THE IMPACT OF CLIMATE CHANGE AND ANTHROPIC INFLUENCE ON FISH POPULATIONS

Adrian Usatîi, Dumitru Bulat, Nadejda Usatîi and Nicolae Șaptefrați

Received: 26.09.2022 / Accepted: 27.10.2022

Abstract: The anthropogenic factor and climate change remain today the main factors determining the qualitative and quantitative changes in the structure and composition of the animal kingdom, including ichthyofauna. Following the radical changes caused by the negative action of anthropogenic factors and the influence of climate change on aquatic ecosystems, in most of them there has been a significant degradation of the structure and numerical value of fish populations. Given the continuous quantitative and qualitative decline of fishery resources, there is a real danger of losing the existing ichthyogenic fund and the fishing importance of natural aquatic ecosystems.

Keywords: adaptation, anthropogenic factor, climate change, ecosystem succession, fish populations

Introduction:

Over the course of the centuries, and especially in recent decades, the natural state of natural fishery and fishery resources has been changed by various anthropogenic activities and is still influenced by these. By the middle of the last century, the fund of natural fishery pools consisted of the Dniester river and the Prut river with their tributaries, 6000 ha of natural lakes and 46-50 thousand ha of puddles, and industrial fishing, predominantly carried out in the estuaries - Cuciurgan and Gura-Bâcului, the lakes - Botna, Crasnoie, Tudora, Putrino, Bublic, etc., from the Dniester River Basin and Lakes Beleu and Manta in the Prut River Basin. At present, their surface is reduced by 70%, and the fund of artificial fisheries includes 3900 objectives with a surface area of about 46000 ha, of which only 30-35% are used in fish farming.

The productive activities carried out initially in the Dniester River basins and the Prut River, and then in most small rivers, have changed their physical environment. Firstly, the biotope and biological aquatic resources that are subject to this influence was directly influenced. The trend of extracting from natural aquatic basins of as many natural riches have led to biological imbalance, radically changed the mechanism for the protection, reproduction and capitalization of aquatic biological resources. Under these

Adrian Usatîi, Dumitru Bulat, Nadejda Usatîi and **Nicolae Șaptefrați:**
Institute of Zoology
Moldova State University
Liceul Teoretic Traian
Str. Academy 1, MD-2028
Chisinau, Republic of Moldova
e-mail: ihtiomoldova@yandex.com

circumstances, there is considerably the unregulated exploitation of fishery resources without the realization of improved measures and compensation for damage caused; direct control has diminished on anthropogenic actions based on the principles of full protection of aquatic ecosystems.

There are several anthropogenic factors such as extraction and excessive exploitation of fishery resources in natural aquatic ecosystems for the maximum satisfaction of man's moment interests without taking into account the need for future generations, domestic and industrial pollution, progressive eutrophication, toxicities, reduction of flows water, and other economic activities.

In recent decades, these factors influenced the aquatic ecosystems of the Dniester River, the Prut River and rivers located in the Dniester (Prut interfluve territory) and the Danube. This shaped essential changes in the biodiversity of hydrobiocenosis, which led to the loss of the viability and importance of rivers in the biosphere and the environment.

Current economic conditions, destruction and diminution of the fisheries fund, global climate change have considerably reduced fish production in ponds, puddles and lakes. In the context of the quantitative and continuous qualitative diminution of fishery resources, the real danger of loss of existing ichthyogenic fund and the importance of natural aquatic ecosystems, which can lead to negative economic consequences for the whole society.

The results of the anthropic impact research and the effects of climate change on the aquatic environment, biodiversity, the achievement of conservation measures and the sustainable use of aquatic biological resources are at the forefront and are given increased attention in all international countries and institutions.

Materials and methods:

At European level, the use of ichtyofauna for the quality monitoring of aquatic habitats is relatively recent (Yoder and Smith 1998; Kashulin et al. 1999; Angermeier and Davideanu 2004; Bhagat 2005; Kennard et al. 2005; Sucman et al. 2006; Iwanowicz 2008; Vidal 2008; Breine 2009; Davideanu 2013; Bulat et al. 2014 etc.). This experience has been systematized and developed through the program FAME (Fish based Assessment Method for the Ecological Status of European Rivers. Contract CE no EVK1 -CT-2001-00094). A group of 25 institutions in 12 countries conducted the program.

Procedure of the bioindication of aquatic ecosystems in the Republic of Moldova after ichthiological indices in line with the Water Framework Directive (CE 2000).

Results and discussion:

Global warming is a phenomenon accepted by the international scientific community, already highlighted by observational data analysis over long periods of time. With global climatic models, it was advisable that the main factors that determine this phenomenon are both natural (variations in solar radiation and volcanic activity) as well as anthropogens (changes in the composition of the atmosphere due to human activities). The early 1990s of the 20th century is considered a "reference point" for the global heating phenomenon. This phenomenon was found on the basis of the observations made at the Chisinau meteorological station, which established that during 1887-1980 the average annual air temperature increased on average, every 10 years, by about 0.05 ^{o}C, which, recalculated yearly/regularly for 100 for years, it is a 0.5 ^{o}C increase.

With a high degree of certainty, it was established that the phenomenon of climate change raises and advances with an accelerated pace, especially over the past three decades. This phenomenon is practically over the entire period of the year, less autumn. In addition, an accelerated intensification of the variability of the index characterizes the average annual and seasonal temperature for the period 1981-2010 has been established. In real time, this variability is manifested by increasing the

Istros – Museum of Braila "Carol I"

frequency of sudden temperature fluctuations, especially during the last winter and spring season, and summer - by the appearance of heat waves. (Annex no. 1… 2020).

Temperature shapes directly and in correlation with other factors, the biocoenoses structure of natural aquatic ecosystems. Aquatic ecosystems in the temperate area are subject to a relatively restricted thermal regime (-30 ºC ÷ + 40 ºC) which causes a water temperature between + 2 ºC and + 30 ºC.

Temperature, by regime fluctuations and correlation with other factors, directly and indirectly, determines the rate of bioactivity, biocoenoses structure and biological productivity in aquatic ecosystems. Each species is characterized by a thermal interval, having a lower limit and a higher limit between which the specific life is carried out. In this period, usually wider, there is an optimal, more restricted value, in which the species is best developing. Most fish species in our waters are eurytherm, supporting variations in water temperature within 0 ºC and 30-35 ºC. During the wintering, most fish species reduce their biological activity and enroll in hibernation. Spring, metabolism is activated, doubling every 10 ºC interval during the warm period of the year. The water temperature directly influences the reproduction of hydrobionts, the period and intensity of feeding, the ability of assimilation etc.

During summer, when the water temperature is quite high, its 5-6 ºC growth (for some species) can reach or exceed the tolerance limit. High water temperatures produce changes in the phytoplankton structure. With the increase in temperature, the diatoms regress and are replaced by the green algae, thus affecting the primary production. At heating up to 20 ºC, primary production is increasing, but at higher temperatures a photosynthesis inhibition occurs, followed by the quantitative decrease in phytoplankton and primary production, which often leads to mass skinning of zooplankton.

The predictions of the climate scenarios for the Republic of Moldova show that what is currently considered extreme phenomena, with rare frequency, with absolute maximum temperatures of 34-35ºC for the reference period 1961-1990, in the future will probably become average maximum summer temperatures. General forecasts for Europe show that the risk of floods increases in Northern, Central and Eastern Europe and that the frequency of droughts currently recorded every 100 years will increase, with the same frequency occurring every 50 years, especially in Europe-South and South-East, including the Republic of Moldova (Lehner et al. 2006).

The assessment of the ecological status of aquatic systems is based on biological, physico-chemical and hydromorphological components, is specific to each type of ecosystem (lotic, lenic, large, medium or small) and involves classification (based on comparison with the reference state, undisturbed, real or hypothetical) in one of the five condition ranks, namely “very good”, “good”, “moderate”, “unsatisfactory” and “bad”.

Some of the most common problems faced by fish species are: oxygen deficiency and organic pollution, thermal and noise pollution, various obstacles to migration, pollution with persistent synthetic compounds, radioactive pollution, etc. Fish can also be used indirectly as bioindicators in the biomonitoring process, namely by the presence of certain parasites, their degree of invasion, their functional state etc.

A special attention in the monitoring process is paid to the action of the toxicants on the fish fauna. Pollutants have a direct negative influence at various levels of integration and organization of life: at the molecular level - structural degradation, additional ATP cleavage; at the cellular level - inhibition of synthesis and self-regulation processes, cell autolysis, disorders in the process of cell division, etc.; at the tissue and organic level - worsening of food assimilation, detachment and deformation of muscle fibers, pathologies at the level of excretion, reproduction, disorders of the immune system etc.; at the organic level - delayed growth, various forms of pathologies, decreased reproductive capacity, death of the

body; at population level - decrease of the herd, reduction of the age structure, increase of the share of females in the population etc.; at the ichthyocenotic level - reduction of the specific structure and disappearance of sensitive species, dysfunction of trophic relationships etc. (Filenko and Miheeva 2007).

At the level of the reproductive system, the polluting factor can cause multiple significant dysfunctions. As an example, the total resorption of sexual products in the trophoplasmic growth phases may indicate sudden worsening of nutritional conditions, overpopulation, the influence of toxicants, inaccessibility to cattle etc. (Shatunovskhiy 1991; Shatunovskhiy et al. 2007).

In all cases, the response of the reproductive system to the action of environmental factors is very varied and depends largely on their intensity and the bio-ecological characteristics of the taxon. The most common disorders of reproductive function in fish collected from different aquatic ecosystems of the Republic of Moldova are: asymmetric development of ovaries and testicles, their abnormal shape, early sexual maturation, changing duration of ovogenesis and spermatogenesis, shifting timing of reproduction, cases of resorption in mass of sex cells in the final stages of growth and development, decrease in fertilization capacity, decrease in the share of individuals capable of reproduction, abortion of eggs with damage to follicular membranes etc. (Fulga et al. 1998, 1999).

Also, in unstable ecological conditions, in the ichthyocenoses of aquatic ecosystems there is an increase in the share of interspecific hybrids. Unfavorable conditions during the reproductive period for a species, can cause disturbances in the process of gametogenesis and respectively the modification of the spawning terms. As a result, when favorable conditions return, there may be overlaps in the reproduction of several species of fish on the same bush, and as a finality - the emergence of hybrids (a phenomenon with increasing frequency in the Dniester River after the construction of the Dnestrovsk Dam, Ukraine).

Data on fish species (example: Bream, Roach, Asp, Perch, Pike etc.) well studied in different environmental conditions, can serve as an important and additional method in the process of biomonitoring and bioindication. In this sense, the morphometric and metric characters subjected to the statistical analysis of the individuals of a species from various aquatic ecosystems can reveal an important ecological picture regarding the well-being of the environment.

In the current ecological conditions, when anthropogenic pressure is continuously maintained on natural aquatic ecosystems, in addition to reducing specific diversity, with the "irreversible loss" of stenobiont fish species, there is the numerical supremacy of small, particularly prolific, high euritope species, competitive and with a high expansive potential (Bleak, Stone Moroko, Prussian Carp, Roach, Silver Bream etc.).

Estimating the quality of the environment can be done not only on the basis of species hypersensitive to changes in environmental factors, but also by the presence in the hydrobiota of species resistant to pollution, their abundance serving as an indicator of unfavorable ecological status. Thus, the phenomenon of bioinvasion can also be used to assess the quality of aquatic ecosystems.

The changes that occur in the structure of some populations of the species are the result of the reaction of adaptation of the population to the changes of the living conditions. Changing the growth rate and sexual maturation time of fish, the age structure of individuals at the first reproduction, the lifespan of mature individuals, the amplitude of variations in the size of spawning eggs - these are the main forms of adaptation of the age structure of the population, oriented to ensure the balance of the herd and the biomass of the population with the provision of food (Lobón-Cervia et al. 2013). These adaptations do not work by the will of the body, but there is sufficient and effective self-regulation. But the regulatory mechanisms that ensure the restructuring of the population and

reproductive properties, work under certain conditions often in limited parameters. The stenobionte species, adapted to the relatively stable supply of fodder and small variations of the herd, have small amplitudes of regulatory adaptations. In euribion species adapted to significant variations in population size and feed provision, the range of regulatory adaptations is wider.

The specific composition of the hydrobiont communities characterizes with higher precision the quality of the environment and constitutes an important characteristic of the state of the communities, of the aquatic ecosystems in general, as well as of its anthropogenic changes (Shuyskiy et al. 2002). If the specific composition of the communities is changed, then, firstly, the changes of the other cenotic features that have also occurred will be irreversible, secondly, the subsequent changes, sometimes very essential and sudden, are very risky and unpredictable. The invariability of the specific composition of the communities, on the contrary, ensures the reversibility of the produced changes, the restoration of the initial properties of the communities after their removal and is the optimal criterion for preserving the main properties of the communities in the conditions of anthropogenic actions. It is very important to correctly evaluate the specific composition of the communities and to appreciate its preservation or modification in the conditions of anthropic actions. For this, it is necessary to know which of the species are regularly found in the studied communities and which are found by chance.

Therefore, the disappearance of some species from the first ones, in the conditions of anthropic actions will demonstrate the anthropogenic modification of the specific composition of the community, and the disappearance of the species that is meet occasionally cannot be interpreted as important. At the "core" of the main species that determine the properties of the community and are subject to evidence for traditional bioindication, until recently, only a few dominant ones were assigned, and the role of species with biomass and low population density were disregarded. But lately it has been shown that the particularities of communities are appreciated by all the complex intraspecific relationships of species (trophic, allelochemical, ethological etc.). At the same time, species play an important role in these relationships, individuals that are encountered even in small quantities, but regularly. The extinction of these species can lead to essential changes in the particularities of communities and even ecosystems, often unpredictable and catastrophic. Even if the species is meet by chance, sporadically, its role in the community cannot be significant, and when evaluating the specific composition of the community, this species, motivated, can be neglected.

In addition, in comparative research for the purpose of bioindication it is impossible to establish whether the rare species has disappeared due to anthropogenic actions or it has simply not been possible to detect it. Therefore, in the studied community it is necessary to highlight the group of species that are frequently found and must be recorded for bioindication, based on the probability of their presence in the community in the initial state.

Quality biological elements for fish fauna

Status "very good". The specific composition and abundance correspond entirely, or almost entirely, to invariable conditions (constant, unchanging, steady). All species of a certain type of disorder-sensitive species are present. The age structure of fish communities may reflect insignificant anthropogenic disorders, but no disturbances are found in the reproduction or development of a particular species.

Status "good". There are insignificant changes in the composition and abundance of species belonging to the communities of species, which can be attributed to anthropogenic actions on the physico-chemical and hydrobiological indices of water quality. The age structure of fish

communities demonstrates disorders that can be attributed as anthropogenic actions on the physico-chemical and hydromorphological indices of environmental quality. In some cases, it is possible to notice the reproduction deficit or the development of certain species that is manifested in the absence of certain age groups.

Status "moderate". The composition and abundance of species differ moderately from the typical communities of species that can be attributed to anthropogenic actions on the physico-chemical and hydromorphological indices of environmental quality. The age structure of fish communities indicates significant anthropogenic changes to such an extent that a moderate number of species either stick or have a very small number.

Status "unsatisfactory". The composition and abundance of fish species differ significantly from the communities of species - type that can be attributed to the anthropogenic impact on the physico-chemical and hydromorphological indices of environmental quality. The age structure of fish communities demonstrates important anthropogenic disturbances insofar as a greater number of species specific to typical communities are absent or have a very low abundance.

Status "degraded". There is a structural-functional degradation of ichthyofauna and populations of all fish species. The ichthyofauna is represented by several toxic-resistant species with unsatisfactory numbers, continuous spatial distribution and having a high degree of morpho-functional pathologies at the individual level. This can be attributed to the extreme anthropogenic actions on the hydromorphological and physico-chemical indices of water quality.

In connection with the significant difference of the specific diversity of the ichthyofauna, of the quantitative and qualitative characteristics of the populations, their modification in the process of ecosystem succession was carried out the typification of the water basins from the Republic of Moldova. For each type of water basin, based on the investigations, groups of fish were highlighted - indicators that characterize the ecological status of ecosystems (in their historical development) in accordance with the Water Framework Directive (2000).

Between the mid-1990s and the present, due to the radical changes caused by the negative action of anthropogenic factors and the influence of climate change on aquatic ecosystems, in most aquatic ecosystems there has been a significant degradation of the structure and numerical value of valuable fish populations. Rare and endangered species have practically disappeared, and many species, in the past common for the ichthyofauna of the Republic of Moldova, have become extremely rare.

The representatives of 3 families: Thymalidae, Salmonidae, Anguillidae have completely disappeared from the composition of the ichthyofauna. The specific diversity of the local ichthyofauna was reduced by 20%, including such valuable and rare species as Russian Sturgeon, Bastard Sturgeon, Mountain Trout, Huchen, European Eel, Grayling, Romanian Barbel etc.

The adhering of the Republic of Moldova to the international conventions in the field of environmental protection requires the effective implementation of the concept of sustainable development, accepted at the World Forum on the Environment. The major goal of the environmental policy in the Republic of Moldova is to restore the optimal level of biological diversity, to develop and implement efficient measures for their conservation according to national and international requirements.

Optimizing the state of affairs requires the implementation of scientifically argued measures for the efficiency of conservation and capitalization of ichthyofauna diversity. Among the most important measures that determine the fish productivity of aquatic ecosystems and fauna diversity are those of reproduction, introduction and acclimatization of valuable fish species.

Conclusion:

In order to preserve the biodiversity of ichthyofauna, measures will be taken to optimize the hydrological regime favorable to flooding of logs that would ensure the natural reproduction of fish, the development of embryonated eggs, passive migration of eggs and juveniles, repopulation of important aquatic ecosystems with valuable fish species and other factors to improve the situation.

Rezumat:

IMPACTUL SCHIMBĂRILOR CLIMATICE ȘI INFLUENȚA ANTROPICĂ ASUPRA POPULAȚIILOR DE PEȘTI

Factorul antropic și schimbările climatice rămân astăzi principalii factori care determină modificările calitative și cantitative în structura și compoziția regnului animal, inclusiv ihtiofauna. În urma schimbărilor radicale cauzate de acțiunea negativă a factorilor antropici și de influența schimbărilor climatice asupra ecosistemelor acvatice, în cele mai multe dintre ele s-a înregistrat o degradare semnificativă a structurii și valorii numerice a populațiilor de pești. Având în vedere declinul continuu cantitativ și calitativ al resurselor piscicole, există pericolul real de pierdere a fondului ihtiologic existent și a importanței piscicole a ecosistemelor acvatice naturale.

References:

ANGERMEIER P.L., DAVIDEANU GR. (2004), Using fish communities to assess streams in Romania: initial development of an index of biotic integrity, *Hydrobiologia* 511: 65-78.

BHAGAT Y. (2005), *Fish indicators of anthropogenic stress at Great Lakes coastal margins: multimetric and multivariate approaches*, M.Sc. thesis. University of Windsor, Windsor, Ontario, Canada.

BREINE J. (2009), *Fish assemblages as ecological indicator in estuaries: the Zeeschelde (Belgium)*, Ph.D. thesis Katholieke Universiteit Leuven and Research Institute for Nature and Forest. INBO.T.2009.1, p.263.

BULAT DM., BULAT D., TODERAȘ I., USATII M., ZUBCOV E., UNGUREANU L. (2014), *Biodiversitatea, bioinvazia și bioindicația (în studiul faunei piscicole din Republica Moldova)*, TP. „Foxtrot", Chișinău.

DAVIDEANU G. (2013), Methodological guide for monitoring the structure of ichthyocenoses, *Joint Operational Programme Romania-Ukraine-Republic of Moldova 2007-2013*, Performitatica, p. 57.

FILENKO O.F., MIHEEVA I.V. (2007), Основы водной токсикологий. Изд. Колос. Москва, с. 143.

FULGA N.I., USATII M.A., USATII A.M. (1998), Razvitiye reproduktivnoy sistemy fitofil'nykh vidov ryb na raznykh etapakh ontogeneza v sovremennykh usloviyakh Dubesarskogo vodokhranilishcha. V: *Problemy sokhraneniya bioraznoobraziya Srednego i Nizhnego Dnestra*, Tezisy Mezhdunarodnoy konferentsii, Kishinev, 6-7 november 1998 g., s. 180-182.

FULGA N.I., USATII M.A., BRUMA I.H. (1999), Morfo-fiziologicheskiye izmeneniya v razvitii gonad u samok tarani i serebryanogo karasya v modifitsirovannykh usloviyakh Dubesarskogo vodokhranilishcha. V: *Sokhraneniye bioraznoobraziya basseyna Dnestra*: Mater. Mezhdunarod. konf. Kishinev, 7-9 oktyabrya 1999 g., s. 243-245.

IWANOWICZ L.R. (2008), *Fish as indicators of aquatic ecosystem health: From the lab to the field* (January 1, 2008), *Electronic Doctoral Dissertations for UMass Amherst.* Paper AAI3339554.

KASHULIN N.A., LUKIN A.A, AMUNDSEN P.A. (1999), Rybi presnyh vod subarktiki kak bioindikatory tekhnogennogo zagryazneniya. - Apatity.- c.142.

KENNARD M.J., ARTHINGTON A.N., PUSEU B.J., HARCH B.D. (2005), Are alien fish a reliable indicators of river health, *Freshwater biology* - V. 50.- P. 174-193.

LEHNER B., DÖLL P., ALCAMO J., HENRICHS H., KASPAR F. (2006), Estimating the impact of global change on flood and drought risks in Europe: A continental, integrated analysis, *Climatic Change* 75: 273-299.

LOBÓN-CERVIA J., VØLLESTAD A., HEINS D.C. (2013), *Ecology of freshwater fish* 19/50

(Fisheries); 45/102 (Marine & Freshwater Biology).

SHATUNOVSKIY M.I. (1991), O narusheniyakh reproduktivnoy funktsii ryb pod vliyaniyem antropogennykh faktorov, V: *Tez. Vses. Soveshch. Reproduktivnaya funktsiya ryb*, 15-17 okt. 1991, Minsk, s.53.

SHATUNOVSKIY M.I., RUBAN G.I. AKIMOVA N.V. (2007), O populyatsionnykh ontogeneticheskikh mekhanizmakh regulyatsii vosproizvodstva ryb, *Uspekhi sovremennoy biologii*. T. 127. No. 1. 2007, s. 87-96.

SHUYSKIY V.F., MAKSIMOVA T.V., PETROV D.S. (2002), *Bioindikatsiya kachestva vodnoy sredy, sostoyaniya presnovodnykh ekosistem i ikh antropogennykh izmeneniy*, Sb. nauchn. dokl. VII mezhdunar. konf. "Ekologiya i razvitiye Severo-Zapada Rossii" – S.-Peterburg, 2 –7 aug. 2002 r. – SPb.: Izd-vo MANAB.

SUCMAN E., VÁVROVÁ M., ZLÁMALOVÁ GARGOŠOVÁ H., MAHROVÁ M. (2006), Fish – useful bio-indicators for evaluation of contamination in water ecosystems,/ *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy*: Vol. 11, Article 3.

USATÎI M. (2004), Teza de doctor habilitat în ştiinţe biologice „*Evoluţia, conservarea şi valorificarea durabilă a diversităţii ihtiofaunei ecosistemelor acvatice ale Republicii Moldova*”, Chișinău, 2004. http://www.cnaa.md/thesis/1614/

USATÎI M., USATÎI A., CREPIS O., ŞAPTEFRAŢI N., BULAT DM., BULAT DN., TODERAŞ I., CEBANU A., DADU A. (2017), *Evaluarea stării resurselor piscicole*, Monografie, Editat conform deciziei Consiliului ştiinţific al Institutului de Zoologie al Academiei de Ştiinţe a Moldovei. – Chișinău, Tipogr. „Balacron”, 142 p.

USATÎI AD., ŞAPTEFRAŢI N., BULAT DM. (2021), *Bunele practici în piscicultură în contextul schimbărilor climatice* (Ghid practic pentru producătorii agricoli), Tipografia „Bons Offices SRL”, Chișinău, p. 80.

VIDAL L.B. (2008), *Fish as ecological indicators in mediterranean freshwater ecosistems*, Dissertation to obtain the Ph. D. degree, University of Girona, Spain, p. 65.

YODER C.O., SMITH M.A. (1998), Using fish assemblages in a state biological assessment and criteria program: essential concepts and consideration, pp. 17-56, in: SIMON T.P. (Ed), *Assessing the sustainability and biological integrity of water resources using fish communities*, Lewis Press, Boca Raton, FL.USA.

*** (2000), Implementarea Directivei-cadru 2000/60/EC în domeniul apei, în România.

*** (2000), Directiva 2000/60/CE a Parlamentului European şi a Consiliului din 23 octombrie 2000 de stabilire a unui cadru de politică comunitară în domeniul apei, Jurnalul Oficial al Uniunii Europene, 15/vol. 6, RO. – P. 193-264.

*** (2014), Strategia Republicii Moldova de adaptare la schimbarea climei până în anul 2020. Anexa nr. 1 la Hotărârea Guvernului nr. 1009 din 10 decembrie 2014.