected near the river mouth. Point sources of contamination in the Bay include an oil tanker wreck (D). The ultimate deposition of fine material received by the Bay is the Gdansk Deep, a major feature of the South Baltic. Coastal tourism is particularly important around Sopot and in the nature conservation area around the Hel peninsula. The Viscat coastal zone limit is placed at 54°50'N (Meybeck at al. 2004).

On the other side of Gdansk Bay the very narrow Hel peninsula is another very active sand bar. Now mostly converted into a nature conservation area, it was previously a Polish army camp, which experiences now limited mass tourism. The Hel peninsula is limiting the Puck Bay, which is very shallow and mostly undeveloped. The tourism has mostly been developed around Sopot. A sunken oil tanker form World War II battles is now an important permanent pollution source of hydrocarbons in Gdansk Bay around which fishing is now prohibited.

The Vistula river plume (10 km long) is generally directed northward. The ultimate depository of fine particles is the Gdansk Deep one out of two major South Baltic Deeps, with the Bornholm Deep North of the Oder River mouth (figure 4). The Gdansk Deep is now characterized by a permanent hypoxia part of which can be attributed to the organic pollution originating from Gdansk Bay and its catchment. Although the Viscat limit has been placed at 54°50'N (figure 6.3.b), the Gdansk Bay influence extends to the Gdansk Deep (Meybeck at al. 2004).

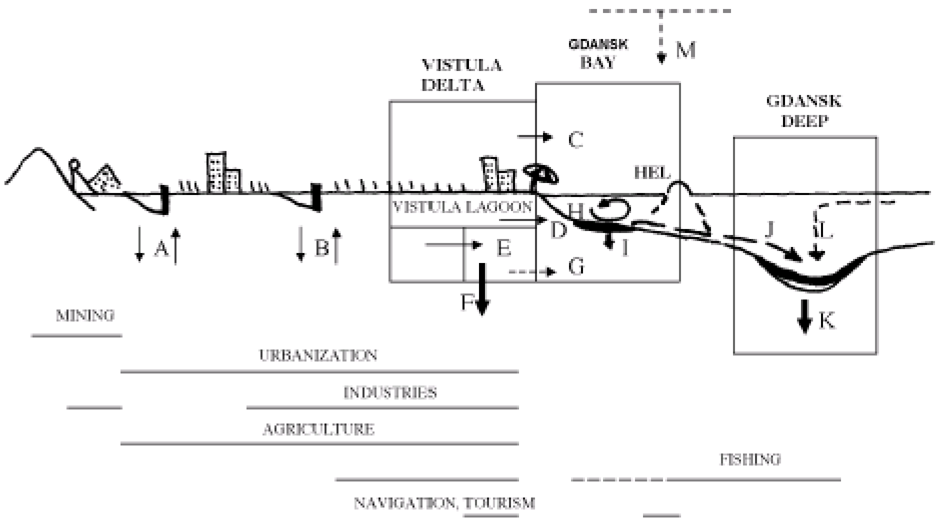

Figure 4: Schematic fluxes and connexions between the Vistula catchment and the coastal zone. The upper Vistula mining products are partially retained in the Goczalkowichie reservoir (A). In the middle basin inputs from Krakow and Warszawa and the Bug sub-basin are also partly retained and/or processed by reservoirs (B). After draining over the last 100 years the Vistula Delta is not any more a major wetland area and the Vistula Lagoon drainage basin (E) is now greatly reduced. Most of inputs to Vistula Lagoon remain in this subcomponent of Gdansk Bay (F) although percolation of dissolved nutrients through the sand bar (G) should be checked. The major inputs to the Bay are those of the Vistula River (D) controlled at Kiesmark gauging satation and of Tricities effluents (C). Nutrients and pollutants are recycled in the Bay (H) then are eventually sedimented or resuspended (J) until they reach their final depository (K) in Gdansk Deep. Direct inputs of material (L) from the open South Baltic to the Deep, now hypoxic and atmospheric inputs (M) of nutrients or pollutants to the system remain to be determined (Meybeck et al. 2004).

3 Assessment approach

The Driver-Pressure-State-Impact-Response-approach (DPSIR) is the analytical framework selected in EUROCAT (in accordance with international programs like LOICZ, GIWA, the EEA and others) to handle these complex humankind-ecosystem interactions. The definition of these terms had to be adapted to the needs of the EUROCAT project. To assist the assessment along the catchment-coast contimuum the partners in workpackage 2 (Indicators and Scenario Assessment) of EUROCAT decided that Drivers, Pressures and Responses need to be formulated for the river catchments as well as for the coastal areas. As the focus of EUROCAT is to view the coastal zone as receptor area of catchment activities, State and Impact indicators need to be developed only for the coastal area. On the other hand State and Impact have to be subdivided into ecological State/Impact and socio-economic State/Impact (Conlijn et al. 2002).

In order to assess drivers, pressures, state, impact and responses as well as their cause-effect relationships, several tools had to be linked with each other (figure 5). Scenarios have been used to identify and assess major drivers and their changes under different socio-economic conditions and different regulation frameworks. A full description of the approach including a comparison of the several EUROCAT case studies is given in Kannen et al. (2004).

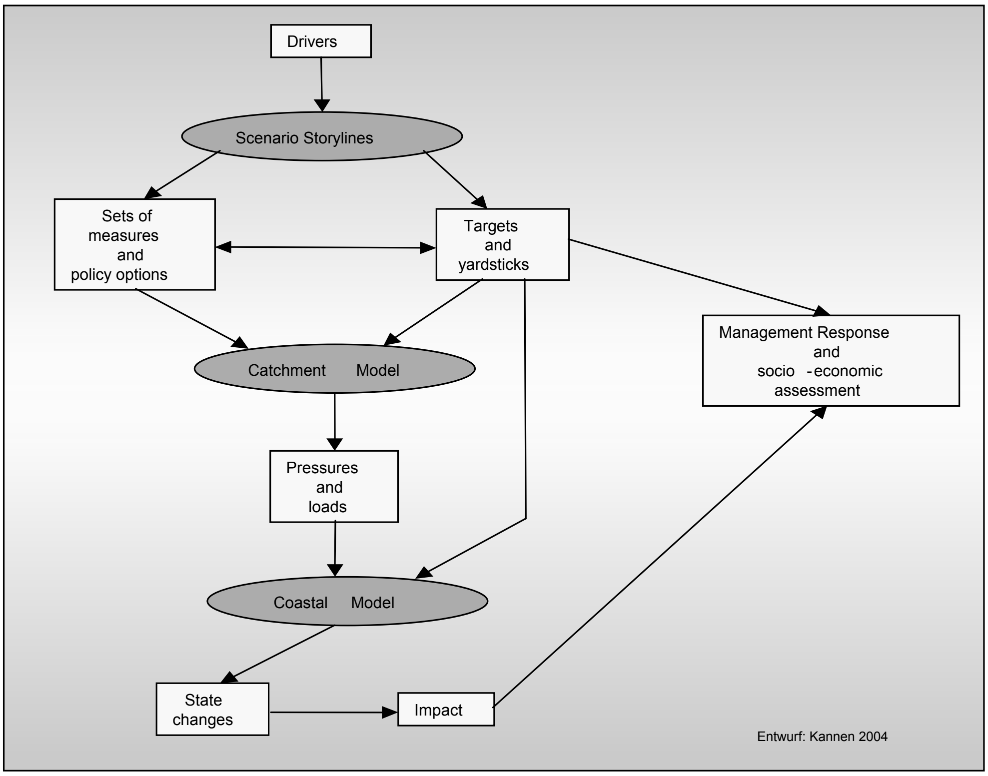

Figure 5: Assessment chain along the catchment coast continuum in EUROCAT (Kannen et al. 2004).

Scenarios represent a preview how different human activities could come into existence, thus causing an impact on the environment and potentially damaging the (coastal) ecological integrity. Furthermore scenarios represent plausible images of the future, in which environmental risk perception and therewith interpretation of environmental risk and (coastal) vulnerability will considerably influence political targets and their implementation (Nunneri et al. 2002).

The scenarios used for the VisCAT case study link economic development with population projections, agriculture policy as well as transport development. The scenarios focus on the political and economic potential to implement environmental standards of the EU in Poland. They result in estimated reductions of nutrient loads that form the input for modelling exercises in the river catchment and in the Bay of Gdansk. This paper will focus on the translation of scenarios to inputs for coastal modelling, using the VisCAT case study as an example.

4 Scenarios for the Vistula case study

In the Vistula-Bay study (VisCat) three basic scenarios defining the rate of economic growth, population projections, agriculture policy as well as transport development have been considered in the assessment (Kowalewski et al. 2003).

1) Policy targets - high scenario. This scenario assumes a 5-6% increase in the GDP rate in 2004-2020. The high rate of economic growth enables the realization of the National Program of Municipal Wastewater Treatment (according to Directive 91/271/EEC). There is a 75% reduction of the discharged nutrient loads in Polish agglomerations above 2 000 p.e. A 1% growth of the population in years 2000-2015 is expected. There will also be a20% rise in migrations to the cities. In agriculture policy application of the Code of the Good Agriculture Practise limits uncontrolled pollution of the environment by natural fertilizers (manure), but the use of mineral fertilizers increases.

2) Policy targets – low scenario. This scenario assumes a lower economic growth between 2 and 4% in 2004-2020. Hence it is not possible to fully implement the National Program of Municipal

Wastewater Treatment (according to Directive 91/271/EEC). Wastewater treatments to be constructed by 2010 will be on line by the Coastal Impact Assessment end of 2015. In agriculture policy, the storage of manure is not improved, but at the same time the use of mineral fertilizers is not increasing either.

3) Deep green scenario. This scenario accomplishes all the objectives of the scenario Policy Targets concerning construction of wastewater treatment plants. Except for this, ecological awareness of the society and the campaign against usage of the laundry detergents with phosphates causes their removal from the market. As a result of this the share of the laundry detergents without phosphates is 90%. Furthermore, it results in lower discharge of phosphates in sewage, thus the load of phosphates from wastewater treatment plants declines by 20% in comparison to Policy Targets scenario. Good Agricultural Practise is introduced and the use of mineral fertilizers is decreasing.

The detailed description of the scenarios is given in the report: Viscat, Report on the redefiniton of scenarios by Bartczak et al., 2003. These scenarios have been investigated within the Vistula River catchment area by using the MONERIS – river catchment nutrient emission model. The results of the application of the MONERIS model, the discharge of total nitrogen and total phosphorus from the Vistula River to the Gulf of Gdańsk, determines the input data for the calculations of the N and P loads from the Vistula River to the Gulf of Gdańsk. The projections of loads are given in table 1.

Scenarios	Load from the Vistula River [10^3 tons/year]							
	N-Tot				P-Tot			
	2002	2005	2010	2015	2002	2005	2010	2015
Policy targets low	114.6	111.7	104.9	104.5	5.86	4.38	3.61	3.46
Policy targets high	114.6	104.8	104.2	104.6	5.86	3.61	3.46	3.47
Deep green	114.6	104.0	104.3	103.5	5.86	3.30	3.32	3.19

Table 1: Loads of total nitrogen and total phosphorus to the Gulf of Gdańsk in three Scenarios (Kowalewski et al. 2003).

In 2002 the total loads of nitrogen and phosphorus were equal to $114.6*10^3$ and $5.86*10^3$ tons. These loads represent 85 % and 79 % of total input from rivers and atmosphere to the Gulf of Gdańsk (including rivers inflowing to the Vistula Lagoon) respectively.

5 Coastal Impact Assessment

5.1 The ecosystem model ProDeMo

The mathematical model of production and destruction of organic matter (ProDeMo) describes basic biological and chemical processes taking place in the sea environment. The ProDeMo model includes 18 state variables, which can be divided into several functional groups: phytoplankton, zooplankton, nutrients, detritus, dissolved oxygen and nitrogen, phosphorus and silicon compounds in sediment (figure 6). The present version of the ProDeMo is a further development of the previous versiontowards complex marine ecosystem model (Kowalewski et al. 2003).

There are two main developments in present version comparing to the previous one. Firstly, the phytoplankton pool has been extended from two to five groups. This feature allows to better describe the seasonal variation of the phytoplankton biomass. Secondly, the sediment layer has been divided into two layers: active and inactive. In the active layer nutrients enter the sediment phase by sedimentation and the model allows their release from the sediment phase to the water phase via mineralization. In the inactive layer there is only a one way nutrient deposition process from the active layer. Phytoplankton includes autotrophic organisms divided into five groups: spring diatoms, dinoflagellate, green algae, blue-green algae and autumn diatoms. Zooplankton is restricted to a group of organisms feeding on phytoplankton. Detritus includes all dead matter (dead phytoplankton and zoological plankton and excrements), which undergo mineralization. Inorganic forms of nutrients include: nitrate nitrogen (N-NO3), ammonium nitrogen (N-NH4), phosphate phosphorus (P-PO4) and silicate silicon (Si-SiO4). Inorganic forms of carbon were not included in the ProDeMo model structure because they do not limit the growth of phytoplankton (Kowalewski et al. 2003).

Due to this the ProDeMo model involves only a partial carbon cycle including phytoplankton, zoological plankton and detritus. Nitrogen, phosphorus and silicon cycles are closed with regard to exchange with bottom sediment and atmosphere. It is similar with the case of dissolved oxygen (O_2) where mass balance equations includes processes taking place in water column, as well as the use of oxygen for mineralization of compounds included in bottom sediment and the exchange through the sea surface. Moreover, the ProDeMo model describes penetration of sunlight inside the sea depth in relation to concentration of phytoplankton and detritus. Processes affecting the change of concentration of particular state variables are described using parameters in the shape of proper mathematical formulae. The result was a set of equations including 151 coefficients whose values were established in course of an extended calibration process. The complete model setup is described together with calibration exercises and simulation in Kowalewski et al. (2003).

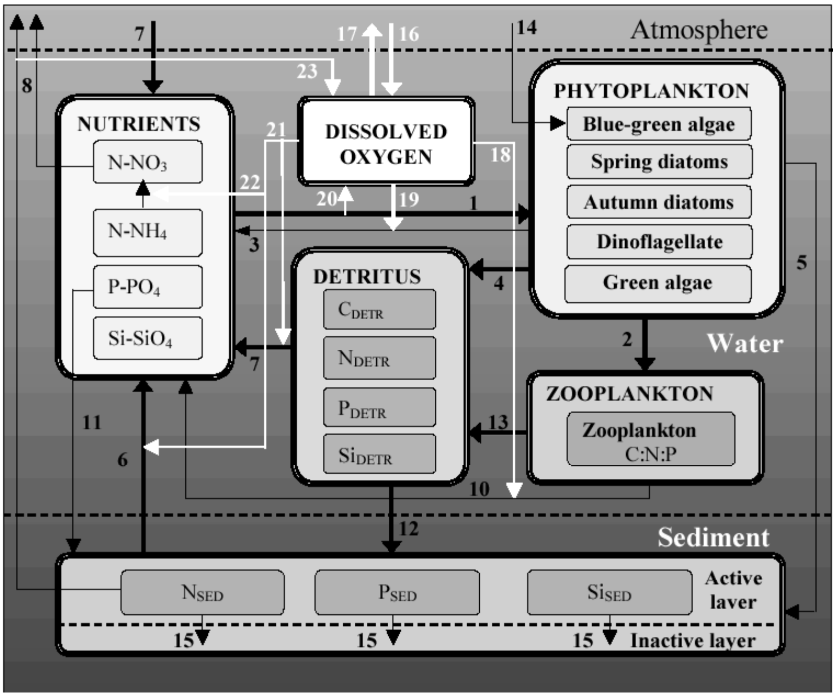

Figure 6: Scheme of the ProDeMo Model. Processes included in the ProDeMo: 1) nutrient uptake by phytoplankton, 2) phytoplankton grazing by zooplankton, 3) phytoplankton respiration, 4) phytoplankton decay, 5) sedimentation, 6) nutrients release from sediment, 7) atmospheric deposition, 8) denitrification, 9) mineralization, 10) zooplankton respiration, 11) sedimentation of phosphorus adsorbed on particles, 12) detritus sedimentation, 13) zooplankton decay, 14) nitrogen fixation, 15) nutrient deposition. Processes influenced the dissolved oxygen: 16) reaeration, 17) flux to atmosphere due to the over saturated conditions, 18) zooplankton respiration, 19) phytoplankton respiration, 20) assimilation, 21) mineralization, 22) nitrification, 23) denitrification (Kowalewski et al. 2003).

The calibrated and validated ProDeMo model has been applied in order to assess the influence of the different economic development scenarios on the ecological state of the Gulf of Gdańsk. The environmental state of the Gulf of Gdańsk has been evaluated for the 2003-2015 projections. The simulations have been carried out as the continuation of the ProDeMo model calculations for the years 1994-2002. Year 2002 has been chosen as a reference year. Loads of total N and total P from the Vistula catchment have been calculated by the MONERIS model (Behrendt et al. 2000) for the

2005, 2010 and 2015 years and these data determined the input data for the ProDemo application in the Gulf of Gdańsk.

A linear distribution has been apply in order to calculate the load values between the years with given data. For the estimation of partition of total nitrogen and total phosphorus into organic and inorganic forms the 2002 distribution pattern has been used. All the remaining input data for the ProDeMo: meteorological conditions, atmospheric deposition, discharges and loads from the other rivers have been defined as in the 2002 year. The forecast of the Gulf of Gdańsk has been investigated by analyses of the following parameters and processes: Total nitrogen and total phosphorus budget calculations, spatial distributions of total nitrogen and total phosphorus, deposition of nitrogen and phosphorus in the sediment, N/P ratio, phytoplankton biomass and primary production. The results from the last year of model simulations, 2010, for each scenario have been compared with the reference year 2002 and the results of the simulations have been compared between each other. A full description of the model application, the calibration and the results is given in Kowalewski et al. (2003).

5.2 Interpretation of model results

The total nitrogen discharged by the Vistula River is reduced in each scenario comparing the forecasts for the year 2015 and the year 2002. Depending on the scenario the reduction of total nitrogen is equal from 8.8 % for Policy target low scenario to 9.7 % for Deep Green scenario. This leads to two conclusions: firstly, the reduction of total nitrogen in all scenarios is rather small (does not exceed 10 %) and secondly the difference in the projections of total nitrogen discharge between the scenarios are very small and can be neglected.

The reduction of total phosphorus discharge for the year 2015 is much larger and is equal from 40.9 % for the Policy target low scenario to 45.5 % for the Deep green scenario. The difference between low and high policy targets scenarios in 2015 are very small. However; in the Policy target high scenario the significant reduction of total nitrogen and total phosphorus is observed even in 2005 year, whereas in low scenario is rather gradual in the 2002-2015 period.

As an example of the many modelling results the N/P distribution for the scenarios is shown in figure 7. The distribution of the N/P ratio has been calculated to analyse the potential limiting conditions (winter conditions) and the real limiting condition under the intensive growth of phytoplankton (summer time). It has been observed that in the reference year 2002, which represents recent biogeochemical conditions, the nitrogen is the limiting nutrient in the large part of the Gulf of Gdańsk (N/P < 16), whereas in all scenarios in 2015 phosphorus limits the growth of phytoplankton in the whole Gulf (N/P > 16). Therefore, there is much less inorganic nitrogen during summer in the reference year 2002 than at the same time of the year during the scenarios projections. On the other hand, the distributions of phosphorus is the opposite.

Primary production depends on three basic factors: nutrient availability, solar radiation and the water temperature. The modelling results show a general tendency: the further from the land towards the open sea, the lower the rate of the primary production. The values for the central part of the Gulf of Gdańsk are almost half the values in the Eastern part of the Gulf. The rate of primary production in the open waters of the Gulf of Gdańsk does not vary significantly among the scenarios, so this part of the Gulf seems to be less sensitive to nutrient changes. The areas with most visible difference between the reference year 2002 and the Policy targets high scenario are located to the North of the Vistula River outlet and along the Hel Peninsula. Here, the loads of nitrogen and phosphorus from the Vistula River have a strong direct impact on the rates of primary production.

N:P ratios in river waters and consequently in the sea water determines effects on the productivity of the water environment. If nitrogen is the limiting nutrient then the reduction of phosphorus loads may not cause any reduction in primary production unless the reduction reaches a certain level (N:P=16). Below this value phosphorus limits the growth of phytoplankton.

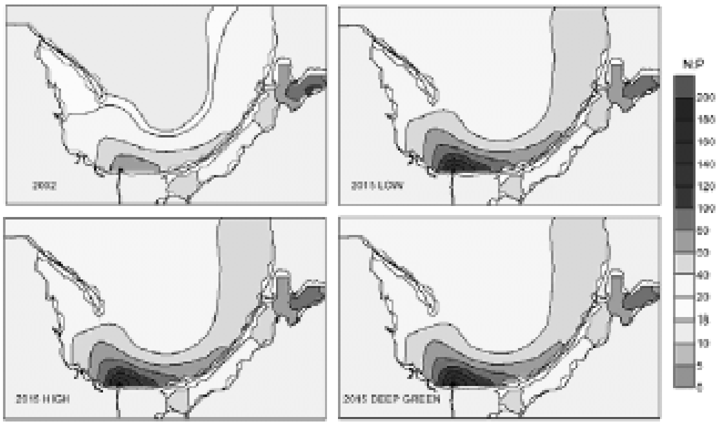

Figure 7: Nitrogen/phosphorus ratios in the Bay of Gdansk for various scenarios (Kowalewski et al. 2003).

Even though the considered scenarios vary in terms of assumptions (economic development, agriculture policy), they do not vary significantly in respect of the total nitrogen and total phosphorus discharged to the Gulf of Gdańsk: the differences in nitrogen loads can be neglected, while the differences in phosphorus loads are rather small (less than 5%). These conclusions have important impact of the analyses of the influence of the Gulf of Gdańsk on the three considered scenarios (Kowalewski et al. 2003):

- The reductions of biological productivity for all scenarios are not very significant comparing to the reductions of phosphorus loads: depending on the scenario from 40.9 % for the Policy target low scenario to 45.5 % for Deep green scenario.
- The lowest biological productivity has been obtained for the Deep green scenario: the primary production is 7.5 % less than in the reference year 2002. The reduction in biological productivity for the Policy targets low and high scenarios are 7.0 % and % 7.1 respectively less than in the reference year 2002.
- The costal waters are the most biologically productive areas of the Gulf of Gdańsk including the recreational area along the beaches in Gdańsk and along the Vistula Lagoon. In the analysed scenarios, the reduction of primary production rate in these areas is rather low.
- The distributions of phytoplankton biomass contents in the Gulf of Gdańsk for the calculated time series are very similar. The differences between three scenarios in the phytoplankton distribution can be neglected.
- Due to the fact that in the analysed scenarios the reduction of phosphorus loads is much higher (more than 40 %) than nitrogen loads (less than 10 %) the phosphorus became a limiting nutrient in the Gulf of Gdańsk. Further reduction of phosphorus load should lead to the reduction of biological productivity in the Gulf of Gdańsk.
- In order to observe further reduction in the biological productivity longer forecast time is necessary.
- Furthermore, the policy targeting on the reduction of nutrients should not limit to the single gulfs or bays but has to cover the whole catchment of the Baltic Sea.

These conclusions highlight the complexity of the impact of catchment inputs impacts on the Gulf of Gdańsk. The coastal waters are the most biologically productive areas of the Gulf of Gdańsk and include recreational areas along the beaches in Gdańsk and along the Vistula Lagoon. The scenario assessments showed that the reduction of primary production rate in these areas is rather low. Because the reduction of phosphorus loads is much higher (more than 40 %) than nitrogen loads (less than 10 %) phosphorus became a limiting nutrient in the Gulf of Gdańsk under the conditions of the scenarios. Therefore, it could be assumed, that further reduction of phosphorus load should lead to the reduction of biological productivity in the Gulf of Gdańsk (Kowalewski et al. 2003).

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References

Bartczak, A., M. Giergiczny, M. Kaniewska, D. Panasiuk, J. Sleszynski & T. Zylicz (2003): Report on the redefiniton of scenarios, Warsaw University Department of Economics report, 23 pp.

Behrendt, H., P. Huber, M. Kornmilch, D. Opitz, O. Schmoll, G. Scholz & R. Uebe (2000): Nutrient Emissions into river basins of Germany. UBA-Texte 23/00, 266 pp.

Colijn F., A. Kannen & W. Windhorst (2003): List of indicators and critical loads. 38 pp.

Kannen A., W. Windhorst & F. Colijn (2004): Scenario based impact assessments for coastal waters. 354 pp.

Kowalewski, M., J. Jedrasik, B. Oldakowski & J. Nowacki (2003): The impact of the Vistula river on the coastal waters of the Gulf of Gdansk. 70 pp.

Meybeck, M., H. Duerr, J. Vogler, L. Lacharte & Y. Gueguen (2004A): Space analysis of catchment/coast relationships. 166 pp.

Nunneri, C., W. Windhorst & A. Kannen (2002): Scenarios and Indicators: A Link for Pressures and Impacts in the Elbe Catchment, following the DPSIR Approach. SWAP Conference Proceedings, Norwich , 2.-4. September 2002.

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