Deliverable 2 (SustainAQ)

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Summary

The EC funded project consortium SustainAQ (institutes, universities and aquaculture SMEs) investigated the status of aquaculture production in Europe, with a particular focus on six Eastern-European countries. The overall objectives of this research project are: (1) to identify limiting factors restricting sustainable production of seafood in Europe, with particular focus on use of recirculation systems (RAS) to overcome these issues; (2) share information concerning the different recirculation systems used in European countries in order to establish the state of the art of existing knowledge. This paper presents the research process and findings of this analysis. The research process consisted of two subsequent steps; (1) identify and evaluate for each partner country the issues hampering sustainable development in the specific national situation (see inventory www.sustainaq.net); (2) selection of three generic case studies to evaluate if the introduction of RAS would improve the overall sustainability of the production process. Financial feasibility was evaluated for each case study using cash-flow projections.

Step 1. Information on aquaculture stakeholders and production in the related Eastern European Countries were collected covering the whole range from national level to farm level and from low tech earthen ponds to highly intensive RAS. Based on the identified and evaluated issues sustainability indicators were identified. These indicators were categorized either as economical, ecological, social or as governance aspect of sustainability. Some of the indicators can be categorized as intermediate. Each sustainability indicator was analysed in its specific national setting. Potential solutions with respect to the introduction of RAS into the production process were evaluated.

Step 2. Based on the inventory, three case studies were designed to show exemplary if the introduction of RAS would improve the overall sustainability of the production process and resolve the case study related issues/indicators hampering sustainable production. For each case study the sustainability indicators have been evaluated. The case studies were focussing on 1) the production of seabass in RAS (broodstock – fingerling) in combination with cage culture depending on the desired final market weight (350g, 600g, or >1kg), 2) the production of sturgeon in RAS for its entire life cycle and 3) the production of carp in RAS for earlier life stages combined with ponds for on-growing. The case studies were selected on representativeness production volume (1 and 3) and generated value (3) . Based on issues hampering sustainable fish production in six Eastern European countries 33 indicators were identified For 21 of these indicators a solution was found, some of them speculative (as those system/system combination do not exist in that country) and highly depending on local conditions and the interaction of RAS introduction with other changes, e.g. in governance. Strong drivers for the application of RAS in the sea bass, sturgeon and carp case studies was the prospect for improved biosecure conditions, less predation, improved temperature and photoperiod control, higher growth and a higher and more efficient production. Mainly economical and ecological issues are resolved in relation to resources (e.g. water, energy, waste) biological parameters (e.g. growth, feed efficiency, predation, hygiene management, and mortality) and stakeholder conflicts (land and water). The financial projections show that net profit depends on local conditions, including the available market. In case 1 and 3 the RAS system is only used seasonally. This is economically not profitable. However, if alternative species can be cultured this might change the economical sustainability. The combination of traditional culture methods (flow though systems, cages or ponds) with recirculation aquaculture systems, improves several sustainability indicators of aquaculture in Eastern European countries. However, RAS introduction cannot resolve all issues limiting aquaculture development in those countries. Several aspects are related to social and governance frameworks and are not to be resolved on that level. Future research on commercial and/or experimental scale is needed to evaluate the benefits of RAS introduction for the improvement of the sustainability of fish production.

Contents

1 Abbreviations

	Abbreviation	Meaning
Currencies	*€*	*Euro/s*
	USD or US$	*American dolar*
	Ft	*Hungarian forints, code and symbol, respectively*
	YTL	*Yeni Türk Lirası (New Turkish lira). From 2009, its official name becomes just "lira", abbreviated "TL".*
Prefixes for the International System (SI) units of measure	*h, k*	*hecto-, kilo-*
	d, c, m	*deci-, centi-, milli-*
Length units	*m*	*Meter/s*
Area units	*ha*	*Hectare*
	Sq. m	*Square meter/s*
Volume units	*L*	*Litre or Liter/s*
	Cub. m/m³	*Cubic meter/s*
Weight units	*g*	*Gram or Gramme/s*
	t or mt	*Tonne/s or metric tonne/s*
Energy units	*J*	*Jule/s*
Power units (electricity)	*W*	*Watt (W=J/s)*
Time units	*y or yr*	*Year/s*
	d	*Day/s*
	h	*Hour/s*
	min	*Minute/s*
	s	*Second/s*
Numeric units	*M*	*Million*
Calendar months	*Jan., Feb., Apr., Aug., Sept., Oct., Nov, Dec…*	*January, February, April, August, September, October, November, December…*
Geometric symbols	*r*	*Radius*
	h	*Height*
	∅	*Diameter*
Temperature units	*°C*	*Celsius degrees*
Sustainability categories	*Ecol.*	*Ecology/ ecological*
	Econ.	*Economy/ economic*
	Gov. or Govern.	*Governance*
	Soc.	*Social*
Aquaculture production systems	*FT*	*Flow-Through*
	RAS or RS	*Recirculating Aquaculture System or Recirculating System*
Fish groups or species	*C. carp*	*Common carp*
	Muss.	*Mussel/s*
	Oyst.	*Oyster/s*
	Stur. or Sturg.	*Sturgeon/s*
	s.n. seabream	*Sharpsnout seabream*
Basics terms	*AQ*	*Aquaculture*
	Bw	*Body weight*
	COD	*Chemical Oxygen Demand*
	CS	*Case Study*
	FCR	*Food Conversion Ratio*
	fw	*Freshwater*
	KHV	*Koi Herpes Virus*
	OM	*Organic matter*
	Q_r	*Flow rate*
	Q_e	*Water exchange*
	SME	*Small-Medium Enterprises*
	Sp. and spp.	*Species (sg.) and species (pl.)*
	sw	*Seawater*
	WP	*Work Package*
	WQ	*Water Quality*
Chemical elements	*N*	*Nitrogen*
	P	*Phosphorous*

Chemical compounds	CO_2	*Carbon dioxide*
	N_2	*Nitrogen*
	O_2	*Oxygen*
Economic terms	*CBA*	*Cost Benefit Analysis*
	IRR	*Internal Rate of Return*
	NPV	*Net Present Value*
	RR	*Rate of Return*
Writing and text marks	*Approx.*	*Approximately*
	Avg.	*average*
	e.g.	*"for example"*
	Fig.	*Figure*
	Gral	*General*
	i.e.	*"that is"*
	Num.	*Number*
	Obs.	*Observations*
	Pl.	*Plural*
	PP	*Power Point presentation*
	p. or pp.	*Page/s*
	Ref.	*Reference*
	Respect. or respectiv.	*Respectively*
	Rg.	*Range*
	Sg.	*Singular*
	Vol.	*Volume*
Others	*Administr.*	*Administration*
	Bottlen.	*Bottleneck*
	Cap.	*Capacity*
	Co.	*Company*
	Conds.	*Conditions*
	Czech Rep.	*Czech Republic*
	E	*Energy*
	Electr.	*Electrical*
	Envir. or env.	*Environmental*
	Hold.	*Holding*
	Juv.	*Juvenil/s*
	m/f	*Male/female*
	Occ. (labour)	*Occasional (labour)*
	Perm. (labour)	*Permanent (labour)*
	Plc.	
	MARA	*Ministry of Agriculture and Rural Affairs (Turkey)*
	Mort.	*Mortality*
	Ltd or Ltd.	*Private company limited by shares*
	Op. costs	*Operating costs*
	Prod. Or product.	*Production*
	Productiv.	*Productivity*
	Seabass Jr.	*Seabass Juniors*
	SRL or S.R.L.	*Private Limited Company*
	Sustain.	*Sustainability*
	T or temp.	*Temperature*
	UFT	*United Food Technologies AG*
	UNEP	*United Nations Environment Programme*
	VAT	*Value Added Tax*
	Vet.	*Veterinary*
	Vol.	*Volume/s*

2 Introduction

The European Project SustainAQ (Framework 6) aims to identify the limiting factors for the sustainable production of aquatic origin food in Eastern Europe. It focuses on the possible use of Recirculation Aquaculture Systems (RAS) as sustainable method for the production of aquatic animals as mentioned in the communication of the European Commission on Aquaculture in 2009. RASs already exist mainly in western countries and proved economically feasible (Schneider et al., 2006). RASs allow controlling the production process including effluents, biosecurity and escapes. Eastern European countries are facing challenges related to their excessive water use waste emission, and others. Therefore, these countries are potential beneficiaries of improved sustainability through RAS use. This project intends to assess the benefits of introducing and applying RAS for Eastern European aquaculture. This project involves three Western European countries (Norway, the Netherlands and France) and six East European countries (Croatia, Turkey, Romania, Hungary, Czech Republic and Poland). Ten research institutions collaborate in different tasks (coordination, data collection, data analysis, etc.), and nine small-medium enterprises (SME) participate in data mining (Table 1). The present data is therefore based on the situation in those countries during 2006 till 2008 before the report got finally compiled in 2008/2009.

2.1 Definitions

To major terms will be used in this document: Sustainability and recirculation aquaculture systems (RAS). These terms need to be defined to avoid misunderstandings and misinterpretations of the present study.

2.1.1 Sustainability

The dimensions of sustainability are often taken to be: environmental, social and economic, known as the "three pillars" (United Nations, 2005). These can be depicted as three overlapping circles (or ellipses), to show that they are not mutually exclusive and can be mutually reinforcing (Uk Forestry Commission, 2008). While this model initially improved the standing of environmental concerns (Ott et al., 2003), it has since been criticised for not adequately showing that societies and economies are fundamentally reliant on the natural world: "*The economy is, in the first instance, a subsystem of human society ... which is itself, in the second instance, a subsystem of the totality of life on Earth (the biosphere). And no subsystem can expand beyond the capacity of the total system of which it is a part*" (Porrit, 2006). The three overlapping circles are often extended by a fourth one "Governance". A simpler definition is given by the IUCN, UNEP and WWF (1991): Sustainability is "*improving the quality of human life while living within the carrying capacity of supporting eco-systems*." The evolution of thinking about sustainability has paralleled historical events that have had a direct impact on human global sustainability. CONSENSUS (a multi stakeholder platform for sustainable aquaculture in Europe) defined in 2006 several sustainability indicators in a ranking from one to three, in three categories: economic, environmental and social, one not excluding the other (EAS, 2007). Public awareness and acceptance, consumer confidence, local integration, public perception, local community satisfaction, consumer satisfaction, fish health control, welfare index, attractiveness of a job, and education/training among others, were classified as social indicators. Sustainable aquaculture generally adopts this approach (Figure 1). Environmentally, aquaculture must reduce the consumption of scarce resources. Aquaculture has to have few or none adverse impacts on the ecosystem, and maintain biodiversity (Ross *et al.*, 2008). Economically, aquaculture needs to be profitable to be continued over the time with profit. In social terms, aquaculture must create livelihoods, improve human wellbeing and equity for all stakeholders, and it needs to be integrated with other production sectors (Ross *et al.*, 2008). Other criteria comprise ethical, biotechnical or governance approaches. This concept can as well be translated in the generally known framework of the three P's (Planet, Profit, People).

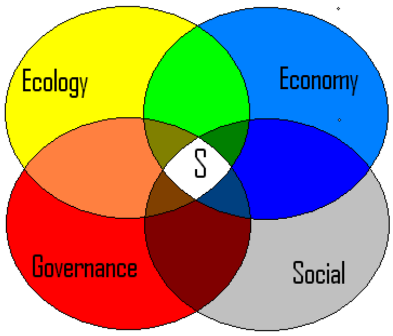


Figure 1: Scheme representing different aspects of the sustainability and their interactions

Table 1: Research institutions from each country taking part on the project

Countries	Research institution (RI)	Species cultured
Norway	Nofima Marine	
Netherlands	Wageningen IMARES Aquaculture and Fisheries Group, Wageningen University	
France	Ifremer	
Croatia	Institute of Oceanography and Fisheries	
Turkey	Trabzon Central Fisheries Research Institute	
Romania	"Dunarea de Jos" University of Galati	
Hungary	Research Institute for Fisheries, Aquaculture and Irrigation	
Czech Republic	University of South Bohemia Ceske Budejovice, Research Institute of Fish Culture and Hydrobiology	
Poland	Polish Academy of Sciences, Institute of Ichthybiology and Aquaculture	
Norway	Villmarksfisk	Arctic char (*S. alpinus*)
France	Comité Interprofessionnel des Produits de lÁquacultur	
Croatia	Maring D.O.O. Seabass Juniors	Seabass/bream Seabass/bream
Turkey	Idagida Ltd Kilic Akvuatek	Seabass Seabass/bream Seabass/bream
Romania	Kaviar House SRL Giarmata Compania de Management Singama Pesco Carja	European Sturgeon Siberian Sturgeon European Sturgeon Several pond spp Cyprinids
Hungary	Innoflex Ltd. Forus Ltd. Shubunkin Fish Production Ltd. Kovacs Antal Jáskiséri Halas Ltd. Szabó Tomorkény Aranyponty Plc. Szeged Fish Ltd.	African catfish Russian sturgeon Carps, catfishes, starlet & ornamental Common carp 70% Common carp 70% Common carp 70% Common carp 85% Common carp 85% Common carp 80%
Czech Republic	Pohorelice Fisheries Co. Kinsky Fisheries Co. APH ponds Breclav Ltd. Ivan Jaros Pansky	Common carp Common carp Common carp Common carp Common carp

Countries	Research institution (RI)	Species cultured
Poland	Golysz	Common carp 90%
	Przyborow	Common carp 90%
	CHRIST sp z.o.o.	Cyprinids

2.1.2 RECIRCULATION, RECIRCULATING or RECIRCULATED AQUACULTURE SYSTEMS (RASs)

RASs are systems used for the production of aquatic organisms which re-use water over and over. This is possible by water purification and oxygen provision. Martins *et al.* (2005) define RASs as land based aquatic systems in which water is re-used after mechanical and biological treatment in an attempt to reduce the needs for water and energy and the emissions of nutrients to the environment. In RASs (Figure 2 and Figure 3) an efficient water treatment system is required, consisting of several units (Box 1):

1. unit for the removal of waste solids (faeces and uneaten feed)
2. unit for the conversion of ammonia into a non toxic form of dissolved nitrogen
3. unit for the removal of carbon dioxide from the water
4. unit for the addition of dissolved oxygen to the water
5. unit for disinfection

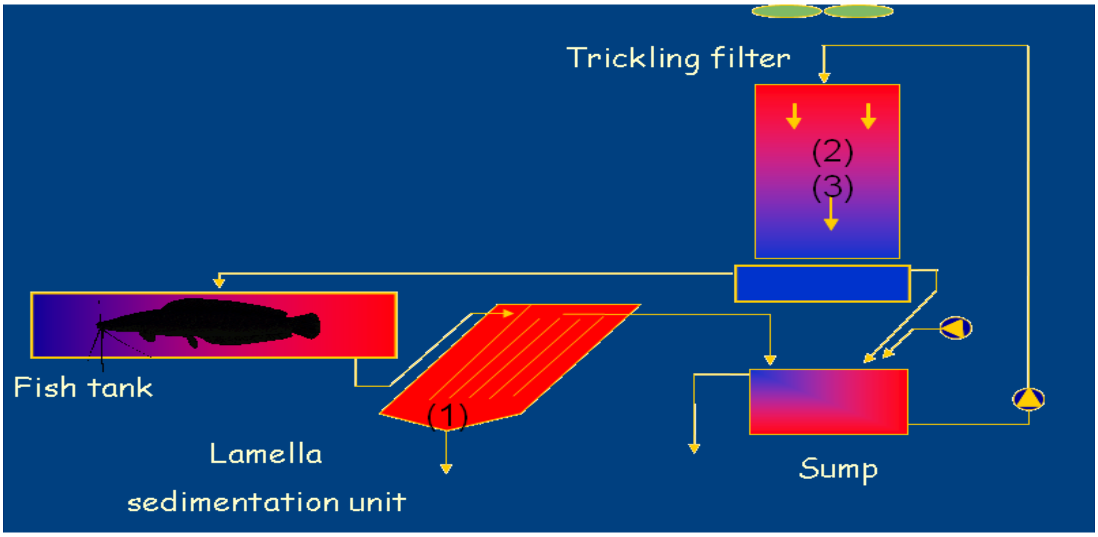


Figure 2: Schematic representation of a commercial RASs for the production of catfish in The Nederlands (Modified from Schneider *et al.*, 2008: "Cost prices and production strategies in European recirculation systems", PP). Scheme after Eding and van Weerd (1999). Numbers correspond to the water treatment units exposed above

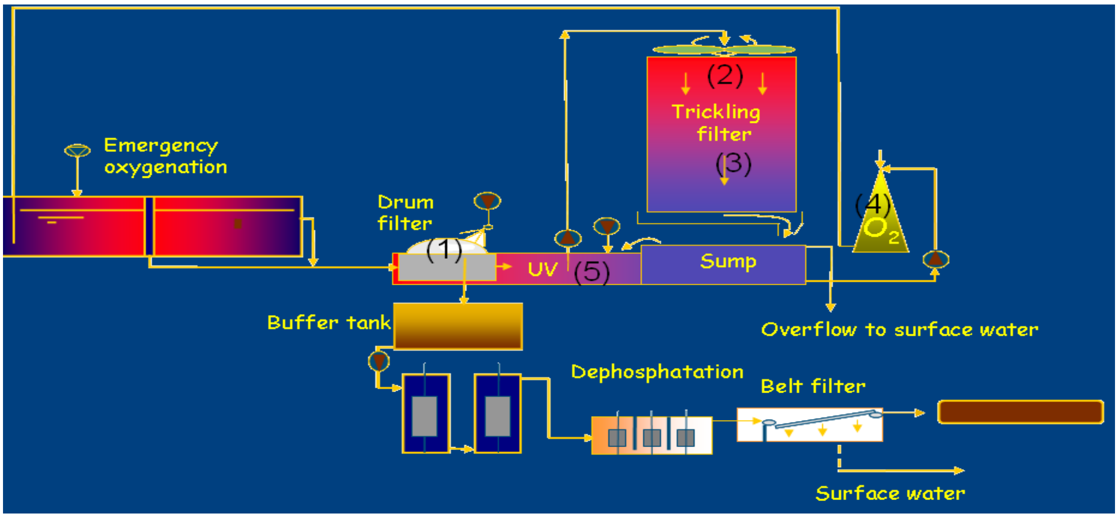


Figure 3: Schematic representation of a commercial RASs for the production of eel (Modified from Schneider *et al.*, 2008: "Cost prices and production strategies in European recirculation systems". Scheme after Eding). Numbers correspond to the water treatment units exposed above.

Box 1: Description of the main wastes, deficiencies and threats in the aquaculture systems, and processes or devices used in RASs to correct them (Losordo *et al.*, 1998, Losordo *et al.*, 1999, Schneider et al., 2008). Numbers in brackets correspond to the water treatment units described above.

(A) WASTES GENERATED, (B) REQUIREMENTS IN THE WATER, & (C) THREATS IN THE WATER	PROCESS OR DEVICES USED FOR CORRECTION OF THE WATER POLLUTANTS, DEFFICIENCIES OR THREATS
(A)	
•Solids –Suspended -Non-Fine –Settleable	(1) Sedimentation tank, mechanical filter (granular or screen), swirl separator
–Non Settleable	(1) Mechanical filter (granular -sand or pelleted media- or screen)
-Fine (<30µ)	(1) Foam fractionation (protein skimming)
–Dissolved	(1) Foam fractionation (protein skimming)
•CO_2	(3) Air stone diffuser, Packed column
•NH_3/NH_4^+	(2) (Nitrification): Fluidized bed filters, Expandable media filters, Mixed bed filters, Tricking filters, Rotating bio contactor.
(B) Oxygen	(4) Air stone diffusers, Packed column, Down-flow contactor, Low-head oxygenator, U-tube
(C) Pathogens, bacteria	(5) (Disinfection): UV light, Ozone contact

As any system, RASs have advantages and disadvantages which make them more or less suitable for an aquaculture activity, depending on the particular situation (Martins *et al.*, 2005, table 2):

Table 2: Advantages and disadvantages of RAS after Martins et al., 2005

ADVANTAGES	*DISADVANTAGES*
Water saving	High capital costs
Less land requirement	High operational costs
Energy saving	Requirement for very careful management (highly skilled labour forces)
Rigorous control of the water quality	Difficulty for treating disease
Low environmental impacts	
High biosecurity levels	
Easier control of waste production	

Advantages of RASs compared to traditional pond and flow-through systems can be quantified in relation to water use, waste discharge and productivity (table 3).

Table 3: Water use, waste discharge and productivity of the aquaculture production systems (Schneider, RAS course, Spain (2008))

System	*Water use (L/kg fish)*	*Waste discharge (ghCOD/ kg fish)*	*Productivity (mt/ha/year)*	*Treatment approach*
Pond	2,000	286	10-15	Ecological
Flow-Through	14,500-210,000	780	Variable	partly technical
RAS	100-900	150	300-2,500	Technical

RASs are also called "closed" systems; however, currently a perfectly "closed" RAS at commercial scale has not been developed. Although some authors have reported about systems at experimental scale (Menasveta *et al.*, 2001; Shnel *et al.*, 2002; Waller *et al.*, 2003; Suzuki *et al.*, 2003; van Rijn *et al.*, 2006). Water is still consumed. The water consumption is water to compensate for evaporation, incidental losses and sludge discharge. System water exchange is reported sometimes as percentage of the total system volume replaced per day (Timmons et al., 2007). RAS have then a water exchange of about 10 % (Menasveta *et al.*, 2001). Systems with 10% or more water exchange are as well referred to as "semi-closed" (www.seafood-norway.com). However, a more adequate unit to measure the level of water replacement is m^3/kg feed, as this relates to the pollution unit feed including solids, COD, N and P (Eding et al., 2000), or m^3/kg fish produced (Shnel *et al.,* 2002). Some work done on the incorporation of denitrification units to eliminate nitrates through conversion into atmospheric nitrogen (N_2) (Menasveta *et al.*, 2001; Shnel *et al.*, 2002; van Rijn *et al.*, 2006; Suzuki *et al.*, 2003). RASs are considered a sustainable option for aquaculture as they reduce the consumption of environmental resources and waste discharge. There is still water consumed and waste emitted. If this discharge is released without appropriate processing, dissolved phosphorous (P) and nitrogen (N) and organic loads (COD) pollute the environment and lead to eutrophication. Sludge (from mechanical filters effluent and biomass sludge from biofilters) forms another environmental threat if released untreated. There are several treatment techniques to cope with solid and dissolved waste fractions (Figure 4). For the treatment of dissolved wastes (N, P and organic matter) in wastewaters, e.g. artificial wetlands can be used. Solid waste (sludge) is commonly stored in settling basins and septic tanks, or it is processed in digesting tanks through anaerobic processes. It can be as well utilized as fertilizer, or be composted (Suzuki *et al.*, 2003; Miller and Semmens, 2002; Timmons er al., 2007; www.fao.org[1]). It can be converted by detritivorous, such as worms (Schneider et al., 2006), or it can also be derived to fuel additional microbial processes whose activities result in the production of methane gas, which can be captured and used as a energy source (www.umbi.umd.edu).

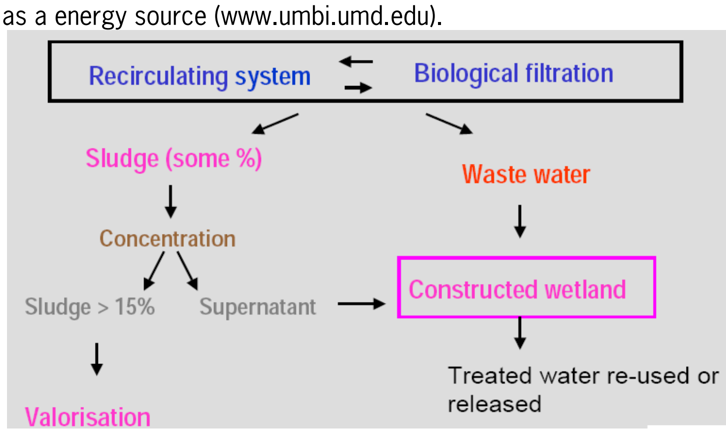


Figure 4: Representation of aquaculture wastes and some management procedures. (Blancheton, RAS course, Spain 2008)

RASs can be applied for hatcheries or for the on-growing phase. RAS are still a small fraction of Europe's aquaculture production systems. They are mainly applied in the Netherlands and Denmark. Other countries that have introduced RAS are Belgium, Estonia, Finland, France, Germany, Greece, Italy, Norway, Portugal, Spain, Sweden and UK; from the Eastern European countries, Hungary, Bulgaria, Croatia, Czech Republic, Moldova, Poland, Romania, Turkey and Ukrania have introduced RASs to some extent. The main species produced in RASs are catfish and eel, next to turbot, seabass, seabream, pikeperch, tilapia, sole, Artic charr, sturgeon, salmon and trout (Martins *et al.*, 2005). Recent changes in Denmark have lead to an increase of trout production in outdoor RAS systems.

3 Project structure

SustainAQ was structured in three work packages (WP) with different complementing tasks and objectives. In WP1, the partner research institutions of the six Eastern European countries generated a document with a shared view on:

- the situation of the aquaculture sector in their respective country,
- the problems hindering the development of the activity,
- the possible contribution of RAS to overcome the identified obstacles.

Considering the preliminary information about the points mentioned above. After a first workshop in Hungary in December 2007, it was decided to select three “case studies”, representative of aquaculture in Eastern Europe to analysis the benefits of RASs application (WP2). All information about aquaculture in the six Eastern European countries and the defined case studies have been collected, processed and presented in: “WP1: Situation of aquaculture in partner countries, main bottlenecks and identification of the case study farms” by IFREMER (2008). Based on the outcome of WP1, WP2 1) evaluates the suitability of existing RAS techniques to solve problems identified under WP1, in relation to local conditions and fish species, and in terms of sustainability and 2) determines necessary technology adaptations to local conditions.

4 Case study definition

For the assessment of RAS benefits for Eastern European countries, their present aquaculture were characterized (seabass production, high value species culture, catfish production, cyprinid culture in ponds). Based on this process three generic case studies were developed were designed to be the challenging ones due common issues in aquaculture among partner countries. The case studies are:

- Marine farms, culturing sea bass during hatchery phase and parts of the growing out phase in RAS or cages.
- Freshwater/brackish or marine farms, culturing high value species such as sturgeon. Sturgeon is an endangered species, production aims therefore on meat, caviar and re-stocking
- Freshwater farms, culturing mainly cyprinids (carps and ornamental fish) in ponds (on-growing), keeping pre-growing fish and broodstock in RAS.

The objectives of each case study are based on the specific issues identified in WP 1 (Table 4). Once the case studies were defined, the partners of each one of the six Eastern European countries decided in which case studies they wanted to participate (
Table 5). The partner research institutes taking part in each case study collaborated with representative farms in their respective countries (Table 6).

Table 4: Case study objectives as agreed in WP 1

Case study	*Type of system proposed*	*Application of RAS*	*Objectives and benefits*
Seabass	Marine RS	For broodstock, hatchery & fingerlings pregrowing	• Biosecure safe conditions • Temperature and photoperiod control • Facilitate vaccination
High value spp.	Fresh water/brackish to Marine water RS	For broodstock, hatchery, & ongrowing	• Biosecure safe conditions • Temperature and photoperiod control
Carp	Fresh water	For broodstock, hatchery, & fingerlings pregrowing	• Biosecure safe conditions • Temperature and photoperiod control

Table 5: Case studies selected by each country (X). In brackets, number of farms that completed questionnaires.

	Case studies		
Countries	1	2	3
Croatia	X (1)	X	
Turkey	X (1)	X	
Romania		X (3)	X (2)
Hungary		X (1)	X (6)
Czech Republic			X (5)
Poland			X (2)

Table 6: Collaborating farms contributing with data, for each case study and from each country

Case study	*Name*	*Species*	*Country*
1	Seabass Juniors	Seabass/Seabream	Croatia
1	Maring d.o.o.	Seabass/Seabream	Croatia
1	Akuatek	Seabass/Seabream	Turkey
1	Idagida Ltd	Seabass	Turkey
1	Kilic Su Urunleri Uretimi Iharacat-Ithalat…	Seabass/Seabream	Turkey
2	Compania de management SRL	European sturgeon	Romania
2	Kaviar House SRL	European sturgeon	Romania
2	Giarmata en SRL	Siberian sturgeon	Romania
2	Forus Ltd	Russian sturgeon	Hungary
3	Singama SRL	Several (cyprinids, European catfish, pike, pike-perch)	Romania
3	S.C. Pesco Carja	Cyprinids	Romania
3	Kovács Antal	Common carp 70%	Hungary
3	Jászkiséri Halas Ltd	Common carp 70%	Hungary
3	Szabó	Common carp 70%	Hungary
3	Tomorkény	Common carp 85%	Hungary
3	Aranyponty Plc.	Common carp 85%	Hungary
3	SzegedFish Ltd.	Common carp 80%	Hungary
3	Shubunkin Fish Production Ltd.	Carps, catfish, starlet, ornamental	Hungary
3	Pohorelice Fisheries Co.	Common carp	Czech Rep.
3	Kinsky Fisheries Zdar nad Sazavou Co.	Common carp	Czech Rep.
3	APH ponds Breclav Ltd.	Common carp	Czech Rep.
3	Ivan Jaros	Common carp	Czech Rep.
3	Pansky	Common carp	Czech Rep.
3	Golysz	Common carp 90%	Poland
3	Przyborow	Common carp 90%	Poland

5 Materials and methods

The analysis of the case studies followed a similar procedure for all three studies (Table 7). The procedure is based in presented data and presented issues using a general framework of judgement for sustainability indicators.

Table 7: Procedure followed in each Case Study (CS)

Section	Contents
Introduction	General presentation of the CS
Background information	Base information at country level (aquaculture sector of the countries involved), and about the collaborating farms' activity
Proposal of RAS application	Includes the projection of a representative farm for the CS -with RAS application-, and an economic viability assessment of the projected farm (cash flow analysis)
Qualitative analysis	Qualitative assessment of the proposed RAS application's contribution to overcome the problems affecting the AQ activity
Quantitative analysis	Assessment of quantitative indicators of sustainability for the proposed RAS application
Conclusions, discussion and recommendations	

5.1 Data sources

The data sources have been either literature references or more importantly generated during WP1. The source documents generated during WP1 are:

- Power point presentations from previous meetings or workshop,
- Documents provided by the research institution partners on the generalities of the aquaculture in the country,
- Documents provided by the research institution about the collaborating farms,
- Questionnaires completed by the farmers,
- WP1: Situation of aquaculture in partner countries, main bottlenecks and identification of the case study farms (Ifremer, 2008)
- Literature

5.2 Sustainability issues

During WP 1 the most important and frequent issues affecting aquaculture activities of the six Eastern European Countries have been collected (Table 8). Those issues have been classified into four categories corresponding to "ecological" (environmental), "economical" and "social" indicators. Additionally, the category "governance" has been added, due to the key role that governance has in ruling environmental, economical and social issues.

Table 8: Issues reported by WP 1 categorized in ecological, economical, social and governance indicators of sustainability. Issues with (**) have been put into Ecology , Governance or Social, but have strong economical components Issues with (*) located in Economy have a strong ecological component.

Category	*Issue*
Ecology	Water quality Water availability/use* Wastes (water & nutrient discharge)* Land availability/use*
	Predation* Pathology** Weather conds. (Env. mortality)** Energy use**/cost Low growth rate**

Category	*Issue*
Economy	Feed use (FCR)** Feed cost/supply Lack fingerlings**/quality/cost Genetics/ Breeding selection** Money cost, interest rate Taxes License cost Investment cost Op. costs Cash flow (rate of return) Design issues/System problems Processing Marketing/Label/LAV spp. Market/Market demand Diversification Traceability
Governance	Feed & fertilizer limits/Other legislation Property* Bureaucracy
Social	Labour qualification Tradition Union networks/Lack of cooperation Conflict with other coastal/land stakeholders* Scientific support

5.3 Data evaluation

Data is analyzed using a two-step method. First It is assessed if the existing RAS technology offers a solution for the identified issues (Table 8). If a solution is not provided directly, system adaptations are evaluated based on local characteristics and species. Secondly financial were evaluated. The feasibility analysis of the proposed system was made using cost-benefit analysis over several years of projection. The preliminary analysis follows a sequence of decisions (Figure 5).

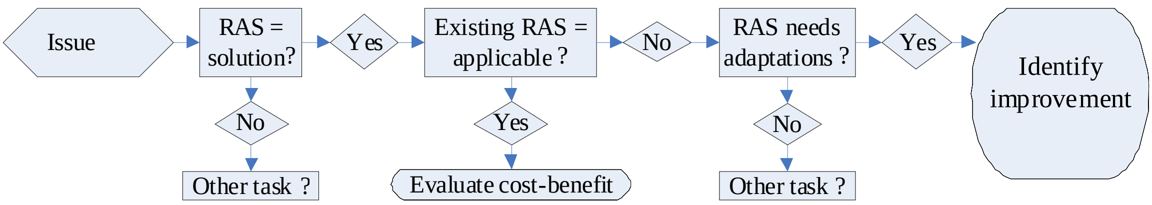


Figure 5: Decision tree followed for the preliminary analysis on WP2

Some issues (Table 8) and proposed RAS applications are subjected to a quantitative and a cost benefit analysis to assess their direct sustainability impact. These indicators are among others water use, water discharge, nutrient discharge (N and P), land use, mortality, energy use, feed use, staff employed, and the rate of return. Possible RAS benefits are assessed by comparing each indicator for two farms: one not applying RASs and the other one virtually applying RAS. The indicator value for the farm not applying RAS is based on information provided by the projects partners about the current situation of real farms in their countries. The indicator values for the farm applying RAS come from theoretical calculations for a projected farm with similar production output than the most common farms found in the involved countries.

6 Results

To cover all potential sustainability improvements of RAS in terms of sustainability issues identified in WP 1 (Table 8), first a general overview is provided before the indicators are assessed in relation to the specific case study.

6.1 General assessment of RAS benefits in terms of sustainability

Based on literature references all sustainability indicators mentioned by the project partners are evaluated in a general context, comparing RAS and other systems, such as flow through or ponds.

6.1.1 Water quality

Water quality (WQ) problems cover mainly two aspects: the quality of the water source, or the quality of the system water. In the first case, WQ can vary in a non predictable way -due to the currents, waves, winds, spills etc. In this aspect, RASs can be a solution as they allow a high independence from the water source and allow maintaining constant water quality, independently from the environmental and seasonal conditions or changes. However, water sources can show impurities or bacteria. In this aspect, two cases are distinguished: 1) that quality problems are incidental, and RASs allow dealing with the problem as water is continuously treated and disinfected and potential pathogens are eliminated (www.umbi.umd.edu); 2) that problems are permanent and severe. In the second case, the possible solutions offered by RASs depend on the specific issue. For example, if the water supply is very turbid, containing too many solids, a sedimentation tank or lagoon can be integrated before the system water inlet to treat the water. The problem becomes more complicated if chemical contaminations and germs occur. In those cases pre-treatments are maybe be applicable. RASs do not offer here any solution. That water source should not be used and another water source has to be utilized. Water quality problems can also refer to WQ inside RAS, even if the water source has good quality. These problems can be due to bad system operation itself (e.g. incomplete nitrification happening in the biofilter and therefore ammonia and nitrite accumulation). Good management and proper RAS design in the first place limit the impact of those issues.

6.1.2 Water availability/use

In land based farms, the required water volume can be a constraint due to its availability: i.e., if there are not significant rivers or wells available, or if there is competition and demand for water by different users. Even if water is available, the costs for using it might be high. In most cases, a reduction in the amount of water needed would be advantageous. The farm would be more independent and conflicts with other water users would be alleviated. The expenses for using water (fees) would be lower, improving the economic sustainability. The amount of required water needed depends on several factors such as species, density, management practices, the degree of risk willing to accept, and of the production technology and its level (Timmons and Ebeling, 2007). In this sense, RASs have proved to demand less water than other traditional systems such as flow-through systems or ponds (Table 9).

6.1.3 Waste (nutrient) discharge

One of the main concerns about aquaculture is effluent discharge, and with it, the nutrient load to receiving water bodies and their environmental impact. Nitrogen and phosphorous can cause eutrophication. Solid wastes can lead to a change in the sediment physico-chemical characteristics and with it, a change in the community structure at the coastal benthos or river. Fees and fines (Polluters Pays Principle, Schneider et al., 2006) counteract this pollution. Flow-through systems and ponds use more water per kg fish produced than RASs (Table 9). The amount of effluent water, and nutrient discharge are comparatively much higher, especially in flow-through systems compared to RASs. Flow-through systems are frequently equipped with mechanical filters at the outlet which reduce the solids input to the environment, although the dissolved N and P load is normally not treated. RASs reduce the effluent water discharge. However, the "zero-discharge" system has not been yet achieved at commercial scale. Still some waste water is generated, which needs to be discharged. With it, there is still a nutrient discharge. The more closed the system is, the less dissolved nutrients will be released (Blancheton, 2000; Figure 6). In any case, if water is drained without appropriate processing, N and P pollute the environment specially when the nutrient concentration is high, even if the water exchange volume is small (Suzuki et al., 2003). RASs allow for a highly controlled waste production and management. Current RASs can be designed with treatment units where the dissolved waste is converted/retained before discharge (e.g., denitrification reactors and dephosphatation units). An alternative is to reuse the effluent for agricultural purposes or in algal ponds (Blancheton, 2000; Schneider et al., 2006). Solid wastes (sludge from filters and other units) can be easily recovered and used as fertilizers or for composting (Chen et al., 1997).

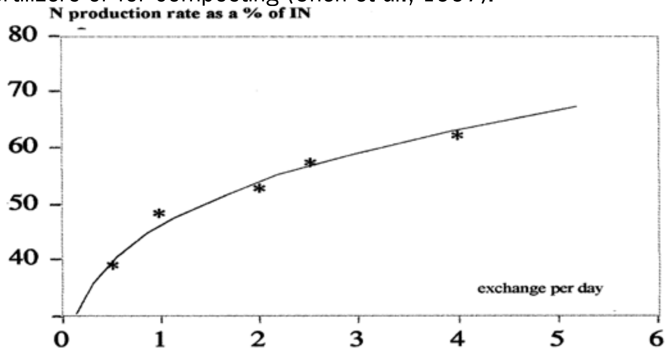


Figure 6: Representation of the dissolved nitrogen released into the effluent (expressed as a percentage of the ingested nitrogen) at different levels of system opening (expressed as a number of the total water volume exchanged per day), after Blancheton (2000).

RAS can significantly reduce the nutrient emission to the outside environment; if measured as Chemical Oxygen Demand (COD), discharge may be reduced to a 10% compared with a common stagnant fish pond (Martins et al., 2005) or even more (table 14). Due to the decrement in nutrient discharge, the costs due to pollution taxes can be diminished (Figure 7).

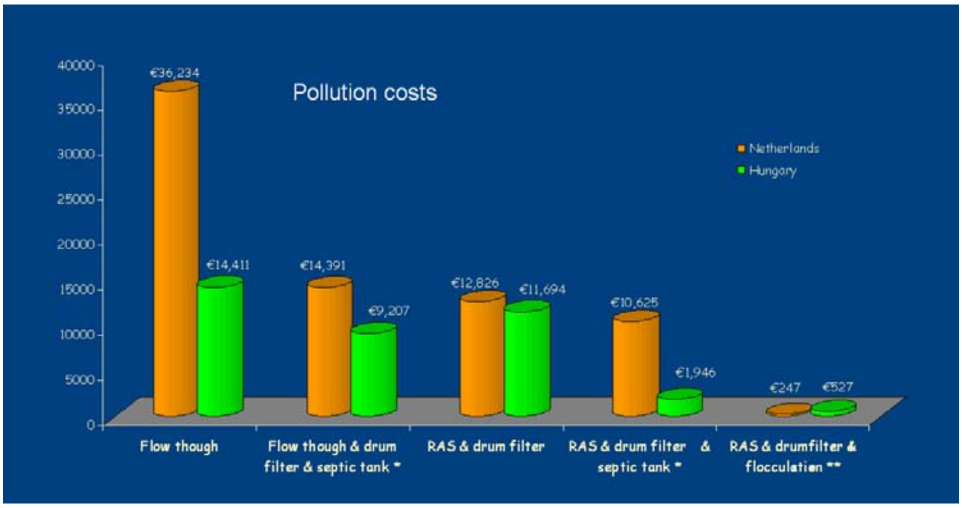


Figure 7: Comparison of costs due to pollution for African catfish culture between FT systems and RAS in Hungary and Netherlands. Source: Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems", PP. Based on (*) Kamstra and vd. Heul (1999), and on (**) Ebeling *et al.* (2005).

6.1.4 Land availability/use

Land availability is a constraint for land-based aquaculture farms. Sometimes conflicts with other land stakeholders arise, and moreover, farmers have to pay taxes for land rights. In this sense, a reduction in the land requirement forms an advantage as conflicts with other users are minimized and the expenses for land are lower. RASs allow the highest production per unit area or volume of all aquaculture system (Timmons et al., 2007), and through this, the land requirements is minimized (table 9).

Table 9: Comparison on water use and productivity (fish density) for seabass RAS and FT systems with a comparable annual production(Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems")

System	*Production capacity (t/y)*	*Replacement water (m^3/kg feed)*	*Avg. temp. (C)*	*Fish density (kg/m^3)*
RAS	70	0.5-1.5	21.5	Up to 100 (mean 70)
FT	100	150	19	30-60

6.1.5 Predation

The most typical predators affecting aquaculture are birds. In addition birds can transmit diseases, weed seeds and parasites from one facility to another (Curtis et al., 1996). Outdoor facilities such as ponds, cages or net pen systems are vulnerable to predation as well as to diseases. To protect outdoor facilities, two types of physical barriers can be used: complete enclosures: screens, cages, nets, which are totally effective but expensive and not practical for many aquaculture sites such as large ponds or partial exclusion systems: wires, lines, fences, which are less effective but quite less expensive. Frightening techniques relying on sight or sound stimuli are as well applied (Curtis et al., 1996). In comparison with outdoor facilities, indoor facilities (such as RASs) control the environment and hence the problem of predation is solved. An additional advantage is the indoor climate management by insulation. RASs can be used as well in the open air, but then the control of the environment is lost (Timmons and Ebeling, 2007).

6.1.6 Pathology

Pathology occurring in a farm causes low fish performance and losses. As explained for predation, outdoor facilities (ponds, cages, net pens…) are more susceptible to have pathology problems. Birds can spread diseases between outdoor facilities and fish are totally exposed to the environmental threats, water-borne contaminants and pathogens, algal toxins and sub-optimal environmental conditions (www.umbi.umd.edu). Indoors systems avoid the diseases spread by predators. However, if diseased fish are introduced into the culture system or the water source is contaminated with pathogens, indoor systems can be seriously affected. In those RASs effective treatments or preventive therapies (such as vaccination or baths) are much more manageable than in outdoor facilities (Timmons et al., 2007). RASs have advantages and disadvantages in relation to pathologies and treatments: on one hand, they carry along themselves a potential for pathogenic microorganisms to become established in the system through the formation of biofilms (King, 2001). Medications used to treat fish disease may be toxic to beneficial bacteria in the biofilter (Martins et al., 2005). Moreover, once a disease affects the farm and treatment is required, carrying it out might be tricky depending on the circuit networks and the possibilities for units isolation. Afterwards system cleaning is needed in order to eliminate the residuals of antibiotics and disinfectants. Then the system has to be restarted requiring time for biofilter colonization by nitrifying bacteria. Rests of antibiotics can as well remain in the filters, being difficult to eliminate. On the other hand, among the indoor systems, RASs are the ones which maintain the highest independence from the water source so that they are not so susceptible to water quality problems which can lead to pathology episodes. Moreover, they allow a high control of water quality parameters in the system, creating a healthier environment for fish culture and helping in health management.

6.1.7 Weather conditions (environmental mortality)

Unfavourable environmental conditions can cause low growth, system and fish damage and economical losses. Sudden or abnormal changes in temperature, upcoming storms, toxic and even non-toxic algal blooms, and other factors affect especially outdoor systems. These factors have less impact in indoor facilities. Among them, RASs offer the advantage that environmental parameters (temperature, salinity, light regime) are artificially controllable. Often they are established at the optimal ranges for a particular species in order to promote the best growth performance. Those artificial conditions can be kept constant all year round, independently of the outdoors weather conditions.

6.1.8 Energy use/cost

Energy expenses are normally among the most important cost factors for fish farms. Normally they rank second after feed expenses (Schneider et al., 2006). Power (electricity, oil, gas) prices are often dictated by national and international economic policies or multinationals. Alternative energy sources such as solar energy or synergies with biogas production, use of otherwise emitted warmth from industrial application, etc. offer a competitive advantage for energy costs (Schneider, et al., 2008). However, the dependency on a symbiotic partner, e.g. a biogas installation or electric power plant, can affect the production process negatively. This can e.g. happen if less warmth is emitted due to seasonal peaks. Some authors claim that the variable costs (feed, fingerlings, electricity and labor) of producing fish in RAS are not different or less than for other production methods (Losordo *et al.*, 1998). Further, RASs, by allowing high yields with year-round production, are more profitable if an appropriate market exists. The savings in energy when using RASs can be attributed to savings in heating, as the water is reused. According to Blancheton (2000), the saving in heating energy required for the production of 1g fingerlings (seabass) in RAS corresponds to approx. 50% of the production cost of fingerlings from a heated FT system (Figure 8), in Mediterranean countries. Cascading flow through systems might allow as well energy re-use but will be in inferior compared to RAS systems (Schneider et al., 2008).

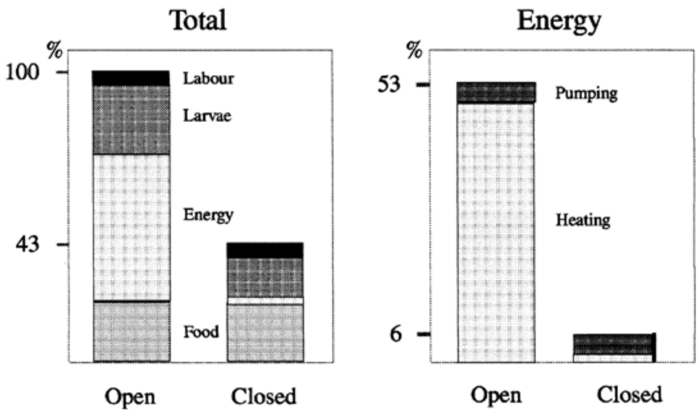


Figure 8: Production costs of seabass fingerlings in FT and RASs (Blancheton, 2000)

It is obvious that the benefits of less heating are achieved in warm-water farms for Mediterranean or tropical species, but in cold water species farms these benefits are insignificant. Only if water-cooling is a cost, similar mechanisms become evident.

6.1.9 Low growth rate

Optimum growth rates are desired in order to get the marketable size of fish in the shortest possible time to make the activity maximally profitable. Seabass cultured in open heated systems or heated RAS need less time than fish in cages to reach the market size of 300-400g(Figure 9).

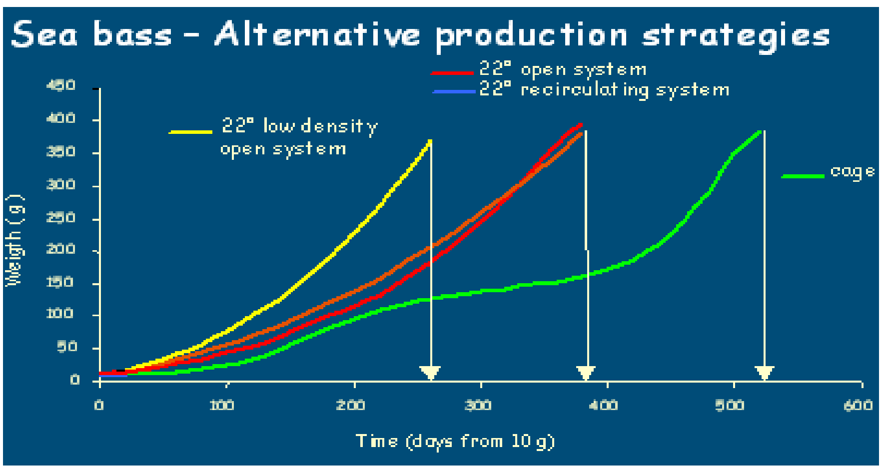


Figure 9: Comparison of growth rates for seabass in land based systems and cages Source: Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems", PP. Courtesy J.P. Blancheton, IFREMER, France. Blancheton et al., 2001)

In RAS, optimum growth conditions can be provided by temperature, salinity or light control. This is realized in an easier and often cheaper way than in FT systems. As result a better growth rate in a healthy and secure production environment is achieved, even during cold or other unfavourable outdoors conditions. It has been shown in seabass that when fish are till a higher weight in RASs before transfer into cages, the required time till the market size is reduced and production costs are reduced (Figure 10). In RASs environmental parameters are controlled to meet the species' requirements and enhance their performance. RASs can be combined with other production systems to achieve the best biological and economic results.

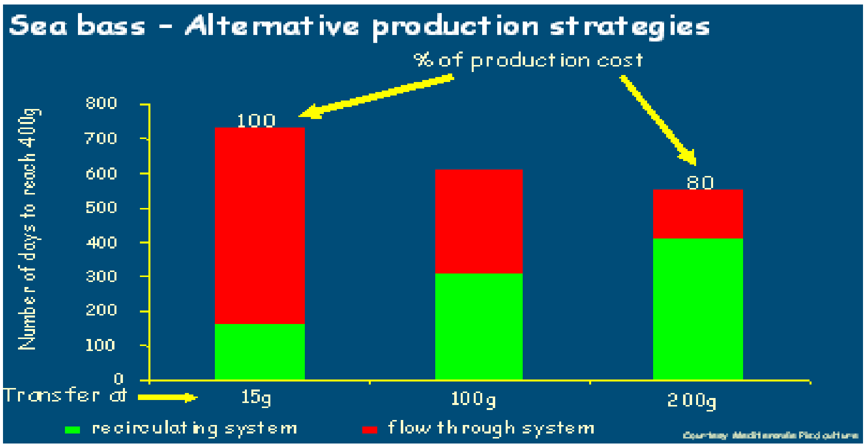


Figure 10: . Comparison of time needed for seabass to reach market size (400g) with different production strategies Source: Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems" PP. Courtesy Mediteranée Pisciculture. Blancheton et al., 2001)

6.1.10 Feed Conversion Ratio (FCR)

FCR relates the amount (weight) of feed used and the fish weight gain. Feed costs are often representing 50% of the overall production costs (Schneider et al., 2006). Lower FCR reduces overall feed expenses and makes farming more profitable. A lower FCR also means a reduction on the pressure (waste input) on the environment, with its economical and ecological consequences. Better FCRs can be achieved by improved feeds and feeding practices. A strong effort in being made for the identification and promotion of sustainable and efficient feed ingredients of aquatic or terrestrial origin. A specific focus lays on alternatives to fish meal and oil. The reduction in the level of marine protein and lipids in feeds has been identified as sustainability indicator (CONSENSUS, 2005). However, low FCR are sometimes only achievable by maintaining a certain fish meal and fish oil inclusion level (Peng *et al.*, 2008; Torstensen *et al.*, 2008). It is claimed that tank production systems (RAS) generally yield better FCR than other systems such as pond systems (Losordo *et al.*, 1998). It can be due to the fact that in RAS factors affecting FCR such as because oxygen saturation of water, temperature, etc. are more accurately controlled than in other systems. They are kept in such ranges that fish performance is maximal. However, some experts dispute that FCR is better in RAS than in other systems. Moreover, feed use (FCR) depends on several factors such as feeding strategy or feed quality, which is independent of the culture system itself. In addition RASs offer other advantages such as easier monitoring of the feeding process. In cage farms, camera installation and video monitoring are required to evaluate feed intake. RASs do not have these requirements, as feed intake is monitored directly.

6.1.11 Feed cost/supply

Feed accounts for one of the highest costs shares of fish production (Figure 11). Currently, most of the fish feeds include fish meal protein which is an expensive ingredient (Figure 12). Due to the lower FCR generally found in RASs, the expenses on feeds are often reduced compared to other systems.

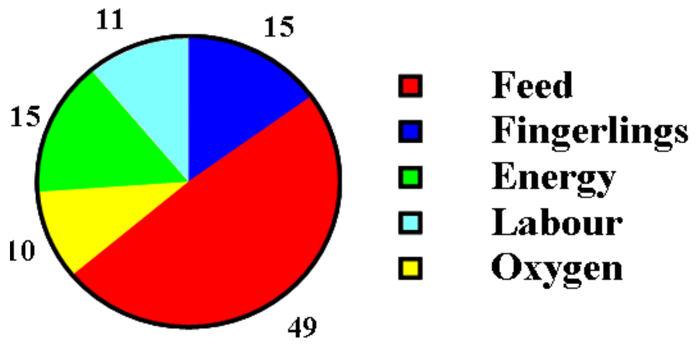


Figure 11: Example of production costs pattern in aquaculture farms. Source: Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems" PP. Data courtesy of commercial farm Mediterranée pisciculture, France, for sea bass.

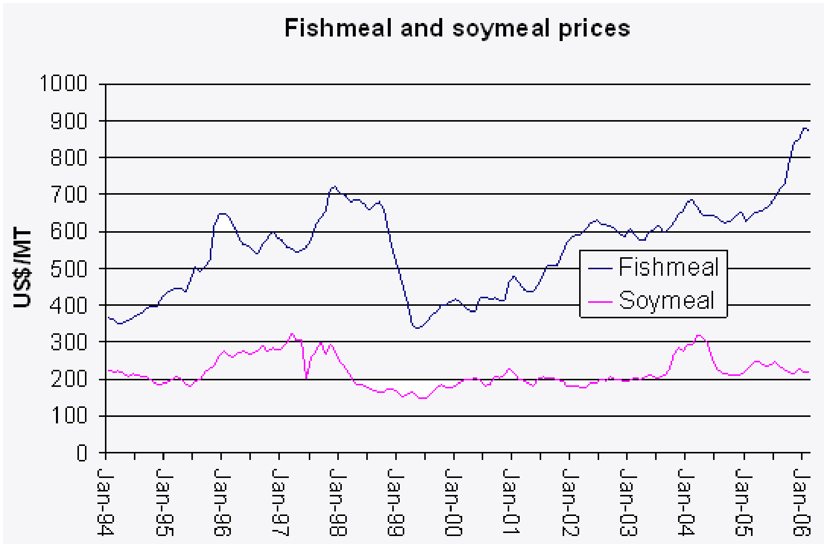


Figure 12: Fishmeal and soybean prices from 1994 to 2006. Fishmeal prices increased steadily in 2005 due to the persistent strong demand. Fishmeal prices reached a record level in early 2006, at USD 880/tonne. During 2005, the price of soy meal went down, which resulted in an increase of the ratio between the two prices well ahead of 4. (Source: www.eurofish.dk[1]).

An alternative to reduce feed costs and increase feed sustainability is the use of alternative ingredients for fish meal and oil (Table 10). These alternative ingredients will change produced waste. As results the system design must match the altered waste loads. Changes in feed composition might therefore impact system performance and productivity negatively and lead to higher production costs (waste fees, higher water exchange, energy use etc.).

Table 10: Ingredients used for fish feeds and their price, in USD/t. (1) Venero *et al.* (2008); corresponds to prices in 2007. (2) Hardy (2000); corresponds to prices in 2000.

Plant materials	**Price** (USD/t)	**Animal products**	**Price** (USD/t)
Cotton seed meal	163[1]	**Fish meal (anchovy)**	**450[2]-1,015[1]**
Soybean meal	249[1]	Meat and bone meal	290[1]
Sunflower seed meal	125[1]	Poultry by-products	282[2]
Peanut meal	166[1]	Feather meal	254[2]
Canola meal	193.5[1]	Blood meal	426[2]
Corn gluten	403[1]		
Wheat gluten	1760[2]		
Brewers yeast	770[2]		

Additionally, in an indirect way, RASs can contribute to reduce the costs of feed and feed ingredients. Due to its high independence on the water source, the location of the farm with RAS can be easier strategically established, close to feed manufacturers and feed ingredients providers. By this way, the feed price and the CO_2 emissions due to transport can be reduced This reduction mean an improvement on the economic and the ecologic sustainability, respectively.

6.1.12 Lack fingerlings/quality/cost

Farms that grow-out fish but do not have their own hatchery for fingerling supply can suffer from a lack of fingerlings or irregular supply. The lack of good quality fingerlings might lead to insufficient product quantity to cover demands. Both aspects depend on the hatchery production and the demand in the area. Even if fingerlings are available, their quality can be poor, resulting in low performance, low resistance to diseases and high mortality. Another problem related to fingerlings is their cost. High costs make farming less profitable especially if the high costs are combined with low quality fingerlings. RASs do not offer any direct solution to these problems. Incorporation of own hatcheries using RASs for their auto-supply might help farmers facing these constraints. RAS offers furthermore the possibility to produce fingerlings close to the grow-out facility, that might be located close(r) to their market. This increases sustainability due to shorter transportation: less CO_2 production and improved fish welfare. In addition, RASs helps to develop hatcheries even in places with reduced water quantity or quality. Moreover, in RASs, all year round larvae production and supply can be achieved.

6.1.13 Genetics/Breeding selection

Fish genetics can be very decisive for the economical success of a farm, as profit depends substantially on fish performance. Broodstock producing high quality seed (in terms of hatching, growth, survival, stress resistance) is the basis for success. Selection programs are often established to obtain high quality fingerlings. RAS are advantageous to other systems being biosecure, avoiding escapes of genetically selected fish which could mix with natural populations.

6.1.14 Money cost/Interest rate

High interest rates make new investments difficult, if profit margins are small and risky. Investments to improve farm technology, carrying capacity, and productivity must therefore be balanced against possible profit. Interest rates are dictated by national and international economic policies and by the ability to accept risk by investors and banks. RAS normally require high capital costs and investments, which is a mismatch with high interest rates. Competitive advantages, as production closer to the market, less stakeholder conflicts, higher production per square unit of area and all year round production might make investments in RAS more attractive than in systems.

6.1.15 Investment costs

The investment costs or capital costs describe those costs required for establishing the system, constructing the project, purchasing the equipment, etc. They usually occur during the initial phase of the project but may be spread over some years by depreciation. Capital costs are the costs of land and its preparation, costs of roadways, shelters, farming equipment (tanks, cages etc), the general site works, etc. Capital costs can be classified as fixed (those costs which are incurred regardless of the scale of the project), variable (those which vary directly with the size of the operation) and semi variable (which vary with the project size, but not proportionately; Muir, 2003). RASs usually require high investment costs, especially capital costs, compared with traditional systems (ponds, FT). However, the RAS advantages might compensate the initial investments on a mid/long term.

6.1.16 License cost

License costs are a matter of governmental policies and legislation. Required licenses can be of different types and they vary from one country to another. In general, cage farms require permits and are subjected to environmental assessments. However, some inland farms have to face license costs for farming native species, as for Siberian sturgeon in Romania (Popescu, from Giarmata). Other license costs are due for water sources such as wells, emission to natural water bodies, and others. RASs do not influence established license costs. RAS can be advantageous if warm water is needed and license costs apply for the use of hot springs, as RAS are less dependent on warm water sources than flowthrough systems.

6.1.17 Taxes

Taxes can be applied for land use, buildings, water use, sanitation, salubrity (healthiness) services and nutrient discharge. There can be silence (noise contamination), profit or income taxes. RASs helps on reducing water consumption, and land requirements, which translates into economic reduction of related taxes. RASs reduce the nutrient load to the environment, so that the payments due to environmental taxes, fines or fees can be lowered.

6.1.18 Operating costs

The operating costs are required to run the project and produce the intended outputs. They include raw materials (seed, feed, chemicals) and labour, as well as costs of maintenance, leases, rents, depreciation, interest and other. Operating costs can be divided into fixed, variable and semi variable (Muir, 2003). Some authors claim that the variable costs (feed, fingerlings, electricity and labor) of producing fish in RAS is not much different than other production methods (Losordo *et al.*, 1998). RAS might consume more electrical power due to pumping, but they save in heating and have due to reduced FCR, less feed expenses. In that way, the total costs of producing fish in RASs can be lower than in other systems such as FT (Figure 13).

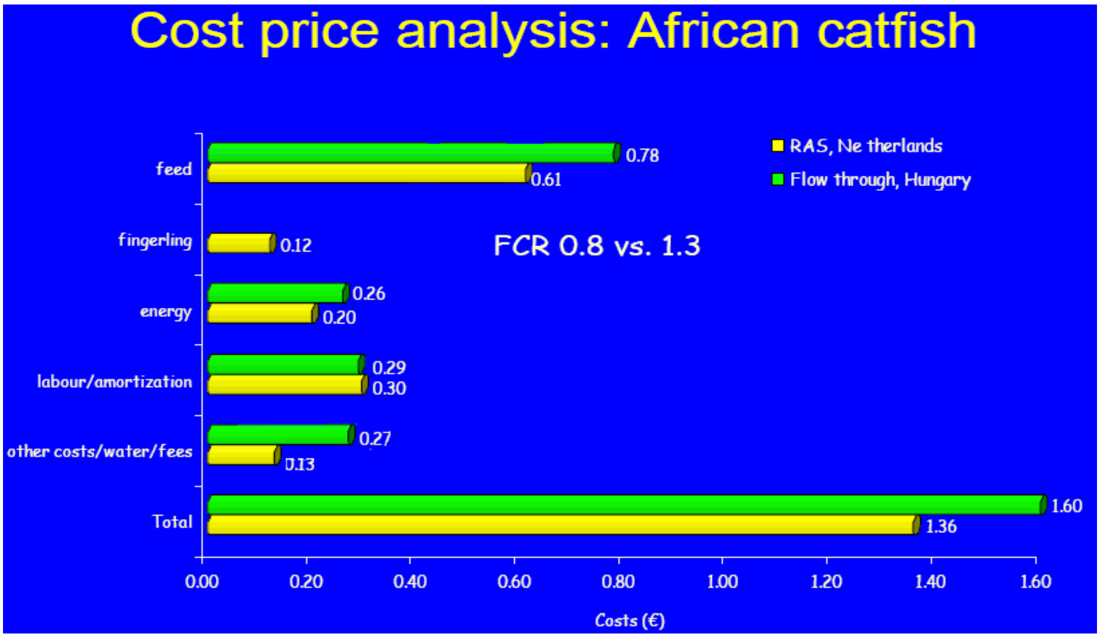


Figure 13: Cost price analysis for African catfish and comparison between its culture in FT systems and RAS (in Hungary and Netherlands, respectively). Source: Schneider *et al.* (2008): "Cost prices and production strategies in European recirculation systems", PP. Catfish based on Scheerboom *et al.* (2005), eel on HESY communication.

6.1.19 Cash flow

The cash flow during a determined time interval represents the distribution of capital and operating expenditures, funds and earnings. Cash flow is often negative at the early stages of a farming activity, followed by increased earnings as production increases. This offsets the initial deficit to create a positive cash flow (Muir, 2003). The success or failure of a business depends on many different factors (management, markets, marketing, competition, fish performance, etc). In this sense, RASs contribute to the best performance through controlled environmental conditions. Fish grow at high densities, higher than in cages or net-pen systems, making the production more profitable. RAS ensure as well all year round productivity. By correct management, peaks in market prices (e.g. eastern or Christmas) can be met with a higher production and margins are optimized. Product uniformity normally results in higher income as those fish products are easier sold to processors at higher prices in regular intervals of delivery.

6.1.20 Design issues/System problems

Design, construction and operation problems of production systems affect the economical success of a farm. RASs do not offer a great advantage as they are mechanically complex and their operation requires understanding the biological and physical processes. Often specialists are required for the design and construction, and skilled personnel for the operation of RASs.

6.1.21 Processing

Lack in fish processing capacity is a constraint for production expansion towards new markets and customers. Processed products are often superior on the market if they meet the consumers' preference in comparison with the unprocessed product. Processing towards value-added products based on low value fish species, is probably most promising to boost fish attractiveness and achieve higher prices. The success of the processed products depends on the particular species and country, consumers' habits and traditions. RASs do not contribute directly to this aspect. However product uniformity and all year round constant and predictable production make chain management from production to processing more efficient. Revenues generated from a successful production/processing chain make high capital costs more attractive.

6.1.22 Marketing/Labels

Sometimes, even if a farm produces satisfactorily, it fails because of a lack of marketing. Good marketing strategies are needed for a successful introduction of products into the market. Good acceptance of the product by the consumers has first priority. In that sense, a product which has been obtained sustainably (three P approach) can have an advantage in the market, especially in markets more conscious and concerned about the environment and fish welfare. Furthermore, consumers' acceptance can be achieved by promoting the health benefits of seafood. The introduction of quality labels or environmentally friendly certifications can increase willingness to buy and the demand for aquaculture products. These certifications serve as a communication tool. Certificates and labels may be visible between businesses only (Business to Business: B2B) or to the final consumer (Business to Consumer: B2C; www.cbd.int). GLOBLAGAP is an example of B2B labels. It is a standard for Good Agricultural Practice (G.A.P.), set for global agriculture. Once certified producers are entered into a database and have easier and immediate access to the huge and lucrative European retail market (www.cbd.int). Labels also help on getting the consumers' confidence and they can be framed into the marketing strategy. RASs are a tool for achieving high quality and more environmentally friendly products that is integratable into a marketing strategy and certification scheme.

6.1.23 Market demand

Market is driven by of demand and supply. Shifts in demand can be due to a change in income levels, rising population, changes in consumers' preferences, changes in the price of substitutes, etc. (Muir, 2003). At the end, the success of a product depends on the consumers' demand and the industry's competition. Related to the demand, the market price of wild supplies and the cost of production are extremely important for the success of farmed products. For example, for many years, the technologies to rear cod were known, but until recently, the cost of production exceeded the market price for wild caught cod. With falling wild cod stocks, this situation has altered in the past five years and cod farming might be as viable option (www.aquatt.ie[1]). However, some stocks are recovering at the moment turning this development around. Cost structures of competitors in various locations are important as the market will favor those with lowest cost of production (www.aquatt.ie[1]). In RASs different species are cultured. RASs permit high culture densities and reductions in the need for water and land. This reduces the production costs. Finally, RASs allow a year-round and uniform production which results in a constant product supply to the market. This favors the product outreach to new consumers due to constant presence, and potentially demand increment.

6.1.24 Diversification

Some aquaculture farms do not diversify, restricting their activity to the production of a single species. Diversification of goods produced allows expanding market opportunities and increases profit options. Such diversification, especially introducing high value species, may result in increase market independency (www.aquatt.ie1). Diversification is only a real advantage if adequate scientific and practical knowledge and financial viability are available. As well the production focus of the farm is not allowed to suffer by diversification.

RASs offer perspectives for species diversification, even for those species for which the local natural environmental conditions are not adequate. Through highly controlled environments, it is often possible to recreate conditions specific for maximum growth and complete life cycle. Moreover, if culturing non-native species, RASs reduce at maximum the risk of escapees. However, in relation to the introduction of new species, it has to be pointed out that customer habits and preferences are difficult to alter. The success of the introduction of new products is never guaranteed. Moreover, some of the potential species that could be cultured in RAS still need scientific research about details on their life cycle for a satisfactory commercial production.

6.1.25 Traceability

Traceability is the ability to follow back every step in a process chain. This trace is chronological and verifiable (www.wikipedia.org). Lack of product traceability potentially generate consumers' distrust and result in lower sales. For traceability in aquaculture, farms have to maintain production records (full history of the stock: movement or transfer of fish between cages, vaccinations, medication, feed types, supplement, harvest) in either paper or electronic format. If the product is processed, the number of the processing plant should appear on any labels from that plant (www.aquatt.ie[2]). RASs are charaterized as a very controlled culture method, allowing an easy monitoring and recording details on water quality parameters, feeds used, pathogenic incidences, cohorts and others.

6.1.26 Feed & fertilizer limits/Other legislation

Extensive fish pond culture faces legal limitations on feed and fertilizer use in some East European countries. Feed limitations are as well in place in Western Europe as in Denmark for trout farms.
RASs do not have problems of fertilizer or feed limits through waste management. They have virtually no limit on feed use.

6.1.27 Property

Property rights and legislation are sometimes unclear and not well defined in Eastern European countries. In some cases, the state owns the land and farmers work on tenant contract or lease. In other cases land has been transferred to farmers and former state-run farms have been privatized (Mladineo). In several cases, the situation about land ownership is unclear. Similar property problems occur close to shore, leading to conflicts between stakeholders (cage farms, touristic sector, environmentalists). Application of RASs does not solve property problems, which are a matter of governmental action or of the private market.

6.1.28 Bureaucracy

Heavy bureaucratic procedures are time and cost demanding. Bureaucracy is often aimed to be reduced, which is a paradox on itself, as it is created often to be complex. Bureaucratic demands might be different depending on aquaculture activity and system. In general cage aquaculture requires more permits and formal controls than land aquaculture. However, the latter faces sometimes heavy bureaucratic procedures such as getting permissions for exploitation of a water source (Forus Ltd.). RASs, with its lower demands on water and land, and the controlled waste emission, might result in some reduction in the bureaucratic processes and permissions, although at the end bureaucracy is a governmental matter.

6.1.29 Labor qualification

A mentioned bottleneck for aquaculture activities is the lack of skilled personnel or inadequate labor qualification or both. The skills and qualifications required depend on the culture system and its technical, mechanical and biological complexity. RASs, due to their complexity, require highly skilled, educated and trained personnel. A good understanding of the biological processes, the species requirements and the effect of the environmental factors on the species' performance are a pre requisite.

6.1.30 Tradition

Tradition and habits play an important role when establishing a new industry or production, or when introducing novel products. This is due to the confrontation of the novel services, techniques or products with what the industry or the population was used to. Traditions and habits are difficult to change. Transition requires time.

Adequate promotion of benefits and advantages for innovation might support the acceptance of the new technique or system. RASs often contradict with traditional aquaculture. RAS is a young discipline compared to pond or flow though culture. At first glance it might not comply with sustainable approaches of extensive aquaculture. None the less it offers several advantages that in good combination with traditional aspects might result in new perspectives.

6.1.31 Union networks/Lack of cooperation

Union networks and cooperation between producers in the same region/country contribute to create a strong production sector. Such networks or cooperation might help to establish a solid market, get representation in the administration, influence policy-makers, and establish or improve a sector. The lack of union and cooperative strategies constitute an issue for aquaculture development. The application of RASs cannot help with this kind of problems. Even more, relationships are required between producers using these techniques with research institutions, in order to overcome technical difficulties.

6.1.32 Conflicts with other coastal/land stakeholders

Conflicts with other land and coastal users are one of the main obstacles for aquaculture development especially in Mediterranean countries. Stakeholder conflicts are typically: a) competition for resources (land and water), b) optical pollution, and c) nutrient emissions. Those conflicts can lead to a strong opposition against aquaculture and can result in closure or forced movement of farms. RASs require substantially less land and water than other production systems. They are more independent from locations directly at shore. This reduces the conflict on water and land use and optical pollution. The latter is a major conflict for cages placed in-shore. In the Mediterranean, an intensive aquaculture has arisen over the past 20 years; large units have been installed and located mainly in the sea (UNEP, 2004), increasing waste emission in those waters. The Mediterranean is more sensitive to nutrient inputs, as it is described as mainly oligotrophic. Its microtidal regime reduces the potential for dilution and dispersion of nutrients especially in closed bays (UNEP, 2004). All this has lead to rapid contamination. RASs reduce the nutrient release, alleviating partially this problem.

6.1.33 Scientific support

Some aquaculture sectors suffer a lack of scientific support. The application of scientific knowledge improves farming activities, making them more efficient and viable. At the same time, research institutions benefit from the feedback and data provided by farms on commercial production conditions.

As RASs are a relatively new technology many aspects of their management are still under investigation. Scientific institutions are interested in establishing collaborations with commercial farms using RASs to monitor their performance and acquire data (fish performance, nutrient retention and discharge, etc). In return, these farms benefit from scientific support and sometimes from subventions when they take part in national or European research projects together with institutes.

6.2 Case study 1: Seabass farming in RAS and cages

6.2.1 Introduction

Case study 1 deals with marine sea bass farms, which at present apply flow-through (FT) system for hatchery and nursery, and grow the fish in cages. The partners involved in this case study are representatives from Croatia and Turkey. The assessment entails valuing the benefits of changing traditional FT systems to RAS, for hatcheries and nurseries. The aim is to create seabass farms with biosecure and safe conditions and better growth performance through temperature and photoperiod control. In a more specific way, the general objectives of this study are:

- Asses the suitability and viability of using RASs for hatcheries (rearing broodstock and fingerlings production) and nurseries (fingerlings pregrowing).
- Asses if RAS increases sustainability, compared with systems and techniques currently employed, and if it solves problems that presently affect these farms.
- Evaluate requirements to apply these systems under local conditions and determine necessary design alternation (adaptations).

Seabass and seabream production has increased in the last years. Stocks have been heavily exploited by fisheries and at present only few hundred tones are caught per year. Currently, the main seabass/bream producers are Greece, Turkey, Spain, Italy, France, Croatia, Portugal, Israel, Cyprus and Libya (Table 11).

Table 11: Seabass production in the main countries, in 2006. Fishstats. Data refer only to marine culture (brackish has not been included).

	Seabass (t)	*%*	*Seabream (t)*	*%*	*Total (t)*	*%*
Croatia	2,400	2.5	1,050	1.0	3,450	1.7
France	3,840	4.0	1,800	1.7	5,640	2.8
Greece	33,884	35.5	43,613	41.7	77,497	38.7
Italy	6,719	7.0	5,838	5.6	12,557	6.3
Portugal	1,209	1.3	1,605	1.5	2,814	1.4
Spain	6,690	7.0	14,526	13.9	21,216	10.6
Turkey	38,408	40.3	28,463	27.2	66,871	33.4
TOTAL WORLD PROD.	94,187		102,388		196,575	

Two countries are involved in this case study: Croatia and Turkey. They are two of the main seabass/seabream producers in Europe. Today, seabass annual production in Croatia corresponds to about 2500 t. Croatia has a relatively long history of fish farming with its own hatching technology that strongly depended on imported aquaculture products (feed, chemicals, and equipment). In 1970s aquaculture companies were governmental and had strong bonds with research institutions. This greatly enhanced the rapid development of fish farming in the country. At that period, a typical marine finfish farm consisted of a small family based farm hatchery, fish cages and two hatcheries. However, during civil war in 1990s, many farms collapsed. The end of war worsen the situation; markets decreased, purchasing power declined, capital prices went high, and farmers were faced with the need of expensive imports of aquaculture supplies. Now, seabass, seabream, and sharp-snout seabream (in smaller range) are the most widely produced species, along with mussels and tuna. Turkey has a seabass production of 38,410 t/y (Table 11, Table 12). In Turkey, there are 15 marine hatcheries (producing a total of 268,750,000 juveniles/y) and 311 marine rearing facilities (producing a total of 93,035 t/y). From these, 229 are cage fish farms (culturing seabass, seabream, tuna, corbs, sargos, mearge, dentex, rainbow trout, etc), 79 are earth ponded farms (culturing seabass/ seabream and turbot), and three are mussel production open water platforms. 45 of the cage farms are off-shore. Within the last five years, offshore systems have increased in an 200%. These farms have more than 1000 t/y production capacities. About 55% of the total cage farms export their production. Government policies support off-shore production (by subsidies payment) and the introduction of new species (turbots, corbs, sargos, mearge, dentes). There is not any specific support yet for RASs or integrated systems application (Table 13).

Table 12: Percentages of the total production each species represents in each country. Calculations based on "WP1: Situation of aquaculture in partner countries, main bottlenecks and identification of the case study farms", documents from research institution partners for WP1, and questionnaire on generalities of Aquaculture in Turkey (by Kurtoglu)

	Carp	trout/ salmonids	sea bass/ seabream	tuna	mussels	oysters
Croatia	26.08	9.13	19.56	29.34	15.65	0.26
Turkey	0.88	42.34	48.91	7.01	0.88	0.00

Table 13: Details on the seabass/seabream production activity in Croatia and Turkey. Facts marked with (*) refer to data for the marine aquaculture activity in general, and not specifically for seabass/ seabream production sector. However, as seabass/seabream production in Turkey represents 85% of the marine aquaculture

	Croatia		Turkey
Spp.	(1) seabass, (2) gilthead seabream, (3) s.n. seabream		(1) seabass, (2) seabream
Number of farms	4 hatcheries, 34 rearing facilities (in 2004)		21 hatcheries* (17 active), 280 farms (201 cage farms and 79 earth ponded farms)
Production system	Hatcheries: mostly FT Rearing: floating cages, semi off-shore or inshore. 1 farm with RAS		Hatcheries: semi closed or closed 201 cage farms, 45 of them offshore; 79 earthponds farm, using sw from well
Production/y	Production of larvae: 7,000,000: Seabass: 6,659,000 Seabream: 324,000 Ongrowing: Seabass: 2000 t (in 2004) Seabream: 2000 t (in 2004)		Hatcheries: 348, 000* juv./y, Ongrowing: 67,000 t/y (in 2006). Seabass: 57.4%: 38,410 t/y approx. Seabream: 42.6%: 28,460 t/y approx.
Size of farms (by production) & number	Hatcheries: large (1 farm) small (3 farms)	Rearing facilities: 50 t/y (30 farms) 800 t/y (1 farm) 200-400 t/y (3 farms)	Rearing facilities*: <50 t/y (130 farms) 51-100 t/y (57 farms) 101-250 t/y (53 farms) 251-500 t/y (17 farms) 501-1000 t/y (37 farms) >1001 t/y (17 farms)
Water source	Marine water or underground salty water in few cases		Marine water or underground salty water

Most Croatian hatcheries are small. The most abundant rearing facilities both in Croatia and Turkey are as well small, with a production of about 50 t/y or less. In Croatia, those small farms contribute most to annual national production, whereas in Turkey, the major contribution comes from big farms with a production >1000 t. The average production per farm corresponds to about 65 t/y for Croatia and to about 200-300 t/y in Turkey. There are four and 15 active seabass/bream hatcheries in Croatia and Turkey, respectively. The production systems used in Croatian hatcheries are flow-through; "closed" or "semiclosed" systems are used in Turkey. In Croatia, seven million seabass/seabream larvae are produced per year. They do not meet national demand, covering only the 30%. Therefore, 8,236,000 larvae more are imported from Italy, Greece and France, at a price of 0.2-0.3 euros/fish. In Turkey it is also necessary to import juveniles: 11,540,000 of seabass (till June 2006), and

18,300,000 of seabream (in 2005). Moreover, the national production is planned to be increased to 60 million juvenile/year more, originating from two new hatcheries. In the 2000s, 34 seabass/bream ongrowing farms exist in Croatia, with a production of 3,000 t of fish per year (2,000 t of seabass and 1,000 t seabream). They are small scale, being owned privately. In Turkey, there are 280 reported ongrowing seabass/bream farms. In both countries ongrowing is practiced mainly in cages. However, in Turkey there are as well some farms growing fish in earthen ponds using water from wells and in Croatia one farm (Maring) is reported to apply RAS for the rearing phase.

6.2.2 The state of art for RAS

RASs are rare in Croatia. There are two farms applying RAS. Another semi-RAS is used in two seabass/seabream hatcheries (Seabass Juniors and Maring). Exceptionally, Maring farm applies RAS for the broodstock rearing facility. In Turkey, the first RAS was built in 1998 for a seabass ongrowing, encounting several design and construction issues. Finally, the produced fish could not compete with the lower production costs in cages. The system was finally converted to a hatchery. Apart from this, small or large scale semi-closed or closed systems have been used in most of the marine hatcheries. There is no aquaculture grow-out system using RAS in Turkey. In the last five years, only one farm (hatchery) was constructed with RAS. The leading authority on RAS and aquaculture in the country is MARA (Aquaculture Department of General Directorate of Agricultural Production and Development). Government policies do not support RASs application.

6.2.3 Contributing farms

Two seabass/seabream farms have contributed with detailed data on their production to this project. One farm was Croatian (Seabass Jr.) and one Turkish (Akuatek). Additionally, some data have been collected about other farms (Maring in Croatia; Idagida and Kilic in Turkey, plus the hatcheries Egemar, Teknomar, Sercin and Calimliyem in Turkey, (Table 14, Table 15 and Table 16).

Table 14: General characteristics of the consulted farms. ([1]) Sp. 1: Seabass; sp. 2: seabream; sp. 3: Sharpnout seabream.([2]) In Sucuraj. ([3]) Tank sizes: 70 cm depth, ∅ 4 m. ([4]) In Drace and Sucuraj. The details of the ongrowing facilities correspond to Sucuraj. ([5]) Cages sizes: 12x6. Inshore. ([6]) Broodstock from another fish farm. Reproduction natural & by photoperiod manipulation. ([7]) In RAS & semi RAS: broodstock, juveniles, early feeding fry. ([8]) Number of tanks: 90. ([9]) Plan: Land based rearing unit with RAS.(*) data referred to hatcheries; (**) data referred to the ongrowing activity; not market: data referred to the whole activity, or data which was not specified if referred to the hatchery or to the ongrowing activity.

Farm names	*Farm unit*	*Production system*	*Number (hatcheries or cages)*	*Spp.[1]*	*Other activity*	*Source of technique*
1-Seabass Jr.	Hatchery* [2]	*semi RAS	*1[3]	*1, 2, 3(?)	No	Literature, experience
	Ongrowing** [4]	**cages	**25[5]	**1, 2, 3(?)		
2-Maring	Hatchery*	*Semi RAS (40%)	Several tanks	*1, 2, 3	-	-
		**RAS (95%)	1 tank	-		
3-Akuatek	Bbroodstock Hatchery* [6]	*RAS/ semi RAS [7]	*2[8]	*1, 2	No	from experts
	Ongrowing**	**Cages [9]	**1	**1, 2		
4-Idagida	Hatchery	RAS	-	1	-	Norway
5-Kilic	Hatchery*	*FT, RAS and semi RAS	*3	1, 2, 3	-	Farm experts and Agean University
	Ongrowing**	**Cages	**11 farms			

The two Croatian farms have started their activity, when the country was going into civil war. RASs are rare in Croatia, but from the four seabass/bream hatcheries, half of them have at least semi-RAS. From the 34 ongrowing facilities, only one has RAS (Maring). The Turkish farms have been recently established, the oldest one being 17 years old. The two Turkish hatcheries mentioned (Akvatek, Idagida) have already RAS or semi RAS, which corresponds to the 13% of the total active hatcheries (15) in the country. The Turkish farms Egemar, Teknomar, Sercin and Camliyem are seabass hatcheries, composed by one hatchery and one cage each, but more details about them are not available. Seven case study farms in Turkey have produced 63% of the total national production.

Table 15: Production data of collaborating farms. ([1]) 1.5 M of seabass and 0.5 M of seabream. ([2]) 12% from 5 to 50-60 g; 3% from 50-60 to 350 g. ([3]) 2 g larvae. ([4]) 2,336 m^3, from which 1136 in use. ([3]) Plan: 60 t/y (in the land based unit). ([6]) 7 g larvae. Turkey Cages: 15% mortality (from 2g to 350 g) on bass, 5 to 10% on sea bream, most of the mortality occurs before 60 g. Very low mortality for sea bream after 60 g.FCR: 1.7 sea bass; 2 with sea bream

Farm	*Production*	*Water use*		*Land use*	*Yield*		*Mortalities*	*FCR*
	(M larvae/y or t/y)	m^3	*m^3/M larvae or m^3/t*	(ha)	*M larvae/ha or kg/ha*	*larvae/m^3 or kg/m^3*	(%)	(kg food/ kg fish)
1	2 (1.5+0.5)[1]	250	125	0.13	15.38	8,000	-	1.3
	45	30,000	666.7	-	-	1.50	12 & 3[2]	
2	1.5	50	33.3	- 25 m2	-	30,000	20 (up to 2 g)	1.3 to 1.5
	-around 10 fish of 2 kg	400	-	- 10 m2	-	-	-	-
3	10 [3]	1,136 [4]	113.6	0.60	16.67	8,803	75 to 80 (up to 2g from egg bass, 90–95% bream)	-
	0 [5]	-	-	-	-	-	-	-
4	12 [6]	5,000	416.6	0.5	24	2,400	-	-
5	90	-3,700	-24,324	-100	-0.9	-21,635	-	-
	12,000	-	-	-	-	-	-	-

The consulted Croatian farms representative for the country. In Croatia hatcheries and rearing facilities are relatively small (<50 t/y). The consulted Turkish hatcheries are about five times bigger than the Croatian ones. The hatchery with RAS (Idagida) makes a more efficient use of land compared with the other hatcheries which have semiRAS. However, there is not a clear difference in water use.

Table 16: Economic parameters of the consulted farms([1]) Assuming a market value of 5 €/Kg (source: www.eurofish.dk[2]). Calculation= ((t/y) x 1000 x 5)÷ ha or m^3. Note: In non-italic, data directly taken from the questionnaires; in italics, calculations done from these data. +: 500 000 euros (hatchery) and 300 000 for the cages facility

Farm	*Capital costs*	*Labour input*	*Expenses*		*Productiv.*	*Marketing*	*Benefit harvest*
	€		€/y	*€/M larvae.y or €/t.y*	€/m^3		€/y
1	+	5	220,000	*110,000*	-	-	-30,000
	-	5	150,000	*3,333*	7.5[1]	Branding of market size fish	550,000
3	1,000,000	22	1,500,000	*150,000*	-	Wholesalers	36158
5	-		-	-	-	-	-
	3 ,947,850	150-	3,247,850	*36,09*		Wholesaling	13,152,150

Detailed economic data are only available for the two farms that completed questionnaires (Seabass Juniors in Croatia and Akuatek in Turkey). Their production scale is different. The number of people employed and the expenses per year are accordingly different. Relative expenses (€/M larvae.y) are similar. Detailed overviews of environmental costs, threats and conflicts are only available for the two farms that completed the questionnaires (Seabass Juniors in Croatia and Akuatek and KILIC in Turkey). Akuatek has to pay fees for water. Stricter laws are seen as a threat for their activity, and conflicts with tourism and green associations affect both farms. In this sense, environmentalists' criticism is perceived as exaggerated. Other important bottlenecks affecting the farms are related to water quality issues, slow growth rate of fish in winter in the cages, diseases affecting fish in cages, lack of processing facilities, heavy bureaucratic procedures, etc.

6.2.4 Projected RAS application

The traditional seabass production cycle is two years. During the two years period, low growth rates are found in winter season due to the lower metabolic rate. During spring and autumn bacterial outbreaks occur, due to rapid changes in water temperature or salinity. Among others vibriosis is found as main threat (http://www.aqua.intervet.com). After the first year, the maximum achieved fish weight is 400 g (Dujakovic, workshop communication). Proposed RAS application covers the broodstock holding unit, the hatchery, and the nursery - pregrowing phase- (Table 17). Furthermore, for the nursery an extended pre-growing period of fish in RAS is proposed up to 150 g. The incubation area is assumed to be a flow-through system in order to eliminate the hatching by-products and also potentially dangerous micro-organisms frequently associated with eggs (Moretti *et al.*, 1999). This contradicts the fact of possible egg incubation in RAS, which has been demonstrated and is currently done in commercial hatcheries (Blancheton, personal communication).

Table 17: Proposal for RAS application in the different stages of seabass production(*) from 50-60 to 150 g; (**) from 150 to 350 & 600 g.

	Hatchery				*Nursery (pre-growing) (2-5 g to 50-60g)*	*On-growing (50-60 g to 300-350g)*
	Broodstock & Spawning	Incubation (≈50 h)	Larvae rearing (till day 45)	Larvae weaning (till day 90-100)		
Current system	FT/RAS	FT	FT/RAS	FT/RAS	Cages or earth ponds	Cages or earth ponds
Change proposed & assessed	RAS		RAS	RAS	RAS	RAS* RAS and/or Cages and/or earth ponds**

Table 18: Traditional and expected time schedule in the seabass production cycle. Adapted from Moretti *et al.* (1999).

	Traditional	***Expected***
Length	≈ 2 years	≈ 1 year
Spawning:	January/ March (Winter 1st year)	September/ October
Rearing fry (till 2-5 g):	Till April-May (Spring 1st year)	Till December-January
Stocking 2-5 g fish into floating cages:	April-May	-
Rearing juveniles (till 350 g):	From ≈April-May (Spring 1st year), & during: Summer, autumn & Winter (1st year) Spring, summer & autumn (2nd year)	-
Rearing fry & juveniles (up to 150 g):	-	Till May
Stocking of 150 g fish into floating cages:	-	May
Harvesting (350 g fish):	≈September (2nd year)/February (3rd year)	≈July-August
Harvesting (600 g fish):	-	End October- beginning November

The natural spawning period is January-March (Moretti *et al.*, 1999). However, by an appropriate adjustment of water temperature and photoperiod, it is possible to anticipate or delay the gonadal maturation and spawning. RASs facilitate and allow an accurate maturation control. In the present case spawning occurs in September-October. Fry could be grown up to two to five gram in about two or three months. Afterwards, pregrowing is carried out in RAS. It is claimed that pre-growing fingerlings in RAS instead of in FT systems reduce production costs by 50% (Blancheton, 2000). Pregrowing is planned in RAS not only up to 50-60 g, but additionally up to 150 g. It is hypothesized that this is realized in 5 months, due to the good culture environment control. In fact it has been shown that the pre and growing phase is faster in RAS compared to cages (fig 9; Blancheton, et al., 2001). It has also been demonstrated that holding fish longer and therefore till a higher weight in RASs before their transference into another culture system reduces time needed for reaching the market size (fig. 10; Blancheton, et al., 2001). Therefore, after growing fish in RAS till 150 g, 350 g cage-reared fish are expected to be obtained by July-August. Some fish are harvested at this typical market size. However, as water temperature is still good till October-November, some fish remain in the cages till harvest in November. The weight expectation for these fish is ~600g. Applying this strategy the production cycle is reduced to one year. This strategy however has some challenges: Cages would be empty during winter and the RAS system would be empty during summer. In winter, temperate species could be grown in the cages. In summer, other species could be grown in RAS. Even more, a small number of seabass could also be left in the RAS during the warm period (instead of stocking them in the cages); by the end of the summer, these fish would be expected to have one kg weight serving another market segment. The combination of cage and RAS is based on: 1) cage farming has a long and strong tradition in Croatia and Turkey. The complete change to land based system is not realistic for short term; 2) cage (outdoors)-reared fish are perceived by the consumers as quality and healthy, while land based reared fish are not (Dujakovic, personal communication). By carrying out the last growing phase in cages, the image quality is maintained; 3) it seems, based on practical data, that fish grown fully in RAS cannot compete at the moment with fish grown in cages due to production costs (Idagida). The lay out is projected for a farm representative of seabass culture in Croatia and Turkey (Table 19). In order to plan the farm, system and tank dimensions, some facts and assumptions have been made (Table 20).

Table 19: Overview of the proposed seabass production system. (*) From Moretti *et al.* (1999); (**) from the proposal by Dujakovic.

Product. phase	*Period*	*Weight rg. (g)*	*System*	***Density (kg/m³)***
Broodstock maintenance	*Spawn: Sept./ Oct.*	-	*RAS 1*	*Up to 2-5 **
Hatchery	Sept./Oct. to Dec./Jan.	0 to 2-5	RAS 2	Up to 20*
Nursery (pre & growing)	Dec./Jan. to May	2-5 to 150	RAS 3	Up to 60**
On-growing	May to Jul./Aug.[1]	[1]150 to 350	Cages	
	Jul./Aug. to Oct./Nov.[2]	[2]350 to 600		

Table 20: Assumption made for the projected sea bass production unit.

Production:	100 t/y
Harvested fish:	600 g
Maximum stocking density at the nursery RAS (previously to transference to cages):	60 kg/m^3
Volume of tanks (nursery):	100 m^3
Overall survival (from egg to market size):	20-25%
FCR:	≈1.5

6.2.4.1 Nursery system (for 2-5 to 150 g fish)

Assuming fish harvest at 600 g from cages, for producing 100 t, 167000 fish of 150g need to be stocked. Assuming zero mortality from stocking to harvest, the initial biomass is 25 t, to be produced in RAS. Assuming a maximum stocking density of 60 kg/m^3 in the RAS, in order to produce 25 t a total volume of ≈450 m^3 is needed for the holding tanks. If tanks of 100 m^3 are used, five tanks would be required. Based on Dujakovic, the tanks are designed in cross-flow (Figure 14).

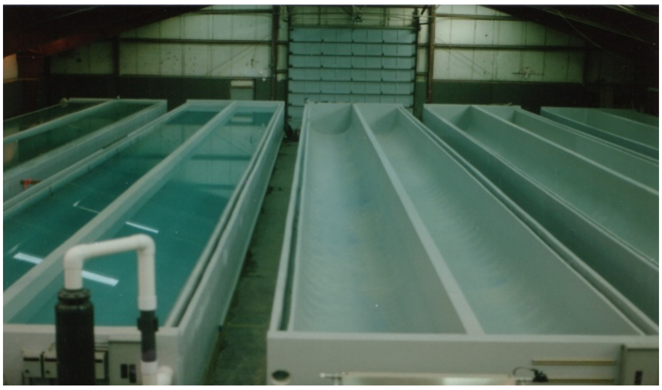


Figure 14: Cross-flow tanks for the sea bass nursery

6.2.4.2 Hatchery system (for growing fish up to 2-5 g)

Assuming a survival of 20% for the overall production cycle, in order to get 167,000 fish, ≈1,000,000 eggs are needed. Not the totality of fish are planned to be harvested at 600 g but part of it at 350 g. Assuming approximately half harvested at 600 g and half at 350 g, in order to reach to 100 t final production, an initial egg number of 2,000,000 is required. Surplus can be commercialized as 2-5 g fingerlings. The hatchery is divided in the rearing area and the weaning area.

6.2.4.3 Broodstock system

The broodstock holding unit is designed as RAS. Based on severalassumptions for the broodstock (Box 2, Morettiet al., 1998). According to the data from Moretti *et al.* (box 3), if 2,000,000 eggs are to be produced, 6.7 kg of female fish are necessary, which corresponds to 4.4 female fish. Then, taking into account the optimal sex ratio, ten female fish are required. IFREMER scientists suggest to consider 20 to 30 females and 20 to 30 males of an average weight bigger than three kg each (so that 120-180 kg of fish), to ensure sufficient reliability of egg production.

Box 2: Calculations on broodstock requirements

Egg productivity
Egg productivity (num./kg bw)= 300,000
Egg productivity (% bw)= 20-25%
Practical fecundity/season: 120,000 2-days old larvae/kg bw

Optimal size & age for spawning

	Size	*Age*
male	0.6-0.7 kg	2-4 years
female	1-2 kg	5-8 years

Optimal sex ratio: 1♀: 2♂

The tanks should have volume of minimum five m^3, but tanks bigger than ten m^3 are suggested by IFREMER (personal communication (Table 21). It has to be remarked that is its difficult to find sufficient land with suitable topographic (flat surfaces) in Croatia. This impact the land prices and therefore the economical feasibility. As well in the proposed project no water treatment unit for emission treatment is included. More data on the Turkish aquaculture projection is provided in the Appendix.

Table 21: Technical details of the proposed systems.

	BROODSTOCK (RAS 1)	*HATCHERY (RAS 2)*			**NURSERY (RAS 3)**
		Incubation area	Rearing area	Weaning area	
Tanks:					
Shape	Round	Round, with conical bottom	Round	Rectangular	Rectangular/circular
Volume	4-20 m^3 *(10 m^3 chosen)*	100-250 L *(200 L chosen)*	6-10 m^3 *(6 m^3chosen)*	10-25 m^3 *(10 m^3 chosen)*	10-25 m^3 recommended *(100 m^3 chosen)*
Depth	1 m	60 cm	1 m	1 m	
Area	10 m^2	A=200 dm^3/6 dm= =33.3 dm^2= 0.33 m^2	A=6 m^2	A=10 m^2	
∅ or dimensions	10=πr^2, so ∅=3.57 m	33.3 dm^2=πr^2, so that r=3.25 dm, and ∅=65 cm	6=πr^2, so ∅=2.8m	5 m x 2 m	20 m x 5 m
Fish density	Up to 10-15 kg/m^3	10,000-15,000 eggs/L	150-250 larvae/L	10-20 fish/L (initial). Up to 20 kg/m^3 (final)	10 kg/m^3 (initial). 50-80 kg/m^3 (final) *(60 kg/m^3 assumed)*
Number of tanks	1-2 tanks *(2 chosen)* [1]	1 tank[2]	2 tanks[3]	7 tanks[4]	5 tanks[5]
Volume total tanks	2 x 10 m^3= 20 m^3	200 L	12 m^3	70 m^3	500 m^3
Area total tanks	20 m^2	0.33 m^2	12 m^2	10 m^2.$tank^{-1}$ x 7 tanks = 70 m^2	
Dimension of room	14 m x 10 m= 140 m^2	3 m x 3 m= 9 m^2	9 m x 6 m= 54 m^2	20 m x 7 m= 140 m^2	35 m x 25 m= 875 m^2

6.2.4.4 Economical Feasibility of the project farm

The economical feasibility of the projected farm was evaluated based on the investment and operating costs and the projected income (Table 22). According to this projection, the investment costs in the first year are about 840.000€.

Table 22: Investment costs (Dujakovic)

INVESTMENT COSTS (euro)	Year 1
(A) Pre-production Expenditures	30,000
(B) Land and Site Preparation	10,000
(C) Civil works - Buildings	153,000
(E) Equipment - Cages	25,000
(F) Equipment - RAS	289,500
(G) Equipment - Processing & Packaging	35,000
(H) Equipment - Waste Management Facility	25,000
(I) Equipment - HVAC System	15,000
(J) Equipment - Service Centres	13,000
TOTAL FIXED INVESTMENT	595,500
TOTAL NET WORKING CAPITAL	244,465
TOTAL INVESTMENT COSTS	**839,965**

Considering operating costs, feed accounts for one of the main expenses. Dujakovic assumes a fish feed cost of 5.3 €/kg, According to Seabass Juniors, farmers in Croatia buy fish feed in Italy and France for ~1€/kg. It is assumed that half production (50 t) will be sold as whole fish. The other half will be sold as fillets, which will account for 22.5 t. In this way, an income of 780,000 € is projected (Table 23). The used sales price seems relatively high compared to market prices between 3-4€/kg in Europe. Such prices reduce the projected income. Data from FishStats for 2006 suggest a price of 4.6 €/kg for Croatia, and a bit lower in Turkey (3.75 €/kg).

Table 23: Income projections (fingerlings sale not included)

Income projection	*Quantity (kg)*	*Unit price (€/kg)*	*Total*
whole fish	*50,000*	*7.50*	*375,000*
fillet 1	*22,500*	*18.00*	*405,000*
TOTAL	*72,500*		*780,000*

According to cash flow analysis, the payback period would correspond to 4 years, and the NPV would be of over 2 million Euros (Table 24). Some assumption and input data are specific for the Croatian situation. The situation might differ in the case of Turkey. However, the projection is generating a general idea of the financial feasibility for the projected seabass RAS-based farm in Eastern Europe.

Table 24: Financial feasibility of the projected farm (Dujakovic)

Total investment	839,965
Equity capital	839,965
Long-term Financing	-
Annual total sales income (fingerling sale not included)	780,000
Annual total costs of product sold (avg.)	501,627
Annual profit before tax (avg.)	278,373
Annual net profit after tax (avg.)	278,373
Internal rate of return	39%
Net present value	2,378,389
Payback period	Year 4
Profit before tax / sales (avg.)	36%
Profit before tax + interest / sales (avg.) (Operational Margin)	36%
Net profit after tax / sales (avg.)	36%
Profit before tax +interest / investment (avg.)	33%
Net profit after tax + interest / investment (avg.)	33%
Sales / investment (avg.)	93%

6.2.5 Qualitative analysis of RAS application

RASs is proposed for seabass culture in Eastern European countries. It is more biosecure than FT. Moreover, RAS offers a better control of culture parameters (temperature, photoperiod). The use of RAS is proposed for hatcheries, nurseries (fingerlings pre-growing), broodstock rearing, extended pre-growing period to a weight of 150 g. The issues refer to the aquaculture sector in general, or to the mariculture sector, mainly seabass production, covering mostly ecological and economical aspects.
Water quality problems are mentioned by farmers in Turkey and Croatia. In Turkey, water quality issues are the main issue for the seabass hatchery Akvatek. Due to its location, it experiences non predictable variations in the water quality due to currents, waves and winds. It is aimed to find a solution to this bottleneck as the timeless turbidity and water quality change affect the production cycle in the semiclosed and open systems. Because of this, the owners are planning to move the farms to a leased location where they would construct the new facilities. In Croatia, insufficient quality of water resources is mentioned as a bottleneck affecting aquaculture. It is not specified to affect concretely seabass. The farm Seabass Juniors states that it has excellent natural resources, including excellent quality sea and freshwater. RASs allow a high independence from the water source and allow maintaining the water quality constant, independently from the environmental and seasonal conditions. In that way, they allow for a healthy and secure production even in the season of diminished water quality. RASs might allow as well the development of aquaculture even in places with limited quality water sources, as the water is treated in the system (sedimentation, UV treatment, nitrification…). However, the possibility of employing limited quality water depends ultimately in the specific quality problem (turbidity, bacterial or chemical contamination).

6.2.5.1 Water use

In Croatia, insufficient quantity of water resources is mentioned as a bottleneck. In Turkey, the Akvatek mentions significant expenses due to water use. It is not clarified if it refers to the energy costs of pumping water (which is typically included by farmers in their water costs; Gyalog, personal communication) or to the particular rights to pay for water use (water source is said to be from the sea). The use of wells is seen as a potential -partial- solution to the Croatian problem of water scarcity sources. Wells are so far unexploited as they are being used only to stabilize winter sea temperature. Moreover, their use presents no technical bottlenecks. RASs can contribute as well to the aquaculture development even in areas with limited water availability as they consume less water.

6.2.5.2 *Wastes discharge*

In Turkey, some marine hatcheries have no water treatment systems, releasing their waste untreated to the environment. However, most of the hatcheries in Turkey are already using semi- or closed RAS. In RASs, waste water can be easily collected and treated and managed. It is not specified if in Croatia and Turkey there are economic penalties for waste discharge exists. If that is the case, RAS would result in a reduction of pollution costs/ fees.

6.2.5.3 *Predation*

Seabass Juniors (Croatia) mentions predation as one of the bottlenecks affecting its activity, although more details are not given. To determine the possibilities of RASs to solve this problem, it needs to be clarified which are the life stages in which the fish suffer from predation. It is assumed that predation happens in cages and not in the indoor hatchery. Indoor facilities, even using flow-through systems or RASs, avoid the predation. RAS is proposed to be applied for the pre-growing phase (fish from two to five grams, extended to 150 g). This range is most probably affected by predation outdoors. As this fish will be held in RAS, predation is avoided. Fish would be released into cages at a size which would be not susceptible to predation any more. If predation affects fish in the cages, then RAS is not providing any remedy.

6.2.5.4 *Pathology*

Pathology results in losses and low growth performance. It reduces farm profitability. An elevated percentage of pathologies is reported to occur in Croatian cages. Seabass Juniors farm mentions to be affected by bacterial, parasite and viral diseases. Infections by Vibrio and Panterella (winter disease) affect cage stages (Dubrovnik, personal communication). It is as well mentioned that in the first phase of rearing fish in cages (fish from 2-5 g to 50-60 g) mortality is 12% -mainly due to Vibrio infections (Dubrovnik, personal communication) but also other diseases and environmental mortality can occur. During the second phase (fish from 50-60 g to 350 g), it drops to only 3%. Pathology affects Turkish hatcheries (up tp 20% mortality). RASs can offer solutions for pathology problems. With the proposed RAS application it is expected that the production cycle will be reduced to one year. Fish will be maintained in RAS up to 150 g (from Sept./Oct. to May). The growing phase in cages is expected to finish before the cold season (November). Therefore, fish will not overwinter outdoors, so that pathology by pasteurellosis can be avoided. As fish spend less time in the cages than usually, there will be a consequent reduction in mortalities compared to outdoors. Moreover, bigger fish released into cages should be more robust against pathogens. In this sense, RAS use results in less mortalities in for both culture steps. In addition, by holding early stages in RAS, fish can be easily manipulated (handled or vaccinated) before their release in cages. Easiness in handling is not exclusive to RASs. FT systems allow for this as well. But compared to FT systems, RASs offer biosecure conditions, avoiding escapes of fish that can compete with natural populations. However, for many of the reported diseases affecting sea bass in Mediterranean countries, there are no preventive vaccines. The treatment consists of baths or alike once fish have been infected (Álvarez-Pelliteiro, 2004). As shown in the case of Akvatek, pathology can also affect hatchery stages. RASs allow a high independence of the water source which eventually might be contaminated. Anyway, once treatment is required in the system, the management of waste water in which chemicals and veterinary products have been used is easier in RASs than in FT systems, the latter one frequently discharging directly to the nature. In spite of the advantages, RASs have some inconveniences related to pathologies: they potentially allow for pathogenic microorganism to become established in the system through the formation of biofilms (King, 2001). Moreover, after a treatment has been applied, the system needs to be cleaned, and the rests of medicines need to be eliminated. Afterwards, the system has to be restarted requiring time for the colonization of the biofilter by nitrifying bacteria. Rests of antibiotics can be as well retained in the filter.

6.2.5.5 *Mortality due to environmental factors*

Weather conditions are mentioned as a bottleneck affecting the activity in Seabass Juniors farm. Unfavourable environmental conditions can cause damage and losses in open production systems. Fish in RAS are not affected by environmental conditions. They can be kept in constant and artificial regimes. For the projected case, these benefits are applicable to the stages hold in RAS (broodstock and fish up to 150 g). During the rest of the ongrowing phase, fish in cages will be affected by environmental conditions. Anyway, as mentioned for pathologies, the phase in cages is expected to be substantially shorter and less impact of adverse environmental conditions outdoors. Moreover, fish released into cages after longer growth in RASs might present bigger robustness to affront adverse conditions. In this sense, RASs for the pregrowing and first ongrowing phases is advantageous compared to cages.

6.2.5.6 Energy use/cost

In terms of pricing, energy costs are dictated by national and international economic policies and multinational's operations. RAS have high power consumption. Therefore high electricity cost is a bottleneck for RAS development in Turkey. Akvatek, having closed and semiclosed hatcheries, states that expenses on fuel and energy are high. For Idagida, electricity and fuel were major expenses of their operating costs when they started growing fish in RAS. They were unable to compete with cage culture. However today RAS is functioning as a hatchery and is a successful business. The main cost price shares correspond to feed and labour. Some authors claim that the variable costs (feed, fingerlings, electricity and labor) of producing fish in RAS are not much different than other production methods (Losordo *et al*, 1998). Moreover, according to Blancheton (2000), the saving in heating energy required for the production of one gram fingerlings of seabass in RAS corresponds to approx. 50% of the production cost of fingerlings from a heated FT system. Moreover, the most controlled culture environment in RASs might lead to better fish performance and economic advantages (shorter time of production, lower expenses in food). These factors compensate for the higher power cost in RAS compared to FT.

6.2.5.7 Low Growth rate

Problems of low growth rates and slow metabolism in the cold period are reported by Seabass Juniors (Croatia). This farm stocks fish in May with two to five g, and fish reach 50-60 g before the first winter. The average market size of 350 g is reached before the second winter, therefore fish spend one winter in cages. Optimum growing rates are desired in order to get the marketable fish size in the shortest possible time span. In RAS, optimum growing conditions can be provided by temperature control, light, etc.. Mentioned benefits are applicable to all stages hold in RAS, but not for ongrowing stages in cages. In the present study, the pregrowing and first ongrowing phase of seabass (growing the fish up to 150 g) is proposed to be in RASs. Fish would not spend any winter in the cages and the low growth rate would be avoided.

6.2.5.8 Feed use (FCR)/Feed costs

FCR is said to be high in Croatian mariculture (between 1.3 and 2, Seabass Juniors) for fish reared in cages. It is claimed that Croatian mariculture needs feeds of the highest quality in order to reduce FCR. Not optimum FCRs are stated as well by Akvatek, although the exact figure is not specified. Feed accounts for one of the highest expenses in fish production. The high feed expenses are due to high FCRs (high amount of feed needed) and to the high feed prices. In Croatia, feeds for mariculture are imported from Italy and France at the price of 1 €/kg (Seabass Juniors). However, Dujakovic (personal communication) mentions a feed price of 5.3 €/kg. In Turkey, feeds for marine hatcheries are both nationally produced and also imported. It is claimed that RAS generally yield better FCR than other systems such as ponds (Losordo *et al.*, 1998). Seabream cultured by Sadek *et al.* (2004) in earthen brackish water ponds realized FCRs between 2.2 and 3.2 depending on the diet. A range typically found in cages is 1.3-2.3. Mozes *et al.* (2003) found for seabream grown during 200 days until 330 g, similar FRC (1.8) and survival in RAS than in FT system. In the annual DSM conference of 2005, D. Fletcher of Mon Aqua Tech Ltd. stated that in a comparison with seabass cultured in cages with a FCR of 1.9-2.3, they found a lower FCR in RAS (1.3). They found as well reduced mortality despite higher stocking densities, and halved culturing period compared to sea cage production (AQUAASIAPAC, 2006). The possible better FCRs in RASs can be due to better controlled factors affecting FCR such as oxygen saturation of water, temperature, etc.

6.2.5.9 Fingerlings supply (product quantity)/Fingerlings quality

The on-growing sector for Croatian mariculture is not self-sustaining, as the fingerling sector covers only 30% of the national demand. About eight million larvae are imported from Italy, Greece and France. As a consequence, there is need to increase production to ten million larvae. Similarly, in Turkey the national fingerling production is insufficient and larvae have to be imported (>11 million seabass in 2006). RASs do not offer any direct solution to this problem, and the expansion of the hatching sector needs to be promoted by governmental measurements or free entrepreneurs. However, RASs can help by the development of hatcheries even in places with reduced water quantity or quality. Moreover, through RASs, all year round production and supply of larvae can be achieved.

Croatian mariculture needs increased fingerlings' quality to reduce mortality (Mladineo). In fact, low quality seed results in low performance, low resistance to diseases and high mortality. RASs do not offer a direct solution for increasing fingerlings's quality. To overcome the low quality of the fingerlings, breeding selection programs need to be promoted. Parental lines need to be created with optimal genetic potential that produce quality seed. In Croatia, there is already a national project for forming autochthonous parental stocks of seabass, in which

Seabass Juniors is involved. But there is no elaborated national program for broodstock selection or control of reproduction. RASs can be used within these programs for creating biosecure conditions and avoiding escapes of farmed fish. RASs might also allow standardizing and specializing reproduction through its accurate control of environmental parameters.

6.2.5.10 Money cost/Interest rate

High money cost and high interests affect Croatian mariculture. Seabass Juniors pays bank interests of 10-13% per year. The high capital costs are the main issues for Croatian farms (Seabass Juniors). High money costs (interest rate) make new investments and/or improving the farm technology, carrying capacity, etc. difficult and not viable. Money cost is dictated by national and international economic policies. RASs normally require high capital costs and relatively high investments, which is not encouraged by high money cost. But RASs can offer competitive advantages, such as less stakeholder conflicts (due to a reduced use of land and water), higher production per square unit of area, production all year round, etc. that could compensate for the high initial capital needed and the high national interest rates.

6.2.5.11 Investment costs

Croatian mariculture farms, and specially small ones, suffer from initial capital costs, and high production costs. High costs do not encourage investors for initiating or improving aquaculture. RAS normally require relatively high initial investments. However, the advantages offered by RASs such as the full control of the environmental factors, better FCRs, savings in water and land, etc., might compensate the initial investments on a mid / long term.

6.2.5.12 Taxes

In Croatia, there is hardly export of mariculture products. Large scale companies export to the EU have to pay high import taxes. This hinders to reach foreign markets. Akvatek states that taxes form a substantial part of its expenses, although it is not specified what those taxes are, such as KDV (additional taxes), and OTV (specific consumption taxes). RASs cannot help to overcome high taxes. Directly, it has no influence on taxes that are fixed by the local of national government. However, RAS helps to reduce the taxes if these are related to e.g. water consumption or land use. RASs also reduce the nutrient load in the environment. Environmental taxes or fines (pollution costs) are therefore at the end often lower than for FT systems.

6.2.5.13 Operational costs

When Idagida started its RAS operating costs (mainly electricity and fuel) in combination with low product price rendered the operation not viable. Today Idagida is a successful hatchery producing in RAS. The responsible state that operating costs are still very high. Akvuatek also has subjectively high operating costs, especially due to expenses in fuel, wages, feed and energy. However, the responsible of the farm states that they are satisfied with the economic result. Among the operating costs, salaries (labour) are main expenses, just after feed expenses (Akvatek, Idagida, Egemar, Teknomar, Sercin, Camliyem). RAS reduces some but not all of the operating costs. E.g., in RASs better FCRs can be achieved, consequently reducing the expenses in feed. RAS as well reduces heating expenses, and expenses due to water and land use or nutrient emission. However, RASs require the employment of skilled people whose salaries are higher. But they can be managed with less people, so that the costs due to wages are maintained at a similar level. Some authors claim that the variable costs (feed, fingerlings, electricity and labor) of producing fish in RAS are not much different than other production methods (Losordo *et al.*, 1998). RASs allow for high yields per surface unit with year-round production. They are therefore profitable if an appropriate market is addressed.

6.2.5.14 Design issues/System problems

Croatian mariculture faces some system and design problems. Cage technology is said to be on a low level, with scarce mechanization and automatization. Technology and equipment are not standardized. Moreover, some difficulties in cage system design are mentioned, although more details are not given. In Seabass Juniors, the responsible is not entirely happy with the labour efficiency. He states that more automatization is needed. The introduction of new aquaculture techniques is mentioned as priority in Turkey, RASs do not intended to substitute cage systems, which are seen as a viable option. However, RASs are proposed for the hatcheries and the pregrowing phase of seabass. RASs are complex systems that have their design and operation issues. As an example, when Idagida was built, they encountered RAS design issues. On the contrary, Seabass Juniors, operates a semi RAS hatchery and two cage sites, without any technical problems at all.

6.2.5.15 *Processing*

Mariculture products in Croatia sell mostly non confectioned and raw. This is also the case for Turkish mariculture. Both countries aim for increasing the confectioning of products to be able to find new markets. In Turkey, the number and capacity of fish processing factories is insufficient according to personal communication. By offering new processed products, farms can have a more uniform market. Products might reach a higher price which amortizes the investment on the processing facilities and makes the whole activity more profitable. RASs contribute to product uniformity and all year round constant and predictable production, which make the chain management from production to processing more efficient.

6.2.5.16 *Marketing/Label/LAV spp.*

Branding is said to be insufficiently developed in Croatian mariculture. There is a lack of national regulations for provision of eco-certifications and branding. Moreover, marketing is said to be inefficient. There is a lack of an elaborated national program for marketing strategies. In Turkey, the lack of marketing structures (on quality, quantity, national and international) affects the aquaculture sector in general. Seabass Juniors has just started the branding of its market size seabass. Akvatek aims to increase their quality standards. For them, quality labels could allow accessing new markets and achieving higher prices.

Good marketing strategies are needed for a successful product introduction into the market. Getting a good product acceptance by the consumers is a priority in marketing strategies. In that sense, a product which has been obtained under a sustainable activity can take advantage in a conscious market with customers worried about environment and fish welfare. RASs are systems which make a more reduced use of natural resources (water, land), energy and discharge less nutrient (Martins *et al.*, 2006). They are environmentally friendly systems, and can help to get eco-certifications, once branding is developed. In Turkey consumers still prefer 'natural' marine fish rather than cultured fish. Consumers' acceptance can be achieved by promoting the socio-economic benefits of aquaculture as less pressure on wild stocks, source of employment, and by promoting the health benefits of seafood. The introduction of labels such as quality or environmentally friendly certifications can increase willingness to pay and the demand for aquaculture products.

6.2.5.17 *Market/Market demand*

Croatian mariculture is affected by an instable and unorganized market (Mladineo; Seabass Juniors). In addition, the market for the larvae is not defined (Seabass Juniors), resulting in an instable economic result of the farm. Export from Croatian mariculture sector is low. Only few large scale companies sell their products to the EU market but they have to pay high taxes. If a fish market is not well organized and insufficiently developed, does not relate to the production system. However, RAS allow all year-round production, which results in constant supply contributing to a more stable market. This, favours the product outreach to new consumers due to its constant presence, and hopefully, the increment on demand. In Turkey, as it has been previously commented, the demand of aquaculture fish is still lower than the demand for 'natural' fish. But this situation can change if products from aquaculture and their sustainable origin and benefits are promoted. Finally, low product prices can sentence a farms' fate, as documented earlier for Idagida. Product prices depend on the forces of demand and offer. However, it has been shown in seabass that when fish are kept longer in RASs before their transfer into another culture system, the time needed for reaching the market size is reduced. This results in a reduction in production costs (fig. 10). This supports the projected application of RASs for the hatchery, pre-growing and first on-growing phase before fish transfer to cages. In this case, the RAS application still allows for good margin of benefits. Product price can be increased if the product is awarded with a premium distinction, to which RASs can contribute due to its environmentally friendly character. Higher prices can be also achieved by selling the product in a new processed form which makes it more appealing.

6.2.5.18 *Diversification*

Diversification allows expanding market opportunities. But the major problems are: 1) customers' acceptance, 2) that a good scientific knowledge on the life cycle is needed, and 3) government support is needed. Croatian mariculture is believed to need diversification and new local markets need to be identified. The target species to be introduced in the Croatian production are rockfish, turbot, halibut, yellowtail, dentex and other sparids (Mladineo). Idagida also plans to add new species to the production activity. Turkish aquaculture priories the increase in number of cultured species. In Turkey, the Government supports the culture of emerging species (bluespoted seabream, redbanded seabream, red pongy, brown mearge, two banded seabream, white grouper, striped seabream, carb, sargos, mearge, common dentex, puntazzo, turbot, tuna). It pays 1 YTL (0.57 €) per kg and per year to producers for market size fish. The hatching sector of new species also receives subsidy: 0.05

YTL (0.03 €) per fry per year (Kurtoglu). However, one of the main problems for diversification in Turkey is that consumers' preferences are focussed on few species and eating habits do not change easily. RASs favour the introduction and culture of new species, as they allow a good control of the physical, chemical and consequently biological aspects. Culture conditions can be adjusted to the specific requirements of the species, and even those species for which the local natural environmental conditions are not adequate can be cultured. With the proposal for RAS application, it would be possible to diversify production, as temperate/cold species could be grown in the cages during the winter, and other species could be grown in RAS during summer. The RAS application as proposed diversifies fish market weight (350 g and 600g before winter and about one kg at later moments).

6.2.5.19 Traceability

The lack of traceability of a product and uncertainty of its history can generate consumers' distrust. For allowing traceability in the aquaculture sector, farms should maintain full production records. In this sense, RASs offer the advantage of being a very controlled culture method, allowing an easy monitoring and recording of details on the culture environmental factors, water quality parameters, feeds used, pathogenic incidences, etc.

6.2.5.20 Legislation

Seabass Juniors states that laws are usually incongruent, not coordinated, and have no uniform application, so that a transparent control by the inspection bodies is required. Moreover, Seabass Juniors misses governmental support in form of subsidies, which would enhance aquaculture development. This could be beneficial for small and medium size companies that otherwise cannot compete with large scale companies. Seabass Juniors also perceives that aquaculture is strictly controlled. The same is stated by Akvatek: in Turkey aquaculture is strictly regulated, more than e.g. agriculture. Strict environmental laws are being applied to the aquaculture sector. In this sense, RASs are advantageous as they are more environmentally friendly and can comply to new strict environmental laws.

6.2.5.21 Property

Undefined ownership laws affect the general aquaculture sector in Croatia (Mladineo). Since 1990, former state-run farms have been privatized, and the new owners protect their interests through the aquaculture section of the Chamber of Commerce. RASs cannot provide solutions to property issues.

6.2.5.22 Bureaucracy

It is claimed that the general governmental policies and legislative approach is slowing down the expansion and development of Croatian mariculture (Seabass Juniors). In Turkey, heavy bureaucratic procedures are affecting the aquaculture sector in general (Kurtoglu), being time and cost demanding for investors. There are in fact not only long bureaucratic processes for the first investment but also after it. Akvatek reports bureaucracy is too heavy and it should be reduced for improved efficiency. Hakan Adamcil, director of Kilic Group, states that bureaucracy, together with expensive fuel and high rental prices, impede the Turkish aquaculture market (www.turkishdailynews.com.tr). In his opinion, "if bureaucratic transactions gain momentum for projects planned by fish farmers, Turkey might be the number one aquaculture market in Europe" (May, 2008). The existence of heavy bureaucratic procedures is independent of the type of production system. However, in general cage aquaculture requires more permits and formal controls than land aquaculture (Schneider, personal communication). Land aquaculture, however, faces sometimes heavy bureaucratic procedures in order to get permissions for its exploitation. RASs, with its lower demands for water and land, and the controlled waste emission, might result in some reduction in the bureaucratic processes and permissions needed, although at the end bureaucracy is a governmental matter. Moreover, the present study proposes the use of RAS for only a part of the production cycle, and the last ongrowing phase would continue in cages. The bureaucracy related to these systems would not be avoided.

6.2.5.23 Labour qualification

Seabass Juniors states that, in Croatia, seabass ongrowing farms have small size character, being owned by private persons with lack in aquaculture knowledge and without any deeper mutual relationship. , due to its complexity, require highly skilled, educated and trained personnel for their successful application. A good understanding of the biological processes, the species requirements and the effect of the environmental factors on the species' is required. Because of this, RASs do not overcome problems with low labour qualification. In essence, scientific collaboration, training workshops, education, and technique and knowledge dissemination are required for the successful application of any system. Not only scientific institutions but also govern bodies could be involved in the development and promotion of these programs.

6.2.5.24 Union networks/Lack of cooperation

A lack of strong relationships between the producers, science institutions and the structures of local inhabitants affect the Croatian mariculture. In some regions, there is no local representative to the farmers (Seabass Juniors). The connections with the decision makers are just formal and weak. In Turkey, one of the priorities is to develop international relationships. Unfortunately, the application of RASs cannot help on overcoming this kind of issues. Even more, optimal relationships are required between producers using these techniques and also with research institutions, in order to overcome technical difficulties.

6.2.5.25 Conflicts with other coastal/land stakeholders

Croatian and Turkish coastal mariculture has conflicts with other coastal users (especially tourism and construction). It experiences opposition from these sectors and environmentalists. The farms' environmental impacts contribute even more to a bad image of mariculture by consumers, and people develop a prejudiced approach to aquaculture. In Croatia, incongruent laws for tourism, agriculture and landscape planning affect mariculture. Mariculture is in competition with tourism for locations in areas with the highest water quality. Their environmental impacts are criticized by local green associations. Those associations attract media attention that influences policy makers, politicians and government bodies. Seabass Juniors experiences this kind of conflicts. Its representative reports that the urbanistic plans change according to the changes in the local government. Tourism companies are as well in strong symbiosis with the local government. Additionally, there are some extreme green associations, not willing for dialogue. However, he states that by creating local employment, the bad image of mariculture is diminished. In Turkey, Idagida reports similar conflicts with tourism and environmentalists, and its representative states that the criticism against aquaculture by the environmentalists is exaggerated. In Croatia, the strategic plan focuses the attention on finding compabilities between the stakeholders to decrease anticipated opposition, and on defining coastal zone management plans for the integration of mariculture. It also proposes the relocation of large installations off-shore. It has been also suggested to assess the costs of switching from inshore cage-rearing to RAS in places where adequate water from wells is available. Combined facilities that integrate touristic offers and fish retail need to be proposed. The responsible of Seabass Juniors insists on that aquaculture facilities must enhance their marketing in the tourism sector.

In Turkey, the Government already took measures by moving cages off-shore; New off-shore facilities must be over 250 t capacity. Off-shore production is supported with subsides. For seabass/ bream production off-shore, farmers are paid 0.85 YTL (0.41 €) per kg of market size fish and per year. Off-shore facilities also receive support for export. The government is also promoting the use of environmentally friendly methods. It works as well on developing integrated coastal management plans (Kurtoglu). Conflicts with other land and coastal users are one of the main obstacles for aquaculture development. It leads to a strong opposition against aquaculture in some areas. In the present study, RAS application is proposed, even not for the entire production cycle, therefore including cage culture. It means that the conflicts in the coastal area would not be completely resolved. However, the integration of seabass culture in RAS and in cages could change people's perception towards aquaculture, as RASs are perceived as more environmentally friendly. RASs reduce the waste input in the environment. Moreover, for RASs, substantially less land than for other production systems is required, as well as less water. Hence, by RAS hatchery instead of FT systems, the conflicts about water and land use with other users can be reduced. However, for the problems concerning cage culture, other solutions such as moving cages off-shore and implementing coastal zone management plans are needed.

6.2.5.26 Scientific support

Croatian mariculture sector reports on its own insufficient scientific involvement. There is no strong relationship and coordination between producers, scientists. Moreover, insufficient zootechnical improvement has been reported, which might be a consequence of this lack of collaboration between sectors. RASs cannot offer a solution to this problem. In fact, RASs are relatively new systems in aquaculture and still much research and development has to be done. For their successful application, collaboration between research institutions and farms is required. Additionally, detailed scientific studies about the ecological processes could reduce the negative image of mariculture. Moreover, scientific research is needed for improving the knowledge on life cycle and requirements of new species.

6.2.5.27 *Other issues*

Other issues, particular for this case study, that were collected by the questionnaire or other sources, are:

6.2.5.27.1 *Harvesting/Moving and grading fish (econ.)*

Seabass Juniors mentions harvesting and moving and grading fish as an issue. It needs to be clarified what these bottlenecks are referring to. Harvesting from indoors facilities and moving fish in RAS does usually not constraint. Seabass Juniors already uses a semiRAS. If this issue refers to moving fishes to and from cages, RAS does not offer a solution. RAS is only planned to be applied for a part of the production cycle but not for the last growing phase. Fish would continue being moved from the RASs system to the cages and finally harvested from there. But by pregrowing fish in RAS, the phase in cages in reduced.

6.2.5.27.2 *Stealing and vandalism (econ., soc.)*

Seabass Juniors suffers losses due to stealing and vandalism. RAS does not solve this problem compared to FT systems located indoors and provided with an adequate security system. Vandalism is a social problem, which *a priori* has nothing to do with the type of production system. Croatian and Turkish mariculture sector experiences conflicts with other coastal users and some representative of those sectors have been willing to participate in dialogues. By applying systems that are environmentally friendlier, the perception of aquaculture can change in people's mind; moreover, by applying RASs some conflicts with coastal users can be reduced. In sum, vandalism could be as well reduced.

6.2.5.27.3 *Absence of a system for environmental quality assessment (econ., soc.)*

Croatian mariculture does not have a system of reliable environmental quality indicators or a program for their regular monitoring. The same holds for Turkey. If these systems would be developed, a more controlled and justified impact assessment of aquaculture could be realized. It would help on correcting bad practices that in fact are in the origin of the bad image of aquaculture. RASs do not help resolving the absence of this kind of monitoring systems, but RASs would benefit from them, as these would legitimize the environmentally friendliness of RASs. The development of these systems for environmental quality assessment is on hand of policy makers.

6.2.5.27.4 *Finding employees (soc., econ.)*

Finding employees is a constraint of Seabass Juniors. RASs cannot help on solving this problem. Even more RASs are technically complex and for their successful application they require highly skilled and trained personnel.

6.2.5.27.5 *Lack of GIS on potential aquaculture areas (gov., econ.)*

In Turkey, potential aquaculture areas are not mapped and consequently carrying capacities of those areas have not been defined. This affects the aquaculture sector. If mapped, a better management of the sites and water sources could be practised. Mapping also facilitates more accurate plans for aquaculture development. RASs application does not offer a solution to this problem.

6.2.5.27.6 *Rents (gov., econ.)*

The difficulty to lease is mentioned among the issues affecting Turkish aquaculture. It seems that long term renting procedures and high rental fees exist, which hamper investors'. Additionally, it is mentioned that short term sea surface renting manipulates farmers' environmental protection attitude to the wrong behaviour. They take the approach of "pollute and leave". RASs cannot offer a solution to this bottleneck. Compared with other systems, they require less land for the same amount of production. This reduces the leased surface,

6.2.5.28 *Conclusions*

In general, RASs are assessed positively as sustainable option for overcoming problems affecting seabass production in Eastern Europe (Table 25). They appear as total or partial solution to some of the problems, or at least as minimal positive contributors for other ones. But in many cases, a change on the government approach, plus legislative and economic support are basic requirements for overcoming many of the bottlenecks. For the ecological problems (water quality, water use, waste discharge, predation) currently affecting the seabass production in Croatia and Turkey, RASs offer total or partial qualitative solutions. Economic problems, those with still a high ecological component (pathology, environmental mortality, energy use, growth rates, FCR or fingerling supply and quality), are totally or partially solved by RASs application. However, especially Croatia suffers from other more purely economic bottlenecks that seem to affect Turkey less. RASs cannot offer any solution. Concretely, Croatia experiments high interest rates, high investment costs, high taxes for export, etc. The

Croatian case is, in fact, a situation of a transitional economy -after the war and the bad macroeconomic environment in the 90's- with all its associated problems. The are other economic bottlenecks (lack of processing facilities, bad marketing strategies, lack of branding programs, market and market demand problems, lack of diversified aquaculture production, lack of traceability, etc.) that affect both countries and which can hardly be overcome by the application of RASs alone. The application of RASs helps on improving some aspects. These bottlenecks are strongly related to the policy approach taken by the governments. Some of these problems are, moreover, issues affecting the aquaculture activity in general, not particularly the seabass production sector.

Table 25: Analysis of RAS suitability to Case study 1

Sustain. aspect	Issue	Country	Solution by RAS technology?		RAS adaptations
			Y/N	Obs.	Obs.
Ecology	Water quality	Cr, Tu	Y	Independence from water source	
	Water availability/use*	Cr, Tu	Y	Less water consumption; less taxes	
	Wastes (water & nutrient discharge)*	Tu	Y	Good wastes management.	
	Predation*	Cr	Y	Predation in cages, avoided indoors.	Fish in RAS till 150 g
Econ.	Pathology**	Cr, Tu	Y	Easy handling, biosecurity, water management, independence from water source	Fish in RAS till 150 g
	Weather conds (Env mortality)**	Cr	Y	Pregrowing fish in RAS: less time in cages & bigger robustness	Fish in RAS till 150 g
	Energy use**/cost	Tu	Y	High electricity use but savings in heating	
	Low growth rate**	Cr	Y	Pregrowing in RASs	Fish in RAS till 150 g
	Feed use (FCR)**	Cr, Tu	Y	Better FCR	
	Feed cost/supply	Cr, Tu	N	Indirectly yes: better FCR (?)	
	Lack fingerlings**/quality/cost	Cr, Tu	Y	All year round production	
	Money cost, interest rate	Cr	N	Money cost: independent matter	
	Taxes	Cr, Tu	Y	Indirectly, by reduced water & land use, & less pollution	
	Investment cost	Cr	N	RAS high investment costs, but also advantages	
	Op. costs	Tu	Y/N	Less feed expenses. No reduction in wages	
	Design issues/System problems	Cr, Tu	N	Might also affect RASs	
	Processing	Cr, Tu	N	Indirectly, RAS promote a successful production chain	
	Marketing/Label/LAV spp.	Cr, Tu	Y	RAS: Environmentally friendly	
	Market/Market demand	Cr	N	Indirectly: all year round supply	
	Diversification	Cr, Tu	Y	Conditions for culturing new spp.	
Govern.	Feed & fertilizer limits/Other legislation	Cr, Tu	Y/N	RAS fulfill strict env. laws	
	Property*	Cr	N		
	Bureaucracy	Cr, Tu	N	Cages for the ongrowing	
Social	Labor qualification	Cr	N	RASs need skilled & trained personel	
	Union networks/Lack of cooperation	Cr, Tu	N	Indeed cooperation might benefit RAS application	
	Conflict with other coastal/land stakeholders*	Cr, Tu	Y	Partially. Less water & land.	
	Scientific support	Cr	N	Indeed RASs need scientific support	

Turkey has progressed compared to Croatia by working on some of these issues. For example, the Turkish government supports the culture of new species with subsides, which favours the diversification process. RASs application can hardly make any contribution to overcome the problems of governance (environmental laws, property laws, heavy bureaucracy) affecting the aquaculture sector. This basically requires a change in the legislative approach. Finally, both countries suffer from social issues. These are lacking cooperation and union networks and conflicts with other stakeholders. Stakeholder conflicts are one of the major issues. There are incongruent laws for tourism, agriculture and landscape planning, together with self-interest agreements between local government and tourism or urban sector. In Croatia, there are no measures being applied at the moment for resolving the conflict, although the strategic plan considers ideas of tourism and mariculture integration, switching to RASs or moving cages off-shore. Turkey has taken a head start and its government has already moved cages off-shore, economically supporting the off-shore production and its export. Problems of lack of qualified labour, or lack of scientific support affect Croatia in addition. In general, RASs application does not overcome these social problems but is affected by them.

6.2.6 Quantitative analysis of RAS application

Quantitative achievements through RASs application have been assessed. The sustainability achievements are estimated by comparing each sustainability indicator for two farms: one not applying RASs, and the other one applying RAS. Both farms are considered to carry out a production of 100 t/y of market size fish and having self-supply fry activity from the hatchery unit (Table 26).

Table 26: Quantitative achievements in sustainability criteria. cursive refers to stage in cages.([1]) From information provided by Blancheton. ([2]) Assuming protein content in feed of 47%. Assuming 20% of N assimilated by the fish, and 80% excreted (solids and dissolved).([3]) Calculated considering a FCR of 1.4, for approximately 286,000 fish up to 150 g, which gives a use of 60,000 kg feed/y. ([4]) Assuming 11.5 g P/kg feed. Assuming 40% of the P assimilated by the fish, and 60% excreted (mainly as solids). ([5]) Taking into account that fish density in FT can account for 30-60 kg/m^3, and in RAS for 70-100 kg/m^3. ([6]) Mozes *et al.*, 2003. ([7]) From Dujakovic's projection.

Sustainability criteria		Current	Projection
Name	**Unit**	**(FT + *cages*)**	**(RAS + *cages*)**
Water use	m^3/kg feed	150[1]	0.5 to [1]
Discharge of N	g/kg feed	60.16[2]	Depending on emission treatment, can be virtually « zero »
	kg/y	3610[3]	
Discharge of P	g/kg feed	6.9[4]	
	kg/y	414[3]	
Land use	ha/t fish	Approximately double than RAS[1,5]	0.0036[1]
Mortality	% losses	*15-20 %*	*< 3 %*[1]
Energy use	kWh/kg feed	Not provided	6 to 7[1]
Feed use (FCR)	kg food/kg fish	1.8[6]	1.4 (for bass)[1]
Staff	Number/t fish	>	<
Rate of return	%	Not provided	39.17[7]

6.2.7 Conclusions and recommendations

This study has focused on assessing the applicability of RASs for seabass aquaculture in Eastern Europe, and its feasibility to overcome problems currently affecting existing systems. The present RAS application has been projected for a hatchery and nursery, with the suggested continuation of the pregrowing phase in RAS up to 150 g, in order to reach 650 g fish in cages within one year. The RAS application seems to be realistic due to: 1) the current status of RASs in the countries involved (the technology already exists and there are some farms already using these systems), 2) the positive attitude of the farmers towards the more sustainable production methods, and 3) the needs of the sector to overcome current problems. After the qualitative analysis, it can be concluded that RASs offer mostly a direct solution for the ecological issues (water quality, predation). RASs offer partly solutions for economic issues especially for those ones which are closely related to the ecological aspects (pathology and mortality, energy use, growth rate and feed use). However, the most purely economic issues (money costs, investment costs) are not solved by RASs application. Those issues corresponding to governance and social aspects (bureaucracy, conflicts with other stakeholders, stealing and vandalism) are only partially overcome. Especially Croatian mariculture lacks government support, which is required for aquaculture development. In general, Turkey shows active governance and good economic conditions for the development and improvement of mariculture. The economic feasibility of the proposed RAS application has been assessed. The projected farm, with a 100 t production/y, would have a payback period of four years, would need a total investment of 840,000 €, and would have an annual net profit of 270,000 €. Subsidies supporting investments in sustainable aquaculture might reduce investment costs. Sustainability is improved quantitatively measured for the present scenario compared to FT/ cages. Water use is reduced 150-300 times, land use is decreased to 50%, FCR is expected to go down to 1.4, and predation is cut down from 15-20 to less than 3%.

6.3 Case study 2: Sturgeon farming in RAS

6.3.1 Introduction

Case study 2 projects farms culturing high value species, such as sturgeon. Sturgeon is selected because it is an endangered species, and because of its value (meat and caviar). The assessment evaluates the benefits of changing the traditional FT system to RAS for hatcheries (fingerlings production) and grow-out facilities. The aim of the RASs application in sturgeon farms is to create biosecure and safe conditions leading as well to better growth performance through temperature and photoperiod control. The partners involved in this case study are representatives from Romania, Hungary, Croatia and Turkey, although only enterprises from Romania and Hungary have contributed with data.
The study objectives are:

- Asses the suitability and viability of using RAS systems for hatcheries (fingerlings production) and for broodstock rearing.
- Asses if RAS makes a difference in terms of sustainability compared to FT systems and solves some issues that currently affect this sector.

Sturgeons are high value species in fisheries and aquaculture mainly due its caviar. Additionally, sturgeon meat is commercialized. There is a growing international market for fertilized eggs, fry and juvenile fish. World sturgeon catches (from wild fisheries) have dramatically decreased in the last years, as wild stocks have collapsed. World production of farmed sturgeon has rapidly increased to more than 3,000 t in 2006, not including China (FishStats; www.fao.org[2]). The demand for caviar is approximately 400-500t/y worldwide (www.worldwildlife.org). This demand can no longer be met by fisheries. Consequently, prices of wild caviar have risen dramatically. Wild caviar accounts for 80% of the annual world's supply (250 t). Farmed caviar accounts for 50-100 t/y (based on industry quickscan). Wild caviar supply is expected to decrease. The supply of farmed caviar is not expected to meet the demand. Production is expected to grow to approximately 80 t/y (predictions for 2010; commercial data). Main producers of farmed sturgeons are China (17,424 t), Russia (2,100 t), Italy (860 t), Poland (300 t), Germany (228 t), Bulgaria (159 t), and Spain (122 t) (FishStats: data for 2006). Main exporter countries of caviar are to Iran, Russia, Kazajkstan, Romania, Germany and Bulgaria (www.fao.org).
Four countries are involved in this case study: Romania, Hungary, Croatia and Turkey. From them, only Romania and Hungary have a significant sturgeon production activity while Croatia and Turkey have none (Table 27). The latter two are interested in participating in this case study as a similar production activity might be established in the future. Sturgeon production in Romania and Hungary is 50 t/y (2005), and 25 t/y respectively. This fish is produced under intensive conditions. It represents less than 1% of the aquaculture production. However, due to the high market value this culture is of relevance compared to the total value of aquaculture production. The value per kilogram fish meat is almost double compared to common carp.

Table 27: Details on the sturgeon production in Romania and Turkey

	Romania	Hungary
Species	• Sturgeon (Russian, Siberian, European, Sevruga)	• Sturgeon (Russian, Siberian, European
Production	• 50 t/y • (<1% of national AQ production)	• ~25 t/y (<1% of national AQ production), • 200,000 fingerlings/y
Number of farms	• >10 farms	• 3 farms exclusively dedicated to sturgeon production, with RAS. • Farms with FT: 2 catfish farms have introduced sturgeon & tilapia. • Some sturgeon produced in extensive or semi-intensive polyculture pond farms • In total, 5-8 farms
Size of farms (by production)	• From 5 to 25 t/y per farm, considering 2 to 10 farms.	• About 12 t/y (considering only farms with RAS).
Production system	• FT and RAS	• Pond & FT (~10 t/y) and RAS (15 t/y)
Water source	• Rivers, wells	• wells
Production cycle	• about 6-9 years	• 6-9 years

The number of farms producing sturgeon in Romania is not well reported. One source (G.M.P., from Giarmata) reports two farms, probably referring to meat production. If caviar production is included, at least three farms are counted (Giarmata, Compania del Management and Kaviar House). Another source (M.M., from Kaviar House Comment Isabelle) states that there are ten or more farms. With these contradictions, the average production per farm can only be estimated coarsely as five to 80 t/y per farm. It seems sturgeon culture develops rapidly in Romania. According to the latest information (Gyalog, Metaxa, personal communication, 2008/2009), there are several new sturgeon RAS farms planned or starting operation in different regions. The total number of farms can only be estimated with more than 10 for the moment. In Hungary, the sturgeon production takes place mainly in intensive farms, applying RAS (15 t/y, in three farms Forus, Silverfish and Rideg & Rideg) and pond & FT (<10 t/y). In those last ones, sturgeon production is carried out as additional activity. Their main production is catfish. From RAS farms, only Forus serves the meat market while Silverfish aims to produce caviar and Rideg & Rideg produces fingerlings. Some sturgeon is also produced in extensive or semi-intensive polyculture pond farms, together with carp. In total, there are five to eight sturgeon farms (personal communication). The average production per farm is 12t/y per farm accounting only for exclusive sturgeon production farms. It seems there is a big demand for this product in Hungary (J.N., from Forus Ltd). There is potential for the production of paddlefish, which has to be hatched in RAS. The fish is stocked in ponds for water purification in polyculture together with cyprinids. The advantage of paddlefish is their market value compared to big head carp (personal communication).

6.3.2 The state of art for RASs

In Romania, at least two sturgeon farms (Compania del Management and Giarmata) use RAS. Generally there is a positive attitude towards RAS, as future alternative for aquaculture. RAS is also positively received because of support given by the European Fisheries Fund for the construction of RAS. In Hungary there are three sturgeon farms applying RAS which account for almost half of the total sturgeon production. RASs can be found as well in an eel farm (although not in operation) and in a hatchery for koi carp fingerlings. Another RAS unit is planned by Jaszkiseri Halas Ltd. to produce barramundi. RASs are seen as alternative for intensive activities and for the introduction of new species. In Croatia no significant amounts of sturgeon are produced. RASs are rare: there is only one RAS eel farm funded with Dutch money, and a semiRAS is used in one seabass/seabream hatchery (Seabass Juniors).

6.3.3 Contributing Farms

Four sturgeon farms have contributed with data on their production to this project, three from Romania (Compania de Management, Kaviar House and Giarmata), and one from Hungary (Forus, Table 28 to Table 31). There are three exclusively sturgeon producing farms in Hungary, and the three of them use RASs at least for part of the production cycle (Forus Ltd, Silverside Ltd and Rideg & Rideg Ltd). From them, only Forus has completed questionnaires for this project. Some data have been collected also about the other two farms.

Table 28: General characteristics of the consulted farms. (1) Sp. 1: European sturgeon -beluga- (Huso huso); sp. 2: Russian sturgeon -ossetra- (Acipenser gueldenstaedtii); sp. 3: Sevruga sturgeon -sevruga- (Acipenser stellatus); sp. 4: Siberian sturgeon (Acipenser baerii); sp. 5: Sterlet (Acipenser ruthenus). (*): data referred to hatcheries; marked with (**): data referred to the ongrowing activity; not marked: data referred to the whole activity, or data which was not specified if referred to the hatchery or to the ongrowing activity.

Country	***Farm names***	***1st year product.***	***Farm unit***	***Production system***	***Number** (tanks, cages…)*	***Specis.**[1]*	***Other activity** (& % of time)*	***Source of techniques***
Ro	1-Compania de management S.R.L.	2003	Ongrowing	RAS	14 tanks	1, 2, 3	Yes (10%)	From research work
	2-Kaviar House S.R.L.	2002	Hatchery Ongrowing	FT	60 tanks (700 L)	1	Yes (80%)	Germany
	3-Giarmata en S.R.L.	2008	Hatchery* Ongrowing**	RAS		*2, 3, 4 **4	Yes (75%)	Germany
Hu	4-Forus Ltd.	1998	Hatchery* Ongrowing**	*FT **RAS		1, 2 (95%), 4, 5	No	Denmark (Interaqua Ltd)

Out of the four Romanian and Hungarian collaborating farms three have already RASs in operation. All of them are recently established. The oldest one (Forus), was founded ten years ago. There are four major sturgeon species being cultured in these farms (European, Russian, sevruga and Siberian sturgeon). The protection status for these species differs in Romania and Hungary. The three Romanian farms contribute only for a part to the total turnover. Most of the farms have imported their techniques from Western Europe. There are at least three new built sturgeon farms in the county of Timis in Romania, operating since october 2008. In other parts of Romania similar enterprises are founded and are preparing or getting into operation. Some information has been collected about these farms:

- Giarmata Farm (Gerald Buchert, owner) with 16500 m^2: A sturgeon farm (Huso huso and other species will be reared there), with 2,200 m3 RAS it is designed to produce eight to ten tonnes of caviar and 80-100 tonnes of meat annually. This will be one of the largest caviar production units in Europe. The investment costs are about two million €. The farm investment is carried out through pre-accession program - SAPARD.
- Fârdea Farm (650 m^2) which belongs to SC Gama Sturio from Lugoj, a 180m^3 RAS farm for Siberian, Sterlet and Russian surgeon. It has been operating since October 2007 and there are stocked 8000 sturgeons. It is designed to produce 6-7 tonnes of caviar. The investment costs are about 600000 €. The farm investment is carried out through SAPARD program.
- A 160 m3 RAS farm. It is an experimental unit of the local Agricultural University of Timisoara consisted of 34 tanks. It has been operating since some years. There are stoked qbout 14000 individuals of *Acipenser ruthenus* and there are expectations for 125 kg fish/m^3.

Table 29: Production data of collaborating farms (numbers refer to Table 28). (*), data referred to hatcheries; (**), data referred to the ongrowing;

Farm	Farm unit	Production	Water use		Land	Yield		FCR
		(M larvae/y or t/y)	m^3	m^3/M larvae or m^3/t	(ha)	M larvae/ha or kg/ha	larvae/m^3 or kg/m^3	
1	Ongrowing**	4 t/y (1,000 fish)	121	30.25	0.2 (Total)	20,000	33.06	-
	Hatchery*	*0.1-0.2 M eggs *0.01 M fry			*0.03	*3.3-6.7 (eggs) *0.33 (fry)	-	
2	Ongrowing**	**1-1.5 t/y (5,000 fish)	42	**28-42	**0.25	**4,000-6,000	23.8-35.7	3
	Hatchery*	*12 t caviar/y					-	
3	Ongrowing**	**172 t/y	11,000	**63.95	2.6	**66,154	**15.64	-
	Hatchery*	*0.1. For own use. Only some fries sold	not applicable	not applicable	not applicable	not applicable	*5,000	1.38-3.48
4	Ongrowing**	**15 t/y	**2,000	***133.3*			***7.5*	

Table 30: Economic parameters of collaborating farms (numbers refer to Table 28). (1) Assuming a market value of 12 €/kg meat, and 500 €/kg caviar (source: www.acadian-sturgeon.com). In non italic, data taken directly from the questionnaires; in italics, calculations done from these data.

Farm	Labor input	Expenses		*Productivity*[1]		Marketing
		€/y	*€/M larvae.y (M egg.y) or €/t.y*	*€/ha*	*€/m³*	
1	10	not reported	*not reported*	*240,000*	*396.7*	Not yet
2	8	150,000	- ***100-150,000*	- ***60,000*	- ***357*	Wholesalers
3	22	not reported		***794,000*	***187.7*	Wholesalers, transformation
4	9	400,000	***27,000*	not applicable	***90*	Adult stock: export to Germany for caviar prod.

Table 31: The environmental costs, threats and conflicts of the sturgeon farms (numbers refer to Table 28).

Farm	*Environmental cost*	*Threats*	**Conflicts with**
1	Water intake, land	• Increasing cost of labour • Stricter law in pollution, degradation of landscape and health standards	Agriculture
2		• Stricter law in water use & impact in biodiversity	-
3	Water tax, land tax	• International transport documents • Stricter law in health standards, pollution, water use & impact in biodiversity	Agriculture
4	Water intake	• Stricter laws in pollution & water use	-

Half of the farms have reported conflicts with the agriculture sector, due to land competition. All of them fear laws becoming stricter with respect to pollution, water use or impacts on biodiversity or landscape. Half of the farms (Compania del Management and Giarmata) have expressed that criticism against aquaculture made by people who want to protect the environment is normally exaggerated, and not justified. Other important bottlenecks affecting the farms are related to water quality issues, waste discharge, energy costs, bureaucracy, labour qualification, and others.

6.3.4 Projected RAS application

The traditional production cycle of sturgeon takes five to six months for 300-400 g fish, two years for two kg fish, and about six to nine years for 11-13 kg fish. By the application of RASs for the entire sturgeon production cycle (Table 32), better growth performances are expected through temperature and photoperiod control. In addition, biosecure and safer conditions are achieved: escapes, mixing of gene pools and contamination of wild species with diseases or parasites are avoided. Finally, with the proposed change, a positive difference in some sustainability parameters (water use, feed use, etc) is expected to be achieved.

Table 32: Proposal for RAS application in the different stages of sturgeon production (www.eurofish.dk3; J.N. from Forus; Mims et al. (2002); Yesaki et al. (2002); http://aquanic.org; Hopkins (2004); Celikkale et al. (2005); Sener et al. (2005). (*) Currently, some farms are already applying RAS in the hatchery and/or the ongrowing facilities in Romania and Hungary.

	Hatchery				On-growing (≈5-6 months, till 300-400 g) (≈2 years till 2 kg) (≈6-9 years till 11-13 kg)
	Broodstock holding facility	Spawning area	Incubation area (≈7-9 days)	Larvae rearing (till day 50-60) (≈ 4-6 cm, ≈10 g)	
Current system*	FT	Sperm & eggs collected in dry	FT	FT	Ponds/FT/RAS
Change proposed & assessed	RAS	“	RAS	RAS	RAS

The case study layout is projected for a representative sturgeon farm for Romania and Hungary. In both countries farms are small scale. Some farms already use RASs, at least for part of the production cycle. A farm with a production of 50-100 t/y of market size fish is most representative. This takes the growing interest in sturgeon production in those countries into account. For the sake of simplification, the projection is limited to Siberian sturgeon (*A. baerii*). Differences in production cycle, fish sizes, etc. have to be taken into account if applying the projections for other sturgeon species.

Three independent projections of sturgeon farms have been collected, from different collaborators. For confidentiality reasons, two of the collaborators will be kept under codified names (HAKI, AQUA, CULTI). The projections differ in design and production (Table 33).

Table 33: Species, productions and other details considered in each projection

		HAKI	*AQUA*	*CULTI*
Stur. spp.		*A. baerii*	*A baerii*	*A. baerii* & *A. ruthenus*
Meat production	t/y	80	50*	100
Caviar production	t/y	9.1	3.5	8.0
Cash flow for…		15 years	15 years	6 years
Location		Hungary	Not specified	Russia

The three projections have been based on 50-100 t meat production per year, and 3.5 to 9.10 t of caviar per year. In HAKI's projection fish will be produced as round fish with caviar unprocessed inside the animal. CULTI does not specify the processed product. AQUA has projected that 10% will be commercialized as round, 50% gutted, 10% as smoked pieces, other 10% as other smoked product, and 20% for filets. The projections differ next to their production as well in the biological performance data (Table 34) and their basic layout (Table 35).

Table 34: Some biological and technical data for the projection.

	unit	*HAKI*	*AQUA*	*CULTI*
Sexing	times/year	2	2-4	-
Maturity females	year	4.5-7	5-8	-
Length production cycle	years	7	5-7	-
Meat output starts…		2nd year (males), 5th year (females)	1st year (small amount)	2nd year (half production)
Caviar output starts…		5th year	1st year (small amount)	3rd year
Caviar/fish bw	%	11	10	-
Fingerling production	pieces/y	40,000 (20,000/6 months)	-	-
Stocking density	kg	16-71kg/m³	-	135,000 (full cap.)
FCR	kg food/kg fish	1.69	-	1.4 - 1.5
Feeding	%bw	2.7 - 0.6	-	0.50

Table 35: Details of the proposed systems

	HAKI	*AQUA*	**CULTI**
Units	·Hatchery ·Grow-out area ·Social building	·Hatchery/Nursery ·Grow-out area ·Processing area ·Technical rooms ·Administr. building (labs, storage rooms…)	·Hatchery/Nursery ·Grow-out area ·Fish holding/ preparation/ recovery unit
Type of system proposed	·50m^3 hatchery ·35 x 150 m^3 earth ponds	·Concrete grow-out modules	·HDPE tanks

The farm proposed by HAKI consists of a 50 m^3 hatchery and 150m^3 earthen ponds for the on-growing phase, exploiting thermal subterranean water and cooling water from a power plant. Based on experiences with the local greenhouse agriculture (tomato, cucumber) and some recently installed intensive plastic-house fish farm, it is suggested to build the system as foiled ponds (Figure 15). AQUA's projection includes a hatchery/nursery, a grow-out unit, a processing unit and an administration building. All farming is conducted indoors. The facility is modular (with single units, Figure 16 and Figure 17). Each basin 100% self sufficient preventing possible disease spread into other units. In the hatchery different units are installed, one open unit, where eggs will be hatched and four closed units where fish fry will be nursed. The grow-out area consists of small grow-out modules (200 to 1,000g fish weight) and big grow-out modules. The grow-out area also includes depuration pools, where fish is cleaned from off-flavour before harvest. All the basins in the grow-out area are planned in concrete. The farm facility includes a room for caviar and filets storage. The farm proposed by CULTI consists on a hatchery/nursery, an on-grow unit, and a fish holding, fish preparation and fish recovery unit. The on-grow unit is composed by seven sub-units. The tanks to be used are made of plastic (HDPE).

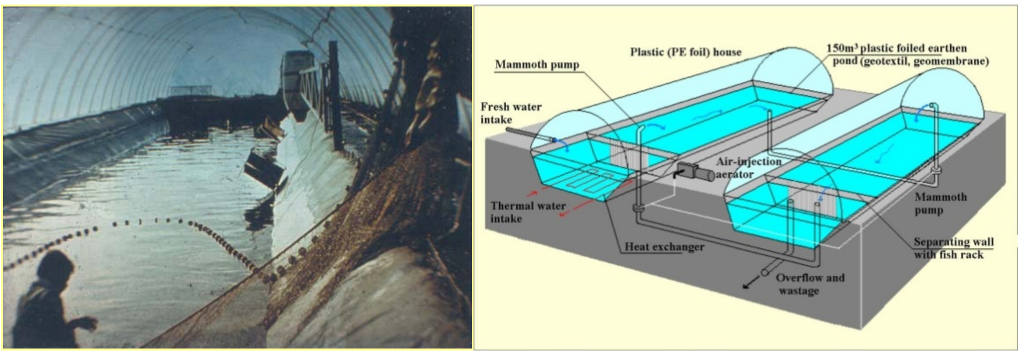


Figure 15: Earthen foiled pond units with plastic tunnels (HAKI's proposal)

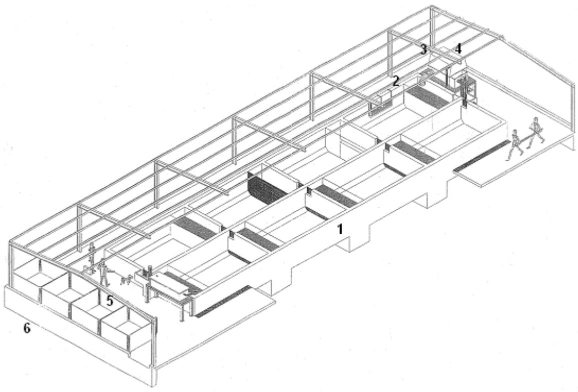


Figure 16: Single cycle unit for the farm projected by AQUA1 Basin/Module Filter. (2 Biological Filter, 3 Aeration of reactors, 4 Mechanical Filter, 5 Denitrification, 6 Selling basins)

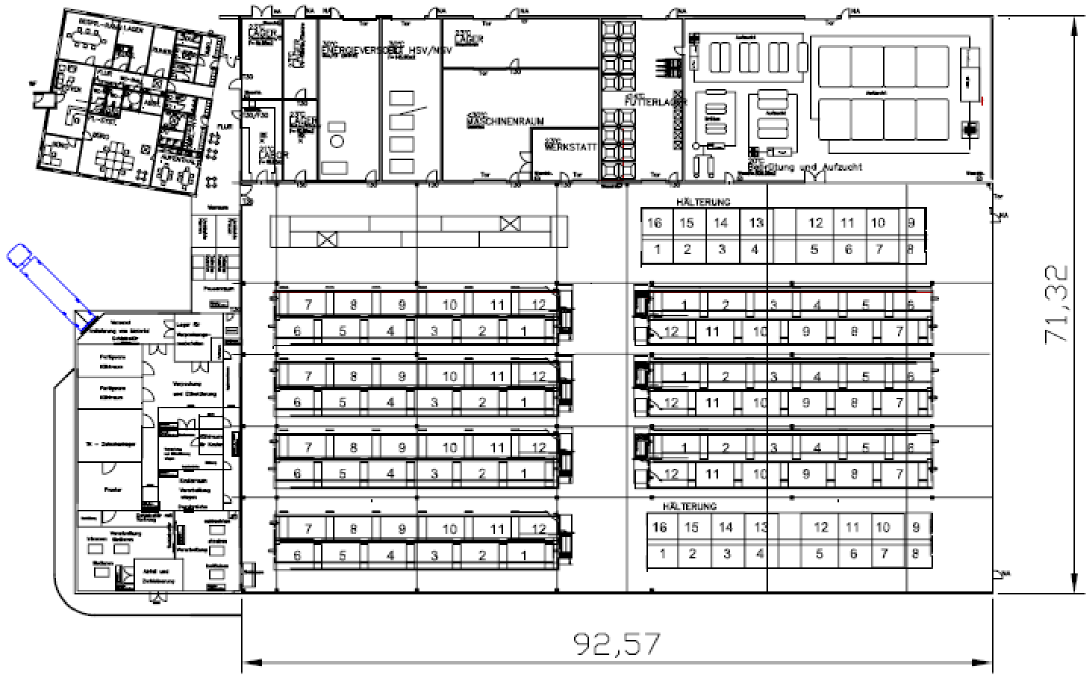


Figure 17: Preliminary layout for the farm projected by AQUA

The economic feasibility of the RAS-based sturgeon farm projections has been assessed for investment and operation costs (Table 36 and Table 37).

Table 36: Investment costs of the projected farms, as much as provided.(a) All calculations have been done in Hungarian Forints (Ft), and converted into euros using an exchange of 1 €=257.15 Ft. (b) 35 earth pond units. (c) The calculated price for the farm system is mentioned as well as 3,862,267 €, excluding taxes and duties. Therefore, the total 7,000,000 € investment might be an under-estimation.

	Details	*Unit*	*HAKI[a]*	*AQUA*	*CULTI*
Land		€	4900	117,605	-
Construction costs	Installation	€	928,000	-	4,000,000
	Building	€	702,000	3,090,359	3,000,000[c]
	Others	€		5,551,112	-
Other fixed assets (during the first years with losses)	Fingerlings	€	95,000		
Biomass	Fish (gral)	€		625,721	-
Current assets during the first years with losses	Electricity, wages, feed, etc.	€	1,754,000		
Others		€		1,602,443	-
Total investment		€	3,483,900	10,987,240	7,000,000

Initial inputs of juveniles and mature fish are required during the start-up phase. The prices for the juveniles are about 1.1-2.3 €/fingerling, depending on the projection. The cost for mature fish are about13-25 €/kg (AQUA). HAKI's projection based farm requires a lower investment (3,483,900 €) compared to the more sophisticated systems (10,987,240 € for AQUA and 7,000,000 for CULTI), although apparently, land costs have not been included in this projection.

Table 37: Land use, water, energy, oxygen and feed consumption and employees estimated for the projected farms.

		HAKI	AQUA	CULTI
AREA AND VOLUME USE				
Area for nursery	ha	not estimated	0.05	not estimated
Area for tanks or ponds	ha	0.53	0.30	0.30
Total area required	ha	2-2.5	0.80[a]	0.86[b]
Total area required	ha/t meat	≈0.030	0.016	0.009
Total volume	m^3	5,300[c]	-	-
WATER CONSUMPTION				
m^3/y		511,000	103,812 (+ 105,030)	61,500 (131,400)
m^3/t caviar		56,154	29,660[d]	16,425
m^3/t meat		6,388	2,076	615
POWER CONSUMPTION				
kWh/y		3,801,840	2,565,160 (electr.), 492,186 (thermal),	*3,609,120*
kwh/kg caviar		418	873.52	*451.14*
kwh/kg meat		46	61.15	*36.09*
OXYGEN CONSUMPTION				
kg O_2/kg feed. day		21	-	-
kg O_2/year		651,525	-	*108,000*
FEED CONSUMPTION				
t/y		139.6	125	*145*
FCR		1.69	2.5	*1.45*
EMPLOYEES				
Number		7	14	2
Insurance	%	not included	-	1
Inflation	%	6-10%	-	-
Interest installation	%	5%	-	6
Interest building	%	not included	-	6
Interest running costs	%	10	-	7
Depreciation installation	%/y	14.5	-	10
Depreciation building	%/y	3	2.5	20
Depreciation machines & equip.	%/y	14.5	10	-
Taxes	%	18	-	-

The total area required per tonne of meat production differs greatly between the three projections, 0.03 ha/t, comparing to 0.016 and 0.009 by Haki, AQUA and CULTI, respectively. A similar pattern is found for water consumption when measured in relative terms of m^3/t of caviar or meat. According to HAKI, due to the low-technical level of its projection, the relative energy consumption is very high, and the energy cost will account for more than 75% of total costs. Comparing consumption in relative terms (consumption per kg of caviar or meat) with the other projections, HAKI's proposal is similar to CULTI's, and is lower than AQUA. Oxygen consumption is estimated by/for HAKI and CULTI, giving very different values (651,525 and 108,000 kg O_2/y, respectively). HAKI uses virtually oxygen free well water that needs to be oxygenised. Feed consumption is estimated from 1.45 to 2.5 t feed/t meat for CULTI and AQUA, respectively. The expenses due to variable operating costs are based on prices and discharge costs (table 49).

Table 38: Prices for inputs and discharge costs for the projected farms and the related expenses as thousand (k) €.

	Unit	HAKI	AQUA	CULTI
Water (intake)	€/m^3	0	2 (tap water)	not included
Energy	€/kWh	0.21	0.05 (electr.), 0.06 (thermal)	0.1
Oxygen	€/kg	0.38	-	0.15
Feed	€/kg	1	0.95	1.35
Wages	€/person.month	755.8	2,228	2,250
Waste water	€/m^3	not applicable	2.5	-
Disposal of sludge	€/m^3	not applicable	Not applicable	Not applicable
Water	€/y	5k	*5k*	-
Energy	€/y	380k – 2,600k	220k (electr.)+ 30k (thermal)	303k
Oxygen	€/y	*88k-352k*	-	16k
Feed	€/y	200k-300k	120k	230k-155k
Vet. products	€/y	11k-15k	8k	-
Wages	€/y	57k	295k	72k
Water discharge	€/y	not applicable	9k	8k

Annual incomes for the projected farms have been calculated based on the sale prices for the final products (Table 39).

Table 39: Sale prices for the final products

	Unit	*HAKI*	*AQUA*	*CULTI*
Meat average (sex not specified)	€/kg	4-5	6	6
Meat: whole fish	€/kg		2.4	
Meat: gutted	€/kg		5.4	
Meat: smoked piece	€/kg		8	
Meat: smoked cutted	€/kg		9	
Meat: fillet	€/kg		8.3	
Caviar	€/kg	400-800	600	500-850

A Cost Benefits Analysis (CBA) has been conducted by Haki for 15 years of operation, starting with 2010. The year of investment would be 2009, so the CBA has been calculated on the 2009 price level, using a 10% discount rate. The price of different inputs are subjected to inflation trough the years. HAKI has used a different inflation rate for each input (8% for wages, 10% for energy, 6 % for feed, according to Hungarian standards). AQUA has done the CBA for 15 years. Depreciations have been considered according to European standards. Costs of financing (interests and redemptions) and/or grants have not been considered. CULTI has done the CBA for six years (Table 40).

Table 40: Cost Benefit Analysis for the three projected farms. (*) Figures vary depending on the caviar price established (from 400 to 800 €/kg).

		HAKI	*AQUA*	*CULTI*
CBA (Cost Benefit Analysis)	years	15	15	6
TOTAL INVESTMENT	€	1,652k	10,987k	3,862k
	€/t caviar	*182k*	*3,139k*	*483k*
	€/t fish	*21k*	*220k*	*39k*
PRODUCTION COSTS	€	4,008k	1,168k	1,710k
	€/kg caviar	*440.4*	*315*	*213.7*
	€/kg fish	*50.1*	*22*	*17.1*
REVENUES	€	3,936k - 7,489k (before taxes)	2,253k	7,400k
PROFIT	€ (before taxes)	0-4.978k	1,008k	-
	€ (after taxes)	0 – 4,082k	-	-
	€ (not provided)	-	-	5,690k
NPV (Cumulative Cash Flow)	€	0– 10,405k	11,751k	11,368k
First year with positive profit (no cumulative)		6	4	3
IRR	%	7.96 – 31.08*		
Return of investment	%	0-189.5	65.2	-
Cash flow return of investment	%	-	125.2	-
Return on sales	%	41.8-69.3	46.8	-
Return on equity	%	-	65.2	-
Return on assets	%	-	55.7	-
Break even point	y	6	5	5

In HAKI's projection the revenues vary according to caviar price (400, 500, 600 or 800 €/kg): 3,936,144 €, 4,824,387 €, 5,712,630 € and 7,489,116 €, respectively. Caviar prices must exceed 417 €/kg to be profitable (supposing 10% discount rate). The NPV varies on 2,266,113 €, 4,954,130 € and 10,404,516 € respectively. The payback period is of 10 years, 9 years and 7 years. The NPV of AQUA is 11,750,858 €. The payback period is 5 years. CULTI's projection gives an NPV of 11,368,297 €, and a payback period of 5 years, similarly to AQUA's.

6.3.5 Qualitative analysis of RAS application

RAS is proposed for sturgeon culture in Eastern Europe. It is envisaged to keep the sturgeon inside RAS for its complete life cycle. It is a more biosecure system compared to FT. RAS offers a better control of the culture conditions (temperature, photoperiod and others).

6.3.5.1 Water quality

Water quality issues are reported for both countries, Romania and Hungary. Kaviar House reports that water supply, which comes from Danube river, is hardly suitable due to contamination and pathogens. This is an issue for fish health and consequently for production. In Hungary, water quality problems are reported by Silverfish Ltd. They do not refer to the water supply but to the water in the system itself. They have a RAS. It seems that, due to the water quality problems, they consider RAS as failure. RASs allow a high independence from the water source and allow maintaining the water quality constantly, independently from the environmental and seasonal conditions and changes. This is different from a situation where the water supply is of permanent bad quality, and in particular, when the problem is urban or industrial contamination (Kaviar House). In this case, the problem is complicate, and if persistent, then that water source would need to be discarded. RAS does not solve this problem. The solution is environmental legislation becoming stricter and effective in protecting the environment from pollution. If water quality inside the system is problematic and the water source is of good quality, then the system might either be erroneously designed or malfunctioning. This leads to an accumulation of bacteria, fish metabolism's excretory products and other malfunctions. This case illustrates that RASs, even though they are a very prospective system, may show technical difficulties. This is why good system design and good skills are indispensable requisites for successful application.

6.3.5.2 Water use

Water use problems are reported for both countries. In Romania, (Compania de management SRL.) stated that the quantity of water used in the farm generates high costs in relation to the input and drain of water as the farm pays taxes for water use. Taking into account that RASs require less water than FT systems per kg production, RAS probably solve this issue. In fact, sturgeons are quite sensitive to unionized ammonia and nitrite concentrations, which have to be maintained below 0.01 mg/L and 0.1 mg/L respectively. In order to get this, an adequate water exchange is required in the flow though systems (Mims *et al.*, 2002). This high water use can be saved by an adequate biofiltration in RAS. For Hungary, water use is reported to be the major problem (Forus Ltd.) The constraints are not water quantities and its economical consequences. Fish farmers owning wells do not have to pay for the water quantity. They only have to pay an small amount for the rights to use subterranean water resources (1.6 MFt per 12 months, 6,257 €. Gyalog, personal communication). This is approximately 3% of the total annual costs. The problem with water use is of bureaucracy. Administrative rules of water intake are very strict. It is not possible to drill new wells until an existing one is ceased. As by the use of RAS the water consumption is reduced. A well will last longer. But if the well is exhausted, the bureaucratic demands for exploiting a new one will remain unless government's regulations have changed by that time. RASs only offer a partial solution for this problem.

6.3.5.3 Wastes

Nutrient discharge is mentioned as environmental issue for both Romania and Hungary. This issue has not been specifically mentioned by the collaborating farm owners. However, it is a constraint concerning in general the aquaculture sector in those countries. For instance, Hungary has a strict polluters pay principle, and FT farms are gradually facing increasing economic problems due to the water-loading fees. Romania will implement a PPP in the near future in practise. These fees are increasing at fixed rates per year. The fees depend on the effluent water quality. In this case, RASs reduces the waste discharge and hence the economical derived consequences. RASs allow for waste collection and emission control, for solids and dissolved nutrients respectively.

6.3.5.4 Pathology

Pathology is mentioned as an issue for the sturgeon production in Romania. If the water is supplied e.g. from the Danube river directly, impacts of antropogenic and industrial pollutions or naturally occurring parasites are imminent and direct. In this case, although RASs are highly independent from the water source and they are provided with disinfection units, the constant influx of bacteria might lead to uncontrollable infections. The solution for this is environmental legislation becoming stricter and effective in protecting the environment from pollution. Approximate annual losses in hatcheries and commercial sturgeon growing sites due to pathologies account for 20% in Russia (personal communication). Reared sturgeons suffer often from parasites, bacterial and viral infections. High stocking densities, organic water pollution, handling, injuries or malnutrition are the usual triggers for bacterial disease outbreaks. Parasitosis develop easily in bad environmental conditions, but during optimal husbandry they are usually detected in very low levels (Mladineo, personal communication). In this sense, RASs might offer advantages for preventing disease outbreaks as water quality parameters are highly controlled. However, RASs applied to sturgeon culture are not exempt of diseases episodes. In intensive RAS grow-out facilities in Hungary, *Flexibacter* and *Aeromonas* species are mostly isolated bacterial agents (Mladineo, personal communication). In Russia, in an study on the hybrid *A. ruthenus* x *Huso huso* grown in RASs, 67 cultures of facultative bacterial pathogens were isolated, 42 only from water in the systems. The species list was identical to pathogens isolated from other systems, and mainly consisted on *Aeromonas*, *Flavobacterium* and *Plesiomonas* spp. Protozoans (*Costia*, *Ichthyophthirius*, *Epistylis*, *Apiosoma*, *Trichodina*, *Triochodinella*), some monogeneans (diclybothrium) and crustaceans (*Ergasilus*, *Argulus*) are especially prone to proliferation in RASs (Mladineo, personal communication). It is hard to judge from available data if RAS versus other aquaculture systems do lower the diversity and load of pathogens in sturgeon culture, as no "tank to tank" studies with same sturgeon species, water quality, age category or genetic heritage have been done. However, results suggest that strict zooprophylaxis and daily zootechnical measures lower the change of disease outbreak in RAS. In general sense, Martins *et al.* (2005) affirm that diseases due to bacteria and other parasites are better controllable in RAS, because relative increased ion concentrations in these systems inhibit bacterial growth and/or the reduced pH levels inhibit parasite development. Finally, RASs are a good option to keep disease-free stocks in safe and biosecure conditions due to the relatively high independence from the water source and the minimum risk of escapes. However, special attention has to be put on the pathological conditions of broodstock brought into the system. It is necessary to get disease free broodstock. Basca (1999), in his parasitological survey in sterlets from Hungarian natural waters, found that almost one third of the wild fish were infected by a cnidarian called *Plypodium hydriforme*. Petochi *et al.* (2007) found on a commercial sturgeon (*naccari* x *baerii*) farm in Italy an iridovirus infection on adults. The source of the virus was unknown, but as sturgeons were originally stocked into the farm without having had previous contact with other fish, it was suggested that the sturgeon hybrids could have harbored the virus with no signs of disease. Treatments of broodstock during quarantine are easier in RASs as no new or only limited pathogenic pressure exists (Martins *et al.*, 2005).

6.3.5.5 Energy cost

According to Forus Ltd. Hungarian energy prices are increasing at a high rate. Energy costs are one of the issues affecting farm viability. Energy expenses are third (17%) of the total costs, after feed (30%) and water use (19%, including rights and pumping costs). Energy expenses are as well among the highest expenses in some Romanian farms (e.g. Kaviar House), although these farms do not claim this as a constraint. Energy cost is dictated by national and international economic policies and multinationals. RASs can help on reducing energy use and costs. Especially savings in heating requirements are major. In farms without thermal water source that require warm water (about 20-25°C) this sparing becomes most evident. Comparable savings in energy use have been seen in sea bass hatcheries (Blancheton, 2000). As sturgeon requires low temperatures (15-16°C in hatcheries, about 18-24°C in the ongrowing, according to Forus; 10-15°C for incubation, 18°C for larvae culture, according to Schneider et al., 2007) not much heating is needed in warm season and FT might be applicable. During warm seasons RASs might then not make a substantial difference in terms of energy use and expenses. However to achieve growth during cold seasons, RAS might be advantageous compared to FT.

6.3.5.6 Feed cost

Feed accounts for one of the highest costs in fish production. Feed costs are claimed to be an issue for the sturgeon farming because feed prices are increasing at high rate, similar to energy costs (Schneider et al., 2008). RASs can reduce feed costs only indirectly through improved FCR. The better FCR in RASs compared to net cages is evident (Table 41), although there is no clear difference reported between RASs and FT. Factors such as feed type, water temperature, fish body weight affect FCR and need to be standardized for proper comparisons.

6.3.5.7 Money cost/Interest rate

Capital in general is mentioned as one of the major issues (Forus Ltd.). Monetary issues are caused by national and international economic policies, and the use of RASs can hardly help on remediating this problem. RASs require high investments. However, they can offer competitive advantages in terms of reducing land and water use and hence stakeholder conflicts, higher productivity, and all year-round production.

6.3.5.8 License costs

License costs are mentioned as constraints affecting sturgeon production activity in Romania and Hungary (Giarmata and Forus). Both have to pay rights for the production of *Acipenser baerii*, *A. gueldenstaedtii*, and *Huso huso*. In this case, RAS does not offer any solution. The issue is related to the species being and regulations, but not to the system. In Hungary, fish farmers exploiting wells have to pay a contribution for the right of using subterranean thermal waters. However, that amount is relatively small (1.6 MFt per 12 months, which corresponds to 6,257 €), and it has not been specifically mentioned as a constraint.

Table 41: Sturgeons FCR in different production systems, partly recalcualted

Rg. bw (g)	*FCR*	*System*	*Water T*	*Density*	*Spp.*	*Author*
10-<1000	1.3	RAS	-	-	various Acipensers	Schneider & Taal (2007)
9-225	1.7	FT	16-22	16.6 kg/m^2	*A. baerii*	Koksal *et al.* (2000)
10-230	≈0.9	-	-	-	*A. transmontanus*	Logan *et al.* (1995)
10-2,000	1.2	RAS	-	-	*A. baerii*	Kolman, www.eurofish.dk[3]
10-2,000	≈1.9	-	-	-	*A. transmontanus*	Logan *et al.* (1995)
95-470	≈1.1	-	-	-	*A. transmontanus*	Logan *et al.* (1995)
279-1,112	5.7	cages	12.7-28.5	12 ind./m^3	*A. gueldenstaedtii*	Celikkale *et al.* (2005)
271-1,141	5.8	cages	12.7-28.6	8 ind./m^3	*A. gueldenstaedtii*	Celikkale *et al.* (2005)

6.3.5.9 *Taxes*

In Romania, taxes are paid for land, water, building, vehicle and silence (noise contamination), apart from VAT, income tax, sanitation tax and salubrity (healthiness) tax (Compania de management SRL, Giarmata SRL). Quantities of used water have become a bottleneck when translated into economic terms. Taxes contribute greatly to the turnover. RASs cannot change the taxes as this relies on governmental regulations. RAS contributes by reducing water consumption, which can be translated economically into lower financial expenses.

6.3.5.10 *Operational issues*

Giarmata (Romania) mentions as one of their main constraints is knowledge about RAS. RASs' operation may present technical difficulties. Skills for dealing with these systems are prerequisites for their successful application. A personal lack of knowledge on the operation affects production and the economic consequences will affect the enterprise.

6.3.5.11 *Market supply*

Forus (Hungary) can currently not supply products all-year-around. They cannot export their fish to Germany during summer because it is too hot for fish transport. However, it seems to be just a minor problem for them as in general they are satisfied with the economic situation (selling prices fixed for each year with a rising trend through the years, great market demand, etc). Although RASs allow extending the production to all-year-around, they do not affect the transportation methods or conditions.

6.3.5.12 *Market demand*

In Romania, the sturgeon market is not yet well developed. There are no market studies available, projection demand, prices and potential. This is one of the major problems for the farms (Compania de management). In contrast, in Hungary the demand is big for sturgeon products and not satisfied (J.N. from Forus). Farmers do not have difficulties to sell all their production. In any case, as there are not many sturgeon producers in Romania and Hungary, there is no overproduction, which helps to maintain prices. RAS do not develop new markets, but RAS can be used for getting an all-year round supply of a uniform product. This might allow reaching out to new markets or extend existing ones.

6.3.5.13 *Bureaucracy*

In Hungary, bureaucracy is said to be a constraint for sturgeon culture especially in relation to water use (Forus Ltd.). Administrative rules for water intake are very strict. In this aspect RASs do not offer specific help. Both FT and RAS are equally affected when drilling a new well before ceasing an existing one and are subjected to the same regulations.

6.3.5.14 *Labour qualification*

In Romania and Hungary, some farms complain about the difficulties of finding skilled employees (Giarmata and Forus). To find qualified personal to deal with the system is imperative due to the technical complexity of RASs. Therefore RASs do not contribute to solve this problem but it even contributes to it.

6.3.5.15 *Other Issues*

6.3.5.15.1 *Finding broodstock*

It is mentioned as the main problem affecting activities at Kaviar House (Romania). This farm mainly produces fingerlings of *Huso huso* for stocking in other farms, apart from a small amount of market size fish. To overcome this problem, the establishment of a broodstock program could be helpful. Kaviar House has already started this initiative together with the Tulcea Research Institute. This is based on the selection of parents with genetic advantage, and the establishment of genetic trades. RASs are suitable for controlled maturation and reproduction through control of environmental conditions.

6.3.5.15.2 *Low growth rates*

Although not mentioned as issue by the collaborating partners, problems of *low growth rate* and mortality affect farms culturing sturgeon in ponds. This is mainly due to low temperatures in winter. Fish weight loss is about 12% during that period. Similar issues are reported as well for the not well insolated units of Forus. Fattening sturgeons in RAS in stable and optimal conditions ensures highest growth rates and lowest FCR. RAS minimizes the costs of water heating and negative effects on environmental parameters (Kolman, www.eurofish.dk[3]).

6.3.5.16 Conclusions on the qualitative assessment

RASs are positively evaluated as sustainable option for overcoming problems affecting sturgeon production in Eastern Europe (Table 42). However, the solutions offered by RASs are sometimes indirect or partial, depending on the particular case. The major constraints affecting the sturgeon farms in Romania and Hungary are economically. For these problems (energy cost, feed cost, financial inputs, license costs, taxes, market demand) RASs can hardly offer a direct solution, as they depend more on national/international policies and administrative regulations. RASs can, however, offer indirect solutions: there are positive economic consequences when reducing resources use. For the specific environmental problems mentioned, RASs can offer several even though some only partly solutions.

Table 42: Analysis of RAS suitability to overcome problems mentioned in case study 2

Sustain. aspect	Issue	Issue	Direct solution by existing RAS technology?		Can RAS be adapted?	
			Y/N	Obs	Y/N	Obs
Ecology	Water quality	Ro, Hu	Y, N	Supply water: Y System water: N	-	
	Water availability/use *	Ro Hu	Y	Water use reduced.	-	
	Wastes (water & nutrient discharge)*	Ro, Hu	Y	Reduced nutrient emission	-	
Economy	Pathology**	Ro	Y	RASs allow strict control of WQ	-	
	Energy use**/cost	Hu	Y	E use: Savings on heating	-	
	Feed use	Hu	Y	Get better FCR		
	Money cost, interest rate	Hu	N	Capital issues: economic policies		
	Taxes	Ro	N	Can help on reducing water & land use: reduce taxes		
	License cost	Ro, Hu	N	License cost of spp production		
	Operational costs	Ro	N			
	Design issues/System problems	Ro	N			
	Market/Market demand	Hu Ro	N Y	Can help with all year round supply		
Gover-nance	Bureaucracy	Hu	N	Water use (Forus)		
Social	Labor qualification	Ro, Hu	N			

6.3.6 Quantitative analysis of RAS application

Quantitative achievements in sustainability criteria through RASs have been assessed (Table 43). The achievements in sustainability are estimated by comparing the magnitude of each sustainability indicator for two farms: one not applying RASs and the other one applying RAS. Both situations have production of between 50 and 100 t/y of market size fish and a caviar production between 3.5 and 9 t/y. The comparison gives the following results:

- Water use is diminished about 280-1,000 times by the use of RASs instead of FT systems.
- Mortality, land use, energy use are lower for RAS than for FT.
- Nutrient discharge from FT farm can be reduced, but if proper waste management is put into place.
- The feed use (FCR) seems differs upon the system type (pond, FT, RAS)
- In terms of economic feasibility, the RAS based farm has a higher rate of return than the FT based farm.

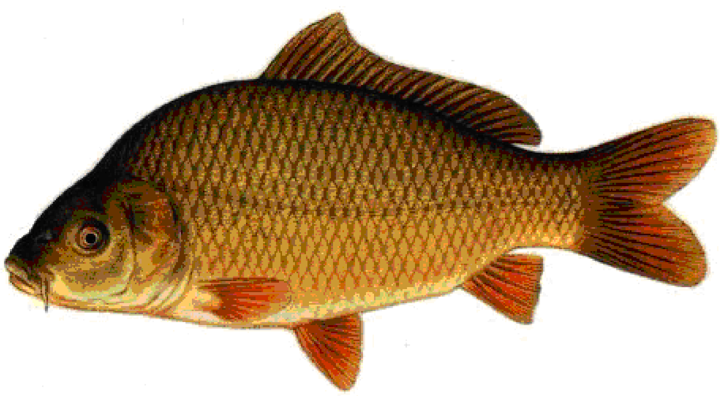
Table 43: Quantitative achievements in sustainability criteria. Data sources: (1) HESY; (2) AQUA projection; (3) from the three projections; (4) HAKI projection; (5) Logan et al. (1995), (6) collected data

Sustainability criteria		Current (FT)	Projection (RAS)
Name	Unit		
Water use	m^3/kg feed	70[1]	0.06 – 0.25[1]
Discharge of N	g/kg fish	~50	0.949[2]
	kg/y	-	47.45[2]
Discharge of P	g/kg fish	Not known	0.073[2]
	kg/y	-	3.65[2]
Land use	ha/t fish	-	0.009 - 0.031[3]
Mortality	% losses	-	none
Energy use	kw/kg fish	-	46[4]
Feed use (FCR)	kg food/kg fish	1.2 - 3[5, 6]	1.5[1]
Staff	Number/t fish	-	0.09[4] – 0.28[2]
Rate of return	%	12-23[3]	47-65[2]

6.3.7 Conclusions

This study has focused on assessing the applicability of RASs for sturgeon aquaculture in Eastern Europe, and its feasibility to overcome problems currently affecting existing systems. The proposed RAS application includes the complete production cycle. This proposal seems realistic and feasible. In fact, there are already some sturgeon farms using RAS in Romania and Hungary. This supports the results of the qualitative analysis. RASs overcome environmental problems (water quality, water use, pathology). However, the solutions offered by RASs are sometimes indirect or partial, depending on the particular situation. As example economic issues (energy cost, feed cost, financial inputs, license costs, taxes) and governance aspects (e.g. heavy bureaucracy) depend on national/international policies and administrative regulations. Three RAS-based sturgeon farm projections have been collected in this study from independent sources. The estimated total investment is different for the three projections due to the different proposals on materials and units (pond-based, concrete-based, plastic tank based). Required investment has been estimated in between 1,652,000 and 3,862,000 €. A payback period of about five to seven years is expected if caviar prices are considered about 600 €/kg. The NPV has been calculated in about 11 million. Some of the potential achievements on sustainability quantitative criteria have been estimated. Water is reduced in a 280-1000 fold from a FT sturgeon farm to the projected RAS-based farm. The FCR differs if FT or pond systems are compared to RAS. The rate of return is about 3 times higher for the RAS farm.

6.4 Case study 3: Carp culture in ponds



Case study 3 deals with farms culturing cyprinids, which at present are based on extensive pond systems. The partners involved in this case study are representatives from Hungary, Poland, Czech republic and Romania.

The assessment entails valuing the benefits of changing the traditional culture method (spawning ponds or FT hatcheries for carps until they are three to five days old, and then growing them in extensive ponds) to a new one with RAS application (RAS hatchery-nursery, with an extended period of carp fry staying indoors before being transferred to ponds). The aim is to create a carp production sector that is less exposed to hazards due to predation and diseases, in which carp have a better growth performance, while maintaining a traditional aspect of carp culture

In a more specific way, the general objectives of this study are:

- Asses the suitability and viability of using RASs for hatcheries (fry production) and nurseries (fingerlings pregrowing).
- Asses if RAS makes a difference in terms of sustainability, compared with the systems and techniques currently employed, and if it solves some problems that presently affect these farms.
- Evaluate requirements to apply these systems for the local conditions and determine alternation (adaptations) to be done on those systems.

6.4.1 Background information

Data from WP1 for Hungary, Poland, Czech Republic and Romania have been summarized before tackling the perspectives of RAS in carp culture.
In all four countries, carp represents the most cultured fish species (Table 44). Most carp are sold alive around Christmas and Easter, though the all year round offer of processed carp is increasing. Some countries report a moderate tendency of increasing domestic consumption of carp which may be related to the ecological farming approach. Czech Rep. is the largest European exporter, consuming around half of its production domestically.

Table 44: Average aquaculture production and production characteristics of carp in the four countries

	unit	**Hungary**	**Poland**	**Czech rep.**	**Romania**
Aquaculture total	1,000 t/y	13.7	37.5	18.5 – 19.7	3.9
Pond surface	1,000 ha	21	50	51	100
Carp production	1,000 t/y	10	18.5	16.6 – 17.8	3.3
Carp production period	y	2.5	3	3 - 4	2 - 3
Carp marketable weight	kg	1-2	1.4	1.5 - 3	2 - 2.5
Market price	€/kg	1.7	1.6	1.8	2.5

In the four countries carp is almost uniquely raised in poly-culture ponds. Productivity varies between farms and between ponds within farms from 300 to 1,000 kg/ha, with an average about 500 kg/ha. Both mineral fertilization and organic manuring of ponds is or will be limited by the legal procedures; only liming is practiced in a limited volume however alike feeding, it is also subject to legal precautions. In most cases, during the last season the market-sized carps are fed with cereals only to supply energy as a supplement to natural food which is rich enough in animal protein (zooplankton, zoobenthos). Considering the trend to environment friendly technologies, the feeding of pellets in ponds will decline to maintain the carp's reputation in both domestic and external markets.

Table 45: The approximate fish species composition in the poly-culture ponds in the four countries

	Czech	**Hungary**	**Poland**	**Romania**
Common carp (*Cyprinus carpio*)	90.8	82.8	90.2	40
Other omnivorous	1.1	4.0	2.5	25
Herbivorous	4.5	12.1	1.8	20
Predatory and carnivore	1.2	1.9	1.9	15
Others	2.7		1.3	

Next to common carp, the fish farmers stock other omnivorous as well as herbivorous and carnivorous species to optimally exploit the pond's natural food-web (Table 45). Most used omnivorous species are tench (Tinca tinca) in Czech and Poland, and gibel or crucian carp (Carassius auratus gibelio) in Poland and Romania. The most stocked herbivorous species are grass carp (Ctenopharyngodon idella), silver carp (Hypophthalmichthys molitrix), and bighead (Aristichthys nobilis). Most stocked carnivorous species are rainbow trout (Oncorhynchus mykiss), perch (Perca fluviatilis), pike (Esox lucius), and in Czech zander (Sander lucioperca) and wels (Silurus glanis), and in Poland: European catfish. There is a great demand for predators (pike, pike-perch) which have a threefold market value (5-6 €/kg) compared to common carp. Pond fish farming sector works exclusively with artificially spawned carp. The Czech live gene bank of carp includes about 20 carp strains. Also the other stocked species are artificially produced. The culture of carps in ponds is a tradition with strong roots in the countries; it is defended for it's multi-purposes including angling, environment and biodiversity. In Hungary farmers may gain up to 30% of their income from subsidies related to protection of migratory birds (Gyalog, personal communication). However, 2009 is the last year of this subsidy and pond production will entirely depend on the profits from fish culture.

Fourteen partners are involved in carp culture, and the average pond area per enterprise is 650 ha, sometimes divided over several sites or farms (Table 46). About half of the farms have other activities and do not focus solely on rearing fish, some produce fish feed themselves.

Table 46: Some characteristics of the 14 carp companies

Country	Name	Pond (ha)	hatchery	Sites own	Sites lease	% c. carp	Other activity	Time use for fish (%)
Hu	Aranyponty Plc.	1,500	2	2	4	85	No	70
Hu	Kovács Antal	80	0	1		70	Meat processing, cereals & cattle	-
Hu	Szabó	250	0	1	1	70	Cereals (40 ha) for fish feed	-
Hu	SzegedFish Ltd.	2,000	1	1	0	80	Cropping fish feed	-
Hu	Jászkiséri Halas Ltd.	156	0	1	0	-	Angling and restaurant	-
Hu	Tömörkény	570	0	1	0	85	Agriculture cropping & service	-
Po	Golysz	862	0	3		90	No	100
Po	Przyborow	300	0	5		90	No	100
Cz	Pohorelice Fish. Co.	1,600	0	several		-	Yes	90
Cz	Kinsky Fish. Zdar nad Sazavou Co.	730	0	yes		-	No	100
Cz	APH Breclav Ltd.	262	0	yes		-	No	100
Cz	Ivan Jaros	102	0	yes		-	yes	60
Cz	Pansky	25.5	0	yes		-	yes	30
Ro	S.C. Pesco Carja	645	0	1	0	-	no	100

The estimated yield varies from 256 to 1,075 kg/ha. The average is 654 ± 229 kg/ha (Table 47). Data on expenditures were available for half of the farms only; the given cost price was 1,833 ± 1,010 €/t. Assuming a market price of 2 €/kg for common carp[1], the average estimated gross income is 73 ± 813 €/ha. The produced fish is marketed through various canals and 11 farms also sell in retail (local and direct sales). However, the margins are threatened due to of predation, mortality, costs of water discharge, etcetera.

Table 47: Some economic parameters of the 14 carp companies

Company	Labor input Perma-nent.	Labor input Occa-sional	Expenses €/t	Marketing	Productivity MT	Productivity kg/ha	Productivity €/ha*
1	61			Angling 70%, direct sales 20%, export 5.5%	1,500	1,000	
2	4	+		Direct selling, wholesalers	86	1,075	
3	8	2	805	Direct selling, export of hybrid carps	150-160	620	741
4	105		1,240	Direct selling, wholesale, export, hypermarket	1,400-1,800	800	608
5	12			Yes, own transportation capacities	60-80	449	
6	22		1,477	Direct selling, wholesalers	300-350	570	298
7	52			No, (high fish quality, hypermarket)	300-600	522	
8	15			80% hypermarket, 20%, local	200-250	750	

1 Prices in the associated countries vary from 1.75 to 2.25 €/kg.

Com-pany	Labor input Perma-nent.	Occa-sional	Expenses €/t	Marketing	Productivity MT	kg/ha	€/ha*
9	88		3,857	Own sale and distribution, retail and wholesale	1,300-1,500	875	-1625
10	15			Export, wholesale, local market	260	356	
11	4		2,115	Retail, wholesale	130	496	-57
12	4		1,250	Wholesale 80%, retail 20%	80	784	588
13	1		2,083	Retail	12	471	-39
14	20			Direct selling, gift	250	388	

(*) Taking a market value of 2 €/kg, and assuming that the given expenditures included hired labour

6.4.2 Problems, threats and conflicts

From the questionnaires, a list of problems, threats and conflicts for the enterprises involved in carp culture was abstracted (Table 48). The environmental cost through payment of fees for water intake has been included in the table to stress the difference between the locations: enterprises in Poland, Rumania, and Czech do not pay those but have a conflict with common water usage.

Table 48: The threats, problems and conflicts mentioned by the 14 carp enterprises

case	Environmental cost	Problem	Threats	Conflicts with
1	Fee water intake		-	Water-work companies
2	Fee water intake	Birds	-	-
3	Fee water intake	Birds	-	-
4	Fee water intake		Bird protection	Environmental protection
5	Water fees		-	-
6	Fee water intake		Nationalization of the ponds	-
7	No		-	Flooding during autumn harvest
8	No		Water shortage, diseases	-
9	No		Nature protection, veterinary regulation	Nature protection, NGO, common water usage, private ownership
10	No		Nature protection	Nature protection, NGO, common water usage, private ownership
11	No		Nature protection	Nature protection, NGO, common water usage, private ownership
12	No		Reduction of farming intensity	Nature protection, NGO, common water usage, private ownership
13	No		Nature protection, decrease of intensification	Nature protection, NGO, common water usage, private ownership
14	No		Legislative measures for land juridical status	-

The information in table 48 demonstrates that water use and effluent discharge are threats to pond aquaculture, causing conflicts with other stakeholders such as common water users, and NGO's advocating for environmental sustainability and nature conservation. Farmers fear the necessity to reduce the intensity of production to comply with European environmental standards. During the meetings several other problems were mentioned. Most generic problems were the predation by birds and mortality caused by the Koicarp Herpes Virus (KHV). Reduction of predation by protected birds (cormorands) by discouraging methods is not accepted by environmentalists. Protection from KHV requires either immunisation, e.g. vaccination, or selection and bio-security.

Future prospects

The carp producers suggested the following options for the future of pond aquaculture:

- use wetland system to treat effluents of intensive aquaculture;
- include a water treatment plant in system;
- build a RAS unit and produce in economic and environmental sustainable way;

- valorise extensive pond systems;
- do family farming without hiring labour;
- improve co-operation between farmers and Eco - Ngo's;
- introduce labels of traceability; and
- increase the share of services (angling, restaurant).

Some farms would like to develop the culture of ornamentals (gold fish) or produce fingerlings. Especially for the first the market seems limited.

6.4.3 Application of RAS

Carp producers in the four countries considered using RAS for the production of fingerlings only. The producers did not consider the idea of nursing or of on-growing young carps in RAS. However, to overcome the constraint related to predation by birds and to mortality due to KHV, scientists of SustainAQ advice to evaluate whether it is efficient to carry out these phases in RAS, also because producers want to be sure to have enough fish to stock into their grow-out ponds. Due to the KHV at the fingerling stages the stocking rate was often too low during grow-out. Table 49 summarizes the phases for which the introduction of a RAS could be evaluated.

Table 49: The current carp farming systems for the four production phases and the phases in which the use of RAS can be evaluated

	Brood-stock	Larvae[1]	Nursery[2]	On-growing[3]	Grow-out[4]
Current carp system	Ponds?	FT/semi-RAS?	Pond	Pond	Pond
Proposed & assessed for carp	RAS	RAS	RAS	Semi-RAS	Pond

([1]) from hatched yolk-sac larvae to swimming-up larvae; ([2]) from swimming-up larvae till 1g and than to 20-100 g fingerling (year 1); ([3]) from fingerling to >0.5 kg (yearr 2); ([4]) from 0.5 to >1.5 kg (year 3).

Nevertheless, the RAS should be adapted to the local conditions and be low-cost (Table 50) Hereafter, for each production phase we comment on the required system assuming a conglomeration of ten production units of 100 ha pond managed by a family. However, the proposed carp production system uses various high cost technologies for a short period only, because the system aims stocking the outdoor ponds in May. To make this cost efficient other commercially interesting species should be hatched, raised and grown, e.g. pike or European catfish, in the other periods.

Table 50: Overview of the carp production system as proposed by the experts from Poland, Czech, Hungary and Rumania during the SustainAQ meeting in Krakow

Phase of production	Period	Weight range (grams)	System	Density	Water T	Observations
Brood-stock maintenance	Breeding in early January					Breeders in-door before winter
Hatchery**	January: 2-4 weeks	0 – 0.5	RAS tank 2-3 m^3 & 0.5 m deep	5-10 kg = 50,000 fish/m^3	23-27	
Nursery**	February-May: 3-4 month	0.5 – 20	RAS tank 4-5 m^3 & 1 m deep	20 kg = 1,000 fish/m^3	23-27	Includes KHV immunisation
On-growing*	May – September	20 – 500	Canals, partial recirculation	Final 100 kg = 200 fish/m^3	23-27	
Overwin-tering	October – 3rd decade May	500	FT ponds, 3 m deep	5 kg = 15 kg/m^2	10-14	Late stocking also prevents bird predation
Pond culture	End May-November	500-2,000		670 fish/ha	> 17	

(*) From October to May the large system can be used for other productions;
(**) From May to January the small system can be used for other productions.

6.4.3.1 PROJECTION OF A FARM WITH RAS APPLICATION

6.4.3.1.1 Technical aspects

The proposed system considers as basic unit a carp farm producing annually 100 t of carp weighing 1.5 kg at least, in ponds with an area of 100 ha. At present the average productivity is just above 650 kg/ha and an average farm of 650 ha produces close to 400 t/y. A 100 ha carp farm has to stock 67,000 fish weighing each at least 0.5 kg. Hatching and nursing (including immunisation) is best done in a specialised enterprise that provides carp for a minimum of ten such farms, thus for 1,000 ha. Starting points for the system design of a 100 ha pond farm producing 100 t carp/y (modified in tables below according to expert opinions) are:

- 1,000 kg/ha of fish weighing on average 1,500 g => 100/1,500 = 67,000 fish;
- Overwintering: 67,000 fish of 500 g in 13.5 m^3 (15 fish/m^2)
- On-growing in pond of 67,000 fish up to 500 g to be held in 1,200 m^3 ;
- Nursing (40% mortality): 112,000 fish of 0.5 g in 70 m^3 (80 m^2);
- Hatching (30%): 160,000 yolk-sac larvae in 5 m^3 (10 m^2);
- 1 female would be enough to produce the fish needed for 100 ha.

An ideal hatchery with selection capacity would have about 500 carp, representing a maximum biomass of three tons. Each breeding female weighing at least 4 kg can deliver 400,000 eggs and considering a survival rate of 60%, 240,000 yolk-sac larvae of 1 g. Further, considering a survival rate of 60% after co-habitation for KHV immunization, an attached nursery could provide 15 million fry (150,000 fish of 20 g per female), which will be enough for 10,000 ha in year two. Such a unit is only interesting if its' market is guaranteed, i.e. if indeed 100 farms of with 100 ha can buy its' fingerlings. Therefore the system proposed hereafter is smaller.
The hatchery consists of two sections each also composed of two distinct but closely connected systems:
Investment: 12,000 + 2,200= 14,200 €; Production goal: 2,000,000 yolk-sac larvae.

1) RAS for 30 females (4-6 kg), of which 60% mature, and 15 males (4-6 kg);
    a. Maximum feed distribution: 3 kg/day
    b. Two tanks of 7 m^3 (maximum fish density 20-30 kg/m^3) with pump and trickling filter.
2) System for hypophysation (individual housing for 3 days)
    a. Water temperature: 23°C ; water system connected to RAS, no bio-filter, only water heating, aeration, recirculation (Q_r = 100 m^3/day), water exchange (Q_e = 2.5 m^3/day).
    b. 8 small tanks/aquaria of 0.25 m^3 for individual housing

For the brood-stock a separate system is needed during hypophysation. The hatching jars are connected to tanks in which the larvae are cultured.
In these calculations, a hatchery keeping 30 breeding females and 15 males in two tanks with a trickling filter is considered; 60% of the females is assumed to be mature. The temperature in the system can be low except during the one month preparatory phase for the breeding. This allows selecting on characteristics required for overwintering also. The brood-stock system is completed with eight small tanks for individual housing during hypophysation. The two systems use the same pump but during hypophysation the outlet water of the small tanks is not (entirely) recirculated but disposed; during hypophysation the Q_e will be at least 2.5 m^3/day. The cost of such a system is estimated at 14,200 €.

The hatchery system is composed of an egg-incubation system and tanks; total cost is estimated at 120,000€. The cost of feeding in the hatchery (average FCR = 3) is based upon the following schedule: day 5 to 10: artemia; day 5 to 15: 'catfish 0'; and day 10 to 25 'tilapia 0' pellets. The hatchery system has an investment volume of 8,000 + 112,000= 120,000 € and a production goal of 1,200,000 carp larvae of 1g:

1) Egg-incubation system:
    a. 12 hatching jars of 10 L each, water temperature 20-23°C and exchange: 0.7-2.5 L/min/jar;
    b. Number of eggs 4 million (1,000 eggs/g) = 4 kg eggs; 100 g eggs/kg vis.
    c. hatching 50% (might be 80-90%) => 2,000,000 yolk-sac fry: 200 g / 10 L hatching jar.
2) Culture system for 2,000,000 carp larvae from swimming yolk-sac to 1 g:
    a. RAS with one 6 kW and one 12 kW pump for 4 tanks of 3 m^3 (0.5 m deep);
    b. Survival yolk-sac larvae up to 1.0 g is 60%: from 2,000,000 fry to 1,200,000 larvae;
    c. Max. density larvae of 1 g : 10 kg/m^3 => 14 round tanks with r=1,75m, h=0.5 m (10 m^3 each) ;
    d. Feeding level 1 g fish = 7.5%, maximum feed load 90 kg/day, starting with artemia

In the nursery the larvae will be grown in three months (February till mid-May) from one to 20 g and immunized against KHV following a co-habitation protocol (AquaVet Technologies Ltd., P.O.B. 565, 30900 st., Zichron Yaakov 30900 Israel). Humeral immunisation cannot be done before the fish are two months. Mortality might be 40% mostly due to immunization; during the cohabitation period an increase of temperature to 30C is required to stimulate metabolism. During his period the fish are fed pellets (35% protein, FCR=1.5). The cost of the nursery system is estimated at 400,000 € and the production goal: 720,000 KHV immunized carp fingerlings of 20 g:

- Survival 60% => 1,200,000 larvae = 720,000 fingerling of 20 g => biomass 14,400 kg;
- Maximum density 30 kg/m³ => 35 tanks of 20 m³ for fish of 20 g;
- Feeding level 20 g fish = 2.5%, => maximum feed load to system 580 kg/day;
- The required recirculation flow rate (Q_r) is estimated at 2,500 m³/h.
- For total volume of 480 m³: a RAS using pure oxygen and 2 high capacity propeller pumps

For the on-growing phase, a system with partial recirculation in canals is proposed; the pond width will depends on cost-benefit of the coverage with plastic greenhouse tunnels. Total required water volume is 1,200 m³, start biomass 1,400 kg and final biomass is 33,500 kg; Maximum feed load to system 850 kg/day; assumed need of labour: 4 people, and of investment cost: 365,000 A trickling bio-filter tower cannot be directly branched to the fishpond because the water temperature will decrease too much and lead to massive fish loss as a consequence of stress. A system with a covered second pond as a warm water reservoir is proposed here; the use of showers may improve aeration further before pumping it to the fishpond; using partial compartments the water stream in the reservoir can be managed and elongated to bring warmest and best aerated water to the fishpond. Between fishpond and warm water reservoir, the water can be led over a floating bed filter for cleaning and aeration.
The required water exchange rate is 1 time/h and the refreshing rate 1/3 per day. The waste water can be evacuated to the production ponds or to wetlands for further cleaning.

The feed should contain 35% protein and the FCR can be estimated at 1.2. In the 120 days from half May until end September the fish can reach 500 grams. If the market requires fish weighing more than 1.5 kg the on-growing phase could be prolonged. To raise 67,000 fish from 20 to 500 grams, the farm needs 350 m³ of covered canals; densities higher than 30 kg/m³ result in various problems and low efficiency. The 20 g fingerling would be bought from a nursery/hatchery.
For overwintering starting September-October; two options are available: in RAS with T= 10-14C, T may be higher if any growth is still needed to be able to reach market size higher than 1,5 kg on average in the second year. A second option is to store the carp in three meter deep flow-through ponds of 0.5 to 1 ha, per ton of carp 2 to 3 L/s of water exchange. For 67,000 fish of 500 g, or 33 tonnes, this means an exchange of 8,600 m³/day. The density during overwintering would be <15 fish/m².

For pond culture, fish weighing >500 g are stocked late May, after migration of the great cormorant, and when water temperature is above 17C to prevent diseases. They will be fed 2-3 times a week with in total 400 kg/ha of cereals (corn + wheat). As long as the fish don't reach table size the ponds may also be fertilized with up to 1,000 kg/ha of cow dung. Final average carp weight is estimated at 1.5 kg. In China growth of 0.75 to 0.9 kg within 130-170 days has been reached with an FCR of 1.3 with a soy-bean and wheat based feed at densities of 180 kg/m³ (Cremer et al., 2006).

6.4.3.1.2 Financial analysis of the projected farm

Family farms are an efficient unit for food production needing a high seasonal labour input. However, for small family farms supplementary investments that increase ecological sustainability are often not feasible because the scale of the enterprise is too small. Separate cost-benefit-analysis (CBA) for the four stages have been done, but regrouping them in two enterprises seems the most practical. The carp hatchery-nursery also keeps brood-stock to produce 20 g KHV immunized fingerlings for 1,000 ha of ponds. The family farm has a RAS for on-growing, a deep pond for overwintering and 100 ha of ponds, to raise the carp from 20 g to market size. Without considering wetlands or croplands, and accounting 40% for infrastructure and access roads, the productive unit needs about 150 ha in total.
The assumed interest rates and the market prices of inputs and products are subject to fluctuations. The xls sheets can be made available to recalculate the CBA for other interest rates than those assumed below:
Point of departure for the cost-benefit analysis is the transformation of a pond based enterprise in Hungary, where the labour cost are highest among the four countries with carp culture (www.fedee.com). Complementary assumptions, not yet mentioned in boxes 5 to 8 are that:

- The pond farm can sell annually 500 angling permits for 10 €/day.
- The farms use a settling wetland to improve the quality and reduce the quantity of outlet water; in these wetlands they culture fish (50 kg/ha) that can be marketed for 2 €/kg. For background on the area needed and used in the CBA: see the section on wetlands.
- Inflation rate is equal for all products and inputs, and not accounted in the CBA/NPV.
- Costs buildings are 100 €/m^2 (equivalent to industrial barn).
- The monthly minimum wage in Hungary[2] is 275 € (70,000 Forints), while the competitive labour cost is 159 €/week, or close to 700 €/month. We used 700 €/month, a wage which is also valid for the Czech Republic.
- Cost of electricity fluctuated dramatically in the past year: an average cost of 60 €/mWh is assumed.
- Oxygen was accounted for 0.36 €/kg, plus 440 €/month for the rental of a tank.
- Electricity use was estimated using the assumption that on average 7 kWh is needed to produce 1 kg of fish in full recirculation systems. Energy use of the system in table 70 was assumed to be 100 MWh/y for a tank of 150 m^3.
- The costs of the technical installations of the proposed system were estimated by experts (see acknowledgements). In table 70, costs of the technical installations were based on a RAS system for Tilapia which is also adapted to carp culture (www.hesy.com).
- For the on-growing system an investment cost similar to the sturgeon system was assumed: 280 €/m^3 of which 40% is to be assumed construction cost.
- Time-span considered for the NPV is 15 years, buildings are discounted over 15 years, and systems over 8 years meaning that investment in RAS is renewed once.
- The hatchery and the nursery are assumed to be managed together by a total of 4 professionals; 2 are accounted for each of the sections. For the on-growing on the individual farm one labourer was accounted, next to the one for the grow-out.

Using the equipment as proposed above, the breakeven cost for producing a 1 g carp would be 28 €/kg (Table 51). The cost of the immunised fingerling, including the cost of the former, would be close to 7 €/kg, or 0.14 €/fish (table 52). The cash-flow of the brood-stock keeping hatchery-nursery enterprise will be positive already in the second year, even when applying the credit interest rates of 13% as common in Hungary. When applying the more common interest rates, e.g. 6% as asked in the Czech Republic, the cost of the fry would be 25 €/kg and the cost of the 20 g fingerling below 6 €/kg or about 0.11 €/fish.

The cost of the 500 g carp after on-growing in the proposed system is estimated at 2.35 €/kg if credit interest rates are 13% (table 66), but around 2 €/kg for interest rates of 6%. However the cost per kg of grown-out carp (>1.5 kg) will be around 2 €/kg (table 54), which is the present market price in most countries.

The number of labourers needed in on-growing is underestimated according to some sources; a 100 ha farm would need one engineer and 4 labourers. The CBA considers that on-growing and grow-out are integrated in the same farm, and a total of two labourers is budgeted. Both CBA included the competitive labour cost which is much higher than actually paid, 5% for unforeseen/contingencies, and an amount for administration. The overall amount available is high enough for the labour required.

[2] Minimum wage in Poland is 330 € (1,130 Zlotys), while the competitive labour cost is 142 €/week, or close to 600 €/month.

Table 51: The cost-benefit analysis of a hatchery with brood-stock, culturing 1,200,000 yolk-sac fry of 1 g, each three months

Cost-Benefit Analysis carp hatchery, Hungary			Year 1				Year 2 to 15		
Income	**(Unit/period)**	**(€/unit)**	**1st Qtr**	**2nd Qtr**	**3th Qtr**	**4th Qtr**			**Totals**
Carp larvea of 1 g (1,000/kg)	1,200	28	33,600	33,600	33,600	33,600	134,400	134,400	2,016,000
Fish from settling ponds (kg)	200	2	67	67	200	67	400	400	
Interest from reservations	3%		-				116	6,019	42,246
Total income			33,667	33,667	33,800	33,667	134,916	140,819	
Expenditures									
Total feed cost			10,800	10,800	10,800	10,800	43,201	43,201	
Cost of hormones	18	0.8	14	14	14	14	58	58	
Cryopreservation (kg/day & €/kg liquid N)	1	0.4	48	48	48	48	192	192	
Labor (€/month)	2	700	4,200	4,200	4,200	4,200	16,800	16,800	
Power (electricity, €/mWh)	8.4	60	126	126	126	126	504	504	
Insurance (% of stock value)		0.50%	168	168	168	168	672	672	
Rent for oxygen production tank (€/y)	1	5,280	1,320	1,320	1,320	1,320	5,280	5,280	
Cost of oxygen (kg/kg feed & €/m^3)	0.3	0.36	140	140	140	140	562	562	
Administration costs (accountant report)	1	1,500	375	375	375	375	1,500	1,500	
Fees for m^3 water use	296	1.6	236	39	79	118	473	473	
Fees for m^3 water discharge	129	1.6	28	28	28	28	111	111	
Interest operational/running costs	18%			477	216				
Interest RAS and payback time (years)	13%	8				33,842	33,842	33,842	
Interest other installations (car, cryo ?)	13%	8				6,252	6,252		
Interest building and payback time (years)	13%	15				11,195	11,195	11,195	
Depreciation RAS installation (years)		8	4,568	4,568	4,568	4,568	18,270	18,270	237,510
Depreciation building		32	509	509	509	509	2,035	2,035	26,452
Depreciation other installations (years)		5	859	859	859	859	3,438	3,438	44,688
Unforeseen	5%		1,127	1,141	1,130	3,685	7,047	6,735	
Total expenditures			24,518	24,812	24,580	78,247	151,430	144,866	2,206,537
Cash flow			15,084	14,790	15,156	- 38,645	7,113	13,677	
Cumulative cash-flow			15,084	29,874	45,030	6,385	13,497	171,604	
Net Present Value		138,583	-206,691				10,571	27,438	
Cost in €/fish produced	0.030								

Note: the hatchery should produce other fish in other seasons to make the investments viable, the assumption is 4*/yr

Table 52: The cost-benefit analysis of a nursery culturing 700,000 immunized fingerling of 20 grams using a RAS system, each 3 months

Cost-Benefit Analysis carp Nursery, Hungary			Year 1				Year 2 to 15		
Income	(Unit/period)	(€/unit)	1st Qtr	2nd Qtr	3th Qtr	4th Qtr			Totals
Fingerling of 20 g (50 fry/kg)	14,400	6.6	95,040	95,040	95,040	95,040	380,160	380,160	5,702,400
Fish from settling ponds (kg)	396	2	132	132	396	132	1,584	792	
Interest from reservations	3%		-				1,060	14,835	111,260
Total income			95,172	95,172	95,436	95,172	382,804	395,787	
Expenditures									
Cost of 1,200,000 larvae of 1 g		0.028	33,600	33,600	33,600	33,600	134,400	134,400	
Total feed cost			13,680	13,680	13,680	13,680	54,720	54,720	
Cost vaccination		0.02		14,400	-	-	14,400	14,400	
Labor (€/month)	2	700	4,200	4,200	4,200	4,200	16,800	16,800	
Power (electricity mW/y, €/mWh)	101	60	1,512	1,512	1,512	1,512	6,048	6,048	
Insurance (% of stock value)		0.50%	475	475	475	475	7,603	1,901	
Administration costs (accountant report)	1	1,500	375	375	375	375	1,500	1,500	
Fees for m^3 water use	1,094	1.6	876	146	292	438	1,751	1,751	
Fees for m^3 water discharge	479	1.6	144	144	144	144	576	576	
Interest operational/running costs	18%			2,382	1,154	558			
Interest RAS and payback time (years)	13%	8				82,521	82,521	82,521	
Interest other installations (car)	13%	5				8,529	8,529		
Interest building and payback time (years)	13%	15				11,062	11,062	11,062	
Depreciation RAS installation (years)		8	11,138	11,138	11,138	11,138	44,550	44,550	668,250
Depreciation building (years)		15	1,072	1,072	1,072	1,072	4,289	4,289	64,340
Depreciation other installations (years)		5	1,375	1,375	1,375	1,375	5,500	5,500	82,500
Unforeseen	5%		3,354	4,156	3,382	8,465	19,438	18,726	
Total Expenditures			71,800	88,655	72,399	179,145	413,688	398,745	6,036,233
Cash flow			36,957	20,102	36,622	- 70,388	22,395	36,547	
Cumulative cash-flow			36,957	57,059	93,681	23,293	45,688	493,929	
Net Present Value		608,400	-474,196				35,781	78,975	
Cost in €/fish produced	0.14								

The nursery should produce other fish (e.g. pike . .) in other seasons to reduce cost/kg; the assumption is 4*/y.

Table 53: The cost-benefit analysis of on-growing 70,000 carp from 20 to 500 g in a closed system as described

Cost-Benefit Analysis carp On-grow, Hungary			Year 1				Year 2 to 15		
Income	(Unit/period)	(€/unit)	1st Qtr	2nd Qtr	3th Qtr	4th Qtr			Totals
fish of 500 g (2 fish /kg)	67,000	2.4			160,800		160,800	160,800	2,412,000
Fish from settling ponds (kg)	13,200	2	4,400	4,400	13,200	4,400	26,400	26,400	
Interest from reservations	6%		-					19,996	138,435
Total income			4,400	4,400	174,000	4,400	187,200	207,196	
Expenditures									
Cost 20 g fingerling (number, €/fish)	70,304	0.132		9,280				9,280	
Total feed cost					57,888		57,888	57,888	
Labor (number and €/month)	1	700	2,100	2,100	2,100	2,100	4,200	8,400	
Power (electricity, €/mWh)	235	60	3,518	3,518	3,518	3,518	14,070	14,070	
Insurance (% of stock value)		0.50%		804				804	
Administration costs (accountant)	1	1,500	375	375	375	375	375	1,500	
Fees for m^3 water use	3,087	1.6			4,940		4,940	4,940	
Fees for m^3 water discharge	1,351	1.6			2,161		2,161	2,161	
Interest operational/running costs	18%					1,633			
Interest and payback (year) installation	13%	8				50,013	50,013	50,013	
Interest and payback other equipments	13%	8				2,084	2,084		
Interest and payback (year) building	13%	15				17,826	17,826	17,826	
Depreciation installation (years)		8	6,750	6,750	6,750	6,750	27,000	27,000	525,868
Depreciation building (years)		15	1,728	1,728	1,728	1,728	6,912	6,912	120,868
Depreciation other equipments (years)		8	286	286	286	286	1,146	1,146	167,615
Unforeseen	5%		724	1,228	3,973	4,301	9,373	10,040	
Total Expenditures			15,480	26,069	83,719	90,614	197,988	211,980	3,176,171
Cash flow			- 2,316	- 12,904	99,046	- 77,449	24,270	10,278	
Cumulative cash-flow			- 2,316	- 15,220	83,825	6,376	30,645	157,697	
Net Present Value		117,993	-287,059				21,239	25,214	
Cost in €/kg fish produced	2.35								

This assumes the system is only used from May to October, other fish species might be grown out in the system for counter-season sale.

Table 54: The cost-benefit analysis of the grow-out of 67,000 carp in a 100 ha pond

Cost-Benefit Analysis carp Grow-out, Hungary			Year 1				Year 2 to 15		
Income	(Unit/period)	(€/unit)	1st Qtr	2nd Qtr	3th Qtr	4th Qtr			Totals
carp of 1.5 kg	67,000	2				134,000	134,000	134,000	2,010,000
Angling permits + 2 kg fish/person	500	10	833	833	2,500	833	5,000	5,000	
Fish from settling ponds (kg)	112	2	37	37	112	37	223	223	
Total income			871	871	2,612	134,871	139,223	139,223	
Expenditures									
Cost of fish 500 g/kg	67,677	1.18		79,523			79,523	79,523	
Total feed cost				6,700	6,700	6,700	20,100	20,100	
Labor (€/month)	1	700	2,100	2,100	2,100	2,100	8,400	8,400	
Insurance (% of stock value)		0.00%		-				-	
Administration costs (accountant report)	1	1,500	375	375	375	375	1,500	1,500	
Interest other installations (car a.q.)	13%	5				28,431	28,431		
Depreciation other installations (years)		5	4,583	4,583	4,583	4,583	18,333	18,333	
Unforeseen	5%		124	4,435	459	1,880	6,898	5,476	
Total Expenditures			7,182	97,716	14,217	44,070	163,185	133,332	2,149,246
Cash flow			- 1,728	- 92,262	- 7,022	95,384	- 5,628	24,225	
Cumulative cash-flow			- 1,728	- 93,990	- 101,012	- 5,628	- 11,257	214,104	
Net Present Value		84,097	-105,628				-8,816	34,233	
Cost in €/kg fish produced	2.1								

Cost of land was not considered. Cost of land in Hungary is close to 2,000 €/ha (www.amcham.hu). For more details on the data for cost-benefit analysis, see annex 1.

6.4.3.2 *Other sustainability aspects of RAS in carp production.*

In this section, an overview of the problems affecting carp producers is done, with an evaluation of RAS applicability and suitability to overcome those bottlenecks, from the sustainability point of view. The environmental pollution from the present and for the proposed system is discussed. The use of wetlands for sediment disposal and nutrient extraction is debated, as well as technological options to reduce load of OM and nutrients in outlet water.

Table 55: Overview of problems and whether or not RAS technology can offer a solution

Sustaina--bility aspect	Constraint or bottleneck of system	Possibility of direct improvement by existing RAS technology?		Priorities/ bottlenecks for RAS adaption.
			Considerations	**Observations**
Ecology	Availability of quality water	Yes	A broad range of technologies are available to improve water quality before farm use	
	Water use quantity & cost	Yes	Water use per kg fish produced can be drastically reduced	
	Effluents discharge	Yes	Large pond areas improve water quality; use wetlands to treat effluents	Groundwater contamination
	Wastes	Yes	Settleable wastes can be collected and treated	Integrated multi-trophic aquaculture
	Land availability/use	Y/N	RAS requires reduced area , but high investment, not profitable for on-growing	
	Predation	No	Except if indoor or intensive	Use of groundwater
Economy	Pathology (KHV)	Yes	Combining genetic selection	Use of groundwater
	Slow growth rate	Yes	Combining higher animal density with better control on feeding in RAS leads to better growth	
	Mortality	Yes	Better control on introduction of pathogens and bird predation	
	Feed cost	No	Better FCR in RAS	
	Feed use	Yes	See 'Slow growth rate'	
	Investment cost	No	Higher investment costs	Reduce pond area and invest in other land use
	Cash flow, interest rate	Y/N	Spreading of sales over longer periods of the year	
	Processing and marketing	No	RAS may effect efficiency	
	Lack fingerlings	Yes	Year round fingerling production	
	License cost	Yes	By reducing envir. impact	How to reward farmers for the creation of 'nature' or 'wetlands'?
Governance	Feed & fertilizer limits	Yes	By the systems	Funding for farm-based research
	Property	Yes	By reducing land use	Creation of stakeholders platforms for floodplains
	Bureaucracy	No		Co-management for monitoring
Social	Labor qualification	No	Need for less but more qualified people	
	Tradition	No		
	Union networks	No	Except by reducing labour need	
	Conflict with other coastal/land stakeholders	Yes	If envir. impact is reduced	Creation of stakeholders platforms for floodplains

The economic sustainability was demonstrated in section 3.4.2. In the current section we estimated the potential improvements on other aspects of sustainability by RAS application. This information is summarized below in some tables and under various headings. The effect on energy use was not estimated.

6.4.3.2.1 Land

For those farmers that need to buy land to start or continue aquaculture, the integration in the European Union has come too soon: prices of land are increasing to a level that RAS are the only feasible option for new investors that do not own a large area of ponds or lakes. However, the present market price (1.6 to 3 €/kg according to the countries) is too low to make an investment in RAS for growing carp from 0,02 to 1,8 kg a profitable option for these new-comers, also given the high interest rates in countries as Hungary (table 56).

Table 56: The cost price per kg carp produced* and the net present value of an investment in recirculation aquaculture with a capacity of 240 t/y for 3 interest rates.

		Interest rate		
	Unit	**4%**	**7%**	**13%**
Net investment	Million €	2.23	2.23	2.23
Net Present Value (NPV) after 15 years	Million €	-8.12	-9.33	-9.96
Cost price for growing carp from 0.2 to 1,8 kg	€/kg fish	3.03	3.19	3.54

NPV = the (inflation corrected) present value of the expected cash flows, less the cost of the investment, over a given period.
(*) Assume that in a RAS carp will grow within one growth period (360 days) to 1,800 grams (Szumiec, 1997).

6.4.3.2.2 Nutrient discharge

According to observations in Poland, during the production season (May-November) 10 tonnes of organic matter (OM) accumulate per ha as sediment: 5 tons OM from phototrophic production and 5 tons from faeces3. In Hungary the extensive fish farms, after an action of Association of Hungarian Fish Culturists, do not pay discharge fees as research has demonstrated that the quality of the discharged water is better than the water that was used for filling the farms from surface water. Measurements in Poland confirm this for the growing season (figure 18). Considering that outflow water is cleaner (<2% of OM) than inflow, discussion will be focused on the sediment which if often discharged in the river after the production season.
At present the average productivity is just above 650 kg/ha and an average farm of 650 ha produces close to 400 t/y. If 1,000 t/ha is produced by distributing 2000 kg/ha of cereals and 1000 kg of cow dung during 190 days a total, while considering feed distributed in the last year only, an estimated 40 kg N/ha and 6 kg P/ha are not retained in the produced carp (table 57). In the proposed production system it is planned to discharge the waste water from the on-growing ponds of 350 m3 in the grow-out ponds. If in previous years the same amount of feed was distributed relative to the fish weight, the total amount of nutrient accumulated in the pond can be estimated at 60 kg N and 9 kg P per 1,000 t of fish.

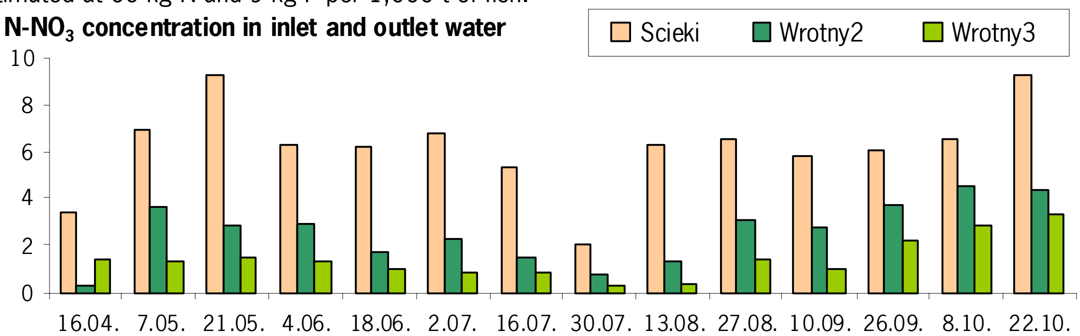


Figure 18: Nitrogen -concentration in household waste water (scieki), in pond inlet (wrotny2) and outlet (wrotny3) water of carp ponds in Poland. Data from Miroslaw, 2007.

[3] **COD = (C/FW)(RMO)(32);** Where C = Concentration of oxidizable compound in the sample; FW = Formula weight of the oxidizable compound in the sample; RMO = Ratio of the num. of moles of oxygen to num. of moles of oxidizable compound in their reaction to CO_2, water, and ammonia. For example, if a sample has 500 wppm of phenol:
$C_6H_5OH + 7O_2 \rightarrow 6CO_2 + 3H_2O$; COD = (500/94)(7)(32) = 1,191 wppm

The nutrient output of a pond has four aspects: (1) the effluent from the regular refreshment water, (2) the waste output at the end of the cycle when the pond is emptied and part of the sludge may be discharged, (3) the losses through seepage and from infiltration and leaching, and (4) the discharge if the accumulated sediments are removed. In a pond system without concrete lining nutrient losses can be huge. Over a six month period a sediment layer establishes in which the accumulation of nutrients has a maximum (Amara et al., 2006). Within a month after starting the culture, the losses after mineralisation in the sediments of nutrients such as N an P through various processes such leaching, infiltration, and immobilisation are larger than the accumulation in the sediment or the fish (Jiménez-Montealegre et al., 2004). The losses will increase with increasing input level (Nhan, 2007). The European norms for maximum output are 170 kg N/ha and 20 kg P2O5 or about 6 kg of P; these norms consider the permissible infiltration of nutrient in ground water. In the proposed system's grow-out pond these norms are not reached for N, while the sludge contains just the maximum permissible value for P. If the outflow water of the on-growing system is lead to the ponds this balance will be heavier. The main problem resides in the P; the N can be recovered in wetlands. As long as the nutrient balance does not exceed the maximum permissible level one may assume to respect the environmental norms (Table 57).

Table 57: The nutrient balance of feeding a 3,260 kg mix of wheat and corn and 1,000 kg of cow dung to produce 1000 kg of carp/ha.

	Nutrient input cereals		*Nutrient input dung*		*Nutrient output in fish*	
	N	P	N	P	N	P
Average content (g/kg)	19.6	3.25	26.7	5.5	25.0	4.5
Total /yr /ha (kg/yr)	64	11	1.5	0.3	25.0	4.5

6.4.3.2.3 Feed

The feed use in the actual system was assumed to be identical per ha while the number of ha used was half when growing carp from 0.02 to 0.5 kg: (40+20)/100 = 0.6. The proposed system used almost the double quantity of feed for on-growing, and just over 1.5 tons during the fingerlings stage. The nutrient discharge was calculated following table 70 and assuming the same waste for the actual system when growing carp from 0.02 to 0.5 kg was identical per kg growth. For the proposed system it was assumed that for growing carp from 0.02 to 0.5 kg nutrients will be recovered for 90% in RAS.

6.4.3.2.4 Water

The present water use is estimated using the available data and assuming the water in the grow-out pond was entirely refreshed once; a 100 ha pond contains 1 million m3. For the actual system we assumed that this was needed two times to reach the same final weight, considering three year was needed to reach the market weight but that density of the younger fish being lower in kg/m3. For the proposed system the water use was calculated as follows: ([(300+1,100)/10]+3,100 + 1,000,000)/100,000. The water discharge was estimated as ([(130+480)/10] +1,350+1,000,000)/100,000.

The hatchery-nursery uses recirculation and the quantity of fresh water needed is limited. In total, close to 1,400 m3 of fresh water and less than 3 ha of wetland are required (see next section). For the on-growing close to 3,000 m3 of fresh water and over 13 ha of wetland are required. The wetlands can be used for recreational fishing and permits can be sold.

Table 58: Estimated quantitative benefits of a carp culture system integrating RAS for hatchery, nursery and on-growing, and doing grow-out in ponds

Sustainability criteria		**Current system without RAS**	**Projected system including RAS**
Name	**Unit**		
Water use	m^3/y/kg fish	20	10
Effluents (water) discharge	m^3/y/kg fish	20	10
Discharge of N	kg/kg fish		
Discharge of P	kg/kg fish		
Land use	ha/mt fish	>3	< 2
Predation	% losses	10 to 40	0.5
Pathology (immunization)	% losses	5 to 80	50
Weather	% losses	0 (adult) to 100 (larvae) %	0.5
Feed use (FCR)	kg food/kg fish	3.0	
Nursery			1.5
On-growing			1.2
Grow-out			3.3

6.4.3.2.5 Economic efficiency

An estimation of the ‘rate of return’ has not been included because this depends too much on the market development, on the impacts of disease, predation and weather conditions, and on the specific farm enterprise (Table 71). The present losses of fish vary within and between farms and countries, and in the table the recorded ranges are mentioned. The average losses are estimated at 10% for Czech, 15 % for Poland and 20% for Hungary. Losses vary according to the stage of culture: in the first year it may vary from 50 to over 80% if the larvae get infected, in the second year 2 up to 40% of the fingerlings may be lost, and in the third year 5-10%. The mentioned future losses remain speculative, even if the KHV is controlled. Losses due to predation allows in some cases even to generate revenue from subventions or compensations.

6.4.4 Discussion and recommendations

The proposed system mainly addresses the prevention of mortality from KHV and of predation by birds, and maintains the ecosystems service function of the open pond culture. The proposed system addresses the pollution problem from the ponds in a very limited manner and may still be subject to critics from environmental NGO’s, and to high fees for water use and for effluent discharge. The wastewater from fish production has three main harmful components: N, P and OM. The OM can be used to produce biogas that can be transformed in electricity. The aim of reducing the N and P content of wastewater should be to efficiently recover these nutrients as fertilisers for crops.

As for the open pond culture, the low density of fish ponds makes recovery of nutrients from the ponds hardly an option. The best option might be to compose a feed/fertiliser that reduces waste; but feed manufacturing is costly and the efficiency needs to be evaluated. A consortium lead by HAKI aims to address this question.

6.4.4.1 Nutrient recovery

The process to recover nutrients from the on-growing in a RAS needs to be evaluated. Producing biogas from the OM in the wastewater might contribute to the farms’ energy need. E.g. per kg OM 0.3 – 0.5 m3 biogas can be produced, with a caloric value of 24 MJ m-3, representing 2.0 – 3.3 kWh. Assuming a digestibility of 80%, the 32 tonnes of aquafeed for the on-growing will produce around 6 tonnes of OM, if 50% of this could be recovered from the water than at least 1.8 MWh can be produced. However this is small compared to the total need for the on-growing and research is needed to study the efficiency of the investment compared to the alternatives. At present, the most efficient way to reduce N from wastewater seems to be its denitrification to N2, thus volatilising the resource which is a loss. No technology to recover P is used in aquaculture. Research is needed to identify production systems that reduce the output of N and P and on waste treatment processes that efficiently capture the N and P from the remaining outflow waste water as fertilizer.

6.4.4.2 Wetlands

Wetlands and open ponds may reduce the need to pay fees for discharging water as (1) nutrients are used in the wetlands, and (2) the evaporation from de surface decreases the quantity of discharge water. If the annual evaporation deficit is 5 cm, 500 m3 evaporates from one ha. The area of wetlands needed depends on the intensity and the quality of the RAS.

The wetlands area needed for water cleaning was calculated using the following parameters, derived from an experiment composed of a recirculation unit, an algae production pond and an open water fish pond (Gál et al., 2007). In the mentioned experiment of Gál et al. (2007), the stocking densities in the fish tanks, the algae ponds and the fish ponds were 50 (African catfish4), 0, and 0.62 kg m-3 (Common carp at 0.38 and Nile tilapia at 0.24 kg m-3), respectively; the ratio of the area of fish tanks, algal pond and the extensive fishpond was approximately 1:22.5:20. The densities of carp in the hatchery and nursery are much lower but the FCR higher and one may count about 1:12:10. The area of the RAS tanks needed to produce the required number of 20 g carp is 75 m3, in total less then 0.2 ha of wetlands and extensive ponds is needed. In the on-growing phase the density may be 100 kg m-3 (while for tilapia 130 kg m-3 is acceptable), but FCR much better than during nursery. Based on 1:45:40, the area needed is estimated at about 3 ha of wetlands and extensive ponds for 400 m2 of on-growing tank surface. The study focussed on some aspects of sustainability such as nutrients, water, and financial margins. The projection of data for these and other parameters remains speculative until research has been done. One could use data of enterprises producing carp in RAS in other countries but the proposed systems are hardly comparable. For example, late stocking is proposed here to reduce predation by migratory birds but perhaps those birds will adapt their schedule because they need to feed before being able to migrate. As the culture of carp is focussed in specific seasons the investments can be recovered only if the systems of the hatchery, the nursery and the on-growing are used for other speculations in the empty periods. Research is needed to choose best options: pike, perch, European catfish. The financial margins depend heavily on investment, interest rates, payback period, and depreciation time. The subventions from programs supporting investment in sustainable agriculture might be very useful to reduce investment costs. The less money one borrows from the bank the easier it is to give the enterprise a positive rate of return. On the other hand reducing the costs of the installation seems crucial. The production of fish in a RAS requires experience. Therefore enterprises are advised to start with one unit to gain know-how on the management of a RAS before further investments. Though cost of electricity is only the third ranking cost factor after investments and depreciation of equipments and feed, it is advised to study the opportunity to invest in a biogas digester to provide electricity. A biogas reactor will not only reduce the cost of energy but also the wastes of nutrients and the fees for discharge (if any). The waste of nutrients remains high during the grow-out in the pond. A project consortium led by HAKI aims to address this problem. The main aims of the proposed system are to shorten the production cycle to 2 years, and to reduce the effects of KHV and bird predation. Therefore a special nursery in a RAS, and on-growing in a newly designed recirculation system are required. Cost efficiency of these systems need to be studied and depend also on mortality during immunisation and on nutrient use efficiency. Though the carp will still be fattened in ponds and organically certified feeds can be used, one may wonder if the carp raised in a more intensive way still (1) get the same consumers' preference, (2) have the same healthy properties with regard to the unsaturated fatty acid composition. To address the KHV problem, to reduce losses due to predation, and to maintain the consumers market of the carp raised in ponds, three questions need to be addressed:

1) Can the Israeli' protocol for KHV immunization through co-habitation be adjusted to other conditions in a cost efficient manner without detrimental environmental effects?
2) Can the density of carp during on-growing be increased to a level (>30 kg/m3) required for cost efficient nutrient recovery?
3) What are the effects of the intensification of the production system during early live (0-20 grams including KHV immunization through co-habitation) on (a) the omega-fatty acid composition and (b) the robustness of the carp during grow-out in ponds?

4 At harvest the density will be just above 300 kg m^{-3}

7 Conclusions

Based on the three case studies covering seabass in RAS and cages, sturgeon culture in RAS and carp culture in RAS and ponds, it is concluded that the application of RAS in Eastern Europe will improve production sustainability. Ecological, economical, social and governance aspects have been analysed and for several of the identified indicators an improvement was determined. The magnitude of those improvements is depending on species and local context. It is recommended to stimulate the introduction, development and application of RAS in Eastern Europe based on the results of this case studies. However, RAS introduction cannot resolve all issues limiting aquaculture development in those countries. Several aspects are related to social and governance frameworks and are not to be resolved on that level. Future research on commercial and/or experimental scale is needed to evaluate the benefits of RAS introduction for the improvement of the sustainability of fish production.

8 Bibliography

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9 Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of Wageningen IMARES.

Approved: of this report~	Ir. Henk van der Mheen Head of Aquaculture Department, Wageningen IMARES
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10 Annex 1: Data for Cost Benefit Analysis (CS 3)

Data for Cost-benefit of carp hatchery with RAS	unit		
Output (number per kg) and larvae/period (kg)		1000	1,200
Price RAS for larvae; m^3 needed and cost per m^3		140.0	860
Cost tank plus trickling filter for broodstock; m^3 needed for 3 species and cost per m^3		42.0	1,000
Required building/unit (cost in €/m^2) (building surface 2 * tank area)		100	723
Car, cryo material (y for depreciation and investment in Euro)		8	
Constant electricity demand, including energy for oxygen production	kW/h		1.0
New intake water (m^3/y) (€/m^2) (35 L/kg feed + 45 L/kg for evaporation)		0.08	296
water discharge (L/kg and total m^3)		35	129
average weight of female breeders and number		5	30
Kg broodstock assuming 60% of female is mature and ratio m/f=1/2			195
egg per female		400,000	
survival rate		60%	
number of larvae 0.5 - 1 g			1,200,000
number of above per m^3		50,000	
Cost of total aquafeed needed	€		10,800
Cost of feed broodstock (average weight in kg) and % of feed per weight unit		5	3%
Cost/kg and quantity of maintenance feed		0.7	1,960
Cost/kg and quantity of flushing feed (30 days)		0.9	176
Period of flushing (days)		30	
Feed larvae, 0.1 g Artemia per 50 mg larvae for the period (€/kg & kg)		60	120
Days feeding artemia		10	
Feed larvae 0.1 g (0.2-0.4 mm), (€/kg) catfish'0'pellets for 4 days at 10% of BW		4	360
Days feeding catfish 0, from day 5 onwards		5	
Average FCR (Feed conversion)		3	
Average weight (g)		0.2	
Feed tilapia 0 (€/kg)		2	1,080
Days feeding Tilapia 0		10	
Average weight (g)		0.4	
Average FCR (Feed conversion)		3	
Unit price electricity		60	€/mWh
Electricity need per period (mWh)		8.4	mWh
Fish price (€/kg)		2	
Interest rate investment		13%	
Investment RAS installation: pay-back time (years)		8	
Investment RAS installation: depreciation in (years)		8	
Investment building: payback in (years)		15	
Investment building: depreciation in (years)		32	
Depreciation in		5	
Interest on deposit		3%	
Insurance (% of stock value)		0.50%	
Annual wage (2 person and salary of 700 €/m)			
		Total	wetland
One-tenth (for low density) of the area fish tanks		18.2	**0.20**
Evaporation from wetland and ponds (m^3/ha)			300

Data for Cost-benefit of on-growing carp with RAS	unit		
Output of fingerling/period (kg) (indivual and total weight)		0.5	33,500
Price technical installations; m³ needed and cost per m³		1200.0	200
Required building/unit (cost in €/m²) (building surface 1.2 * tank area)		1440	80
Pump for overwintering pond and other material (years depreciation and investment)		8	
Constant electricity demand, including energy for oxygen production	kW/h		27
New intake water (m³/y) (€/m²) (35 L/kg feed + 45 L/kg for evaporation)		0.08	3,087
water discharge (L/kg and total m³)		35	1,351
larvae / fry stocked (weight at start and number)		20	70,304
survival rate		95%	
number of fingerling 20-500 g (weight at end and number)		500	67,000
number of above per m³		200	
Cost of total aquafeed needed	€		57,888
Fingerling feed 35% protein (€/kg)		1.5	38,592
Days feeding 35% protein		140	
Average FCR (Feed conversion)		1.2	
Feed tilapia 0 (€/kg)		2	0
Days feeding			
Average FCR (Feed conversion)		1	
Unit price electricity		60	€/mWh
Electricity need (mWh) (110 MWh for 150 m³)		234.5	mWh/y/cb
Fish price (€/kg)		2	
Cost of vaccination per fish		0.00	
Average FCR (Feed conversion)	%		
Interest rate investment		13%	
Investment RAS installation: pay-back time (years)		8	
Investment RAS installation: depreciation in (years)		8	
Investment building: payback in (years)		15	
Investment building: depreciation in (years)		15	
Depreciation in		8	
Interest on deposit		3%	
Insurance (% of stock value)		0.50%	
Annual wage (2 person and salary of 700 €/m)			
			Total
Area fish tanks		1200.0	**13.20**
Evaporation from wetland and ponds (m³/ha)			300

Data for Cost-benefit of carp Nursery with RAS	unit		
Output of fry/period (number per kg and total weight in kg)		50	14,400
Price technical installations; m³ needed and cost per m³		360.0	1,100
Required building/unit (cost in €/m²) (building surface 2 * tank area)		100	715
Car and other material (years depreciation and investment in Euro)		5	
Constant electricity demand	kW/h		11.5
New intake water (m³/y) (€/m²) (35 L/kg feed + 45 L/kg for evaporation)		0.08	1,094
water discharge (L/kg and total m³)		35	479
larvae / fry stocked		1,200,000	
survival rate		60%	
number of fry 1 - 20 g			720,000
number of above per m³		2,000	
Cost of total aquafeed needed	€		27,360
Feed fry 35% protein (€/kg)		2	13,680
Days feeding Aquafeed 35% protein		60	
Average FCR (Feed conversion)		1	
Feed tilapia 0 (€/kg)		2	0
Days feeding			
Average FCR (Feed conversion)		1	
Unit price electricity		60	€/mWh
Electricity need (mWh)		101	mW
Fish price (€/kg)		2	
Cost of vaccination per fish		0.02	
Average FCR (Feed conversion)	%		
Interest rate investment		13%	
Investment RAS installation: pay-back time (years)		8	
Investment RAS installation: depreciation in (years)		8	
Investment building: payback in (years)		15	
Investment building: depreciation in (years)		15	
Depreciation in		5	
Interest on deposit		3%	
Insurance (% of stock value)		0.50%	
Annual wage (2 person and salary of 700 €/m)			
			Total wetland
One-tenth (for low density) of the area fish tanks		36.0	**0.40**
Evaporation from wetland and ponds (m³/ha)			300

Data for Cost-benefit of carp grow-out on ponds	unit		
Output of fish/period (kg)			100,500
Price technical installations; m^3 needed and cost per m^3		558.3	0
Required building/unit (cost in €/m^2) (building surface 1.2 * tank area)		50	0
Nets and other harvesting material (years depreciation and investment)		5	
Constant electricity demand, including energy for oxygen production per unit of 360 m^3	MW/y		0
New intake water (m^3/y) (€/m^2) (35 L/kg feed + 45 L/kg for evaporation)		0.08	3,216
water discharge (L/kg and total m^3)		35	1,407
larvae / fry stocked (weight at start and number)		0.5	67,677
survival rate		99%	
number of fish 500-1500 g (weight at end and number)		1.5	67,000
number of above per m^3		120	
Cost of total aquafeed needed	€		7,035
Wheat (€/kg)		0.15	20,100
kg per ha (or per tonne)		400	
Corn (€/kg)		0.2	20,100
kg per ha (or per tonne)		400	
Unit price electricity		60	€/mWh
Electricity need per unit (mWh) (110 MWh for 150 m^3)		0.0000	mWh
Fish price (€/kg)		2	
Cost of vaccination per fish		0.00	
Average FCR (Feed conversion)	%		
Interest rate investment		13%	
Investment RAS installation: pay-back time (years)		15	
Investment RAS installation: depreciation in (years)		15	
Investment building: payback in (years)		15	
Investment building: depreciation in (years)		15	
Depreciation in		5	
Interest on deposit			
Insurance (% of stock value)		0.00%	
Annual wage (2 person and salary of 700 €/m)			
			Total
Area fish tanks		558.3	**0.11**
Evaporation from wetland and ponds (m^3/ha)			500

Country data for Cost-benefit of RAS with carp		Czech	Hungary	Comments from Hungary
Average output weight per fish	kg/fish	2.50	2.00	avg. market size fish
Fish price (weight 1.5 to 2 kg)	€/kg	2.00	2.10	
Fish price (weight 2 to 2.5 kg)	€/kg	2.20	2.00	
Fingerling price	€/kg	4.00	2.50	
Cost larvae feed (Artemia)	€/kg	60.00	80.00	
Cost of feed 'catfish 0'	€/kg	4.00	0.72	
Cost of feed 'tilapia 0'	€/kg	2.00	0.70	
Cost of feed for on-growing (35% protein)	€/kg	3.00	0.70	
Price of wheat	€/kg	0.15	0.12	
Price of corn	€/kg	0.20	0.09	
Interest on deposit	%	1.00	11.00	
Interest on long term loan for investment	%	6.00	20.00	
Interest on loan for running cost	%	1.00	20.00	
Insurance (% of stock value)	%	0.50		
Cost of wage salary (competitive labour cost)	€/month	700	570	avg. manual worker in agriculture
Unit price electricity	€/mWh	15.00	160.00	
Cost of license to pump ground water	€/m³	0.00	0.00	no fee currently
Cost of drinking water	€/m³	1.60	0.80	
Cost of discharging water	€/m³	1.60	0.90	
Investment cost of carp hatchery	€/million larvae	1000		
Running cost of carp hatchery	€/million larvae	200		
Labour need for hatchery/nursery	p/million larvae	0.25		
Present labour need for farm with 100 ha pond	persons	0.50	5.00	at least 4 workers + 1 engineer
Cost of liquid nitrogen and oxygen	€ /L	0.40	0.36	
Cost of hormones for spawning.	€/fish	0.80	2.80	1 kg requires 3-5 grams of hyphopyhis

11 Appendix 2: Economic Analysis and Sustainability of Turkish Marine Hatcheries

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11.1 Abstract

The economic analysis of 7 leader marine fish hatcheries was performed and sustainability of Turkish marine hatcheries was evaluated. For this purpose, the fixed cost including investment cost and the operational cost containing of feed, labor, energy, fuel, water, oxygen, and medicament costs were determined for each facility. Also, production methods, species and marketing techniques of each firm was investigated and conflicts, opportunities, projections, structuring and sustainability of the sector were evaluated.
As a result, it was seen that the ratio of total cost to total income changed between 22% and 97.8%. Also, it was concluded that the most important stakeholders of the sector were the conflict between different sectors using the same site and formal bureaucratic procedures.

11.2 Introduction

The industry has developed to such an extent that Turkey is currently the third largest farmed finfish producer in EU and second largest producer of both sea bass and sea bream after Greece and of rainbow trout after Norway. Production figures in last 5 years show that Turkey is among first 12 countries with fastest developing aquaculture sector. Turkish aquaculture development was driven by availability of sheltered sites and good water quality, governmental supports, high private sector interest, rapid development of specific marine hatchery technologies, rapid biotechnical developments in live feed, pathology, artificial food, cages, self rationalization of sector and transformation from the production driven strategy to a market oriented strategy, and low labor cost (Okumuş and Deniz, 2007).
Today marine Aquaculture plays an increasing important role in the total fishery products. it share of total Aquaculture and fishery production were around 59% and 13% in 2005, and 55% and 19% in 2006 (Okumuş and Deniz, 2007) by volume respectively and it was much higher in value terms. Sector can be characterized by limited species and system diversity, small scale farms, a production oriented approach and export dependent (EU) market. In 2006 total marine aquaculture production as sea bass, sea bream, mussel and others covered 55% of total Turkish aquaculture production (Okumuş and Deniz, 2007).
Marine aquaculture in Turkey is located in the Ege Region, where geographical and hydrographical conditions suit to the cultured species. There are 60 earth ponded and 229 cage farms in the Ege Region, and 12 farms in the Mediterranean and Blacksea Regions (Okumuş and Deniz, 2007).
Total Turkish fisheries and aquaculture production involves 38.381 tones marine capture, 46.115 tones inland capture, 69.673 tones marine aquaculture and 48.604 tones inland aquaculture productions in 2005. Over the last decade, marine aquaculture increased from 1,3% to 12,8% of the total fisheries when total aquaculture production increased 39% to 59% (Okumuş and Deniz, 2007). Whereas marine fish hatchery reproduction number was 200-250 million larvae in 2005 (Okumuş and Deniz, 2007), sea bass, sea bream and other Mediterranean species total larvae production has been reached to number of 348 million in 2007 (Okumuş and Deniz, 2007).
Liu and Sumaila, (2007) conducted an economic analysis of open netcage and sea-bag systems for salmon aquaculture to examine the profitability of salmon aquaculture operations between these two systems. The study showed that netcage systems are more financially profitable than sea-bag systems when environmental costs are either not or only partially considered. Sea-bag systems can be financially profitable only when they produce fish that achieve a price premium. An economic analysis of a hypothetical small-scale marine recirculating aquaculture

system (RAS) is conducted for ongrowing small, wild black sea bass *Centropristis striata* by Copeland et al. (2007).
Omondi et al. (2001) conducted a partial economic analysis for Nile tilapia *Oreochromis niloticus* L. and sharp toothed catfish *Clarias gariepinus* polyculture in central Kenya. Ponds were sampled monthly to measure fish growth, and drained completely after 20 weeks. A partial economic analysis indicated minimal net profits of US$ 251US$ 132, US$ 44 and US$ 94 for treatments 1–4, respectively, because of high feed and seed costs.
Losordo and Westerman (1994) investigated an analysis of biological, economic, and engineering factors affecting the cost of fish production in recirculating aquaculture systems. The results of a model sensitivity analysis indicate that while improvements in the performance efficiency of system components did not greatly affect fish production costs, reductions in feed costs and improvements in the feed conversion ratio caused the greatest reduction of production cost of all of the operational variables investigated. The analysis further indicates that the greatest gains to be realized in improving profitability are those associated with increasing the productive capacity or decreasing the investment cost of a recirculating fish production system.
Sıaw-Yang et al. (1989) summarized the economic aspects of production models and discusses the economic feasibilities and some marketing requirements of a proposed fisheries-aquaculture development at Malaysia. Burbridge et al. (2001) presented a critical review of current social, economic and policy issues relevant to marine aquaculture (mariculture) in Europe. Tools for identifying the full range of social, economic and environmental issues that influence the sustainable development of mariculture are examined. Under present sectoral approaches to policy, investment, development planning and natural resources management, these issues continue to be treated in isolation.
Sustainability and sustainable development are complex issues that are difficult to define and apply in aquaculture. According to Black (2001), sustainability is where environmental effects meet socio-economics and markets. Some European countries have already developed legal frameworks and policies for managing aquaculture development. Aquaculture is frequently regulated by many agencies under a variety of laws (e.g. Greece, Portugal, Finland), though in some countries there is an integrated legal framework (e.g. UK). Developing a comprehensive regulatory framework for the sector is often legally and institutionally complex (Henderson and Davies, 2001). It has been argued that existing administrative and legal frameworks need to be reviewed and adjusted to address the changing characteristics and needs of the sector and to set out clearly the privileges and responsibilities of aquaculturists (Henderson and Davies, 2000). A simulation model of sustainability of coastal communities was developed by McCausland et al. (2006). The studies were conducted about sustainability in aquaculture by Tisdell (1999) and Bailly and Willmann (2001). Chopin et al. (2001) studied integrating seaweeds into marine aquaculture systems on the behalf of sustainability. Beveridge et al. (1997) presented the relationships between aquaculture and the environment In Asia, focusing on the demands for environmental goods and services among different sectors for sustainable development. The sustainability in Aquaculture for an integrated salmon–mussel production system was investigated by Whitmarsh et al. (2006).
González et al. (2003) applied 12 modified and 5 new sustainable development indicators and developed a sustainable index for 21 out of the 33 semi-intensive shrimp farms in Sonora, Mexico, to measure their sustainable development, during the year 2000.
Despite the rapid growth of aquaculture and the growing awareness of environmental issues, few studies have been made which address these issues objectively. Experience has shown repeatedly that without some form of intervention, short term financial perspectives will tend to dominate development decisions to the detriment of environmental and social objectives.
Ideally the technical and economic assessment as described above should be summarized in the form of overall "sustainability" profiles of alternative development options and technologies, so that rational comparisons can be made, trade-offs assessed, and planning and management decisions made. This information is essential for any kind of environmental assessment, cost benefit analysis, or participatory decision making (GESAMP Report, 2001).
In this study, the economic analysis of 7 leader marine fish hatcheries was performed and sustainability of Turkish marine hatcheries was evaluated. The economic analysis of these facilities were conducted depending on fixed investment cost, operating cost such as feed, labor, energy, fuel, water, oxygen, medicament, etc. Also, the production methods, species, amount of production, marketing, production volumes, total capacities of production, fish farm area and building or specialized installation were taken in to account. Furthermore, constrains and opportunities, future projections, reorganizations and sustainability of the aquaculture sector in Turkey were evaluated

11.3 Materials and Methods

In this study, 7 facilities which are leader in marine hatchery production in Turkey were investigated. The economic analysis of these facilities were conducted depending on fixed investment cost, operating cost such as feed, labor, energy, fuel, water, oxygen, medicament, etc. The production methods, species, amount of production, marketing, production volumes, total capacities of production, fish farm area and building or specialized installation were taken in to account.
Constrains and opportunities, future projections, reorganizations and sustainability of the aquaculture sector in Turkey were evaluated.
The economic analysis also includes fixed and indirect operating costs, such as salary, insurance, maintenance, interests and depreciation which are usually independent of the level of production and variable cost such as seed, feed, fertilizer, chemical and drugs, labor, water and energy, harvesting and post harvest and miscellaneous costs, which vary with output. Also, total production, total cost of production, gross revenue, net return, benefit cost ratio (net return / total cost), cost of input per unit of output (kg), value of unit of output, amount of output (kg) per unit of tank volume (m^3) and cost of input per unit of tank volume (m^3) were evaluated.
Data collection, classification and analysis consist of the year of 2007. For this purpose, the farms were surveyed and questionnaire study was done. All data were obtained face to face interviews with farmers and experts. Seven marine fish hatcheries which have higher juvenile production capacity in Turkey were selected. Data relating with the harvesting and stocking rates, species, labor, feeding, consumption of water and energy, maintenance, individual production of species, selling prices, fish production activities, marketing, etc. were recorded.
The investment cost for per fish is given in Eqs. (1-2).

$$ICPF(€) = \left(\sum_{i=1}^{4}(IC)_i/(YA)_i\right)/TNF,\ i = \begin{cases} 1-building/office \\ 2-system/pond/cage \\ 3-installation/\inf rastructure \\ 4-processin g/storage \end{cases} \quad (1)$$

$$ICPF(\%) = ICPF \times 100/TCPF \quad (2)$$

where, IC, YA, TNF, i and TCPF are investment cost, year of amortization, total number of fish, kind of investment and total cost for per fish, respectively.
Feed cost for per fish is defined in Eqs. (3-4).

$$FCPF(€) = \left(\sum_{j=1}^{n}(AFPF)_j \times (NF)_j \times FP \times PPK\right)/TNF \quad (3)$$

$$FCPF(\%) = FCPF \times 100/TCPF \quad (4)$$

where, AFPF, FP, NF, PPK and j are amount of feed for per fish, feeding period, number of fish, price of per kilogram and species of fish, respectively.
Labor cost for per fish is calculated by Eqs. (5-6).

$$LCPF(€) = \left(\sum_{k=1}^{n}(NS)_k \times (SS)_k \times 12\right)/TNF \quad (5)$$

$$LCPF(\%) = LCPF \times 100/TCPF \quad (6)$$

where, NS, SS and k are number of stuff, salary of stuff and group of salary, respectively.
The energy cost for per fish is given in Eqs. (7-8).

$$ECPF(€) = \left(\sum_{p=1}^{12}(EC)_p\right)/TNF \quad (7)$$

$$ECPF(\%) = ECPF \times 100/TCPF \quad (8)$$

where, EC and p are energy cost and number of month, respectively.
The fuel cost for per fish is defined by Eqs. (9-10).

$$FUCPF(€) = \left(\sum_{p=1}^{12}(FUC)_p\right)/TNF \quad (9)$$

$$FUCPF(\%) = FUCPF \times 100/TCPF \quad (10)$$

where, FUC is fuel cost.
The water cost for per fish is calculated in Eqs. (11-12).

$$WCPF(€) = \left(\sum_{p=1}^{12} (WC)_p\right) / TNF \quad (11)$$

$$WCPF(\%) = WCPF \times 100 / TCPF \quad (12)$$

where, WC is water cost.
The oxygen cost for per fish is evaluated with Eqs. (13-14).

$$OCPF(€) = \left(\sum_{p=1}^{12} (OC)_p\right) / TNF \quad (13)$$

$$OCPF(\%) = OCPF \times 100 / TCPF \quad (14)$$

where, OC is oxygen cost.
The medication cost for per fish is given in Eqs. (15-16).

$$MCPF(€) = \left(\sum_{p=1}^{12} (MC)_p\right) / TNF \quad (15)$$

$$MCPF(\%) = MCPF \times 100 / TCPF \quad (16)$$

where, MC is medication cost.
The other cost for per fish is defined in Eqs. (17-18).

$$OTCPF(€) = \left(\sum_{p=1}^{12} (OTC)_p\right) / TNF \quad (17)$$

$$OTCPF(\%) = OTCPF \times 100 / TCPF \quad (18)$$

where, OTC is other cost.
The operating cost for per fish is calculated by Eqs. (19-20).

$$OPCPF(€) = FCPF(€) + LCPF(€) + ECPF(€) + FUCPF(€) + WCPF(€) + OCPF(€) + MCPF(€) + +OTCPF(€) \quad (19)$$

$$OPCPF(\%) = FCPF(\%) + LCPF(\%) + ECPF(\%) + FUCPF(\%) + WCPF(\%) + OCPF(\%) + MCPF(\%) + +OTCPF(\%) \quad (20)$$

The total cost for per fish is given in Eqs. (21-22).

$$TCPF(€) = ICPF(€) + OPCPF(€) \quad (21)$$

$$TCPF(\%) = ICPF(\%) + OPCPF(\%) \quad (22)$$

The total income is calculated as fallows,

$$TI(€) = \sum_{j=1}^{n} (PAL)_j \times (PL)_j + \sum_{j=1}^{n} (PAMS)_j \times (PMS)_j + \sum_{j=1}^{n} (PAE)_j \times (PE)_j \quad (23)$$

where, PAL, PL, PAMS, PMS, PAE and PE are production amount of larvae, price of larvae, production amount of market size, price of market size, production amount of egg and price of egg, respectively.

11.4 Results and Discussion

11.4.1 Economic Analysis

The investment cost for per fish (%) is presented in Table 1 for seven marine hatchery facilities. To evaluate the investment cost, the building/office, system/pond/cage, installations/infrastructure and processing/storage outgoings are taken into consideration. It is seen that the total investment cost for per fish varies from 4.02% to 35.08%. The lowest investment cost occurs for facility II which the processing/storage is 0.00% and installations/infrastructure is 2.95% which it is the highest expense for facility II. The highest investment cost is obtained for facility VI which the system/pond/cage expenditure is 15.03% and the installations/infrastructure is

%12.53. Although, the building/office and the processing/storage are 0.00% for facility V, the investment cost for per fish performs as 25.39%. When the facility V and VI compared with the other facilities it is seen that the investment cost for per fish (%) is too high. Also, it is observed that the building/office expenditure has the lowest ratio while the installations/infrastructure expense has the highest ratio inside of the investment costs when the seven facilities are taken into consideration.

Table 1. Investment cost for per fish (%)

	Akvatek *I*	*Teknomar* *II*	*İda Gıda* *III*	*Egemar* *IV*	*Serçin* *V*	*Çamlıyem* *VI*	*Kılıç* *VII*
	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish
Building /Office	0,45	0,71	0,60	0,51	0,00	2,51	0,29
System /pond/cage	1,94	0,36	2,62	2,23	5,08	15,03	1,75
Installations /Infrastructure	2,98	2,95	4,03	3,43	20,31	5,01	0,59
Processing /Storage	0,30	0,00	0,40	0,34	0,00	12,53	1,46
Total	**5,67**	**4,02**	**7,65**	**6,51**	**25,39**	**35,08**	**4,09**

Table 2 shows the operating cost for per fish (%) for seven Turkish marine hatchery facilities. The outgoings of feed, labor, energy, fuel, drinkable water, oxygen, insurance, fees, medication and other costs are considered to determine the operating cost for per fish (%). It is observed that the total operating cost for per fish (%) changes between 15.90% and 92.19% when the seven facilities are taken into consideration. It is seen that the lowest operating cost takes place for facility II which the fuel is 7.43% as maximum outgoings of operating cost for per fish (%). The highest operating cost for per fish (%) is obtained for facility I which the fuel is 24.49% as maximum expenditure of operating cost and also labor and feed outgoings are 23.81% and 16.67%, respectively. It seems that the feed expenditure has the highest ration inside of operating cost as the seven facilities are considered. Also, labor, fuel and energy outgoings have high ratio inside of operating cost for per fish. However, it is concluded that when the facility has suitable water resource with regard to temperature for production, the fuel outgoings, which it has an important ratio of operating cost, disappears. It is observed that the lowest operating cost is insurance and only a facility spends as 0.07% of operating cost for insurance.

Table 2. Operating cost for per fish (%)

	Akvatek *I*	*Teknomar* *II*	*İda Gıda* *III*	*Egemar* *IV*	*Serçin* *V*	*Çamlıyem* *VI*	*Kılıç* *VII*
	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish	cost share % per fish
Feed	16,67	2,65	7,67	16,00	8,89	17,58	8,77
Labor	23,81	2,65	15,89	8,00	7,56	2,42	5,85
Energy	12,24	1,54	3,73	2,67	4,32	3,14	0,71
Fuel	24,49	7,43	3,78	0,00	2,04	0,00	0,00
Drinkable Water	0,85	0,08	0,00	0,00	0,05	0,00	0,02
Oxygen	2,23	0,26	0,98	0,64	2,53	0,12	3,33
Insurance	0,00	0,00	0,00	0,00	0,00	0,00	0,07
Fees	0,00	1,10	0,10	0,00	2,59	1,18	0,01
Medication	1,70	0,18	1,11	1,14	5,07	0,05	0,23
Other costs	10,21	0,00	11,11	4,57	0,00	0,00	0,00
Total	**92,19**	**15,90**	**44,36**	**33,03**	**33,04**	**24,49**	**18,99**

The distribution of incomes and outcomes for seven Turkish marine hatchery facilities is given in Table 3. While the investment cost changes between 95.000 € (facility I) and 3.990.000 € (facility VI) the operating cost varies from 516.000 € (facility II) to 3.247.850 € (facility VII). It is seen that the operating cost is higher than the investment cost except facility VI which the ratio of investment cost is 58.9% while the ratio of operating cost is 41.9%. Also, the total cost changes between 646.140 € (facility II) and 6.776.000 € (facility VI). It seems that the total income varies from 1.680.000 € (facility I) to 17.100.000 € (facility VII) and the total incomes are higher than the total outcomes for all seven facilities. The total incomes given by Eq. (23) have been calculated by multiplying the production amount of species shown in Table 4 with the price of egg, larvae and market size given in Table 5. However, it is seen that the profit of the facilities changes between 36.158 € (facility I) and 13.152.150 € (facility VII) while the ratio of total outcomes to total incomes varies from 22.0% (facility II) to 97.28% (facility I). Also, the ratio of total outcomes to incomes is 23.1%, 38.4%, 52.0%, 59.1% and 61.1% for facilities VII, IV, III, VI an V, respectively.

Table 3. Distribution of incomes and outcomes for facilities.

		Akvatek I	*Teknomar II*	*İda Gıda III*	*Egemar IV*	*Serçin V*	*Çamlıyem VI*	*Kılıç VII*
Investment Cost	€	95.000	129.500	137.750	285.000	571.250	3.990.000	700.000
	%	5,8	20,0	14,7	16,5	43,5	58,9	17,7
Operating Cost	€	1.548.842	516.640	798.434	1.445.015	743.362	2.786.000	3.247.850
	%	94,2	80,0	85,3	83,5	56,5	41,1	82,3
Total Cost	€	1.643.842	646.140	936.184	1.730.015	1.314.612	6.776.000	3.947.850
Total Income	€	1.680.000	2.938.750	1.800.000	4.500.000	2.150.000	11.463.360	17.100.000
Profit	€	36.158	2.292.610	863.816	2.769.985	835.388	4.687.360	13.152.150
	%	2,2	78,0	48,0	61,6	38,9	40,9	76,9
Total Cost/ Total Income	%	97,8	22,0	52,0	38,4	61,1	59,1	23,1

Table 4 presents the production of the species for seven facilities. As shown in Table 4, ten species as sea bream, sea bass, common dentex, puntazzo, two banded sea bream, common sea bream, corb, blue spotted sea bream, mearge and white grouper are produced by seven facilities. Almost %96 of Turkish marine hatchery production is sea bass and sea bream (Table 4). The sea bass is the highest produced specie as 119.800.000 larvae/year and it is produced by all facilities. Also, the sea bream is produced by all facilities except facility III as 88.950.000 larvae/year. It is seen that the facility II produces seven different species as 7.600.000 larvae and 200 kg eggs in year 2007. The facility IV grows six different species as 25.000.000 larvae/year while the facility VI produces three species which are sea bream, sea bass and puntazzo as 60.000.000 larvae and 240.000 kg market size fish in year 2007. The facility VII producing sea bream and sea bass has the highest production capacity as 90.000.000 larvae in 2007. The total larvae production capacity of fifteen Turkish marine hatcheries is 348.000.000 (Okumuş and Deniz, 2007) while the total production capacity of the seven facilities is 214.100.000 in 2007.

Table 4. Production amount of species for facilities.

Species	*Akvatek I*	*Teknomar II*	*İda Gıda III*	*Egemar IV*	*Serçin V*	*Çamlıyem VI*	**Kılıç VII**
	larvae/year kg/year	larvae/year kg/year	larvae/year kg/year	larvae/year kg/year	larvae/year kg/year	larvae/year kg/year	larvae/year kg/year
Sea bream	6.000.000 -	3.750.000 -	- -	10.000.000 -	5.000.000 -	19.200.000 76.800	45.000.000 -
Sea bass	2.000.000 -	3.000.000 -	12.000.000 -	10.000.000 -	10.000.000 -	37.800.000 151.200	45.000.000 -
Common dentex	- -	200.000 -	- -	- -	- -	- -	- -
Puntazzo	- -	200.000 -	- -	- -	- -	3.000.000 12.000	- -
Two banded sea bream	- -	150.000 -	- -	- -	- -	- -	- -
Common sea	-	150.000	-	-	-	-	-

bream	-	-	-	-	-	-	-
Corb	-	100.000	-	1.500.000	-	-	-
	-	-	-	-	-	-	-
Blue spotted sea bream	-	50.000	-	-	-	-	-
	-	-	-	-	-	-	-
Mearge	-	-	-	2.500.000	-	-	-
	-	-	-	-	-	-	-
White grouper	-	-	-	1.000.000	-	-	-
	-	-	-	-	-	-	-
Egg	-	-	-	-	-	-	-
	-	200	-	-	-	-	-

Table 5 shows the price of larvae, egg and market size for per kg each facility and specie. It is seen that the prices of sea bream, sea bass, puntazzo and corb change depending on facilities. The facility V has the lowest price for sea bream and sea bass, which sea bream and sea bass have the highest production capacity as 208.750.000 larvae/year, while the facility I and facility VII have the highest price for sea bream and sea bass, respectively. Also, it is observed that the each facility producing larvae apart from sea bream and sea bass has the same price for all species but the price of each specie changes depending on facility.

Table 5. The price of egg, larvae and market size.

Species	*Akvatek I*	*Teknomar II*	*İda Gıda III*	*Egemar IV*	*Serçin V*	*Çamlıyem VI*	**Kılıç VII**
	larvae/€	larvae/€	larva /€	larvae/€	larvae/€	larvae/€	larvae/€
	kg/€	kg/€	kg/€	kg/€	kg/€	kg/€	kg/€
Sea bream	0,225	0,22	-	0,20	0,17	0,19	0,20
	-	-	-	-	-	4	-
Sea bass	0,165	0,16	0,15	0,15	0,13	0,16	0,18
	-	-	-	-	-	4,3	-
Common dentex	-	0,275	-	-	-	-	-
	-	-	-	-	-	-	-
Puntazzo	-	0,275	-	-	-	0,25	-
	-	-	-	-	-	5	-
Two banded sea bream	-	0,275	-	-	-	-	-
	-	-	-	-	-	-	-
Common sea bream	-	0,275	-	-	-	-	-
	-	-	-	-	-	-	-
Corb	-	0,275	-	0,20	-	-	-
	-	-	-	-	-	-	-
Blue spotted sea bream	-	0,275	-	-	-	-	-
	-	-	-	-	-	-	-
Mearge	-	-	-	0,20	-	-	-
	-	-	-	-	-	-	-
White grouper	-	-	-	0,20	-	-	-
	-	-	-	-	-	-	-
Egg cost (kg/€)	-	7000	-	-	-	-	-

11.4.2 Sustainability

There have been many definitions of sustainable development. One of the most widely quoted and agreed is: *"Development that meets the needs of the present without compromising the ability of future generations to meet their own need"* (GESAMP Report, 2001). Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (GESAMP Report, 2001). Phillips et al. (2001) argued that sustainability could be split into three separate components: social sustainability, economic sustainability and environmental sustainability.

The production capacity (in m^3), land usage, production systems and production type which are important for sustainability of Turkish marine hatcheries are given in Table 6. The total production capacity varies between 4.210 (facility III) and 21.635 (facility VII) larvae/m^3. When the production capacity (in m^3) increases high production can be obtained in small tank volumes. This is very important for facilities which have land constrain. The areas of fish farms change from 5.500 (facility IV) to 100.000 m^2 (facility VII) on land and only facility VI has 460.000 m^2 on the sea, which this facility produces sea bream, sea bass and puntazzo as market size. Because the aquaculture sector conflicts with tourism and construction sectors, the land problem will be important in near future. The marine fish hatcheries have become intense in Muğla, Aydın and İzmir located in the Ege Region. However, same region is densely used for summer sea tourism. The social, cultural and economical expectations of allocation units from tourism are considerably high in this region. The tourism sector assuming the economic center of this century employ the media against to other sectors especially aquaculture sector. Therefore, there are serious conflicts between aquaculture sector and tourism and other sectors expecting income.

It is seems that the land problem has a negative effect on the sustainability of Turkish marine hatcheries. Also, the environmental problems restrain the aquaculture sector. Recent years, approaches relating with the protection of environment negatively affect the aquaculture sector. Especially, the marine fish production cage systems installed near the costal zone and assumed that they have negative effects on the biological environment have to be transferred to the open sea which the environmental interaction is lower than the costal zone. So, fully-controlled and environment- friendly aquaculture systems should be preferred by producer and supported by the government. It is observed that closed, semi-closed, open, earth pond and off-shore production systems are used in Turkish aquaculture sector. Recirculation aquaculture systems (closed) can be used where suitable land or water is limited, or where environmental conditions are not ideal for the species being cultured (Hutchinson et al., 2004). Also, the RAS reduces the cost of water heating or cooling and labor requirements, and improves the feed conversion rate. However, the RAS requires high operation and initial investment costs and highly qualified technicians. In this regard, the advantages of the RAS can be enumerated as follows (Hutchinson et al., 2004): All aspects of the production environment may be controlled to achieve the optimum growth; low water consumption per tone of fish produced; impact on the external environment minimized by containing and treating wastewater; the production facility can be operational all year round. In fact, recirculating aquaculture systems represent relatively new technology with a wide variation in system design and quality available. It is seen that the closed system will be important for sustainability of Turkish marine hatcheries in near future. Semi-closed and closed systems are used for marine fish larvae production in Turkey. However, because of the high investment and operating costs and low cost production systems such as cages and earth pond supplied salty-underground water, the recirculating aquaculture systems (RAS) have not been used for market size fish production yet. As seen in Table 6, four facilities (facility I, facility II, facility IV, facility VI and facility VII) use recirculation aquaculture system. Semi-closed and open production systems are usually used in Turkish marine hatcheries (see Table 6). However, earth pond and off-shore production systems are rarely used in Turkish marine hatcheries (see Table 6). Also, production type is important for the sustainability of Turkish marine hatcheries. Only one facility (facility VI) uses all production type (broods, eggs, larvae and market size) (see Table 6). Facility I, facility II, facility IV and facility VII produce broods, eggs and larvae. While the facility III obtains the eggs from broods gathered from nature, the facility V provides from other facilities. The point of view sustainability, the generation of species should be prevented. For this purpose, the broods used for production should be possibly provided from nature. If the hatchery-based broods use for production the healthy broods should be selected. It can be said that to produce different species is another important factor for sustainability of Turkish marine hatcheries. To produce different species provide different tastes and alternatives to the consumer and thus farmers reach to the different markets. As seen in Table 5, facility II, facility IV and facility VI produce eight species (sea bream, sea bass, common dentex, puntazzo, two banded sea bream, common sea bream, corb and blue spotted sea bream), five species (sea bream, sea bass, corb, mearge and white grouper) and three species (sea bream, sea bass and puntazzo), respectively. However, it is important to get eggs during the year for sustainability of aquaculture sector. As seen in Table 5, Facility III has constrains to get eggs during the year. The fully controlled systems (RAS) can be used as wide spread season reproduction performance and for best quality and quantity production.

Table 6. Production capacity, land usage, production systems and production type

	I	*II*	*III*	*IV*	*V*	*VI*	**VII**
Total capacities of production (in m^3)	8.800	13.636	4.210	6.493	7.800	12.900	21.635
Fish Farm Area (m^2)	6.000	12.000	14.000	5.500	20.000	25.000 on land 460.000 on sea	100.000
Tank Volume (m^3)	Total 2.336 1.136 in use	550	Total 5.250 2.850 in use	3465	1.920	4.650	4.160
Building or specialized installation (m^2)	5.400	4.000	5.000	3850	2.860	15.000	20.000
Closed	Yes	Yes	No	Yes	No	Yes	Yes
Semi-closed	Yes	Yes	Yes	Yes	No	Yes	Yes
Open	Yes	No	No	Yes	Yes	Yes	Yes
Earth pond	No	No	No	No	No	No	Yes
Off-shore	No	No	No	No	No	Yes	No
Broods	Yes	Yes	No	Yes	No	Yes	Yes
Eggs	Yes	Yes	Yes	Yes	No	Yes	Yes
Larvae	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market size	No	No	No	No	No	Yes	No

The main constrains of the Turkish marine hatcheries given in Table 7 were determined with a questionnaire study by face to face interviews with farmers and experts. As seen in Table 7, water and land problem are the most constrains for the Turkish marine hatcheries. When the water quality and quantity are not suitable for a specie it is necessary the treatment of the water. This is achieved by mechanical filter used to remove the solid particles, by biological filter used to achieve the biological filtration process, by heating and cooling systems used to provide suitable temperature for species and by UV system used for disease control. The recirculating aquaculture system, which has high investment and operating costs, is used for this purpose. Moreover, to find qualified employee is another constrain of the Turkish marine hatcheries according to the farmers and experts.

Table 7. The main constrains of Turkish marine hatcheries

	I	*II*	*III*	*IV*	*V*	*VI*	*VII*
Water (Quality, Quantity)	High	High	Less	High	No	No	No
Land	Little	High	Less	High	No	High	No
Knowledge About The Species/Technical Aspects	No	No	Middle	No	No	No	No
Availability/ Quality Of Fie	No	Less	High, We couldn't get eggs in September	No	Middle, Brodstock management and spawning are done another hatchery	No	No
The Market	No	No	No	No	No	No	No
The Capital	No	No	High	No	No	No	No
Rights Of Production	No	No	No	Less	Little	High, (sea surface renting is so high)	No
To Find Employees	No	High	High	Middle	Middle	High	No
Administrative Rules	No	Middle	No	No	No	No	No
Competition With Other Activities (To Be Specified)	No	No	No	No	No	No	No
Financial Inputs	No	No	Middle	No	No	No	No

Facilities I and II have been established Çandarlı Gulf in the north of İzmir. The Çandarlı Gulf has been fed by middle size rivers transferring the alluvium to the Gulf. Also, Çandarlı Gulf is environmentally under threat because of petro chemistry and ship recycling industries installed in the south of Gulf. Facility I, which it has open, semi-closed and closed production systems, is highly affected by the negative environmental variation of Çandarlı Gulf. Also, this facility directly discharges the waste water of the system to the Gulf. The point of view sustainability, this kind of facilities has disadvantages because of irregular flow chart, environmental effects and high operating cost. Facility II intensively uses closed system, so the water provided from the Çandarlı Gulf is so limited. Thus, facility II is slightly affected by the negative environmental variation of the Gulf. This facility has limited land and uses high ratio of land, so this is a negative effect the point of view sustainability. When the technological applications are taken into account this facility has more advantage than other facilities. Facility III is established in Anatolian side of the Dardanelles and the water is directly provided from the Dardanelles by pump. Although, the facility has advantage because it has focused only production of sea bass, it is important to add new species, having economic value, to the production the point of view sustainability. Facility IV has disadvantages such as quality and quantity of water and land and advantages such as five species production and technological applications the point of view sustainability. Facility V and facility VII have used the salty-underground water and used water has been directly discharged to the Bafa Lake. In the short time period, it can be seen that this kind of facilities has advantages but in long time period they have disadvantages such as environmental and ecological. If the facilities don't use discharge water treatment and completely recirculating aquaculture systems, they will come across with environmental reactions. The advantages of the facility VII are that it has research and development unit and integrated facility. These advantages are more important for the sustainability of facility VII. But the floating and water discharge and land problems are the most disadvantages of the facility. Facility VI has the highest production type such as broods, eggs, larvae and market size and RAS has been used for broods stocking and eggs and larvae production. The most important advantage of the facility is that it has hatcheries, cages production and feed production and fish processing factories. The discharge water has been directly transferred to the sea medium. At the moment, there are no pollution sources and this can be seen as an advantage but the bay, which the facility is installed, is near the tourism region and is open the tourism investments. The facility can come across with tourism sector near future or future because of waste water transferring to the sea. Nevertheless, it seems that this facility has the most advantages among the all facilities because of location and structure.
The below remarks were obtained face to face interviews with farmers and experts:

- ✓ 86% of the facilities exchange information with universities, institutions and experts relating with the aquaculture,
- ✓ 57% of the facilities belong to one or several professional organizations such as Aquaculture Federation, Aquaculture Union, Aquaculture Association, Chamber of Agriculture
- ✓ 71% of the facilities have own Research and Development Unit or collaborations with the Universities for Research and Development
- ✓ 57 % of facilities don't have head or local representative
- ✓ All facilities have been controlled by Ministry of Aquaculture and Rural Affairs, Ministry of Environment and Forestry and Local Administrations
- ✓ According to the 43% of the facilities, the aquaculture sector has not been strictly controlled when it is compared to other sectors and there is no auto control into the aquaculture sector.
- ✓ 86% of the facilities think that local policies affects to the aquaculture sector via restrictions relating with waste management, tourism and environment subjects.
- ✓ According to the facilities, some regulations relating with aquaculture should be introduced such as: Bureaucracy must be decreased, potential aquaculture places must be previously determined, government should be pathfinder and neutral among the all sectors, Ministerial Units relating with the aquaculture must be collect under a Unit, Aquaculture Unions should be effective and authorized, auto control should be provided into the aquaculture sector and the public should be informed about aquaculture.
- ✓ The facilities fear from the laws, which is becoming stricter, relating with the pollution, water uses, market, impacts on biodiversity and work contracts
- ✓ According to the facilities, increasing of the quality standards on the production, objective arrangement among the sectors, scientific investigation of the all invest projects about aquaculture sector, supporting of the cage production systems and widespreading of processing facilities will develop their activities.
- ✓ All facilities agree on that upgrading of the quality standards will increase their incomes and rate of market.

- ✓ The facilities estimate that the farms with high technology and high capacity, RAS, any marketing size fish production models, cage production, new species production and processing will be valuable in future.

11.5 Conclusion

The economic analysis of 7 leader marine fish hatcheries was performed and sustainability of Turkish marine hatcheries was evaluated. The ratio of total cost to total income changed between 22% and 97.8%. The production capacity (in m^3), land usage because of the serious conflicts between aquaculture sector and tourism and other sectors using the same site, production systems, production type and environmental problems are important for sustainability of Turkish marine hatcheries. Although the RAS requires high operation and initial investment costs and highly qualified technicians, it is seen that it will be very important for sustainability of Turkish marine hatcheries because of land, quality and quantity of water and environmental problems.

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The influence of macro-economic factors on production and consumption of aquatic products in the world was evaluated. World aquaculture production and its growth were analyzed in terms of commodities, species, countries and regions. Special attention was given to interpreting the consequences of the results obtained on policy and planning of future aquaculture development.