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The Black Sea – Recipient of the Danube River

Editorial

Dear Reader

The scientific concept of the „catchment approach", which is implemented by river basin management, is widely accepted. In practice, this means that the effects of any impact in a river basin such as point and diffuse sources of pollution, deforestation, reservoirs and hydromorphological alterations will be transported or shifted downstream and affect people living in these areas. Lakes and oceans are at the lower end of the basin and, hence, recipients of the rivers water and its load of nutrients, pollutants and sediments. It is time to dedicate an issue of Danube News to the Black Sea and to focus on the effects of the Danube as the major tributary. The Danube's great influence winds like a red thread through all articles, but it would also be interesting to see this context with other large tributaries such as Dnieper and Dniester. The Danube MONERIS model showed that the nutrient load has diminished from the 1990s. Nutrient retention by floodplains and dams, in particular the Iron Gate dams, remain subject of further research, as the hypothesis of silica depletion in the Black Sea triggered by Iron Gate retention proved false. On the other hand, sediment retention clearly affected Black Sea shore erosion, and the sediment budget is still debated.

The Black Sea is commonly known by its mysterious large anoxic zone that makes up to 81 % of its total volume. Bacterial metabolism, anaerobic sulfate reduction, and methane and ammonium oxidation in particular, were subject of intensive scientific research from the 1950s. Then, ongoing eutrophication became an urgent topic. Nutrient cycling and food webs were negatively affected. Another threat to the marine ecosystem was overfishing as exemplified by the highly endangered anadromous sturgeons that migrate into the Danube for spawning. Invasive species stress the native populations of fish, mollusks and macrophytes. Climate change can influence the physical behavior of the sea (temperature, currents). Numeric modeling of the Black Sea is an important tool to understand the functioning of abiotic and biotic marine processes, and will help to develop sound and useful Black Sea protection strategies.

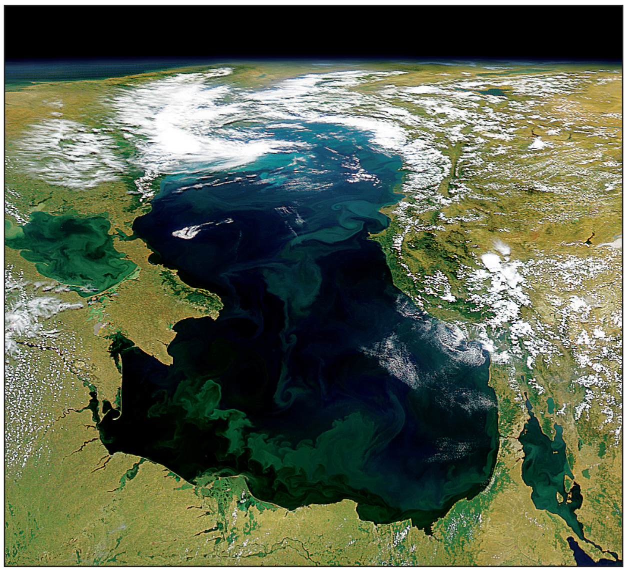

Figure 1. The Black Sea seen from space in west to east direction (25 February, 2008). The large-scale gyres near the Danube Delta (bottom of photo) reflect floating algal blooms and document eutrophication (credit by SeaWiFS Project, NASA/Goddard Flight Center, and ORBIMAGE)

Today, we have much scientific evidence about human impacts on the Black Sea, particularly in the near-shore shelf areas where marine benthos and fish are suffering from pollution. Construction of shore protection against erosion added morphological impacts to marine life. Danube News 22 gives special emphasis to the marine and brackish biota that are the foundation of biodiversity and ecosystem services. The different views of the five articles presented reveal across disciplines a common agreement of recent recovery of the Black Sea ecosystem. As a consequence, the marine environment needs the same protection as freshwater environments, and – if effectively implemented – the benefits for nature and human society become evident.

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The influence of the Danube River and other tributaries on the Black Sea

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Introduction

The Black Sea has a surface area of 420 000 km^2. The average depth is about 1240 m and the maximum depth 2212 m. 81 % of the water mass is anoxic. The hydrographic regime is characterized by low-salinity surface water of river origin overlying high-salinity deep water of Mediterranean origin. A steep pycnocline centered at about 50 m is the primary physical barrier to mixing and is the cause of the stability of the anoxic interface. The bacteria in the bottom waters quickly consume all the oxygen and the sea is anoxic below a depth of about 180 meters. Below 150 to 200 m hydrogen sulphide (H_2S) is present.

The relation between the surface area of the Black Sea and its catchment area of 2 300 000 km^2 *(Figure 1)* with a population of 190 Million inhabitants indicates a high sensitivity of the Sea against anthropogenic pressure, where nutrient discharges leading to eutrophication are considered as the most crucial ones. The most sensitive region in the Black Sea marine system in respect to eutrophication is the Azov Sea (surface area: 38 000 km^2) – a very shallow water (maximum depth: 13 m) receiving discharges mainly from Don River (catchment size: 422 000 km^2). This is followed by the Western Black Sea coastal area, which includes the north-western continental shelf with a surface area of about 80 000 km^2 and a depth of less than 200 m. The Rivers Danube, Dnieper and Dniester are discharging into this part of the Black Sea. Their watershed covers about 60% of the catchment area of the Black Sea (including Azov Sea) and they have a contribution of almost 80% to the freshwater inflows to the Black Sea (without Azov Sea).

Among these rivers the Danube is the largest. Its catchment size is 817 000 km^2, hosting a population of 82 Million people. The Danube is contributing with about 78% to the freshwater inflow into the Western Black Sea. Its contribution to the land based nutrient loads discharged to the Western Black Sea is estimated to be about 80% for nitrogen and 75% for phosphorus (Lampert et al. 2004).

The Danube River Basin and the Black Sea: Sharing the burden

From the 1970s to the early 1990s, the North-Western and Western Black Sea coastal area suffered from chronic harmful algal blooms, oxygen deficiencies, as well as the mass mortalities of wildlife in the region. An excessive input of nutrients was the main reason for this development, and the Danube River was identified as major source for nutrients in this part of the Black Sea ecosystem. In particular, eutrophication problems close to the mouth of the Danube Delta as well as on the coast north and south of the Delta are a result of direct Danube influence. In the north the effects are intensified by influences of Rivers Dniester and Dnieper.

Looking more in detail it becomes clear that the Western Black Sea is highly heterogeneous; all parameters of sea water vary not only in time but significantly also in space due to the different depths of Danube plume influence and local characteristics. Correspondingly, different levels of eutrophication with decreasing tendency from the Danube Delta to the south can be observed *(e.g. Table 1)* (daNUbs 2005).

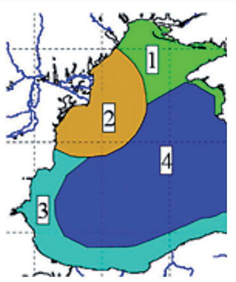
A first visible eutrophication-related effect in an aquatic ecosystem is the intense algal proliferation, causing misbalances with possible ultimate consequences – prolonged oxygen deficiency and mortality of macroalgae and benthic animals. The following

Figure 1. Black Sea Catchment (envirogrids, 2010)

Area	$Si\text{-}SiO_4$	$P\text{-}PO_4$	$N\text{-}NO_2$	$N\text{-}NH_4$
Sulina	1795	56	63	146
Constanta	387	17	12	85
Bay of Varna	126	9	2.1	48

Table 1. Average values of nutrient concentrations (mg/m³) for the period 2001–2003 at Sulina (Danube waters), Constanta (Romanian near-shore waters) and in the Bay of Varna (Bulgarian waters nearby Cape Galata)

regions of characteristic chlorophyll a patterns (algal proliferation) related to Danube influence (especially nutrient loads to the Black Sea) were identified in the Western Black Sea *(Figure 2)* (daNUbs 2005):



R1 – North-western Shelf
R2 – Area of direct Danube river-water influence
R3 – Western and southern Shelf
R4 – Central Western Black Sea

Figure 2. Regions of characteristic chlorophyll a patterns and different level of Danube influence

Region 1 (26 000 km²) covers the north-western shallow shelf area (R1) and it is influenced by the Danube at southerly winds and also by the Rivers Dniester and Dnieper. In the northern part of R1, due to the input of nutrient-rich river waters and the shallowness of the sea, high surface chlorophyll values can be observed throughout the year.

Region 2 (34 000 km²) covers the area in front of the Danube Delta (R2), which is directly affected by the river water and is defined as an area within an orbit of 100 km radius around the Danube Delta. Evidently, phytoplankton production processes in this region are strongly determined by the inflow of nutrient-rich river waters.

Region 3 (36 000 km²) includes the coastal waters of the narrow shelf belt along the Western, South-Western and Southern Black Sea coast (R3). The western shelf is influenced by Danube transformed waters, especially during high Danube inflow. The pathway of Danube transformed waters is mostly located in the 5–30 km wide offshore zone of the western coast of the Black Sea. The phytoplankton productivity in this region is also controlled by smaller inlets with respective nutrient sources mixed by coastal winds and currents.

Region 4 (104 00 km²) covers the central-offshore area of the Western Black Sea including the Rim current and the Crimea-induced eddy street in the northern and north-western part (R4). The central part of the Western Black Sea generally exhibits low surface chlorophyll, except the eddy street, which is partly affected by pigment-rich waters from R1 and R2 and also by vertical nutrient transport as a consequence of front and eddy formation.

Due to the strong advection in the Western Black Sea, an overlapping of the borders of these regions must be considered. The levels of eutrophication in R1 and R2 are comparable, whereas R3 and R4 are characterized by lower concentrations of nutrients and lower phytoplankton standing stock, respectively. Enhanced phytoplankton production in the Danube River plume (R2) takes place during the whole year and shows a good correlation with the Danube River water and nutrient discharges. The Danube waters themselves do not transfer large amounts of living phytoplankton biomass into the Black Sea, where most of the freshwater algae do not survive (Velikova et al. 1999).

Good news, for now

Studies from the beginning of this decade (daNUbs 2005) show that the situation in the Western and North-Western Black Sea shallow waters has been considerably improved since the early 1990s due to reduced nutrient inputs. Eutrophication levels have decreased and water transparency has increased, with an improvement of the near bottom oxygen regime. The Black Sea has experienced a regeneration of phytoplankton and other organisms necessary for the health of the ecosystem. Zooplankton is regenerating only slowly and fish stock is still out of balance.

The improvements are the consequences of decreasing nutrient discharges, especially of phosphorus, into this part of the Black Sea. These current low discharges are caused by the improved nutrient removal from waste water in Germany, Austria and the Czech Republic and reduced phosphate discharges from detergents in other countries. The economic crisis in central and eastern European countries had a consequence on the environment, including the closure of large livestock farms and agricultural point sources, the dramatic decrease of the application of mineral fertilizers and the closure of nutrient discharging industries, like the fertilizer industry (Kroiss et al. 2006).

The threat and the solution

Management of nutrients to avoid excessive discharges through the river system into the coastal areas has to consider the whole basin. Agriculture driven by the demands of human nutrition, waste water management, as well as combustion processes are the main sectors causing nutrient discharges from the land to the sea. For sustainable development of the Western Black Sea ecosystem, the nutrient discharge from the Danube River should be further diminished or at least kept at the present level. It has been shown that the economic development in the Danube Basin may reverse the improvement of the quality of the North-Western and Western Black Sea ecosystem, if nutrients are not properly managed. Policy measures have to be proactive and should focus on continuous and long-term control of all sources of nutrients: waste water management, agriculture, and combustion processes.

In order to avoid deterioration of the current situation, national governments under the leadership of the International Commission for the Protection of the Danube River (ICPDR) have declared the total area of the Danube Basin as sensitive area. This facilitates the financial support of investments for waste water treatment with nutrient removal from international donor funds. Furthermore, a consequent implementation of measures to limit nutrient emissions from agriculture is necessary. These measures should be based on the best available agricultural practices for reduction of nutrient losses from agricultural areas and a limitation of the intensity of agricultural production. A management policy like this would meet the objectives of protecting ground and surface water quality and abating the coastal eutrophication in the North-Western and Western Black Sea shallow waters (Kroiss et al. 2006).

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Sediment budget along the Danube Delta: Coastal currents vs Danube River input

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Introduction

In modern times deltas all over the world are subject of intense pressures from human activities. While some European deltas are completely changed by regulation of water and sediment flow (e.g. Rhine Delta) some are still relatively natural such as the Danube Delta. This delta began to form approximately 12 000 years ago, when a gulf accumulated sediments and after a succession of lobe formation the Danube Delta took the actual shape (Panin et al. 1983). The Danube River discharges into the Black Sea through three branches: Kilia, transporting around 58% of the water and sediments, Sulina, the major waterway, 19%, and Sf. Gheorghe, 23% (Bondar et al. 1992). Hydromorphological alterations in the Danube and its Delta adversely affect the stability of the Black Sea coast by increasing the natural erosive trends or even reversing the accumulative trends into erosive.

Present status of the Danube Delta coast

The present status of the delta shoreline is the result of the combined action of both natural and human factors. In the last 2000 years the deposition of sediments brought by the Danube River took place mainly in the Kilia and Sf. Gheorghe lobes, while Sulina lobe was continuously retreating (Panin & Jipa 2002). Human interventions, such as embankments and dam construction along the Danube River and its tributaries reduced drastically the volumes of

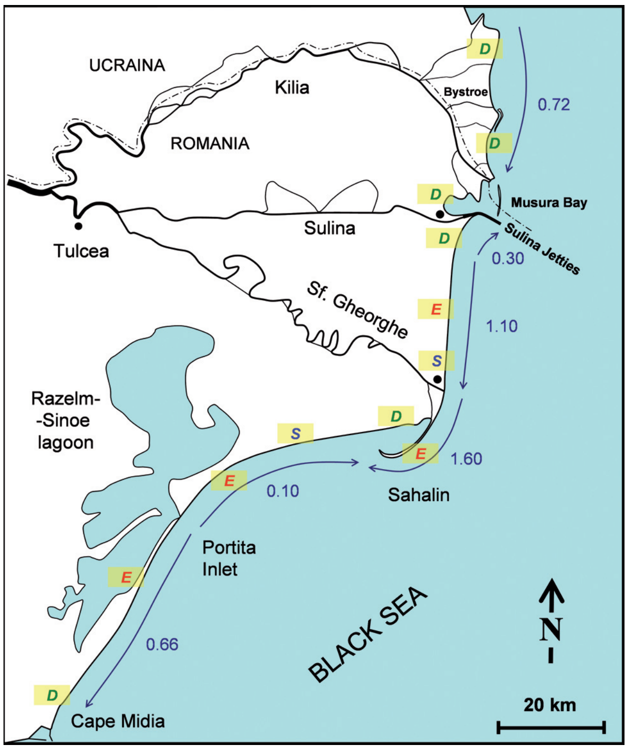

Figure 1. Danube Delta. In blue the direction of main currents and volumes of sand (in million m^3/year) transported alongshore. Yellow boxes show the beach zones with erosion (E), deposition (D) or stability (S)

sand reaching the coast. Moreover, engineering works such as Sulina Jetties disturbed the natural transportation of the sediments in the near-shore area. As a result large parts of the wave dominated Danube Delta coast are retreating except the Kilia lobe *(Figure 1).*

Coastal sediment transport and budget

The coast confined by Sulina Jetties and Portiţa Inlet was extensively investigated. Complex numerical modeling was used along with local measurements and observations to compute the alongshore sediment transport rates and the sediment budget and evaluate the future position of the shoreline (Dan et al. 2009). Sediment transport computation is based on various information (sediment and water characteristics, closure depth, etc.) and a setting of a wave climate modeled from 11 years of wind records (at Sulina meteorological station and offshore of Portiţa Inlet). The wave climate is dominated by northern directions with the majority of significant storms occurring during the wintertime. The calculated sediment budget completes the quantitative in situ investigation of the Danube Delta coast.

Due to the Sulina Jetties *(Figure 2)* the generally southward oriented alongshore current and sediment transport reverse their direction for a small distance (8 km) just south of Sulina contributing to the intense sedimentation in Musura Bay (just north of the Sulina Jetties). The rate of transport reaches 0.3 million m^3/year and the beach is advancing at rates of 5 to 8 m/year. Southward, the alongshore current is returning to the dominant direction and the transport increases from 0 at the so-called "division point" to 1.1 million m^3/year close to Sf. Gheorghe mouth. The abrupt increase of sediment transport generates intense erosion and the average retreat rates of the coast in the central part of *Sulina–Sf. Gheorghe* beach are between 9 and 13 m/year with a maximum of 20 m/year. To the historical retreat of the Sulina lobe the human induced erosion is added making this area very vulnerable to catastrophic events.

The Sahalin spit island, formed more than a century ago, is a very dynamic geomorphologic feature with an average rate of elongation (towards southwest) of 100–140 m/year and an average rate of migration (towards mainland) of 23 m/year. At century time scale this area is strongly retreating, but cycles of spit islands formation and evolution represent an advance mechanism for the Sf. Gheorghe lobe. Behind the Sahalin spit island the coast is advancing due to the sheltered environment which allows sedimentation. This spit island is a peculiar environment and its rapid dynamics is explained by the combined action of the cross and alongshore processes (Dan et al. 2008). Due to the sudden change in shoreline orientation, from north-south to east-west, this coast is particularly difficult for investigation in terms of wave induced sediment transport. However, complex numerical modeling coupled with findings from investigation on its historical evolution revealed a mechanism of evolution based

Figure 2. View from Sulina lighthouse (situated at the seaside extremity of the Sulina Jetties), eastward. The fresh water plume is directed to the right (southward) by the alongshore currents

on successive realignments of the spit island. The net alongshore sediment transport increases from 1.1 million m^3/year at the connection of the spit island with the mainland to 1.6 million m^3/year in the central part and rapidly decreases to almost zero at the southern tip. In the same time, cross-shore processes such as overwash transport approximately 1 million m^3/year from the sea-side to the bay-side through overtopping and breaching the spit island. The elongation of the spit island is supported by the alongshore currents which transport sediments delivered by the river and the marine up drift current towards the southern part of the spit island, while the rapid mainland migration is determined by the cross-shore processes. The position of the spit island at certain time is given by the interaction between the alongshore processes which tend to develop the island north–south and the cross-shore processes rolling the spit island from east to west.

Southward, the beach sector *Sahalin–Portiţa* Inlet has a low amplitude of the alongshore sediment transport, around 0.1 million m^3/year, and it is almost stable with episodic events of erosion mainly due to the breaching of the sand barriers which separate small lakes from the sea. The northern part of the sector *Portiţa Inlet–Cape Midia* is retreating, while the southern part is advancing due to the accumulation of sediments generated by the Midia Harbour jetties.

Direct river influence on sediment dynamics of the coast

The sediments discharged by the Danube River into the Black Sea play an important role in the dynamics of the Danube Delta coast. The erosive or accreting state of the deltaic beaches is largely determined by the amount of sand available. The volumes of sediments reaching the coast decreased dramatically in the last two centuries due to the engineering works made along the Danube River and its tributaries as well as on the coast. While the volume of fine sediments (mud, silt) increased by soil erosion from intensive agriculture, the quantity of sand (the main component of the beaches) decreased mainly due to embankments, river regulation and numerous dams. Measurements indicate that the Iron Gate dams I and II built in 1970 and 1983 approximately 900 km upstream of the Danube Delta reduced the sediment discharge into the Black Sea by about 50% (Panin & Jipa 2002).

The majority of the Danube Delta coast is wave dominated, meaning that the main factor shaping the coast are the waves and their induced currents. An exception is Kilia Delta where the large volumes (approximately 3 million metric tons/year, Bondar et al. 1992) of sand discharged by the river cannot be transported by the waves and therefore the shoreline is advancing. The large majority of sediments transported alongshore are deposited in Musura Bay contributing to its rapid sedimentation. Sulina Branch, the major waterway from Danube Delta, discharges between 0.85 and 1.3 million metric tons/year of sand. The sand is accumulated in the Sulina Channel and in the vicinity of Sulina mouth. The dredging works carried out to maintain a minimum depth of 7 m for navigation remove large parts of these sediments which consequently are lacking in the near-shore system. Sf. Gheorghe Branch discharges between 0.75 and 1 million metric tons/year of sand. The river sediments along with the marine up drift sediment input constitute the sediment source for the development of the Sahalin spit island.

Future measures to stop Danube Delta and Black Sea coastline erosion

The future position for the next 25 and 50 years of the shoreline in the Sulina–Portiţa Inlet area was investigated using numerical modeling which took in account not just wave induced sediment transport, but also the relative sea level rise (the combined effect of the land subsidence with the general sea level rise due to Holocene warming of climate) estimated at a present rate of approximately 3 mm/year. The sector just south of Sulina Jetties will continue its advancing despite the relative sea level rise reaching a position that is 155 m (in 25 years) and 265 m (in 50 years) more off-shore than today. In the central part of Sulina–Sf. Gheorghe beach sector the erosion is enhanced by the relative sea level rise, so the shoreline will retreat with 80–300 m over 25 years and with 170–555 m over 50 years. The short beach strip just north of Sf. Gheorghe mouth will advance with maximum 70 m due to the river sediment supply. For the Sahalin spit island quantitative predictions are difficult to be made. However, if no actions which reduce significantly the sediment input will be made then the spit island will continue its elongation and migration. The cycle will be closed when the southern tip will connect with the mainland turning the bay behind the island into a lagoon (as those formed earlier along the Danube Delta coast). The sector Sahalin–Portiţa Inlet will slightly retreat (30–65 m in 50 years) mainly due to the relative sea level rise. All these computed shoreline retreats are minimum rates, but previsions made by the Intergovernmental Panel on Climate Change anticipate much higher sea level rise due to the climate change (up to 1m in 2100, Meehl et al. 2007) which can constitute a major threat for all the deltaic beaches.

The dynamics of the Danube Delta coast is driven by both natural evolution and human intervention and the result of the permanent interaction between the available sediment, mainly delivered by the Danube River, and the waves and marine currents. Large parts of the coast are eroding, and this erosion will keep similar rates for at least 50 years if no major interventions will take place in the area. Reversing or at least stopping the erosive trends for the majority of the Danube Delta coast can be made if the natural patterns and rates for the sediment circulation are restored. As highlighted above, any decrease in the sediment discharge of Danube River (especially sand) will adversely affect the coast stability. Hard structures for navigation or beach protection should be avoided and soft measures, such as sand bypassing and artificial nourishment of the active beach should be preferred.

More specific, for the Kilia Delta the structures built at Bystroe channel mouth as well as the diversion of larger water volumes on the channel can affect negatively the local littoral sediment circulation. The erosion in the central part of Sulina–Sf. Gheorghe beach can be stopped if the 1 million m^3/year missing volume of sand would be replaced with the dredged sand from Sulina channel (approximately half of the needed volume) and with sand by-passed from Musura Bay. Due to its peculiar evolution the human intervention in the Sahalin spit island should be avoided. For the rest of eroding parts of the deltaic coast sustainable protection would be artificial nourishment of the active beach when needed.

Seen in the past as a solution to nourish the “starving” beaches, channels dug to connect the main branches with certain parts of the coast are not a viable solution. These channels would cause severe disequilibrium in the local sediment circulation which will generate not just beach erosion but severely damaging the unique Danube Delta ecosystems.

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Historical legacy of Danube River nutrient discharge and eutrophication in the North-Western Black Sea – Nutrient recycling in the shelf sediments

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Introduction

The Black Sea's north-western shelf is a shallow area of about 50 000 km^2 with a water depth less than 150 m. The semi-enclosed Black Sea drains a catchment that contains large proportions of 15 countries thereby receiving waste-waters from more than 100 million people. Through the major inflowing rivers Danube, Dniester and Dnieper, which together discharge 279 km^3 fresh water per year (212 km^3 yr^{-1} for the Danube itself, more than 75% of the total river input into the Black Sea), the north-western shelf receives particularly high nutrient loads (i.e. nitrogen, phosphorus and silica in various forms). The cumulative impact of surplus nutrients from the rivers and favorable climate conditions stimulated huge algal growth (eutrophication – overfertilisation with nutrients and biologic production of biomass) on the north-western shelf from the 1970s to 1990s. The functioning of the ecosystem had been disrupted by sequences of increased water turbidity, increased deposition of organic matter on the shelf's seafloor, disappearance of the sea grass and benthic macroalgae communities due to shading, increased oxygen consumption by the sediment community and collapse of the mussel beds due to low or no oxygen in the near-seafloor water (Mee et al. 2005). The nutrients entering the Black Sea shelf may be recycled many times through deposition of organic material in the sediments and subsequent release of nutrients following decomposition. This 'memory effect' of sediment and recycling of nutrients plays a critical role in maintaining eutrophic conditions, and in enclosed seas such as the Black Sea, can lead to prolonged and devastating occurrences of 'dead zone' phenomena. Recurrent widespread seasonal bottom water hypoxia caused deterioration of the benthic (seafloor) ecosystem over a time period of over 20 years (see article of M-T Gomoiu on p.11).

The eutrophication, in combination with overfishing, invasion of alien species like the comb jelly *Mnemiopsis*, and climatic variations led to regime shifts and collapse of the ecosystem (Mee 1992). Following the collapse of industry and agriculture in eastern European countries in the 1990s, resulting in less fertilizer application and the end of large-scale industrial livestock farming that decreased riverine nutrient discharges led to a decrease in occurrence of large-scale bottom water hypoxia, and allow for a slow recovery of the pelagic and benthic ecosystems. The non-linear nature of the recovery and the ecological instability of the north-western shelf is evident e.g., in the spread of opportunistic species and the re-occurrence of large-scale bottom water hypoxia e.g. in 2001. This article summarizes the findings of several studies on benthic nutrient cycling and Danube River nutrient discharge (EU-FP5 EROS 2000 & 21, INTAS 99-01710, GEF Black Sea Ecosystem Recovery Project, International Joint Royal Society Project 2006/R4).

Study site and methods

Benthic fluxes of oxygen and nutrients were measured in the Black Sea in spring 1997 and 1998, summer 1995 and 2006 and winter 2008 close to the Romanian and Ukrainian coasts (within the Danube River plume, on the Danube Prodelta and close to the Dniester Mouth, *Figure 1)* by using an in-situ benthic flux chamber lander and via lab incubation of sediment cores. On each location, indicated in *Figure 1,* the lander was moored on the seafloor for 24 hours (see detailed description in Tengberg et al. (1995) and Friedrich et al. (2002)). The 1995 benthic flux data were taken from Friedl et al. (1998), 1997 data from Friedrich et al. (2002), 1998 data from Grégoire & Friedrich (2004) and 2006 and 2008 data from Friedrich et al. (2009). In summary, the nutrient analyses were done photometrical according to Deutsche Einheitsverfahren (1998) German standard (www.wiley-vchde/contents/dev/devihhtml) on board ship and in the AWI lab. Oxygen was recorded in-situ using a *Seabird* Beckmann oxygen probe and *Aanderaa* optode coupled to a *Seabird* data logger. The calculation of benthic fluxes is described in Friedrich et al. (2002). Averaged fluxes of all sampling stations for the 1990s were calculated from the 1995, 1997 and 1998 measurements. Similarly, 2000s fluxes were calculated from the 2006 and 2008 fluxes.

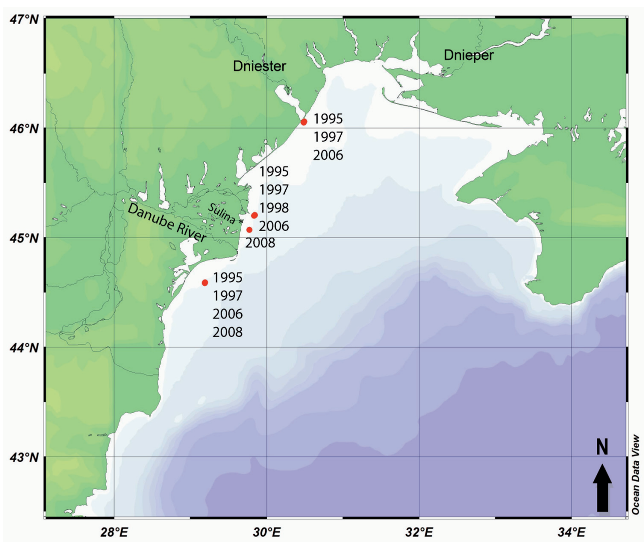

Figure 1. Map of the north-western Black Sea. Location of benthic flux measurements are indicated by red dots

	N-NH4 tons year^{-1}		N-NO3 tons year^{-1}		P-PO4 tons year^{-1}		Si-SiO4 tons year^{-1}	
	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s
Benthic flux	61 653	55 673	4 642	2 867	8 038	5 501	269 229	305 647
River discharge	16 374 ± 7 347	16 803 ± 7 818	499 166 ± 214 164	139 589 ± 48 055	19 092 ± 6 932	11 852 ± 2 288	300 780 ± 121 045	378 255 ± 110 038

Table 1. Benthic nutrient fluxes from the sediment to the water in the Black Sea, and Danube River nutrient loads at Sulina discharged into the Black Sea, in tons year^{-1}. The error of the load calculations represents the standard deviation. Standard deviation of benthic fluxes is given in Figure 2. 1990s and 2000s represent the averages of the years 1988 to 1999 and 2000 to 2004, respectively. The benthic fluxes have been extrapolated to the 7650 km^2 near-shore area within the Danube River plume. This area is characterized by high fluxes of detrital organic matter to the sediments. (NH_4 = ammonia, NO_3 = nitrate, PO_4 = phosphate, SiO_4 = silica)

The Danube River nutrient measurements at the Sulina station close to the river mouth to the Black Sea were done during the monitoring program of the National Institute for Marine Research and Development, according to ICPDR protocols. Danube nutrient loads were calculated by multiplying the concentrations by the discharge (data from GRDC - Global Runoff Data Centre). The data from 1988 to 1999 and from 2000 to 2004 were combined to the 1990s and 2000s average loads, respectively.

Results and Discussion

The north-western shelf is the most productive area of the Black Sea Basin. It has been classified as eutrophic (Nezlin et al. 1999). A model estimated primary productivity to 220 g C m^{-2} yr^{-1} (i.e. high production of phytoplankton, microscopic single-celled algae) and total production to 10^7 t C yr^{-1} (Grégoire & Lacroix 2003); thus, it contributes 23% of the total basin-wide primary production of 5×10^7 t C yr^{-1} (130 g C m^{-2} yr^{-1}) (Grégoire & Friedrich 2004). The nutrients from the Danube River fuel to a large extent the primary productivity. In the river plume, the water column is strongly stratified throughout the year (in winter, the mixed layer depth is lower

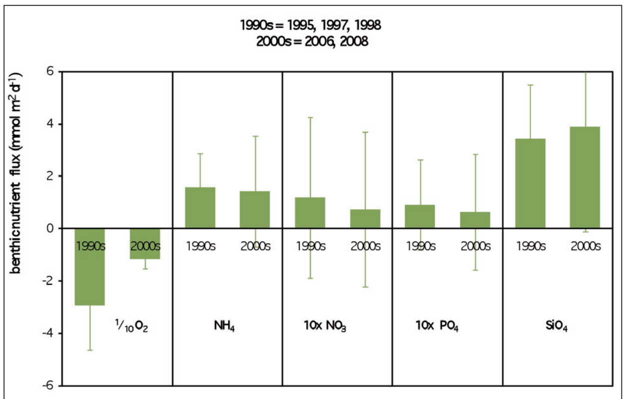

Figure 2. North-western Black Sea shelf average benthic nutrient fluxes from the sediment to the water, within Danube influence. Negative values indicate consumption of the component. The error bars represent the standard deviation. 1990s (n=14) and 2000s (n=18) represent the averages of the years 1995, 1997, 1998, and 2006, 2008, respectively. Note, for better visualisation oxygen consumption is divided by 10, whereas nitrate and phosphate fluxes are multiplied by 10

than 20 m) and continuously enriched in nutrients allowing a permanent growth of the phytoplankton at nutrient saturation conditions with seasonal modifications in the bloom intensity. These highly productive waters are separated by a strong haline front from less productive more saline offshore waters (Grégoire & Friedrich 2004). During the 1990s, the Danube River discharged annually more than 16 thousand tons ammonia, about 500 thousand tons nitrate, 19 thousand tons phosphate and 310 thousand tons silica into the Black Sea. The molar N:P ratio (i.e. Redfield ratio, where 15 is the ideal ratio for phytoplankton growth) was as high as 60, indicating that inorganic nitrogen was discharged in huge excess to phosphate into the Black Sea *(Table 1).* Such high nutrient loads, combined with favorable climate conditions, led inevitably to high biologic productivity, i.e. strong eutrophication. In addition, the increase in the N:P ratio towards high values way above 15 led to shifts in the phytoplankton composition. Not only the number of algae blooms increased, also a shift from diatoms (silica-shelled algae) to flagellates (non-silica-shelled algae) occurred. During the summer months, so-called "red tides" caused by dinoflagellate *Exuviaella cordata* occurred (Sorokin 2002). Following the collapse of the eastern European economies in the 1990s, river nutrient loads began to decrease. In the early years of the 2000s, the nitrate and phosphate loads of the Danube River decreased significantly; i.e. by 3.6 and 1.6 times, respectively *(Table 1).* In contrast, ammonia loads did not change. The molar N:P ratio decreased from 60 to 29. The silica loads increased slightly.

The surplus organic matter settled to the seafloor and accumulated in the sediments. The decomposition of this organic matter consumed oxygen in the water near the seafloor. The amount of organic matter to be decomposed was so large that in the summer months, when little water mixing occurred, almost all oxygen was consumed. This resulted in the so-called hypoxia that lasted weeks to months. In addition to the consumption of oxygen, the nutrients (nitrogen, phosphorus, silica) stored in the organic matter were released. This results in a flux of nitrate, ammonia, phosphorus and silica from the seafloor to the water. In addition to the nutrients released from freshly decomposed organic matter, efflux from decomposition of organic matter in underlying sediments occurs. The released nutrients are mixed into the upper water layers during stormy weather, further fuelling biologic productivity. From the 1990s to the 2000s, the benthic oxygen consumption decreased significantly by about 50% *(Figure 2).* This indicates that less fresh organic matter had settled to the seafloor and been decomposed. The reduced river nutrient load in the 2000s seems to have led to a decrease in biologic productivity. In contrast, the benthic fluxes of ammonia, nitrate and phosphate did not decrease significantly from the 1990s to the 2000s *(Figure 2).* The benthic flux of silica even increased. This indicates that even long after the decrease of river nutrient discharge and deposition of fresh organic matter on the seafloor the release of nutrients from the seafloor continues for many years. Comparing the riverine nutrient loads with the nutrient release from the sediment in the nearshore area of high organic matter deposition on the seafloor shows that almost four times more ammonia is released from the seafloor than discharged by the river *(Table 1).* The phosphate release from the seafloor equals up to 50% of the riverine load. Silica is released in the same order of magnitude like river discharge. The nutrients released from the seafloor continue to fertilize the water and thereby fuel biologic production. Therefore, it takes decades until the long-term impact of eutrophication diminishes. The memory particularly of an enclosed sea like the Black Sea therefore is long. In consequence, it may take a long time until nutrient reduction policies in the catchment to reduce the river nutrient loads show a positive effect on the state of the marine ecosystem.

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The regulation of Black Sea fish stocks

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Introduction

Over the decades, the environment of the Black Sea has deteriorated dramatically in terms of its biodiversity, habitats, fishery resources, aesthetic and recreational value and water quality. Increasing loads of nutrients from rivers caused an overproduction of micro-phytoplankton, which in turn blocked the light reaching the sea plants and algae, essential components of the sensitive ecosystem of the North-Western shelf. The entire ecosystem began to collapse (Prodanov et al. 1997; Zaitsev & Mamaev 1997; Daskalov et al. 2008).

Pollution, linked with irrational exploitation of fish stocks, triggered a sharp decline in the fishery resources. To make matters worse in the mid 1980s, a jellyfish-like species *(Mnemiopsis leidyi)*, which was accidentally introduced from the ecosystem seaboard of America in the ballast water of a ship, invaded the Black Sea. Its diet included eggs and fish larvae and the tiny animals which are food for small fish.

Interaction between environmental, biological and anthropogenic factors generated feedbacks resulting in harmful plankton blooms, hypoxia, and hydrogen sulphide production, adversely affecting the ecosystem as a whole and fish stocks in particular. The complex nature of ecosystem responses to human activities calls for more elaborate management approaches than currently provided by traditional environmental and fisheries assessments and regulations (Radu et al. 2006; Daskalov et al. 2008).

The state of fish stocks and peculiarities of fish stock management

In the Black Sea area the state of stocks for the majority of fish species with commercial value is generally near to the lowermost level of safe biological limits (Zaitsev & Mamaev 1997; Nicolaev et al. 2004; Radu et al. 2006; Daskalov et al. 2008). The experts generally agreed that the decline of marine living resources is mainly caused by eutrophication (excess nutrients from agriculture, municipal waste, industry, etc), harmful substances (sources from agriculture, industry, municipal waste, etc), hydraulic works, alien species, climatic changes and unregulated commercial fisheries. The negative effects of these impacts are hard to be controlled. For instance, in the absence of regulations of catch limits at a regional level the states may develop an intensive fishing in waters where anchovy and horse mackerel form agglomerations, which can affect decisively the stocks of spawners (Nicolaev et al. 2004).

The Black Sea fisheries has declined since the 1970s *(Figure 1).* The species structure of the catches mirrored only partly the composition of Black Sea ichthyofauna because the type of used gear influences the ratio between the different fish species. As a general rule, the pelagic species, small-sized and with short-life cycle, continue to be dominant in catches (Prodanov et al. 1997; Radu et al. 2006).

The main characteristics of deteriorated and threatened fish stocks in the Black Sea and peculiarities of the management at regional level can be described as follows:

– The majority of fish species having commercial value are shared within Economic Exclusive Zone (EEZ) of many states (sprat, whiting, anchovy, horse mackerel, dogfish, turbot, etc).
– Migratory species (anchovy, horse mackerel, bluefish, bonito) have spawning, feeding and wintering habitats located in EEZ of different states.
– Highly endangered sturgeons (Reinartz 2002) are still threatened by overfishing; their stocks can be conserved by bans of commercial fisheries as decreed by Turkey (more than 15 years ago), Ukraine (since 2000) and Romania (since 2006); however, such one-sided measures, as well as insufficient restocking and inefficient control of poaching cannot solve this transboundary problem; concerted actions of all Black Sea countries are required.
– There are strong technical interactions, with the same species being exploited by different types of fishing boats and gear, and biological features, with complex predator-prey interactions involving most exploited species.
– Depletion of the small pelagic stock appears to have increased population explosion of planktonic predators (jelly fish and ctenophores) which have competed for food with fish, and preyed on their eggs and larvae.
– Presently there is no regional fishery management organization in the Black Sea area; the fisheries regulatory framework is promoted by each coastal country being not harmonized at regional level, even in the case of shared or migratory species.
– The lack of an adequate management in the Black Sea fisheries is also evidenced by the fact that in spite of apparent decline of stocks, the fishing effort (in the Black Sea area) continued to increase.
– The fishing is carried out in a competitive framework without any agreement between the countries on limits to fishing.
– There are large differences in the economic and technical structure of the fleets exploiting the fishery resources of the Black Sea among the countries, making regional cooperation a more demanding exercise.
– The development of small-scale fisheries, in particular in former communist countries, needs a new and transboundary approach by national authorities.
– Fishery research in the Black Sea region remains sparsely equipped and funded.
– Several regional organizations are concerned with the Black Sea, in particular with fisheries management and the protection of the environment, which seek to further work together through specific arrangements. These organizations include the General Fisheries Commission for the Mediterranean (GFCM), the Commission on the Protection of the Black Sea against Pollution (BSC) and the Organization of the Black Sea Economic Cooperation (BSEC).
– There are several ongoing cooperation initiatives among these organizations, involving also the countries directly, aiming at setting a common framework for sustainable fisheries management in the Black Sea. Despite these initiatives, however, cooperation in fisheries research and management across the region still needs to be strengthened.

Recommendations regarding the future management of fishing resources at regional level

The main priorities for sustainable fisheries in the Black Sea region are:

– strengthening the regional legal framework for sustainable management, establishing a regional organization through negotiation on signing of legally binding documents for fisheries;

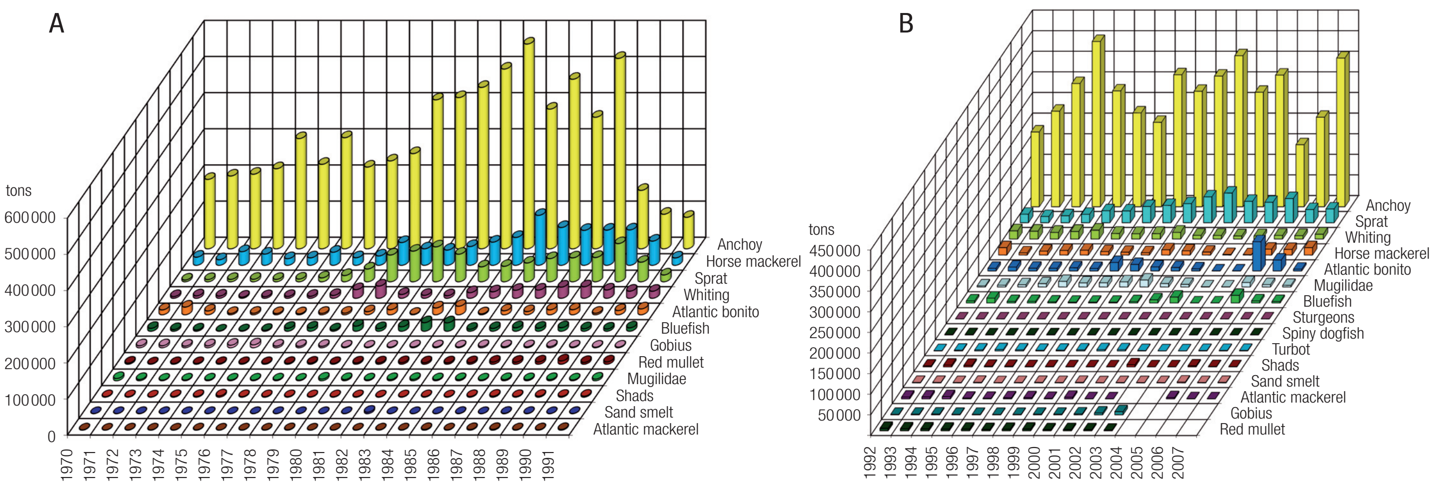

Figure 1. Evolution of the catches for main commercial fish species in the Black Sea area: (A) 1970 –1991; (B) 1992– 2007

- common policy of Black Sea countries for development of small-scale fisheries sector including harmonized fisheries regulation measures;
- developing and implementing regionally agreed fish stock assessment methodologies;
- harmonizing the development strategies of the fishing sector with those of environmental protection, through implementing the concept regarding the fishing management based on the ecosystemic approach and the FAO Code of Conduct for a responsible fishing;
- development of specific indicators for the Black Sea to monitor and assess the state of key resources/habitats;
- selection of key demersal species and their habitats and development of recovery plans for them;
- undertake concerted actions to combat illegal fishing and to establish regional consultation mechanisms between the Black Sea coastal states;
- extend/designate protected marine areas of regional significance and establish a network for the Black Sea.

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The North Western Black Sea shelf and brackish, transitional waters: outstanding sea-life and brackish biota

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A unique sea in the world

The Black Sea has been known since ancient times for its vast historical riches; this region is home to the legend of Jason and the Argonauts in search of the Golden Fleece, as well as to the Biblical account of Noah's Ark and the flood, which awakens a great scientific interest nowadays (Ryan & Pitman 1998). Today it is considered to be unique in the world through its diversity and environment characteristics:

- semi-enclosed sea (surface 4.2 x 10^5 km^2, maximum depth 2212 m, total volume 534 000 km^3);
- low salinity as compared to other seas (17–22 psu vs Mediterranean Sea 38–39 psu);
- a large meadow of *Phyllophora* red algae and some smaller areas covered by *Zostera* or algae associations;
- three concentric belts of filter-feeders *(Corbula – Mya, Mytilus, Modiolus)* and a few smaller mosaic communities of other species;
- ideal feeding grounds for commercial fishes (sturgeons, anchovies, turbot, sole fish, gray mullet, etc.);
- meromictic sea and the world's largest marine anoxic basin (81% of the volume, i.e. below 150–200 m the water is anoxic and enriched with hydrogen sulphide H_2S);
- highly influenced by the freshwater input from tributary rivers (Danube 55%, Dnieper 12%);
- troubled history as the sea has undergone phases with nearly complete replacement of its creatures.

The Black Sea basin can be divided into four physiographic areas: continental shelf (29.9% of the total sea surface), steep slope (27.3%), deep basin (30.6%) and abyssal plains (12.2%) *(Figure 1)*. In the north the sea is linked to the shallow Sea of Azov by the Kerch Strait. One of the most prominent physiographic features is the presence of a vast continental platform (less than 200 m deep) in the northwest (about 25% of the total sea surface, including the Romanian shelf).

Three general areas can be distinguished along the Romanian shore (Wijsman et al. 1999) according to the sediment characteristics and macrobenthos communities: (1) The area just in front of the Danube Delta where large amounts of nutrients and suspended solids are discharged. High sedi-

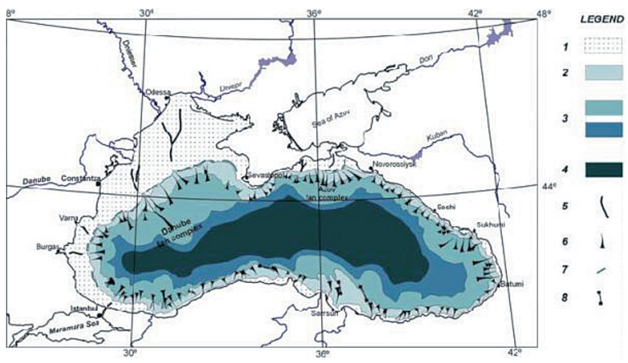

Figure 1. Geomorphological zones of the Black Sea. 1 – continental shelf; 2 – steep slope; 3 – deep basin; 3a – complex structures of great depth; 3b – depth threshold; 4 – abyssal plain; 5 – paleo-channels on the continental shelf, filled with fine recent and Holocene sediments; 6 – main valleys, underwater canyons; 7 – paleo-shore platform close to the fracture; 8 – fracture zones occurring in depth morphology. (after Panin 2008)

mentation rates of fine-grained sediments and high benthic mineralization rates characterize this area. The macrobenthos community is dominated by deposit feeders. (2) The northern part of the continental shelf where an anticyclonic gyre is located. The majority of the Danube discharges are transported to this region characterized by low sedimentation rates. However, the deposited material contains a larger fraction of fresh organic matter as compared to the delta area, resulting in high benthic mineralization rates. Suspension feeders dominate the macrobenthos community. (3) The southern part of the continental shelf is characterized by low sedimentation rates and low rates of benthic mineralization. Suspension feeders dominate the macrobenthos community.

Black Sea biodiversity origin

The Pontic fauna (originating 9000–7000 years ago, Degens & Ross 1974) shows varied origins, heritages from various ecological types of waters which filled the depression of the sea basin in the course of geological times. At present we find a veritable mosaic of forms, from the subarctic ones and those similar to Indian Ocean forms derived from the extensive Tethys Sea (50–60 million years ago – endemic and relict species) to more recently invading fresh and brackish water species and to Mediterranean forms.

The immigration from the Mediterranean Sea and Atlantic Ocean has been a historic process of long duration that has continued to the present. The physical conditions, however, produced a particular biological environment permitting only a very small number of restricted species endowed with special qualities (special resistance and accommodation mechanisms) to invade and live in the Black Sea waters. Its reduced salinity and different ionic composition require osmotic adaptation and plasticity; different thermal conditions, the lack of tides and the presence of hydrogen sulphide in the bathial region exclude immigration of deep-sea animals. Out of 6450 Mediterranean species of benthic invertebrates, only 1790 species were recorded in the Black Sea. The species of the Black Sea benthos belongs to three categories: species

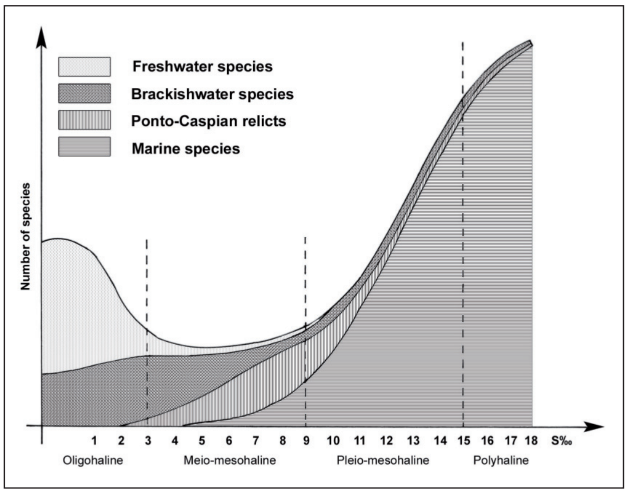

Figure 2. Distribution diagram of different physiological types of species from the Black Sea fauna according to salinity gradient (after Bacescu et al. 1971)

of marine origin (84.2%), autochthonous relict species of Ponto-Caspian type (5.5%) and autochthonous brackish or freshwater – euryhaline species (10.3%) *(Figure 2).* A secondary selection of immigrated fauna, particularly at the middle and infra-littoral belt level, is driven by salinity variations in zones directly influenced by fresh water influx (336 km^3/year) from tributaries such as the Danube River.

Invasive species: a major problem for the Black Sea

Against the background of eutrophication (Gomoiu 1992), there has been another important ecological event – the increasing rate of exotic species immigration since the 1970s (Gomoiu 1998). The most spectacular appearance of alien species along the Romanian coast was that of the soft shell-clam *Mya arenaria,* the big snail *Rapana venosa* and the American comb jelly *Mnemiopsis leidyi.*

M. arenaria was first reported near Odessa in 1966, then rapidly spread along the Romanian shore. After this invasion, simplification occurred in the mollusc community structure as a result of the competition between the native fauna and the new immigrant which out-competed other species completely by its larger size and strong nonselective biofiltration "pumps". Now *Mya* has a special role in the littoral ecosystem: it represents a trophic basis for benthophagous fishes, releasing a great quantity of larval plankton which provides food for planktivorous fishes, forms a strong biofiltration belt contributing to the purification of littoral waters, and constitutes a source of material for shell sands and beach deposits.

Rapana venosa, a native species of the Sea of Japan, was first reported in 1947, although it was considered to have settled in the Pontic Basin earlier in 1930–1940. This large voracious predator rapidly colonized the seabed of the shallow water coastal area, practically around the whole sea; in 1963 *R. venosa* was found along the Romanian shores, nowadays becoming a species with commercial value, gathered by divers.

The American comb jelly, *Mnemiopsis leidyi,* was introduced through ship's ballast water in the early 1980s. With no natural enemies around, its population soon exploded, consuming vast amounts of zooplankton, larvae and fish eggs. Eventually, this caused the collapse of pelagic fish populations and a major shift in the marine ecosystem. The mass occurrence of *Mnemiopsis* has contributed to the sharp decrease in 26 commercial fish stocks, including anchovy and chub mackerel. Local shellfish fisheries, indigenous jellyfish and even endemic dolphins also have suffered.

The lessons learned from the ongoing introduction of exotic species in the Romanian coastal waters can be summarized as follows: The impact of alien species is complex and unpredictable; toxic and harmful species need more attention; monitoring of species biodiversity (microflora and microfauna in particular) is absolutely necessary; legal measures and regulations are important to limit the invasion of new species; understanding of the biota can only be achieved by training young specialists in marine biology and taxonomy.

Changes in the North Western Black Sea ecosystems

The Pontic biota was investigated in five stages: (1) Fundamentals of specific biodiversity (1790–1910); (2) Bases of qualitative ecology (1910–1945); (3) Quantitative aspects of ecosystems (1945–1970s); (4) Increasing ecological changes (1970s–late 1990s); and (5) Signs of ecosystem recovery (late 1990s–present).

For almost 100 years science has relied on the fundamental scheme of the Black Sea benthal biocoenoses (Zernov 1913), which has been carefully completed by successive generations of scientists *(Figure 3).* After a long period of "ecological stability", the first signs of disturbance appeared in the early 1970s (Bacescu et al. 1971). Before the 1960s it was a very productive sea yielding abundant fish catches and providing important feeding areas for commercially important species migrating from the Mediterranean at regular intervals. But fish stocks have since collapsed through a combination of overfishing, pollution and the invasion of alien species. In comparison with the reference state of the sea in the 1960s, the ecological changes in the early 1990s were striking: Increasing concentrations of inorganic and organic nutrients caused rapid eutrophication of the coastal waters as demonstrated by chronic algal blooms, increasing organic matter in sea water and sediments, occurrence of hypoxic and anoxic events, mass mortality of benthic organisms, drastic reduction of biodiversity, etc. With the increase in sea pollution the contaminated zones extended from coastal to off-shore waters. The vegetal and animal benthic community structures were simplified and homogenized, and the reduction of the filter-feeder populations diminished self-purification. Some opportunistic forms (especially worm populations causing sediment bioturbation – *Melinna palmata)* and, temporarily, some exotic species recently pervading the Black Sea *(Mya, Scapharca, Rapana* etc.) thrived and induced important quantitative fluctuations of all benthic populations. Intensified coastal morphodynamic processes increased erosion.

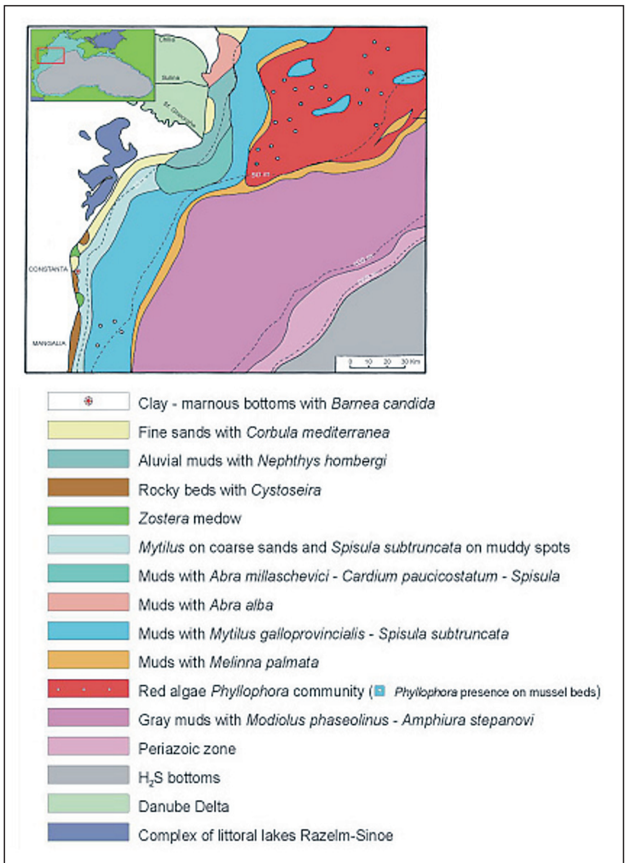

Figure 3. Benthic biocoenosis at the Romanian Black Sea coast (after Bacescu et al. 1971)

The major causes of these changes, in particular along the Romanian coast, were closely related to the Danubian System including the river, its catchment area and the delta (Langmead et al. 2009). Formerly the Danube was healthy and wholly beneficial, fertilizing the sea, favoring high productivity at all trophic levels and sustaining the rich fisheries, the red or brown algae meadows, the mussel and other living resources.

The ecological state of the Western Black Sea coastal waters has improved significantly since the early 1990s: Reduced nutrient inputs (due to reduction measures and economic recession in the Lower Danube countries) has led to reduced eutrophication and fewer algal blooms, slight recovery of animal populations on the seafloor *(Mytilus galloprovincialis* and *Dipolydora quadrilobata),* and an improved regeneration of macrophytes *(Cystoseira – Figure 4).* However, recovery of the benthic system is rather weak, although the existence of two-year old mussels seems promising and contrasts with the situation in the late 1980s when all new recruits were killed by the annual appearance of the periodic anoxic waves. Significant areas of the seabed had been suffering from anaerobic conditions, but such problems have disappeared almost completely, the conditions being now similar to those that prevailed until the 1960s.

Outlook: Could the recent signals from the Black Sea be optimistic?

The available recent data provide clear evidence of the overall reduction of nutrients in the marine environment during the last decade (Tarasova 2002). Further, oil-related pollution (in particular poly-aromatic hydrocarbons - PAH that induce carcinogenic and mutagenic effects) decreased in the marine waters of all coastal states and usually does not exceed the national water quality standards, being below detection limits since 1999. Presently neither persistent organic contaminants (mostly polychlorinated biphenyls - PCB and organo-chlorine pesticides) nor radionuclides pose a threat to human health and biota in the Black Sea.

There are still uncertainties and it is too early to draw a high confidence conclusion on the recovery since the evalu-

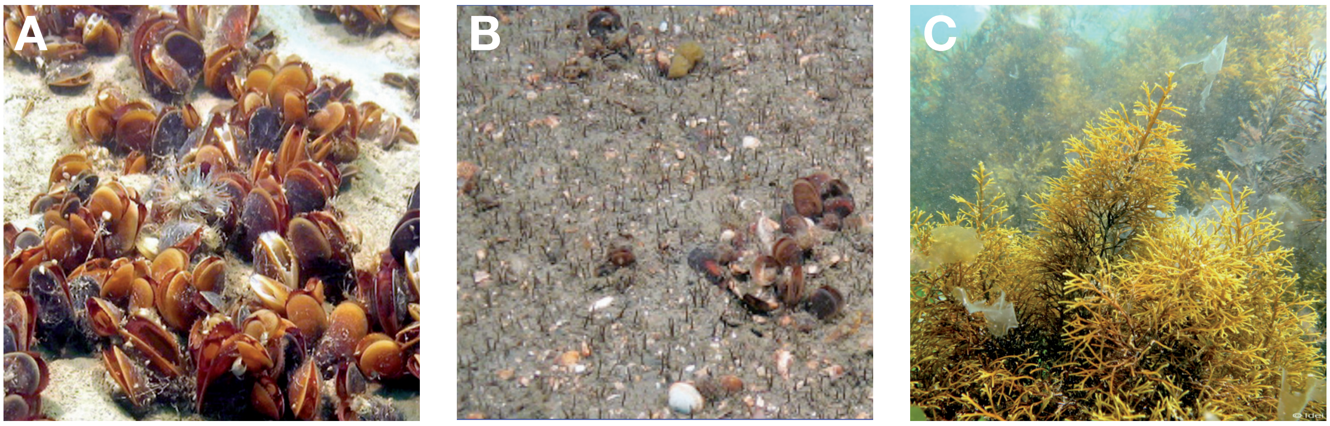

Figure 4. Typical representatives of the Black Sea benthic fauna:
(A) Black Sea mussel (Mytilus galloprovincialis) on recently recovered mussel bed
(B) A denser population of the opportunistic polychaeta species Dipolydora quadrilobata, recently penetrated and well adapted on the sedimentary bottoms of the NW Black Sea
(C) Brown algae recovering populations Cystoseira barbata start to cover the coastal hard bottoms again. (Photos: A. Teaca)

ation of the ecosystem state represents a complex, laborious, time consuming and rather imprecise process. In particular, the role of global changes is less known: the improvements in the Western Black Sea ecosystem could be generated by some favorable climatic conditions over the last decade. Fish stocks in these waters are still out of balance due to ongoing anthropogenic impacts such as over-fishing, habitat loss and degradation (feeding grounds), and alteration of genetic status (e.g., sturgeon populations are close to extinction).

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In brief information

IAD welcomes new president, Dr Thomas Hein, BOKU, Vienna, Austria

Ivana Teodorovic: University of Novi Sad, Serbia, President of IAD 2005-2010,
e-mail: teodorovic@beocity.net

IAD General Member Assembly held during the IAD 2010 Conference in Dresden elected a new president of IAD for the term 2011-2016: Dr Thomas Hein (age 42), assistant professor at the Institute of Hydrobiology and Aquatic Ecosystem Management at the University for Natural Resources and Applied Life Sciences, Vienna, Austria. Since 2008 he is the Scientific Managing Director of WasserCluster Lunz, and he also serves as the Editor in Chief of "River Systems". Thomas Hein is limnologist with broad research interests in wetland/floodplain and landscape ecology including nutrient dynamics, interactions between aquatic and terrestrial ecosystems promoting the catchment approach, development of conservation and restoration strategies for riverine landscapes, and implementation of nature conservation in river basin management. Dr Hein has been an active member of IAD and AC-IAD for many years and leader of IAD Expert Group Biotic Processes. The IAD community hopes that his fresh ideas, great enthusiasm, and dedication to the principle goals and visions of IAD will mobilize the potential of our Association for the benefit of the Danube River Basin.

38th IAD Conference in Dresden, June 22–25, 2010 – Conference Summary

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The idea of the 38th IAD Conference held in Dresden, Germany, was to exchange scientific and managerial experience focused on two large European Rivers, the Danube and the Elbe. While there is common understanding of riverine ecosystem function and river basin management including the difficult implementation of measures in an economically driven world, the two river systems show distinct differences e.g. in the ratio of discharge/catchment area, delta vs. estuary, and importance for navigation.

Major topics presented and discussed during the conference were:

- *Climate change* models for Europe predict a general increase of temperature in air and rivers as well as a precipitation increase in winter and decrease in summer affecting the hydrological regime and most prominently riverine floodplains. The documented water temperature increase of 0.7–1.2 °C between 1901 and 2006 in the Austrian Danube and further increase predicted for 2050 confirms the general trend found in other European rivers.
- *Floodplains* were documented as hotspots of (declining) biodiversity and as such provide outstanding ecosystem services. The still ongoing pressures on riverine hydromorphological structures call for large-scale restoration that, however, can only improve lateral connectivity and ecosystem function but not bring back reference conditions. Lessons in hydrology can be learned from suboptimum restoration measures (e.g., Belene Island in the Lower Danube, Srebarna Lake and adjacent wetlands).
- *Fish migration* in both rivers is disrupted by dams which isolate populations and bias natural reproduction. The longitudinal connectivity remains an important issue also for sediment transportation.
- *Invasive species* (e.g. crayfish and molluscs) proved to be a threat for native communities in Hungary. Although many questions remain open, evidence of negative impacts by invasive species is accumulating (see http://www.europe-aliens.org, http://ec.europa.eu/environment/nature/invasivealien/index_en.htm).
- *Zooplankton* (crustaceans, rotifers and protozoans) have been intensively investigated in the side arms of the Hungarian Danube River. It remains to combine their functional importance with that of phytoplankton, bacteria and fish to elucidate food-web interactions and floodplain ecosystem function.
- *Sediments* are Significant Water Management Issues (SWMI) in terms of bed load sediment transport and budget, forming of islands, pioneer habitats, and contaminant accumulation. Sediment management in accordance with natural flow (floods) is especially required in ports for navigation (e.g. in the Elbe estuary).
- *Toxic pollution,* organic chemicals (i.e. pesticides) and emerging substances gain increasing importance for riverine biota, and the Spear method using traits instead of taxa lists may provide a progress and replace the Saprobic Index and other biological indices to indicate the ecological status of aquatic environments.
- It was agreed that *science must be the basis of sound water management* strategy and implementation (within the EU WFD); in practice, learning by doing stresses the pragmatic approach beyond scientific theory. In view of the three main drivers (climate change, land use change, demographic change) and the pressure of economy (future infrastructure projects, navigation, hydropower, flood protection) it seems, however, that many of the ideas presented were beyond the "real world", and further strong efforts for implementation are still needed.

105 short abstracts for oral and poster presentations are published in the Conference Book of Abstracts, while 63 extended abstracts are published in the Conference Proceedings on a Memory Stick. (Both are available for download on www.iad.gs). A selection of full papers will be published in a special volume of "River Systems" in 2011.

The professional organization by Dr Fritz Kohmann (BfG Koblenz), Dr Hildegard Feldmann and Ogarit Uhlmann (F&U confirm Leipzig), supported by the IAD Organizing and Scientific Committees are greatly acknowledged.

Figure 1. The Conference excursion led to Saxony Switzerland where the Elbe River formed bizarre sandstone formations (Bastei). Of particular scientific interest were the sandstone surfaces turning the original yellowish-brownish colour into black after some 50 years (as seen on the historical buildings in Dresden). Leaching of distinct minerals by weathering and oxidation of Molybdenum and Manganese (and partly Iron) create a hard crust that allow freestyle climbing and mitigate further erosion of the soft rock material. Newest hypotheses about involvement of cyanobacteria in this process are being evaluated at the University of Dresden. (Credit by internet)

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Hydrological catchment of the River Danube

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