REVIEWS IN Aquaculture

Reviews in Aquaculture, 1–18 doi: 10.1111/raq.12260

# Multifunctionality of pond fish farms in the opinion of the farm managers: the case of Hungary

József Popp[1], Emese Békefi[2], Szabolcs Duleba[3] and Judit Oláh[4]

1 Faculty of Economics and Business, Institute of Sectoral Economics and Methodology, University of Debrecen, Debrecen, Hungary
2 National Agricultural Research and Innovation Centre, Research Institute for Fisheries and Aquaculture (NARIC HAKI), Szarvas, Hungary
3 Department of Transport Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics, Budapest, Hungary
4 Faculty of Economics and Business, Institute of Applied Informatics and Logistics, University of Debrecen, Debrecen, Hungary

**Correspondence**
Judit Oláh, Faculty of Economics and Business, Institute of Applied Informatics and Logistics, University of Debrecen, Böszörményi út 138, H-4032, Debrecen, Hungary.
Email: olah.judit@econ.unideb.hu

Received 16 February 2018; accepted 6 June 2018.

## Abstract

Freshwater fish ponds, besides producing fish, function as valuable aquatic habitats, contribute to the maintenance and enrichment of the quality of the ecosystem, play an important role in water and landscape management, provide services for various recreational activities and contribute to the preservation of the cultural heritage. The multifunctional character of pond fish farming has been recognized for long time; however, recently it has also been realized that the deliberate multidirectional use of fish ponds (production, angling, recreation, education, etc.) offers additional economic benefits. Experience with the operation of multifunctional fish farms in Hungary has clearly shown that the diversification of activities is a promising alternative during the development of sustainable pond fish farming. However, further efforts are required to investigate the specificities and applicability of the various factors and also the optimal ratio between them to utilize the opportunities offered by multifunctional use of freshwater fish ponds. Research on multifunctional pond fish farming has mainly been limited to descriptions of the various functions of fish ponds, for example environmental services. However, the attitude of farm managers towards the possible multifunctional use of their farming system has never been investigated. In this study, the importance of the various existing or potential functions of a pond fish farm and their role in the future development of multifunctional pond fish farms have been investigated through the analysis of the appraisal of experienced farm managers by analytic hierarchy process. The results of the research provide empirical evidence that can be used for the elaboration of policies, development strategies, R&D and the legal frameworks needed for the sustainable development of multifunctional pond fish farming.

**Key words:** analytic hierarchy process, multicriteria decision-making, multifunctionality, pond fish farming, preservation, sustainability.

## Introduction

Aquaculture is the world's most diverse farming system in terms of the number of species, methods and environments where farms are located (Hishamunda & Ridler 2002; Harvey *et al.* 2007; FAO, 2009). Global fish production increased by 24% between 2006 and 2015 and rose to 167 million tonnes (on average over 2013–2015), as claimed by (OECD/FAO, 2017a). The total fish production for human consumption was 147 million tonnes (about 88% of the total), and aquaculture accounted for nearly 50% of the fish consumed. Fish originating from aquaculture are expected to represent 57% of the fish consumed by 2025. The continued growth in fish consumption will mainly derive from aquaculture production. The expected average annual growth rate of aquaculture will slow from 5.4% to 3.0% per annum between 2015 and 2025 (OECD/FAO, 2017a,b). Aquaculture has great potential to expand and intensify sustainably in order to meet the demand for fish in 2050, as the human population is predicted to continue to grow for the next 40 years before stabilizing at a minimum of 9 billion people (Godfray *et al.* 2010). The sustainable development of aquaculture requires adequate consideration of interactions among environmental, social and economic factors that accompany any development (Chua 1992; Word Bank, 1998; NACA/FAO, 2000).

As experience with aquaculture grows worldwide, the concept of sustainable aquaculture is increasingly recognized to incorporate both the spatial and temporal dimensions of environmental, economic and social parameters. Practitioners have discovered that sustainable aquaculture must not only maximize benefits, but also minimize the accumulation of detrimental effects, as well as other types of negative impacts on the natural and social environment (Frankic & Hershner 2003). The future vision of FAO includes the goal of 'ecosystem well-being', such that 'aquatic ecosystems are utilized in an optimal way that maintains social, economic, food and ecosystem service benefits'. Achieving this goal and overcoming country-specific constraints require the sustainable use and conservation of aquatic ecosystems and biota, making the best use of all available options, in rapidly changing circumstances (Harvey *et al.* 2007).

It should be noted, however, that aquaculture shows a high diversity in various regions of the world and also in terms of aquatic environments, systems, technologies and cultured species. Freshwater was the source for 62% of the world aquaculture production in 2015 (56% by value); of this, 65.9% were carp and other cyprinids which are mostly cultured in ponds using semi-intensive methods – water fertilization with inorganic and organic fertilizers and supplementary feeding with low-protein materials (Bostock *et al.* 2010; FAO FishStatJ, 2017). Freshwater pond aquaculture, which is the major type of fish production in Asia, is also dominant in some Eastern European countries, including Hungary. Even if there are obvious climatic, hydrological and other differences between Asian and Eastern European aquaculture, the drivers of development are very similar. Besides environmental factors (availability of resources) and economic factors (satisfying market demand and making a profit), the importance of social factors is increasing, in both developed and developing countries (Stead 2005; Bueno 2008; Krause *et al.* 2015). However, despite efforts to address social issues in aquaculture development programmes, it is argued that aquaculture has not yet reached its potential largely because, to date, there has been little attempt to manage this sector's activity by taking into account its multiple and varied dimensions (social, ecological, economic). Instead, the focus has been production-oriented (Krause *et al.* 2015).

Freshwater pond fish culture is a specific segment of aquaculture that has always been closely linked to rural life and has inseparably combined the social, ecological and economic dimensions of fish farming activity. These dimensions are collectively referred to as ecosystem services. Currently, there is a particular need to take into consideration the multifunctionality of pond ecosystems during the development of management (Millennium Ecosystem Assessment Board, 2005; Landuyt *et al.* 2014). Wetland ecosystems that are important parts of Europe's biodiversity include also man-made fish ponds. A significant number of birds, mammals and other species groups depend on freshwater wetlands for breeding or feeding (Biodiversity Information System for Europe, 2018). Although there are differences in the type and level of ecosystem services of the various wetlands, man-made fish ponds are not fundamentally ecologically different from the 'natural' ones (De Marco *et al.* 2014). In terms of services, ponds offer sustainable solutions to key issues of water management and climate change such as nutrient retention, rainfall interception or carbon sequestration (Céréghino *et al.* 2014). It should also be mentioned that the establishment and operation of fish ponds compensated somehow for the loss of wetlands due to drainage that has been common practice in Europe for centuries (Hegedűs 2016; EPCN, 2007).

Integration of fish culture with various water-related activities (e.g. duck culture, vegetable production on pond dikes) has been a common feature of freshwater pond fish culture for centuries, even if the term 'multifunctionality' was not known in earlier periods of aquaculture development. Although 'multifunctionality' is an inherent attribute of freshwater pond fish culture, its importance has not been recognized for a long time and the development of multifunctional fish farming took place spontaneously (Popp *et al.* 2018). The pioneers of multifunctional pond fish farming development were open-minded and innovative farm owners and managers, who recognized the social need for specific services provided by fish ponds. One of the first steps was when fish farms opened their gates to anglers, who otherwise had been unwanted visitors in pond fish farms for many years. Providing angling services was the entry point for other touristic services such as catering and hotel services. The contribution of pond fish farms to the maintenance of valuable wetlands as aquatic habitats has becoming increasingly important, in parallel with the growing urbanization and industrialization in many regions in the world, as well as in Europe. It should be noted, however, that the values of the ecosystem services of pond fish farms have not been properly recognized and the damage caused by wild animals has not been properly compensated.

Although multifunctionality is a basic feature of pond farms, the nonproductive functions and the specialities of non-product-type outputs and all related opportunities were discovered at a later phase than occurred in agriculture. Practical results prove that through diversification and the complex utilization of resources, multifunctional pond farming provides a higher and more secure income for farmers, in such a way that their activity contributes to maintaining and strengthening biodiversity conservation, and leads to a better knowledge of nature and to the social acceptance of fish farming. In multifunctional pond farms, ecological services are connected to recreation and environmental education. With the growing importance of conserving natural values, the significance of ecological services granted by multifunctional pond farms is also growing. The efficient use of natural resources for food production has always played an important role in Hungary, which is a small landlocked country where agriculture is an important sector, not only in food production but also in rural development (Popp *et al.* 2018).

In this study, we use the term multifunctional fish farming as multifunctional use of fish ponds when certain functions of the fish pond have been enhanced using managerial interventions to increase or optimize economic and social benefits. Practical results and experience are admittedly well utilizable in the development of multifunctional pond farms; however, the scientific analysis of the unique features of different functions, their adaptation in certain conditions and the comparison of their importance is becoming more and more necessary to make pond farms able to utilize the opportunities of multifunctionality. Although there are some scientific descriptions available for the different functions of aquaculture, especially for ecosystem-related services (Troell *et al.* 2009; Fang *et al.* 2014), and there are also a few analyses aiming to determine the value of certain functions (Turkowski & Lirski 2011), no investigation has been carried out into the value judgements related to multifunctionality by pond farm managers, which crucially determines the future of this unique pond farming method. The scientific survey carried out among managers provides information which helps work out R&D and technical training programmes, policies, strategies, legal measures and subsidies supporting the systematic development of multifunctional pond farming.

This research has a totally different perspective on the analysis of pond fish farming than other papers in the scientific literature. In this study, the present and future of the sector is considered as a decision-making problem for the farmers involved in this sector. Thus, multicriteria decision-making (MCDM) is required and evaluators with significant professional experience – farmers, experts in pond fish farming – are involved as stakeholders. As the applied methodology must also be relevant, as a result of a thorough selection procedure, analytic hierarchy process (AHP) has been chosen. To the best of our knowledge, this is the first attempt to describe the multifunctional fish farming sector using an MCDM method and within that group, using AHP.

## Multifunctional pond fish farming

### The growing significance of multifunctionality in the Hungarian pond fish farming sector

Forty five per cent of the gross production value of the Hungarian fisheries sector is provided by the table fish production of pond farms. Fish farming gives 2.5% of the gross production value of domestic animal husbandry and around 1% of total agricultural production. Based on its contribution to product output and gross production value, the economic significance of Hungarian fisheries sector may seem very low; however, considering the value of the non-production-type functions resulting from its multifunctional role, it is an important element of the national economy (Szűcs & Szőllősi 2014). Of the total fishpond area of 29 800 ha available in Hungary in 2016, activities including fish production as their basic component were performed on 26 480 ha (i.e. 89% of the total fishpond area), and these activities also have an important role in the preservation and improvement of the quality of wetlands, in water resource management and, in general, in the improvement of the livelihoods of the rural population (AKI, 2017).

Fish production in Hungary is composed of pond fish production (about 83%) and intensive fish production in tanks (17%). The total fish production of Hungary was 23 499 tonnes in 2016; pond fish production amounted to 19 530 tonnes, of which food fish production equalled 13 015 tonnes (the difference was due to the rearing of the broodstock and the next year's stocking material). In Hungary, pond fish production is mostly focused on the rearing of common carp, and the multi-year average of the share of common carp in annual fish production is around 62%. Silver carp, bighead carp, grass carp and predatory fish such as Northern pike, wels catfish and zander play a smaller part in production (AKI, 2017).

The most important development objective of the Hungarian fisheries sector is to increase domestic fish consumption. In spite of the slow but steady growth of per capita fish consumption over several years, its value is still only 5–6 kg annually in live weight equivalent (including imported marine fish), while in the European Union the average annual per capita fish consumption is 25.8 kg (as live weight) (European Market Observatory for Fisheries and Aquaculture Products (EUMOFA), 2017). It is a great challenge for the sector to supply the population with healthy and fresh domestic fish products which fully comply with food safety requirements in the face of growing fish product imports.

The other fundamental objective of the fisheries sector development is to meet the anglers' demand for locally reared native fish species. Both objectives are well served by multifunctional pond farms, whose activities familiarize people with fish, the advantages of fish consumption, and the aquatic environment, thus contributing to raising the interest in fish and, ultimately, to increasing fish consumption. In addition, multifunctional pond farms directly offer angling services and the share of the population interested in this popular leisure activity is growing. Today, the number of anglers in Hungary has already exceeded 400 000 (4% of the total population), and thus, angling has a large societal importance in the exploitation of the resources of natural waters, which also affects pond aquaculture. One of the promising directions of pond aquaculture development in Hungary is towards the increase in multifunctionality, which contributes to the provision of economic, environmental and social conditions of sustainability alike.

## Characteristics of multifunctional pond fish farming

Multifunctionality, or multifunctional agriculture, is a term that generally indicates that agriculture can produce various noncommodity outputs in addition to food. International organizations (e.g. the OECD, the FAO) have elaborated 'working definitions' of multifunctionality; however, the term is still subject to different interpretations (FAO, 1999; OECD, 2001). It is generally acknowledged that multiple commodity and noncommodity outputs are jointly produced by multifunctional agriculture, although it has also been recognized that the markets for some of the noncommodity outputs (externalities or public goods) function poorly or are nonexistent services. Agricultural products have a well-delineated market, but agriculture increasingly offers non-food-producing services that either lack methods for the determination of their value or for which existing methods are imperfect.

Taking note of its multifunctional characteristics, the EU pays special attention to supporting agriculture in the framework of the Common Agricultural Policy (CAP), which is regarded as protectionism by some non-European economic groups, for example the 'Cairns Group', as well as the USA (Givord 2001). Without doubt, there are disproportionate features in the agricultural support system of the EU, but the tasks following from the multifunctional character of agriculture, such as ecological farming or the contribution to preserving and enriching natural values, and thus, services meeting different special societal demands will enjoy support in the long term.

The generally accepted criteria of multifunctionality are also valid for pond aquaculture, and there are many similarities between multifunctionality in agriculture and in pond aquaculture. It should be noted, however, that the conditions of multifunctionality are much more available in a natural-like pond farm than in most agricultural farms. It follows from the very nature of pond aquaculture and its closeness to nature that fish ponds do not only serve fish production but, as wetlands, provide living conditions for many animals and plants (Bekefi & Varadi 2007). Typical fish ponds are earthen enclosures in which the fish live in a natural-like environment, feeding on the natural food growing in the pond itself from sunlight and nutrients available in the pond water (SustainAqua, 2009).

While multifunctionality is one of the fundamental features of pond farms, the recognition of the characteristics and potential of nonproductive functions and nonproduct outputs occurred much later than in agriculture. Multifunctional pond farming was first presented at an international forum (based on a Hungarian example) in 2004 (Lévai & Váradi 2006). The development of multifunctional farming, which requires more flexibility and entrepreneurial skills, was positively affected by the business-friendly measures of the period following the fall of Communism in Eastern Europe, both in Hungary and in the former so called communist countries in Eastern Europe and in the former states of the Soviet Union. Practical results and experiences prove that multifunctional pond farming provides a higher and more predictable income for farmers through diversification and complex utilization of resources, while it also contributes to preserving and enriching biodiversity, deepening knowledge of the natural world, and improving the public acceptance of fisheries. Today, social expectations do include the demand not only for healthy and safe fish products, but also, among others, for their environmentally friendly and resource-efficient production. Multifunctional pond farms whose visitors can learn directly about fish production can be very useful in raising environmental awareness of pond farming. This is because one of the important elements of multifunctional pond farming is openness and 'social communication' where, in addition to learning about sustainable fish production, visitors to the farm can also explore the aquatic environment, fish species and aquatic wildlife, as well as the positive impact of fish ponds on the natural environment, water management and the landscape (Váradi 2007).

Multifunctional pond farming is a complex activity performing mostly 'provisioning' (productive), 'regulating and habitat' (environmental) and 'cultural' (societal) functions. It should be noted that the individual functions cannot always be clearly separated as, for instance, the fulfilment of societal demands also appears in production and in environmental services. The basic functions of multifunctional pond farms and the related activities are shown in Table 1 (Váradi 2007).

Depending on their characteristics, individual pond farms represent the different functions to different levels

**Table 1** Basic functions of multifunctional pond farms and the related activities

| Basic functions | Activities |
| --- | --- |
| *Provisioning, productive function* | |
| Aquatic food | Fish production with special regard to ecological fish production |
| Animal products | Rearing of indigenous breeds (e.g. Hungarian grey cattle, Mangalica pig) |
| Plant products | Cultivation of vegetables and ornamental plants |
| Genetic material | Maintenance of *in situ* gene banks |
| *Regulating function* | |
| Climate | Regulating of air humidity |
| Waste | Processing of organic matter getting into the ponds from their environment |
| Water | Water retention and groundwater regulation |
| Gases | Oxygen production |
| Diseases | Breaking the infection chain, disease localization |
| Recreation and tourism | Angling, bathing, birdwatching, horseback and bicycle excursions, narrow-gauge train trips around the ponds, restaurant and hotel services |
| *Habitat function* | |
| For animals | Aquatic birds, mammals, reptiles, amphibians, insects |
| For plants | Aquatic plants |
| *Cultural function* | |
| Education | Organization of children's camps and events, operating open-air ethnographic and other museums |
| Research | Performing pilot experiments, organization of professional demonstrations and scientific meetings |
| Cultural | Organization of gastronomic, singing, dancing and musical events |
| Aesthetic | Enriching the aesthetic effect of the landscape (e.g. natural-like ponds, islands, parks) |

Source: Váradi (2007).

and extents. Besides fish production, the most widespread functions are angling- and tourism-related. The primary driver of the diversification of pond aquaculture and the provision of supplementary functions (services), in addition to fish production, is the wish to maintain and increase farming efficiency. In this way, incomes from service provision and the related subsidies appear on the revenue side in addition to fish sales.

Apart from the fundamental benefits generated by ponds such as fish production and angling, fish ponds also contribute to the appearance of many nonproductive functions, which can be classified within the following areas (Drabiński *et al.* 2010; Kuczyński 2010): water economy, biodiversity, landscape management, cultural values and other utilities specific to fish ponds, grouped on six levels: complex water economy, natural environment protection, economic and breeding advantages, recreation and water sports, aesthetic and cultural assets, stimulation of employment and economic benefits (Guziur *et al.* 2003). Ponds play a special role in the landscape, especially in regions where no lakes are present (Turkowski & Lirski 2011). In general, the high fertility of ponds favours abundant growth of plants, which provide habitats for a large number of animals. Ponds therefore create suitable conditions for preserving rich fauna and flora. Conservation of biodiversity yields many actual and potential benefits for people, for their economy, culture, knowledge and social behaviour (Turkowski & Lirski 2011).

Fish ponds supply food and water, facilitate local flood control, contribute to sustaining biodiversity and also provide cultural services by enriching our knowledge and giving us spiritual and aesthetic experiences. One of the reasons why these nonproductive services provided by fish ponds are not given adequate recognition, neither by the general public nor by the state and local government institutions, is the fact they are difficult to express in monetary units (Turkowski & Lirski 2011).

Three criteria (visual ecology, functional morphology and financial profitability) in the perceived attributes can also be used as indicators of the density of obstructing objects in the multifunctional lake environment (Tallar & Suen 2017). Our findings also confirmed that the use of a visual approach in identifying and measuring the aesthetic value of multifunctional lakes is very helpful in terms of providing information related to the development of improved multifunctional lake management practices. Managers and designers can create and maintain landscapes in multifunctional lake areas (Lovell & Johnston 2009) that fulfil multiple purposes associated with their ecosystem services by manipulating empirically derived aesthetically relevant attributes and cultural and social influences on preference, to achieve specific environmental and aesthetic goals that are also category-specific (Briffett 2001; Tallar & Suen 2017).

The provision of ecosystem services is a characteristic function of multifunctional fish farms, which also represents a considerable value. Pond managers already commit themselves to preserving and increasing the value of the natural environment (e.g. preserving the aquatic and riparian vegetation, providing habitats for birds and other aquatic animals, improving the quality of surface waters) at their own expense even above their economic optimum. Pond farming is based on direct utilization of the natural resources available, and thus, farmers are and have always been interested in preserving the quality of the aquatic environment. However, it is highly controversial that fish farmers are obliged to sustain the bird populations attracted by the wetlands created and maintained by them without any compensation. It can be stated that societal demands and societal contributions are not yet in balance, which means that pond farms (in particular, the multifunctional ones) bear the financial burden of preserving and improving natural values. Ecosystem services are generally defined as the benefits people obtain from ecosystems (Assessment, 2003), that is the natural goods and services used by people directly or indirectly during their lives. In the case of multifunctional fish farms, ecosystem services are understood in two ways. On the one hand, an adequately managed natural-like pond farm provides the same ecosystem services as natural ecosystems (De Marco *et al.* 2014). A natural-like pond farm provides services for the natural ecosystems which have been degraded by various external impacts. For instance, pond farms provide resting and nesting habitats for some bird species whose living conditions cannot be ensured by degraded natural ecosystems (e.g. drying wetlands). Research on evaluating the services of natural ecosystems reaches back some decades (Costanza *et al.* 1997, 2017; De Groot *et al.* 2002), but little information of this kind is available on agricultural ecosystems. According to the results of a comprehensive study by Polish researchers, the average value of the productive function of an extensive and a semi-intensive fish pond was 4830 EUR $ha^{-1}$ $year^{-1}$ in 2010, while the value of nonproductive functions was more than ten times that amount, that is 52 857 EUR $ha^{-1}$ $year^{-1}$ (Turkowski & Lirski 2011). Detailed data on the ecosystem services of fish ponds are missing for Hungary, similarly to the quantification of these services from an ecological point of view or their expression in monetary terms. The exploration and quantification of these useful services is important for both the entire fish production sector and its individual players, as the substantiation of these data could entitle them to financial compensation or assist in recognizing that they maintain areas and farming practices that provide essential functions for the whole of society. As ecosystem services mostly consist of nonmarketable goods and are not quantified in such a way as to allow their comparison with economic services or the capital produced, they are only insufficiently taken into account in policy decisions.

## Possibilities of developing multifunctional pond farming

The potential of multifunctionality in the development of sustainable aquaculture has been demonstrated in various regions of the world where pond fish farming has an important role in aquaculture. Aquaculture activities have been improved significantly in recent years, aiming at increased production targets (Hadipour *et al.* 2015). The socio-economic benefits derived from aquaculture expansion provide nutritious foods and improve the lifestyle of the poor, as well as generating income and employment opportunities, diversifying fish production, and creating scope for earning foreign exchange through export of high-value products (Hossain & Das 2010). A good fit means the integration of aquaculture with human activities in general (Edwards 1998), in other words as ecological aquaculture (Costa-Pierce 2002, 2010).

Freshwater aquaculture development necessarily affects, and is affected by, human activities such as agriculture, fisheries, irrigation and urban development (Soto *et al.* 2008). Multifunctional farms often seek to lower the monetary costs associated with acquiring external inputs. They reduce their use of external inputs and increase the quality and efficiency of the use of internal inputs. Thus, the multifunctional farm has much in common with a farm with low external inputs. It is important to note, though, that this response (multifunctionality plus low-external-input agriculture) cannot be applied everywhere, or by everybody (van der Ploeg 2016).

A major developmental goal of carp farming in Central and Eastern European countries is to maintain the condition of existing fish ponds so that they may continue to function as wetlands with the potential to preserve habitats for diverse fauna and flora, as well as rural landscapes and economies (Soto *et al.* 2008). Multiple functioning of fish ponds is now considered to be a strength of pond aquaculture by the aquaculture fraternity (Szűcs & Szőllősi 2014) as they have been shown to preserve habitats for diverse fauna and flora as well as maintain the rural landscape for aquaculture and the local economy. In multifunctional landscapes, places (i.e. areas with rainwater-harvesting ponds) can nurture outdoor activities (i.e. walking, hiking, jogging) and other forms of health-associated activities, environmental learning (i.e. nature, ecosystems and biodiversity), communal meetings, and an escape from urban and industrial atmospheres. The locations of trails, wildlife viewing areas, and settings for educational programmes often associate spatially with the locations of wetlands (Moore & Hunt 2012). Building fish ponds has made the landscape more useful for humans as well as for nature: without aquaculture, there would be no water bodies; had wetlands not been converted into fish ponds, they would have been developed into agricultural land.

The development of multifunctional pond fish farming is a major issue in regions of Central and Eastern Europe, where pond fish farming plays an important role in food supply and rural development. Hungary is a leading country in the region, where multifunctional pond fish farms have been developed and are in operation. The results and experiences of the operation of existing multifunctional pond fish farms indicate the potential for the development of the multifunctionality of pond fish farms, taking into account the constraints of conventional pond fish farming (Bosma & Verdegem 2011). Conventional pond fish farms are facing the challenge of how to raise productivity while maintaining environmental sustainability. The development of multifunctionality could be a response to these challenges. Based on our experiences, innovative managers of multifunctional pond fish farms are also more open to the application of new fish production technologies, such as combined intensive–extensive systems and integrated multitrophic aquaculture (IMTA) systems that make it possible to increase fish production in a confined intensive unit, while maintaining ecosystem services in the large extensive component of the pond system.

While the provision of ecosystem services is a general characteristic of extensive pond farms, this activity is more consciously undertaken in multifunctional pond farms, and it is also linked to recreation and science education. As the importance of preserving natural values is growing, the significance of ecosystem services provided by extensive pond farms, including multifunctional ones, is also increasing. However, it must be noted that there is no well-developed and universally accepted method for the determination of the value of the ecosystem services in fish ponds. Therefore, further research in international cooperation is required in this field.

While the conditions for multifunctionality are mostly available in extensive pond farms, the results and experiences received there can be used well in other aquaculture systems, too, with special regard to integrated ones. The EU has launched a programme aiming to familiarize the population, mostly children, with aquaculture and fisheries. In this framework, visits to farms are organized for schoolchildren. The possibility for farm visitors to see work processes without disturbing them is an increasingly important aspect when planning the facilities of future fish farms. The establishment of visitor centres where interested visitors can become acquainted with fish and aquatic wildlife in addition to the farm itself will also be an aspect of special importance during the planning and construction of fish farms in the future.

On the basis of the last decade's experiences of Hungarian multifunctional pond fish farmers, their advantages and disadvantages can be summarized as follows (Bekefi & Varadi 2007):

Advantages:

- better economic stability and continuous liquidity (during the year) due to different agricultural activities;
- extra income from different services (tourism, angling);
- higher proportion of profits within the revenue (higher return on sales);
- eligibility for subsidies supporting environment-friendly farming;
- possibility of ecological farming;
- more favourable image and public perception of the farm.

Disadvantages:

- the establishment of a multifunctional farm requires extra investment;
- the management of complex farming practices is a complex task;
- provision of services is an activity entirely different from fish farming;
- a relatively large farm size is a must;
- establishment and location of the farm in an attractive natural environment.

New programmes for the development of multifunctional pond farms need to be launched to make use of the advantages and eliminate the disadvantages. There is a need for further analyses and scientific studies to lay down the foundations of such programmes. These include the determination of the value of non-food-production services, among which ecosystem services have a special significance for pond farms. Socio-economic studies improving the knowledge of societal demands towards multifunctional pond farms are also needed, and scientific surveys of entrepreneurial skills are important, too, as the planning and management of multifunctional pond farming programmes are entirely different from those of traditional pond farming. Because of the close linkages of multifunctional pond farming with the wider society, the application of nontraditional management methods is more important here. The success of these depends on human resources, which can be developed, among other things, through targeted professional training courses. At the same time, the governance, legal framework and funding systems need to be transformed in a way that supports the development of multifunctional pond farming, which is the key to the survival of pond fish production, a sector with ancient traditions. The application of methods new to the field of aquaculture research is required during the research work which lays the foundations for these developments. One such method is the AHP, whose application is especially justified during the development of complex systems whose successful operation is based on the purposeful coordination of multiple functions.

In the recent research carried out in this field, alternatives were not included – unlike with the traditional AHP models – as the aim was to analyse the importance of the hierarchical elements in a possible development decision and to determine the perspective of the sector but not to decide among given alternatives.

## Materials and methods

Analytic hierarchy process provides a method of generating a ranking of farmers' problems. It also generates weights which can be used in conducting sensitivity analyses when evaluating the financial profitability and sustainability of aquaculture projects. In the case of aquaculture farming in Jamaica, we showed that tilapia production in Jamaica faced several challenges, but that those problems can be solved at the farm level with minor adjustments and that consideration of farmers reveals preferences at the policy level (Jolly *et al.* 2011).

Recent years have seen an increasing role of aquaculture in social and economic development at national levels. This growing importance has called for the need for adequate planning to avert potential negative impacts of aquaculture and for policies that ensure a good distribution of benefits accruing from the development of the sector, thereby ensuring its sustainability. Experts have agreed that the MCDM framework using AHP as a measurement technique is a suitable method for assessing socio-economic impacts in a situation where multiple attributes (Oláh *et al.* 2017) are important and cannot easily be reduced to a single monetary measure of impacts, as is the case in aquaculture. Important recommendations were made for the FAO to pursue its endeavours in the documentation and analysis of policy formulation and impact assessment processes (Garcia *et al.* 2000). These included, among other things, case study documentation of the use of AHP, CBA (cost–benefit analysis) and another techniques to test and compare the applicability and results of these methods in assessing the socio-economic impacts of aquaculture.

Analytic hierarchy process procedures consist of the following steps, based on Duleba *et al.* (2012, 2013) and Koç and Burhan (2015):

1 Attaining all relevant elements of the complex decision and composing the hierarchical structure of the problem.
2 Creating questionnaires based on the hierarchy using pairwise comparisons among the elements.
3 Selecting the evaluators or evaluator groups.
4 Conducting the evaluations, in most cases with the help of an instructor.
5 Computing the consistency ratio that reflects the consistency of the evaluations and omits the nonconsistent results.
6 Calculating the weight scores of each decision element (the most popular is the right-side eigenvector calculation, but there are other possibilities, e.g. the logarithmic method).
7 Determining the final weights of the elements (if there are alternatives, the evaluations of the alternatives of the decision).
8 Sensitivity analysis of the results for analysing the stability of the final weight scores.
9 Ex post discussion on the AHP analysis.

Having created the new sophisticated hierarchical model for the problem, it is possible to conduct a questionnaire survey based on the AHP. In the survey, pairwise comparisons have to be made by the evaluators following the hierarchical decomposition of the problem.

The pond fish farms problem can be understood by examining a hierarchical structure of multifunctional functions and its possible outputs. The hierarchical structure was designed and explained in three levels: the multifunctional outcome at the highest level of the structure, functions of fish ponds (type of outputs) at two intermediate levels, and the main outputs of different functions forming the base of the structure. This three-level structure is presented in Table 2.

In the questionnaire for the pairwise comparison, we used a 1–9 scale as shown in Table 3. Such comparisons are rather easier to understand and answer by fish farmers than the simultaneous comparison of all objectives within the same structural level.

During the survey, each evaluator filled 16 matrices and, as the number of fish farmers was 12, a total of 192 matrices had to be checked in terms of consistency. Seven of the twelve farms operate as multifunctional pond farms, and the remaining ones also show a readiness to expand their scope of activities in the near future, thus shifting towards multifunctional farming. These twelve farms accounted for 51.2% of the pond area and for 62.7% of common carp production in Hungary. Evidently, all $2 \times 2$ matrices are per definitionem consistent; thus, $3 \times 12$, that is 36, matrices were not checked. Of the 156 relevant matrices, only 14 were not tolerably inconsistent, that is 8.97%, which verifies the created hierarchy and survey model. In addition, even the inconsistent matrices were below a consistency ratio value of 0.2 (the threshold in AHP is 0.1), so only a minor modification was required to make these matrices consistent (with the agreement of the evaluators).

Referring to the special characteristics of pairwise comparison matrices ($n \times n$ in the case of '$n$' number of factors, all elements are positive and the matrix is reciprocal for the main diagonal, so $a_{ij} = 1/a_{ji}$), the eigenvector of each matrix can be easily computed using (Saaty 1977) the eigenvector method based on (1).

$$Aw = \lambda_{\max} w \tag{1}$$

Saaty proved that $w$ is the most powerful eigenvector (due to the maximum eigenvalue), so it characterizes matrix '$A$' the best. During the evaluation process, the evaluator (decision-maker) fills the provided pairwise comparison matrix $A$ $[a_{ij}]$; afterwards, the $w = (w_1, w_2, \ldots, w_n)$ weight vector must be calculated. '$w$' fulfils the criterion that the $w_i/w_j$ proportions approximate the values of each $a_{ij}$ given by the evaluator in the matrix '$A$'. This procedure

**Table 2** Multifunctional pond fish farm outputs

| | | | |
|---|---|---|---|
| Multifunctional pond fish farm outputs | 1. Production functions and outputs | 1.1. Producing healthy and safe products | 1.1.1. Producing live fish for food |
| | | | 1.1. 2. Production of high added-value fish products |
| | | 1.2. Guaranteeing that safe and healthy food meets with animal welfare and ethical criteria | 1.2.1. Consideration of animal welfare and ethical standards |
| | | | 1.2.2. Improved technological discipline |
| | | | 1.2.3. Improvement of technical conditions (dredging of ponds and harvesting pits) |
| | | 1.3. Ensuring adequate income and increased competitiveness of farms | 1.3.1. Maximizing profit by increasing productivity |
| | | | 1.3.2. Proportional income sharing in the sector or within the company |
| | | | 1.3.3. Maintaining national and international competitiveness through innovation |
| | | | 1.3.4. Development using own resources |
| | | | 1.3.5. Development using external (project) funds |
| | | | 1.3.6 Applying market communication tools (own products, landraces, logo, website, social media, media appearance) |
| | | 1.4. Preservation of genetic resources and production of brood fish | 1.4.1. Own landrace (*in situ* gene bank) |
| | | | 1.4.2. Production of fingerlings |
| | | 1.5. Production of natural materials (reed, algae, shellfish, crustaceans, etc.) | 1.5.1. For human consumption |
| | | | 1.5.2. For animal feed |
| | | | 1.5.3. For energy purposes |
| | 2. Environmental functions and outputs | 2.1. Conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats (considering good environmental and nature conservation practices) | 2.1.1. Providing appropriate environmental conditions for fish production |
| | | | 2.1.2. Conservation of habitats for water-related animals and plants |
| | | | 2.1.3. Preservation of good quality of surface waters |
| | | | 2.1.4. Bird scaring techniques or reducing damage caused by birds |
| | | 2.2. Regulatory functions (microclimate, organic waste, gas, water, diseases) | 2.2.1. Microclimate (atmospheric humidity) |
| | | | 2.2.2. Reduction of organic matters emission |
| | | | 2.2.3. Water retention (the possibility of water-saving water recycling) |
| | | | 2.2.4. Appropriate oxygen level in the aquatic environment |
| | | | 2.2.5. Prevention of diseases (maintaining the healthy fish stock) |
| | | 2.3. Preservation and improvement of the rural landscape | 2.3.1. Maintenance of diversity of natural-like conditions and landscape elements (importance of the maintaining 'green areas') |
| | | | 2.3.2. Maintenance of water bodies (possible increase in water area) |
| | 3. Social functions and outputs | 3.1. Recreation and tourism | 3.1.1. Recreational fisheries, services for anglers |
| | | | 3.1.2. Birdwatching |
| | | | 3.1.3. Gastronomy |
| | | | 3.1.4. Hiking (other outdoor recreation) |
| | | 3.2. Dissemination (of knowledge) in connection with the water/aquatic environment and fish | 3.2.1. Knowledge concerning fish (for adults) |
| | | | 3.2.2. Knowledge concerning the water environment (for adults) |
| | | | 3.2.3. Knowledge concerning fish (for children) |
| | | | 3.2.4. Knowledge concerning the water environment (for children) |
| | | 3.3. Maintenance and improvement of the quality of rural life | 3.3.1. Employment in fish production |
| | | | 3.3.2. Employment in fish processing |
| | | | 3.3.3. Employment in services |
| | | | 3.3.4. Corporate social responsibility (improving the quality of life for rural communities) |
| | | 3.4. Preservation of cultural heritage | 3.4.1. Preservation of cultural heritage |
| | | | 3.4.2. Organization of exhibitions and events |
| | | | 3.4.3. Participation in ethnographic research |
| | | | 3.4.4. Publications (printed and electronic) |
| | | | 3.4.5 Development of professional knowledge (aquaculture and fisheries journals, conferences, study tours) |

must be carried out for all matrices following the hierarchical structure of the problem.

In the case of multiple evaluators (12 involved farmers participating in our survey), the geometrical mean is advised (Saaty 2008) to apply as (2).

$$f(y_1, \ldots, y_l) = \Pi_{h=1}^{l} (y_h)^{1/l} l \geqslant 2, (y_1, \ldots, y_l) \in I^l \quad (2)$$

where '$f$' is a function that summarizes the individual evaluations and '$l$' is the number of evaluators. In addition, $y_h$ represents the properly indexed matrix element of the evaluator '$h$', and $I^l$ is a set of positive numbers.

Having aggregated all participants' evaluations, the eigenvector method was applied; then, the final scores of each factor were determined regarding their position in the hierarchy (Table 2). The following formula exhibits the computational process (3).

$$w_{ci} = \frac{w_j}{w} \frac{w_{ij}}{\sum_{k=1}^{n} w_{ik}} = \left( \frac{w_j}{w} \frac{1}{\sum_{k=1}^{n} w_{ik}} \right) w_{ij} \quad (3)$$

where $j = 1, \ldots, m$ and $w = \sum_{i=1}^{m} w_j$, $w_j > 0$ $j = 1, \ldots, m$ represents the related weight coordinate from the previous level, $w_{ij} > 0$ $i = 1, \ldots, n$ is the eigenvector computed from the matrix in the current level. $w_{ci}$ $i = 1, \ldots, n$ is the calculated weight score of the current level's elements.

Formula (3) means that having calculated the normalized eigenvector of the related matrix, the proper eigenvector coordinate has to be multiplied by the related weight coordinate from the linked previous level. This represents the hierarchical linkages of the factors in the problem examined.

It is evident that the decision-maker evaluations most likely do not fulfil the perfect consistency criterion (cardinal transitivity) of the theoretical pairwise comparison matrices: $a_{ij}\, a_{jk} = a_{ik}$. Thus, the consistency index has to be calculated to check whether the inconsistency of the evaluation matrix A can be tolerated or not. This is also a part of the AHP method, and the following procedure has to be applied (4).

**Table 3** The analytic hierarchy process pairwise comparison scale

| Degree of importance | Definition |
|---|---|
| 1 | Very slight importance of one output over the other |
| 3 | Moderate importance of one output over the other |
| 5 | Both outputs are equally important |
| 7 | Demonstrated importance of one output over the other |
| 9 | Extreme or absolute importance of one output over the other |

Source: Authors' own construction.

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \quad (4)$$

where CI is the consistency index, $\lambda_{\max}$ is the maximum eigenvalue and $n$ is the number of rows in the matrix.

The average values of the consistency indexes are determined using random-generated (probably inconsistent) pairwise comparison matrices for all $n$ and marked RI. In this way, CR can be determined (5):

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (5)$$

For positive and reciprocal matrices, $\lambda_{\max} \geq n$, so the quotient is non-negative. Based on expert consensus and also on the software Expert Choice 11.5 protocol, the CR can be accepted if its value is less than 0.1.

## Results and discussion

The preliminary coordination meeting and the trial filling in significantly contributed to the successful evaluation of the results of the questionnaire survey conducted among Hungarian pond fish farmers. The farm managers questioned in the framework of the survey clearly viewed productive functions as the most important during the operation of a pond farm ($W_p = 0.632$), assigning lower importance to the environmental ($W_e = 0.258$) and social functions ($W_s = 0.11$). This opinion of the managers seemingly contradicts the study results showing that the value of the nonproductive functions (various, mostly ecosystem services) of a fish pond is several times higher than the value of productive functions (source: personal interviews/communication) (Table 4).

At the same time, farm managers obviously assess the preference order of the individual pond farm functions based on the concrete pond farm incomes instead of the results of theoretical calculations, even if they are aware of the role of ecosystem services and their environmental and social value. This ratio would probably be different if the ecosystem services provided by the pond farm were recognized financially.

If, at the 2nd level of the evaluation, the significance of the different factors is studied among productive functions, it can be clearly seen that the management of a profit-oriented pond farm regards the production of healthy and safe fish products as the most important ($W_{pn} = 0.39$). At the same time, it is worth noting that farm managers assign special importance to the production of products complying with animal welfare and ethical functions ($W_{pn} = 0.23$), which indicates the intention to meet consumer demands at the highest possible level. The two mentioned functions were also placed on one of the first three positions during

**Table 4** The preference order of identified multifunctional pond fish farms outputs – 1st level

| Preference | Type of multifunctional outcomes | Normalized generic weights score (*W*) | |
|---|---|---|---|
| 1 | Outputs of production function | A1 | 0.632 |
| 2 | Outputs of environmental function | B1 | 0.258 |
| 3 | Outputs of social function | C1 | 0.110 |

Source: Authors' own construction.

the evaluation of the importance of all pond farm functions (Table 5).

At the same time, it can also be concluded that farm managers seemed to assign low importance to the production of natural materials ($W_{pn}$ = 0.06) during the evaluation of productive functions. However, this function ranked seventh during the evaluation of the importance of all pond farm functions, that is higher than the functions of recreation or tourism.

This seems somehow controversial; however, this could also indicate that pond farm managers consider fish production as a priority mainly due to the lack of information on the opportunities offered by the production of other materials (e.g. various aquatic plants, algae and plankton), and it may also indicate that they are open to new concepts and recognize the potential of integrated multitrophic aquaculture (IMTA) systems when longer term development opportunities of the whole farm complex are considered. Therefore, it is important to continue and expand the R&D work on the development of IMTA systems, as well as to widely disseminate its results.

**Table 5** The preference order of identified production function outputs – 2nd level

| Preference | Type of production function outcomes | Normalized specific weights (production) | |
|---|---|---|---|
| 1 | Producing healthy and safe products | A11 | 0.392 |
| 2 | Guaranteeing safe and healthy food meeting animal welfare and ethical criteria | A12 | 0.226 |
| 3 | Ensuring adequate income and increased competitiveness of farms | A13 | 0.214 |
| 4 | Preservation of genetic resources and production of brood fish | A14 | 0.109 |
| 5 | Production of natural materials (reed, algae, shellfish, crustaceans, etc.) | A15 | 0.059 |

Source: Authors' own construction.

**Table 6** The preference order of identified environmental function outputs – 2nd level

| Preference | Type of environmental function outcomes | Normalized specific weights (environmental) | |
|---|---|---|---|
| 1 | Conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats (considering good environmental and nature conservation practices) | B21 | 0.625 |
| 2 | Regulatory functions (microclimate, organic waste, gas, water, diseases) | B22 | 0.250 |
| 3 | Preservation and improvement of the rural landscape | B23 | 0.125 |

Source: Authors' own construction.

**Table 7** The preference order of identified social function outputs – 2nd level

| Preference | Type of social function outcomes | Normalized specific weights (social) | |
|---|---|---|---|
| 1 | Dissemination (of knowledge) in connection with the water/aquatic environment and fish | C32 | 0.307 |
| 2 | Recreation and tourism | C31 | 0.291 |
| 3 | Maintenance and improvement of the quality of rural life | C33 | 0.288 |
| 4 | Preservation of cultural heritage | C34 | 0.114 |

Source: Authors' own construction.

Analysing the ranking of environmental functions, it can be seen that the respondents viewed the 'conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats' function as by far the most important ($W_{en}$ = 0.62) compared to the 'regulatory' ($W_{en}$ = 0.25) and 'landscape preservation' ($W_{spec}$ = 0.12) functions (Table 6).

Studying the significance of social functions, recreation/tourism, knowledge dissemination and maintenance of employment/rural life quality were assigned similar importance, but the respondents regarded the dissemination of knowledge of the aquatic environment and fish as being of special importance, with a specific weight ($W_{sn}$ = 0.307) even higher than that of the 'recreation and tourism' function ($W_{sn}$ = 0.291) (Table 7). This reflects the farmers' recognition of the fact that increasing interest in fish serves their business interests by increasing the demand for fish as food on the one hand, and for

**Table 8** The preference order of identified multifunctional outcomes – 2nd level

| Preference | Type of multifunctional outcomes | Final *W* | |
|---|---|---|---|
| 1 | Producing healthy and safe products | A11 | 0.248 |
| 2 | Conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats (considering good environmental and nature conservation practices) | B21 | 0.161 |
| 3 | Guaranteeing safe and healthy food meets with animal welfare and ethical criteria | A12 | 0.143 |
| 4 | Ensuring adequate income and increased competitiveness of farms | A13 | 0.135 |
| 5 | Preservation of genetic resources and production of brood fish | A14 | 0.069 |
| 6 | Regulatory functions (microclimate, organic waste, gas, water, diseases) | B22 | 0.065 |
| 7 | Production of natural materials (reed, algae, shellfish, crustaceans, etc.) | A15 | 0.037 |
| 8 | Dissemination (of knowledge) in connection with the water/aquatic environment and fish | C32 | 0.034 |
| 9 | Preservation and improvement of the rural landscape | B23 | 0.033 |
| 10 | Recreation and tourism | C31 | 0.032 |
| 11 | Maintenance and improvement of the quality of rural life | C33 | 0.031 |
| 12 | Preservation of cultural heritage | C34 | 0.012 |

Source: Authors' own construction.

**Table 9** The preference order of identified production function outputs – 3rd level

| Preference | Type of production function outcomes | Normalized specific weights | |
|---|---|---|---|
| 1 | Producing live fish for food | A111 | 0.737 |
| 2 | Own landrace (*in situ* gene bank) | A141 | 0.592 |
| 3 | For human consumption | A151 | 0.527 |
| 4 | Consideration of animal welfare and ethical standards | A121 | 0.514 |
| 5 | Maximizing profit by increasing productivity | A131 | 0.410 |
| 6 | Production of fingerlings | A142 | 0.408 |
| 7 | For animal feed | A152 | 0.341 |
| 8 | Improved technological discipline | A122 | 0.302 |
| 9 | Production of high added-value fish products | A112 | 0.263 |
| 10 | Proportional income sharing in the sector or within the company | A132 | 0.202 |
| 11 | Improvement of technical conditions (dredging of ponds and harvesting pits) | A123 | 0.184 |
| 12 | Maintaining national and international competitiveness through innovation | A133 | 0.148 |
| 13 | For energy purposes | A153 | 0.132 |
| 14 | Development using own sources | A134 | 0.129 |
| 15 | Development using external (project) funds | A135 | 0.064 |
| 16 | Applying market communication tools (own products, landraces, logo, website, social media, media appearance) | A136 | 0.047 |

Source: Authors' own construction.

angling and other recreational services on the other. Entrepreneurs' endeavours to increase the consumption of fish as a healthy food product produced in an environmentally friendly way are considered especially important and have a statistically significant impact on domestic fish consumption (AKI, 2017).

Table 8 demonstrates clearly the ranking of the 2nd level, where the conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats is the second most important function in the list ($W$final = 0.16) after fish production ($W$final = 0.25), ranking higher than such productive functions as ensuring adequate income and increased competitiveness ($W_{\text{final}}$ = 0.13). At the same time, the regulatory function took the sixth position in the overall list ($W_{\text{final}}$ = 0.06), ranking higher than, for example, the function of recreation and tourism. Similarly to farmers, society also increasingly recognizes the role of pond farms, among

**Table 10** The preference order of identified environmental function outputs – 3rd level

| Preference | Type of environmental function outcomes | Normalized specific weights | |
|---|---|---|---|
| 1 | Maintenance of diversity of natural-like conditions and landscape elements (importance of maintaining 'green areas') | B231 | 0.813 |
| 2 | Providing appropriate environmental conditions for fish production | B211 | 0.514 |
| 3 | Appropriate oxygen level in the aquatic environment | B224 | 0.294 |
| 4 | Water retention (the possibility of water-saving water recycling) | B223 | 0.244 |
| 5 | Conservation of habitats for water-related animals and plants | B212 | 0.208 |
| 6 | Preservation of good quality of surface waters | B213 | 0.197 |
| 7 | Maintenance of water bodies (possible increase in water area) | B232 | 0.188 |
| 8 | Prevention of diseases (maintaining the healthy fish stock) | B225 | 0.182 |
| 9 | Reduction of organic matters emission | B222 | 0.145 |
| 10 | Microclimate (atmospheric humidity) | B221 | 0.135 |
| 11 | Scaring birds or reducing damages caused by birds | B214 | 0.081 |

Source: Authors' own construction.

**Table 11** The preference order of identified social function outputs – 3rd level

| Preference | Type of social function outcomes | Normalized specific weights | |
|---|---|---|---|
| 1 | Employment in fish production | C331 | 0.513 |
| 2 | Recreational fisheries, services for anglers | C311 | 0.488 |
| 3 | Knowledge concerning the water environment (for children) | C324 | 0.353 |
| 4 | Knowledge concerning fish (for children) | C323 | 0.338 |
| 5 | Preservation of cultural heritage | C341 | 0.337 |
| 6 | Organization of exhibitions and events | C342 | 0.281 |
| 7 | Gastronomy | C313 | 0.271 |
| 8 | Employment in fish production | C332 | 0.242 |
| 9 | Knowledge concerning fish (for adults) | C321 | 0.177 |
| 10 | Employment in fish processing | C333 | 0.177 |
| 11 | Participation in ethnography research | C343 | 0.149 |
| 12 | Hiking (other outdoor recreation) | C314 | 0.139 |
| 13 | Knowledge concerning the water environment (for adults) | C322 | 0.132 |
| 14 | Development of professional knowledge (aquaculture and fisheries journals, conferences, study tours) | C345 | 0.121 |
| 15 | Publications (printed and electronic) | C344 | 0.113 |
| 16 | Birdwatching | C312 | 0.102 |
| 17 | Corporate social responsibility (improving the quality of life for rural communities) | C334 | 0.064 |

Source: Authors' own construction.

other things, in the preservation of wetlands and the enrichment of biodiversity (Markwell & Fellows 2008; Blayac *et al.* 2014).

The subfunctions evaluated at the 3rd level contain a further breakdown of the functions of the 2nd level (Table 9). This allows us to evaluate further functions appearing in the different areas. Within the category of producing healthy and safe products, the production of live fish is clearly the most important aspect for the farmers ($W_{pn}$ = 0.737), followed by maintaining their own landraces within the category of preserving genetic resources ($W_{pn}$ = 0.592). Based on eigenvector values, the third most important subfunction of this category is the production of products intended for human consumption ($W_{pn}$ = 0.527), which also confirms the wish of farmers to meet changing consumer demands to the highest possible extent. Consideration of animal welfare and ethical standards ($W_{pn}$ = 0.514), maximizing profit by increasing productivity ($W_{pn}$ = 0.410) and fingerling production ($W_{pn}$ = 0.408) also rank high in this list. To our surprise, the function of applying market communication tools ranked last, 16th, although it must be noted that it took a medium position (31st position of the total of 44) in the overall ranking shown in Table 12, together with a number of important functions such as employment in fish processing or the maintenance of water bodies or possible increase in water area.

**Table 12** The preference order of identified multifunctional outcomes – 3rd level

| Preference | Type of multifunctional outcomes | Final *W* | |
|---|---|---|---|
| 1 | Producing live fish for food | A111 | 0.18294 |
| 2 | Providing appropriate environmental conditions for fish production | B211 | 0.08291 |
| 3 | Consideration of animal welfare and ethical standards | A121 | 0.07338 |
| 4 | Production of high added-value fish products | A112 | 0.06533 |
| 5 | Maximizing profit by increasing productivity | A131 | 0.05537 |
| 6 | Improved technological discipline | A122 | 0.04311 |
| 7 | Own landrace (*in situ* gene bank) | A141 | 0.04098 |
| 8 | Conservation of habitats for water-related animals and plants | B212 | 0.03365 |
| 9 | Preservation of good quality of surface waters | B213 | 0.03180 |
| 10 | Production of fingerlings | A142 | 0.02823 |
| 11 | Proportional income sharing in the sector or within the company | A132 | 0.02732 |
| 12 | Maintenance of diversity of natural-like conditions and landscape elements (importance of maintaining 'green areas') | B231 | 0.02631 |
| 13 | Improvement of technical conditions (dredging of ponds and harvesting pits) | A123 | 0.02629 |
| 14 | Maintaining national and international competitiveness through innovation | A133 | 0.01998 |
| 15 | For human consumption | A151 | 0.01964 |
| 16 | Appropriate oxygen level in the aquatic environment | B224 | 0.01900 |
| 17 | Development using own sources | A134 | 0.01739 |
| 18 | Employment in fish production | C331 | 0.01711 |
| 19 | Water retention (the possibility of water-saving water recycling) | B223 | 0.01578 |
| 20 | Recreational fisheries, services for anglers | C311 | 0.01546 |
| 21 | Scaring birds or reducing damages caused by birds | B214 | 0.01308 |
| 22 | For animal feed | A152 | 0.01272 |
| 23 | Prevention of diseases (maintaining healthy fish stock) | B225 | 0.01178 |
| 24 | Knowledge concerning the water environment (for children) | C324 | 0.01178 |
| 25 | Knowledge concerning fish (for children) | C323 | 0.01126 |
| 26 | Reduction of organic matters emissions | B222 | 0.00935 |
| 27 | Microclimate (atmospheric humidity) | B221 | 0.00875 |
| 28 | Development using external (project) funds | A135 | 0.00870 |
| 29 | Gastronomy | C313 | 0.00859 |
| 30 | Employment in fish processing | C332 | 0.00757 |
| 31 | Applying market communication tools (own products, landraces, logo, website, social media, media appearance) | A136 | 0.00643 |
| 32 | Maintenance of water bodies (possible increase in water area) | B232 | 0.00607 |
| 33 | Knowledge concerning fish (for adults) | C321 | 0.00064 |
| 34 | Employment in services | C333 | 0.00554 |
| 35 | For energy purposes | A153 | 0.00492 |
| 36 | Hiking (other outdoor recreation) | C314 | 0.00440 |
| 37 | Knowledge concerning the water environment (for adults) | C322 | 0.00440 |
| 38 | Preservation of cultural heritage | C341 | 0.00419 |
| 39 | Organization of exhibitions and events | C342 | 0.00348 |
| 40 | Birdwatching | C312 | 0.00324 |
| 41 | Corporate social responsibility (improving the quality of life for rural communities) | C334 | 0.00215 |
| 42 | Participation in ethnography research | C343 | 0.00185 |
| 43 | Development of professional knowledge (aquaculture and fisheries journals, conferences, study tours) | C345 | 0.00150 |
| 44 | Publications (printed and electronic) | C344 | 0.00140 |

Source: Authors' own construction.

The overview of the 3rd level ranking of environmental functions shows that the maintenance of the diversity of natural-like conditions and landscape elements ($W_{en}$ = 0.813) was regarded as by far the most important, followed by the function of providing appropriate environmental conditions for fish production ($W_{en}$ = 0.514) (Table 10). This result indicates a possibility of the contributions that the application of environmentally conscious farming practices and environmentally friendly fish production methods by pond fish farmers contributes to maintaining and enriching biodiversity and improving the environmental conditions.

Analysing the ranking of social functions at the 3rd level reveals that employment in fish production ($W_{sn}$ = 0.513) is the most important aspect for the entrepreneurs. Angling was considered the second in rank ($W_{sn}$ = 0.353), followed

**Table 13** The sensitivity analysis calculation (B-factors)

| | $w_j$ | $w'_j$ | $w_{ij}$ | Original score | Original rank | New score | New rank |
|---|---|---|---|---|---|---|---|
| B1 | 0.2584875 | 0.3 | | | | | |
| B21 | | | 0.624531008 | 0.161400 | 2 | 0.187400 | 2 |
| B22 | | | 0.250178803 | 0.064700 | 6 | 0.075100 | 5 |
| B23 | | | 0.125290189 | 0.032400 | 9 | 0.037600 | 10 |
| B211 | | | 0.513564343 | 0.021431 | 7 | 0.028866 | 4 |
| B212 | | | 0.208440191 | 0.008698 | 14 | 0.011716 | 11 |
| B213 | | | 0.196968361 | 0.008219 | 15 | 0.011071 | 12 |
| B214 | | | 0.081027104 | 0.003381 | 26 | 0.004554 | 20 |
| B221 | | | 0.135377833 | 0.002263 | 30 | 0.003048 | 27 |
| B222 | | | 0.144637761 | 0.002418 | 29 | 0.003257 | 24 |
| B223 | | | 0.244006567 | 0.004079 | 23 | 0.005494 | 19 |
| B224 | | | 0.293809637 | 0.004911 | 21 | 0.006615 | 17 |
| B225 | | | 0.182168201 | 0.003045 | 28 | 0.004102 | 22 |
| B231 | | | 0.812500000 | 0.006802 | 18 | 0.009162 | 15 |
| B232 | | | 0.187500000 | 0.001571 | 35 | 0.002114 | 31 |

Source: Authors' own construction.

by knowledge dissemination on fish ($W_{sn}$ = 0.338) (Table 11). This confirms the pond fish farmers' recognition of the fact that increasing interest in the aquatic environment and fish and improving knowledge of nature is an aspect of special importance, not only at an adult age but also in childhood. In this way, they contribute to a better social acceptance of the fisheries and aquaculture sector, as ecosystem services are also linked to the dissemination of scientific knowledge in multifunctional pond farms.

The following conclusions can be drawn in connection with the final ranking of the 3rd-level functions (Table 12). Farm operators clearly regarded the production of live fish for food as the most important ($W_{final}$ = 0.1829). When examining the first twenty positions of the ranking, they are clearly dominated by economic functions. Of the environmental functions, subfunctions within conservation, maintenance and protection of natural values/resources/ecosystems, biodiversity and valuable natural habitats were included among the twenty most important ones. The importance of these for farmers was revealed both at the 2nd evaluation level and from the results of the ranking within their own functions, and therefore, the results can be considered consistent. Consistency can also be seen when comparing the social functions with the results of the 2nd level and the ranking within their own functions, as the 'employment in fish production', 'angling' and 'raising the interest of children in fish and the aquatic environment' functions were the most important of the social functions for managers.

As the last phase of the calculation, sensitivity analysis (SA) was conducted to examine the stability of the results. In current conditions, weight scores can be considered stable; however, the SA revealed a very important phenomenon. In the case of the weight score of the 1st level element B1 is raised from 0.258 to 0.3, so only by approximately 0.04 points; the ranking of B22 on the 2nd level moves into 5th; thus, this element will be very significant among all the second-level factors. Consequently, if the dominance of the economic factors is only slightly mitigated in the future, the controlling function – microclimate, prevention of diseases – (B22) will be among the most crucial factors of fish farming.

For the 3rd level of the structure, the same modification causes another interesting change; the role of B211 (providing suitable conditions for fish production) becomes the 4th most important of all 3rd-level elements. Its ranking changes from 7th to 4th. It must be emphasized again that the weight alteration of B1 was very slight, so this impact can be considered as surprisingly significant. Based on personal interviews during the evaluation process of this AHP procedure, experts expect a slight mitigation of economic factors in the short term and a more significant fall in the long term; thus, examining this change is justified.

This part of the sensitivity analysis calculation (B-factors) is presented in Table 13. As following the AHP SA procedure, eigenvector scores derived from the pairwise comparison matrices ($w_{ij}$) are not modified (see Formula 3); however, $w_j$ is changed respectively based on SA modifications ($w'_j$). Table 13 exhibits not only the original and new scores of the factors but also the original and gained ranking of each factor.

## Conclusions

Pond farms, which are a part of the rural economy, are valuable wetlands, contribute to preserving and enriching ecosystem quality, play an important part in water management and forming the landscape, provide services for different recreational activities and contribute to preserving cultural values, all this in addition to producing fish. The Hungarian experience of operating multifunctional fish farms clearly shows that the diversification of fish farming activities offers good opportunities for the development of sustainable pond farming.

The operation of well-managed pond fish farms can be considered as sustainable using the natural resources efficiently, minimizing environmental impact, providing public goods and making profit for the farmers (SustainAqua, 2009; Bosma & Verdegem 2011). However, a major issue in pond fish farming development is how to preserve the benefits offered by traditional pond fish farming and at the same time increase production and employment opportunities without compromising sustainability. Multifunctional pond fish farming is one of the answers when traditional and innovative functions of a pond fish farm are systematically integrated into a complex system that among others applies the principles of resource use efficiency and circularity during its operation.

Pond fish farming contributes to the preservation of natural values and the improvement of environmental conditions by strengthening environmentally conscious farming and applying environment-friendly fish production methods. Therefore, a more active promotion of these methods continues to be a task of special importance for the future. The diversification of activities and the using of the opportunities offered by multifunctionality continues to be one of the development directions of pond farming. However, in addition to supporting the openness of pond managers to innovation and their willingness to develop, improvement in the conditions of multifunctional farming, implementation of targeted support programmes and better understanding of its characteristics, as well as the interrelationships between the different functions, are also required.

This study shows that while farm managers naturally regard the productive function as the most relevant, they are aware of the important role of socially expected ecosystem services. Therefore, it can be concluded that the judgements of farm managers are not an obstacle to a better use of the special characteristics of pond farms for the benefit of society and the natural environment. A better understanding of the characteristics of multifunctional fish farming and the linkages between the various functions is needed, which requires further, well-defined research programmes. Multifunctional pond farms can contribute considerably to improving rural livelihoods and maintaining and enriching biodiversity if their social and environmental benefits are better recognized and supported.

As a limitation of the research, it must be emphasized that the interdependencies of the factors within the hierarchical structure have not been examined due to the nature of the applied method, that is AHP. Nonhierarchical connection requires another method, analytic network process (ANP); however, at this stage, because of the dominance of the structural connections – verified by experts – the interdependencies were neglected. Another limitation is that there was no distinction made between evaluator groups, for example multifunctional farmers versus nonmultifunctional farmers, although evaluator number 6 was also separately analysed. As an observation for further research, we aim to examine the evaluations groupwise, considering the characteristics of the evaluators. Furthermore, a consideration of all kinds of connections within the decision system is also planned. It is also advisable to make the aggregation of the scores in another way than using the geometrical mean, in order to highlight the creation of consensus among the participants of the survey.

Despite the above-mentioned limitations, the procedure introduced is capable of implementation in other countries and markets, and the created model can be applied for analysing other decisions related to multifunctional fish farming.

## Acknowledgements

Comments from László Váradi, President of the Network of Aquaculture Centers in Central and Eastern Europe (NACEE), are much appreciated.

## Author contributions

Emese Békefi and Szabolcs Duleba conceived and designed the experiments and analysed the data. Emese Békefi performed the experiments. József Popp and Judit Oláh contributed analysis tools. All authors contributed significantly to the writing of the manuscript.

## References

AKI (2017) *Statisztikai jelentések. Lehalászás jelentés XXII. évf.* Agrárgazdasági Kutató Intézet, Budapest, Hungary.

Assessment ME (2003) *Ecosystems and Human Well-being: A Framework for Assessment*, p. 245. Island Press, Washington, DC.

Bekefi E, Varadi L (2007) Multifunctional pond fish farms in Hungary. *Aquaculture International* **15**: 227–233.

Biodiversity Information System for Europe (2018) Available from URL: https://www.eea.europa.eu/publications/bise.

Blayac T, Mathé S, Rey-Valette H, Fontaine P (2014) Perceptions of the services provided by pond fish farming in Lorraine (France). *Ecological Economics* **108**: 115–123.

Bosma RH, Verdegem MC (2011) Sustainable aquaculture in ponds: principles, practices and limits. *Livestock Science* **139**: 58–68.

Bostock J, McAndrew B, Richards R, Jauncey K, Telfer T, Lorenzen K *et al.* (2010) Aquaculture: global status and trends. *Philosophical Transactions of the Royal Society B: Biological Sciences* **365**: 2897–2912.

Briffett C (2001) Is managed recreational use compatible with effective habitat and wildlife occurrence in urban open space corridor systems? *Landscape Research* **26**: 137–163.

Bueno PB (2008) Social risks in aquaculture. In Bondad-Reantaso MG, Arthur JR, Subasinghe RP (eds). *Understanding and Applying Risk Analysis in Aquaculture*. FAO Fisheries and Aquaculture Technical Paper. No. 519, pp. 209–228. FAO, Rome, Italy.

Céréghino R, Boix D, Cauchie H-M, Martens K, Oertli B (2014) The ecological role of ponds in a changing world. *Hydrobiologia* **723**: 1–6.

Chua T-E (1992) Coastal aquaculture development and the environment: the role of coastal area management. *Marine Pollution Bulletin* **25**: 98–103.

Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B *et al.* (1997) The value of the world's ecosystem services and natural capital. *Nature*, **387**: 253.

Costanza R, de Groot R, Braat L, Kubiszewski I, Fioramonti L, Sutton P *et al.* (2017) Twenty years of ecosystem services: how far have we come and how far do we still need to go? *Ecosystem Services* **28**: 1–16.

Costa-Pierce BA (2002) Ecology as the paradigm for the future of aquaculture. In Costa-Pierce BA (ed.) *Ecological Aquaculture: The Evolution of the Blue Revolution*, pp. 339–372. Blackwell Science, Oxford, United Kingdom of Great Britain and Northern Ireland.

Costa-Pierce BA (2010) Sustainable ecological aquaculture systems: the need for a new social contract for aquaculture development. *Marine Technology Society Journal* **44**: 88–112.

De Groot RS, Wilson MA, Boumans RM (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* **41**: 393–408.

De Marco P, Nogueira DS, Correa CC, Vieira TB, Silva KD, Pinto NS *et al.* (2014) Patterns in the organization of Cerrado pond biodiversity in Brazilian pasture landscapes. *Hydrobiologia* **723**: 87–101.

Drabiński A, Jawecki B, Tokarczyk-Dorociak K (2010) The role of carp fish ponds in the water management of the river basins. In: Cieśla M, Kuczyczyński M (eds) *Multifunctionality in Pond Aquaculture in Poland. Perspectives and Prospects*, pp. 24–29. Editorial House "Wieś Jutra, Warsaw University of Life Sciences, Warszawa.

Duleba S, Mishina T, Shimazaki Y (2012) A dynamic analysis on public bus transport's supply quality by using AHP. *Transport* **27**: 268–275.

Duleba S, Shimazaki Y, Mishina T (2013) An analysis on the connections of factors in a public transport system by AHP-ISM. *Transport* **28**: 404–412.

Edwards P (1998) A systems approach for the promotion of integrated aquaculture. *Aquaculture Economics and Management* **2**: 1–12.

EPCN (2007) Developing the pond Manifesto. *Annales de Limnologie – International Journal of Limnology* **43**: 221–232.

European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) (2017) EU consumer habits regarding fishery and aquaculture products. Final Report.

Fang J, Zhang J, Jiang Z, Mao Y (2014) Development of Integrated Multi-trophic Aquaculture in China. World Aquaculture Adelaide, South Australia, June 7–11.

FAO (1999) Taking stocks of the multifunctional character of agriculture and land. Paper prepared for FAO/Netherlands Conference on: The multifunctional character of agriculture and land" Maastricht, Netherlands, September 12–17, 1999.

FAO (2009) *The State of World Fisheries and Aquaculture 2008*. FAO, Rome, Italy.

FAO FishStatJ (2017) Software for fishery statistical time series. The State of World Fisheries and Aquaculture 2017.

Frankic A, Hershner C (2003) Sustainable aquaculture: developing the promise of aquaculture. *Aquaculture International* **11**: 517–530.

Garcia S, Staples D, Chesson J (2000) The FAO guidelines for the development and use of indicators for sustainable development of marine capture fisheries and an Australian example of their application. *Ocean & Coastal Management* **43**: 537–556.

Givord D (2001) Defending the European rural and agricultural model at the WTO. The European rural model. Winter 2000/2001 In: *LEADER Magazine*.

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF *et al.* (2010) Food security: the challenge of feeding 9 billion people. *Science* **327**: 812–818.

Guziur J, Białowąs H, Milcarzewicz W (2003) *Pond Fisheries*. Oficyna Wydawnicza Hoża Pub, Warszawa, Poland.

Hadipour A, Vafaie F, Hadipour V (2015) Land suitability evaluation for brackish water aquaculture development in coastal area of Hormozgan, Iran. *Aquaculture International* **23**: 329–343.

Harvey B, Soto D, Carolsfeld J, Beveridge M, Bartley DM (2007) Planning for Aquaculture Diversification: The Importance of Climate Change and Other Drivers. FAO Technical Workshop, 23–25 June 2016, FAO Rome. FAO Fisheries and Aquaculture Proceedings No. 47. Rome, Italy, pp. 166.

Hegedűs H (2016) Wetland ecosystems in Hungary's nature conservation areas and problems relating to their economic utilization, from the aspect of nature conservation. *Academic and Applied Research in Military and Public Management Science*, **15**: 121.

Hishamunda N, Ridler NB (2002) Macro policies to promote sustainable commercial aquaculture. *Aquaculture International* **10**: 491–505.

Hossain MS, Das NG (2010) GIS-based multi-criteria evaluation to land suitability modelling for giant prawn (*Macrobrachium rosenbergii*) farming in Companigonj Upazila of Noakhali, Bangladesh. *Computers and Electronics in Agriculture* **70**: 172–186.


 

Jolly CM, Ligeon C, Hishamunda N, Wright V (2011) Factors influencing the Environmental and Financial Sustainability of Aquaculture Production in Jamaica. In: 2011 West Indies Agricultural Economics Conference, July 17–21, 2011. Caribbean Agro-Economic Society, St. Vincent, West Indies.

Koç E, Burhan HA (2015) An application of analytic hierarchy process (AHP) in a real world problem of store location selection. *Advances in Management and Applied Economics* **5**: 41.

Krause G, Brugere C, Diedrich A, Ebeling MW, Ferse SC, Mikkelsen E *et al.* (2015) A revolution without people? Closing the people-policy gap in aquaculture development. *Aquaculture* **447**: 44–55.

Kuczyński M (2010) Pond aquaculture as the tool for sustainable development. In: Cieśla M, Kuczyński M (eds) *Multifunctionality in Pond Aquaculture in Poland. Perspectives and Prospects*, pp. 17–23. Editorial House Wieś Jutra, Warsaw University of Life Sciences, Warszawa.

Landuyt D, Lemmens P, D'hondt R, Broekx S, Liekens I, De BT *et al.* (2014) An ecosystem service approach to support integrated pond management: a case study using Bayesian belief networks – highlighting opportunities and risks. *Journal of Environmental Management* **145**: 79–87.

Lévai F, Váradi L (2006) The development of a multifunctional pond fish farm in collaboration with a research institute. Wierzba, Poland, 26–29 May. EIFAC Occasional Paper. No. 37. FAO. In: Proceedings of the EIFAC Symposium on Aquaculture Development – Partnership between Science and Producers Associations, Rome, Italy, pp. 83–86.

Lovell ST, Johnston DM (2009) Creating multifunctional landscapes: how can the field of ecology inform the design of the landscape? *Frontiers in Ecology and the Environment* **7**: 212–220.

Markwell KA, Fellows CS (2008) Habitat and biodiversity of on-farm water storages: a case study in Southeast Queensland, Australia. *Environmental Management* **41**: 234–249.

Millennium Ecosystem Assessment Board (2005) *Ecosystems and Human Well-being: Synthesis. Millennium Ecosystem Assessment*. Island Press, Washington, DC.

Moore TL, Hunt WF (2012) Ecosystem service provision by stormwater wetlands and ponds – a means for evaluation? *Water Research* **46**: 6811–6823.

NACA/FAO (2000) Aquaculture development beyond 2000: the Bangkok Declaration and Strategy. Conference on Aquaculture in the Third Millennium, 20–25 February. Bangkok, Thailand, pp. 27.

OECD (2001) *Multifunctionality: Towards an Analytical Framework*. OECD, Paris, France.

OECD/FAO (2017a) *Agricultural Outlook 2017–2026*. OECD-FAO Food and Agriculture Organisation of the United Nations, Paris.

OECD/FAO (2017b) *Agricultural Outlook, OECD Agriculture Statistics (Database)*. Food and Agriculture Organisation of the United Nations, Rome.

Oláh J, Nestler S, Nobel T, Popp J (2017) Ranking of dry ports in Europe - Benchamrking. *Periodica Polytechnika Transportation Engineering* **46**: 95–100.

van der Ploeg JD (2016) *Family Farming in Europe and Central Asia: History, Characteristics, Threats and Potentials (No. 153)*. Wageningen University and Research Centre, Wageningen, the Netherlands.

Popp J, Váradi L, Békefi E, Péteri A, Gyalog G, Lakner Z *et al.* (2018) Evolution of integrated open aquaculture systems in Hungary: results from a case study. *Sustainability* **10**: 177.

Saaty TL (1977) A scaling method for priorities in hierarchical structures. *JMPsy* **15**: 234–281.

Saaty TL (2008) Decision making with the analytic hierarchy process. *International Journal of Services Sciences* **1**: 83–98.

Soto D, Aguilar-Manjarrez J, Hishamunda N (2008) Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007. In: FAO Fisheries and Aquaculture Proceedings. No. 14. FAO/Universitat de les Illes Balears, Palma de Mallorca, Spain.

Stead SM (2005) A comparative analysis of two forms of stakeholder participation in European aquaculture governance: self-regulation and integrated coastal zone management. In: Gray TS (ed.) *Participation in Fisheries Governance*, Vol. **4**, pp. 179–192. Springer, Dordrecht, the Netherland.

SustainAqua (2009) A handbook for Sustainable aquaculture, EU FP6 project, Integrated approach for a sustainable and healthy freshwater aquaculture. Project N: COLL-CT-2006-030384.

Szűcs I, Szőllősi L (2014) Vertikális és horizontális integrációs lehetőségek a hazai haltermékpálya mentén. In: *Az átalakuló, alkalmazkodó mezőgazdaság és vidék: tanulmányok: XIV. Nemzetközi Tudományos Napok*. Eszterházy Károly Egyetem, Gyöngyös, Hungary.

Tallar RY, Suen J-P (2017) Measuring the aesthetic value of multifunctional lakes using an enhanced visual quality method. *Water* **9**: 233.

Troell M, Joyce A, Chopin T, Neori A, Buschmann AH, Fang J-G (2009) Ecological engineering in aquaculture-potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. *Aquaculture* **297**: 1–9.

Turkowski L, Lirski A (2011) Non-productive functions of fish ponds and their possible economic evaluation. In: Lirski A, Pyć A (eds) *Carp Culture in Europe. Current Status, Problems, Perspective*, pp. 25–42. IRŚ Olsztyn, Olsztyn, Poland.

Váradi L (2007) Extensive aquaculture in freshwater and its contribution to rural development. In: Conference on European aquaculture and its opportunities for development, 15–16 November 2007, Brussels, Belgium.

Word Bank (1998) Sustainable aquaculture. Rural Development Department. No. 22.