HYDROPOWER AND FISHERY ON THE DNIESTER RIVER: SOME IMPACT ESTIMATES

[1]I. Trombitsky, [1,2]O. Cazanteva, [1]R. Corobov, [2]Dum. Bulat
[1]International Association of River Keepers Eco-Tiras, Chisinau, Moldova
[2]Institute of Zoology of Moldova

Резюме. Изучена динамика промыслового рыболовства в Днестре на территории Молдовы в период до и после строительства гидроэлектростанций. Констатировано существенное уменьшение промысловых уловов, особенно ценных видов рыб. Использованный подход позволяет также оценить экономические потери рыболовства, как одной из экосистемных услуг, в результате гидростроительства в русле реки.

Introduction

Hydropower projects are often promoted as a "clean and green" source of electricity, and from this perspective many countries are stepping up their hydropower expansion. According to a survey of Ocko and Hamburg (2019), the hydropower is currently a leading renewable source of energy, contributing two-thirds of global electricity generation from all renewable sources combined. An electricity generation from hydropower is expected to grow by 45 to 70% by 2040, depending on future policies, with 3,700 new hydroelectric facilities either planned or under construction. The last inventory of massive hydropower presence in European rivers (Schwarz, 2019) reveals a total of 30,172 hydropower plants (HPPs), out of which 21,387 already exist, 8,507 are planned to be built, and 278 are already under construction. Numerous HPPs also exist or are planned for construction in the Black Sea basin (Havrilyuk et al., 2019; Vejnovic, 2017).

At the same time, there is no debating that hydropower plants have a significant negative effect. In particular, large dams, especially that are in a river's mainstream (Yuichiro et al., 2020) had well-documented negative impacts on inland fisheries throughout the world, creating obstructions, breaking fish traditional migration routes and preventing returning to their feeding areas and spawning grounds. In certain locations, fish stocks have collapsed to an endangered level. The rivers damming affects also the diversity of fish species (especially rare) and may lead to the cessation of their further reproduction and even disappearance (Xie *et al.,* 2018; Zhang et al., 2018). These evident negative consequences of hydropower on freshwater fishing have triggered the numerous assessments and economic valuation of corresponding loss. As the latest works concerning the Dniester River can be mentioned Bulat (2017), GEF et al. (2019) and UNDP et al. (2019).

The aim of this paper is to present results of a more comprehensive statistical assessment and economic evaluation of hydropower plants impact on the Dniester fish stocks.

Methods

Generally, *freshwater ecosystems* incorporate fish/fishery and aquaculture products. Information on these products is available in two forms: either as an absolute value or as a relative value. The *absolute value* is presented in monetary terms as a "total value" (e.g., total value of all fish catches in the area per year). The *relative value* is presented by a figure relative to a single unit of measurement (e.g., "value per ton caught" or "value per m^3 harvested"). In the first case, the absolute value is related to a single hectare or square kilometer; in the most economic values a hectare is recommended ("value per hectare"). In the second case, there is a need to calculate the absolute value by multiplying a value per kg/ton/m^3 with the overall amount produced or harvested. One example of calculation is given in GEF (2018, p. 35).

Also, when assessing the loss of ecosystem services provided by fishing, any study should take into account not only a decrease in fish productivity resulting from negative impacts, e.g. of hydropower or global warming, but also change in the water bodies and water ecosystem areas, particularly of fresh waters. For example, if an evaluation shows the water volumes, needed for river ecosystems wellbeing, have decreased, this situation leads accordingly to an additional loss of these ecosystems service to provide fishing.

The task to be solved in this work has determined a choice of applied methods, which included two principal components:

The study of *time trends* in historical data. Usually, a trend analysis of observations series provides useful information for understanding any changes caused by one or another factor. In the present study, trends were used to estimate tendencies in fish catches before and after the Dniester reservoirs filling.

- *A simple descriptive analysis* to describe basic features of changes in fish catches and stocks.
- An initial material there was mainly based on information from available literature. All statistical analyzes were performed, using appropriate tools provided by the *Microsoft Excel.*

Results and discussion

As a start point for this research there was selected the excellent diagram of long-term dynamics of the volumes of commercial fishery in the Dniester River (Fig. 1). Even a visual analysis indicates its significant reduction, undoubtedly associated with the Dniester's HPPs construction. In particular, the first sharp reduction took place in the 1950s and was caused by the Dubasari HPP construction; the second, equally obvious catches decline, which occurred in the 1990s, was due to the commissioning of the Dniester hydropower complex (DHPC). The total decrease in the stocks of commercial fish catches in the territorial boundaries of Moldova amounted to about 90-95 tons per year.

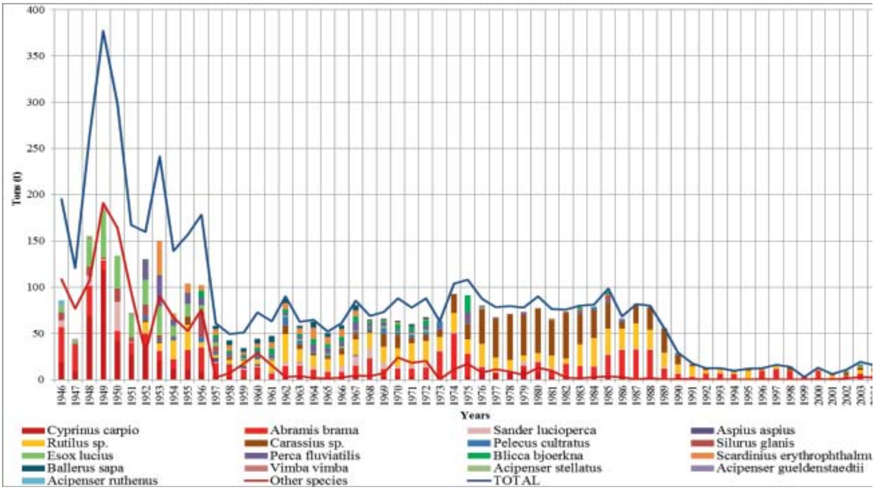

Fig. 1. Dynamics of the commercial catch of fisheries in the Dniester River by its volume (tons) and species (Source: Institute of Zoology of Moldova, analyzed by Bulat, 2017)

For a more detailed study of the dynamics of the observed fall in fish catches, the appropriate regression analysis was carried out (Fig. 2). The second-degree polynomial regressions, most reliably describing the process under study, were constructed both for all commercial fish species in total and for their categories with different commercial values. Four categories that were selected included: *high value species (*Starry sturgeon, Sturgeon Starlet); *mean value species* (Common carp, Pike-perch, Weal, Pike, Vimba); *low value species* (Bream, Asp, Roach, Crucial carp, Sablefish, Perch, White bream, Rudd), and *other species*. However, the regression relationships for highly valuable fish species were not built because their very small catches were recorded only from 1946 to 1949, with a sequential decrease from 6 tons to 1.7 tons (only 11.8 tons for this period in total).

A purely visual analysis of the obtained dependencies allows drawing two main conclusions. First, a high statistical significance is observed for all regressions, and the correlation ratio ***r***, which is more than 0.7 in all cases, characterizes a strong dependence of a catch on year. Secondly, the gradual replacement of high- and medium-valuable fish species by less valuable ones. This is clearly seen when to compare the relevant trends. Thus, along with the general decrease of fish stocks, the stocks of commercially valuable species have decreased especially significantly. In quantitative terms, this conclusion is well confirmed by the data in Table 1.

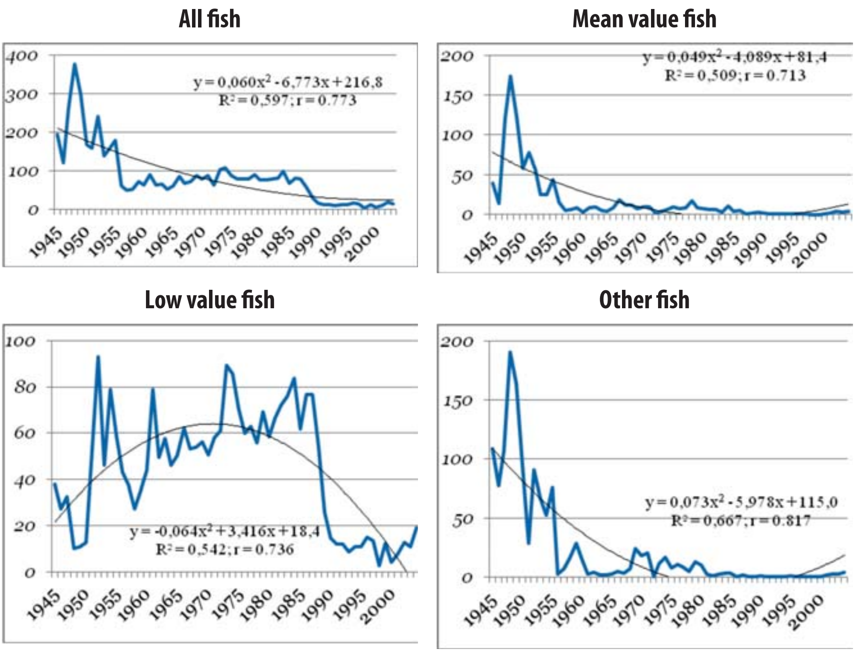

Fig. 2. The second-degree polynomial trends of fish catches of different commercial value

To assess additionally the impact of hydropower plants on these processes, the catches were divided into three time periods: before damming the Dniester for Dubasari HPP construction (1946-1953); between this damming and the second damming for DHPC contraction (1954-1983) and the subsequent years (1984-2005). So, after the first damming, the average annual catches of mean-valuable fishes decreased by almost eight times, after the second damming – by another five times, thus decreasing for sixty year from about 83 tons to 2.1 tons per year. At the same time, if catches of a low-value fish in this period initially increased from 34.8 tons to 58 tons/year, then at the beginning of the current century they decreased by only 6.4 tons/year compared to the pre-damming period. On the whole, the value of fishing as an ecosystem service of the Dniester falls threateningly.

Table 1. Catches of various values fish in the Dniester River in different time periods, tons

Time period	Statistics	Fish values			Total
		Mean value	Low value	Other	
1946 -1953	Mean	83.1	34.8	107.8	*227.1*
	Max	174.0	93.1	191.0	*376.8*
	Min	14.0	10.1	28.7	*120.8*
1954 – 1983	Mean	10.7	58.0	14.8	*83.5*
	Max	43.8	89.4	75.7	*178.3*
	Min	2.2	27.4	0.0	*49.5*
1984-2005	Mean	2.1	28.4	1.1	*31.7*
	Max	11.0	84.1	3.8	*98.5*
	Min	0.0	2.9	0.0	*2.9*

This situation is well demonstrated by one more example. Prior to HPPs construction in the Naslavcea–Camenca sector of Dniester River, the main commercial fish species were sterlet *Acipenser ruthenus*, European carp *Cyprinus carpio*, vimba *Vimba vimba*, sheatfish *Silurus glanis*, nase *Chondrostoma nasus* and barbel *Barbus barbus* (Ярошенко, 1957). However, today the commercial fish are largely superseded by low-value, short-cyclic and invasive species, where three-spined smelt *Gasterosteus aculeatus*, bitterling *Rhodeus amarus* and bleak *Alburnus alburnus* dominate (Bulat, 2017).

A negative tendency in commercial fishing, expressed as a significant decrease in recorded catches and change in their structure, is also observed in the Dubasari reservoir (Fig. 3), despite the great efforts on their maintenance. So, in 1998-2010 about 94 tons of fish tries were released into the Dubasari reservoir for this aim (Usatîi et al., 2016).

The hydropower impact on fish stock in the Dniester River is also strengthened by general ecological situation in the basin. Its permanent deterioration here also plays certain role, negatively affecting the ecological state of main aquatic ecosystems. Their quality status in the Dniester River is presented in Table 3 where categories of quality were defined according to the Water Framework Directive (WFD, 2000). Based on the structural-functional status of a fish fauna, this directive has highlighted five quality categories of aquatic ecosystems.

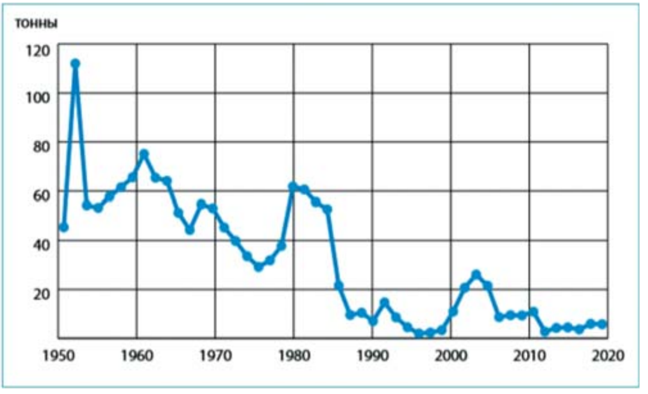

Fig. 3. Commercial catch of fish in Dubasari reservoir, tons. Source: Usatîi et al., 2016

Table 3. Attribution of the ecological quality classes to aquatic ecosystems in the Dniester River based on IBI 9 (Index Biotic Integrity) values (WFD, 2000)

Ecosystem type	Ecosystems' area	Biotic Integrity Class	Quality category in accordance with the Water Framework Directive (2000/60 EC)	
Lotic	Dniester	Poor	IV	Weak
Slow	Dubasari reservoir	Poor	IV	Weak

Source: Bulat, 2017

Economic valuation of fishing losses

Economic Valuation (EV) as a common approach, taken from the field of environmental economics (Plottu and Plottu, 2007), aims to create a single monetary metric, which combines all activities within certain area, to express the value of each activity in a common monetary measure. It is also a useful tool for exploring what types of values every ecosystem service provides and thus helps to determine the cost required to conserve these values. Differences in the problems to be studied require differentiation of approaches to their solution. Any ecosystem is the interacting and dynamic system consisting of biotic and abiotic elements, which are not a static composition; the provision of ecological services is a result of these elements specific interactions. Only a *healthy* ecosystem can provide the full set of its potential services. Thus, the task of economic valuation is not to assess only a potential value of these services, but mainly – their real value resulting from the losses caused by different impacts.

The value of an ecosystem service in monetary terms depends also on a number of other factors, including whether it will be possible to use this service on a long-term sustainable basis. Moreover, within any scheme involving the application of market mechanisms to ecosystem services valuation, one of the main challenges is to determine their "true" value. There is no universal method for this, and in practice a number of approaches are used. Specific information on the various valuation methods is contained in different documents, e.g. GEF (2018) and TEEB (2010).

Most ecosystem services are not traded on markets, but there are some that are. First of all, as such there are so-called provisioning services, which provide products that are derived directly from an ecosystem (fishing is among them). Although these services differ significantly by their cost from region to region or from country to country, it is relatively easy to express them as a single local value and then to evaluate economically, using local market prices.

In this work, for economical evaluation of the above discussed fisheries losses, three approaches have been used:

1. Cost of direct losses. Before the beginning of hydro construction on the Dniester River, fish productivity in the river's part from Ribnita to Palanca was 6-7 kg/ha (Ярошенко, 1957). Based on the area of river and lake ecosystems located here (143.41 km^2), the fish stock was 93.2 tons; approximately the same amount was a real annual catch before the construction of the DHPC. Currently, the catch amounts to about 20 tons and the resulting difference (about 73 tons) represents the loss in the fishery's provisioning ecosystem service. Based on the price of freshwater fish, established by GLOBEFISH[1] (FAO, 2020), which in 2019 was $2.35 for kg, the observed losses were more than $172 thousand per year.

Similarly, it is possible to estimate the loss of annual fishing catches in the Dubasari reservoir that decreased from 60 tons in the 1980s to 2-3 tons at present (about $135 thousand per year), despite the measures taken for its artificial stocking.

[1] GLOBEFISH is a multi-donor funded project within the FAO Fisheries and Aquaculture Department responsible for providing up-to-date trade and market on fish and fishery products.

The costs of maintaining the habitat services. If to consider the cost of ecosystem conservation and maintaining as a value of losses of its ecosystem services, then the cost, for example, of maintaining the fish spawning grounds *(nursery habitat)* can be considered as certain equivalent of the damage done to this ecosystem. So, the cost of 150.15 tons of fries of various fish species, launched e.g. in 1998-2018 in Dubasari reservoir for maintaining its fish stock, amounted to 6.3 million MDL[2]. Undoubtedly, this figure is also one of components of economic valuation of the HPPs caused damage to the Dniester ecosystem services as a whole.

2. The cost of losses in fishery cultural services was indirectly estimated by the scale of amateur fishing. Currently, 15,000 fishermen are registered in Moldova, and for amateur fishing on the Dniester it is necessary to purchase a fishing ticket. Revenues from sport fishing are estimated at 2.5-4.5 million MDL, or about 145-260 thousand USD per year. An increase or decrease in the number of amateur fishermen is a reliable indicator of the ichthyofauna conditions in the river basin.

Conclusion

The results of the presented work show the importance of additional in-depth studies on the impact of hydropower on fishery, which usually is not taken into consideration in hydropower development plans. It is required to transit from purely descriptive statistics, which mainly fix the observed effects and their consequences, to analytical studies. Only such approach allows revealing the inevitable patterns in the observed processes, including the economic valuation of their potential damages.

Acknowledgements

The current work was realized in frames of the Joint Operational Black Sea Programme 2014-2020, the Project BSB 165 "HydroEcoNex", with the financial assistance of the European Union. The content of this publication is the sole responsibility of the authors and in no case should it be considered to reflect the views of the European Union.

References

1. Bulat, Dum, 2017: *Ihtiofauna Republicii Moldova: amenințări, tendințe și recomandări de reabilitare*: Monografie. Acad. de Științe a Moldovei, Chișinău, 343 p.

[2] According to Fish Protection Service of Moldova. https://ru.sputnik.md/society/20180425/18782986/dnestr-ryba.html

2. GEF, 2018: GEF guidance documents to economic valuation of ecosystem services in IW projects, GEF IW: LEARN, 171 p.
3. GEF, UNDP, OSCE, UNECE (2019) Management plan of the transboundary Dniester River Basin. Part 1: General characteristics and assessment of conditions (Draft). Available at: https://dniester-commission.com/wp-content/uploads/2019/07/Dniester_TDA_July2019.pdf
4. FAO, 2020: GLOBEFISH Highlights. A quarterly update on world seafood markets. Available at: http://www.fao.org/3/ca7459en/ca7459en.pdf
5. Havrilyuk R, Gabrielian A, Sultanov E, Trombitsky I, Stankevych-Volosianchuk O, Tarasova O (2019) Implementation of ecosystem approach and ecosystem services in hydropower sector of EaP countries: state and challenges. Kyiv,76 p. Available at: http://necu.org.ua/category/publish/
6. Ocko IB, Hamburg SP (2019) Climate Impacts of Hydropower: Enormous Differences among Facilities and over Time. Environ Sci Technol. Available at: https://pubs.acs.org/doi/10.1021/acs.est.9b05083.
7. Plottu E. and Plottu B., 2007: The concept of Total Economic Value of environment: A reconsideration within a hierarchical rationality. *Ecological Economics* 61(1): 52–61.
8. Schwarz U (2019) Hydropower pressure on European rivers: The story in numbers. WWF, RiverWatch, EuroNatur, GEOTA. Available at: https://balkanrivers.net/sites/ default/files/European%20Hydropower%20report%202019_w.pdf
9. TEEB, 2010: The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Pushpam Kumar P. (Ed). Earthscan, London and Washington.
10. UNDP, OSCE, UNECE (2019). Analysis of the effects of the Dniester Reservoirs on the state of the Dniester River, 53 p. Available at: https://zoinet.org/wp-content/uploads/2018/01/hydropower-effects_final_ENG.pdf
11. Usatîi, Ad., Usatîi, M., Șaptefrați, N., Dadu, A., 2016: *Resursele piscicole naturale ale Republicii Moldova*. Balacron, Chișinău, 124 p.
12. Vejnovic I (2017) Broken rivers: the impacts of European-financed small hydropower plants on pristine Balkan landscapes. CEE Bankwatch Network
13. WFD, 2000: The EU Water Framework Directive – integrated river basin management for Europe. Available at: *https://ec.europa.eu/environment/water/water-framework/index_en.html*

14. Xie JY, Tang WJ, Yang YH., 2018: Fish assemblage changes over half a century in the Yellow River, China. *Ecol Evol*. 00:1–10. https://doi.org/10.1002/ece3.3890
15. Yuichiro Y., Han S.L., Bui H.T., et al., 2020: Impacts of Mainstream Hydropower Dams on Fisheries and Agriculture in Lower Mekong Basin. *Sustainability* 12: 2408, doi:10.3390/su12062408.
16. Zhang C., Ding L., Ding C., Chen L., Sun, J., Jiang, X., 2018: Responses of species and phylogenetic diversity of fish communities in the Lancang River to hydropower development and exotic invasions. *Ecol. Indic*. 90: 261–279.
17. Ярошенко М.Ф., 1957: Гидрофауна Днестра. Москва, Изд-во Акад. наук СССР, 168 с.