Fishponds as an element of surface waters network – overview, history, function

JOSEF K. FUKSA

Keywords: fishpond – fish production – carp – sediment – climate

ABSTRACT

Historically, fishponds are a part of our landscape and Christmas carp is also a part of our culture. This paper describes the history of fishpond management and the different functions of fishponds – the development of fish production as food, the influence on quality of surface waters, the influence on climate and on hydrological regime of the landscape, and the issue of fishpond sediments – their removal and further use.

As there is no general pond register in the Czech Republic, so (as part of the DivLand project) we created the Map of water bodies and fishponds in Czech Republic, based on the ZABAGED (primary base of geographical data in the Czech Republic). For water bodies with an area over 1.0 ha, a public database (xls) was created; bodies over 5.0 ha were classified into groups (fishponds, reservoirs, flooded areas, lakes). The database also contains accessible data on the quality of fishpond sediments. Fishpond sediments are a favourable material for improving the quality of agricultural soils; problems with their use are mostly technical and economical.

INTRODUCTION

History of fish farming

The Czech Republic is widely known as a fish farming country, and ponds have been a standard part of the Czech and Moravian landscape since the Middle Ages. Monastery ponds have been documented since roughly the 11th century, and the system of their dams and outlets gradually developed. An important written confirmation for the then already established fish farming was the draft *Majestas Carolina* code, by which Charles IV wanted to support the development of cities and economic entrepreneurship; however, under pressure from the nobility, he had to declare it lost on 3rd October 1355. Charles's chronicler, Beneš Krabice [1], in addition to general attention to the royal support for pond farming, explicitly mentions the establishment of the Great Pond, today Mácha's Lake, in 1366 (and the "discovery" of a new fish, barbel, in Bohemia). After the end of the general economic decline during the Hussite Wars, economic recovery began, limited among other things by a significant decrease in the population and workforce (wars, plagues). A significant factor was the change in the attitude of the nobility, who no longer made money from warfare (big and "small") and started business. That started disputes with cities, etc. The establishment of ponds had one paradoxical advantage – the possession of flooded land was "definitive" and not as many people were needed to operate the ponds as for field farming [2]. In addition, the "Friday fasting" still applied, limiting the consumption of meat to "less nutritious types", i.e. fish, crayfish, etc., including imported saltfish and dried codfish. This is how fish farming began to develop successfully for fish production, but also for landscape regulation – its drying and irrigation. Today, South Bohemia is a classic pond area; however, in the 15th century it was different – the historical Pernštejn fishponds on the Elbe pond systems in Moravia, etc. were particularly important. In fertile landscapes, however, a substantial part of ponds was drained and turned into fertile fields in the 18th century.

Among the "fishmasters", knight Kunát mladší Dobřenský of Dobřenice (1465?–1539) clearly stands out; he worked as a royal fishmaster before 1500, and later worked for the Czech nobility, including the Rožmberk family (Dvořiště, Koclířov, Tisý). In 1513, he began systematically working for the Pernštejn family. For them, he managed, for example, the completion of the Opatovice channel and the construction of Čeperka, apparently the largest pond in Bohemia (> 1,000 ha, later converted into a field; the village of Čeperka is documented since 1777). His descendants collected debts for work even after Ferdinand I. He had a stork in his coat of arms, which today is a direct symbol of wetland fauna, and the Dobřenský family still own estates in the region. Josef Štěpánek Netolický (1460–1538), a simple serf, who learned the "craft" from Kunát Dobřenský (probably during surveying of Horusický pond) worked in the Třeboň region, and, for example, introduced targeted summer pond drying to increase fish production. Štěpánek was rewarded, among other things, by being freed from serfdom (1515). A generation later, in the middle of the 16th century, his work was followed up by the famous "Rožmberk regent" Jakub Krčín, from Jelčany and Sedlčany (1535–1604), who surveyed his first pond in 1565. Unlike the Dobřenský family, however, the Krčín family did not continue after the battle of Bílá hora (many daughters, evangelical religion, etc.).

The still-cultivated Třeboň tradition somewhat overshadows the Pernštejn fish farming on the Labe, especially the activity of Vilém II of Pernštejn (1438–1521) who, in 1491–1498, built the Opatovice Canal on the Labe to supply his pond system, which is still functioning today. According to Dubravius and the commentary on translation [3], Pernštejn claimed, among other things, that a pond is more stable than a field against the vagaries of the weather. Other writings dealing with the issue of fish farming have also appeared. In 1540, Jan Brtvín from Ploskovice published *This book contains two pages...* , a general guide to holding the right faith and running a proper farm, which also deals with fish farming. The work was then republished under the title *Hospodář (Farmer)* in 1587 by Daniel Adam from Veleslavín. Dubravius – Jan Skála from Doubravka and Hradiště (1486–1553) has an essential place among the "wise old men". He studied law and successfully managed the economy of Olomouc Bishop Stanislav Thurzo for a long time. In 1541, he received priestly ordination almost at the same time and was appointed bishop of Olomouc as Jan XVIII. In Wroclaw (the second largest city of the Kingdom of Bohemia) in 1547, Dubravius publisher the book *De Piscinis* – a systematic "technical manual" on pond management, which he wrote at the request of one of the Fugger family. The Fuggers (related to the Thurzo family) were an important business family, perhaps the richest in Europe at the time, which financially supported the Habsburgs, owned Slovak copper mines, etc. By 1599, Dubravius's book had already been published in English, and then it was repeatedly published in Latin. It wasn't until 1906 that a well-edited German translation was published in Vienna; it was a sensation for Czech pond owners. Parts of the work were published in Czech only after 1900, and a complete Czech translation only in 1953 [3]. A. Schmidtová's translation *O rybnících (On fishponds)* also contains her thorough historical commentary. Dubravius described pond farming in detail – from the selection of a place, construction and maintenance of the pond, via the selection and breeding of fish (carp) to the economic side, including sales. Historically, ponds have developed and disappeared according to the general economic situation, which is basically still true today. A typical example is the disappearance of a significant part of the ponds around the Elbe, giving way to profitable agricultural land, in contrast to the relatively less productive (but romantic) Třeboň region, and others. Also, the list of functions of the ponds (in addition to the original source of fish as meat once allowed during Lent – the Lent used to be 140–160 days per year, of which 51 days of strict fasting) is considerably broader and generally also includes the regulation of water regime and microclimate as well as other ecosystem functions [4]. Historically, ponds were important for fortification and also in the field of unifying ownership and land use – flooding the area was a general solution. Today, recreational, sports, and other functions have been added; the other functions were already known by Charles IV and his chronicler Beneš Krabice from Weitmile. In contrast, fortification and power engineering functions, often associated with fish production, disappeared. Until the "steam age", the power of water, fed by ponds, was practically the only major source of kinetic energy for mills, hammer mills, sawmills, etc. Local droughts often meant hunger because there was nowhere to grind grain.

Importance of ponds and fish production today

There can be found many lists of ponds in various historical periods and regions of the Czech Republic. However, if we are looking for a systematic recording of their occurrence, we will find that there is no list or register of ponds in the Czech Republic. The basic source of information are therefore "only" various yearbooks, which, on the other hand, provide validated data. There is a so-called *Modrá zpráva (Blue Report)* – Report on the state of water management in the Czech Republic in 2020, published jointly by the Ministry of Agriculture and the Ministry of the Environment [5]. From it we learn only the following general data, which are repeated in other documents and differ only slightly for previous years. According to this report, there are approximately 24,000 ponds in the Czech Republic covering a total (cadastral) area of 52,000 ha. The area of ponds and valley reservoirs used for fish farming is 41,000 ha; however, the area of reservoirs is insignificant in the balance of fish farming. The total yield from the ponds is 19,300 tons of fish, with 85 % being carp. (Approximately half of the rest is taken up by the breeding of salmonid fish in flow-through systems, i.e. not in ponds.) By simple calculation, the average production of all Czech, Moravian, and Silesian ponds is 471 kg/ha/year. The given production does not include coarse fish, but with standard two-year management, this means that during the fishing out the second year after stocking, the production or yield is 940 kg of three-year-old carp per hectare. In the chapter "How many carp should be stocked in each pond", Dubravius says: *"After choosing the carp, we must first decide on how many carp should be placed in each pond according to its size. For, if you burdened the ponds with a greater number of carp than they can support, you could also burden yourself with a loss, because fish withered and thin from hunger must also be sold at a thin and meagre price. If you stocked fewer carp in the pond than there should be, you could again suffer quite a lot of damage due to the loss of fish. However, it is possible to avoid both problems, namely by using the right amount, which is desirable for each pond."* Today's yields far exceed anything the old fishermen could even imagine before World War 1 – it is the result of intensive fertilization of ponds and artificial feeding of fish at today's technological level. However, this applies to food production in general. Today, the basis for calculating the yield of the pond, or the number of fish stocked, is the so-called natural production, which is, however, much higher than before artificial fertilizers. The situation report of the Ministry of Agriculture "Fish 2021" [6] states: *"More than half of the total production of the main farmed fish – common carp – is based on natural food (zooplankton, benthos), which has a high content of animal protein. The energy component of the feed ration is supplemented by unmodified cereals. That results is carp of high consumption quality."* (We dare to question this optimistic statement of the producers further.)

About 42 % of the fish produced are sold alive in the Czech Republic, about 47 % are exported, the rest is "processed fish products". The average citizen of the Czech Republic consumes 1.2 kg of freshwater fish per year; if we include sea fish, it is 6 kg per year. Recorded catches "on the rod" amount to about 3–4 thousand tons, again mainly carp. Therefore, if all the catches of fishing union members were eaten, theoretically a maximum of 0.4 kg of fish consumption per average citizen would be added. The given data on production, catches and consumption are supplemented by data from the Statistical Yearbook of the Czech Republic 2019 [7]. The basic document for the development of the Czech fishery, the Fisheries Operational Programme 2021–2027 [8], on fish consumption in the Czech Republic states: *"Fish consumption in the Czech Republic does not change much over time and is very low (2018: 5.5 kg per person per year, or only 1.29 kg per person per year of freshwater fish) compared to the EU average (25.1 kg per person per year)."* The Operational programme also confirms the above-mentioned data on ponds: *"In the Czech Republic, fish is bread for production by more than 93.5 % in ponds, the most represented fish is common carp (over 82 %). There are over 24,000 ponds and small water reservoirs with a total area of approximately 53,000 ha in the Czech Republic, which hold more than 420 million m^3 of water. Most of the ponds that are in run today were built in the 15th and 16th centuries and are still used for fish production."*

METHODS AND RESULTS

Database of ponds

The question still remains: What is hidden behind the "standard" annual data *"There are about 24,000 ponds in the Czech Republic with a total area of 52,000 ha"*? It is certainly a cadastral area, and in 2021–2023 we dealt with this issue as part of the project "*DivLand – Centre for Landscape and Biodiversity*" (TA CR, No. SS02030018). In the sub-task of WG C – "Agrosystems and soil", part of WPC3 includes the sub-project WA C 3.3 "*Application of sediments to soil*", focused on the use of pond sediments as a means of improving the quality of agricultural land. One of the outputs is the "Map of water bodies of the Czech Republic" [9], processed primarily as a map of ponds as possible sources of sediments to improve soil quality. Like all outputs of the *"DivLand"* project, it is processed in the one kilometre network (grid) used by the European Environment Agency (EEA). As the basis for the database of water bodies, we chose the Basic Geographical Data Base of the Czech Republic (ZABAGED), Chapter 4 Water management. According to ZABAGED data, there are over 8,500 water bodies larger than 1 ha in the Czech Republic. It shows that the majority of the 24,000 ponds mentioned in the yearbooks are small ponds. For such small ponds, a significant difference between the cadastral area and the actual area of the water surface can generally be expected. It can also be assumed that their economic importance is at most local and that they do not represent a serious technical issue for handling sediments. That is why we did not include them in our database.

All water bodies larger than 1.0 ha (8,728 items) are included in the database, but we did not further specify water bodies between 1 and 4.99 ha. For water bodies larger than 5 ha, we classified them into basic types according to various sources:

— RYB (pond): The structure has a dam and a discharge device, it is possible to fish it out, or it shows in the documents that it is kept a fishery.
— PN (reservoir): The structure has a dam but does not have the attributes of a pond (discharge, outfishing system, etc.).
— ZP (flooded area): The structure usually does not have a raised artificial dam, the surface is at the level of the terrain, a nearby watercourse, or groundwater in the floodplain. There are usually two basic types: flooded mining facilities (sand pits, gravel pits) and separate river branches.
— JEZERO (lake): It includes the Šumava lakes, regardless of possible anthropogenic interventions. They are the subject of nature conservation, i.e. outside the project area.

In many cases, the inclusion of a water body in a type is not absolute; however, this should not be an obstacle to using the map and database (second generation 2023), which is generally accessible at *www.dibavod.cz/divland-rybniky-sedimenty*. Under the recommended abbreviation FUKOMAT, it is already commonly used as a tool for various purposes. Anyone can download and save the database (xls) and, in case of "disagreement", send proposals for modifications to TGM WRI.

Database content and comparison with general data

A comparison of our results shows that the summary "yearbook" data on the number and area of ponds in the Czech Republic do not contradict the data from our database. Our bottom-up analysis thus confirms the yearbook top-down data; the classic potential concerns about the existence of a "second globe inside the Earth" [10], always necessary when compiling overall balance sheets, etc., were not confirmed. The unspecified share (difference) consists of small ponds (< 1 ha), which have an average area of 0.37 ha – they are therefore economically insignificant and also without fundamental issues with handling sediments. There is not a lot of available data on sediments, but it seems that the issue with their contamination applies mainly to small ponds, village ponds, etc. If their sediments were to be classified as waste, their volumes do not represent a fundamental issue for disposal, landfilling, etc.

The summary of results and data comparison can be seen in *Tab. 1*; we recommend opening the Map and Database for details.

Tab. 1. Comparison of summary budget of fishponds [5] with the Map and Database DivLand

Balance	Number	Total area [ha]	Average area [ha]	[% of areas]	[% of number]
Ponds according to MoA [5] and Yearbook	52,000	24,000	2.17	100.00	100.00
Map of DivLand ponds (according to ZABAGED)					
Ponds > 1 ha (record)	46,143	8,304	5.56	88.74	34.60
Ponds < 1 ha (calculated)	5,857	15,696	0.37	11.26	65.40
Of which ponds > 5 ha	32,400	1,839	17.62	62.31	7.66

DISCUSSION

In the following text, we would like to comment on three important aspects of the function of ponds – productive and non-productive fishponds and pond sediments.

Production function of ponds

However optimistic the above "official" assessment of the situation of pond farming practices and the "natural quality" of carp meat by fish producers is, data from hydrobiologists shows a less optimistic development. Around 1850, the production of Třeboň ponds was 30 kg/ha/year; the "classic" Šusta [11, 12] gives a range of 11–94 kg/ha. Among other things, Šusta introduced an innovation that increased production – the breeding one age fish/carp from stocking to fishing. Data from 1950–2010 were processed for a large set of production ponds of the Třeboň and Blatná fishpond systems by Pechar et al. [13]; their data is summarized in *Tab. 2*.

Tab. 2. Progress of fish production of Třeboň and Blatná fishpond areas according to Pechar et al. [13]

Period	Production [kg/ha]
1951–1960	190
1961–1970	290
1971–1980	420
1981–1990	520
1991–1993	480
1994–1997	490
2000–2001	530
2009–2012	510

The production jump in the period from 1971 is the result of additional feeding; until then, the development of natural food was supported by fertilization (organic fertilizers, mineral nitrogen, phosphorus) as a standard. Gradually, however, the production ponds switched to highly hypertrophic systems with a high supply of nutrients in the sediments, and standard trophic, or ecological relationships/pyramids "nutrients > phytoplankton > zooplankton (and benthos) > fish" [14, 15] play a secondary role in production ponds today [16], despite the declarations of producers [6] about the ratio of natural fish food. In addition, there appears now mundant production of trash fish and relatively high water temperatures, which threaten hypertrophic systems with fatal drops in the concentration of oxygen in water (nighttime declines and consumption during accumulation of fish in the fishing grounds). Currently, we see high production of fish, achieved by fertilizing ponds with nitrogen and phosphorus to increase primary production and production of natural food (zooplankton, zoobenthos) and the necessary artificial feeding, especially with cereals. With high stocks in the second production year (i.e. before fishing out), natural food is often insignificant and production is conditioned by feeding. Intensive disturbing up of sediment by the carp leads to zero abundance of zoobenthos and probably also to more intensive mineralization of the sediment and generally to a lower production of greenhouse gases (methane, nitrous oxide), as the sediments are mechanically aerated. This can be positive news. In the overall balance of greenhouse gases today, the production of methane (and nitrous oxide) in agriculture is equal to the role of carbon dioxide, but with the fact that the production of methane and nitrous oxide cannot be separated from food production. The greenhouse gases production (and release into the atmosphere) also increases in sediments and wetlands and is supported both by increasing production and eutrophication of aquatic and wetland ecosystems and by increasing average temperature [17, 18]. Nijman et al. [19] experimentally demonstrated how removing sediment (and phosphorus with it) reduces the total production of greenhouse gases under a unit surface area. There are many options and procedures for "sustainable farming" in ponds [20], but they generally conflict with yields and other economic factors. However, they undoubtedly support the quality of the meat of fish produced [6]. The actual effect of the feed on the composition of the pond sediments does not need to be considered in general as an increase. In addition, feed control excludes the supply of toxic or "problematic" substances, etc., that is, with the exception of the possible application of "medicines and dietary supplements" for fish stock, vegetation control, etc., in line with Section 39, paragraphs 7 and 12 of the Water Act (Act 254/ 2001 Coll., as amended in 2018).

Ways to efficient fish production obviously affect water quality in ponds as well as water quality in watercourses below them, both during the growing season and draining during outfishing. In addition, a significant proportion of sediments from ponds enters the downstream river basin during the harvest; both management and erosion in the basin contribute to their formation. However, the share of sediment input by erosion in the basin is probably significant even at high stocks. It is generally stated that about 50 % of agricultural land in the Czech Republic is threatened by erosion today and the average loss is calculated as 2.8 tons of soil/ha/year. The current limits in the so-called anti-erosion decree (*Decree on the Protection of Agricultural Land from Erosion, No. 240/2021 Coll.*) are set at a loss of 9 tons per year for deep and 2 tons per year for shallow soils. The routes by which erosion material reaches the ponds are complicated – on the one hand, it is a direct flush, which can be prevented by modifying the surrounding vegetation, and, on the other hand, it is the already mentioned gradual transport through the pond system from harvest to harvest. e.g. from draining to draining. General erosion details are the subject of other *"DivLand"* sub-projects in WG C – "*Agrosystems and Soil*". Thus, the ponds in the catchment function as a phosphorus retention system (including phosphorus in fish biomass); however, the system does not last forever – it functions on the assumption that it is occasionally dredged up with sediments and taken away from the reach of erosion. Therefore, the general issue is how to extract the sediments and how to store them – economically and for the general benefit. The most reasonable is traditional storage in agricultural land as their main original source. All literary sources recommend it, but in practice there are many obstacles – legislative, technical, and economic (more on that later).

Other pond functions

A pond/fishpond is a general term, but it is and must be always legally defined. In Czech legislation, Act No. 99/2004 Coll., on pond farming, etc., defines the term pond as follows: *"A water work which is a water reservoir intended primarily for fish breeding, in which the water level can be regulated, including the possibility of its discharge and fishing out; the pond is made up of a dam, a reservoir, and other technical devices."* What applies fundamentally and at all times is the technical possibility of level regulation, discharge, and fishing. What is meant by "primarily fish breeding" is in a loose relationship to other "non-production" functions of ponds, important since the Middle Ages and today complemented by recreational, sports and certainly also cultural and aesthetic functions (landscape protection, etc.). For a broader concept of more general functions, we can find a comment on the mentioned "production" definition on the website of the Ministry of the Environment: *"The term 'pond' is not defined by the Nature Conservation and Landscape Protection Act. For the purposes of Act No. 99/2004 Coll., on pond farming, exercise of fishing rights, fishing guard, protection of marine fishing resources and on the amendment of certain laws (Fisheries Act), a pond is understood as* 'a water work which is a water reservoir intended primarily for fish breeding, in which the water level can be regulated, including the possibility of discharge and fishing; a pond is made up of a dam, a reservoir, and other technical devices'. *This definition cannot be considered sufficient for the protection of ponds as important landscape elements. In addition to reservoirs meeting the definition according to the Act on Fisheries, the term 'pond' in the sense of an important landscape element must also include small water reservoirs that fulfil the ecological stabilization functions of a pond in the landscape (e.g. types of semi-natural stabilization and purification reservoirs, reservoirs with a predominance of recreational functions etc.)."* However, special status is defined for a number of ponds and pond systems within the framework of nature conservation and landscape protection, especially protection within the framework of the Ramsar Convention, to which the Czech Republic acceded in 1990 (Communication No. 396/1990 Coll.). Of the 14 Ramsar sites or Wetlands of international importance in the Czech Republic, five are focused on pond systems and river landscapes (RS 2 Třeboňské rybníky, RS 3 Novozámecký and Břehyňský rybník, RS 4 Lednické rybníky, RS 5 Litovelské Pomoraví, RS 6 Poodří). A fundamental European document in the field of water protection is the EU Water Framework Directive (2000/60/EC), which requires the definition of standing water bodies from an area of 50 ha. The corresponding "implementation" Decree No. 49/2011 Coll., on water bodies defines a total of 74 water bodies of standing water (reservoirs) in the Czech Republic, of which only 15 are ponds (including Mácha's lake). Other large ponds (there are almost 100 ponds with an area of more than 50.0 ha in the Czech Republic) in the system of water bodies function as parts of sub-basins and, of course, as "heavily modified" water bodies. The objectives of the Framework Directive – to bring ponds to a "good ecological potential" – therefore respect their purpose, i.e. fish farming, or other functions arising from their status (nature conservation, etc.). The relevant River Basin Management Plans necessarily include monitoring of sediments; however, in contrast with routine monitoring of e.g. water quality, they have a six-year evaluation cycle, and thus a specific approach to evaluating the success of bringing them to the level of Good ecological potential. Regarding the sustainability and other functions of ponds in the landscape, the Situation Report "Fish 2021" [6] says: *"In addition to fish production, ponds are also used to fulfil indispensable non-production (ecosystem) functions in the landscape, such as water accumulation and retention, flood protection, and biological purification of water. Ponds are important refugia for nesting birds and create suitable protective territories for animals, fulfil a recreational function, eco stabilization functions and contribute to the preservation of species biodiversity."* According to the letter of the Situation Report, these functions are therefore generally fulfilled. However, the Fisheries Operational Programme 2021–2027 [8], approved by the government of the Czech Republic and adopted by the European Commission, is an instrument for drawing funds according to Regulation (EU) 2021/1139 of the European Parliament and of the Council of 7th July 2021. Its goals are summarized in chapter 1.2.1. Vision of Czech aquaculture in 2030:

"Visions of the future development and state of Czech fisheries must reflect the current state and focus of production fisheries in the Czech Republic. Furthermore, it is necessary to take into account other non-production functions that ponds and fishermen fulfil on the one hand and on the other environmental and climate goals, including the SRP goal. The following visions were defined in the VNSPA (= Multi-year National Strategic Plan for Aquaculture):

- *Strengthening the importance of traditional and modern forms of aquaculture.*
- *Maintaining production from traditional aquaculture at least at the current level through modernization and innovation of existing technologies and breeding facilities, including preservation of the environmental benefits of fish farming.*
- *Increasing the production of other species of fish, especially fish of prey, through the construction of new, modern, environmentally friendly fish farms.*
- *Increasing the share and assortment of processed freshwater fish, modernization, innovation and concentration of processing capacities.*
- *Strong market position of fishing enterprises.*
- *An aquaculture sector resilient to climate change, public health and environmental crises."*

Pond farming is a Czech specialty in Europe, or, in the sense of the previous text/quotation, rather a "traditional form of aquaculture". In the Czech Republic, there are a number of subsidy programmes supporting the "non-production functions" of ponds, which are, however, managed and subsidized by several centres (Ministry of Agriculture, Ministry of Environment, Ministry of Industry and Trade), so it is not easy to summarize them. Within one of these programmes, for example, up to 10,000 CZK/ha/year can be obtained for summarized "individual non-production functions" for ponds with an area of 2–5 ha, which approximately corresponds to the final retail price (including VAT) of a 100 kg of Christmas carp in 2023 (= a quarter of the average production/ha/year). Beyond the area of landscape and climate protection, there are also live issues between production management and the protection of species (e.g. cormorants), which are also dealt with by the subsidy system.

Pond sediments — both waste and raw material

The total volume of water ponds is estimated at up to 600 million m^3, which corresponds to the average depth of a Czech pond of about 1.2 meters. The real volume or depth is estimated in the cited sources to be about a third lower – the cause is a high degree of silting. Based on the summary data, the average height of the mud layer is 40 cm, which corresponds to the data from the Operational Programme [8] and the real water volume of 420 million m^3. The mud at the bottom of the pond has a variable structure; the upper layer is "light", the lower layers are compacted, so the balance includes the question of estimating the total dry matter. The areal distribution of sediments in ponds is also significantly heterogeneous – lighter organic sediments migrate to deeper parts of ponds, etc. During draining ponds, the horizontal migration of sediments is particularly pronounced, and after discharge, the remaining sediments are partially drained and compacted opposite to the state in a full pond. As a standard for "general balancing", the value of 40 % of dry matter for a mixed sample of the upper 15 cm of muddy sediment from the middle part of the production pond can be taken, with an organic carbon content of about 10 % of dry matter. Sediments are created in two ways: as residues of primary and secondary production in the pond itself (fish excrement, feed residues, etc.) and as a supply of material from the catchment area – mainly soil washes – directly into the pond from its surroundings or with a tributary. Both inflows have a significant seasonal character, in the basins of some ponds there occur discharges of treated municipal wastewater, including sewer overflows. Sediment transport through the catchment downstream is determined by the natural hydrological regime (rainfall and flows), but also significantly by the operation/regime of the pond area. Even during the production season, the sediments in the pond travel to the deepest part; when discharging the pond, they are concentrated here, and they leave the discharge device further downstream, mostly to the next pond of the pond system. This is associated on the one hand with a general threat to the quality of water in watercourses, and on the other hand with a threat to the fish stock concentrated close to the dam before the fishing out due to a lack of oxygen. In the current period of increased frequency of warm autumns, this risk is increasing. Silting of ponds is an undesirable phenomenon known to the "old men" as well, and the mud exported from the ponds during desilting was then provided to the estate employees as a reward to improve the soil. Summer drying, already known under Štěpánek Netolický, led to the mineralization of the mud and the subsequent increase in pond production. From the point of view of pond management, sediments ("mud") are generally waste that must be removed from ponds to maintain their function and productivity, but not "waste in today's sense".

A number of expert studies are available on the actual desilting of ponds, handling of sediments and the importance of application to soil [20–24]; our study deals only with the pond register and the analysis of the legislative environment.

From the point of view of the circular economy, extracted pond sediments are a suitable material for improving the quality of agricultural soils. On a general level, the advantage of their application is therefore quite clear. It is important that the pond sediments are not yet contaminated by point sources in the lower reaches of the rivers. The current Waste Act (Act No. 541/2020 Coll.) respects the classic definition of waste and states in Section 4 "Waste" that:

1. *Waste is any movable property that a person gets rid of, has the intention to get rid of or obligation to get rid of.*
2. *It is considered that a person has the intention to dispose of a movable property if it is not possible to use it for its original purpose.*

However, sediments extracted from ponds are exempted and discussed in the law in Part 2 "Biologically degradable waste" in Section 70 "Sediments": "*If the sediments extracted from the beds of watercourses and water reservoirs are intended for use on land constituting an agricultural land fund in accordance with the requirements established by the Act on Fertilizers and the Act on the Protection of Agricultural Land Funds, the plots constituting an agricultural land fund on which they will be used do not have to be equipment intended for waste management; their originator and the person who uses them on the plots of land forming the agricultural soil fund do not keep ongoing records for these sediments in accordance with Section 94 and do not submit reports in accordance with Section 95. For these sediments, records are kept in accordance with the Act on Fertilizers (No. 229/2021 Coll.) and according to the Act on the Protection of Agricultural Land Funds (No. 231/1991 Coll.).*" In essence, this means that the role of pond sediments is shifting from "waste" to "raw material or fertilizer" in the sense of the new waste law, in line with the development of the European circular economy. The use of sediments intended for storage on agricultural land is based on Section 3a of Act No. 334/1992 Coll., on the protection of agricultural soil funds (as amended) and Decree No. 257/2009 Coll., which determines the limit values of pollutants both in the sediment itself and in the soil to which the sediment is to be applied. This corresponds to the standard of the European circular economy, even though Czech pond farming is unique within the European concept of aquaculture. In addition to ponds, the Operational Programme [8] also assumes the development of more intensive aquaculture, which is not the subject of this text.

From a general point of view, the usability of pond sediments for improving agricultural land is complicated mainly due to technical and economic issues. The sediments must be extracted from the ponds, drained (= solidified, which requires an intermediate landfill) and transported to suitable locations at the appropriate time and applied to the soil. The time suitable for application to the soil is generally very limited, which is associated with "social" problems, i.e. the will and willingness of agricultural landowners to use pond sediments.

CONCLUSIONS

- Ponds are an important part of the Czech landscape and culture, as well as part of food production. It is also an important grant title.
- From the point of view of food production, fish farming is not essential for nutrition in the Czech Republic, but it has a significant share in the total consumption of fish meat. However, the cultural and landscape-forming importance of ponds is essential.
- There is no official pond database available in the Czech Republic.
- We analysed the records of ponds in the Czech Republic based on ZABAGED and prepared a publicly accessible map of water bodies in the Czech Republic with an attached database of ponds over 5 ha. Both the map and the database can be accessed at *www.dibavod.cz/divland-rybniky-sedimenty*. Anyone can download the database and we will be grateful for comments.
- The production of carp meat in ponds is high today due to supplemental feeding, which is associated with the loss of diversity of the original pond fauna and flora. However, part of the ponds is under control of nature conservation.
- Pond sediments generally represent an important source of material for improving the quality of agricultural land. The issues with their application are more technical and economic than purely legislative; however, it is necessary to respect the current regulations for the protection of soils from pollutants.

Acknowledgements

The text was written as part of the project "DivLand – Centre for Landscape and Biodiversity" of the Technology Agency of the Czech Republic, No. SS02030018 and its part WPC3 "Management of agrosystems and soil protection", subproject WA C 3.3 "Application of sediments to soil".

References

[1] KRABICE Z WEITMILE, B. Cronica ecclesiae Pragensis – Kronika pražského kostela. 1374. In: BLÁHOVÁ, M. et al. (ed.). *Kroniky doby Karla IV*. Praha: Svoboda, 1987, pp. 173–268.

[2] ČORNEJ, P. *Český stát v době jagellonské*. Praha, Litomyšl: Paseka, 2012. 236 pp.

[3] DUBRAVIUS, J. *De piscinis*. 1547. Překlad a historický komentář A. Schmidtová „O rybnících". Prague: Nakladatelství Československé akademie věd, 1953. 77 pp.

[4] FUKSA, J. K. Ekosystémové služby – nový pohled na ochranu a užívání vod. *Vodní hospodářství*. 2008, 58(11), pp. 398–403.

[5] FOUSOVÁ, E., KOUBOVÁ, J., JIROUDOVÁ, L. (eds.). *Zpráva o stavu vodního hospodářství České republiky v roce 2020*. Prague: Ministry of Agriculture, Ministry of the Environment, 2021. 151 pp.

[6] MOŘICKÝ, J., MAREŠ, L., ŽENÍŠKOVÁ, H., CHALUPA, P. (eds.). *RYBY. Situační a výhledová zpráva 2021*. Prague: Ministry of Agriculture, 2022. 39 pp.

[7] Český statistický úřad. *Statistická ročenka České republiky 2021*. Prague: Czech statistical office, 2022. 815 pp.

[8] Anon. *Operational Programme Fisheries 2021–2027. Text Approved by Resolution of the Government of the Czech Republic No. 101/22, Sent to the European Commission for Approval*. Prague: Ministry of Agriculture, 2022. 54 pp.

[9] MAKOVCOVÁ, M., KOŘÍNKOVÁ, B., FUKSA, J. K. *Zdroje sedimentů pro potenciální využití na zemědělské půdě. Mapa ČR s vyznačením potenciálních zdrojů sedimentů pro využití na zemědělské půdě (> 1 ha) s databází. Verze 2, 2023*. Output of the DivLand project, accessible at www.dibavod.cz/divland-rybniky-sedimenty

[10] HAŠEK, J. *Osudy dobrého vojáka Švejka za světové války. Kniha 1, kapitola 1*. Prague: Published by A. Sauer and V. Čermák at Žižkov, Kolárovo nám. 22, Part I, Book 1–8, 1921, pp. 5–253.

[11] ŠUSTA, J. *Výživa kapra a jeho družiny rybničné*. 1884. Translation and reissue. Třeboň: CARPIO, 1997. 180 pp.

[12] ŠUSTA, J. *Fünf Jahrhunderte der Teichwirtschaft zu Wittingau: ein Beitrag zur Geschichte der Fichzucht mit besonderer Berücksichtigung der Gegenwart. Pět století rybničního hospodaření v Třeboni*. 1898. Translation and reissue. Třeboň: CARPIO, 1995. 212 pp.

[13] PECHAR, L. Století eutrofizace rybníků – synergický efekt zvyšování zátěže živinami (fosforem a dusíkem) a nárůstu rybích obsádek. *Vodní hospodářství*. 2015, 65(7), pp. 1–6.

[14] HRBÁČEK, J. Relation between Some Environmental Parameters and the Fish Yield as a Basis for a Predictive Model. *SIL Proceedings, 1922–2010*. 1969, 17(2), pp. 1 069–1 081. Available at: https://doi.org/10.1080/03680770.1968.11895953

[15] KOŘÍNEK, V., FOTT, J., FUKSA, J., LELLÁK, J., PRAŽÁKOVÁ, M. Carp Ponds in Central Europe. In: MICHAEL, R. G. (ed.). *Managed Aquatic Ecosystems*. Amsterdam: Elsevier, 1987, pp. 29–62.

[16] VRBA, J., BENEDOVÁ, Z., JEZBEROVÁ, V., MATOUŠŮ, A., MUSIL, M., NEDOMA, J., PECHAR, L., POTUŽÁK, J., ŘEHÁKOVÁ, K., ŠIMEK, K., ŠORF, M., ZEMANOVÁ, K. Nevstoupíš dvakrát do téhož rybníka – předběžná zpráva o stavu dnešních hypertrofních rybničních ekosystémů. *Vodní hospodářství*. 2018, 68(8), pp. 1–5.

[17] BEAULIEU, J. J., DELSONTRO, T., DOWNING, J. A. Eutrophication Will Increase Methane Emissions from Lakes and Impoundments during the 21st Century. *Nature Communications*. 2019, 10(1), p. 1 375.

[18] DAVIDSON, T. A., AUDET, J., JEPPESEN, E., LANDKILDEHUS, F., LAURIDSEN, T. L., SØNDERGAARD, M., SYVÄRANTA, J. Synergy between Nutrients and Warming Enhances Methane Ebullition from Experimental Lakes. *Nature Climate Change*. 2018, 8(2), pp. 156–160.

[19] NIJMAN, T. P. A., LEMMENS, M., LURLING, M., KOSTEN, S., WELTE, C., VERAART, A. J. Phosphorus Control and Dredging Decrease Methane Emissions from Shallow Lakes. *Science of the Total Environment*. 2022, 847, 157584. 12 pp.

[20] FAINA, R. Alternativy k tradičnímu pojetí rybářské intenzifikace na rybnících v CHKO Třeboňsko a na rybničních rezervacích. In: POKORNÝ, J., ŠULCOVÁ, J., HÁTLE, M., HLÁSEK, J. (eds.). *Třeboňsko 2000. Ekologie a ekonomika Třeboňska po dvaceti letech*. Třeboň: UNESCO/MAB. ENKI, o. p. s., 2000, pp. 192–196.

[21] KUBÍK, L. *Hodnocení sedimentů vodních ploch (toky, rybníky, vodní nádrže). Průběžná zpráva 1995–2017*. Brno: UKZÚZ – Central Institute for Supervising and Testing in Agriculture in Brno, Agricultural Inputs Section, 2019. 116 pp.

[22] BAXA, M., ŠULCOVÁ, J., KRÖPFELOVÁ, L., POKORNÝ, J., POTUŽÁK, J. Výsledky dlouhodobého screeningu kvality rybničních sedimentů v České republice. *Vodohospodářské technicko-ekonomické informace*. 2020, 62(1), pp. 4–10.

[23] BAXA, M., ŠULCOVÁ, J., KRÖPFELOVÁ, L., POKORNÝ, J., POTUŽÁK, J. The Quality of Sediment in Shallow Water Bodies – Long-Term Screening of Sediment in Czech Republic. A New Perspective of Nutrients and Organic Matter Recycling in Agricultural Landscapes. *Ecological Engineering*. 2019, 127, pp. 151–159.

[24] BAXA, M., BAXOVÁ CHMELOVÁ, I., BENEDOVÁ, Z., DURAS, J., HRUBEC, R., KRÖPFELOVÁ, L., NOVOTNÝ, O., POKORNÝ, J., POTUŽÁK, J., SVOBODA, T., ŠULCOVÁ, J. *Technologický postup recyklace živin z rybničních sedimentů s využitím sacího bagru, integrované stanice pro dávkování flokulantu a geotextilních vaků pro lokální aplikaci v mikropovodí. Certifikovaná metodika schválená osvědčením č. UKZUZ 113316/2017*. Třeboň: ENKI, o. p. s., PLOSAB, s. r. o., 2017. 51 pp.

Author

RNDr. Josef K. Fuksa, CSc.
✉ josef.fuksa@vuv.cz

T. G. Masaryk Water Research Institute, Prague

This article was translated on basis of Czech peer-reviewed original by Environmental Translation Ltd.

DOI: 10.46555/VTEI.2024.03.001

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line).