Journal of Environmental Protection and Ecology 14, *No 2*, *468–479* (*2013*)

Water pollution

INFLUENCE OF GLOBAL CHANGE ON BIOLOGICAL ASSEMBLAGES IN THE DANUBE DELTA

C. STOICA*, E. STANESCU, I. LUCACIU, ST. GHEORGHE, M. NICOLAU

National Research and Development Institute for Industrial Ecology – ECOIND, 71–73 Drumul Podu Dambovitei Street, 060 652 Bucharest – 6, Romania
E-mail: *ecoind@incdecoind.ro*

Abstract. The effects of global changes on the water quality of the Danube delta (St. Gheorghe branch) were investigated using the causal framework DPSIR, model used for describing the interactions between society and the environment adopted by the European Environment Agency (EEA): driving forces, pressures, states, impacts and responses. It is known that interactions between climate change and other drivers of change including hydromorphological modification, nutrient loading, acid deposition and contamination by hazardous substances represent sources of environmental pressures for biological assemblages. This study was done by surveying the ecological status described in EU Water Framework Directive (EU-WFD) using the biological quality elements: composition and abundance, diversity, sensitive/tolerant species, biomass (phytoplankton, macroinvertebrates) in one of the most productive socio-ecological system. The assessment of biological assemblages was based on laboratory data, results of field experiments over 3-year period (2009–2011) and aspects of hydrophysical, hydrochemical and ecological change, those being early indicators of climate change in aquatic ecosystems. Under reduced flow, combined with increasing temperature and global radiation, phytoplankton biomass increased, in contrast the flood pulses have caused dilution effects on nutrients, and therefore significantly lower phytoplankton biomass. The floods and changes in flow regimes have also an impact on the bed and bank structures, so the benthic macroinvertebrates diversity was reduced, was observed the loss of sensitive taxa and changes in community composition. A strong reduction in non-point inputs of pollutants would be necessary to be counterbalancing the possible climate-induced effects on biological assemblages.

Keywords: the Danube delta, water quality, biological assemblages, climate change, disturbed environment.

AIMS AND BACKGROUND

River water quality is a key for their functionality as ecosystems in order to meet human needs. Global change might jeopardise these functions by converted climatic conditions and adjusted land use[1]. Global change impacts the nutrient budgets[2], water temperature and distortions in river flow, which can affect stream fauna[3]. A reason for this is that climate change does not necessarily show constant patterns,

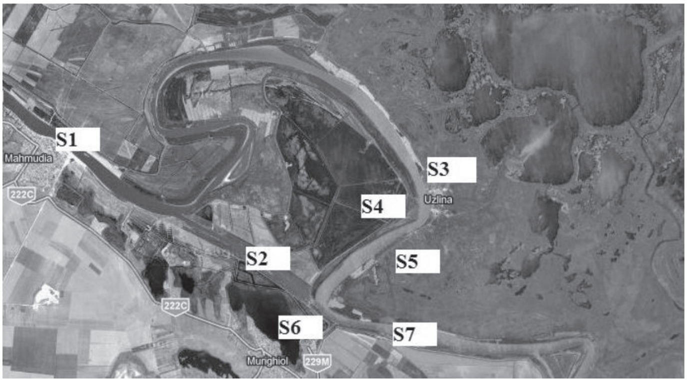
---

[*] For correspondence.

so that on a local and regional scale the magnitude and the management of climate change impacts are sustainable[4]. The water temperature and flow may affect various biological, chemical and hydrodynamical processes within the river system that can intensify or moisten each other. Indirect effects appear when diminishing water availability due to increasing temperature or decreasing precipitation causing transformations in management of water systems. Thus, global change does not influence meteorological conditions, but socioeconomic conditions. This study was done by surveying the ecological status described in EU Water Framework Directive (EU-WFD) using the biological quality elements: composition and abundance, diversity, sensitive/tolerant species, biomass (phytoplankton, macroinvertebrates) in one of the most productive socio-ecological system. The European Water Framework Directive establishes a framework for the protection of groundwater, inland surface waters, estuarine waters, and coastal waters and its final objective is achieving at least 'good ecological quality status for all water bodies by 2015' (Ref. 5). This legislation has several well-defined objectives: (i) to prevent deterioration, to protect and to enhance the status of water resources; (ii) to promote sustainable water use; (iii) to enhance protection and improvement of the aquatic environment, through specific measures for the progressive reduction of discharges; (iv) to ensure the progressive reduction of pollution of groundwater and prevent its further pollution, and (v) to contribute to mitigating the effects of floods and droughts. The status will be based on the biological, hydromorphological and physical and chemical quality elements. The present study emphasises interactions of the biological communities and the main drivers on the site scale.

EXPERIMENTAL

Study area. The Danube river is the second longest river in Europe, flowing from southern Germany to the Romanian coast of the Black Sea. The Danube delta contains the largest natural wetlands in Europe, parts of which have World Heritage Site designation. St. Gheorghe branch is the most southern branch of the Danube delta. It starts at a 108 km distance from the sea (Ceatalul St. George), with a median flow (Tulcea branch). Its width is variable (150 to 550 m), and the depth is between 3 to 27 m below the water[6]. The all 7 sampling sites established along the St. Gheorghe branch are presented in Fig. 1.



S1 Mahmudia
S2 Artificial Channel
S3 Upstream Uzlina
S4 Uzlina
S5 Downstream Uzlina
S6 Murighiol
S7 St. Gheorghe Branch

Fig. 1. Distribution of sampling sites in St. Gheorghe branch

The approach was based on the conceptual model which identifies across space and time scales the 'nature and man coupled systems' or the 'socio-ecological systems' and on the analytical DPSIR frame. It focuses on the links between socio-economic drivers and pressures, changes in biodiversity, ecosystem and landscape structure, and the ability of ecosystems to provide services to the coupled socio-economic system[7]. The analysis of pressures and impacts must consider how pressures would be likely to develop, prior to 2015, in ways that would place water bodies at risk of failing to achieve ecological good status if appropriate programs of measures were not designed and implemented[8]. In this way, IMPRESS (2002) established the driver, pressure, state, impact, response (DPSIR) approach[9–11] as a possible analytical framework for determining pressures and impacts under the WFD. Hence, 'Driving Forces' are considered normally to be the economic and social policies of governments, and economic and social goals of those involved in industry. 'Pressures' are the ways that these drivers are actually expressed, and the specific ways that ecosystem and their components are perturbed. These pressures degrade the 'State' of the environment, which then 'Impacts' on human health and ecosystems, causing society to 'Respond' with various policy measures, such as regulations, information and taxes; these can be directed at any other part of the system[12] (Fig. 2).

In this case, on the scale of the Danube basin have been developed and applied, in the second half of the XX century, a series of policies and management plans that were based exclusively on the principles of neoclassical economics.

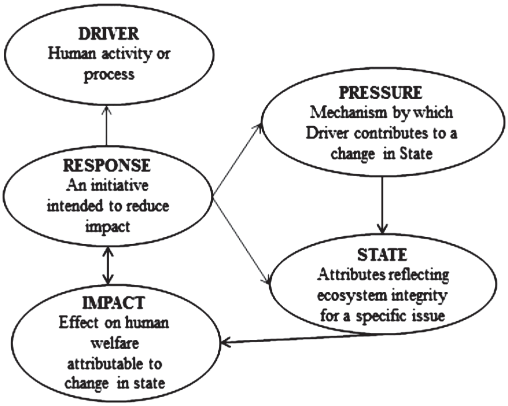


Fig. 2. DPSIR framework

There were pursued a wide range of economic and social objectives, including the following drivers which have been identified in determining the structural and functional changes of delta water system:

(a) the policy objective of expanding arable land areas and increase agricultural production;

(b) industrial and urban development;

(c) using the hydroelectric potential of the Danube and its main tributaries and flood protection;

(d) deal with the effects induced by periods of drought on crops;

(e) development and maintenance of navigation conditions and infrastructure.

RESULTS AND DISCUSSION

The assessment of biological assemblages was based on laboratory data, results of field experiments over 3-year period (2009–2011). Significant changes were found in the last two decades, in terms of hydrological pulse frequency[13]. There is an expression of climate change, which in turn was modulated by structural local changes (Table 1). It was emphasised that regulate water flow inside the Danube delta by dredging the existing channel or opening new channels, resulted in a tripling of refresh rate and consequently a reduction of water time retention from 1 to 4 months[14].

Table 1. DPSIR framework applied on the Danube delta system

Drivers	Pressure	State	Impact
Expansion of arable land Increasing agricultural production and livestock Hydroelectric energy production Extension and intensification of shipping Urban development and industrialisation Climate-change	– conversion of ecosystems and floodplains in agro-ecosystems – over-exploitation of natural resources – increasing organic pollution – increasing material and energy inputs into agricultural production systems – growth of solid and liquid flow – diffuse emissions – solar radiation	– oxygen concentration – habitat structure – diversity of substrate – changes in banks	– biophysical structure erosion – eutrophication – reduction of solid flow – hydrological changes – changes in biotic community structure (qualitative and quantitative composition, sensitive taxa/tolerant age structure, etc.) – erosion of biological and ecological diversity – reducing of ecosystems functions and their economic value – distance changes (the Black Sea) – reduction of informational support and production functions.

Based on analysis of hydrological data recorded in 1921–1992, Bondar[15] showed a slight increase (about 5%) of hydrological pulse amplitude. Computer models predicted that global change will cause redistribution of biological diversity, changes in adaptive potential of species.

The analysis of biological samples and interpretation of the results have been made in accordance to the Norm concerning the reference objectives for the surface water quality classification (Order MMGA No161/2006) in order to establish the ecological status of water bodies and to the Directive 2000/60/EC of the European Parliament and of the council establishing a framework for Community action in the field of water policy.

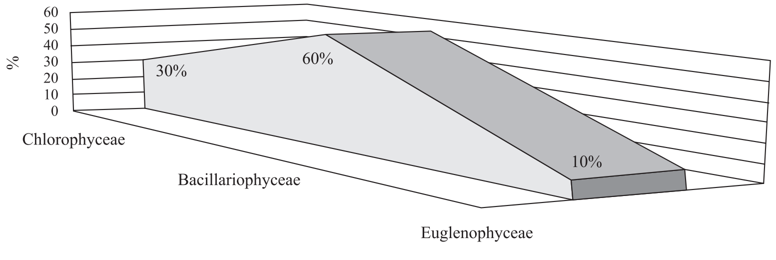


Fig. 3. Main groups of algae abundance in the St. Gheorghe branch control sections during 2009–2011

The analysis of the biotic communities in the all sampling sites focused on the quantitative (numerical density, biomass, abundance after numerical density and biomass) and qualitative component (dominant species, indicator species)[16]. During February 2009 – October 2011, the highest numerical density as well as biomass were S6 (the Murighiol channel) and S7 (the St. Gheorghe branch) control sections with degree of development of the phytoplankton community. Chlorophyta and diatoms contributed about 90% of total biomass (Fig. 3).

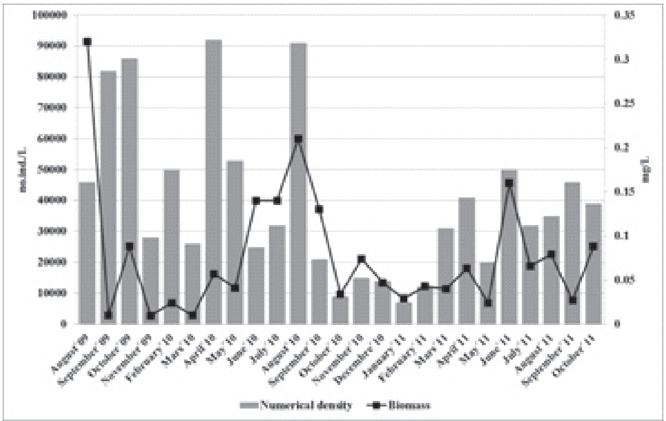


Fig. 4. Variation of numerical density and biomass of phytoplankton in S1 during 2009–2011

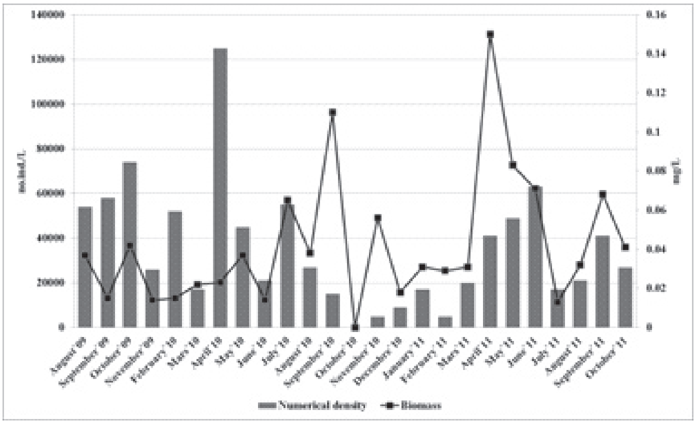


Fig. 5. Variation of numerical density and biomass of phytoplankton in S2 during 2009–2011

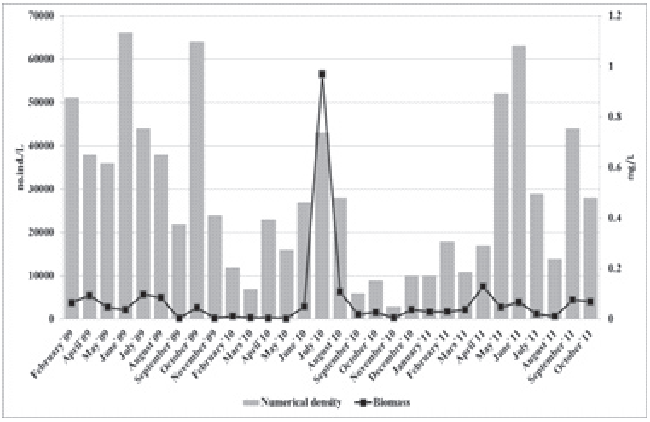


Fig. 6. Variation of numerical density and biomass of phytoplankton in S3 during 2009–2011

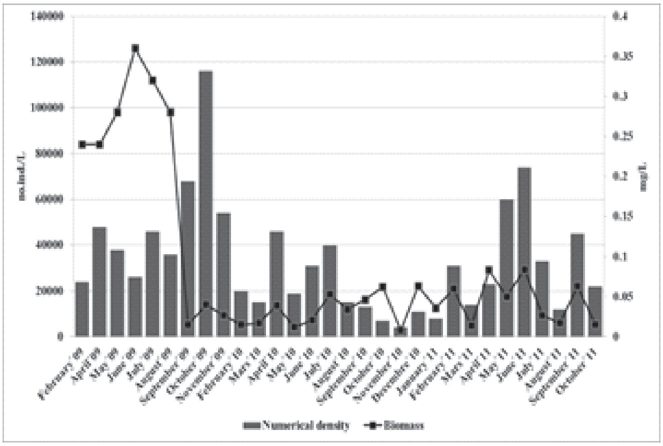


Fig. 7. Variation of numerical density and biomass of phytoplankton in S4 during 2009–2011

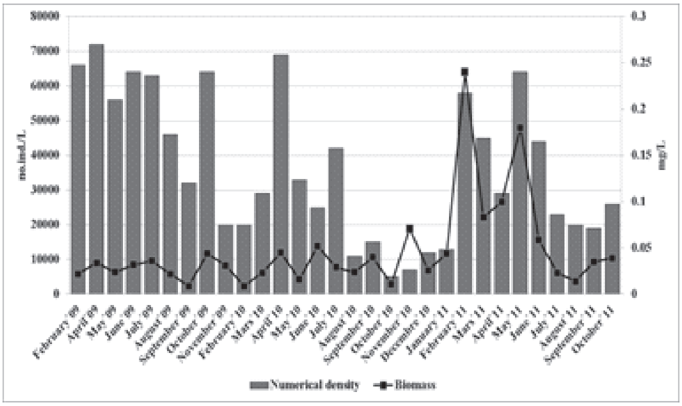


Fig. 8. Variation of numerical density and biomass of phytoplankton in S5during 2009–2011

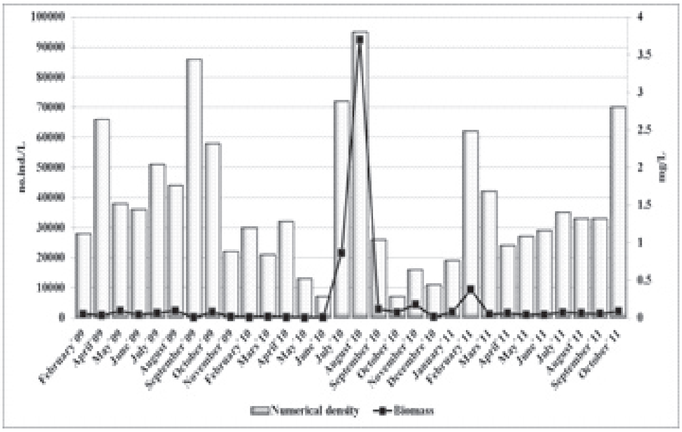


Fig. 9. Variation of numerical density and biomass of phytoplankton in S6 during 2009–2011

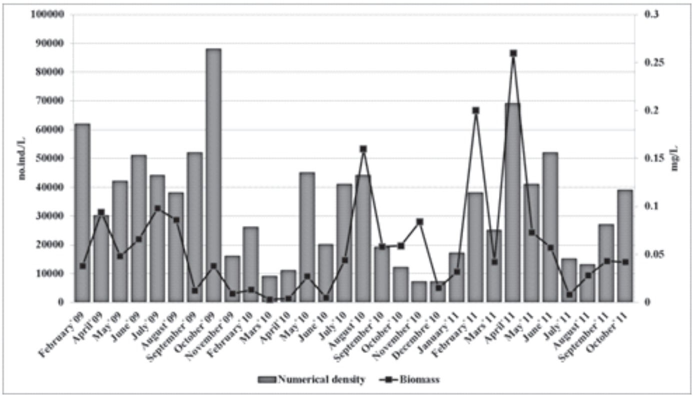


Fig. 10. Variation of numerical density and biomass of phytoplankton in S7 during 2009–2011

Due to short life-cycles, phytoplankton organisms respond quickly to changes in the aquatic environment. Elevated concentrations of organochlorine pesticides in control sections studied (see Figs 4–10), beyond permissible levels, led to lower productivity of aquatic biological systems, phytoplankton species with the ability to accumulate and store pesticides in water cells by slowing the process of photosynthesis. Due to heavy rains in 2010, the concentrations of total phosphorus and total nitrogen were above the limit allowed in the aquatic ecosystem, leading to increased phytoplankton biomass production causing immobilisation of nutrients and limiting the amount of light entering the ecosystem. Nutrient concentrations showed a strong interdependence between the effects of phytoplankton biomass resulting in a change of dominant processes: primary productivity from breathing. Thus, phytoplankton biomass increased with nutrient concentration in March 2010 – January 2011, resulting in disturbances within the food chain (e.g. increase of macroinvertebrate grazers). Also, a low flow conditions, increasing global temperature and radiation, has led to increased phytoplankton biomass and respiration in S2, S5 and S7 in the period February to April 2011. In the delta, flood effects on biological assemblies lasted on average 4 months. Increased algal biomass production rate resulted in the immobilisation of large amounts of oxygen dissolved in water in the degradation of organic matter, accumulation of excess amounts of nutrients, which caused disturbances on the natural flow of nutrients and increasing mortality rates in the consumers[17]. High flow, radiation and increased temperatures, lack of light and pressure had an effect on phytoplankton zooplankton in 2009 and 2011. Decreased algal biomass within the periods specified resource limitation can not be attributed to the growth of phytoplankton, zooplankton pressure only. At the fine scale, temperature rises can decrease the viscosity of water, which in turn could increase nutrient diffusion around phytoplankton cells, influencing competition for nutrients between species, and also increase sedimentation rates[18]. This is particularly important for diatoms, due to their high propensity for sinking as a consequence of their dense silica frustules, and other non-motile species. As mentioned previously, nutrient availability can be altered by increased temperature. Species that can take up nutrients better than others are going to have a competitive advantage. Since diatoms, in general, have large cells and high nutrient requirements, it is expected that these organisms are going to be strongly affected by this phenomenon[18]. In the study by Suzuki and Takahashi[19], *Chaetoceros* sp. showed a small range for growth of around 12°C, and preferred cooler temperature (–1°C to +10°C), while other species, such as *Skeletonema costatum* had a range for growth of 25°C with an optimum (15–25°C) in the warmer end of the range. Even among algae from the same group, temperature ranges for optimum growth can be quite different and correspond to the temperature of the water in which these species occur.

Benthic macroinvertebrates are commonly applied for the quality assessment of rivers[20]. Our good knowledge of their environmental requirements and of species response to various environmental factors has led to these organisms being widely used as (bio) indicators in water management[21,22].

The community composition can be affected by changed climate conditions and thus lead to modified growth rates of the phytoplankton and zooplankton communities, e.g. the mussels might colonise the river and exploit the food resources provided by the algae. As Unionid mussels had intensely colonised the Danube before the heavy anthropogenic pollution, also invading species like *Corbicula fluminea* and *Dreissena polymorpha* already arise. The highest frequency of *Corbicula fluminea* along the Danube has been reported[23]. The growth of *Corbicula fluminea* seems to be under present conditions, limited mainly by low winter temperatures that may be different under conditions following climate change[23].

The biological analyses in all control sections have aimed the quantitative and qualitative component determination. Species of gastropods (*Theodoxus danu-*

bialis, *Planorbis planorbis* (β)) and lamellibranchiate (*Dreissena polymorpha, Sphaerium corneum* (β), *Anodonta cygnea*) were represented in all control stations, especially in the control S3 (Upstream Uzlina), S4 (Uzlina) and S5 (Downstream Uzlina). Oligochaeta were present in increasing numbers in most locations and in terms of insect larvae, Diptera group have played an important role in lotic aquatic ecosystems.

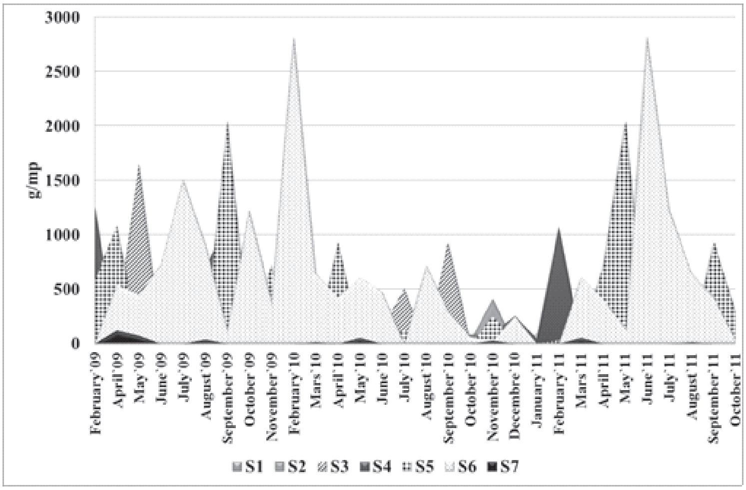


Fig. 11. Variation of benthic communities biomass in the St. George branch during 2009–2011

Regarding diversity, the most heterogeneous groups are Diptera and Oligochaeta. The fauna is dominated by Crustacea (Amphipoda and Isopoda) in terms of abundance while Mollusca was the predominant group regarding biomass[24]. Due to their size Bivalvia make up more than 80% of the whole biomass, followed by Gastropoda (10 to 35%). Most of them indicate ß-mesosaprobic water quality due to their national classification, which results in an overall good ecological status due to their dominance. Oligochaeta, Chironomidae and crustaceans although most abundant groups, have a minor role in total biomass. The highest value of biomass was recorded in May 2009 S3 – Upstream Uzlina (1659.78 g/m^2) (Fig. 11).

CONCLUSIONS

A strong effect of global change on the Danube flow due to climate and other anthropogenic influences has been predicted on a worldwide scale. The impact of climate change on river flow is currently subject of intensive researches[25,26].

In conclusion, climate change leads to a replace of the dominating processes (primary productivity versus respiration) along the Danube delta. The floods and changes in flow regimes had also an impact on the bed and bank structures, so the benthic macroinvertebrates diversity was reduced and loss of sensitive taxa and changes in community composition were observed. A strong reduction in non-point inputs of pollutants would be necessary to countervail the possible effects on biological assemblages.

REFERENCES

1. A. FISCHLIN, G. F. MIDGLEY, J. T. PRICE, R. LEEMANS, B. GOPAL, C. TURLEY, M. D. A. ROUNSEVELL, O. P. DUBE, F. TARAZONA, A. A. VELICHKO: Ecosystems, Their Properties, Goods, and Services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Eds M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, C. E. Hanson). Cambridge University Press, Cambridge, 2007, 211–272.
2. A. DUCHARNE, C. BAUBION, N. BEAUDOIN, M. BENOIT, G. BILLEN, N. BRISSON, J. GARNIER, H. KIEKEN, S. LEBONVALLET, E. LEDOUX, B. MARY, C. MIGNOLET, X. POUX, E. SAUBOUA, C. SCHOTT, P. VIENNOT: Long-term Prospective of the Seine River System: Confronting Climatic and Direct Anthropogenic Changes. Sci Total Environ, **375**, 292 (2007).
3. J. D. ALLAN, M. PALMER, N. L. POFF: Climate Change and Freshwater Ecosystems. In: Climate Change and Biodiversity (Eds T. E. Lovejoy, L. Hannah). Yale University Press, New Haven, 2005, 272–290.
4. J. H. CHRISTENSEN, B. HEWITSON, A. BUSUIOC: Regional Climate Projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 2007.
5. WFD: Directive 2000/60/EC of the European Parliament and of the Council Establishing a Framework for the Community Action in the Field of Water Policy (Water Framework Directive) adopted on 23.10.2000, published in the Official Journal (OJ L 237) on 22.12.2000, 2000.
6. C. BONDAR: Study of the Concequences of Bastroe Canal Construction in Romania Danube Delta Biosphere Reserve on the Environment. GeoEcoMar Raport, Bucharest, 2004 (in Romanian).
7. A. BORJA, I. GALPARSORO, O. SOLAUN, I.MUXIKA, E. MARIA TELLO, A. URIARTE, V. VALENCIA: The European Water Framework Directive and the DPSIR, a Methodological Approach to Assess the Risk pf Failing to Achieve Good Ecological Status. Estuar Coast Shelf S, **66**, 84 (2006).
8. IMPRESS: Guidance for the Analysis pf Pressures and Impacts in Accordance with the Water Framework Directive. Common Implementation Strategy Working Group 2.1, 156 pp. Office for Official Publications of the European Communities. Retrieved on July 12, 2005 from http://forum.europa.eu.int/Public/irc/env/wfd/library, ISBN: 92-894-5123, 2002.
9. OECD: Organisation for Economic Co-operation and Development (OECD) Core Set of Indicators for Environmental Performance Reviews. OECD Environment Monographs No 83, Paris. Retrieved on 13 March, 2005 from http://www.oecd.org/ dataoecd/32/20/31558547.pdf, 1993
10. M. ELLIOTT: The Role of the DPSIR Approach and Conceptual Models in Marine Environmental Management: An Example for Offshore Wind Power. Mar Pollut Bull, **44**, IIIEVII (2002).
11. European Commission: Towards Environmental Performance Indicators for the European Union (EU). A European System of Environmental Indicators. First Publication, (2002).
12. http://glossary.eea.europa.eu.
13. A. VADINEANU, N BOTNARIUC, S. CRISTOFOR, Gh. IGNAT, C. DOROBANTU: Transitions of the Danube Delta Aquatic Ecosystems Trophic Status during 1982–1987. Protection of Nature and Environment, **33** (1), 27 (1989) (in Romanian).
14. C. BONDAR: Aspects hydrologiques dans l'etude de cas Delta du Danube; Danube Delta–Black Sea System under Global Changes. Impact, **1**, 48 (1996).
15. S. HENNINGER: A Methodology and Tools for Applying Context Specific Usability Guidelines to Interface Design. Interact Comput, **12**, 225 (2000).

16. C. STOICA, I. LUCACIU, M. NICOLAU, F. VOSNIAKOS: Monitoring the Ecological Diversity of Aquatic Danube Delta System in Terms of Spatial-temporal Relationship. J Environ Prot Ecol, **13** (2), 476 (2012).
17. F.VOSNIAKOS, G.VASILE, T. ALBANIS, J.PETRE, E. STANESCU, L. CRUCERU, M. NICOLAU, M. KOCHUBOVSKI, D. GJORGJEV, K. NIKOLAOU: Comparison Study of Physico-chemical Parameters Evaluation between Danube River Delta and Axios-Vardar River Valley (2003–2009). Nato Sci Peace Secur, **1**, 257 (2011.
18. L. PEPERZAK: Climate Change and Harmful Algal Blooms in the North Sea. Acta Oecol, **24**, 139 (2003).
19. Y. SUZUKI, M. TAKAHASHI: Growth Responses of Several Diatom Species Isolated from Various Environments to Temperature. J Phycol, **31**, 880 (1995).
20. S. BIRK, D. HERING: Waterview Web-database – A Comprehensive Review of European Assessment Methods for Rivers. FBA News, No 20, Winter 2002, Freshwater Biological Association, Hohenwarsleben, 42002 (2002).
21. W. S. DAVIS, T. P. SIMON: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, Florida, 1995.
22. V. H. RESH, R. H. NORRIS, M. T. BARBOUR: Design and Implementation of Rapid Assessment Approaches for Water Resource Monitoring Using Benthic Macroinvertebrates. Aust J Ecol, **20**, 108 (1995).
23. U. JUEG, M.L. ZETTLER: Die Molluskenfauna der Elbe in Mecklenburg-Vorpommern mit Erstnachweis der Grobgerippten Körbchenmuschel *Corbicula fluminea* (O. F. Müller 1756). Mitteilungen der NGM, **4** (1), 85 (2004).
24. G. RISNOVEANU: Oligochaeta In the Lower River Danube. Rom J Biol Zool, **48** (1–2), 37 (2003).
25. N. R. VINEY, B. C. BATES, S. P. CHARLES, I. T. WEBSTER, M. BORMANS: Modelling Adaptive Management Strategies for Coping with the Impacts of Climate Variability and Change on Riverine Algal Blooms. Glob Change Biol, **13**, 2453 (2007).
26. S. E. BUNN, A. H. ARTHINGTON: Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environ Manage, **30**, 492 (2002).

Received 27 January 2013
Revised 3 April 2013