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AQUACULTURE – A WORLD-WIDE ECOLOGICAL REVOLUTION

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Abstract. This paper presents a global overview of the current status of aquaculture in 2010. Intensive development of aquaculture compared with fishery capture was due to an increase in world population and a stagnation of fishery capture. The comparative fish capture and aquaculture productions were presented at world level and by region. A top ten of world and European countries involved in aquaculture, the main species used in aquatic controlled growth systems, the global human consumption and per capita food fish supply, the importers and exporters of fish and fishery products were also considered. The contribution to the nutrition security, the great expense involved in research and application of biotechnologies, increase the number of jobs and services, need for environmental and biodiversity preservation provide to aquaculture the status of a world-wide ecological revolution.

Key words: World and Romanian aquaculture, fish cage aquaculture, per capita food fish supply.

Introduction

1. **Why Aquaculture?** Because waters represent two-thirds of the earth's surface, providing a lot of new and important food resources.
2. **Why revolution?** Because at a point in the human history has moved from hunting of animals to cultivation of them, as a new food source.
3. **Why at global level?** Because the nutrition security is global required.
4. **Why ecological revolution?** Because the efficiency of aquaculture is possible only preserving the quality of environment and biodiversity (Natura 2000).

These motivations arise from the next considerations (FAO, 2012):

- the human population reached seven billion people, requiring new sources of food;
- the world fishery capture during the last two decades is stagnant at 90 million tonnes;
- the aquaculture production (fish, crustaceans and molluscs) is continuous increasing, reaching 60 million tonnes in 2010, with an economic value of 119 billion US$;

- the number of aquatic species grown in controlled systems have reached 600, in 190 countries;
- the global human consumption is 128.3 million tonnes, with 18.4 kg per year per capita food fish;
- more than 16 million people work in aquaculture.

World aquaculture

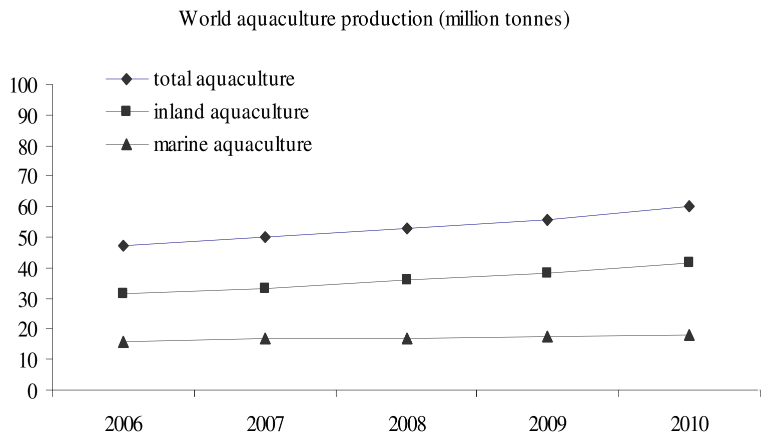

Figure 1. World aquaculture production (2006-2010) (FAO, 2012).

Fig. 1 illustrates an increase in world aquaculture production of fish, crustaceans and molluscs, reaching now about 60 million tonnes. The inland aquaculture is about 40 million tonnes, and the marine aquaculture is about 20 million tonnes. The motivation consists of an increase in human needs for food.

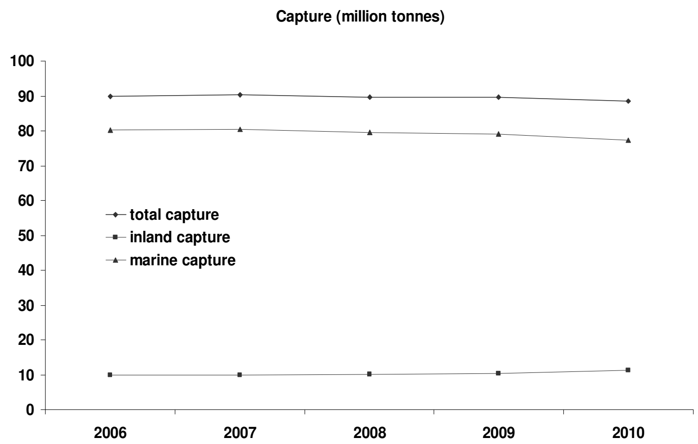

Figure 2. World fisheries production (2006-2010) (FAO, 2012).

Fish global capture production (Fig. 2), between 2006 and 2010, continues to remain stable at about 90 million tonnes. Marine waters ensure a fisheries capture production of 77.4 million tonnes and the inland waters contribute with 11.2 million tonnes.

This stable world fishery is based on the overfishing.

Since 1975, Bonnefous has been observed that:

- the capture uses abusively the fish stocks;
- the capture not preserves the ecological equilibrium of flora and fauna;
- costs involved in the fish capture are greater than the benefits.

The regions with a highest capture fish production are Northwest Pacific and Northeast Atlantic.

Concerning fishery production per fisher or fish farmer, in 2010, at world-wide level, this was about 2.3 tonnes per person per year by capture and 3.6 tonnes per person per year by aquaculture.

There are great differences of fishery production per fish farmers: Africa – 8.6 tonnes per person, China – about 7 tonnes and Norway - 187 tonnes per person.

The human consumption of the world fishery production obtained by capture and also by aquaculture is about 128.3 million tonnes of the total production (145.5 million tonnes). The difference is represented by non-food uses.

Per capita food fish supply presents an increasing trend, reaching now an average rate of 18.6 kg per year. In the industrialized countries, per capita food fish supply is about 28.7 kg per year, and in African countries is 9.1 kg per year. In Latin America and Caribbean, the per capita food fish supply is 9.9 kg per year.

According to FAO, 2012, the average rate of the world per capita food fish consumption increased from 9.9 kg in the 1960s to 11.5 kg in the1970s, 12.6 kg in the 1980s, 14.4 kg in the 1990s, 17 kg in 2000s and 18.6 kg in 2010.

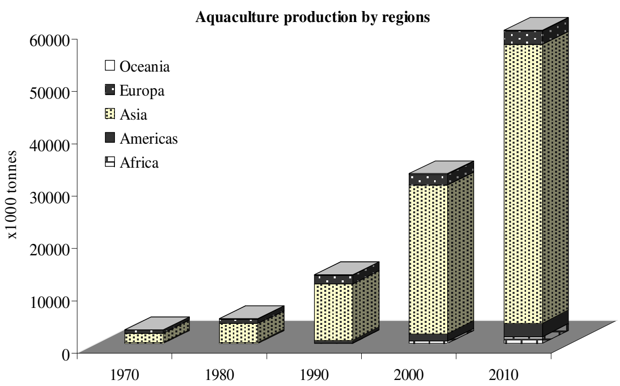

Figure 3. The aquaculture productions by regions (the 1970s-2010) (FAO, 2012).

The highest per capita fish consumption is in China – 31.9 kg; between 1990 and 2009, the increase of the average annual rate was 6 % per person. The proteins and micronutrients from fishery products are very important for human health. In 2009, 16 % of world population assured the animal proteins of fish.

The most important aquaculture productions (Fig. 3) are counted in Asia, about 53 million tonnes, China giving 36 million tonnes, followed by the American countries with 2.5 million tonnes from which the North America gives 656000 tonnes, the Europe with 2.5 million tonnes from which the EU countries give 1.25 million tonnes and non-EU countries with 1.25 million tonnes. The African countries give 1.288 million tonnes.

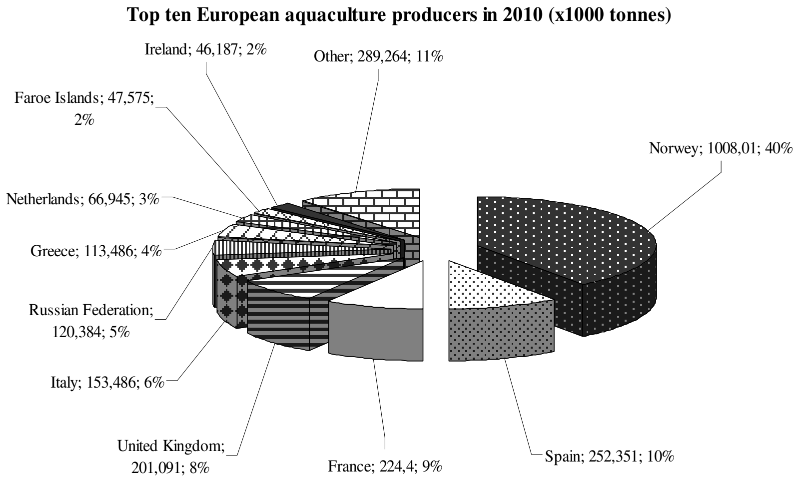

Figure 4. Top ten European aquaculture producers in 2010 (FAO, 2012).

Between the first ten European countries showing the most important productions in aquaculture, the Norway gives about 1 million tonnes of fish. Tacon and Halwart, 2007, consider that the Norway is the first country in the world that applied the fish cages system, in 1971. The factors that favoured this system are represented by an optimal water temperature induced by the Gulfstream and an appropriate relief of fiords, protecting the fish cages from the destructive action of waves.

Norway is followed by Spain, France, the UK, Italy, Russian Federation, Greece, Netherlands, Faroe Islands, Ireland and others.

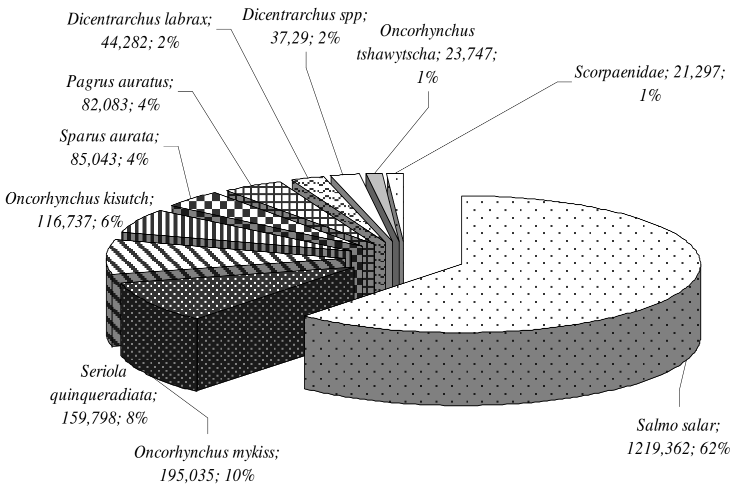

Figure 5. Top ten species/taxa in marine and brackish water cage aquaculture (Tacon and Halwart, 2007).

Fish species with the most important production in cage aquaculture system, excluding the China, are illustrated in Fig. 5. The most important production belongs to *Salmo salar,* with 1.2 million tonnes, becoming especially from the Norway. Three trout species (*Onchorhynchus mykiss, O. kisutch* and *O. tshawytscha*), from cage aquaculture, realized also an important production - about 335000 tonnes.

Sturrock *et al.,* 2008, show that the time necessary for introduction of a new species into an aquaculture system, until the commercial flow, is about ten years.

Bostock *et al.*, 2008, estimate that the European aquaculture production will increase until 2025 at 3.4 million tonnes, with about one million tonnes more than the productions in 2010.

The most important top ten importers of fish and fishery products in 2010 (billion US$) are USA with about 15.5, Japan with 15, Spain with 6.6, China with 6.1, France with 5.9, Italy with 5.4, Germany with 5, UK with 3.7, Sweden with 3.3 and Republic of Korea with 3.1.

The most important top ten exporters of fish and fishery products in 2010 (billion US$) are China with about 13, Norway with 8.8, Thailand with 7.1, Viet Nam with 5.1, USA with 4.6, Denmark with 4.1, Canada with 3.8, Netherlands with 3.5, Spain with 3.3 and Chile with 3.3.

Romanian aquaculture

The Romanian aquaculture productions have the same motivations with those presented in the world:

- the decrease of the fish capture;
- the increase for the food based on fish.

In the Operational Programme for Fishery, Romania, 2007-2013, there are specified the following productions, obtained by capture and aquaculture, in 2005:

- the fish capture in the Black Sea: 2026 tonnes compared with 16000 tonnes, in 1989;
- the Romanian oceanic fish capture: 142000 tonnes in 1989, stopped in 1993;
- the fish capture in inland waters: 4000 tonnes compared with 9000 tonnes in 1995;
- extensive aquaculture provides 7248 tonnes, compared with 50000 tonnes in 1989 (*Cyprinidae* – 85%; trout – about 15%);

The fish requirement on the internal consumption, in 2005, was about 92696 tonnes, of which 79422 tonnes was imported and only 13274 tonnes come from internal production. Per capita food fish consumption was 4 kg in 2005, compared with 18.6 kg on the world level.

Considering the trout in Romania, it is evident a production about 1000 tonnes, obtained from the 25 hectares salmon water.

Compared with the aquaculture in other European countries, i. g. Norway with 1 million tonnes, and Spain, France and UK with 200000 tonnes each of them, Romania unregistered insignificant values for the trout production.

This work presents a possibility to extend the trout intensive aquaculture in cage system on the hydroelectrical reservoirs, already made in Romania. In Tab.1 there are only the main reservoirs, with a total surface of 8333 hectares, compatible with this biotechnology.

As a case study, the Bicaz reservoir, the largest of the mountainous reservoirs from our country, during the last five decades, was used for experimentation and for application in production of intensive growth of trout in fish cages. This biotechnology corresponds to the Integrative System of Aquaculture elaborated by Ackefors and Rosen, 1979, completed by Miron *et al.,* 1983, with a limited production without ecological disequilibrium, assuring a preservation of the water quality and biodiversity.

The previously presented national Programme not specified the capture and aquaculture productions belonging to the great hydroelectrical reservoirs, even though they represent about 8000 hectares. Applying the fish cage aquaculture system on these reservoirs, it could be possible to obtain about 16000 tonnes trout per year.

For this propose, Miron *et al.*, 1983, have been published a work for implementing the intensive trout aquaculture in the Bicaz Reservoir, the largest of Romania, beginning with the 1960s.

In the first step of experimentation of this aquaculture system, an ecological diagnosis of this ecosystem has been elaborated, analyzing the abiotic factors (Miron and Crăciun, 1968), and the biotic factors: phytoplankton (Cărăuş, 1965; Cărăuş, 1973), zooplankton (Miron and Grasu, 1964), zoobenthos (Miron, 1965; Miron, 1968), bacterioplankton (Măzăreanu, 1968), nekton (Miron, 1961; Battes, 1970; Battes *et al.*, 1971).

It was established an oligotrophic status of the Bicaz reservoir, with the next trophic network: phytoplankton (6000 tonnes), zooplankton (600 tonnes), small fish (60 tonnes) and predator fish (*Salmonidae* – 6 tonnes). Considering this surface of the 3000 hectares of the Bicaz reservoir, a production of 2 kg trout per hectare per year could be obtained by capture, far below market demands. Considering this ecological diagnosis, the most suitable species for this intensive growth was the rainbow trout (***Onchorhynchus mykiss***), with ecological valences larger than the river trout (***Salmo trutta fario***).

After 50 years of building the Bicaz reservoir, the bioproduction in the natural trophic network recorded only 50 % of the initial production (Miron *et al.,* 2010).

In the second part of this research was experimented the trout behavior in captivity in fish cages, from different points of view: reproductive (Miron, 1970; Miron and Battes, 1972), nutritional (Misăilă *et al.*, 1979; Misăilă *et al.*, 1983); and territorial ethology (Miron, 1971; Morariu *et al.*, 1972). Biochemical and ecophysiolgical research on the rainbow trout was also made, in intensive growth conditions in reservoirs (Artenie *et al.*, 1972-1973).

It becomes thus possible the experimentation and application of the biotechnology of intensive growth of trout in floating fish cages on the hydroelectrical mountainous reservoirs (Miron *et al.,* 1984).

This third step of the aquaculture production system has required new technical solutions, patented as inventions: the structure and functioning of the trout floating farms on the reservoirs (Miron *et al.*, 1988, Fig. 6, 7 and 8); the development of the juveniles (Miron *et al.*, 1975); optimizing growth rate of trout (Miron I., and Miron L., 2006); the pellet feed efficiency (Misăilă *et al.,* 1983); installation for the plankton collection (Miron L., and Miron I., 2006).

Figure 6. The trout floating farm on the Bicaz reservoir.

Figure 7. Ploscaru floating farm on the Bicaz reservoir.

Figure 8. The Vodă trout fish farm on the Bicaz reservoir.

Table 1. Main reservoirs from Romania providing trout aquaculture potential (A-hydroameliorations and industrial use, H-hydroenergy, E-eutroph, M-mezotroph, O-oligotroph) (Miron *et al.,* 2010).

Nr	Reservoir	Catchment	Surface (ha)	Maximum depth (m)	Trophic state	Use	Aquaculture surface (ha)
1	Poiana Uzului	Trotuş	335	75	O	A	6.7
2	Leşu	Crişuri	147	56	O	A	2.9
3	Gozna	Bârzava	260	40	O	A	5.2
4	Secu	Bârzava	150	30	O	H	3
5	Trei Ape	Bega-Timiş	53	30	O	H	1.06
6	Fântânele	Someş	990	92	O	H, A	19.8
7	Gilău	Someş	70	10	O	H	1.4
8	Tarniţa	Someş	215	97	O	H	4.3
9	Valea lui Iovan	Cerna	296	107	O	H	5.92
10	Cerna	Cerna	261	40	O	H	5.22
11	Valea de peşti	Jiu	31	53	O	H	0.62
12	Vidra	Lotru	1035	109	E	H	20.7
13	**Bicaz**	**Bistriţa**	**3000**	**92**	**O-M**	**H**	**60**
14	Bâtca Doamnei	Bistriţa	235	15	E	H	4.7
15	Pângăraţi	Bistriţa	155	15	E	H, A	3.1
16	Vaduri	Bistriţa	115	15	E	H	2.3
17	Sadu	Sadu	72	58	E	H	1.4
18	Vidraru	Argeş	893	155	E	H	17.8
19	Petrimanu	Lotru	20	48	E	H	0.4
Total			**8333**				**166**

The trout production in these farms (Fig. 6, 7 and 8), in addiction to the trout farm on the Brădişor reservoir, represents about 400 tonnes trout per year. The spreading of the trout growth biotechnology on these 166 hectares (representing 2 % from total surface of these reservoirs) available for this aquaculture system, with the natural ecological equilibrium preservation, could lead to about 16000 tonnes of trout per year.

There are not available data in 2010 concerning the fish aquaculture production on the Romanian shore of the Black Sea. The unfavourable structure of this shore for the floating cages farms application impose the use of the rigid submersible cages, made in USA, by Farmocean and Ocean Spar Sea Station (Sturrock *et al.,* 2008).

Considering the mussel aquaculture production, we recommend the application of the Invention Brevet 116761 B, OSIM, Romania (Miron *et al.,* 2001).

Conclusions

At world level, reporting to 2010 data, the fish capture production is stagnant during the last two decades, at about 90 million tonnes. The aquaculture production is increasing, reaching 60 million tonnes.

In Romania, reporting to the existing data in 2005, the fish capture production is about 2000 tonnes in the Black Sea and 4000 tonnes in inland waters, showing an dramatic value comparable with 1989, when 25000 tonnes have been available.

The production of the extensive aquaculture in inland waters is about 7200 tonnes from which 85 % carp and 15 % trout.

Per capita food fish consumption in Romania (2005) was about 4 kg, compared with 18.6 kg at the world-wide level or 28.7 in developed countries.

The production of the intensive trout aquaculture in fish cages on the mountainous reservoirs could reach about 16000 tonnes.

The sustainable aquaculture is possible only using an ecosystemical approach, assuring in the same time the production and also the preservation of the environment and biodiversity (Nature, 2000).

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