# Consequences of the Flow Regime Changes of some Tributary Waters of the Danube and the Sustainable Administration of the Water Resource

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**Abstract:** Natural ecosystems represented by the surface waters, which have developed during a long period prior to the human intervention, are replaced, modified and fragmented in a short period of time through dams, some linkage systems between the rivers through the old riverbeds and newly built channels and through the arrangement of the banks. In the water catchment area of the Danube, the effects of the major human intervention over the geographical area, especially over the large tributary rivers of this large stream, such as Argeș river, and also on most of the smaller running waters are harder and harder to monitor, to anticipate and to correct. The natural flowing regime of some tributary waters of the Danube has been considerably changed; thus, significant changes happen to the hydrological, physical-chemical and biological features of the waters through the emergence of some lake ecosystems, with a fragile balance. Important changes emerge at the level of some physical-chemical and biological qualitative indicators, such as: the turbidity, the dissolved oxygen content, the oxidation and mineralization of the organic material, malfunctions of some the self-cleaning processes, the accumulation of biogenic substances, eutrophication, the accumulation of mineral substances in the bed areas, the replacement of the river biocoenosis with a lake biocoenosis, the development of plankton, especially of the productive forms, the malfunction of the structure and dynamics of the fish fauna etc. The impact of human activity has a bad influence, in most of the cases, on the quality of the water in the dam lakes. The sustainable management of the water resources of these lakes, through the nearby urban and rural communities requires a knowledge of the environmental problems that are generated by the human impact and their removal or minimization.

**Keywords:** human impact; dam lakes; eutrophication; sustainable exploitation

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## Introduction

Due to the increase of the water demand, generated by the growth of the population and also by the diversification of the economic activities (the emergence of some water-consuming industrial fields, the introduction of some plant cultures that require a larger water consumption, tourism etc.), the need of setting up, on various flowing waters, of some accumulation lakes has emerged in Romania since the 50's of the past century, with a diverse functionality, though mainly built in order to ensure a constant water consumption.

On a series of rivers, including the Danube River, various and complex hydrotechnical settings have been done, which aimed not only the building of accumulation lakes, but also the modification of the banks and the cutting of some twists in order to ease the navigation, strips in order to avoid the flooding and also to provide arable surfaces originating in the previous meadow of the rivers etc.

All these settings have proven to lead to unpredicted, controversial or doubtable economic and ecologic consequences; these are very diverse and their amplitude is sometimes hard or even impossible to anticipate. In the areas with high human pressure, such as the counties with a higher density of the population, with urban agglomerations or areas with intense agricultural or industrial activities, the effects are much more visible on large areas of the rivers flowing through those areas; we can give such examples in the case of rivers such as Dâmbovita, upstream of Morii Lake, Olt (at the exit from the Gorge that took its name until its spilling in the Danube), Argeş river (starting upstream of the Vidraru Lake until nearly its spilling; all these flowing waters were hydro-technically modified on large areas of their course, significantly changing their flow regime, with one of the most diverse consequences from the ecologic perspective. The Danube is also included in this category. Of the total surface of the Lower Danube Meadow, 513.000 ha (92%) are on the Romanian territory, 5% on Bulgarian territory and 3% on the Ukrainian territory; also, of the total surface of the hydrographic basin, of 805300 $km^2$, 29% are in Romania's border (www.asas.ro). In fact, the most typical example of human intervention on the flow regime of flowing water in the hydrographic basin of the Danube is the River Danube itself. We will present a short history of these changes, which are "copied" at a lower scale in the case of more rivers (excepting the ones in the River's delta), having the same ecological consequences. It is interesting to study the situation of the river Danube, as a model for what happened because of anthropogenic intervention.

Though the Danube's Meadow has allowed, since ancient times, an extensive agricultural and fishing use, which has shown that the potential of this wet are can be exploited according to what is today known as sustainable development, there has been the temptation of draining areas of the meadow through stripping.

The first stripping of the Danube on the Romanian soil was made by a Dutch company in 1895, on a surface of 476 ha (www.asas.ro).

Regarding the stripping of the Danube, two opposite concepts has been expressed by the specialists; thus, the great scientist Grigore Antipa, the founder of the ecologic hydro-biologyin Romania (Brezeanu & Cioboiu, 2010) has intuited and warned on the danger represented by the stripping ideas of the Danube's banks, such as to reach an enlargement of the arable surface, at the expense of the flooding meadow. The previously mentioned authors show that, in his volume, „Regiunea inundabilă a Dunării – starea actuală şi mijloacele de a o pune în valoare", issued in 1910, Grigore Antipa notices the fact that "the stripping of the Danube would lead to unpredictable consequences as the large ponds form an organic whole with the River, which, through stripping, would turn into unproductive ponds" or he mentions that "Draining the ponds without replacing them with other humidity sources, at least equal to them, would lead to a misbalance in the economy of the nature, which would have dangerous effects on the future of the agriculture and generally for the climate of the region and everything that belongs to it". Antipa was the promoter of the naturalist conception, which predicted the stripping of the higher meadow (app. 130.00 ha); adversely, another significant personality, Anghel Saligny, proposed the unsinkable stripping of the Danube on nearly all the Romanian flow of the River (the engineering conception) (www.asas.ro). The engineering conception prevailed and, ever since, and especially during the socialist period, 64 of these strips were made, 953 in the Danube's Meadow and 11 in the Delta (the largest being the Great Island of Braila), the maximum surface of these modified areas being 4300 km$^2$ (84% of the Romanian area of the meadow), which took place in 1987 (www.asas.ro). The environmental problems generated by the stripping were completely ignored. In Fig.1 we display the evolution of these stripped areas. Another human intervention with major hydrological, economic and ecological effects is also represented by changes made to ease the navigation on different sectors of the Danube course, and especially on the Maritime Danube sector (Brăila-Sulina), of 170 km (Gâştescu, 2010). To this extent, we firstly remember the periodical dredging activities, in order to maintain a navigable channel of approximately 20 feet on the Maritime Danube. This has ecologic consequences especially on the benthal organisms, which are strongly affected, the substratum being dredged. Second, with a destabilizing effect on the hydrological balance and the natural flow, we remember the cutting of the turns, in order to shorten the navigable route. Even since the second part of XIX$^{th}$ century, cuttings started in the Maliuc area (“The Big M”), ended in 1902. Subsequently, work on banks have transformed the Sulina Channel-branch into a dammed, strongly modified channel. Turns cutting was also made on the St. Gheorghe Channel-branch, between 1985 and 1990, shorting the maritime route from 108,2 to 69,7 km (Gâştescu & Ştiuca, 2008). Advanced hydrotechnical work, through channeling and draining had been made on more than half of the Romanian area of the Danube. Gâştescu & Ştiuca (2008) mention, with negative effects, the reeds harvesting program which led to the destruction of the rhizomes of numerous species of local plants and their replacement with opportunist hygrophile plants (sedge and rushes), which led to the decrease of the biodiversity.

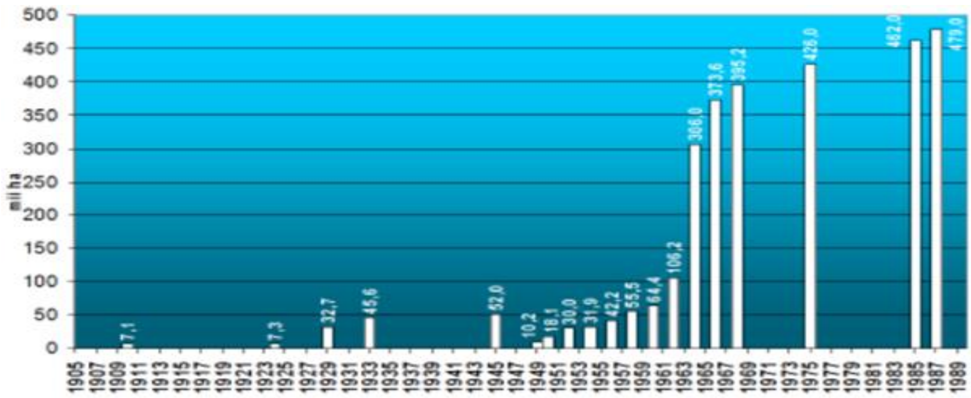


**Figure 1. The evolution of the sinkable and unsinkable strips in the Romanian area of the Danube (including the activity in the Delta)**

*Source: www.asas.ro*

All these untimely changes have induced a large misbalance in the hydrology of the River, the misbalances being major, unpredicted, hard to correct (or impossible to), with very high costs. The thing that is pretty curious is that, despite of the fact that the consequences are obvious; such hydrotechnical work has also been applied on a series of many other rivers, without learning from the experience with the Danube.

The work on the courses of the rivers, irrespective of their amplitude, brutally modifies many of the physical features of them (the slope, the depth of the thalweg, the inclination of the banks, the constitution of their materials, and speed of the stream). All these have direct or indirect consequences on all the departments of the ecosystems, firstly causing the reduction of the natural habitats' diversity and implicitly the number of present species. The main consequences of the stripping is the breaking of the connection between the river with its flooding meadow and the reduction, through this, of the ecosystems' diversity, at the same time, leading to large disturbances in the functioning of the water table. What happened on the Danube, it has also happened on many rivers, but of course, on a smaller scale (with exception to the Delta phenomena).

## Materials and Methods

In order to analyze the situation of a series of rivers from the perspective of the consequences of the hydrotechnical work, we have made numerous inland activities (the itinerant observation method), especially on the sectors of Argeş, Râul Doamnei, Topolog, Ialomiţa, Cheia, Ghimbav and Dâmboviţa rivers. The determination of the locations was made using a GPSMAP® 76CSx device; the precision of the measurements regarding the altitude and the distances was ± 7m (20 feet). The images on the field were taken using a VIVITAR 8235; AGFA PHOTO SELECTA 16 and Canon Eos 1300D-BK photo devices. Water samples were periodically collected, from more locations; the algae sample was studied using the sections' method in refractory light, using OPTIKA B-253 and Optica B.350 microscopes for the determination of the algae, we have used the PETERFI & IONESCU, 1977 and HINDAK, 1978 determinators. The role of the algae as bio indicators of the status of the aquatic environment is highly significant and the presence of certain species or algae communities represent the basis of the determination of the pollution degree and the status of the biotope, as well as of the modifications that existed subsequently to the change of the hydrological regime. (Telcean & Cupşa, 2005) To collect algae we used snoods for plankton.

## Results and Discussions

The physical, chemical and hydro-ecological interactions, determined by the work on the river (River) system – flooding area, represent a major objective of the research on the knowledge and understanding of these processes, pursuing the protection of the environment and in accordance to the durable exploitation and recovery of the natural capital.

Argeş River is one of the rivers in Romania that has been the subject of intense human pressure and this is why our research were mainly focused on it. Practically, strictly, we cannot even tell that the river has an area in which the human influence is missing. Argeș went from flowing water into a succession of lakes on a large part of its length. The river was the subject of regularization, by cascade building a series of accumulations - Oieşti, Cerbureni, Curtea de Argeş, Zigoneni, Vâlcele, Budeasa, Bascov, Prundu, Goleşti, Mihăilesti, in order to ensure the water demand and their judicial management.

The building of accumulation lakes leads, in a relative short time, to the emergence of some important changes of the qualitative – physic – chemical and biological features of the water in these lakes, changes that are also obvious in the case of the succession of lakes on the Argeș. Firstly, what radically changes is the hydrological regime, passing from a vortex flowing, that is specific to the rivers (especially on their superior and middle courses), to a laminar flow, the stream lines being quasi-parallel (specific to the dams). Of course, this does not exclude the formation of vortexes, but they are not specific, having a local feature. The flowing speed becomes much lower, in the case of the lakes succession. This determines significantly deep changes regarding the structure of the biocoenosis, many species of animals and also plants, that are specific to flowing waters, disappearing and being replaced by others that are adapted to the nearly stationary waters.

The lakes located on this river on the sector between the urban centers of Curtea de Argeş-Goleşti (Curtea de Argeş, Zigoneni, Bascov, Goleşti lakes) have a semi-stationary regime, the flowing speed of the water being relatively high. In the area where the water is stationary, due to the accumulation of more favoring factors, the algae population develops very fast. In these areas, the quantity of oxygen in the water is much lower compared to the areas of the lakes where there is a regeneration, a replacement of the water volume. The quality of the water in the lakes on Argeș River is highly influenced by the hydrological regime and by the conducted evacuations made to ensure the downstream usage.

The emergence of these relatively stationary waters on the place of the former flowing waters mainly leads to the very frequent emergence of the eutrophication phenomenon, called hypertrophication by some specialists. (Petre & Teodorescu, 2007) During many of our infield visits, this phenomenon had been often noticed during the summer, on areas of almost all lakes on the Argeș, and also on the Olt, Dâmboviţa, where the water reaches depths between 1-1,5m near the banks.

On Ialomiţa river, even also on the accumulation lakes in the mountain area (Bucegi), on the Scropoasa and Bolboci lakes, we have noticed eutrophication in its primal stage, during summer, near to the shore, in successive summer seasons (between 2014 and 2015); the case of the Scropoasa lake, which is not as large as the previous one, the hypertrophication process has been even more obvious. Thus, in the summer of 2007, 2009, 2010, 2011 and 2013 the eutrophication extended on large areas starting from the shore towards the center of the lake, excepting the southern area, where the spilling happens. We appreciate that the eutrophication included nearly a third part of the lake's surface in 2009, 2010 and 2011, also favored by the partial warping and thus, of the lower depth of the water.

On a series of rivers in Romania the main objective of building dams and creating the accumulation lakes and also of building dams was the avoidance of floods. It is obvious that the accumulation lakes have more functions (water supply, production of electricity, fish farming, tourism and leisure etc.). It is necessary to apply ecological technologies for the sustainable use of water from the storage lakes (Miron, 1999). On the mountain rivers, banks are protected by gabions (Cheia River, Ghimbav River, in Leaota Mts. Etc.) and on the middle course there are concrete banks (Doamnei River) (Dorobăţ & Udroiu, 2014). They have a negative impact, functioning as ecological barriers.

The high density of the population along some sectors of some rivers in the hydrographic basin of the Danube also generates certain hydrological problems. In fact, all urban settlements, larger or not, are located tangent to a flowing water or are the flowing water passes through them; this is also available for the rural communities. We can give as an example the 63 villages from the hydrographic basin of Topolog, tributary water of Olt, the original basis of the villages being locate at a medium distance of 1.72 km from the flowing water. (Roşu, 2007) The impact of these rural settlements, but especially of the rural ones, is manifested in different ways. The waterproofing of the soil is one of the causes leading to the growth of teeming process of the rainfall waters, such that, in order for them to be drained, rainfall water regularization work is needed, in order to limit the debits introduced in the rivers compared to the taking over capacity of them. Hence, we reach the need of building rainfall (metheorical) water retention basins and, implicitly, an effect – the modification of the natural frame, of the physico – chemical and ecological structures of the hydro-systems.

The biological and ecological consequences of the modification of the flowing regime are very diverse and some of them are not completely known.

The longitudinal disruption of a river course, as the result of buildings dams, creates obstacles against the migration of different organisms, especially fishes. Practically, some species disappear, namely the ones that cannot reach the egg submission places, the ecological niche being occupied by other species. For many animal species, the habitat fragmentation emerges as these water eyes or these shores with high inclination represent an impassible obstacle. (Bleahu, 2004)

An example regarding the effects of hydrotechincal management on a river course is represented by Vâlsan river, tributary water of Argeș; the presence of the *Romanichthys valsanicola* fish species, which is an endemith of the ichtyofaunaof Romania and of the Danube's basin, listed on the Red List of Species in Europe, has diminished, being nowadays represented by just a small sector of Vâlsan, being considered the most endangered species in the ichtyofauna of Europe. (Vlăduţu, 2005) The changes regarding the structure of the biocoenosis are dramatical, starting from the ones in the microfauna level. As a result of the accumulation lakes building, we notice qualitative changes of the microfauna on the vertical, fron the level of the benthos until the surface of the water. As an example, in the created lakes, the ephemeroptera is predominant, that is specific to the areas where the sedimentation is predominant, compared to the case in which, is the river has not been modified, the area would have been dominated by the species that are specific to the erosion or transportation (on the upper and middle course) areas would have dominated. (Vlăduţu, 2005)

There are also significant changes from the ornithological perspective. Thus, during the winter season, we notice a large bird concentration (especially Anseriformes order), which use the lakes on the middle sector of Argeș; this is possible, as some lakes do not completely freeze on their surface, neither during their most frosty winters. (Conete, 2014) The author mentioned that the highest Anseriformes species was identified on Budeasa lake (19), followed by Bascov (12); another thing is very interesting, the fact that during the cold season, the number of individuals increases, and alongside with the increase of the temperature, the number of birds decreases. Practically, this means that the emergence of the lakes represents an opportunity for the birds, as there were favorable conditions for the avi-fauna elements to pass through the winter, a difficult season. (Conete, 2011)

Though, in the case of bird species, large fluctuations of the water level in the dam lakes in Romania, irrespective of the river they were built on, endanger the existence of some bird fauna components.

There is a large number of birds that are sensitive, as we can enumerate several of them*: Mergus serrator*, *Podiceps cristatus*, *Hydroprogne caspia*, *Larus canus*, *Calidrix pugnas*, the management of the water level according to the ecological requirements of the species being very important. (S.O.R., 2015; Conete & Gava, 2013) We have collected water samples from the surface of the lakes to analyze the algae content of the phytoplankton in more lakes, during the summer period, at a 1-2m from the shore (Tab. 1). The algae species that appear in the phytoplankton content show that in the areas with a very low depth, lower than 1m, during warm summer seasons, close to the shore, the eutrophication is a frequently met phenomenon. Upstream from the accumulation lake we also notice the decrease of the level of the water table (the piezometric level), which leads, in several years from the construction of the dam, to the disappearance of the natural forest vegetation which develops in the meadow. Such phenomena have been noticed on the Danube and also on the Prut river (upstream of the Stânca-Costeşti dam), on Argeş, Olt etc.

**Table 1. Eutrophication degree on some dam lakes**

| Lake | River | Collecting date (month) | Eutrophication degree |
|---|---|---|---|
| Bascov | Argeș | 08. 2013<br>07. 2014 | high<br>high |
| Budeasa | Argeș | 08. 2013<br>07. 2014 | high<br>high |
| Goleşti | Argeș | 08. 2013<br>07. 2014 | high<br>middle |
| Scropoasa | Ialomiţa | 08. 2013 | middle |
| Bolboci | Ialomiţa | 08. 2013 | low |
| Rm. Vâlcea | Olt | 07. 2015<br>08. 2015 | middle<br>middle |
| Vâlsan | Vâlsan | 08. 2014 | low |
| Mărăcineni | Doamnei | 06. 2013<br>07. 2013<br>07. 2014 | middle<br>middle<br>low |
| Pecineagu | Dâmbovița | 07. 2013<br>07. 2014 | low<br>low |
| Râuşor | Târgușor | 07. 2013<br>07. 2014 | middle<br>low |

## Conclusions

By modifying the flowing longitudinal profile of a river, gaps are created as a result of dams and the flowing regime modifies (regarding the speed and the stream lines); thus, obstacles are created in the migration of different organisms, especially of the fishes.

By concrete constructions on the banks, the habitats change in the case of more species, for which the passing of the river is impossible, leading to the endangering of the species survival.

The change of the flowing regime by building accumulation lakes and the passing from lotic ecosystems to lentic ones; this change of the ecosystems is certainly made alongside the significant change of the biocoenosis.

The balance of such lentic ecosystems, with human origin, is fragile; variations of the water level, sudden evacuations for de-colmatation lead to stress and the impossibility of adaptation or survival of numerous species.

The eutrophication phenomenon is highly deeper and emerges on a highly frequent scale in those lentic ecosystems, compared to the case when only lentic ecosystems would exist (rivers with no human intervention).

We can also signal some positive aspects of building human dam lakes; thus, the lakes can have favorable effects on the ornithofauna, the shelter role in difficult winter periods being very important to the survival of some bird species.

Upstream from the accumulation lakes, we notice a decrease in the level of the water table, which has a quite fast negative effect on the forest that spreads on the river's meadow.

The fields in the old meadow, freed from water through draining and dams, are the subject of salting, being low productive and needing permanent high investment in order to be fertile.

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