DANube macroregion: Capacity building and Excellence in River Systems (basin, delta and sea)

- DANCERS -

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Strategic Research and Innovation Agenda in the Danube – Danube Delta - Black Sea Macrosystem

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EXECUTIVE SUMMARY

The DANCERS project through a combination of stakeholder engagement, review of historical projects and programmes and state of the art science has built upon the EUSDR to develop a Strategic Research and Innovation Agenda (SRIA) to focus scientific effort across the entire Danube – Danube Delta – Black Sea (DBS) system. The added value of the implementation of this agenda will be a move towards sustainable development resulting from scientifically grounded and informed decision-based – both integrated across disciplines and the full extent of the DBS system.

The development of the SRIA was achieved using a cross-disciplinary team of scientists who through a series of workshops worked directly with stakeholders from research and education, government and industry to identify their needs and the current opportunities. This was used to inform the scientific research direction to derive current state of the art and this knowledge in conjunction with a review of historical and current research projects and programmes was utilised to effectively shape the SRIA.

The document introduces the issues and challenges involved (Section 1), outlines the approaches used to develop the SRIA (Section 2) and the corresponding results (Section 3) were used to identify twenty one research topics. All of these correlated with at least two or more of the EUSDR Pillars (Connect the Region, Protecting the Environment, Building Prosperity, Strengthening the Region) and are detailed in Section 4.

Overall conclusions on the direction of Research and Innovation in the DBS System and the relevance and potential benefits of implementing research under one or all of the suggested SRIA research topics is included in the list on Section 5.

1.0 INTRODUCTION

This document outlines the processes involved in determining a research agenda for the Danube – Black Sea (DBS) Region and the proposed agenda that was derived from the DANCERS partnership in consultation with regional stakeholders. The rationale behind developing an agenda for research and innovation was to ensure that the future research and innovation priorities in the region would align with EU research funding policy and priorities set by the EUSDR, meet the needs of stakeholders, identified any new opportunities to expand at pan-European and global levels. Such alignment is essential if future research and innovation is to support sustainable development and ensure that the DBS System can achieve good ecological / environmental status whilst simultaneously realising social and economic expectations in the region.

1.1 Background

Globally**,** freshwater and marine systems and their transition zones – including deltas and shallow seas - are experiencing growing environmental problems, as a result of increasing population pressure and associated development, presenting major challenges to balancing economic and societal needs with sustainable environmental management. In Europe, pollution from agricultural and urban centers and hydraulic engineering for navigation, hydropower production and flood protection are widely recognised to inhibit the achievement of good ecological / environmental status in coastal and inland waters. At the same time, economic sectors such as shipping/navigation and hydroelectric power generation depend on minimum water volumes for their functioning while significantly altering complex dynamics associated with sediment movement, water flow, and increasing the potential for alien species introduction. These pressures act in concert with climate change, in which current models anticipate crucial changes in extreme weather conditions (Döll and Zhang, 2010) and the alteration of the water regime of freshwater and oceanic systems (Doney et al. 2012; Ruckelshaus et al. 2013). These problems must be solved in an integrated manner in order to best develop sustainable solutions that balance economic and societal needs with environmental protection. To a significant extent, our approach to problems such as these has been discipline- specific. Considerably more cross-disciplinary research is essential to address current and emerging environmental problems to deliver sustainable and innovative solutions to major societal challenges, including environmental protection and job creation (e.g. EU Blue Growth).

The DBS region has a complex recent geopolitical history and includes some of the richest and poorest areas in Europe. With a basin >800,000 km^2 in area and a catchment that spans 19 countries (Figure 1), the Danube River is the most international river in the world, connecting people with differing economic, social, cultural, political and environmental heritages. As a result, there are many challenges in environmental management and in, for example, balancing habitat conservation and restoration (e.g.the EU 2020 Biodiversity targets) whilst achieving economic development. The complexity of the basin is further exemplified by the fact that not all of the basin countries are in the European Union (11 of them include Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland, Slovakia, Slovenia, Romania); however, the 8 non-Member States (Albania, Bosnia and Herzegovina, Macedonia, Moldova, Montenegro, Serbia, Switzerland, Ukraine) are members of the International Commission for the Protection of the Danube River (ICPDR) and committed to implementation of the EU Water Framework Directive. The Black Sea (>430,000 km2 in area) is also of high ecological importance as a semi-enclosed sea, whose salinity and vertical stratification creates the largest anoxic basin in the world. This structure is largely controlled by freshwater inputs from the major rivers, of which the Danube is the largest. Further complicating the ecological management of the Black Sea is its international

setting, surrounded by 6 countries: Bulgaria, Georgia, Romania, the Russian Federation, Turkey and the Ukraine.

Figure 1: The Danube – Black Sea System

Within this context, the EU Coordination and Support Action (CSA) project DANCERS (DANube macro-region: Capacity building and Excellence in River Systems (basin, delta and sea) seeks to mobilize actors and resources from public and private sources to increase investment and research and innovation to enhance river-delta-sea management in the Danube macro region (covering also the Danube Delta and the Black Sea).

This Strategic Research and Innovation Agenda (SRIA) was developed with the perspective of the entire DBS System in order to achieve integrated approach to basin management. The needs of policy-makers and industry were considered when identifying science, infrastructural, and educational targets needed to achieve these goals. This document outlines the scientific and innovation agenda, while the infrastructural and education agendas were considered under separate work tasks.

Significant pressures were previously identified in the Danube Region by ICPDR and formulated in the DRB management plan (ICPDR 2009) and the updated version (ICPDR 2015), with respect to water quality, hydromorphological alterations, river and habitat continuity interruption, hydrological alteration, and newly emerging management issues such as invasive alien species (IAS), the protection of all sturgeon species and increasing the adaption capacity to climate change effects. The EUSDR developed to address a wide range of regional issues, grouped issues under four pillars and eleven priority areas (Table 1, below):

Connect the Region	Protecting the Environment	Building Prosperity	Strengthening the Region
Priority Area (PA) 01: Mobility	**Priority Area (PA) 04:** Water Quality	**Priority Area (PA) 07:** Knowledge Society	**Priority Area (PA) 10:** Institutional capacity and cooperation
PA 02: Energy	**PA 05:** Environmental Risks	**PA 08:** Competitiveness	**PA 11:** Security
PA 03: Culture & Tourism	**PA 06:** Biodiversity, landscapes, quality of air and soils	**PA 09:** People & Skills	

Table 1: EUSDR Pillars and Priority Areas

This provided the starting point for DANCERS, which is envisaged as a supporting action to help achieve the environmental objectives for the DBS Region. Specifically, DANCERS seeks to

develop, with expert and stakeholder involvement, a strategic agenda in research and innovation, infrastructure, and education that will achieve sustainable economic growth while maintaining ecological integrity of the **DBS System**.

To this end, DANCERS Workpackage 3 [Agenda Development] was tasked to build upon outputs from Workpackages 1 [Mapping knowledge gaps] and 2 [Understanding stakeholder needs] in order to work with stakeholders in order to produce three discrete but interconnected outputs:
(1) A regional, Strategic Research and Innovation Agenda (SRIA) to provide scientific direction needed for integrated management of river-delta-sea systems in the Danube Region.
(2) A detailed plan for new investments in integrated research infrastructure that builds on existing infrastructure in the natural sciences across the Danube – Danube Delta – Black Sea system and with the wider European domain.
(3) Human capital development programme to build capacity for the proposed integrated management approach, including recommendations for educational programs at the technical, as well as undergraduate, MSc, PhD and postdoctoral levels.

The subsequent sections of this document detail the development of the Strategic Research and Innovation Agenda. It is complimented by two other documents, publicly available from DANCERS (Deliverables 3.2 Detailed plans and concepts for a new regional research infrastructure and 3.3 Human capital development programme), which describe the development of the detailed new infrastructure plan and the human capital development programme respectively

1.2 The Need for the Strategic Research and Innovation Agenda (SRIA)

The SRIA aims to contribute to achieve the EU Vision for the Danube Region namely to connect the region while increasing prosperity and protecting the environment [EUSDR, H2020]. The EUSDR Vision, as illustrated in Table 1, suggests strategic objectives for any prioritization process to focus on reducing fragmentation by spreading excellence and on growth by ensuring sustainability. It is obviously essential to develop and present future research and innovation priorities in a comprehensive using a holistic and integrated approach. These should build upon existing initiatives, capacities and capabilities and any new proposed development should be linked to missing landscape or identified niches and resources available for environmental research and innovation in the aquatic field.

Since FP7 DANCERS commenced, two major initiatives for new research infrastructures have been developed: a) Danube River REsearch And MAnagement (DREAM); and b). International Centre for Advanced Studies on River-Sea systems (DANUBIUS-RI). These two projects have the status of Flagship Projects in the EUSDR (Priority Action 7). It is the intention that these two projects are synergistic and can both tackle aspects of research outlined in the SRIA with complementary distributed research infrastructures., which clustered together are complementary in scopes, responsibilities and research agendas.

SRIA will make an important contribution to public policies, environmental regulation and management of public programmes and public-private initiatives in the region and within the EU. In order to achieve this, the SRIA should improve focus investments and policies to institutional and infrastructural frameworks (see Deliverable 3.2) that enable improved educational systems (see Deliverable 3.3) and entrepreneurial culture in the environmental sector.

2.0 APPROACH

Development of the Strategic Research and Innovation Agenda (SRIA) was produced by the DANCERS Project Partnership (see Table 2, below) in consultation with a range of experts and stakeholders from the Danube Region with a diverse backgrounds across the scientific research, education, government and industry sectors.

INSTITUTE	COUNTRY	FIELD OF EXPERTISE
Institutul National De Cercetare-Dezvoltare Pentru Geologie Si Geoecologie Marina (GeoEcoMar)	Romania	Geology, sedimentology and gephysics of the Danube River – Danube Delta – coast – Black Sea ICZM Global climate change
Consorzio Per La Gestione Del Centro Di Coordinamento Delle Attivita Di Ricerca Inerenti Il Sistema Lagunare Di Venezia (Co.Ri.La)	Italy	Environmental Impacts Geomorphology Biodiversity
Zentrum Fuer Soziale Innovation (Zsi)	Austria	Network management, Policy dialogue, Comms & dissemination
Institutul National De Cercetare Dezvoltare Pentru Stiinte Biologice Romania	Romania	Biodiversity Environment risk Biology & ecology
Wassercluster Lunz - Biologische Station Gmbh (WCL)	Austria	Ecosystem science Environment-society Interface challenges
Universitaet Fuer BodenKultur Wien (BoKu)	Austria	Natural sciences, Engineering Economics,
Centre Internacional d'Investigació dels Recursos Costaners (CIIRC)	Spain	Hydrodynamics Water quality, Coastal morphodynamics
Hellenic Centre For Marine Research	Greece	Oceanography/Hydrology Marine Biology Fisheries / Aquaculture
The University Of Stirling (with Birmingham and Hull Universities, and the Scottish Universities Environmental Research Centre)	UK	Earth observation and analytical techniques, Human behaviours, Biological, environmental and aquatic systems
University College Cork (UCC)	Ireland	Governance Geomorphology Aquatic environments
Bundesanstalt Fuer Gewaesserkunde	Germany	Quantitative hydrology, Ecology
Institut Francais De Recherche Pour L'exploitation De La Mer (IFREMER)	France	Ocean Resources Marine Monitoring Sustainable development
United Nations Educational, Scientific And Cultural Organization –Institute of Water Education (UNESCO-IHE)	Netherlands	Hydrological modelling Nutrient impacts, and Basin Management
Univerzitet U Novom Sadu	Serbia	Stakeholder identification Web-based tools Gap analysis
Szechenyi Istvan University	Hungary	Data collection & analysis Integrated management of rivers-deltas-seas.

Table 2: Partners in the DANCERS Consortium

The process involved three key steps (1) Mapping national, EU and international research/initiatives on river-delta-sea systems (2) Understanding the needs in knowledge transfer among science, economy and policy makers (3) Reviewing the State of the Art within River-Delta-Sea Systems. The approach adopted is detailed in the following sections.

2.1 Mapping national, EU and international research/initiatives on river-delta-sea systems

The Danube has been the focus of a long series of research programmes dedicated to river, delta and coastal management, funded at national and European scales (Feldbacher et al. Submitted). Similarly, the Danube Region has a long history of cooperation at institutional levels and this continues. Participation, however, has tended to be unevenly distributed across the region with some countries being significantly more active than others (Achtnicht et al. 2014) and has rarely addressed the needs of the whole basin in an integrated manner, to cover also the coastal sea.

Integrated water resource management (IWRM) recognizes the interconnectedness of social, economic, hydrological and ecological needs in river basins and associated coastal zones. Thus, the IWRM approach uses the basin as the managed unit, and recognizes the dynamic relationships between stakeholders and central governments who must work together to meet sustainable development goals. Thus, IWRM aims to balance the needs of stakeholders with those of the environment. In principle, it achieves this through the coordination of management across sectors and the active engagement of stakeholders and policy-makers at multiple scales, including local, national, and international (Global Water Partnership, 2009)l. This is the philosophy behind the SRIA for the DBS region.

In addition to a philosophy of IWRM, central to the development of the research strategy was also the assessment of relevant research initiatives that have already taken place within the Danube Region. A metadatabase was developed, which compiled information on environmental management related projects undertaken within the Danube Region over the last 20 years (Feldbacher et al. submitted) This provided the basis to assess: (i) the temporal and spatial distribution of research projects; (ii) the dominant funding institutions; (iii) the thematic priorities for research projects in the Danube Region. It also provided the context in which to discuss best practice in water management in relation to the International Commission for the Protection of the Danube River (ICPDR) and the cyclic nature of recent research funding initiatives. The detail of the methodology and results is presented in Feldbacher et al. (submitted).

The overarching aim in producing an agenda for research and innovation was to review and evaluate the outcomes and uptake of existing and on-going research within regional, EU and international scientific projects and initiatives that concern riverine, delta and sea systems. Specifically, the gaps between science and policy were critically reviewed, particularly with a view on how research at different scales (e.g. local, regional, nation-state) or in specific domains (e.g. river basin or delta or sea) are integrated and whether research to date has robustly informed society and policy. Additionally, a range of international projects that were designed to support and inform policy decisions in key industrial sectors were more closely examined to determine their impact on policy-makers and the relevant industrial sector. These included aquaculture, fisheries, energy, navigation, coastal protection and aggregate extraction (e.g. CONSCIENCE (EU FP6), COEXIST, CORALFISH, MESMA (EU FP7)). The

methods, tools and approaches adopted as a result of the research were assessed in terms of their efficacy and adaptability to a range of environments and geographical locations. Key challenges, such as climate change adaptation, and innovative approaches designed to mainstream adaptation into policy were also investigated using the outcomes from a range of projects.

The results of the analysis delivered a range of information concerning the experiences of both successful and unsuccessful attempts to engage industry and policy-makers with the products of science. Overall, where approaches have been unsuccessful in gaining societal, industrial and political buy-in, knowledge on the reasons behind this failure are outlined. This knowledge is essential in order to avoid a replication of the outcomes when developing and applying such approaches in the development of tools in the Danube Region. It is also vital if the axes of challenges facing the region are to be met effectively and to achieve a reduction in the science / policy gap that currently exists on the Danube Region.

2.2 Understanding the needs in knowledge transfer among science, economy and policy makers.

In addition to the analysis of the last 20 years of research funding in the DBS- system, stakeholder views were solicited regarding the strengths and weaknesses of existing innovation and research. Separate workshops were conducted with representatives of the three main stakeholder communities: (1) science and education; (2) industry; and (3) policy makers, decision makers, and administrators. The outcomes from each workshop were combined and synthesized in an integrated and comprehensive Strength, Weakness Opportunities Threat (SWOT) analysis in a fourth workshop that included all partners and representatives from the stakeholder groups. A knowledge matrix was developed summarizing the findings according to three main pillars of research and development: (i) Science and Innovation agenda; (ii) Research Infrastructures; and (iii) Human Capital. The knowledge matrix identifies what is perceived to be working well, what is required, and what needs to be strengthened in the DBS System.

The workshops were supplemented by an online questionnaire (http://heras.geoecomar.ro/vot/index.php/776625/lang-en), which was designed to obtain the opinions of relevant stakeholders with regard to priorities for basic and applied environmental research in the field of water research in the DBS System. The questionnaire considers both current and future activities that will be required under Europe 2020 strategy and the strongly related HORIZON 2020 (The EU Framework Programme for Research and Innovation). The aim of the survey was to analyse and assess the current environmental research needs in the region in order to identify a framework for water research related activities. These are grouped under the following three Research and Development pillars to identify a framework for future research cooperation at regional, national and multinational joint efforts:

- Strategic Research Agenda;
- Research Infrastructures;
- Education and Training Agenda.

2.3 Reviewing the State of the Art within River-Delta-Sea Systems

A series of review papers were invited for a special issue of the international journal *Science of the Total Environment* to identify the state of the art and best practice in river-delta-sea systems, with the DBS as a case study. Physical, chemical and biological aspects of river delta sea systems, their observation, and the social and economic aspects including educational requirements were considered. These articles

used the DBS as case study and put it in context with other similar systems world-wide and described the value of the DBS as a model system as well elucidated the unique features for the basin worthy of further study. The papers will be peer reviewed by independent international experts through robust editorial channels, and the special issue papers collectively provided the third source of evidence to help define the tools and instruments required to boost knowledge transfer, enhance Research and Innovation cooperation for the environment at the more integrated strategic level.

Initial dialogue was facilitated during the Workshop with the scientific community, where researchers from across the Danube Region and Europe candidly discussed the need for an Agenda and the current and potential future direction for research and innovation. This provided the opportunity to distil knowledge from an array of key experts with skill ranging from biomolecular/biochemical level through stable- and radioisotope tracing techniques, physical- and ecological-process characterisation to specialists in quantitative earth observation. In addition to their subject fields, the assembled participants possessed relevant experience within the policy arena, conservation and environmental management, regulation and industry engagement. This was supplemented by the questionnaire described above which sought to elicit the views of workshop participants and in a wider audience through on-line deployment. The outcomes from the Workshop and the responses from the questionnaire were then subject to further interrogation as part of the SWOT analysis conducted at the joint synthesis workshop which considered the Research and Innovation, and also the infrastructure and educational, needs for the Danube Region.

This analysis and the earlier outcomes and responses were then reviewed in the context of current (and proposed) research and innovation initiatives both from within the Danube (e.g. as a potential focus topic for the Danube Region Research and Innovation Fund-DRRIF) and the wider Europe Region (e.g. Horizon 2020, Joint Programme Initiatives – Water, Oceans) to inform the final development of the Agenda.

3.0 RESEARCH AND INNOVATION CHALLENGES AND NEEDS

The challenges in research and innovation based on the review of historical research projects and programmes, the workshops and associated questionnaire are detailed in Sections 3.1 and 3.2. These are complemented by consideration of the state of the art and the needs in the DBS System in Sections 3.3 and 3.4.

3.1. Review of historical research projects and programmes

A significant number of projects (478) were collated onto an on-line database - https://wcl-geo.boku.ac.at/geonetwork/srv/eng/search - and an overview of the projects is given in Table 3 below. This was utilised to determine the focus, both spatially and sectorally, of research projects and to catalogue their scientific output.

Records in DANCERS metadatabase	**No of projects**
Total (Status May 2015)	**478**
Composition:	
returned questionnaires	263
direct entries into metadatabase	252
Deleted:	
duplicates/multiples/not of interest	37
Geographic location	
Upper Danube	203
Middle Danube	143
Lower Danube	167
Danube delta	137
Danube coastal zone	50
Western Black Sea	117
Core category	
Scientific Agenda	280
Research Infrastructure	48
Human Capital	50
Thematic Area	
Life Sciences	167
Earth Sciences	148
Socio-Economics	99
Multidisciplinary	194
Funding Type	
EC - DG R&I	98
EC-Other	46
Structural Funds (ERDF, IPA, Cohesion)	50
National R&D	150
National Other (environmental monitoring, maintenance of navigation)	49
International (UN and other)	51
Other	34
Programme Type	
Environmental monitoring and measurements	170
Maintenance of navigation	37
Other	77
Research - Human Resources&Education	14
Research - scientific ideas and scientific cooperation	56
Research - development and upgrading of research infrastructure	154

Table 3: Projects uploaded to the DANCERS metadatabase

An analysis of the data shows apparent disparate national research efforts in the Basin, and, though there were noted exceptions, a limited amount of stakeholder involvement. Since stakeholder involvement is a central philosophy of IWRM, projects need to include this in

order to address the complex dynamics along the continuum of the River-Delta-Sea system in an integrated way. The SRIA will build on results and relationships from projects identified as best practice to ensure increased stakeholder involvement in scientific projects and programmes.

The current challenges in environment and economic development in the Danube support the need to consider the DBS system as a single and integrated macro-system linking source to sink. This has been recognized for several decades by major international organizations – including the International Committee for the Protection of the Danube River (ICPDR - http://www.icpdr.org/main) and the Commission on the Protection against Pollution of the Black Sea (http://www.blacksea-commission.org), but few initiatives, if any, cover the entire system together. Some of these initiatives are described below, and it is the aim of the SRIA to build on these in order to further integrate the DBS system.

Danube Region

The European Union Strategy for the Danube Region (EUSDR) aims to implement an integrative policy in the region and enhance cross-border cooperation to achieve the overarching EU goal of sustainability (COM 400, 2009). The objectives of EUSDR are fourfold: (i) connectivity; (ii) protecting the environment; (iii) building prosperity; and (iv) strengthening the Danube Region.

This strategy, for the first time, considers environmental protection in the Danube Region alongside social and economic policies. The EUSDR was adopted by the European Commission in June 2011, and comprises 11 Priority Areas:

1. To improve mobility and inter-modality
2. To encourage more sustainable energy
3. To promote culture and tourism, people to people contacts
4. To restore and maintain the quality of water
5. To manage environmental risks
6. To preserve biodiversity, landscapes and the quality of air and soils
7. To develop the knowledge society
8. To support the competitiveness of enterprises
9. To invest in people and skills
10. To step up institutional capacity and cooperation and
11. To work together to tackle security and organised crime.

The existence of the EUSDR is a major catalyst for the better focus of the efforts made by the funding agencies, in a way that allows the fulfillment of these Priority Areas. DANCERS final Deliverables are all documents which help the implementation of these strategic goals into reality, in the specific field of Integrated River Basin Management.

During the DANCERS project lifetime a series of major initiatives appeared and were granted special status in the EUSDR, hence the need to take into account these initiatives and build on them. In Priority Area 7, four projects were granted the status of Flagship Projects for the Danube Region, meaning that they were accepted by the EUSDR signatory governments as having a strategic political and practical importance. These were DRRIF (Danube Region Research and Innovation Fund), Danube Future, DREAM and DANUBIUS-RI.

DRRIF's primary objective is to identify, mobilize and distribute funds in order to support the development of research and innovation activities in the countries of the Danube Region (http://groupspaces.com/KnowledgeSociety/pages/workinggroup3drrif). The existence of DRIFF may support the more effective and quicker implementation of the DANCERS Strategic Research and Innovation Agenda, due to the similar goals to strengthen the knowledge based

society in the Danube Region – with specific focus on river basin management which covers also the sea and coastal areas. It could take on the results and findings of the Strategic Research and Innovation Agenda noting that currently the DRRIF establishment is supported by a feasibility study commisioned under PA 7 with a first draft of the concept scheduled for mid 2015.

Danube Future (http://www.danubefuture.eu/) is another Flagship Project in the EUSDR which groups together the major universities and has as main objective (http://www.danubefuture.eu/) bringing young scholars to the forefront of international research and hence developing the strengths of higher education in the region in internationally competitive contexts. The DANCERS D3.3. document will be made available to Danube Future as a ready made material to reach the Flagship Project goal in the field of integrated basin management.

In Priority Area 7, of the EUSDR, which is to create a knowledge society, one specific action is *"To strengthen the capacities of research infrastructure".* This envisages a secondary action: *"To establish joint international research centres for advanced studies*" to attract world-class scientists and provide modern research infrastructure. Two EUSDR Flagship Projects in Priority Area 7 are major Research Infrastructure projects dedicated to address this action, DREAM and DANUBIUS-RI. Both DREAM and DANUBIUS-RI Flagship Research Infrastructure projects are complementary and address in a hollistic manner the integrated management of the DBS System. DREAM is focussing mainly on strengthening the existing capabilities and developing of new ones within the Region in order to offer solutions to critical activities such as hydropower and navigation, while DANUBIUS-RI aims to be the pan-European distributed RI dealing with the integrated management of river-sea systems in an interdisciplinary manner and to contribute to better integrating the Danube Region with the other river-sea systems in the European Union. These projects were granted the Flagship status since the beginning of the DANCERS project, so a project consortium decision was made to develop Deliverable 3.2. as a plan to cluster the facilities of the 2 RIs.

Besides the Flagship Projects, there are other major initiatives and EU funded projects dedicated to the Danube Region. The most relevant is Danube-INCO.NET, an FP7 funded coordination and support action for the official EU Strategy for the Danube Region (EUSDR) in the field of research and innovation (R&I). Danube-INCO.NET focuses mainly on two of the Priority Areas (PA): PA 7 'Knowledge Society' and PA 8 'Competitiveness'. The project supports the policy dialogue, creates networks, and analyses and supports R&I activities. DANCERS has been interconnected with the Danube-INCO-NET since its beginning, as the latter coordinating team is member of the DANCERS consortium and the DANCERS coordinator is member of the Strategic Advisory Board of Danube INCO NET .

Danube River Basin wide coordination activities related to water issues

In 1985, the Danube countries adopted the Bucharest Declaration on Water Management of the Danube River. In 1991, these countries and the EC issued the Danube River Protection Convention (DRPC) which, together with the Water Framework Directive (WFD) of the European Union, became the major legal instrument for cooperative cross-boundary water management in the Danube Basin. In September 1991, 24 countries, GEF/UNDP, EC and NGOs jointly agreed to set up the Environmental Programme for the Danube Basin (EPDRB). In 1994, the DRPC was signed by 11 countries (Germany, Austria, Czech Republic, Slovakia, Hungary, Croatia, Slovenia, Bulgaria, Romania, Republic of Moldova and the Ukraine) and European Commission. The DRPC came into force on October 22, 1998. By 2005, all of the Danube Basin countries (including Serbia, Montenegro, Bosnia and Herzegovina) had become Parties to the DRPC.

To implement the stipulations of DRPC, and EPDRB as well as to ensure the sustainable and equitable management of water resources in the Danube Basin, the International Commission for the Protection of the Danube River (ICPDR) was established on October 27, 1998. The ICPDR comprises delegations of all Contracting Parties to the DRPC, and representatives of ministries, civil society and the scientific community. Technical expert groups provide ICPDR with science-based information and strategic input. At present, over 25 NGOs and other stakeholder groups have observer status in the ICPDR providing further support to Danube River protection.

ICPDR (http://www.icpdr.org/main) has had a critical role in the protection and restoration of the environment in the Danube Region, from the Black Forest mountains to the Danube Delta. It draws and periodically renews the Danube River Basin District Management Plans, where clear measures are formulated with respect to water quality (organic pollution, nutrient pollution, hazardous substances pollution, etc.), hydromorphological alterations, river and habitat continuity interruption, hydrological alteration. Hence DANCERS Strategic Research and Innovation Agenda actively supports the ICPDR activities towards implementation of the environmental objectives for the Danube Region.

The Global Environment Facility (GEF), established in 1991, helps countries to fund and carry out projects that contribute to global environment protection. The GEF International Waters (IW) targets trans-boundary water systems. The Danube Basin was for GEF-IW the first IW regional programme that was funded in 1992. The United Nations Development Programme (UNDP), established in the region before 1989, has facilitated GEF projects supporting the reduction of trans-boundary nutrient pollution in the Danube River Basin.

The European Union has been the major force in the drive for Integrated River Basin Management (IRBM) in the Danube since 1991. The European Commission is an original Contracting Party to the DRPC and contributes substantially to the management of the Danube River Basin. The EU environmental legislation includes directives for biodiversity protection (such as Birds and Habitats directives, andthe establishment of Natura 2000 network of protected areas) and sets water quality targets for drinking and bathing water, emission limits, urban waste water treatment, etc. One of the most comprehensive directive is the Water Framework Directive which considers the aquatic ecosystems as part of river-basin. It covers surface and groundwater, rivers, lakes, transitional and coastal ecosystems and aims to achieve a “good status” for all EU water bodies, setting objectives for water protection well into the 21st century. The objectives and the Joint Program of Measures to achieve this status are included in the Danube River Basin Management Plan (ICPDR, 2009) and will be revised every six years in order to allow an adaptive management. It requires cross-border cooperation and encourages multi-stakeholder cooperation as well as cooperation with NGOs and local communities.

One example of efforts to engage stakeholders is through an EU Task Force termed DABLAS (DAnube BLAck Sea), which was charged with improving communication between appropriate stakeholders throughout the entire macro-system. DABLAS was developed in response to an EC Communication adopted in 2001 (COM/2001/615 final), which highlighted priority actions required to improve the environmental situation in the region. It was tasked with providing a platform for co-operation to protect water and water-related ecosystems in the DBS System and comprised representatives from countries in the DBS system, the International Commission for the Protection of the River Danube (ICPDR), the Commission on the Protection against Pollution of the Black Sea, International Financing Institutions (IFIs), the EC, interested EU Member States, other bilateral donors and other regional/ international organizations with relevant functions.

The Danube River European Commission was established in 1856 as an international body charged with ensuring and improving international navigation on the lower reaches of the river and the general socio-economic development of the region. The Commission consisted of representatives from the Austria-Hungarian Empire, France, United Kingdom, Prussia, Russia, Sardinia and the Ottoman Empire, and observers from Moldova and Walachia. Later, in 1878, the Kingdom of Romania was accepted as a member of the Danube Commission.

The Commission was transformed in 1938 into the Administration of the Lower Danube, under the coordination and control of Romania. This Administration was closed in 1940 by Germany according to the so called "Vienna Agreement". After the Second World War, in 1954, the Intergovernmental Danube Commission was established in Budapest, Hungary, to enforce the provisions of the International Convention of navigation on the Danube River, signed in 1948 in Belgrade. The current Danube Commission is made up of representatives from the following member states: Austria, Bulgaria, Croatia, Germany, Hungary, Moldova, Romania, the Russian Federation, Serbia, Slovakia, and the Ukraine. In addition, there are four countries with observer status: France, Turkey, the Netherlands and the Czech Republic. The Intergovernmental Danube Commission is charged with ensuring optimal conditions for international navigation on the Danube River. One of the operational organisations of the Commission is the Fluvial Administration of the Lower Danube located in Galati, Romania.

Hydro-biological research of the Danube River and the Danube Delta was implemented as international programmes, with the International Association for Danube Research (IAD) being among the first. The IAD is a scientific NGO founded in 1956 in Vienna by members of the Austrian Academy, Romanian Academy and Bulgarian Academy of Sciences. Subsequently, researchers from other Danube countries joined the IAD, and today the association has partners in 14 countries of the Danube Basin. Since the beginning, , The IAD has worked to ensure data comparability and has facilitated important publications, including the Danube monograph by Liepolt (1967) and others.

Other environmental research and advocacy in the basin is conducted by the NGO, World Wide Fund for Nature (WWF) founded in 1961. It is the largest environmental organization working in the field of nature conservation. It has approximately 5 million members worldwide and an active network in over 100 countries. Through its Danube-Carpathian Programme, the WWF is a leading partner in implementing the preservation, restoration and sustainable management of nature in the Danube Region.

The Black Sea

The Black Sea riparian / estuarine countries (Bulgaria, Georgia, Romania, the Russian Federation, Turkey and the Ukraine) signed in 1992 and ratified in 1994 the Convention on the Protection of the Black Sea against Pollution (*Bucharest Convention*). It has three protocols on the control of land-based sources of pollution, on waste dumping and on joint action in the case of accidents such as oil spills) and a Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea. These protocols (from 1996, updated in 2002 and 2009) are implemented by the Commission on the Protection of the Black Sea Against Pollution (*the Black Sea Commission or BSC*) along with a Permanent Secretariat, (established in 2004) which act as an intergovernmental coordination body.

The main challenges of the Black Sea Convention are: to combat pollution from land-based sources and from maritime transport, to achieve sustainable management of marine living resources and to pursue sustainable human development in the region.

Among the main general environmental policy measures of the Convention are the following:

- Pollution reduction from rivers, priority pollution sources, vessels;

- Conservation of biological diversity, expansion of protected areas, promotion of sustainable fisheries;
- Introduction of Integrated Coastal Zone Management (ICZM), promotion of Environmental Impact Assessment (EIA), ecologically sound technologies, public involvement in environmental decision making, green tourism and sustainable livelihood; and
- Regulatory and legal tools.

The updated (2009) version of the Black Sea Strategic Action Plan (BS SAP) describes the policy actions required to meet the major environmental challenges now facing the Black Sea, and includes a series of management targets. A Black Sea Integrated Monitoring and Assessment Programme (BSIMAP) was developed.

The Danube Delta Biosphere Reserve

When the Danube Delta Biosphere Reserve (DDBR) was established in 1990, the Danube Delta Biosphere Reserve Authority (DDBRA), a public institution under the coordination of the Romanian Ministry of Environment, was created. It is an organization charged with the following responsibilities:

- Conservation and protection of the natural heritage of national interest in the Danube Delta Biosphere Reserve;
- Encouragement of sustainable use of the natural resources; and
- Provision of support, based on the results of research, for management, education, training and services.

Some of the main attributions of DDBRA are:

- To assess the ecological status of the natural heritage and to take the necessary measures for biodiversity conservation and protection;
- To establish and implement ecological reconstruction measures of the deltaic ecosystems and to decide on adequate legal measures for the protection, improvement and restoration of environmental quality;
- To manage public land of national interest within the DDBR and to take measures to restore and protect its physical and geographical units;
- To organize and implement the survey and control of the enforcement of and compliance with the legal provisions on the protection measures established in the DDBRA statute;
- To take part in the elaboration and implementation of the plans and programmes for protection of local interests, for conservation of the cultural heritage, as well as for improving the quality of life, civilization and living standards of local people;
- To draw up management objectives for biodiversity conservation and sustainable development in the DDBR (the Management Plan of the DDBRA), to design and to implement the protection plans and programs against flooding and natural calamities;
- To evaluate the status of natural resources and their level of exploitation with respect to their potential for regeneration and ecosystem support capacity.

The Romanian side of the Danube Delta Biosphere Reserve represents 80% of the total surface of the Danube Delta, while the remaining 20% belongs to Ukraine. On the Ukrainian side, the Danube Biosphere Reserve was established in Vilkovo in 1998 as a unit of the National Academy of Sciences of Ukraine. Both Biosphere Reserves cooperate well in the frame of ICPDR and currently they are jointly developing the Management Plan of the Danube Delta.

A significant volume of scientific effort is framed under the Ecosystem Approach but in reality tends to focus on a single sector or concentrate on the Social or Environmental components to the detriment of the Economic considerations (or vice

versa). Numerous tools and approaches have been suggested (reproduced - repackaged in different but similar formats) but whilst there is usually evidence of application during the specific project period it is unclear if these are subsequently mainstreamed into routine policy operations post project. This is not an uncommon problem or new issue and has been highlighted previously. There have, however, been some notable exceptions, for example the WISER project ((www.wiser.eu) whose publications fed into the policy process for WFD. (Hering et al, 2010, Howarth, 2006)

Assessments have been made across the wide range of International and EU policy and legal instruments related to the management of rivers, catchments, delta and coastal sea and their incorporation at national level. These universally suggest that policy advocates the implementation of integrated approaches to planning and management. Paradoxically, research projects themselves tend to be focussed around sectoral interests for example "Aquaculture and Maritime Spatial Planning (MSP)" or "Energy and MSP" rather than MSP for a location or region. This is not surprising and mirrors the divergence between policy and legislation at EU level, as illustrated in Table 4 (below).

	Integrated Maritime Policy (2007)	Maritime Strategy Framework Directive (2008)
Overarching aim	A framework for promoting maritime economic development and integrated management of different activities	A framework for achieving good environmental status of marine waters through the implementation of an ecosystem-based approach
Role of MSP	MSP as a mechanism for balancing different uses of sea space	MSP as a mechanism to apply spatial and temporal distribution controls and in that way to assist in achieving 'good environmental status'
Role of MPAs	Conservation and MPAs as one of the uses of sea space	Conservation through MPAs at the core of its implementation
Legal Power	Soft policy (no legal actions will be taken for non-compliance)	Legally binding (Member States can be taken to the European Court of Justice for non-compliance)
Authority	DG MARE	DG Environment
Approach to Sustainability	Based on 'soft' sustainability	Based on 'hard' sustainability

Table 4: Comparison between the Marine Strategy Framework Directive and Integrated Maritime Policy (Qiu and Jones, 2013).

Research, however, has revealed that the relationship between certain instruments, tools and processes are not yet fully resolved, in terms of both physical and competency e.g. maritime spatial planning and integrated coastal zone management. A large volume of work has critically reviewed the concept and delivery of sustainable development, concluding that integrating objectives for development and growth against the need to safeguard ecological integrity and environmental quality will raise significant challenges for rivers, catchments, delta and coastal sea planning and management communities.

There have been several projects looking at integrating science and policy, notably EU FP6 SPICOSA, has proved viable at a number of locations as evidenced by Hopkins et al. (2011). However, the systems approach advocated can only be implemented if there is political will to support the monitoring effort required to underpin it. As routine monitoring is absent in a large proportion of coastal areas, the appears to be a

need to scientifically determine why society continues to allow major policy decisions to be taken and good decision making to be compromised by the lack of relevant data.

Key policies, notably the Water Framework Directive (WFD - 2000/60/EC) have generated a considerable volume of scientific effort to support of its effective implementation but despite the Directive explicitly citing coastal waters effort tends to be focussed on water quality in the riverine component solely with little consideration of the marine. Integrated Catchment Management is an approach that considers the entire system but in Europe it has been effectively distilled down to water quality in rivers (WFD) with the coastal component dealt with using other instruments (ICZM Protocols, MSFD). This is reflected in the scientific community where the riverine, estuarine and coastal and marine research communities, remain, in general although not exclusively, polarised.

Differentiation between the marine and coastal domains is further reinforced by recent legislative developments, such as the MSP Directive which has limited reference to Integrated Coastal Zone Management (ICZM) and how it relates to MSFD which suggests that politically it is seen not to apply to coastal regions. In addition, research has questioned the role of EU policy in effecting change at the local level needs as it would appear that legislation drafted to improve environmental quality such as the WFD and the MFSD becomes so watered down during the drafting process that its impact in terms of improved management is limited. Terms such as "good ecological status" are ambiguous and this coupled with a lack of prescribed monitoring protocols leads to differing levels of compliance across the EU. This and differing national approaches make the application of inflexible scientific tools and approaches and this is particularly difficult for the trans-boundary management considerations, including science, in the Danube Region which has the added complication of EU and non-EU countries.

Throughout the Danube basin high nutrient loads have resulted in nutrient enrichment of the river and Black Sea. In the eastern part of the basin intensive agriculture, urban settlements and drainage of riparian wetlands provided major impacts until the fall of the Soviet empire in 1989 (Kimstach et al., 1998; Goriup & Goriup, 2015). In the 1970s and 1980s heavy nutrient loads resulted in anoxia and ecological regime shifts in the Black Sea, complicating later, and future, restoration measures (Mee et al., 2005). In the western portion of other basin the EU Common Agriculture Policy (CAP) have, similarly, driven diffuse nutrient loading from land to water. Such loadings in the basin have been estimated by the MONERIS model for nutrient emissions (Schreiber et al., 2005). Tackling diffuse pollution is more complicated and thus a secondary priority, than point source pollution even though it is not necessarily a lesser problem (Artioli et al., 2008; European Commission, 2003; Hering et al., 2010), although regional policy provided in ICPDR (2009) "aspires to reduce the total amount of nutrients entering the Danube and its tributaries to levels consistent with the achievement of good ecological status in the Danube River and to contribute to the restoration of an environmentally sustainable nutrient balance in the Black Sea".

The difficulty is that while tensions between agricultural and environmental policies in Europe remain, cross compliance of WFD targets with economic drivers and ambition for subsidised food production will remain a significant challenge. Recent moves towards further "greening" of the CAP have been met with criticisms from range of bodies (e.g. House of Commons, 2012; Westhoek et al., 2012), and managing the impact of diffuse nutrients will likely remain as major concern into the foreseeable future.

Numerous projects have looked at policy from a range of sectors, coastal protection, aquaculture, environmental management, aggregate extraction (CONSCIENCE, COEXIST, CORALFISH, MESMA) and their outcomes have fed into policy. These do tend, however, to deal with a single sector or at best a chosen sector and its interaction with a selection of other (usually) conflicting uses. It is very difficult to get representation from all the relevant sectors around the table to collectively discuss either their policy issues or their research needs and this reluctance was also evident in DANCERS with limited participation by industry sectors despite the best efforts of project partners.

3.2 Understanding stakeholder views on current status of research and innovation in the Danube

Following the three stakeholder workshops and as a direct output from the synthesis, Table 5 (below) shows the outputs from the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis

Strengths
• Common understanding of existing environmental problems within the Danube Region – among research communities in Danube Region countries • National Funding (to find solutions for national problems) • Existing international cooperation (i.e. in the FPs, SEE TCP, CBC, bilateral programmes, involvement of Researchers in EU or global research initiatives, even if partly focused on river or sea research) • Existing inter- and multidisciplinary studies (even if so far with limited geographical focus, not covering the whole River Basin including the connected sea, or focused on specific topics) • Researchers cooperate with Administrations (successful pilot actions exist and were acknowledged by some representatives of the administrations) • Champions with excellent initiatives exist with business, administrations and the public • Research assistance to water management at national level • Established Messages (like the "Sturgeon 2020" Flagship Project within EUSDR)
Weaknesses
• Stakeholder involvement in research coordination actions is insufficient • In some Danube Region countries there is a limited administrative capacity to absorb research, education and training funds (even though there are countries where almost 100% R&D funds have been committed and used) • Limited number of research providers, not fully exploiting the existing research potential (i.e. contracting always with the same research service providers on national level, not looking for competition) • Lack of an overall perspective of the entire Danube – Black Sea macro-system leading to a non-alignment of research priorities taking into consideration the river basin-delta-sea system • Non-alignment of strategies and instruments /coordination • Lack of sustainable management of natural resources and ecosystems at the scale of the Danube River – Danube Delta – western Black Sea (taking into account of the entire macro-basin). • Not very effective communication of results from researchers to decision makers, administrations and the public. Communication between river basin and coastal – marine end users is limited. • Persistent lack of good intercalibration for WFD parameters in the entire river basin, including the coastal waters (despite the number of initiatives running) • Missing Harmonization of data in the entire basin (including the coastal sea) • Limited stakeholder involvement in many research projects • Limited number of basin – scale initiatives vs. national projects

Opportunities
• Understanding of the full connected system river-delta-sea • Harmonisation of research goals and methodologies to support better research Programmes (Programme logic alignment and quality support, set up of better indicator sets for R&I programmes = structural support to stakeholders of national research and innovation programmes) • Setting the R&I Agenda relevant to EU 2020 Societal Challenges – also covering Horizon 2020 challenges (considering the Water EIP, Water, Climate and Ocean JPIs) • Acknowledged need to support the setup of the Danube River Basin Management Plan with the active involvement of researchers
Threats
• Complex administrative processes at national level endanger further alignment of international or coordinated research actions • Non availability and accessibility of best available technologies (cost factor, information, disclosure by industry) • Non timely response of actors - Urgency for action i.e. climate change • Possible rapid alterations suffered by the European natural habitats (e.g. risk to lose the subject of research) • Segregation of the connected natural system driven by un-coordinated interventions/isolated interventions in the system

Table 5: Outcomes of the Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis for Research and Innovation

Four interlinked Research and Innovation challenges were identified as most relevant to DANCERS, namely:

- **Ecosystem and ecosystem services**
- **Societal Challenges related to integrated water resources management**
- **Human Modifications and the role of blue/green infrastructures**
- **Water Quality**

These are discussed below and were used to inform the review process and the development of papers as detailed in the next section.

Biodiversity, Ecosystem Conservation and Ecosystem Services

The availability and diversity of fish fauna in the world's major river-delta-sea systems has been a major attraction to societies through the centuries (Banaduc et al., submitted). In this regard the DBS system has been equally important in contributing to the high diversity fish fauna and biomass within the Delta region compared with other large European rivers. Whilst many species of fish, including sturgeon, have survived significant environmental change over geological timescales, recent anthropogenic impacts from river regulation, damming, embankments, water abstraction, nutrient pollution (Humborg et al., 1997), heavy metal (Zrnčić et al., 2013) and organic (Kirschner et al., 2009) pollution, riverine landuse change (Wien 2002) and poaching (Liska et al., 2009), have had a major impact on species decline (Sandu, 2013).

The accidental or deliberate introduction of alien species is a key issue affecting present day aquatic habitats. The lack of natural predators has contributed to the invasion of such alien species and their impact on indigenous populations has often been dramatic. The Black Sea is one of the most impacted seas from this point of view, with species like the *Rapana venosa* gasteropod almost extinguishing oyster populations, whilst *Mnemyopsis leidyi* ctenofor has almost destroyed the entire Black Sea fish population from the late 1980s and remain a global threat (Gomoiu & Skolka,

1996). In the Danube River upstream from the delta the critical issue of the alien species was not acknowledged until the second half of the 2000s.

Ecosystem services (ESS) are defined as the benefits people obtain from nature (Millennium Ecosystem Assessment, 2005), the value of such services to humans, and the derived benefits, are reflected in a number of ways: (i) *provisioning services*, i.e., material outputs from ecosystems such as food, fresh water, raw materials and medicinal resources; (ii) *regulating services*, i.e. the services that ecosystems provide by acting as regulators of, for example, climate, pollution; (iii) *cultural services*, the non-material benefits obtained from ecosystems such as recreation and mental and physical health, tourism, aesthetic appreciation and inspiration for culture, art and design, spiritual experience and sense of peace; and, (iv) *supporting services*, which underpin almost all other services and include habitat for species and maintenance of genetic diversity (Farber et al. 2006; Millennium Ecosystem Assessment, 2005; Chee, 2004).

Current and projected trends relating to resource use and climate change will affect the health of ecosystems, and potentially undermine the services they provide, which will in turn have implications for human well-being (Maes et al. 2013). In the case of Europe, pressures on aquatic ecosystems and the services they provide are evidenced by instances of water scarcity in certain regions (e.g. Farmer et al. 2008) and catastrophic flooding in others, coupled with impacts connected, for example, to the over-exploitation of water for agriculture, forestry, aquaculture, urban-living, pollution, and the modification of water-bodies (Water JPI, 2014).

To meet current and future challenges associated with the maintenance and protection of healthy ecosystems, and to ensure appropriate policies and practices are implemented to safeguard human well-being linked to ecosystem services, will require an integrated approach. The *ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way* (Convention on Biological Diversity, 2000). Within Europe, the ecosystem approach to management is central to the delivery of legal instruments to achieve good environmental / ecological status of aquatic resources – namely the Marine Strategy Framework Directive and Water Framework Directive (Farmer et al. 2012; Roxburgh et al. 2012; Borja, 2005).

Ecosystem approach and ecosystem based management (integrated basin management) are interdisciplinary in nature (Water JPI, 2014), foster effective science-policy interaction, and are not constrained by administrative boundaries, or siloed working. In the case of the Danube catchment this implies regional cooperation that harnesses the identified strengths (e.g. existing levels of international cooperation) and opportunities (e.g. excellence in training) and addresses weaknesses (e.g. non-alignment of strategies and instruments) and threats (e.g. barriers to capacity building). A key feature of the ecosystem approach is an emphasis on the value and importance of stakeholder participation, which is significant for two reasons: 1) a multi-stakeholder approach brings together representatives from many disciplines and facilitates a sharing of knowledge and allows for different perspectives to be considered; and, 2) greater stakeholder input has the potential to deliver more informed decision-making at strategic and management levels, and address current and future information and knowledge gaps. The latter is particularly relevant as, while the value of ecosystem services to human well-being is established (Millennium Ecosystem Assessment, 2005), our understanding of the ecosystems, their components and the delivery and maintenance of services is incomplete (Cardinale et al. 2012).

The need for an improved understanding of ecosystem services has been acknowledged at an Europe-wide level, with advances in our understanding having potential to support implementation of EU policy and legal instruments regarding aquatic resources (Water JPI, 2014).

Roxburgh et al. (2012) demonstrated how a network of stakeholders drawn from industry and public sectors collaborated to improve understanding and implementation of the ecosystem approach at a regional scale (Celtic Seas). Similarly, coordinated efforts have been undertaken at regional seas level to implement the ecosystem approach, e.g. Baltic Sea (HELCOM, 2013). As such the DANCERS consortium made a significant effort to engage stakeholders, not only from research and education but with backgrounds in industry and policy making, to inform the development of the Strategic Research and Innovation Agenda.

Societal Challenges related to integrated water resources management

Supporting inclusive, innovative and reflective societies is a main priority toward a sustainable European integration. The need for more innovation is a prerequisite for a renewed understanding of a rapidly changing world. This understanding is supported by strong multidisciplinary approaches, including physical, environmental, social sciences and humanities and information and communication technologies. The European research and innovation strategy (HORIZON 2020) addresses these priorities with its emphasis on excellent science, industrial leadership and tackling societal challenges. Priority to Societal Challenges aims to bring together interdisciplinary resources and knowledge to meet the following challenges:

SC 1: Health, demographic change and wellbeing
SC 2: Food Security, sustainable agriculture, marine and maritime research and the bio-economy
SC 3: Secure, clean and efficient energy
SC 4: Smart, green and integrated transport
SC 5: Climate action, resource efficiency and raw materials
SC 6: Inclusive, innovative and reflective societies
SC 7: Secure societies to protect freedom and security of Europe and its citizens

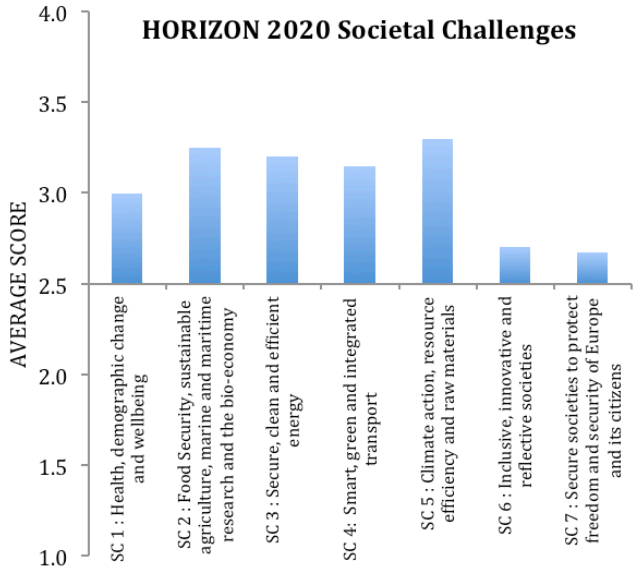

Figure 2 Results from the DANCERS online survey. All Societal Challenges categories scored above the average score of 2.5 and thus were considered relevant for the Danube -Black Sea System

DANCERS explored the priorities and relevance and of HORIZON 2020 Societal challenges for the DBS System by obtaining information during all the workshops organized with stakeholders (scientists, businesses, public administrators) and as part of an online survey. All categories of Societal Challenges were considered relevant by all participants in DANCERS workshops and surveys.

As can be seen in Figure 2, which show the results of the on-line survey, three categories ranked highest in terms of importance : SC5 Climate action, resource efficiency and raw materials; SC2 Food security, sustainable agriculture, marine and maritime research and the bio-economy; SC3 Secure, clean and efficient energy.

Further insight in the priorities of each of three most relevant categories of Societal Challenges (SC5, SC2, SC3) was obtained during the DANCERS workshops. In particular, with regard to SC5 (Climate action, resource efficiency and raw materials) all the subcategories were deemed highly relevant for the DBS System (shown here in order of decreasing relevance): 5.2 Sustainably managing natural resources and ecosystems; 5.1 Fighting and adapting to climate change; 5.5 Developing comprehensive and sustained global environmental observation and information systems; 5.4 Enabling the transition towards a green economy through eco-innovation; 5.3 Ensuring the sustainable supply of non-energy and non-agricultural raw materials.

Similarly, for Societal Challenges 2 (Food Security, sustainable agriculture, marine and maritime research and the bio-economy) the following subcategories were ranked according to their importance for the region:

2.1 Sustainable agriculture and forestry;
2.3 Unlocking the potential of aquatic living resources;
2.2 Sustainable and competitive agri-food sector for a safe and healthy diet;
2.4 Sustainable and competitive bio-based industries.

With respect to Societal Challenges 3 (Secure, clean and efficient energy), DANCERS results indicated all subcategories to be relevant (here ranked in order of decreasing relevance):

3.5 New knowledge and technologies;
3.6 Robust decision making and public engagement;
3.7 Market uptake of energy innovation, empowering markets and consumers;
3.2 Low-cost, low-carbon electricity supply;
3.1 Reducing energy consumption and carbon footprint through smart and sustainable usage;
3.4 A single, smart European electricity grid;
3.3 Alternative fuels and mobile energy sources.

In DANCERS, the SWOT analysis (see Section 3.2, Table 5) carried out at the Synthesis Workshop indicated that in the DBS System, the priorities of HORIZON 2020 Societal Challenges can be readily tackled, relying on the common understanding of existing environmental problems within the Danube Region, national funding that can supplement HORIZON 2020 funding, strong existing international cooperation, existing inter- and multidisciplinary studies. However in succeeding in this goal, further emphasis should be put in covering the whole River Basin including the delta, coast and the connected sea.

In addition, DANCERS addresses the issues of regional **sustainable development,** another priority objective of Horizon 2020, and understood as a pattern of resource use that has to meet current and projected human needs while preserving the environment.

Human Modifications and the role of blue/green infrastructures

It is widely acknowledged and accepted that the environment has been significantly impacted by human activity. The significance of this period of anthropogenic disturbance on the environment is now referred to in the scientific literature as the Anthropocene: the current epoch in which human agency is recognised as a global geophysical force (Steffen et al., 2007). Successive advances in science and technology over the centuries have enabled the planet to support ever-growing populations and today our aquatic environments are central to food and energy production (Tyler et al., submitted). As a result, surface waters face multiple and confounding pressures from climate forcing, eutrophication and other natural and anthropogenic driven environmental perturbations operating at local and global scales (MEA, 2005; IPCC, 2007; Ormerod et al., 2010). These have contributed to a reduction in biological diversity, the spread of invasive species and loss of key regulatory ecosystem services; as reflected in deteriorating water quality and increased vulnerability and susceptibility to environmental hazards. The following provides a summary of the range of issues that need to be addressed.

Climate change is resulting in complex signals with varying and often contradictory effects on river-sea systems, as temperature increase and precipitation patterns and the magnitude, occurrence and frequency of extreme events may vary in different ways in various parts of the basins (Fowler & Archer, 2006). In the Danube – Black Sea System there are several studies showing that the upper part will be subject to more rainfall (and associated higher risk of floods), while in the Lower Danube there are areas at risk of desertification (ICPDR, 2012). Even though the ICPDR managed to develop a strategy for adaptation to Climate Change in 2012, the recent development in monitoring and complex modeling now provide the basis for more detailed understanding and the development of a strategy and action plan, which should become part of the future version of the Danube Region Management Plan. This, in turn, would support bespoke plans to be developed for each area of the basin. Deltas and low lying coasts are also globally under major threat from climate change derived sea level rise and increased number of extreme events (Day et al., 2008). Even though it is considered to be less vulnerable to Climate Change impacts due to the low population density and its status as Biosphere Reserve (Delta Alliance, 2012), the Danube Delta is still at risk to be highly impacted by sea level rise and, mainly by the effect of increased number of storms. Giosan et al. (2006) described how recent Danube Delta evolution over the past 5 millennia has been made under a relatively stable sea level of the Black Sea. However, the combined impact of reduced sediment supply from the catchment (Panin, 1996) and increased storms is putting the future of the delta shoreline at significant risk.

The last 100 years has witnessed a significant reduction in floodplain landscapes, impacting on biodiversity and ecosystem services such as flood regulation and nutrient retention. This has largely been driven by human induced landuse change and engineering work such as dam construction (Hein et al., submitted). An estimated 80 % of the aerial extent of floodplains has been lost in the Danube River Basin, impacting largely in the middle and upper reaches and 75% of the floodplains have a high or very high potential for restoration (Schwarz et al., 2010). Despite this potential, Hein et al. (submitted) highlights the need for stakeholder engagement to assess needs and acceptance whilst governance structures and resources are supressing the potential implementation. The Danube Delta has been less impacted, maintaining its natural state with only a few examples of bad practice and alteration (Sánchez-Arcilla et al., submitted). Nevertheless, as with many deltaic systems, sediment starvation, with a 30-40% reduction in sediment supply from the catchment which coupled with issues of channelization has become and critical in the Danube Delta resulting in intense erosional processes of the littoral environment progressive prograding delta shoreline (Panin and Jipa, 2002)

One of the major human interventions in river-delta sea systems has dealt with the construction of dams, dykes and other flood protection hard structures. Addressing local needs (e.g. dams retaining water for hydropower purposes but also for safe and stable navigation and flood protection purposes), these works have generated major impacts downstream (e.g. Poulos & Collins, 2002). Abstraction of water uses for agriculture along river basins has also contributed to critical changes in the water regime downstream, probably the most famous and in the same time critical example being the impact of Sir Daria and Amu Daria rivers on the Aral Sea (Macklin, 2007). The Danube – Black Sea System was no exception from these interventions. Damming of the river for hydropower, flood protection and safe and continuous navigation, occurring over the last 150 years, together with the damming of most of the major tributaries and embankments of most of the river have generated a major impact on the natural water and sediment dynamics in the region (Habersack et al, submitted). The cutting of canals along the main Danube Delta tributaries for navigation purposes, channelization of the delta territory and building of jetties at the Danube mouths played critical roles in altering the natural water and sediment dynamics (e.g. Panin, 1998, Giosan et al, 1999, Ungureanu & Stanica, 2000).

More broadly, the cultural heritage built up in the Danube Region from the springs in the Black Forest to the Black Sea, covering several millennia of continuous inhabiting and several layers of civilizations superimposed in time. These include influences from Ancient Greeks in the Danube Delta, Romans along the entire length of the river, to the Byzantine, Ottoman and Habsburg empires. These have resulted major archaeological and cultural and attractions and the subsequent growth of a major tourist industry, with cruises in the upper and middle part, covering Bratislava, Vienna and Budapest being of global interest.

It is generally agreed we are only now starting to appreciate the magnitude of human-induced environmental change. This presents considerable difficulties in managing environmental risk throughout the Danube Region and the Black Sea Coast. However, management of environmental risk is essential in ensuring environmental protection, in protecting key ecosystem services and in maximising the use of green infrastructure. It is also essential in minimizing societal impacts arising, for example, from variations in water quantity (flooding; drought and water scarcity) and water quality.

This requires a holistic, cross-disciplinary approach exemplified by the current status of the floodplains of the Danube. One of the goals of the EU Floods Directive (EU-Directive 2007/60/EC) is to avoid further deterioration of the ecological status of rivers due to dam construction, and to reduce flood risk by increasing “room for the river” instead (Pahl-Wostl, 2006). The latter provides scope for the restoration of floodplain wetlands and adaptive management and can make use of green infrastructures such as floodplains for water storage during flood events. The complication is that flood protection must comply with the aims of both the EU Water Framework Directive (EU-Directive 2000/60/EG) and the EU Floods Directive (EU-Directive 2007/60/EC) by targeting integrated river basin management (Habersack et al., 2015). This recognises that settlements, agricultural production, forestry, hydropower generation, navigation, the economic development of the catchment, but also nature protection are among the drivers commonly opposed to allowing floodplains to regain their natural flooding dynamics (Moss, 2008; Buijse et al., 2002).

Water Quality

Water quality (river, lakes and groundwater bodies) is fundamental to human wellbeing and sustainable development. In common with many catchments, the Danube River Basin has experienced significant changes in water quality including: physical (temperature; suspended sediment; bed-load transport), chemical (e.g. ammonium, nitrate, nitrite, phosphorus and

emerging pollutants) and biological water quality. These reflect multiple factors including changes in: i. land use; ii. point and diffuse pollution (from agriculture, industry and individual households), and iii. the catchment water cycle as a result of climate change and anthropogenic modifications of the drainage basin.

The Danube collects wastewater from more than 100 million people in the catchment as it extends into the territories of 19 countries. The quality and quantity of water, suspended sediment and associated particles in the Danube River are therefore strongly linked to anthropogenic activities within the watershed (McCarney et al., 2011) with far reaching impacts beyond the Danube and its riparian zone into the Western Black Sea extending to the deep sea region and South towards the Bosporus. Nutrient rich water from the Danube has led to eutrophic conditions in the Delta and coupled with a strong natural thermohaline that in turn has driven hypoxia in the western Black Sea shelf (Friedrich & Janssen et al., 2014). Frequent and intense algal blooms have resulted in a significant deposition of organic matter leading to frequent hypoxic and anoxic events with serious consequences for pelagic and benthic ecosystem structure and functioning, as well as for living resources, tourism, and recreation (Mee et al., 2005). Although nutrient loading has reduced following the post economic collapse and introduction of the WFD, the long term implications of a warming climate coupled with storminess may prolong the impact of these eutrophic conditions. Within the catchment, as management of nutrient and organic pollution has improved, attention has moved towards other pollutants such as heavy metals, persistent organic compounds, endocrine disruptors and pharmaceutical compounds (Chapman et al., submitted). However, a fundamental limiting factor for basin wide investigation is the lack of harmonized monitoring in terms of methodology and observation frequency making historical reconstruction of, and estimates of, the impact of environmental change drivers difficult.

The DANCERS workshops highlighted specific water quality problems through the DBS System. Fundamentally of concern is the degree to which changes in water quality may impact **ecosystem sustainability**: illustrated, for example, by:

1. the effects of eutrophication throughout the catchment and in the Black Sea (e.g. Oguz et al., 2008). Pollutants are characterised by different and complex behaviour in the environment, and depending upon their concentration and local environmental conditions, they can be associated with acute or chronic toxicity to biota. Inevitably, the situation with respect to water quality varies through the DRB: typically in the upper basin, reaches are characterized by good water quality (albeit with a highly regulated flow regime), whilst water quality is poorer in the lower basin. Throughout the DRB, water quality is affected by diffuse agricultural pollution, highlighting the importance of developing and implementing agricultural best practise, and indicating the importance of the Common Agricultural Policy.
2. sediment transport dynamics: there are marked changes in sediment transport as a result of interruptions to the continuum of bed-load transport with sediment deposition in impounded reaches and a sediment deficit in free-flowing river sections, mainly due to dams. Sediment transport is further modified by dredging for navigation, and river engineering work, such as groynes, that contribute to increased river bed erosion in some reaches, and sediment aggradation between groynes (Technum et al. 2008).

This illustrates the importance of maintaining **river continuity** (from the catchment headwaters downstream) and lateral connectivity between rivers and their floodplains which has wide-ranging environmental implications. The effects of variable patterns of sediment erosion and aggradation, include wider ecological and environmental degradation with the clogging of hyporheic interstices leading to reduced oxygen availability, the loss of spawning grounds and riparian zone degradation affecting algal communities, invertebrates and fish (e.g. Petkovska & Urbanic, 2015).

There are considerable uncertainties with respect to persistent organic compounds, endocrine disruptors and pharmaceutical compounds. In common with many river basins, there is a lack of detailed knowledge of the levels of hazardous substances in the Danube River (ICPDR, 2014), and an urgent need for chemical and effect-based monitoring tools to inform new models of exposure and risk assessment (Brack et al., 2015). These require the application of sound science, and specifically good understanding of pollutant sources, transport pathways and ultimately the fate of pollutants.

Fundamentally, catchment managers require significant help in identifying and monitoring specific compounds and appropriate ways of controlling or mitigating problems (such as untreated urban runoff). Addressing current WQ challenges requires i. a basin-scale approach providing an holistic view of the impacts of activities and their interactions within the basin; and ii. new tools that build upon existing data-sets to model changes in key WQ determinants and improve the scientific basis for integrated catchment management (monitoring networks to capture spatial and temporal variability; standardisation of monitoring protocols; harnessing new / recent advances yielding real-time and basin-wide observational data).

Whilst eutrophication of surface waters presents a significant challenge, it also presents opportunities for resource recovery. Given the threat of shortages in essential agronomic nutrients by 2050 (Cordell et al., 2009; Quilliam et al., 2015), coupled with an elevated risk of nutrient transfer from land to water (which is predicted to increase under projected climate change scenarios), there is growing pressure to explore novel and innovative routes for nutrient recovery from materials hitherto regarded as waste. One option that may hold potential is the harvesting of aquatic plant biomass from eutrophic waters on the assumption that the assimilation of nutrients by primary producers in eutrophic waters provides a gateway to the recovery and re-use of these 'lost' nutrients. Subsequent processing of this harvested biomass could provide the recovery resources suitable for fertiliser, livestock feed and biofuels, whilst also delivering multiple ecosystem benefits including habitat restoration (Quilliam et al., 2015)

3.3 Outcomes from Reviewing the Start of the Art

The DANCERS consortium collaborated in producing 12 manuscripts which were submitted to the internation journal *Science of the Total Environment*. Collectively these papers review key (and current) science disciplines and questions which impact and influence the research and science agenda for the Danube region.

A key element of this exercise was to seek to highlight best practice, the existing strengths and weaknesses in research specifically within the Danube region, set against exemplars from outside the basin. While the region is experiencing multiple pressures from natural and anthropogenic drivers, there were a number of common themes across many of the manuscripts including;

1. The need to identify 'trajectories' of change (within and between disciplines) to quantify the environmental (eco)system evolution;
2. Recognition of environmental complexity (and the difficulties in distinguishing 'natural' change from those resulting from climate change and anthropogenic activity);
3. The importance for specificity (spatial and temporal) in environmental characterisation and the need for research to span multiple scales (with attendant problems for data capture, management and modelling);
4. The desirability for cross-disciplinary research approaches that extend beyond the confines of individual academic disciplines;
5. The importance of adopting a catchment-wide approach (e.g. in environmental characterisation and quantifying material fluxes through the catchment) that recognises environmental process dynamics.

Within these themes there were common areas of concern including (in some cases) a lack of systematic data collection conforming to standardised Quality Control (QC) protocols. Furthermore, there was evidence of considerable variation in model performance and in the attendant uncertainties of model output and forecasts.

There are, however, a number of opportunities, highlighted when looking forward at new and emerging developments in individual disciplines. For example, new techniques in remote sensing and data management.

3.4 Needs

The SWOT analysis demonstrated that while there is common recognition of the environmental problems among stakeholders in the Danube Basin, coherency in approaches between countries and among stakeholders needs to be improved. Some strong national and bi-lateral research initiatives have been conducted (e.g. Clean Black Sea Working Group). Integrated basin management requires expansion of these already good collaborations to broader participation in order to create a perspective of the entire Danube-Black-Sea System. It was also noted that harmonization of methodologies for data collection and QA/QC are needed in order to implement WFD and MSFD. These observations present an opportunity to align a research agenda that is relevant to EU 2020 Societal Challenges, the EUSDR and other strategic research agendas such as JPI Water for the Danube Region.

In addition to disparate national research efforts in the Basin, stakeholder involvement is needed in order to ensure the usability of the scientific results in policy and industry. This observation is supported by the analysis of the metadatabase which showed that coordination between upper, lower, and middle Danube is needed with respect to economic development – particularly for navigation and hydropower. For example, national and international projects aimed to remove navigation bottlenecks (e.g. TEN-T) may present consequences to sensitive and high-value ecological areas downstream. Some research and restoration projects (e.g. Integrated River Engineering Project [IREP] on the Danube East of Vienna) have been aimed to both mitigate and understand sediment losses and transport (Reckendorfer et al. 2005). Another example of the need for greater integration is in addressing the damaging effects of invasive species. The Danube is linked to the North Sea basin by the Rhine-Main-Danube Canal (Southern Invasive Corridor), which increases the potential for invasive species in the basin. However, most studies in invasive species have been conducted in the Black Sea region, where the situation had become critical for decades (e.g. Gomoiu & Skolka, 1995). Studies in the freshwater side have increased since 2009 (Feldbacher et al. Submitted), but increased transportation between these two basins calls for whole-basin awareness among stakeholders and research that addresses these challenges at the basin-delta scale. These are only some of the examples that informed the conclusion that a greater integration between stakeholders along the Danube continuum with better scientific understanding is needed to sustainably develop the region. Projects that address these complex dynamics along the continuum of the River-Delta-Sea system in an integrated way which include stakeholders are required to achieve integrated, sustainable management that balances societal needs with environmental protection. Below we discuss some specific research needs that arose from discussions with stakeholders with the idea that these needs are linked to the EUSDR (Figure 3).

One of the pillars of the EUSDR is “connecting the region” (Figure 3). One way to do this through sustainable management is by maintaining habitat continuity throughout the Basin, both longitudinally and laterally – conserving and restoring the Danube

"Green Corridor." Impoundment (creation of reservoirs by damming), water flow and water quality, sediment transport and the effect of human alteration of the hydrogeomophology are key components that need to be addressed holistically from source to sink. Specifically, upstream-downstream linkages in sediment dynamics need to be understood at multiple scales. For example, dammings cause sediment starvation on local and basin scales. At local scales, the river reaches downstream from impoundments often become incised with increased bank erosion. This in turn increases bank-full capacity and therefore reduces river-floodplain connection, as well increases the chance of flooding downstream. Furthermore, habitat quality in these reaches changes: saprophytes, can no longer survive in deeper, faster-flowing water, and habitat for invertebrates and fish are lost. At the basin scale, sediment retention deprives the Delta and its coast from much needed sediments to maintain the unique habitats. Dredging channels for navigation can also cause unintended changes in habitat downstream by changing erosion dynamics and flow rates. In addition to the proximate controls on sediment transport, climate change also has the potential to alter sediment transport and hydrogeomorphology at longer time scales (Hein et al. Submitted). To address these complex dynamics, innovative research in sediment and water management is needed to determine how to maintain an acceptable habitat quality and connectivity while achieving the economic and societal needs for navigation, hydropower, and flood protection.

Habitat continuity also needs to be considered with respect to maintaining appropriate water flows and connectivity particularly related to endangered and economically important species such as the sturgeon. The lack of knowledge on habitat condition and change along with and trends in fish fauna are a major hindrance in the development of effective environmental management strategies (Banaduc et al., submitted). Whilst a programme for the protection of Sturgeon is being implemented by the Danube Sturgeon Task Force (DSTF) and the EUSDR, supplementary data on habitat quality, environmental change drivers and prediction is required. Furthermore, research into the effectiveness of fish passageways in restoring populations and the spatial variation in population is required. These research tools should include state-of-the-art DNA and isotope studies to fully understand population dynamics, changes in diet and food web structure, and the effect of conservation measures. These techniques are also applicable to the Delta region where aquaculture and over-fishing also present challenges to maintaining viable fish populations and biodiversity. Such research presents strong possibilities for empowering key stakeholders such as, e.g., fishermen, in citizen science activities, and can provide another way to connect the region while improving prosperity through the sustainability of livelihoods.

Understanding the potential pathways for invasive species and factors that influence the success of invasive species is critical. In other regions, invasive species have benefited from human-disturbed systems, including the introduction of hard substrate, altered nutrient regimes, or altered food web structure through predator-removal caused by, for example, over-fishing. While attention since the early 1990's has focused on the Black Sea due to the introduction of invasive species at multiple trophic levels which have considerably altered the original food web structure, research is now only starting to be considered in the upper part of the Danube (Hein et al. Submitted). Unintended species introduction and the risk for proliferation of alien species also needs to be understood along the whole corridor, especially with the development of new shipping channel that connects the Danube, and the Black Sea Basin, to the Rhine River (Baltic/North Sea Basin) (Hein et al. Submitted). The enormous cost of invasive species to the economy of the region, justifies this research priority as important to maintain prosperity (EUSDR; Figure 3) and calls for increased

education of the many stakeholders who have the possibility to prevent new invasions. The need to address this critical issue in an integrated manner and at the basin scale approach was also identified by the ICPDR (2009).

Agricultural intensification, urbanization, and increased tourism are other pressures that affect water and habitat quality in the basin. The effect of these developments on nutrient loading and organic matter processing needs to be understood, including taking into account the social and cultural contexts and economic drivers. Important among these drivers include tourism, especially for the fact that specific ecosystems of the Danube have always been popular for ecotourism, but this has increased in importance over recent decades and requires careful management. Agricultural intensification, encouraged by EU Common Agricultural Production (CAP) and the desire for increased subsidized food production also drives nutrient loading, especially in the western part of the basin (Schreiber et al. 2005). These changes in land use and land cover all have implications for diffuse and point-source pollution. Recovering the nutrients presents an economic opportunity to reuse these nutrients from the harvesting of aquatic plants and algae. Quilliam et al., (2015) recommend an integrated ecosystem approach, by evaluating the economic, social, environmental and health-related dimensions of resource recovery from such biomass. They advocate that the recycling of aquatic plant biomass is coupled to the remediation of eutrophic waters resulting in the sustainable production of feed and fertiliser, whilst providing multiple downstream benefits and minimising environmental trade-offs.

Analogous to understanding sediment transport and processing dynamics, nutrients, organic matter, and pollutants need to be understood at both local and basin scales. At local scales, both diffuse and point sources may play an important role in, for example the over-enrichment of reservoirs. However, at the basin scale, complex retention mechanisms within the basin (including of reservoirs) may mitigate the export of materials to the Black Sea. Transport, retention and processing are future expected to change in coming years along with climate change and increased extreme whether events, which have the potential prolong and perhaps intensify the eutrophication problems and the nature of “hot-spots” associated with other types of pollution. These dynamics are critically important to understand because the source and transport dynamics must be targeted in any effective management strategy that aims to reduce loading to the Delta System. A fundamental limiting factor for basin wide investigation into these dynamics is the lack of harmonized measurements in terms of methodology and observation frequency with adequate spatial and temporal coverage in the basin. Therefore, research is needed in the most cost-effective and strategic measurement scheme for pollutants, including nutrients, at the basin level, and process-based models that can take into account hydrological and biogeochemical cycling and transport dynamics need to be developed.

When new areas are opened for restoration or for investment tourism, e.g. through efforts to re-connect river floodplains to the river, or to open important archaeological sites to tourism, research on the effectiveness of these activities in terms of key ecosystems services is required. This includes aspects on carbon storage, nutrient retention and biodiversity (e.g. the Birds Directive, 2009/147/EC), as well as the historical and cultural values associated ancient and historical sites present in the basin. Research into the societal response along with the economic and cultural benefits is required. This kind of research also provides opportunity to connect the region through shared cultural, historical, and ecological heritage.

In summary, new tools are needed for an integrated understanding of how pressures from human modifications in hydrogeomorphology, species deletions and

introductions, nutrient loading, and pollutants (including micro-plastics and pharmaceuticals) are propagated via water and sediments downstream and laterally into the riparian zones and flood plains. Such tools should include model development for the basin which includes aspects of habitat quality relevant to the WFD and Floods Directive (Directive 2007/60/EC), including nutrients, macrophytes, invertebrates, and fish, A model should be able to quantify the effect of multiple pressures (specifically hydropower, nutrient inputs, navigation, known and emerging pollutants) on habitat quality in the Danube – delta – Black Sea. This should be a tool for managers to assess effects on ecological status of the river-delta-sea in relationship to the WFD and provide a basis for decision making and discussion about management choices with stakeholders. Model development should include data generated by new empirical research and focused process studies that are targeted with new investments in research infrastructures.

With specific regard to climate change and sediment supply, management plans are urgently required to develop specific adaptation pathways. Furthermore, Hein et al (submitted), demonstrated that significant knowledge gaps remain in relation to climate change effects, the impact of altered sediment budgets, connectivity between restored areas and the impact of invasive alien species. Research on the efficiency of restoration and the societal response and benefits is therefore required.

There is a clear need for an innovative water and sediment management to reduce the fragmentation of the river-delta-coast continuum (both longitudinal and lateral, giving the river space to "breathe"), allow the transfer of sediments from source to sink and the migration of the native species, which have been critically affected by the disruption of their habitats. Sediment management solutions must offer the right balance in allowing safe and permanent navigation conditions while contributing to the restoration of the alluvial plains (the "Danube green corridor") which, at its turn, represents a method of building with nature the necessary "green" flood protection.

Although nutrient loading has reduced following the post economic collapse and introduction of the WFD, the long term implications of a warming climate coupled with storminess may prolong the impact of these eutrophic conditions. Within the catchment, as management of nutrient and organic pollution has improved, attention has moved towards other pollutants such as heavy metals, persistent organic compounds, endocrine disruptors and pharmaceutical compounds (Chapman et al., submitted). However, a fundamental limiting factor for basin wide investigation is the lack of harmonized monitoring in terms of methodology and observation frequency, making historical reconstruction of and estimates of the impact environmental change drivers very difficult.

The lack of knowledge on habitat condition and change along with and trends in fish fauna are a major hindrance in the development of effective environmental management strategies (Banaduc et al., submitted). Whilst a programme for the protection of Sturgeon is being implemented by the Danube Sturgeon Task Force (DSTF) and the EUSDR, supplementary data on habitat quality, environmental change drivers and prediction is required.

Whilst ecotourism has always been a phenomenon in the Danube region, this has increased in importance over recent decades and requires careful management. From The specific Danube ecosystems are other major tourist attractions. Comprehensive research studies are needed to put in value the archaeological potential, but mainly to properly manage tourism without major negative impacts on the river and delta environment

In the Danube River upstream from the delta the critical issue of the alien species has not been acknowledged till the second half of the 2000s. The need, now is to address this critical issue in an integrated manner and at the basin scale approach has been identified (ICPDR, 2009).

3.5 Opportunities

DANCERS has identified the research challenges and needs that face the DBS system, whilst also demonstrating that we are witnessing a revolution in sensor development and deployment from in situ to space along with a step change in analytical capability in the laboratory and field. This includes: (i) Earth observation (EO) and the development of in situ technologies through EC Framework Programmes and ESA's Copernicus programme launching the next generation Sentinel platforms; (ii) near real-time processing and management of Big Data from in situ sensors and EO data; (iii) advanced geo- and biochemical analytical platforms, the latter describing genotypic and phenotypic diversity in increasing detail. As result, this is an opportune time to monitor with new harmonised measures, with matching QC, the biological, physical and chemical behaviour of the DBS system at the regional scale. These advances, together with developments in data capture, processing and modelling, enable us to quantify the extent of environmental change (and system dynamics) at rates, resolutions and detection thresholds far in advance of those that were previously feasible. Such data will yield unprecedented insights into the connectivity and response of the DBS system to natural and human induced drivers of change. In addition to providing new understandings, the real challenge lies in how to utilize these advanced tools to their greatest potential, and ensure environmental sustainability in the context of growing human-induced stresses whilst correcting mistakes of the past through new initiatives such as resource recovery. To achieve this there is need for an overarching Strategic Research and Innovation Agenda (SRIA) that is dedicated to the Integrated Management of the DBS system. This SRIA requires promotion and implementation and development of a highly educated human resource that is trained within a "source – to – sea" philosophy that has the implementation of an integrated management of the DBS system at its core (see Deliverable 3.3). Alongside this there is a need for development of a distributed research infrastructure within the implementation of the SRIA that exploits and facilitates development of human capital. This will allow for the improved, and sustainable, exploitation of the Danube Region and its resources within Europe (see Deliverable 3.2). These activities will essentially "fill the gap" in water cycle research infrastructures (as requested in the EUSDR PA7 list) as well as strengthen the connectivity between fresh and marine water systems their sustainable management.

4.0 THE STRATEGIC RESEARCH AND INNOVATION AGENDA (SRIA) FOR THE DANUBE

4.1 Introduction

Scientifically coherent solutions for integrated river-basin-sea management require an interdisciplinary approach that is well communicated and able to inform decisions of society, industry and governments. In this way, the necessary sustainable and innovative solutions can be developed to address the major societal challenges. The EU Strategy for the Danube Region determined priorities to strengthen and connect the region while increasing prosperity and protecting the environment (Figure 3).

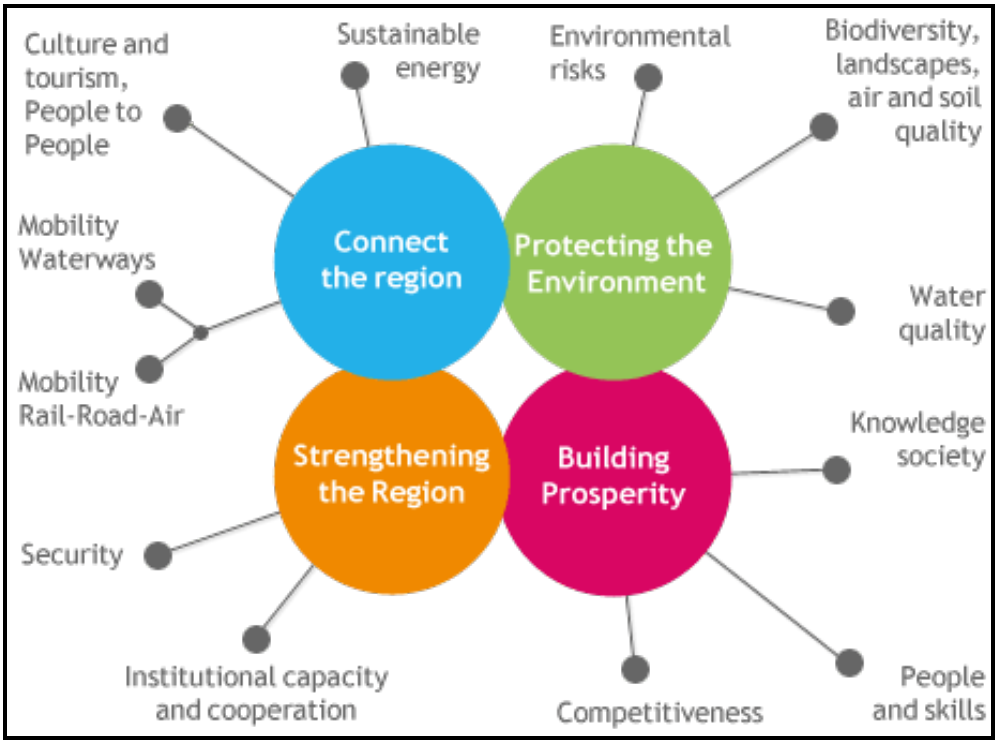

Figure 3: Pillars and Priority Areas of the EU Strategy for the Danube

As stated, the DBS System has to be considered as a single and integrated macro-system from its source to the western Black Sea and therefore the Strategic Research and Innovation Agenda (SRIA) is designed to support Integrated Management of the System and reinforce this approach. The SRIA aims to address the needs of the region including the improvement of the institutional and infrastructural conditions needed to connect the basin more strongly in terms of collaboration and exchange while addressing the scientific needs for holistic management, including economic development and environmental protection.

There were significant pressures identified in the Danube River Basin District by the ICPDR and formulated clearly in the DRB management plan, with respect to water quality, hydromorphological alterations, river and habitat continuity interruption and hydrological alteration. These correlate strongly with the priority research and innovation themes identified with stakeholders in DANCERS: Ecosystem and ecosystem services, Societal Challenges, Human Modifications and Water Quality. The proposed SRIA below addressed these research priorities in the context of Pillars and Priority Areas of the EU Strategy for the Danube.

4.2 DANCERS SRIA Research Priorities for the Danube – Black Sea System

1. **Restoring Ecosystem continuity throughout the DBS System**
   Two centuries of engineering works have heavily impacted the ecosystems in the Danube River – Danube Delta – NW Black Sea continuum. Dams cut the longitudinal continuity, while embankments and polder transformation cut off the lateral connectivity, by losing most of the flood plains. Science must contribute to the restoration of both longitudinal and lateral connectivity of the various Danube ecosystems by implementing solutions to work with Nature, and not against it.

2. **Pathways of transport and accumulation of litter(plastic) and pollutants (including emerging pollutants) in the DBS System and their impacts on local ecosystems**
   The Danube River is responsible for substantial inputs of litter, which accumulates in the Danube Delta area and the Black Sea. The high flow rate of the Danube River, act synergistically with the strong bottom sea currents in the Black Sea, as a result litter accumulates on the seafloor. To minimize the litter load, which affects both the fresh- and marine- environment, we have to understand the transport and accumulation pathways. This knowledge will support the problem solving at the sources from the entire basin. Innovative waste management schemes should be introduced for regions where such schemes do not exist, in addition to better management of the river outflows in extreme flooding events. These innovative schemes will minimize all categories of litter (meso-, macro-, micro-) and their corresponding effects on the biota with the freshwater, transitional and marine environments.

3. **Ensuring safe and continuous navigation while restoring the Danube green corridors (with strengthened natural protection from floods)**
   There is a need to reconcile the demands of navigation with the challenges of environmental restoration in the Lower Danube. Inland navigation and connection with the maritime transport are essential drivers for economic development in the Danube – Black Sea Region as well as worldwide. To ensure a permanent and safe waterway, dredging is needed. However, solutions applied so far have not been effective in achieving sustained navigation during periods of low water flow. Smart and innovative "nature based" solutions that involve the integrated management of sediments and maximize the uses of their ecosystem services are required to ensure continuous navigation and reconcile with the plans of the green corridors development. The results will pioneer the effective management strategies which will have generic value other river-sea systems in Europe and beyond.

4. **Mutual ecological and economic benefits from ecosystem restoration of eutrophied ecosystems in the Danube – Black Sea interaction zone**
   A better understanding is needed to characterise, optimise and value the immediate and wider environmental benefits arising from ecosystem restoration in degraded waterbodies. For example, there may be both economic and ecological benefits and trade-offs in, for example, harvesting plant and algal biomass from transitional eutrophic waters in the Danube Delta Biosphere Reserve. This is an underexplored research theme that has applied relevance not just in the Danube Delta, but also across the whole of the EU region. Other benefits could include nutrient reclamation, water quality remediation, increased recreational value and the exploitation of high-value product. The latter may include, for example, new markets for traditional products, such as reeds. Research is needed to help underpin and advance an agenda that aims to create win-win situations in resource use and ecosystem remediation.

5. **Dealing with Eutrophication in the Danube – Black Sea interaction zone by using algae as 2nd Generation Biofuels**

Recent developments of refineries using algae as second generation of biofuels may provide smart and innovative solutions to deal with eutrophication phenomena in the NW Black Sea. Danube born nutrient discharges contribute to the explosive development of algal populations in the sea under the influence of the river. Efficient use of the algae as raw materials for biofuel refineries require the profound understanding of freshwater – marine water interactions, variation of nutrient loads supplied by the Danube to the Black Sea, life cycle of algae development and blooming phenomena as well as forecasting of dynamics of the marine area where the algal blooms would evolve. All these factors are critical for the establishment of a performant algae harvesting plan with the double function of providing raw material for biofuels and retention of river-born nutrients from the Black Sea waters.

6. **Using latest Earth observation (EO) technologies coupled with in situ measurements for an upgraded DBS System environmental monitoring scheme**
   Capitalising on the launch of ESA's next generation EO capabilities coupled with in-situ sensor technologies, long term research sites to develop an innovative high resolution and long lasting observation system for transboundary basin scale water management in the Danube River-Delta-Black Sea system. Effective management of large transboundary river-sea basins such as the Danube is hindered by the lack of standardisation in approaches and frequency of basin scale monitoring to characterise water quality, changes in biodiversity and hydrology, a situation that can be further compounded by geopolitical complexities. The development of sensor networks and concerted observation provides the opportunity to overcome these obstacles to provide new insights and consistent measures. Such sensors can also provide a platform to develop novel passive and active sensors for the detection of emerging pollutants, such as those associated with pharmaceuticals, hospital, industrial and domestic discharges including wastes that persist such as plastics and micro-plastics. Sensor networks coupled to biodiversity assessments and combined with Earth observation data, exploiting next generation platforms from ESA's Sentinel programme, and complex numerical modelling are likely to provide new understandings of the fate and impact of these pollutants, responses of organisms and the hydrological connectivity and functioning of the Danube River-Delta-Black Sea. Such an approach will facilitate more effective regulation and management to mitigate against the impact of pollutants on aquatic ecosystems and society.

7. **Developing sustainable agricultural practices (crops, husbandry) while obtaining good water quality in the DBS System**
   The EU Common Agricultural Policy aims at obtaining sufficient and safe quantities of food by applying latest scientific and technological innovations in regulation and management practices that protect the environment. One of the biggest challenges is to implement this goal in very large areas, such as the Danube River Basin. Innovative methods are needed to achieve this goal whilst also obtaining good water quality in the Danube River – Danube Delta – NW Black Sea.

8. **Understanding river-sea interaction processes in the Danube Delta transitional environments**
   Implementing European policies in transitional environments needs to be undertaken within a framework that allows for a better understanding of their functioning to maximise the benefits of their implementation and minimise any detrimental impacts on ecosystems, society and water quality. Several European policies connect in transitional areas in the river-sea continua, such as estuaries, deltas, lagoons and other coastal wetlands, such as WFD, MSFD, Flood Directive, and ICZM. A fundamental understanding of the functioning of the complex, dynamic and vulnerable transitional environments and their relation to social and economic aspects as well as to global change, are the basis for

more effective management and thus make better use of the potential of the afore mentioned policies. A true holistic and interdisciplinary approach is needed to significantly increase our understanding of these transitional systems. Such understanding will be the basis for the more effective management of these systems and their relation to the river-sea continuum.

9. **Managing dams and reservoir lakes as critical sediment traps and bottlenecks for river habitats continuity in the DBS System**
   Dams act as traps, interrupting the natural flow and continuum of water, sediments and biota. As a result they contribute to changes in ecosystems and the considerable accumulation of sediments in the related barrage lakes. Pollutants also accumulate in these lakes, transforming them into potential ecological „time bombs". Detailed knowledge and inventory of these sediments along with their potential ecological impacts of any contaminant is needed along with an estimate of the accumulation and migration processes to develop adequate sediment bypassing solutions to prevent critical environmental incidents.

10. **Restoring natural habitats in the Danube floodplains – Danube Delta and lagoon systems as support for fisheries revival.**
    Destroying the floodplains and their associated wetlands and closing the Danube Delta lagoons from the free exchange with the sea, have been some of the critical factors in the failure of the fisheries in the Danube River – Danube Delta – Black Sea system. Plans to support fisheries revival and sustainable aquaculture must include actions to restore the spawning grounds and nursery habitats for native fish and other aquatic species, increasing the exchange of water and resources between channel and floodplain, and using this connectivity to increase ecosystem resilience to external drivers such as climate change and invasion.

11. **Understanding Climate change impacts on the DBS System by applying the latest generation of models**
    Dynamics of climate change and the related impacts are different in the various parts of the Danube River – Danube Delta – Black Sea system. Latest generations of climate models are powerful tools to understand the impacts and prepare detailed adaptation and mitigation management plans from current regional approach to micro scale dimensions. This will allow development of adequate adaptation and mitigation plans based on high detailed scenarios. To understand the impacts of climate change, records of the thermal dynamics in lakes, lagoons and flowing waters is required to understand the impacts of climate change. Where historical records are missing, some reconstruction of surface water temperatures along with other essential climate variables (ECVs) is possible from Earth observation data.

12. **Managing water resources for human use by implementing new technologies for water abstraction, purification, distribution, collection, treatment and reuse in the DBS System**
    There are considerable uncertainties concerning the flux and storage of carbon from the headwaters of the Danube, through large alluvial river-floodplain reaches in the middle of the catchment, to the freshwater – marine transitional zone of the Danube Delta and the Black Sea. For example, floodplain wetlands in the Danube and its tributaries can potentially function as both a carbon store and a carbon sink, and where closely integrated with river systems they can represent an important source of carbon for the Black Sea, albeit with considerable seasonal variation. Fluxes of dissolved organic matter (DOM) from wetlands are the largest and most bioavailable pool of fluvial DOM, which affect the transport of organic pollutants, particle surface and colloid chemistry, photochemistry of natural waters and nutrient availability in freshwater systems. DOM

also contributes to chemical processes in natural water bodies by altering surface-water acidity, and affecting metal speciation and ion-exchange between the water and sediment phase. Significantly, to-date DOM has been relatively poorly studied across the freshwater – marine transitional zone in the Danube Delta: DOM is generally likely to be dominated in the headwaters of the Danube by inputs of terrestrially-derived DOM and dissolved organic carbon (DOC) concentrations are high; while the controls on DOM downstream are often related to the rate of water movement. However, the subsequent transformation of DOM in freshwater – marine transitional zone within the Delta is uncertain, yet this knowledge is fundamental to closing the carbon cycle.

13. **Harmonising scientific data and monitoring protocols in the DBS System**
Integrated management of the DBS system can be successfully implemented only by fully understanding processes in the upstream – sea continuum and by having compatible and harmonized indicators of state. This requires a harmonisation of the monitoring protocols used & scientific data collected in freshwater, transitional and marine parts of the system. Common standards following European and international standards and best practices must be implemented. Ultimately, the aim is to generate robust quality data to inform and enable efficient and effective management of water quality issues across the Danube basin, and to translate this best practice to other large river basins also. The harmonization and optimization of sampling approaches and monitoring systems and associated protocols needs careful attention, not only concerning the adoption of standard methods but also with respect to co-ordinated scale appropriate (both spatial and temporal) monitoring.

14. **Unfolding the cultural heritage potential of the DBS System by using scientific tools**
The strategic location and natural resources of this region has made it attractive to settlers for millennia. As a result the area is known to contain a wealth of historic and prehistoric sites. This important cultural resource is also threatened by land use change, development and significantly climate change. Remote sensing teamed with geo-archaeology are potentially among the most efficient tools for uncovering cultural heritage sites and conducting cultural risk assessments in the extensive DBS continuum. Such approaches could also inform future management of these cultural landscapes and the sites they contain to ensure their continued preservation. The OECD has identified cultural tourism as one of the fastest growing global tourism markets. Regional tourism could take advantage of these tools and new cultural heritage objectives to sustainably develop new attractions and business opportunities.

15. **Reducing future risks of invasive species in the DBS System**
Understanding the potential dispersal pathways for invasive species and factors that influence their success is critical. Invasive species have benefited from human-disturbed systems, including the introduction of hard substrate, altered nutrient regimes, or altered food web structure through predator-removal. The potentially devastating impact invasive species may have on the DBS system must be reduced by (i) exhaustive risk management plans dealing with all human activities that may represent future routes of introduction and transmission and (ii) by identifying the attributes of native communities that promote resilience to invasion.

16. **Interdisciplinary scientific support for the successful implementation of the Sturgeon 2020 Flagship Project in the DBS System**
Interdisciplinary research integrating environmental and socio-economic issues is needed for the successful and sustainable implementation of the Sturgeon 2020 Flagship Project of the EUSDR. Existing projects and programmes must be coordinated to focus on solve the most important uncertainties and critical questions related to the restoration of the sturgeon populations, raising awareness and broader understanding of communities

and the development of new economic opportunities related to aquaculture and conservation of sensitive environments in the DBS system.

17. The DBS System Atlas

Decision support systems covering in an exhaustive way the entire DBS system are major tools to be used by all categories of managers. An electronic atlas should provide harmonized layers of information from the physical and environmental aspects to land use, activities and social issues. The atlas would thus provide a critical support to understand the effects of the development and implementation of various policies.

18. Innovative means to harness water energy in the DBS System

Harnessing energy from water and other renewable sources in a way that does not significantly affect the ecosystems is a major issue for the DBS system. Innovative engineering schemes are needed for an effective energy generation, from the river water flow to the marine waves and currents. Specific cogeneration devices alternatively using energy from wind, water and solar sources are needed to solve the critical problem of constant supply.

19. Promoting Cross Border Environmental Stewardship in the DBS System through Citizen Science

Systematic and timely monitoring of large river-sea systems with complex geopolitical histories remains challenging. Infrequent monitoring and field sampling which is not harmonised restricts any understanding of the health of the catchment and the spatial and temporal heterogeneity in the biodiversity and quality of its surface waters. Surface waters are vital for the delivery of goods and services that are critical to human wellbeing and survival. However, monitoring these waters in the DBS Sea is restricted by economic and logistical constraints. These constraints are limited further by the lack of cross-border harmonisation in monitoring and management at the catchment scale. Engaging citizens in the role of monitoring through the development of citizen observatories can change the monitoring paradigm whilst also empowering citizens in governance and their environmental awareness. A number of emerging technologies, including smart-phones and inexpensive sensors which can be widely distributed now provide the framework for effective monitoring of water quality. Data streams from both citizen science projects and earth observation sensors (e.g. on buoys) can be used in research and education, as well as better inform management decisions. This is particularly helpful in understanding the connectivity between the landscape and surface waters at high spatial and temporal resolution and at a catchment scales, and in forming a cohesive and connected region among citizens and managers across the widely diverse histories and cultures in the region. In addition to delivering a step change in environmental monitoring, this approach can also promote the aspiration of citizen-based environmental stewardship.

20. Dynamics of Dissolved Organic Matter in the DBS system

There are considerable uncertainties concerning the flux and storage of carbon from the headwaters of the Danube, through large alluvial river-floodplain reaches in the middle of the catchment, to the freshwater – marine transitional zone of the Danube Delta and the Black Sea. For example, floodplain wetlands in the Danube and its tributaries can potentially function as both a carbon store and a carbon sink, and where closely integrated with river systems they can represent an important source of carbon for the Black Sea, albeit with considerable seasonal variation. Fluxes of dissolved organic matter (DOM) from wetlands are the largest and most bioavailable pool of fluvial DOM, which affect the transport of organic pollutants, particle surface and colloid chemistry, photochemistry of natural waters and nutrient availability in freshwater systems. DOM also contributes to chemical processes in natural water bodies by altering surface-water

acidity, and affecting metal speciation and ion-exchange between the water and sediment phase. Significantly, to-date DOM has been relatively poorly studied across the freshwater – marine transitional zone in the Danube Delta: DOM is generally likely to be dominated in the headwaters of the Danube by inputs of terrestrially-derived DOM and dissolved organic carbon (DOC) concentrations are high; while the controls on DOM downstream are often related to the rate of water movement. However, the subsequent transformation of DOM in freshwater – marine transitional zone within the Delta is uncertain, yet this knowledge is fundamental to closing the carbon cycle.

21. Cross-cutting SRIA activities in the DBS System

Establishment of a Steering Body comprised of senior scientists and stakeholders from across the region and with backgrounds in education, research, industry, government and environmental management and protection to promote the SRIA. Development of a roadmap for either individual, or a combination of research priorities, to include monitoring of progress and assessment of the impact resulting from the publication of the SRIA. Planned revision of priorities after 5 years to re-assess their relevance to the DBS System and in the context of scientific advances and changes in funding directions.

DANCERS SRIA Research Priorities		Priorities of R &I themes from DANCERS				Pillars and Priority Areas (PA) of the EUSDR			
		Ecosystem / Eco.services	Societal Challenges	Human Modifications	Water Quality	Connect the Region	Protecting the Environment	Building Prosperity	Strengthening the Region
1	Restoring Ecosystem continuity	+	+	+	+	1 / 3	6	8	10
2	Pathways of transport and accumulation of litter (plastic)		+	+	+		5 / 6	7 / 8	10
3	Ensuring safe and continuous navigation while restoring the Danube green corridor	+	+	+	+	1 / 3	5 / 6	8	10
4	Resource Recovery from Eutrophication	+	+	+	+		4 / 5 / 6	8 / 9	10 / 11
5	Dealing with Eutrophication	+	+	+	+		4 / 5 / 6	8 / 9	10 / 11
6	Using latest Earth Observation technologies coupled with in situ measurements		+		+	1	4 / 5	7 / 8	10 / 11
7	Developing sustainable agricultural practices while obtaining good water quality		+	+	+	3	4 / 6	7 / 8 /9	10 /11
8	Understanding river-sea interaction processes	+		+	+	1	4	9	10 /11
9	Managing dams and reservoir lakes as critical sediment traps and bottlenecks for river habitats continuity		+	+	+	1 / 2	4	7 / 9	10
10	Restoring natural habitats in the Danube floodplains – Danube Delta and lagoon system as support for fisheries revival.	+	+	+	+	1 / 3	6	7 / 9	10
11	Understanding Climate change impacts by applying the latest generation of models		+	+	+	2	5 / 6	7 / 9	10

Key: PA 01| Mobility |, PA 02| Energy, PA 03| Culture & Tourism, PA 04| Water Quality, PA 05| Environmental Risks, PA 06| Biodiversity, landscapes, quality of air and soils, PA 07| Knowledge Society, PA 08| Competitiveness, PA 09| People & Skills, PA 10| Institutional capacity and cooperation, PA 11| Security

Table 6a: The proposed SRIA research priorities (1-11) and their relevance to the priority R & I themes identified with stakeholders in DANCERS with reference to the EUSDR Pillars and Priority Areas.

DANCERS SRIA Research Priorities		Priorities of R &I themes from DANCERS				Pillars and Priority Areas (PA) of the EUSDR			
		Ecosystem / Eco.services	Societal Challenges	Human Modifications	Water Quality	Connect the Region	Protecting the Environment	Building Prosperity	Strengthening the Region
12	Managing water resources for human use by implementing new technologies for water abstraction, purification, distribution, collection, treatment, reuse	+	+	+	+	3	4	7 / 8 / 9	10/11
13	Harmonising scientific data		+	+	+	1 / 2 / 3	4 / 5 / 6	7 / 8 / 9	10/11
14	Unfolding the cultural heritage potential by using scientific tools	+	+	+	+	1 / 3	6	7 / 9	10
15	Preventing the intrusion and expansion of invasive species	+	+	+	+		5 / 6		7 / 9
16	Interdisciplinary scientific support for the successful implementation of the Sturgeon 2020 Flagship Project	+	+	+	+	1 / 2 / 3	4 / 5 / 6	7 / 8 / 9	10 / 11
17	The Danube River- Danube Delta – Black Sea Atlas		+		+	1 / 2 / 3	4 / 5 / 6	7 / 8 / 9	10 / 11
18	Innovative means to harness water energy		+	+	+	2		8	10
19	Promoting Cross Border Environmental Stewardship through Citizen Science	+		+	+		4 / 5 / 6	7 / 9	
20	Carbon biogeochemistry		+	+	+		4 / 5 / 6		
21	Cross-cutting SRIA activities	+	+	+	+	1 / 2 / 3	4 / 5 / 6	7 / 8 / 9	10 / 11

Key: PA 01| Mobility |, PA 02| Energy, PA 03| Culture & Tourism, PA 04| Water Quality, PA 05| Environmental Risks, PA 06| Biodiversity, landscapes, quality of air and soils, PA 07| Knowledge Society, PA 08| Competitiveness, PA 09| People & Skills, PA 10| Institutional capacity and cooperation, PA 11| Security

Table 6b: The proposed SRIA research priorities (12-21) and their relevance to the priority R & I themes identified with stakeholders in DANCERS with reference to the EUSDR Pillars and Priority Areas.

4.3 Maximising the impact of the SRIA

The SRIA should be promoted and implemented by qualified personnel, trained and familiar with the "source – to – sea" philosophy as the way to implement the integrated management of the river-delta-sea system. The associated educational plan (see Deliverable 3.3), will foster innovative learning systems to increase competencies of employees in all working sectors, including entrepreneurship in environment field. The SRIA will be underpinning by existing and proposed new research infrastructures, mainly through the cooperation of two Flagship Projects, DREAM and DANUBIUS-RI, from the EU Strategy for the Danube Region (Priority Action 7) and detailed under Deliverable 3.2.

The proposed strategic research and innovation agenda is specifically designed to address these priorities. It also supports an integrated approach, the need to engage stakeholders at all levels, across all sectors, and is oriented towards ecosystem based approaches as indicated stakeholder inputs. This is a key philosophy of the SRIA itself and as such it supports the inclusion of stakeholders' needs from the ground up so that scientific endeavours are aligned with efforts to address societal and economic challenges which are in turn reflected in policy instruments. The SRIA also promotes the unique opportunity afforded by the Danube to conduct state-of-the-art science in a river-delta-sea system and the potential to apply the knowledge gained and techniques developed in the Danube Region to other large ecosystems. The international research programme proposed coupled with open access policies, investments in infrastructure and human capacity should attract the best professionals from all sectors from across the globe.

4.3.1 Harmonization with other SRIAs and European initiatives

The proposed SRIA contained by this document will be submitted to all the relevant actors with a role in decision making in the European Research Area, such as the JPI Water and JPI Oceans, or the various Era Nets containing also countries from the Danube region, aiming to support development of harmonizing actions in the Danube Region (river-delta-sea). Access is open to all the final deliverables of FP7 DANCERS, which are freely available on the project website (www.dancers-fp7.eu). Since the FP7 DANCERS project ended by May 31st 2015, proposed actions can be taken and further strengthened, developed and implemented according to the specific needs of all potential users, without requiring any negotiations with the project consortium.

4.3.1 Links to education and infrastructure

Agenda should inform the planning of the availability and development of research infrastructures, distributed at regional level, linking the DBS system, covering all aspects of environmental sciences.

- Inform an education programme at undergraduate, MSc, PhD and postdoctoral levels designed to strengthen the human capital in the field of an innovative integrated management for the DBS system.
- DBS system provides an example to make integrated school based education of use not only to the Region, but to all potential interested individuals (from scientists and managers to business community and wider public) from Europe and elsewhere.

4.3.3 Delivering the new agenda

The vision will be achieved by implementing a range of existing National and European instruments (dedicated collaborative R&I programmes of the Funding bodies from the Danube Region, Water and Ocean JPIs, ERA Nets in the fields of water resources, structural funds) and by attracting the financial interest of the business

community.

The agenda will help the interaction with other international and European agencies / directorates and coordination of regional efforts, in research, education to improve the environmental management of a whole macro-system.
Its implementation will also clarify the interface and improve the communication between the research community and decision makers, and business. It will encourage communities of practices networking (best practices) and citizen sciences.

In the end, the way forward for a sustainable Research and Innovation Programme in the Danube Region (River, Delta and Sea) is the development of an Art. 185 of the EC. This is a long process but must be seen as an ultimate goal. The Agenda is a step towards the development of such a programme for the entire region.

4.3.4 Timescales

Even though several of the proposed actions are available for faster implementation, the entire Strategic Research and Innovation Agenda can be implemented over longer than a decade. This requires enhancement of collaboration between the Research funding agencies, ministries and Academies of science. There is thus a Need for a Basin-wide (covering the coastal sea) Strategic Programme jointly developed by the countries within the Region. The results should be used and implemented in order to implement the EUSDR into reality.

4.4. Funding opportunities for the implementation of the Strategic Research and Innovation Agenda

Even though the EU Strategy for the Danube Region was approved several years ago, all these signatory countries have not yet finally agreed on common "smart specialisation areas" or "Danube Wide cross border research domains" that could solve specific issues, unless foreseen in DANUBE programme or bilateral programmes. However, national and European instruments are in place to solve some issues.

4.4.1. National Funding Sources:

Countries within the area have specific tools to implement their research policies. National funding of Research and Innovation in the countries from the Danube Region is generally performed under the coordination of Research National Agencies (generally Ministries or State Agencies under the coordination of Ministries) and the Academies of Science or Academies (in the case of Romania).

A few examples of funding opportunities made available by the national funding agencies are:
Romania – National Plan for Research, development and Innovation (PN3). This is the main instrument for RDI funding in Romania. Although is not yet launched, its priorities are already mentioned in the National Strategy for RDI (2014-2020). The relevant priorities regard: a) bioeconomy, b) space and security and, most important, c) energy, environment and climate change. The implementation agency is ANCSI (National Authority for Scientific Research and Innovation).
Austria – offers a wide range of services for Austrian enterprises, research institutions and researchers – from the management of public funding programmes to consulting services in all phases of technology development and innovation, from support for integration into European research programmes and networks to the promotion of Austria's interests at the European and the international level (see https://www.ffg.at/en). The main topics taken into consideration are: Life Sciences, Information Technology, Material and Production, Energy and Production, Mobility, Space, Safety and Security, Human Resources

Hungary has two main programs for R&D funding respectively NKFIA (see http://nkfih.gov.hu/funding/nkfia/proposals) and OTKA (see http://nkfih.gov.hu/funding/otka).

The National Academies of the Danube Region countries, grouped as the Danube Academies Conference, have a major role in developing common research topics, and thus support implementation of the SRIA. They can contribute to the development of common strategies and means of implementation of joint topics for research throughout the entire region.

The DRRIF (Danube Region Research and Innovation Fund) Flagship Project may play a critical role in coordinating the funding bodies towards the implementation of a joint Strategic Research Agenda.

4.4.2. Joint Programming Initiatives (JPI)

JPI Water Challenges
JPI Water is one of the ten JPIs identified by relevant societal challenges, which aim to strengthen coordination and cooperation among EU Member States and Associated Countries, in themes that represent urgent and far-reaching problems which are better solved by joining energies at European and International level.
The Water JPI (http://www.waterjpi.eu) is harmonizing national Research, Development and Innovation (RDI) agendas and developing joint actions (projects, mobility and infrastructure) in the water sector. It groups as partners 20 funding agencies (EU Member states and Associated Countries); while 4 other funding agencies are Observers. A Strategic Research and Innovation Agenda is under discussion to be implemented (http://www.waterjpi.eu/index.php?option=com_content&view=article&id=378&Itemid=770). From the Danube – Black Sea Region, Austria, Germany, Moldova and Romania are full members, while Hungary has the status of Observer.

JPI Ocean
JPI Ocean is a cooperation platform of EU member states and associated countries to the EU DG R&I Programme who invest in marine and maritime research. Supported by the European Commission by a CSA project (named CSA OC EAN), calls for proposals are opened for participation of research organisations. A number of pilot actions were developed. Pilot actions are small-scale trials or test cases, limited in time and scope. They are implemented to demonstrate the added value of JPI Oceans as a coordinating and integrating platform (see http://www.jpi-oceans.eu/csa-activities). The pilot actions were: Multi-use of infrastructures for monitoring, Ecological aspects of micro-plastics in the marine environment, Ecological aspects of deep-sea mining, intercalibration for the EU Water Framework Directive. The 2 Danube Region member states are Germany and Romania.

Common topics for research and innovation in the various aspects of the DBS integrated management can be developed under the coordination of JPI Water. Another option are the joint calls that should bring together both JPI Water and JPI Oceans, in topics such as the river-sea interactions and exchange of organisms and matter.
A *sine qua non* condition is nevertheless the active involvement of all Danube Region countries in the Water JPI – and of Bulgaria in JPI Ocean.

4.4.3. Joint Funding exercises under the coordination of the different ministries from the Danube Region countries (ministries of transport & environment)

Various topics considered of critical interest (from implementation of a proper monitoring system to ensuring safe navigation of some transboundary river stretches) are the topics of joint funding exercises from national authorities and/or ministries, such as the ministries of

transport and those for the environment. Existing Danube Region organisations and commissions facilitate the development of such programmes.

4.4.4. European Commission

4.4.4.1. DG Research and Innovation

HORIZON 2020

Although HORIZON 2020 does not cover regional aspects in research across Europe, scientific issues addressed by DSRIA stressed various aspects on river-delta-sea systems which are valid for all over Europe. Therefore H2020, respectively SC 5 –Environment as well as SC 2 – Blue Growth should be considered as the main funding sources, even marginally, some other societal challenges might present topics related to river-delta-sea systems. It has to be stressed that other pillars in H 2020 could be possible to be addressed even not directly related to this scientific area (e.g. pillar 1 – Marie Sklodovska Curie, SME instruments, etc.).

SC5 - **Climate action, environment, resource efficiency and raw materials** (water issues) are more related to water technologies rather than water as: "fresh water" "river basin research" or similar areas. Activities in this call address: integrated approaches to water and climate change adaptation and mitigation; bringing innovative water solutions to the market; and harnessing water research and innovation results for the benefit of industry, policy makers and citizens in Europe and globally (WP 2014-2015 of H2020-SC5). However, there are specific topics that should be addressed as: "Harnessing EU water research and innovation results for industry, agriculture, policy makers and citizens."
SC 2 – **Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy** appears to be very close to the river-sea system research. "Blue growth - Unlocking the potential of Seas and Oceans". Several topics may relate to river-sea systems as long as they address some of issues related to fresh water – sea interactions (party covered by integrated coastal zone management). Additionally, in the case of off-shore activities related to marine research (not deep-sea) in areas impacted by rivers, researchers from the Danube Region may also successfully participate. Such an example is BG-7-2015: Response capacities to oil spills and marine pollutions.

4.4.4.2. DG REGIO

The DANUBE Programme

The Danube Transnational Programme (2014-2020) is built around four thematic priority axes: 1. Innovative and socially responsible Danube region, 2. Environment and culture responsible Danube region, 3. Better connected and energy responsible Danube region, 4. Well-governed Danube region. The programme does not pay money of research, but supports the use of science and innovation to solve specific problems in the region.
The programme will invest EUR 202.3 million from the ERDF and EUR 19.8 million from IPA II for transnational projects in the Danube basin territory. Eligible partners will, therefore, come from 8 EU countries - Austria, Bulgaria, Croatia, the Czech Republic, Germany (only Baden-Württemberg and Bayern), Hungary, Romania, Slovakia, Slovenia; and 5 non-EU countries - Bosnia and Herzegovina, the Republic of Moldova, Montenegro, Serbia, part of Ukraine. Some potential topics that fit the SRIA are presented below:
1. "2.1.1 Investment priority 1b) promoting business investment in R&I, developing links and synergies between enterprises, research and development centres and the higher education sector ... " This priority may be the one continuing the activities done in FP7 DANCERS.
2. "2.2.1 Investment priority 6c) Conserving, protecting, promoting and developing cultural and natural heritage", even there are lots of issues on tourism. An example of indicative action is "Development and practical implementation of education, training and capacity building to support quality tourism, eco-tourism and environmental transport solutions"

3. "2.2.2 Investment priority 6d) Protecting and restoring biodiversity and soil and promoting ecosystem services, including through Natura 2000, and green infrastructure". Focus should be given on large-scale bio-corridors such as Mura-Drava-Danube Transboundary Biosphere reserve, habitat conditions along the Danube River and other key green infrastructures including the Danube Delta. Support should target protected areas and their relevant adjacent areas.

Bilateral (cross border - CBC) cooperation programmes
Specific programmes like AT-SK, AT-HU, RO-HU, RO-MD, RO-BG and similar will make available funding for projects aiming to solve major bilateral societal problem in the Danube – Black Sea Region. For the period 2014 – 2020 just a few of these bilateral programmes have been already approved by the EC (DG REGIO) but draft documents are already available. The specific calls should anyway be launched during 2015.
These CBC programmes are major source of funding for many of the parts concerning development of infrastructure with strong societal role.

4.4.4.3. Other EC Programmes funded by other Directorates.

DG ENV is a major initiative dealing with the environmental problems in the Danube – Black Sea, either through the dedicated LIFE+ Programme or through specific calls focussed on critical topics.

DG MOVE also funds a series of major projects aiming to solve the critical problem of safe navigation along the Danube – Black Sea corridor, as well as the problem of multimodal transport in the Region. All these projects require strong knowledge skills and several parts of the Strategic Research and Innovation Agenda can be jointly covered in collaboration with these programmes.

DG MARE is another major programme coordinator aiming to implement the Marine Strategy Framework Directive in Europe. Its calls – dedicated to the fulfilment of this goal, can also be of major interest in the case of marine areas under the influence of major rivers (such as the NW Black Sea under the influence of the Danube).

4.5. Private Funding

Linking research to industry is a very difficult task. Especially the environmental research, which is not among the areas where private funding is easy to grow, a special effort should be made through concrete actions. There are some specific niches where knowledge is a key tool for companies operating in Danube area. Although industrial lead is still lacking behind, there are good examples can be found in transport sector where Danube River is an important connectivity mean among countries and important quantity of goods is shipped from one country to another. As an example transportation companies (both for goods as well as touristic purposes) are keen to know what are the most suitable “navigation channels” on the Danube. It is important also to mention that Danube connects Europe via Constanta harbour (not only Danube Region). Many goods imported from Asian continent (e.g. China) enter in Europe via Constanta. Energy companies of relevance for the entire system are those dealing mainly with renewables. Traditional oil and gas companies are mainly focussed on Black Sea (where important off-shore oil & gas resources have already been discovered and some exploited) and their main interest in the Danube part of the section is related mainly with safe transport.

5. CONCLUSIONS

- Given previous historical differences, and even divergent, approaches to effective management of the Danube Region, the EU Strategy for the Danube Region and Europe 2020 now afford the focus and impetus to strengthen the area and ensure improved connectivity with the rest of Europe.
- In order to address the research and innovation needs of stakeholders in the DBS System, future research funding programmes should include targeted transnational calls that promote cross-disciplinary research and stakeholder engagement .
- The DANCERS SRIA Topics as proposed are in line with H2020 programme and the identified priorities in the EUSDR, but highlight specific the specific challenges and opportunities in the DBS system.
- The key issues related to the DBS System, as identified by stakeholders, relate to connectivity across the entire system, harmonisation of sectoral and societal requirements and environmental protection including changes in biodiversity.
- Significant scientific effort will be required coupled with standardised methodologies and harmonisation of approaches across the DBS System in order to provide the understandings required for effective holistic management and the development of policy instruments required to drive improvements in environmental quality and competitiveness for the Region and across Europe.
- Dancers has reaffirmed that technological advances can support the monitoring across the DBS System but that these will only be effective if there is buy-in from key stakeholders including citizens across the region. Effective and careful implementation will lead to world leading research and innovation that will have the definite potential to be economically, environmentally and socially transformational for the Danube Region.
- Science and innovation drive change and DANCERS has provided guidance through the SRIA as to where effort can be directed in order to derive the maximum return from research investment.
- Science and innovation have an essential role in strengthening the region but this will only be realised if scientific, political, industrial and societal stakeholders treat the DBS System as the single system advocated and promoted in the SRIA.

REFERENCES

Achtnicht, M. et al. (2014) Socio-Economic Assessment of the Danube Region: State of the Region, Challenges and Strategy Development – Final Report. Study commissioned by the Ministry of Finance and Economics Baden-Wuerttemberg on behalf of the European Commission.

Artioli, Y. et al., 2008. Nutrient budgets for European seas: A measure of the effectiveness of nutrient reduction policies. Marine Pollution Bulletin, 56(9), pp.1609–1617.

Borja, A. (2004) The European water framework directive: A challenge for nearshore, coastal and continental shelf research. Continental Shelf Research, 25(14): 1768–1783.

Chapman, D., Bradley, C., Gettel, G. Hatvani, I.G., Hein, T., Kovács, I., Liska, I, Oliver, D.M., Tanos, P., Trásy, B. (Submitted). Progress in water quality monitoring and management in large rivers and catchments, with specific reference to the Danube River. Danube Special Issue, *Science of the Total Environment.*

Cardinale, B.J., Emmett Duffy, J., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A.,Mace, G.M., Tilman, D., Wardle, D.A., Kinzig,A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D.S. and Naeem, S. 2012. Biodiversity loss and its impact on humanity. Nature, 486: 59–67.

Chee, Y. E. (2004) An ecological perspective on the valuation of ecosystem services. Biological Conservation, 120: 549–565.

Convention on Biological Diversity (2000) COP 5 Decision V/6 The ecosystem approach.

Day J.W., Giosan L. 2008. Survive or subside? Nature Geoscience 1, 156 - 157

Döll, P. & Zhang, J. (2010) Impact of climate change on freshwater ecosystems: a global-scale analysis of ecologically relevant river flow alterations. *Hydrology and Earth System Sciences*, 14: 783-799

Doney, S. C., Ruckelshaus, M., Emmett Duffy, J., Barry, J. P., Chan, F., English, C. A., Galindo, H. A., Grebmeier, J. M., Hollowed, A. B., Knowlton, N., Polovina, J., Rabalais, N. N., Sydeman, W.J. & Talley, L. D. (2012). Climate change impacts on marine ecosystems. Annual Review of Marine Science, 4: 11-37.

Doru,B.S., Rey, S.P., Thrichkova,T. Lenhardt, M. (Submitted). The Danube River - Danube Delta - Black Sea a turning plate of major interest for the past, present and future fish fauna, Danube Special Issue, *Science of the Total Environment.*

European Commission, 2003. Achievements and Obstacles in the implementation of Council Directive 76/464/EEC on Aquatic Pollution Control of Dangerous Substances (1976-2002), European Commission - DG Environment, Brussels.

Farmer, A., Bassi, S., Fergusson, M., Lasage, R., Mudgal, S. and Benito, P. (2008) Water Scarcity and Droughts. Report of study requested by the European Parliament's Committee on the Environment, Public Health and Food Safety.

Farmer, A., Mee, L., Langmead, O., Cooper, P., Kannen, A., Kershaw, P. and Cherrier, V. (2012) The Ecosystem Approach in Marine Management. EU FP7 KNOWSEAS Project. ISBN 0 - 9529089 - 5 - 6.

Feldbacher, E., Paun, M., Reckendorfer, W., Sidoroff, M., Stanica, A., Strimbu, B., Tusa, I., Vulturescu, V., Hein, T., (Submitted). Twenty years of research on water management issues in the Danube Macroregion – past developments and future directions. Danube Special Issue, *Science of the Total Environment.*

Fowler, H. J.; Archer, D. R. 2006. Conflicting signals of climatic change in the Upper Indus Basin. Journal of Climate. 19/17, 4276-4293

Giosan L., Bokuniewicz H., Panin N., Postolache I. 1999. Longshore Sediment Transport Pattern along the Romanian Danube Delta Coast, Journal of Coastal Research 15(4), 859-871.

Giosan, L, JP Donnelly, S Constantinescu, S Filip, I Ovejanu, A Vespremeanu-Stroe, E Vespremeanu, GAT Duller. 2006. Young Danube delta documents stable Black

Sea level since Middle Holocene: morphodynamic, paleogeographic and archaeological implications. Geology 34 (9): 757-760.

Global Water Partnership (2009) and the International Network of Basin Organizations (INBO)' A Handbook for Integrated Water Resources Management in Basins, Elanders, ISBN: 978-91-85321-72-8

Gomoiu M.T., Skolka M. 1996. Changements recents dans la biodiversite de la Mer Noire dus aux immigrants, GeoEco Marina 1, 49-66.

Goriup, P. & Goriup, N., 2015. Evolution of Policies and Institutions for Conservationof the Ukrainian Danube Delta. In K. Iordachi, C. and Van Assche, ed. The Biopolitics of the Danube Delta. Nature, History, Policies. Lexington Books, London, pp. 319–344.

Hein, T., Schwarz, U., Habersack, H., Nichersu, I., Preiner, S., Willby, N., Weigelhofer, G. (submitted). River restoration, water framework directive, floodplains, Danube River, flood protection. Danube Special Issue, *Science of the Total Environment.*

Hering, D. et al., 2010. The European Water Framework Directive at the age of 10: a critical review of the achievements with recommendations for the future. The Science of the total environment, 408(19), pp.4007–19.

Hopkins, T. S., Bailly, D., & Støttrup, J. (2011). A systems approach framework for coastal zones. Ecology and Society, 16(4): 25.

House of Commons Environment, Food and Rural Affairs Committee, 2012, Greening the Common Agricultural Policy, Vols 1 and 2, HC 170, London: The Stationery Office Limited

Howarth, W., 2006. The progression towards ecological quality standards. Journal of Environmental Law, 18(1), pp.3–35.

ICPDR, 2009. Danube River Basin District Management Plan, ICPDR, Vienna.

ICPDR Strategy for Adaptation to Climate Change, 2012 downloadable at http://www.icpdr.org/main/publications/programmes

Kimstach, V.A. et al., 1998. A water quality assessment of the former Soviet Union., E & FN Spon, London; New York.

Maes, J., Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F, Paracchini ML, Keune H, Wittmer H, Hauck J, Fiala I, Verburg PH, Condé S, Schägner JP, San Miguel J, Estreguil C, Ostermann O, Barredo JI, Pereira HM, Stott A, Laporte V, Meiner A, Olah B, Royo Gelabert E, Spyropoulou R, Petersen JE, Maguire C, Zal N, Achilleos E, Rubin A, Ledoux L, Brown C, Raes C, Jacobs S, Vandewalle M, Connor D, Bidoglio G (2013) Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg.

Mee, L. et al., 2005. Restoring the Black Sea in Times of Uncertainty. Oceanography, 18(2), pp.100–111.

Macklin, P. 2007. The Aral Sea Disaster. Annual Reviews of Earth and Planetary Sciences, 35: 47-72

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-Being:Synthesis. Island Press, Washington. 155 pp

Panin N. 1996. Impact of global changes on geo-environmental and coastal zone state of the Black Sea. GeoEcoMarina 4: 19-29.

Panin N. 1998. Danube Delta: Geology, Sedimentology, Evolution, Association des Sedimentologistes Francais, Paris, p. 64.

Panin N., Jipa D. 2002. Danube river sediment input and its interaction with the north-western Black Sea. Estuarine, Coastal and Shelf Science, 54 (3): 551-562.

Poulos S.E. & Collins M.B., 2002. A quantitative evaluation of riverine water/sediment fluxes to the Mediterranean basin: natural flows, coastal zone evolution and the role the dam construction. (In:) Jones S.J. & Frostick L.E. (eds) Sediment Flux to Basins: Causes, Controls and Consequences. Geological Society, London, Special

Publications, 191, 227-245.

Reckendorfer, W., Schmalfuss, R., Baumgartner, C., Habersack, H., Hohensinner, S., Jungwirth, M. & F. Schiemer 2005. The Integrated River Engineering Project for the free-flowing Danube in the Austrian Alluvial Zone National Park: contradictionary goals and mutual solutions. Archiv für Hydrobiologie Supplement 155, 613-630

Roxburgh, T., Dodds, L., Ewing, J., Morrell, T., Sutton, E., Varas, J., L., G., Viada, C., Teleki, K., Siciliano, D., Vallet, E., O'Mahony, C. and Twomey, S. (2012) Towards Sustainability in the Celtic Sea: A guide to implementing the ecosystem approach through the Marine Strategy Framework Directive. Report of LIFE+ Project – Partnerships Involving Stakeholders in the Celtic Sea Ecosystem (PISCES).

Ruckelshaus, M., Doney, S.C., Galindo, H.M., Barry, J.P., Chan, F., Duffy, J.E., English, C.A., Gaines, S.D., Grebmeier, J.M., Hollowed, A.B., Knowlton, N., Polovina, J., Rabalais, N.N., Sydeman, W.J. and Talley, L.D. (2013) Securing Ocean Benefits for Society in the Face of Climate Change. Marine Policy. 40: 154-159

Stanica A, Dan S, Ungureanu G. 2007. Coastal changes at the Sulina mouth of the Danube River as a result of human activities. Marine Pollution Bulletin 55: 555-563.

Stanica A., Panin N. 2009. Present evolution and future predictions for the deltaic coastal zone between the Sulina and Sf. Gheorghe Danube river mouths (Romania). Geomorphology 107: 41-46.

Stanica A., Dan S., Jimenez J. & Ungureanu G. 2011. Dealing with erosion along the Danube Delta coast. The CONSCIENCE experience towards a sustainable coastline management. Ocean & Coastal Management 54, 898-906.

Qiu, W. and Jones, P.J.S. (2013). The emerging policy landscape for marine spatial planning in Europe. Marine Policy, 39: 182-190

Tyler, A.N., Hunter, DP., Spyrakos, E., Groom, S., Constaninescu, A., Kitshcen, J., Paun, A. (Submitted). Developments in Earth observation for the assessment and monitoring of inland, transitional, coastal and shelf-sea waters. Danube Special Issue of *Science of the Total Environment.*

Ungureanu, Gh, Stanica, A., 2000. Impact of human activities on the evolution of the Romanian Black Sea beaches, Lakes and reservoirs: Research and Management, 5, 111-115.

Westhoek, H., van Zeijts, H., Witmer, H., van den Berg,M., Overmars, K., van der Esch, S. & van der Bilt,W., 2012, Greening the CAP: An analysis of the effects of the European Commission's proposals for the Common Agricultural Policy 2014 -2020, The Hague, PBL Netherlands Environmental Assessment Agency.

Wiens, JA (2002) Riverine landscapes: taking landscape ecology into the water, Freshwater Biology Volume 47, Issue 4, pages 501–515, April 2002 DOI: 10.1046/j.1365-2427.2002.00887.x