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9. Stakeholders' perception on algal blooms in Danube Delta, as decision support for aquatic ecosystems

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Abstract: This paper aims to assess the level of perceptions of stakeholders on algal blooms in aquatic systems of Danube Delta in order to apprehend potential adaptation and mitigation strategies for the future, and to analyze for political targets and deficits. Hence, by means of questionnaires were engaged 24 stakeholders representing natural resource managers, local authorities, scientists, NGO's. Even though the results indicated that not all stakeholders are aware with algal bloom terminology, stating a lack of institutional communication and availability of information to the public in the area, it was an overall consensus that the phenomenon represents more than a serious issue for deltaic aquatic ecosystems. The level to which national, regional and local resources can be focused on treating algal blooms issues depends in part of the strengths and interests in the area.
Keywords: algal (cyanobacterial) bloom, stakeholders' perception, aquatic ecosystems, Danube Delta

INTRODUCTION

Since the end of 1970, up until 1990, the nutrient emission from the anthropogenic sources along the Danube River strongly influenced the amount of the nutrients accumulated into the Danube Delta's ecosystems (Gâștescu & Știucă, 2006). Besides these accumulations (in addition to these accumulations), the hydro-morphological transformation inside the Delta increased the inflow average of water input from approximately 260 m^3/s at around 1951 to 620m^3/s in the 1960-1990 period, contributing to the process of eutrophication which was much earlier visible in lakes than in canals or Danube branches (Oosterberg et al., 2000; Postolache, 2006).

Eutrophication, global warming and hydraulic works on Danube River worked together and synergistically and inevitably led to modification of phytoplankton assemblage in Danube Delta (Oosterberg et al., 2000). Under increasing anthropogenic impact on surface water bodies, already loaded with an excessive historical release of nutrients from intensive agriculture and extreme weather events it has been recorded an increasing trend of cyanobacteria blooms in Danube Delta (Török, 2014, Török et al., 2017: Török et al., 2018).

The occurrence of high cyanobacteria biomass in phytoplankton communities coupled with low autotroph to herbivores energy-transfer efficiency has an impact on water quality which leads to changes both at the bottom and the top of the food chains (Monchamp et al., 2017).

Distribution of cyanobacteria in Danube Delta's lakes revealed high concentration of biomass values exceeding the thresholds of risk, spotted during the warm season. The lakes can be included in the risk category both for cyanobacterial occurrence and for the total algal biomass. Further, aggregation of cyanobacteria-concentrated by wind activity - could have high impact on aquatic biodiversity-considering its potential toxic effect, which increases the risk of toxin related health problems-in resting or feeding areas of the wildlife protected species if no action to mitigate their effect is taken (Török et al., 2018).

Danube Delta is faced by serious algal bloom risks due to eutrophication and climate change, being vulnerable to ecological decline, which also involves challenging issues of biodiversity conservation, wetlands' restoration and improving the human well-being. The awareness and the effects of algal

blooms on aquatic ecosystems represent an issue of stakeholders' interest, mainly for administrators of protected area but as well for water resource managers.
In order to look into the current status of awareness to the effects of eutrophication on biodiversity and the impact of cyanobacteria development on aquatic ecosystems, testing the stakeholders' perception of the algal bloom in Danube Delta and the political support to the mitigation management measures was adopted in the present paper as a high stake of examinations. The stakes of this analysis are to identify which are the drivers that could promote the use of political support, but also which are the constraints.

MATERIALS AND METHODS

Data collection

Data collection was carried out in the frame of AQUACROSS project (Funk et al., 2018). The targeted audiences especially consisted of stakeholders involved in Danube Delta settlements management, but not only. The surveys were held in May and July 2018, being conducted by face-to-face meetings. The questionnaire contained 18 opened and closed questions. This method is known as a way to provide the drafting of the survey with quantifiable and in-depth results (D.K. Bird, 2009). The questionnaire was divided in three parts. The first section was designed to capture knowledge on algal bloom and cyanobacteria ("Have you heard about algal blooms?", "If you have not heard, would you be willing to attend seminars or meetings with specialists on this topic?", 'Have you heard about cyanobacteria blooms?"). The aim of the second section was to assess the perception on legislation and governance with role in diminishing / combating algal blooms. In the third section, stakeholders were asked to assess if they can influence decision-making at the political level to develop strategies for the management of algal bloom and if they apply an ecosystem-based management. The last section tackled the issue of measures which could be implemented to mitigate the phenomenon and potential consequences of these measures.

Data analyses

Standard descriptive statistics were used to define the stakeholders' perception of algal and cyanobacterial bloom in aquatic systems in Danube Delta. The answers of both opened and closed questions were coded and analyzed by category of stakeholders with interest in algal bloom: public authorities, natural resource management, inspection and environmental control, research and environmental related NGO.
Responses to closed questions were recorded as binomial (yes/no), or appreciated with Likert scale, having a 1-5 range (where "not really important / not really serious/major negative" =1, "little important / little serious / negative" =2, "important / serious / without" =3, "considerable important / serious / positive" =4, "very important / very serious / major positive"- 5).
Based on both expert judgement and scientific review, the measures pre-prepared in the questionnaire, were designed to cover both control (to suppress or destroy algal blooms) and mitigation - dealing with an existing or ongoing bloom, and taking whatever steps are necessary or possible to reduce negative impacts (Anderson, 2009).
Based on questionnaires' results was designed the Bow Tie diagram (Liu Z, 2017).

RESULTS AND DISSCUSIONS

During conducted survey 24 stakeholders representing natural resource managers, local authorities, scientists, NGOs have been identified.

Stakeholders' awareness about algal (cyanobacterial) bloom: Almost all respondents indicated that they are aware of the occurrence of the phenomenon in aquatic ecosystems (82% for algal bloom and 60% for cyanobacterial bloom), being able to recognize it, but they are not familiar with the scientific terminology (Figure 1).

It was an overall consensus from stakeholders that algal (cyanobacterial) blooms represent more than a serious issue for deltaic aquatic ecosystems (Figure 2), with major negative impact on aquatic biodiversity, human communities that depend on fish resource, water quality and human body through toxins bioaccumulation (Figure 3).

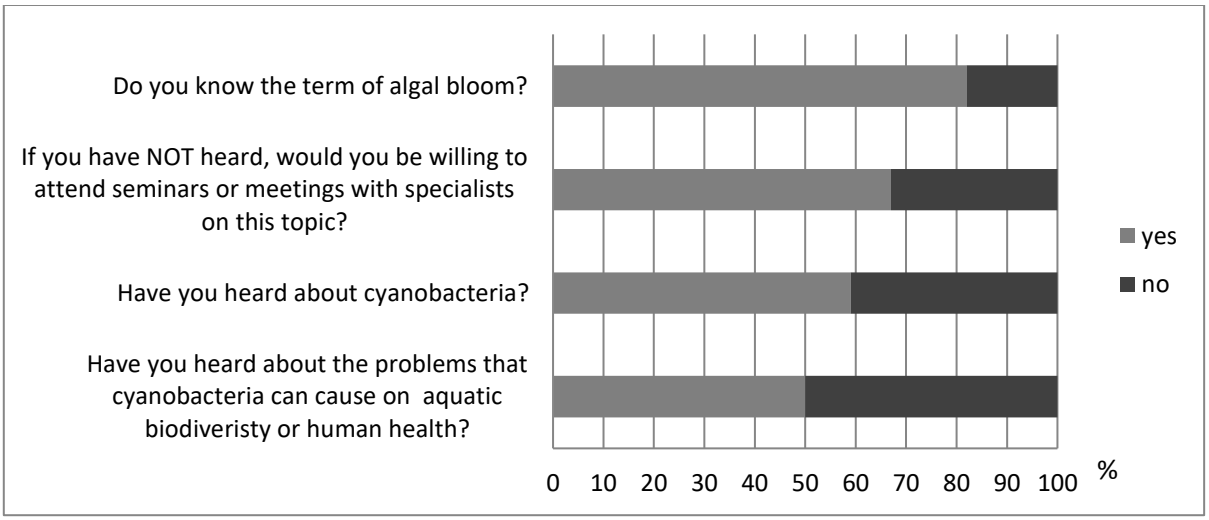

Figure 1. Knowledge of stakeholders about algal and cyanobacterial bloom in aquatic ecosystems of Danube Delta

The development and proliferation of algal cyanobacterial blooms in Danube's aquatic ecosystems result from a combination of natural and anthropic factors (Pinay 1992, Gils et al. 2005, Miloradov et al. 2014). Respondents were given 6 choices of such factors, of which they had to highlight the perspective that best suits with theirs, by using Likert scale.

Overall, stakeholders considered that waste water discharges (average=3.8) and lack of waterbody connectivity (average=3.6) represent the most important trigger factors for algal blooms in the delta, followed by climate change (average=3.0) and agriculture (average=2.9).

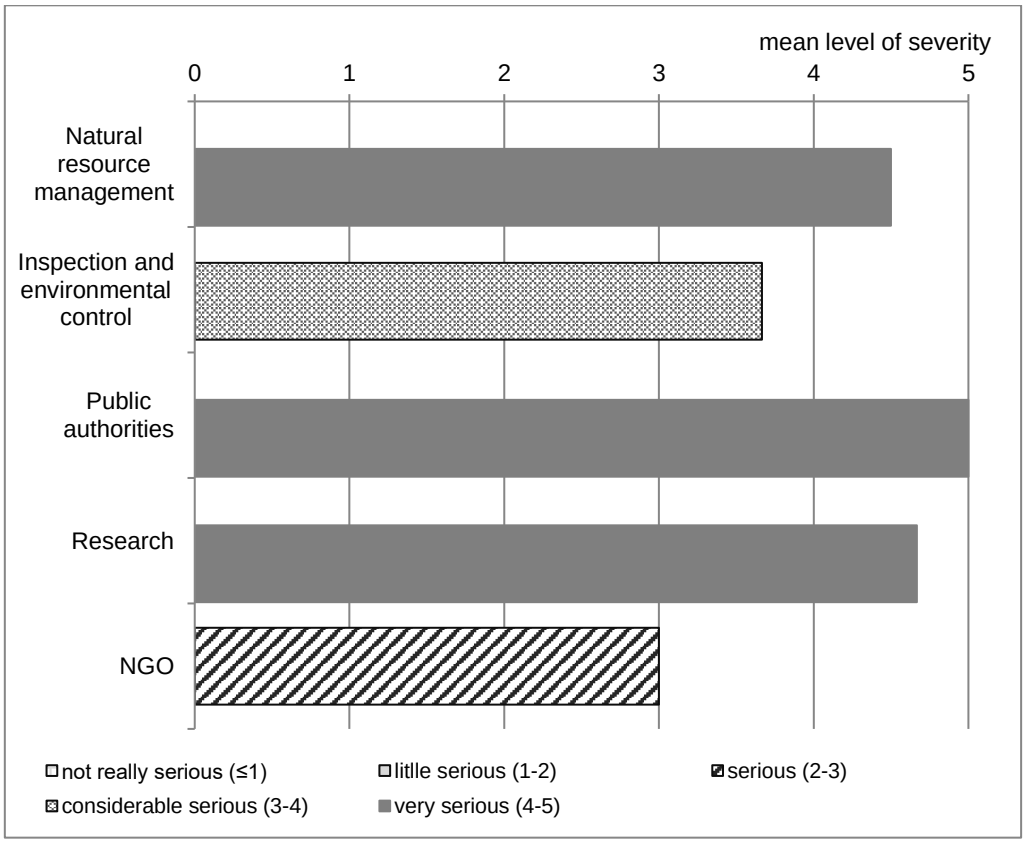

Figure 2. Level of severity of algal bloom in aquatic ecosystems of Danube Delta, perceived by category of stakeholders

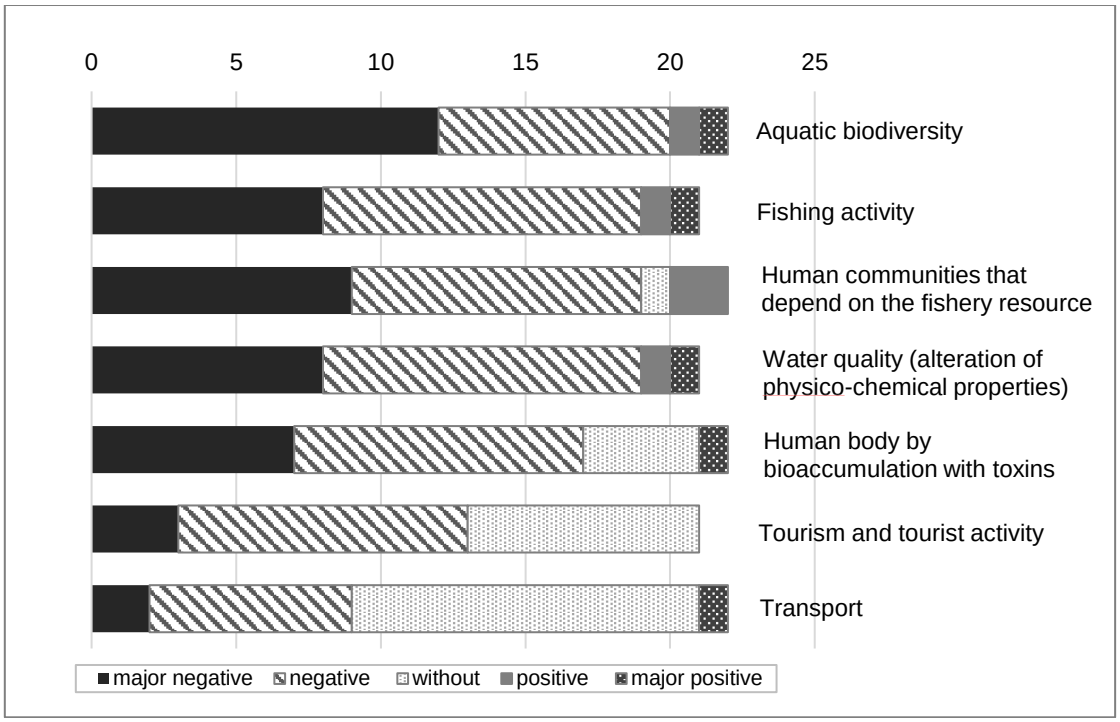

Figure 3 Level of impact of algal bloom on socio-ecological component, perceived by stakeholders

The main concerning factor for public authorities is the lack of water body connectivity (average=4.4), an issue also mentioned as a priority within Danube Delta Integrated Development Strategy (DDISD,2016) which requires physical interventions to restore natural water circulation and key habitat areas, either by dredging /desilting of selected channels and lakes, either breaching of dykes and dams to allow flooding of disused agriculture/aquaculture/ forestry polders (re-naturalization). The fact that Danube Delta is facing the aquatic ecosystems pollution through untreated sewage/waste water from the inhabited islands (DDISD, 2016) has led public authorities to position waste water discharges on a second position in terms of importance (average=4.2) when it comes to algal blooms' factors. At the opposite side lies the natural resource management group that considered water body connectivity (average=2.2) the least important trigger factor mainly because these institutions are the ones responsible for maintaining water quality within Danube Delta.

On the other hand, it is widely recognized that both for monitoring purpose or for maintaining surface waters quality status there are substantial economic costs (Török et al., 2019; ***, 2018).

The cost that society faced for the health risk reductions are an important nonmarket benefit of improving water quality and should be accounted in future cost–benefit analyses. Regarding the future values or evaluations of this process, an important factor is the perceptions about the health risks related to water and the general attitudes towards the environment (Hunter et al., 2012). Due to the lack of action for the mitigation of the phenomenon, the way in which blooming of cyanobacteria is perceived is one of the most widespread problems related to eutrophication of inland waters in Romania

Water pollution from pesticides and fertilizers used in the agricultural polders was thought to have a high impact on aquatic ecosystems, mainly by NGO's, research and environmental control groups, although data on the extent of the use and impact are generally lacking (Gasparotti, 2014: DDISD, 2016)

Legislation and Governance: Romania has made remarkable progress over the last 20 years, but some issues in connection with the implementation of EU environmental policy and law, are still present. With regard to water quality, Romania still needs to improve its water policy in line with the Water Framework Directive, to improve and enhance coordination and the administrative capacity of the authorities and agencies involved in implementing EU legislation, in particular for water, waste management and the protection and management of Natura 2000 sites (***, 2019).

Regarding policies and Directives of the EU, stakeholders unanimously considered they have an important role in combating algal blooms (Figure 4), yet showing a certain lack of confidence when it comes to their transposition and implementation at national level. During the survey, 2 representatives of public authorities mentioned that they are aware of the existence of aforementioned directives by heaving heard about them briefly, but have no knowledge of their content, attitude that highlights the need for local awareness actions related to policies.

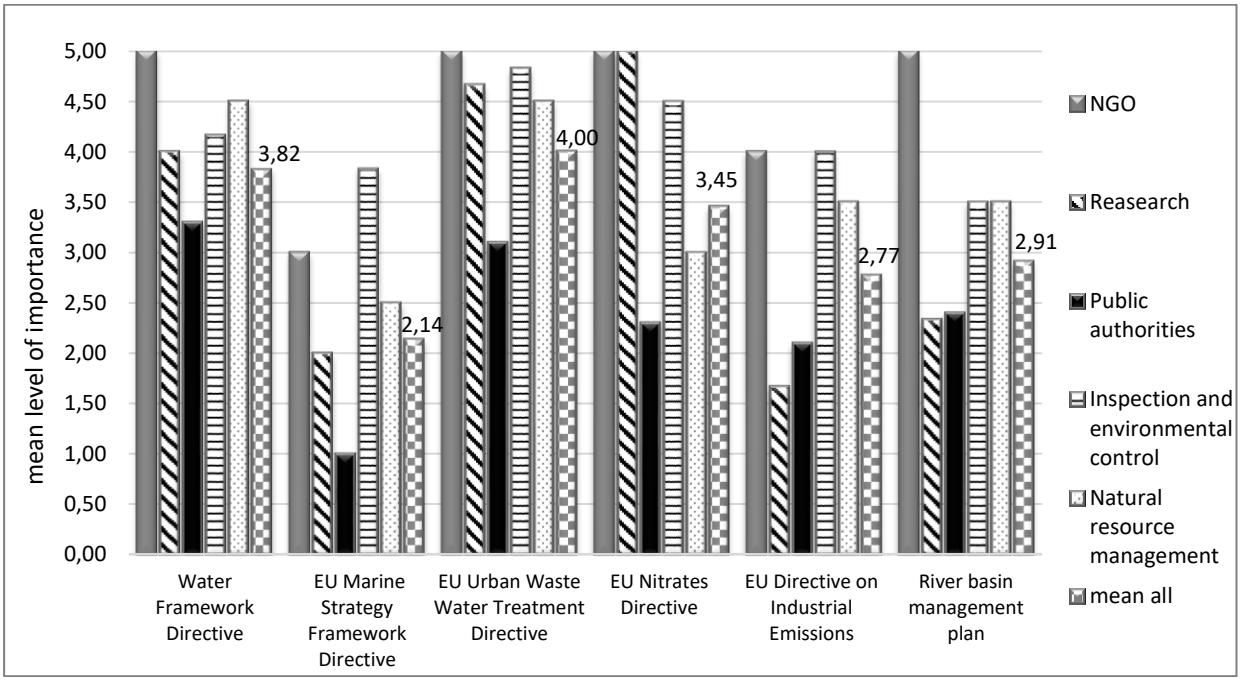

Figure 4. Level of importance of legal frameworks with role in diminishing / combating algal blooms, perceived by category of stakeholders

Representative of natural resource management group mentioned that the governance is more top-down regulated, raising the issue of the need for legislative review by taking into account current local conditions, what has been done and what has been reported until now.

Research group considers that policies and directives with role in combating / diminishing algal blooms may require improvements in the achievement of certain regional objectives, and the transition to new water protection stages. Furthermore, the necessity of following the implementation plans of the directives after their transposition into the national legislation has been highlighted.

Control and Mitigation measures: The results show an agreement between respondents when it comes to control measure of improving the sewage treatment system (with the highest average score of 4.4), coming in response to the main driver factor identified (waste water discharges). This shows that it is a very important aspect in the studied area, the localities in Danube Delta do not have centralized sewerage systems that collect the waste waters at the level of the whole locality, and the existing treatment plants perform only the mechanical pre-treatment of the domestic waters.

The second measure considered by stakeholders most important for deltaic aquatic ecosystems is reducing the use of chemical fertilizers (average=3.80), but with different perceptions among stakeholders. Meanwhile research and NGO groups are ranking it as very important measure for long term ecological improvement, public authorities and natural resource managers consider little important, as within the delta it is stipulated by law that land users should ensure the fertilization of land only with organic fertilizers.

Management and Institutional collaboration: There is no local strategy for the management of algal blooms in the Danube Delta. Moreover, representatives of local councils mentioned that they are notified by local people of the occurrence of algal blooms in aquatic ecosystems on their commune's territory (e.g. in Holbina, Militova lakes, Cordon-Litoral channel), but they cannot take actions because they are not the administrators of the affected water bodies. Hence, they consider that the entitled institutions to

record and diminish the phenomenon are the ones that administer the natural resources, stressing the lack of institutional collaboration and harmonization of interests among stakeholders. Moreover, they have raised the problem of institutional overlapping when it comes to natural resource management, a true obstacle in achieving ecological goals.

Another type of constraint encountered is the lack of financial resources to support ecosystem-based management, related mainly to the priorities and needs among decision-makers, in algal bloom topic. Additionally, they believe that human resources within their institutions do not have technical/ scientifically competencies in the field of algal blooms and its management. The base factor for an ecosystem-based management implementation relies on the priorities of stakeholders and decision-makers, whose financial and human resources will be focused on treating conservational and environmental issues depending in part on the strengths and interests on the impact and the effects of algal blooms that occur in deltaic aquatic ecosystems (Figure 5). This can be attributed to the fact that stakeholders and decision-makers appreciate the importance of environmental damages in connection with social and economic interests, with risks and distribution of costs and benefits (Belacurencu, 2007).

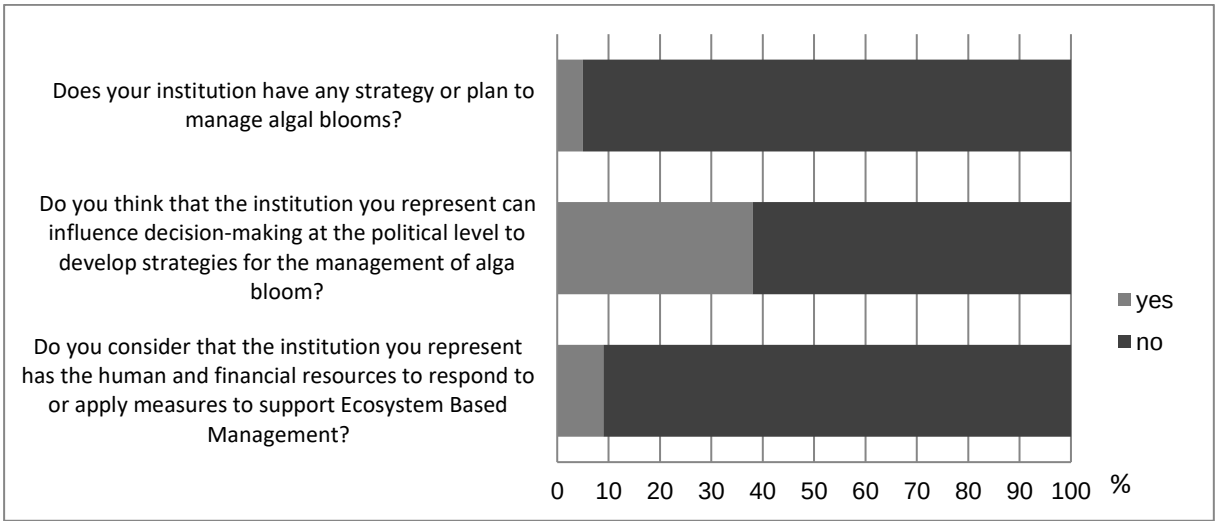

Figure 5. Stakeholders' perception of institutional support for algal blooms management and mitigation

Researchers, NGO and natural resource management groups consider that they can influence decision-making at the political level to develop strategies for the management of algal bloom, through extensive efforts for monitoring and research activities carried out in the field, rising awareness and enhance communication of scientific recommendations to the decision-makers and general public. Representatives of public authorities specified that since they are not the owners of water bodies, they cannot influence political decision-making but can only report algal bloom situations when they occur and present the risks exposed.

Designing the Bow tie diagram is meant to describing and analyzing the pathways of risk from hazards linked to the outcomes of management measures. It provides a systematic approach of assuring control over environmental, health and safety hazards and has been recently adopted for the ecosystem approach which aims to protect and maintain the natural ecosystem while at the same time ensuring that it produces the ecosystem services from which society obtain cultural and economic benefits. It consists of a fault tree on the left side identifying the possible events causing the top event (algal blooms in Danube Delta) and an event tree on the right side showing the possible consequences of the top event based on the failure or success of safety barriers (Liu Z, 2017).

Based on stakeholder process was designed a complex model causal-effect built around one main problem – algal (cyanobacterial) blooms in aquatic ecosystems of Danube Delta (Figure 6). The right-side lists consequences resulting from the event. Controls are positioned along the pathways of risks on the left (solutions preventing the problem from happening) and on the right (mitigation/ compensation and recovery from the event).
Escalation factors can undermine the effectiveness of a given control and can also be added with additional barriers. Hence, the scheme accommodates uncertainty in risk management.

Causes. Extreme climatic events (increased temperatures, changes in seasonal patterns) (Doroftei, Mierla, 2012, Doroftei and Anastasiu, 2014) can have major ecological consequences for aquatic ecosystems in the delta, causing changes to the hydrological regime, fluctuations in temperature and increased nutrients concentration, which can be exacerbated with anthropogenic influences: water pollution from pesticides and fertilizers used in the agricultural polders, waste water discharges and morphological alterations. Changes in these environmental factors result in connectivity loss and reduction of aquatic ecosystems' services and functions. It is these 'causes' that result in the 'main problem' – algal blooms.

Consequences. Consequences result from the 'main problem'. Reducing aquatic ecosystems' services and functions or excess nutrients can result in many interlinking consequences, mainly environmental (loss of biodiversity, fish mortality, chemical water alteration), economic (impact on commercial fishing, tourism activity) and social (impact on human activities that depend on fishing, bioaccumulations with toxins).

The controls measures positioned on the left are the solutions preventing the issue from occurring, and can further reduce the severity of the consequences, meanwhile *the mitigation measures* column represent the measures which should be considered to recover, once the algal bloom event took place. Both control and mitigation measures use a mixture of legislation, water management plans and changes in behavior and mentalities to manage algal bloom.

The escalation factors can be considered as the restrictive ones that can damage the efficiency of both control and mitigation measures, such as institutional conflicts regarding the ownership status of water bodies that puts barriers to the implementation of control or mitigation measures, or appropriate governance implementation by taking into account current local conditions.

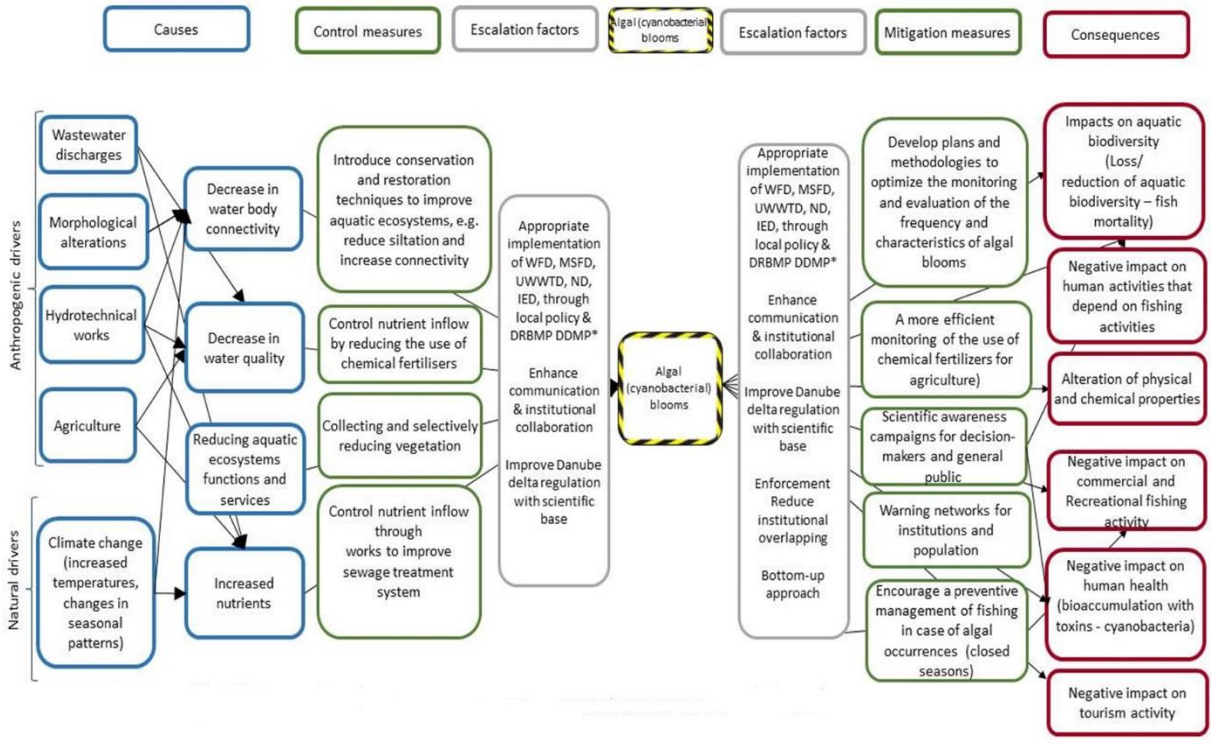

Figure 6. Bow-tie diagram for algal (cyanobacterial) blooms in Danube delta case, based on based on stakeholder process (WFD-Water Framework Directive, MSFD - The EU Marine Strategy Framework Directive, UWWTD - EU Urban Waste Water Treatment Directive, ND – Nitrates Directive, IED – Directive on Industrial Emissions, DRBMP – Danube River Basin Management Plan, DDMP – Danube Delta Management Plan)

The bow-tie conceptual model is highlighting in details the control and mitigation measures to be addressed for the found shortcomings, measures that use a mixture of legislation, water management plans and changes in behavior and mentalities needed to improve the current situation (Figure 7).

Key to control and mitigation measures

Ranked high importance

1. ecological reconstruction of aquatic ecosystems: increase connectivity between water bodies to reduce siltation
2. increase connectivity: dredging must be done to maintain water flows for water oxygenation
3. water management: develop planning approaches and methodologies to optimise the monitoring of algal blooms
4. water management: develop monitoring systems of the use of chemical fertilisers
5. regional and local legislation: enforce nutrient action plans to control nutrient inflow from agriculture and sewage systems

Ranked with medium importance

6. capacity building (academic, public, NGO's collaboration) and awareness about nutrient pollution and its association with algal blooms among decision makers and general public
7. science: focus should be on enhancing collaboration between institutions to develop and implement Early Warning System prototype
8. technology: collecting and selectively reducing vegetation
9. technology: improvement in the treatment of sewage

Ranked with low importance

. *10. Fisheries management:* closed seasons of fishing in case of algal bloom occurrence

Figure 7. Key to control and mitigation measures for algal blooms in Danube Delta aquatic ecosystems

Policy recommendations

✓ a specific action plan addressing the risks associated with impact of algal blooms on aquatic ecosystems, accompanied with mitigation and adaptation measures need to be developed by the biosphere reserve authority in collaboration with other decision – makers and stakeholders in order to improve ecological conditions;
✓ since governance is more top-down regulated, there is the urgent need for legislative review by taking into account current local conditions;
✓ when considering algal blooms management, questionnaires responses emphasized the importance that management measures need to fit local needs and consider spatial and seasonal water quality management;
✓ in order to converting the river ecosystems into more bio-balanced ones it is necessary to streamline and simplify certain administrative procedures and reduce institutional overlapping when it comes to natural resource management and algal blooms management, a true obstacle in achieving ecological goals;
✓ development of a legislative and management framework that regulates and controls nutrient inflow in aquatic ecosystems;
✓ a better transposition and implementation at national level of European Directives;
✓ strengthening the linkage between Danube Delta and Danube River policymakers to adopt special legislative changes to reduce algal blooms all over the Danube Basin.

CONCLUSIONS AND RECOMMENDATIONS

The research findings regarding stakeholders' limited knowledge and their lack of interest in algal bloom and cyanobacterial blooms occurring in aquatic ecosystems of Danube Delta should attract the attention of the biosphere reserve management. As stated by several group of stakeholders, this is mainly due to lack of institutional cooperation and communication within the case study area.

Several national and local institutions have overlapping roles when it comes to natural resource management. These overlapping situations can make it very difficult to agree upon and implement important management decisions related to algal blooms.

Due to the strong linkage between Danube Delta and Danube River policymakers should exploit at local and regional level actions that can increase the institutional cooperation that is needed to mitigate the effect of cyanobacteria blooms and its potential toxic effect on aquatic diversity. Those actions must be addressed to reducing algal blooms all over the Danube Basin.

Regarding policies and Directives of the EU, stakeholders unanimously considered them important in their role in combating algal blooms in aquatic Ecosystems of Danube Delta, yet they show a certain lack of confidence in directives, considering that the current policies and strategies for managing the algal blooms require a better transposition and implementation at national level.

A sustainable way of action for algal blooms in aquatic ecosystems in Danube Delta has to be supported by strong cooperation and communication among stakeholders at all levels of governance, mainly strengthening the linkage between Danube Delta and Danube River policymakers to reduce algal blooms all over the Danube Basin.

Furthermore, there is a need for building awareness at local and regional levels among stakeholders and general public about this worldwide phenomenon but also both national and international policy decisions related to it. One deficit for algal bloom management in the area is lack of harmonization of interests and priorities among stakeholders and institutional overlapping which can make it very difficult to agree upon and implement important management decisions. Also, the capacity and effectiveness nature resource manager and other stakeholders need to be strengthened in order to improve aquatic ecological conditions. Strengthening steps could include both technical and institutional (human resources) aspects.

The results could be used in other aquatic ecosystems to help plan and mitigate algal blooms in the future, by having into consideration:

- the need for legislative review by taking into account current local conditions (bottom-up approach)
- institutional overlapping which might hinder conservation efforts - an obstacle to achieving the goals of ecological conservation and environmentally sustainable development
- policymakers should exploit at local and regional level actions that can increase the institutional cooperation that is needed to mitigate the effect of cyanobacterial blooms and its potential toxic effect on aquatic biodiversity. Those actions must be addressed to reducing algal blooms all over the Danube Basin.

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