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Feasibility of the sustainable freshwater cage culture in Hungary and Romania

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Abstract. The intensive cage culture has an adverse effect on the quality of waters due to the high nutrient discharge of intensive fish culture. The combination of the intensive cage and the extensive aquaculture exploits the advantages of traditional pond farming and intensive fish culture systems. Valuable predatory fish species can be produced in the intensive part of the system, whilst the integration of an extensive pond as a treatment unit results in decreased nutrient loading to the environment and increased nutrient recovery in fish production. The combination of cage and pond fish farming is a new method for predatory fish production in fishponds. By the exploiting of the traditional fish ponds with intensive fish production in cages makes possible for the traditional carp farmers to increase their production capacity, diversify the cultured species and recycle the nutrients within the production systems.

Key words: cage culture, fishpond, integrated aquaculture, waste reusing, sustainability.

Introduction. Development of the European aquaculture industry showed a significant growth in production volume during the last fifty years. However in the last 10-20 years all the growth can be attributed to marine cage culture, as there were no rise in the production in other subsectors of European aquaculture: freshwater fish farming has been stagnating since the 90's, while brackish aquaculture and marine shellfish farming has gone through a serious depression in the last 10-15 years. Cage mariculture went through the most serious technological development and economic rationalisation (cost cutting) in the latest years making salmon farming and mediterranean fish farming the most competitive subsectors of European aquaculture. Nowadays marine cage culture (mainly salmon, trout, seabream, seabass and - to a lesser extent - cod farming) accounts for more than 60 percent of total European aquaculture and contributes 75 percent to total finfish culture.

European freshwater aquaculture is currently based on a larger number of species, although carp and rainbow trout are still the dominant species. The demand for carp or low valued herbivorous fish is constant or slightly decreasing (Adamek et al 2009), but there is a significant need for valuable boneless carnivorous fish. However, the common carp production in pond fish farms in Central Europe will be dominant in the future; new production techniques can be applied for increasing the profitability of the farms.

European finfish aquaculture is dominated by marine cage culture (salmonid and Mediterranean fish species), which accounts for 70-75% of total European finfish farming both in terms of quantity and value (FAO FishStat Plus). Mariculture in cages went through the most serious technological development and economic rationalisation (cost cutting) making salmon and seabream/seabass farming the most competitive subsector of European aquaculture with nearly 6 percent annual growth in the last decade while inland aquaculture and shellfish farming has been stagnating.

Although freshwater cage aquaculture is very important in Asia (China, Vietnam, Indonesia and Philippines are the largest producers, mainly catfish and tilapia are produced in cages), in Europa it is not notably prevalent yet. The most remarkable freshwater cage culture in the region is reported from Russia and Turkey, more than 10,000 tonnes of fish farmed in freshwater cages in these countries (Cardia & Lovatelli

2007; Tacon & Halwart 2007); the dominant species are trout and sturgeons. Cage culture plays also a significant role in Bulgarian aquaculture (Hadjinikolova et al 2010). The majority of Bulgarian trout and sturgeon production comes from cages in dam lakes, and to a lesser extent carps are also produced in cages.

Freshwater aquaculture in Central and Eastern Europe which is based on farming in semi-static waters may profit from applying certain elements of marine cage culture in ponds, lakes and reservoirs. In Asian freshwater aquaculture cages in ponds has been used for a long time. Hungarian farmers recently adopted this technology in a minor scale (so-called pond in pond system, Füllner et al 2007) that proved to be cost effective as higher value fish can be raised in these systems in intensive conditions (feeding, high population density) with low energy input compared to other intensive systems (flow-through systems in raceways and recirculation aquaculture systems). Constructing pond in pond systems in existing ponds, lakes and reservoirs requires seriously lower investment cost than other types of farming systems.

Environmental impact of cage aquaculture. Although cage culture allows the farmer access to new untapped aquatic resources and potential sites (including lakes, reservoirs, rivers, estuaries), intensification of aquaculture production also brings increased environmental risks. It is essential to minimize the potential environmental and ecosystem impacts of cage technology, which for the most part are operated as single species (i.e. monoculture) open farming systems, with little or no regard usually given to the utilization of the waste outputs from these open farming systems as valuable nutrient inputs for the co-culture of other complementary aquatic species.

Well designed and carefully managed cage cultures also provide limited but important possibility for freshwater aquaculture. The advantages of cage culture are: existing utilised waterbodies can be exploited; technical simplicity with which farms can be established or expanded; lower investment costs compared to land-based farms and easier stock management and monitoring than in pond culture. However the cage culture also has several drawbacks: stock is vulnerable to external water quality problems (e.g. algal blooms, low oxygen) and the environmental impact.

The impacts of cage culture on the aquatic environment are more pronounced than those of other aquaculture methods. The cage culture adopts high-density breeding technology and consumes a great quantity of external feedstuff. The excess feedstuffs can cause serious organic pollution, especially nitrogen and phosphorous loading, and also may cause fish diseases and destroy the integrated function of the waters (Wen et al 2007). The environmental impact of intensive fish farm effluents is well-recognised. Decomposition of both waste feed and fish excreta largely reduces the oxygen content and increases the nutrient concentration in the receiving water, which may result in eutrophication. The main environmental pollutants – the carbon, the phosphorus and the nitrogen – derive from fish feed residuals and fertilisers. Nutrient retention into fish biomass varies only between 20 and 30% of the introduced fish feed (Hargraves 1998; Brune et al 2003). The impact of cage aquaculture on the environment is an attractive subject for scientist in the recent years, especially in costal waters and estuaries. Gowen & Bradburg (1987) found that 76% of organic carbon and nitrogen of fish feed get into marine environment from salmon cage culture. Wallin & Hakanson (1991) indicated that the utilisation ratio of phosphorus in fish of cage culture is only 15% to 30%.

Cage culture is intensive-culture and affects enormously their ambient waters. During the past 20 years, as marine cage culture expended very rapidly, marine environment of costal cage farm sites was worsen. But the environmental effect of cage culture in the freshwater is similar to the marine cage culture. The impacts are numerous, including water pollution, impact on the sediment, genetic pollution, chemical pollution, and their resulting impacts on biodiversity.

Concerning the environment the intensive cage culture has similar nutrient loads on the waters than the flow-through systems. They has no any water or waste treatment unit or capacity, thus these systems load all the wasted nutrients directly to the surrounding environment and causes deterioration effect of waters. Nevertheless cage culture is relatively simple and cheap system, and the non-integrated use of cage culture generally is not environmentally sustainable due to the above mentioned reasons.

However, the using of cages with the strong integration with the traditional pond culture could be an environment-friendly and sustainable production technology which is able to reduce the nutrient loads into the environment and diversify the production. On the following chapters we give some examples the sustainable cage production technologies.

Steps towards the sustainable cage production systems. The expected growth of the volume and intensity of fish production and the new environmental legislation made necessary the development and application of new and environment-friendly aquaculture technologies. Considerable efforts are being made for minimising the negative impact of fish farm effluents on the environment, such as the use of recirculation systems with biofilters, the application of wetland systems and sedimentation ponds, and special equipment for effluent treatment. The aquatic ecosystems including fishponds have a growing role in the treatment of effluents from intensive agriculture. Several international and Hungarian research projects proved that the natural and constructed aquatic ecosystems are able to treat communal and agricultural sewage (Lakatos 1998; Vymazal 2001; Kerepeczki et al 2003). Integrated pond systems have a long tradition in Asia. In an integrated pond system, waste serves as nutrient for fish production generating additional profit for farmers (Chang 1987; Liu & Cai 1998).

Naylor et al (2000) summarised the necessary steps for the sustainable fish production as follows: expansion of the farming of low trophic level fish; reduction of fish meal and fish oil inputs in feed; development of integrated farming systems; and promotion of environmentally sound aquaculture practices and resource management. Whereas due to the changing consumer preferences, the production of valuable high quality carnivorous fish in intensive systems fed with artificial feed is increasing.

The research on the development of environmental friendly fish production technologies point out that fishpond ecosystem can treat the waste from intensive aquaculture – including cage culture – and integrating intensive aquaculture with fishpond systems is also ecological viable. In the course of waste treatment in a fishpond the excess nutrients are removed by biological processes and part of the nutrients are converted into fish flesh. The principle of the investigated method is to treat the effluent water enriched with organic and inorganic nutrients of intensive fish ponds in an extensive pond. In the extensive pond, a part of the nutrients is utilised through various biological production processes and their other part is fixed in the pond sediment, and the water treated or purified is recycled to the intensive fishponds. The application of the combined production system contributes to the ecological sustainability and production of marketable fish.

***Fishponds as a tool for waste treatment**:* The polyculture ponds have been used for centuries. Even today, four of the most widely cultivated fish species are produced together in the same pond: silver carp (a phytoplankton filter feeder), grass carp (a herbivorous, macrophyte feeder), common carp (an omnivorous detritus bottom feeder) and bighead carp (a zooplankton filter feeder). This type of system efficiently utilizes available food and water resources. The fishponds are able to retain high amount of nutrients. A survey study stated that the retained nutrients by fishponds represented on average 74% of organic carbon, 53% of nitrogen and 74% of phosphorus introduced into the fishponds. In the fishponds, the ratio of organic carbon, nitrogen and phosphorus accumulated in fish biomass was 6.8%, 18.4% and 10.4%, respectively. By the estimation of the environmental impacts of the investigated fishponds it can be stated that the fishponds were able to improve the water quality, as 48% and 62% less nitrogen and phosphorus were discharged into the recipient water bodies, respectively. However 78±126% more organic carbon was discharged with the effluent from the fishponds, than received with the inlet and supplement water primarily through the increased organic suspended solids concentration in the effluents by the fish production. There were large differences between the nutrient budget of the inlet and outlet water among the various fish ponds. According to our studies, it was found that the nitrogen content of the effluent water depends on nitrogen concentration in the sediment. In that ponds where the nitrogen concentration was extremely high in the sediment the nitrogen concentration in the effluent at drainage were higher than in the intake water, as well. There was no any relationship between the production intensity and the nutrient content in the effluent, hence it can be stated that the production intensity can be increased without serious impact on natural waters (Gál et al 2011).

The observations proved the pond fish culture is one of those few animal husbandry methods that has no deterioration effect on the environment. Moreover during the pond production of fish flesh – which has a proven health promotion effect on the human nutrition – excess nutrients discharged from other animal husbandry units can be utilised in fish ponds. In the pond culture excess nutrients are converted into harvestable products results in reduced waste discharge and protection of the natural resources. Contrary to intensive animal husbandry and intensive aquaculture the pond culture allows the use of renewable natural resources. Using proper pond management practices and building on the processes in the pond ecosystem, economically viable fish production can be practiced with minimised nutrient discharge into the natural waters, protecting this way the natural environment.

A possible solution for the sustainable cage culture: combination of cage and extensive fishponds (cage-in-pond system). One of the techniques, which can increase the production of the high valued species, is the combined pond-cage rearing method. The combined pond-cage rearing is an integrated system where cage culture is integrated with semi-intensive pond culture with feeding artificial diets in cages and without feeding and fertilizing in open ponds to utilize natural foods from cage wastes. This integrated aquaculture system has been developed for catfish-tilapia rearing (Lin & Diana 1995). Freshwater cages can be placed in several open water bodies like fishponds, rivers, lakes, reservoirs, power stations cooling water etc (Füllner et al 2007). The advantages of cage rearing are well known. Cage rearing utilises existing water bodies, are easy to harvest and enable fish to use the natural productivity of water bodies, such as reservoirs. Densities in small freshwater cages are high, ranging from 200-700 fish/m^3 depending on species cultured and preferred market size. Production levels vary with species produced but usually range from 90 to 150 kg/m^3 (Masser 1998). Considerations for cage culture as with any production scheme cage culture of fish has advantages and disadvantages that should be considered carefully before cage production becomes the chosen method (see Table 1).

During the development of environmental friendly fish production technologies it seems to be the obvious solution that intensive aquaculture is integrated within fishpond systems. The principle of this method is to treat the effluent water enriched with organic and inorganic nutrients of intensive fish ponds in an extensive pond. There, a part of the nutrients is utilised through various biological production processes and the other part is fixed in the pond sediment. The water treated or purified is recycled to the intensive fishponds. The application of the combined production system contributes to the ecological sustainability and production of marketable fish.

The bellow study on the combination if the intensive and extensive pond farming is partly based on the research conduced in the frame of project called SustainAqua (www.sustainaqua.org). The aims of the project is to expand the knowledge base of European freshwater aquaculture farmers by the research and training them to improve production methods, process efficiency and profitability, develop different techniques for optimising the nutrient, water and energy management and diversified the cultured aquatic products.

The overall objective of Hungarian case study of SustainAqua project is helping the traditional carp farmers to use their water more efficiently by producing valuable species in their reservoir or extensively used ponds in order to diversify their production and increase the economical performance of fish production. The principle of this research was based on a linkage of intensive and extensive aquaculture production methods and different species that occupy different niches in the food web into one single integrated system, so that wasted nutrients could be recycled. This results in higher nutrient utilisation efficiency and reduced environmental emissions; at the same time the production per unit of water intake increases. The purpose of the task was to develop a new method for predatory fish production in pond systems and to increase the nutrient utilisation of fish production (more information about the case study: Gál et al 2009). The goals of the innovation were to: (1) increase production capacity; (2) diversify the cultured species and (3) recycle the nutrients within the production system.

Summary of the SustainAqua research on the combination of intensive and extensive pond fish farming: The key of the operation of combined systems is the treatment and nutrient processing capacity of the extensive pond, which could be increased using different technological elements such as aeration, water mixing, periphyton application and C:N ratio manipulation (Azim 2001; Gál et al 2007; Asaduzzaman et al 2008). By the manipulation with the direction and intensity of the biological processes (i.e. aerobic decomposition, primary production) in the extensive pond makes possibility to develop a small pond fish production system with high nutrient loading capacity.

The experiments were carried out in ponds (area 310 m^2, depth 1 m) serving as extensive units, where cages were placed as intensive units (volume 10 m^3), one in each pond. A paddlewheel aerator was applied in each pond to provide sufficient oxygen concentrations and maintain the water circulation between the intensive and extensive units. Three different setups of extensive ponds were tested: the additional artificial plastic substrate for periphyton development equalled 0, 100 and 200% of the pond surface area, because the widely tested perfiphyton density had been 100% of the pond water surface area at low and medium nutrient loads (Azim 2001) in tropical fishponds. The periphyton based aquaculture is a technology for increasing the natural food production in the pond and its utilisation for fish production. The application of periphyton in an extensive pond built for wastewater treatment could be improve the purification capacity of ponds as well.

The average feed-originated loads were 1.2, 1.9 and 2.8 gN m^2/day in 2008, 2009 and 2010, respectively. In the intensive units African catfish were cultured and fed with pellet – the initial stocking biomass was 200, 300 and 400 kg (20-40 kg/m^3) in 2008, 2009 and 2010, respectively. Common carp were stocked in each extensive unit and raised without any artificial feeding. Combined systems allow to multiply the overall production intensity as compared to traditional pond culture. The key to the proper operation of such combined systems is the right balance between the nutrient load of the intensive part and the treatment capacity of the extensive pond; hence the aim of this research was to determine the nutrient processing capacity of combined pond systems, evaluate the potential of nutrient reusing and investigate the application of periphyton for additional fish production and the water quality.

The combination of the intensive and extensive aquaculture exploits the advantages of traditional pond farming and intensive fish culture systems. Valuable predatory fish species can be produced in the intensive part of the system, whilst the integration of an extensive pond as a treatment unit results in decreased nutrient loading to the environment and increased nutrient recovery in fish production. The intensive rearing can be performed in cages or in in-pond floating tanks, which are placed in the extensive pond environment. In the intensively managed part of the system valuable carnivorous fish can be cultured in controlled conditions and fed with artificial diets. The uneaten feed and the fish metabolic wastes can be utilised in the extensive part and can increase the fish yields. Compared to the nutrient utilisation efficiency of about 20-25% in most intensive culture systems, it could be increased up to 30-35% in integrated pond systems, resulting in less nutrients discharge to the receiving waters. The application of the combined intensive-extensive pond fish production system could contribute to the better use of water resources and the sustainability of aquaculture. Results of the case study proved that combination of intensive aquaculture with extensive fishponds enhances the nutrient utilisation efficiency and fish production in a combined system.

The relative investment cost of such combined fish production system is much lower comparing the traditional fishponds and intensive indoor systems (instead of 3-6 million HUF 0.4-0.8 million HUF only to produce 1 ton fish). The general fish yields are around 1 t/ha in traditional ponds, but in combined systems it can be increased up to 20 t/ha. However, the nutrient discharge from the traditional fishponds is very low because of the improved nutrient utilisation efficiency. Meanwhile the nutrient discharge of combined system is such low than the traditional fishponds because of the nutrient reutilisation.

The applied technology of cage-in-pond system is simple: a compartmentalised unit for intensive production placed in a traditional fishpond. Cages or tanks could be used as the intensive unit operating with close interactions with the fishpond. The fishpond operates as a biological filter and treats the wastes from the intensive unit. The fish yields in the extensive fishpond can be enhanced by provision of additional surface for increased periphyton production. Based on our results the additional fish production in the extensive unit was the highest where the periphyton area was 100% of the pond surface. The key of the safe operation of the system is the balance between the nutrient loading of the intensive unit and the treatment capacity of the extensive pond. With the adequate size of the extensive pond the appropriate water quality for fish production can be maintained and the nutrient discharge into the recipient natural waters can be minimised. Paddlewheel aerators could contribute to the adequate water circulation between the intensive and extensive units and maintain the optimal oxygen level. The pond system operates as a closed system; there is no effluent water discharge to the environment during the culture period, and the water is drained from the ponds only at fish harvest. Only the evaporation and seepage should be regularly compensated. The evaporation is higher in a continuously aerated pond system than in traditional fishponds, the expected rate of the water compensation could be 150% of the total volume annually.

The combination of the intensive and extensive aquaculture exploits the advantages of traditional pond farming and intensive fish culture systems. Valuable predatory fish species can be produced in the intensive part of the system, whilst the integration of an extensive pond as a treatment unit results in decreased nutrient loading to the environment and increased nutrient recovery in fish production. The intensive rearing can be performed in cages, which are placed in the extensive pond environment. In the intensively managed part of the system valuable carnivorous fish can be cultured in controlled conditions and fed with artificial diets. The uneaten feed and the fish metabolic wastes can be utilised in the extensive part and can increase the fish yields. Compared to the nutrient utilisation efficiency of about 20-25% in most intensive culture systems, it could be increased up to 30-35% in integrated pond systems, resulting in less nutrients discharge to the receiving waters. The application of the combined fish production system in cage-in-pond system could contribute to the better use of water resources and the sustainability of aquaculture. Results of the case study proved that combination of intensive aquaculture with extensive fishponds enhances the nutrient utilisation efficiency and fish production in a combined system.

Table 1

Pros and contras of the cage-in-pond system application

Advantages	*Disadvantages*
Simple technology with a low investment and operation costs	Less controllable production conditions (i.e. temperature fluctuations)
Improved nutrient utilisation efficiency and additional income by the additional fish production	Water quality affected primarily by natural biological processes
Low nutrient discharge into the natural waters	Limited growing period (from April till October in Hungary)
Low energy demand for fish production	Winter storage of fish should be solved
Lower water consumption comparing other pond farming practices	
Concentrated production reduces the losses caused by predators	

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References

Adamek Z., Gál D., Pilarczyk M., 2009 Carp farming as a traditional type of pond aquaculture in Central Europe: prospects and weakneses in the Czech Republic, Hungary and Poland. European Aquaculture Society Special Publication **37**:80-81.

Asaduzzaman M., Wahab M. A., Verdegem M. C. J., Huque S., Salam M. A., Azim M. E., 2008 C/N ratio control and substrate addition for periphyton development jointly enhance freshwater prawn *Macrobrachium rosenbergii* production in ponds. Aquaculture **280**:117–123.

Azim M. E., 2001 The potential of periphyton-based aquaculture production systems. Dissertation, Wageningen University, The Netherlands.

Brune D. E., Schwartz G., Eversole A. G., Collier J. A., Schwedler T. E., 2003 Intensification of pond aquaculture and high rate photosynthetic systems. Aquacultural Engineering **28**:65-86.

Cardia F., Lovatelli A., 2007 A review of cage aquaculture: Mediterranean Sea. In: M. Halwart, D. Soto and J. R. Arthur (eds). pp. 156–187, Cage aquaculture – Regional reviews and global overview, FAO Fisheries Technical Paper. No. 498. Rome, FAO. 2007, 241 pp.

Chang W. Y. B., 1987 Fish culture in China. Fisheries **12**(3):12-15.

FAO, FAO FishStat Plus; www.fao.org

Gál D., Szabó P., Pekár F., Váradi L., 2003 Experiments on the nutrient removal, retention and discharge of a pond ecosystem. Hydrobiologia **506**(1):767-772.

Gál D., Pekár F., Kerepeczki É., Váradi L., 2007 Experiments on the operation of a combined aquaculture-algae system. Aquaculture International **15**:173-180.

Gál D., Kerepeczki É., Kosáros T., Hegedűs R., Pekár F., Váradi L., 2009 Water treatment of intensive aquaculture systems through wetlands and extensive fish ponds – Case studies in Hungary In: " SustainAqua – "Integrated approach for a sustainable and healthy freshwater aquaculture" SustainAqua handbook – A handbook for sustainable aquaculture, 26-42.

Gál D., Pekár F., Kosáros T., Kerepeczki É., 2011 Potential of nutrient reutilisation in combined intensive-extensive pond systems. Aquaculture International, (in press).

Gowen R. J., Bradbury N. B., 1987 The ecological impact of salmon farming in coastal waters: A review. Oceanography Marine Biology Annuals Review **25**:563-575.

Hadjinikolova L., Hubenova T., Zaikov A., 2010 Status and Development Tendencies of Freshwater Aquaculture Production in Bulgaria. Bulgarian Journal of Agricultural Science **16**(3):398-405.

Hargreaves J. A., 1998 Nitrogen biogeochemistry of aquaculture ponds. Aquaculture **166**:181-212.

Füllner G., Gottschalk T., Pfeifer M., 2007 Experiments for the production of hybrid striped bass in in-pond circulation system. Aquaculture International **15**:241-248.

Kerepeczki É., Gál D., Szabó P., Pekár F., 2003 Preliminary investigations on the nutrient removal efficiency of a wetland-type ecosystem. Hydrobiologia **506-509**:665-670.

Lakatos G., 1998 Constructed wetlands for wastewater treatment in Hungary. In: Constructed wetlands for wastewater treatment in Europe. Vymazal J., Brix H., Cooper P. F., Green M. B., Haberl R. (eds.), Backhuys Publishers, Leiden, The Netherlands, 191-206.

Lin C. K., Diana J. S., 1995 Co-culture of Catfish (*Clarias macrocephalus* x *C. gariepinus*) and Tilapia (*Oreochromis niloticus*) in Ponds. Aquatic Living Resources **8**:449-454.

Liu J. X., Cai Q., 1998 Integrated aquaculture in Chinese lakes and paddy fields. Ecological Engineering **11**:48-59.

Masser M. P., 1998 What is cage culture? SRAC Publication No. 160 available online http://srac.tamu.edu

Naylor R. L., Goldburg R. J., Primavera J. H., Kautsky N., Beveridge M. C. M., Clay J., Folke C., Lubchenco J., Mooney H., Troell M., 2000 Effect of aquaculture on world fish supplies. Nature **405**(1):1017-1024.

Tacon A. G. J., Halwart M., 2007 Cage aquaculture: a global review. In: M. Halwart, D. Soto and J. R. Arthur (eds), pp. 1-16, Cage aquaculture – Regional reviews and global overview, FAO Fisheries Technical Paper. No. 498. Rome, FAO, 2007, 241 pp.

Vymazal J., (ed.) 2001 Transformation of nutrients in natural and constructed wetlands. Backhuys Publishers, Leiden, The Netherlands, 519 p.

Wallin M., Hakanson L., 1991 Nutrient loading models for estimating the environmental effects of marine fish farms. Marine Aquaculture and Environment. In: T. Maekinen, (ed.) Marine aquaculture and the environment, Nord, Nordic Council of Ministers, Copenhagen, pp. 39–57.

Wen Y., Wei X., Shu T., Zhou J., Yu G., Li F., Huang Y., 2007 Forms and balance of nitrogen and phosphorus in cage culture waters in Guangdong Province, China. Chinese Geographical Science **17**(4):370-375.

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