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GROWTH TECHNOLOGIES FOR THE COMPLEX EXPLOITATION OF AQUATIC BASINS FROM THE TRADITIONAL FISH FARMS

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Abstract

The growth technologies for the complex exploitation of the aquatic basins from the traditional fish farms are regarding the location of some intensive growth modules such as battery of net pens (total surface/module 2000 m^2) or floating cages (total volume/module 576 m^3), within fish ponds. These growth modules allow obtaining additional quantities of fish on the same unit area and raising valuable species of different ages like catfish, carp, sturgeon, tilapia, etc, through the efficient exploitation of aquatic bioresources. For administered feed, FCR was in the range of 1.5-2.5 kg of feed/kg fish weight gain. Applying the growth technology into combined system it is possible to achieve a total production of 2,400 - 2,800 kg/ha (60-65% achieved in the host pond and 35-40% in the battery of net pens or floating cages). Bioeconomic studies demonstrates the profitability of the combined system and the developed technology, obtaining a profit rate of 1.26 for the pond-net pens system, respectively 1.56 for the floating cages-pond system.

Key words: *combined system, floating cages, net pens, polyculture, pond.*

INTRODUCTION

Romania has an important fishing potential represented by accumulation lakes (natural or artificial), dams, ponds, large rivers, high capacity irrigation canals. At this moment, their exploitation is carried out in extensive and semi-intensive systems, the productions being variable, depending on the natural productivity of the respective basins, most of the times, the production level being modest (FAO, 2013; MNSPA, 2014).
In the context of sustainable aquaculture, the challenges are set by the intensification of conventional aquaculture and the emerging integration within and between value chains (Little et al., 2016). Fish farmers need to better manage the growing demand for animal protein, adapting their service to needs and capacity (Marin et al., 2020).
The Fish Culture Research and Development Station Nucet (F.C.R.D.S. Nucet) proposes for traditional fish farming two combined fish growing system. Specifically, growth technologies for the complex exploitation of water basins in traditional fish farms have in mind the placement of intensive growth modules (such as floating cages, net pens) on the surface of fish ponds, which would allow obtaining additional quantities of fish on the same unit surface and growth of valuable species (catfish, carp, sturgeon, tilapia, etc.), in the conditions of efficient exploitation of aquatic bioresources (Billard & Marcel, 1985; Keramat, 2013).
The principle of the used method is based on the link between aquaculture production systems and the growth of fish species that occupy different niches in the food chain, in a single integrated system, so as to achieve the complex use of aquatic bioresources, nutrient recycling and reducing the effects on the growth environment (Bagental, 1978; Pope et al., 2010).
The proposed combined system aims to increase production capacity, diversify species, recycle nutrients in the production system, while testing the limits of the intensive growth system (Muir, 2000; Bucur et al., 2016).

MATERIALS AND METHODS

The technology of complex exploitation of the water basins from the traditional fish farms

imply the realization of two experimental models:
1. The first growth model in the combined system involved the placement of intensive growth modules (net pens battery) in a fish pond (Figure 1).

Figure 1. Battery of net pens located in the pond (*Original photo*)

Fish species for intensive farming are: carp (*Cyprinus carpio*) and catfish (*Silurus glanis*). This model is adapted to fish basins with a water depth of 1.5-2.0 m (Stickney, 2002).

a) *Main features*
The technology offers the possibility of intensive growth of carp and catfish in net pens located in ponds or reservoirs (where there is the possibility of maintaining a constant water level), with the administration of granulated feed and obtaining a high quality fish for restocking or market;
- the realization of the net pens does not imply high costs. The characteristics of the growth installation are the following:
  - net pens battery with an area of 2 000 m^2;
  - the surface of a net pen - 200 m^2;
  - height of the net pen - 2 m;
  - net pen length - 20 m;
  - net pen width -10 m;
- average water depth in net pens - 1.6 m (minimum 1.2 - maximum 2 m);
- the net pens battery is a closed enclosure with galvanized wire mesh with a mesh of 10 mm, fixed on pine pillars with a thickness of 15-20 cm, reinforced at the top with fir cabinets with a width of 10 cm and a thickness of 5 cm.
- the surface of the net pen battery represents maximum 10% of the total surface of the water basin in which they are located.

b) *Stocking formula*
For a net pen with an area of 200 m^2 and a minimum water depth of 1.2 m, the stocking formula (monoculture) is:
- carp C_1: 200 ex/net pen;
- catfish Sg_2: 200 ex/net pen.

c) *Average weight of fish for stocking*:
- carp C_1: 150 g/ex;
- catfish Sg_3: 700 g/ex.

d) *Fish feeding*
The carp feeding in the net pens battery was done with the Fish Feed Carp 32/2, 32/6, 32/8, 32/10 E Floating feed, produced by Furajny Hrany Ltd Lovech (Table 1).
Tthe catfish feeding in the net pen battery was done with the Aller 45-15 granulated feed, with the 7.2 mm granule size (Table 2).

Table 1. Chemical composition of feed Fish Feed Carp 32/2, 32/6, 32/8, 32/10 E Floating

Components	Values
Protein	32%
Lipid	10%
Raw fiber	2.9%
Calcium	1.4%
Phosphorus	1.8%
Moisture	10.0%
A vitamin (E672)	10000 $IU.kg^{-1}$
D_3 vitamin (E672)	2000 $IU.kg^{-1}$
E vitamin	200 $mg.kg^{-1}$
C vitamin	250 $mg.kg^{-1}$

Table 2. The structure on nutritional components of the Aller 45-15granulated feed

Components	Values
Protein	45%
Lipid	15%
Ash	7%
Cellulose	2.5%
Carbohydrates	29.5%
A vitamin (E672)	2500 $IU.kg^{-1}$
D_3 vitamin (E672)	500 $IU.kg^{-1}$
E vitamin	150 $mg.kg^{-1}$
C vitamin	100 $mg.kg^{-1}$

e) *The host pond stocking formula (1.0 ha module), in which the net pens battery is placed:*
- paddlefish P_2: 270 ex/ha;

- carp C_2: 450 ex/ha;
- grass carp Gc_2: 45 ex/ha;
- silver carp Sc_2: 45 ex/ha;
- pikeperch Pp_2: 90 ex/ha.

f) *Average weight of fish for stocking*:
- paddlefish P_2: 1400 - 1600 g/ex;
- carp C_1: 500 - 700 g/ex;
-grass carp Gc_2: 400 - 600 g/ex;
-silver carp Sc_2: 700 - 900 g/ex;
-pikeperch Pp_2: 400-600 g/ex.

g) *The growth cycle duration*: 150 days from the stocking time (end of April - beginning of May).

h) *Manure administration in the host pond*: 1000-2000 kg/ha (the amount being determined by the results of water analyzes).

2. The second growth model in the combined system involved the construction and placement of a floating cages module in a fish pond. Intensive rearing of the following fish species was carried out: paddlefish (*Polyodon spathula*), tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) (Figure 2).

Figure 2. The floating cages platform located in the pond (*Original photo*)

The growth model is adapted to fish basins with greater water depth.

a) *Main features*
Technology for intensive growth in floating cages located in a pond or reservoir (where there is a possibility to maintain a constant high water level), of paddlefish, tilapia and carp, offers the possibility of raising these species, with the administration of granulated fodder and can obtain high-quality fish intended for stocking or market.
The growth unit is composed of eight floating cages which have a square shape (Figure 2). The size of a single floating cage: 6 m x 6 m x 2 m, the cage surface - 36 sqm and the entire module surface is 288 sqm; useful volume - 72 m^3/floating cage; total volume: 576 m^3/module.
The floating cages are made of knotless fishing nets fastened on a frame fixed to the peripheral floats. On the frame, the fishnet is caught at the top at a 0.8 m height above the water (to prevent fish from escaping); in water, it is immersed cca 2 m.
Between the base of the cage and the bottom of the pond is at least 0.5 m, to allow the water flow to pass under the module, thus entraining some of the remaining organic waste.
The growing units surface (floating cages), does not represent more than 10% of the total surface of the water basin in which they are located.

b) *Stocking formula*
For a floating cage (72 m^3) with an 36 m^2 area and an average depth of 2.0 m, the stocking formula (monoculture) was the following:
- carp C_1: 500 ex/cage;
- paddlefish P_0: 1000 ex/cage;
- tilapia T_1: 1000 ex/cage.

c) *Average weight of fish for stocking*:
- carp C_1: 150 g/ex;
- paddlefish P_0: 20 g/ex;
- tilapia T_1: 70 g/ex.

d) *Fish feeding*
The carp and tilapia feeding from the floating cages was done with Fish Feed Carp 32/2, 32/6, 32/8, 32/10 E Floating feed, produced by Furajny Hrany Ltd Lovech (Table 1).
Feeding of the *Polyodon spathula* that was stocked in floating cages was done with floating feed Catco Pre Grower feed 15 EF, 2 mm grain size, produced by Coppens International GmbH (Table 3).

e) *The host pond stocking formula (1.0 ha module), in which the floating cages platform is placed*:
- paddlefish P_2: 270 ex/ha;

- carp C_2: 450 ex/ha;
- grass carp Gc_2: 45 ex/ha;
- silver carp Sc: 45 ex/ha;
- pikeperch Pp_2: 62 ex/ha;
- tench Te_4: 28 ex/ha.

Table 3. The structure on nutritional components of Catco Pre Grower 15 EF feed

Components	Values
Protein	50%
Lipid	15%
Fiber	0.9%
Ash	9%
Phosphorus	1.3%
Calcium	1.9%
Sodium	0.4%
A vitamin (E672)	10000 $IU.kg^{-1}$
D_3 vitamin (E672)	1382 $IU.kg^{-1}$
E vitamin	200 $mg.kg^{-1}$
C vitamin	150 $mg.kg^{-1}$

f) *Average weight of fish for stocking*:
- paddlefish P_2: 1400-1600 g/ex;
- carp C_1: 500-700 g/ex;
- grass carp Gc_2: 400-600 g/ex;
- silver carp Sc_2: 700-900 g/ex;
- pikeperch Pp_2: 400-600 g/ex;
- tench Te_4: 350-450g / ex.

g) *Growth cycle duration*: 150 days from the stocking time (end of April - beginning of May).

h) *Manure administration in the host basin*: 1000-2000 kg/ha (the quantity being determined by the results of water analyzes).

In both technological models, the ponds where the floating cages are located, will be exploited by stocking them with high economic value fish species like: carp, pikeperch, paddlefish, tench.
When choosing these fish species, it was first took into account the bioproductive characteristics that make them fit into the category of the valuable species, and secondly, their specificity to capitalize on various links in the food chain in the respective growth basins biocenoses.
The carp is a bentophagous species, consuming fodder, the sturgeon is mainly zooplanktonophagous, tench is detritophagous, and the pikeperch is a predator that will feed on wild fish species without economic value which, which compete for food with farmed fish. Uneaten fodder left by carp, as well as the resulting manure will stimulate the development of zooplankton, the trophic base for paddlefish (Costache et al., 2000; Costache et al., 2004).
In order to maintain the ecological balance and the sustainable exploitation of the ponds are introduced into the stocking formula the Asian species of cyprinids: silver carp and grass carp in a percentage of about 10%.
During the growing season, for the carp, grass carp and tench in the host pond, a combined feed with PB 22.22% was administered, consisting in the following ingredients: wheat, barley, corn, soybean and sunflower grists and fodder yeast (Oprea & Georgescu, 2000).
The feed was manually distributed in 3 rations/day, the whole growing period. The daily ration was a 0.8-5% of the total fish biomass. Every month, a control fishing was carried out to assess health condition and establish feed rations (Bogatu & Munteanu, 2008).
The environmental conditions were determined by physico-chemical and hydrobiological analyzes performed by taking monthly water samples from the growth basins.
The determination of the main hydrochemical parameters was done by known classical methods.
Temperature, dissolved oxygen and *pH* were determined using the WTW Multi 3320 multiparameter kit.
The organic substance - expressed by the chemical consumption of oxygen in potassium permanganate, was determined by the volumetric method (STAS 9887/74), and the principle of the method is to oxidize organic substances from water using potassium permanganate. The result of the analyzes can be expressed in two ways: mg $KMnO_4.l^{-1}$ and $mgO_2.l^{-1}$. Nitrite (NO_2-), nitrates (NO_3^-), and were determined by spectrophotometry (STAS 8900/1-71). The ammonium ion (NH_4^+) was determined from ammoniacal nitrogen; is determined spectrophotometrically (STAS 8683/83). The phosphorus ion ($P_2O_4^{3+}$) was also determined spectrophotometrically (STAS 10064/75). The determination of carbonates and bicarbonates was done volumetrically.

RESULTS AND DISCUSSIONS

Results obtained at F.C.R.D.S. Nucet, in the experiment of growing fish in a combined system, floating cages-pond and net pens-pond, after 150 days, are presented below.

1. Indicators of economic feasibility of the growth technology for the complex exploitation of the water basins from the traditional fish farms (net pens battery - pond system):

a) *Technological indicators at the end of the growth cycle obtained in the battery of net pens:*

- losses: 10-15%;
- total production: (C_{1-1+} + Sg_{3-3+}): 510 - 550 kg/net pen, of which:
  - carp (C_{1-1+}): 230-250 kg/net pen;
  - catfish (Sg_{3-3+}): 280-300 kg/net pen.
- individual mass at the end of the growth cycle (g/ex):
  - carp (C_{1+}): 1200-1600 g/ex;
  - catfish (Sg_{3+}): 1500-1700 g/ex.
- individual net growth (g/ex):
  - carp (C_{1+}): 1100-1400 g/ex;
  - catfish (Sg_{3+}): 800-1000 g/ex.
- Feed Conversion Ratio (FCR):
  - carp (C_{1+}): granulated feed with PB 32%, FCR = 1.6 kg of feed/kg fish weight gain;
  - catfish (Sg_{3+}): granulated feed with PB 45%.
- FCR = 1.9 kg of feed/kg fish wheight gain.

b) *Technological indicators at the end of the growth cycle, for the pond (1.0 ha module), in which the net pen battery is placed:*

- losses 5-20%;
- total production: 1500-1700 kg/ha, of which, by species:
  - paddlefish P_{2-2+}: 650-750 kg/ha;
  - carp C_{2-2+}: 650 - 700 kg/ha;
  - grass carp Gc_{2-2+}: 40-60 kg/ha;
  - silver carp Sc_{2-2+}: 80-120 kg/ha;
  - pikeperch Pp_{2-2+}: 60-80 kg/ha.
- average weight at the end of the growth cycle (g/ex*)*:
  - paddlefish P_{2+}: 2700-3000 g/ex;
  - carp C_{2+}: 1600-1900 g/ex;
  - grass carp Gc_{2+}: 1400-1500 g/ex;
  - silver carp Sc_{2+}: 2500-2700 g/ex;
  - pikeperch Pp_{2+}: 800-1000 g/ex.
- individual net growth (g/ex):
  - paddlefish P_{2+}: 1200-1500 g/ex;
  - carp C_{2+}: 1000-1300 g/ex;
  - grass carp Gc_{2+}: 900-1000 g/ex;
  - silver carp Sc_{2+}: 1700-1900 g/ex
  - pikeperch Pp_{2+}: 300-500 g/ex.
- Feed Conversion Ratio (FCR): 2.5 kg feed/kg fish wheight gain (only for consuming species (carp and grass carp), combined feed with PB 22.22%.

2. Indicators of economic feasibility of the growth technology for the complex exploitation of the water basins from the traditional fish farms (floating cages - pond system):

a) *Technological indicators obtained at the end of the growth cycle obtained in floating cages*:

- losses 10-20%;
- total production by species:
  - carp C_{1-1+}: 500-600 kg/cage;
  - paddlefish P_{0-0+}: 280-320 kg/cage;
  - tilapia T_{1-1+}: 280-300 kg/cage.
- average weight at the end of the growth cycle (g/ex):
  - carp C_{1+}: 1200-1400 g/ex;
  - paddlefish P_{0+}: 350-400 g/ex;
  - tilapia T_{1+}: 500-600 g/ex.
- individual net growth (g/ex):
  - carp C_{1+}: 1000 - 1200 g/ex;
  - paddlefish P_{0+}: 300-350 g/ex;
  - tilapia T_{1+}: 400-500 g/ex.
- Feed Conversion Ratio (FCR):
  - carp C_{1+}: 1.5 kg feed/kg fish weight gain, granulated feed with PB 32%;
  - paddlefish P_{0+}: 1.8 kg feed/kg fish wheight gain, granulated feed with PB 50%;
  - tilapia T_{1+}: 1.5 kg feed/kg fish wheight gain, granulated feed with PB 32%.

b) *Technological indicators obtained at the end of the growth cycle, for the pond (1.0 ha module), in which the floating cages platform is placed*:

- losses 9-20%;
- total production: 1600-1800 kg/ha, of which by species:
  - paddlefish P_{2-2+}: 680-750 kg/ha;
  - carp C_{2-2+}: 800-850 kg/ha;
  - grass carp Gc_{2-2+}: 40-60 kg/ha;
  - silver carp Sc_{2-2+}: 80-120 kg/ha;
  - pikeperch Pp_{2-2+}: 40-50 kg/ha;
  - tench Te_{4-4+}: 10-20 kg/ha.
- individual mass at the end of the growth cycle (g/ex):
  - paddlefish P_{2+}: 2800-3000 g/ex;
  - carp C_{2+}: 2000 - 2200 g/ex;
  - grass carp Gc_{2+}: 1300-1500 g/ex;

- silver carp Sc_{2+}: 2500-2800 g/ex;
- pikeperch Pp_{2+}: 800-1000 g/ex;
- tench Tc_{4+}: 600-700 g/ex.

- individual net growth (g/ex):
  - paddlefish (P_{2+}: 1300-1500 g/ex;
  - carp C_{2+}: 1400 - 1600 g/ex;
  - grass carp Gc_{2+}: 800-1000 g/ex
  - silver carp Sc_{2+}: 1700-2000 g/ex;
  - pikeperch Pp_{2+}: 300-500 g/ex;
  - tench Te_{4+}: 200 - 300 g/ex .
- Feed Conversion Ratio (FCR): 2.5 kg feed/kg fish wheight gain (only for consuming species (carp, grass carp and tench), combined feed with PB 22.22%.

The fish from the combined growth systems benefited from the following environmental conditions regarding the water temperature. The main physical parameter with major importance in fish farming, the water temperature, was between14 and 16°C during the fish stocking in two systems.

The evolution of the average monthly water temperature, during the growth cycle of the fish is shown in the figure below (Figure 3).

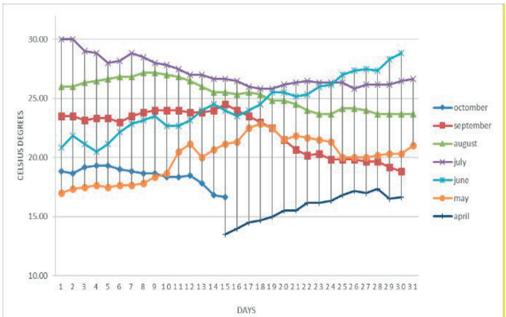

Figure 3. The evolution of the average monthly water temperature, during the growth season

Table 4. The main chemical parameters of the water, during the growing season

Parameter	U.M.	Recorded values	
		net pens battery - pond system	floating cages - pond system
pH	upH	6.8-7.4	6.9-7.5
Alkalinity	ml HCl. l^{-1}	2.6-3.5	2.8-3.8
Total hardness	(°D)	5.5-7.2	5.6-6.8
Dissolved Oxigen	mg $O_2.l^{-1}$	5.1-12.1	5.2-11.5
CCO-Mn	mg $KMnO_4.l^{-1}$	12.8-25.7	14.8-28.5
	mg $O_2.l^{-1}$	3.23-6.50	3.74-7.21
Nitrites (NO-2)	mg.l^{-1}	0.018-0.208	0.012-0.158
Nitrites (NO-3)	mg.l^{-1}	0.221-0.413	0.253-0.385
P from PO_4	mg.l^{-1}	0.028-0.210	0.025 - 0.285
Ammonium NH^+_4	mg.l^{-1}	0.141-0.250	0.163-0.350

The analysis of the water chemistry results shows that there are no notable differences between the values of the investigated hydrochemical parameters. The Table 4 shows the limits recorded (minimum and maximum) in the two combined growth systems.

Among the most important hydrochemical parameters, dissolved oxygen is a limited factor in the growth and survival of fish. The Figure 4 shows the level of dissolved oxygen in the water of the two growth systems, expressed in mg.l^{-1} O_2, during the entire growth cycle.

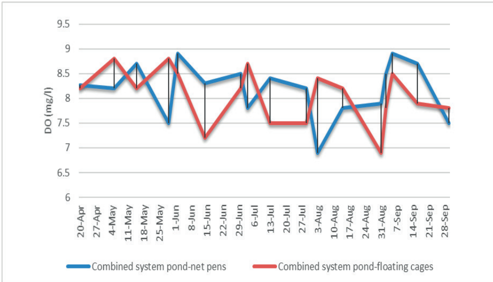

Figure 4. The level of dissolved oxygen (mg $O_2.l^{-1}$) recorded in the two growth systems

The values of the investigated hydrochemical parameters are within the normal range. The hydrochemical parameters were maintained within normal limits only by ensuring the optimal flow of water refreshness in the two combined fish farming systems (5-10 liters/sec/ha).

CONCLUSIONS

In the pond and net pens battery, the growth technology in combined system, makes possible a total production achievement of 2400-2700 kg/ha, of which 60-65% is realized in the pond, and 35-40% in net pens battery (10 cages/battery), without additional aeration, only with a permanent water intake (5-10 liters/sec/ha).

In the case of the combined net pens battery - pond system, the bioeconomy studies demonstrate the profitability of the developed system and the elaborate technology, by obtaining a 1.26 profit rate.

In the pond and floating cages platform, the growth technology in combined system makes possible a total production achievement of 2600-2800 kg/ha, from which 60-65% is achieved in the pond, and 35 - 40% is obtained in floating cages, without additional aeration, only with a permanent intake of water (5-10 liters/sec/ha).

In the case of the combined floating cages - pond system, the bioeconomy studies demonstrate the profitability of the developed system and the elaborate technology, by obtaining a 1.56 profit rate.

The growth technology in intensive system like net pens and floating cages, located in ponds, is distinguished by the feasibility of applying in practice the developed technology with favorable arguments for the aquaculture sector being materialized by:

- investment recovery in a very short time;
- installation simplicity and low costs for building the investment;
- the possibility to achieve a production planning in time, depending on the needs of the market and consumption;
- high production per unit area;
- the quality of the obtained production by the fish species that are the object of the growth and the individual weight of the fish realized at the harvest;
- high biological material survival rate;
- the possibility of introducing mechanization and automation of the various stages of the technological process;
- reducing the growth period, simultaneously reducing the risk factor;
- superior capitalization of the administered fodder;
- allowing the introduction into the growth culture of some valuable fish species highly sought on the market, with sufficient materialized quantities by diversifying and increasing the production quality;
- offers the possibility to develop processing and marketing capacities, generating new jobs in rural areas;
- does not present technological risks, is non-aggressive, in a normal correlation with the environment and alines to the responsible aquaculture principles;
- determines the creation of an agri-food chain: production → processing → marketing and facilitates the association of economic agents in the sector;
- the investment costs for the design and realization of experimental growth models (floating cages/net pens) located in ponds represent only 10-15% of the capital invested in arranging one hectare of pond surface.

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