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Feasibility case study in Belarus on the feasibility of Danish recirculation technology

Peder Nielsen, Martti Naukkarinen, Armands Roze, Nikolai Barulin and Alfred Jokumsen

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Description

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Title Feasibility case study in Belarus on the feasibility of Danish recirculation technology		
Year 2014	**Pages** 39 + appendixes	**ISBN** 978-952-303-091-6
Abstract The overall objective of the feasibility study was to investigate the feasibility and the possibility of developing the aquaculture production under the given circumstances in Belarus. This by implementing technologies known from the Danish model fish farm concept for recirculation aquaculture systems (RAS). The case study was also partly performed to test the feasibility study guidelines, published as part of the Aquabest project (Nielsen et al. 2014). In Belarus the development of the fish farming sector is much dependent on state programs, i.e. five year plans as a guideline for expansion of the sector. There might be a huge potential for increased aquaculture production in Belarus by implementing modern fish farm technology, although certain risk factors have been identified. These include investments costs, production costs, sales prices, management etc. However, succesful implementation of the technologies requires establishment of formalized education and training of personnel at all farms using the recirculation aquaculture technology.		
Keywords Feasibility, Recirculation Aquaculture Systems (RAS), Model Fish farm, Education, Training, Environmentally friendly fish production, Jobs, Fish Processing		
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Additional information Front page: Feasibility study delegation at Belarus State Agricultural Academy, Gorki, Belarus		

Contents

1. Background for the study

Aquaculture has been the fastest growing food production sector globally for decades (FAO, 2012) due to the growing demand for fish products for human consumption and protection and quotas on wild fish stocks. However, opposite to the global trend, aquaculture production in the Baltic Sea Region has stagnated. It is widely accepted that aquaculture has great potential to feed the growing human population in the area of declining wild stocks ("Blue Revolution"), but new production has to be built on sustainable practices and technologies.

The European Union has identified this challenge and has adopted aquaculture as a flagship project in the EU strategy for the Baltic Sea Region. The Baltic Sea Region Programme 2007-2013 funds projects contributing to the implementation of the EUSBSR. Aquabest, a project of 14 partners from 8 countries, was selected for funding by The Baltic Sea Region Programme 2007-2013.

This feasibility study has been conducted to rationally evaluate strengths and weaknesses of a business opportunity to introduce and transfer the Danish concept of recirculation aquaculture technologies to Belarus and subsequently to other regions in the Baltic Sea Region (BSR). It is also a field test for Aquabest feasibility study guidelines (Nielsen et al. 2014).

The overall objective of the feasibility study has been to investigate the feasibility and the possibility of developing the aquaculture production under the given circumstances in Belarus, by implementing technologies known from the Danish model fish farm concept for recirculation aquaculture systems (RAS).

The specific objectives are:
- To estimate the demand for new technology in Belarus subsequently in the BSR region.
- To create an overview of the production costs in relation to the market requirements.
- To make an overview of the technology level of the sector, educational skills and experience in aquaculture, in Belarus.
- To identify any critical risk factors, which have to be monitored and/or mitigated.

2. Introduction to the country/region

2.1. Geography and population structure of Belarus

Belarus is situated in Eastern Europe, with borders to Russia, Ukraine, Lithuania, Latvia and Poland. Belarus occupies an area of 207,600 km^2 and stretches 560 km from north to south, and 650 km from east to west. Some main data on population is provided in the Tables 1-3, and in Figure 1.

2.2. Geographical conditions

Overall Belarus is a flat country. The highest point is Mount Dzyarzhynskaya in Minsk region with an altitude of 345 m above sea level. The lowest point is the Neman Lowland in Hrodna region on the border to Lithuania with an altitude of 80 – 90 m above sea level. In Belarus there are 20 800 rivers and about 11 000 lakes. Most of the lakes are found in the north and north-western regions. The main basins of rivers are Dzapadnaja Dvina, Dnepr, Neman and Pripjat (Figure 2).

Soil in Belarus is characterized by different pod sol soils. Under the surface layer sand and fine sand is common. Finer soils like clays exist too in some areas. 25% is peat covered swamp located mainly in Minsk, Brest and Homel regions.

Non – renewable resources of Belarus includes rich deposits of potash salt and salt rock. Further chalk and marl deposits are among the largest in Europe and most demanded by concessioners. Natural resources also include pitch coal, iron ore and peat deposits.

The groundwater resources are well known. There are big aquifers with documented potential quantity and quality. 95% of municipal and industrial water is underground water. Soil profiles are documented and pointed in maps and can be used for preliminary evaluations. There are a number of boreholes around the country that are under surveillance with a lot of information about water quality and the function of the borehole.

2.3. Infrastructure and access to markets

The infrastructure is well established. The bigger roads have very high standard and the main roads are also in fair condition. Normal electricity in houses is 220V and the 3-phase current 360V.

The total aquaculture production was in 2012 approx. 16 000 tons, corresponding to approx. 1.6 kg/cap/year. Belarus is divided into six different administrational regions and the pond fish farmers who produce mainly carp are allowed to sell their production only inside the region where they are located or to export. This is not the practice for trout, sturgeon, catfish and white fish production. There has been in recent years some export of live fish to Russia, Lithuania, Latvia, Poland and other countries.

In all Belarus there are six fish processing factories, with a future plan of establishing three new ones. Farmed trout has been sold alive from certain supermarkets and directly from tanks on market places. This is not any more possible. When the programs to increase production of farmed trout etc. becomes a reality, it will be necessary to have plants to gut the fish and pack it in isolated Styrofoam boxes with ice. This way it is possible to deliver the bigger amounts of farmed trout to consumption.

Existing fish processing plants are to be modernized and new plants will be constructed following the five year plan 2011-2015. For further information see Chapter 3 and Appendix 3. Market chain through the processors might become significant if the size of produced fish meets the demand of processors.

2.4. Climate, temperatures and precipitation

Belarus has temperate continental climate, mild moist winters and warm summers. The temperate continental climate is formed under influence of air masses from the Atlantic, and is characterized by a rainy unstable summer and a mild winter with frequent thaw periods.

The average air temperature in Belarus (1981 – 2010) was from 5.7 ºC in Gorki and Orsha to 8.2 ºC in Brest. During winter the air may be warmed up to – 5 to – 7 ºC in the daytime and cooled down to – 11 to – 13 ºC during the night. During summer the daytime temperature may be about + 21 - + 23 ºC and at night – about +11 - +13 ºC.

The southern and south western areas of Belarus are the warmest of the country. Within the last 30 years the annual average temperature has increased by 1 ºC. Further temperature fluctuations and amplitudes have increased and extreme weather conditions are becoming more common. Ref.(http://www.pogoda.by/). Precipitation is 500 - 700 mm per year.

Table 1. Size and development of population structure 1996 – 2013 (http://belstat.gov.by/homep/en/indicators/population.php)

	1996	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Population size (beginning of year) [1], thous. persons	10 177	9 957	9 900	9 831	9 763	9 697	9 630	9 579	9 542	9 514	9 500	9 481	9 465	9 464
of which:														
male	4 767	4 668	4 638	4 600	4 562	4 526	4 489	4 461	4 440	4 426	4 418	4 408	4 398	4 398
female	5 410	5 289	5 262	5 231	5 201	5 171	5 141	5 118	5 102	5 088	5 082	5 073	5 067	5 066
Share in total population, percent														
urban	68,1	70,1	70,5	70,9	71,4	71,8	72,2	72,7	73,2	73,9	74,5	75,1	75,8	76,3
rural	31,9	29,9	29,5	29,1	28,6	28,2	27,8	27,3	26,8	26,1	25,5	24,9	24,2	23,7
Natural increase, decrease (-) of population, thsd. persons	-37,6	-48,6	-57,9	-54,7	-51,1	-51,4	-41,7	-29,4	-26,0	-25,8	-29,1	-25,9	-10,6	…

Table 2. Life expectancy at birth of the population http://belstat.gov.by/homep/en/indicators/population.php)

	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total population	68,6	69,0	68,5	68,0	68,5	69,0	68,8	69,4	70,3	70,5	70,5	70,4	70,6	72,2
men	62,9	63,4	62,8	62,3	62,7	63,2	62,9	63,6	64,5	64,7	64,7	64,6	64,7	66,6
women	74,3	74,7	74,5	74,1	74,7	75,0	75,1	75,5	76,2	76,5	76,4	76,5	76,7	77,6
Urban population	69,3	70,0	69,8	69,4	70,1	70,6	70,5	71,0	71,8	71,9	72,1	72,1	72,2	73,5
men	63,8	64,6	64,3	63,9	64,4	65,0	64,9	65,3	66,2	66,3	66,5	66,4	66,4	68,0
women	74,6	75,4	75,3	75,1	75,7	75,9	76,1	76,5	77,1	77,3	77,3	77,6	77,8	78,5
Rural population	66,6	66,1	65,2	64,4	64,7	65,0	64,5	65,3	66,4	66,6	66,4	66,1	66,4	68,4
men	60,6	60,4	59,2	58,5	58,6	59,0	58,2	59,2	60,3	60,4	60,3	60,1	60,3	62,7
women	73,2	72,9	72,6	71,9	72,5	72,6	72,7	73,0	73,9	74,4	73,9	73,8	74,1	75,3

Table 3. The total average monthly salary 2012 in USD (http://belstat.gov.by/homep/ru/indicators/wages.php).

	Республика Беларусь
Total	431,4
Agriculture, hunting and forestry	319,4
FISHING, FISH FARMING	**320,0**
Industrial	487,1
mining	645,4
manufacturing	491,8
production and the distribution of electricity, gas and water	432,8
Construction	504,7
Trade, repair of vehicles, household goods and personal items	404,5
Hotels and restaurants	307,1
Transport and communications	487,2
Financing activities	706,0
Real estate, renting and business customers	518,0
Research and development	565,1
Education	319,4
Health care and social services	345,7
Community, social and personal services	345,6
Activities, recreation and entertainment, culture and sport	352,3

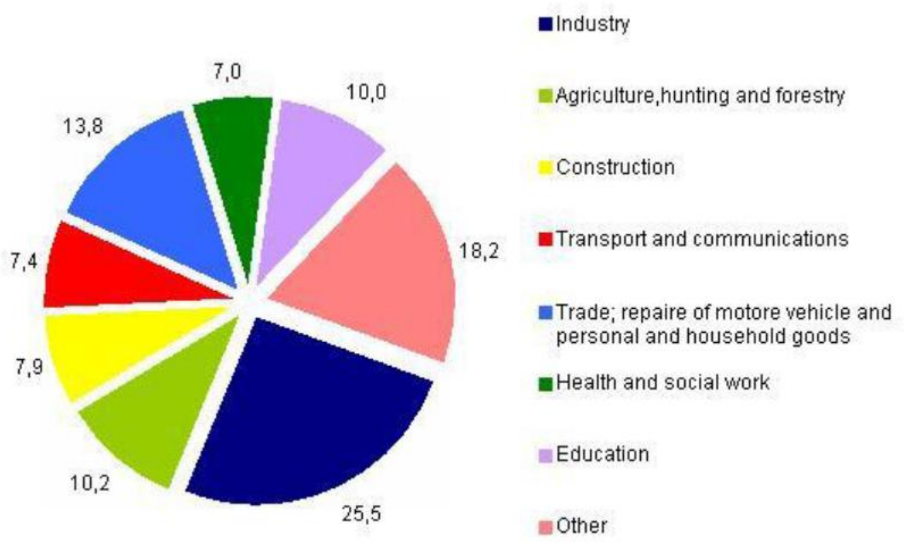


Figure 1. Employment by economic activities in 2012 (http://belstat.gov.by/homep/en/indicators/labor.php).

Figure 2. Basins of the biggest rivers: Neman, Daugava and Tsap Bug.

3. Current relevant policies and legislation

3.1. Policies and legislation

Aquaculture in the Republic of Belarus is not a licensable type of activity. The primary laws mentioned are administrated within the six regions in the Republic of Belarus. These regions are: Homel region, Vitebsk region, Minsk region, Brest region, Magileu region and Hrodna region. Each area covers an area of about 30.000 – 40.000 km^2. Further information is given in Appendix 1 and 2.

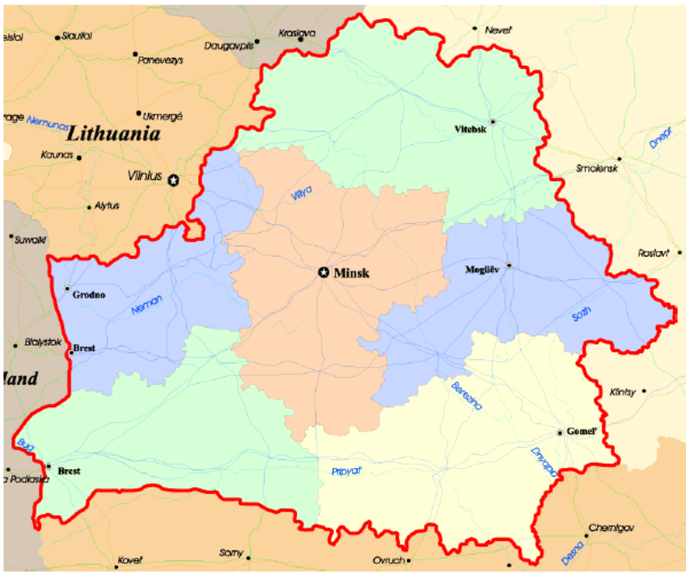


Figure 3. Six administrative regions of Republic of Belarus.

3.2. Government and sector policies

Present status of aquaculture in Belarus is that most of the produced fish are cultured in ponds, some in net cages placed in rivers, lakes, water storage basins etc. and only a minor production is taking place in RAS systems.

In 2010 the production of market size fish was 15 214 ton, increasing in 2011 to 18 125 ton. It is planned to increase the production up to 25 000 tons in 2015, including 3 900 tons of trout, sturgeon and European catfish (which are in the five year plan called “valuable fish” species because of their taste and higher price). Only 100 tons of “valuable fish”, was produced in 2010.

The production of Salmonids is mainly in the northern region of Belarus, while the production of catfish and sturgeon is mainly taking place in the southern part. Industrial farming of especially high value species (catfish, sturgeon and Salmonids) in RAS systems began in Belarus in the late 1980s. However due to lack of information about design and management of RAS systems there has been a decrease in the productions since the mid-90s. In addition to the production of catfish, Salmonids and sturgeon, which only constitutes a minor part of the annual total production in Belarus, the following species are produced: common carp (85% of total production), bighead carp, grass carp, rainbow trout, pikeperch, bester, paddlefish, beluga, pike, crucian carp, silver carp, peled, sharptooth catfish, tench, Lena sturgeon, starlet, European catfish, golden carp, and channel catfish. Some production data is presented in Figures 4-6.

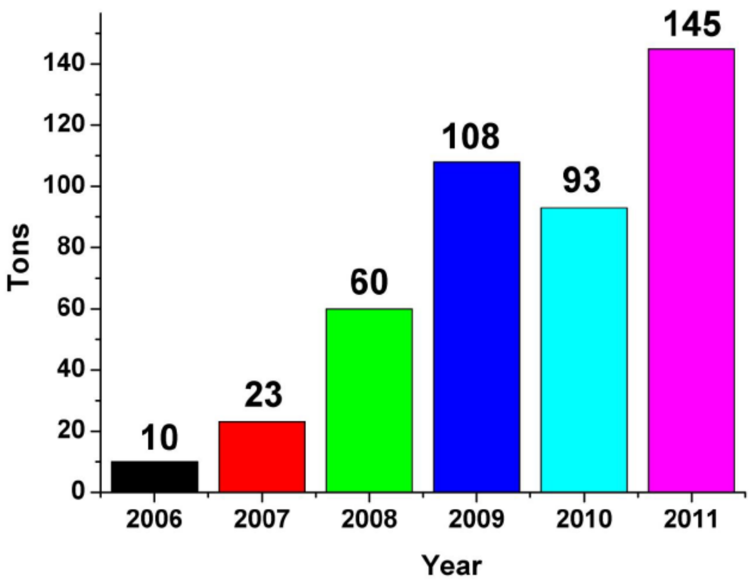


Figure 4. The realized production of catfish, sturgeon and trout from 2006 – 2011.

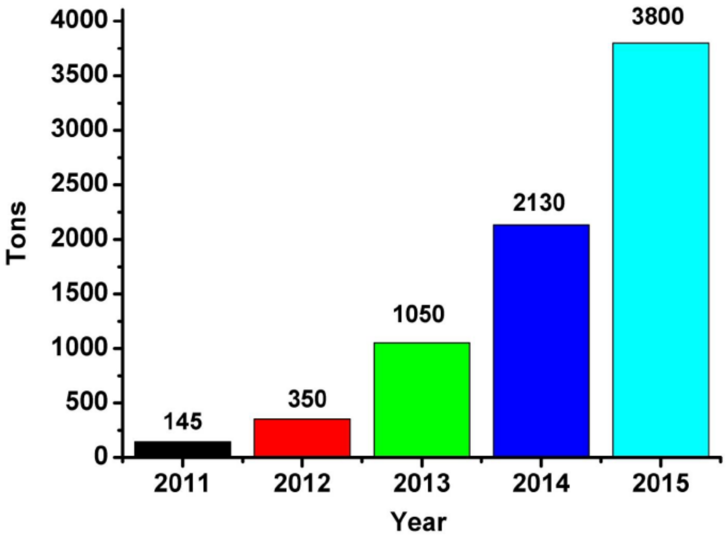


Figure 5. The planned production of trout, catfish, sturgeon towards 2015.

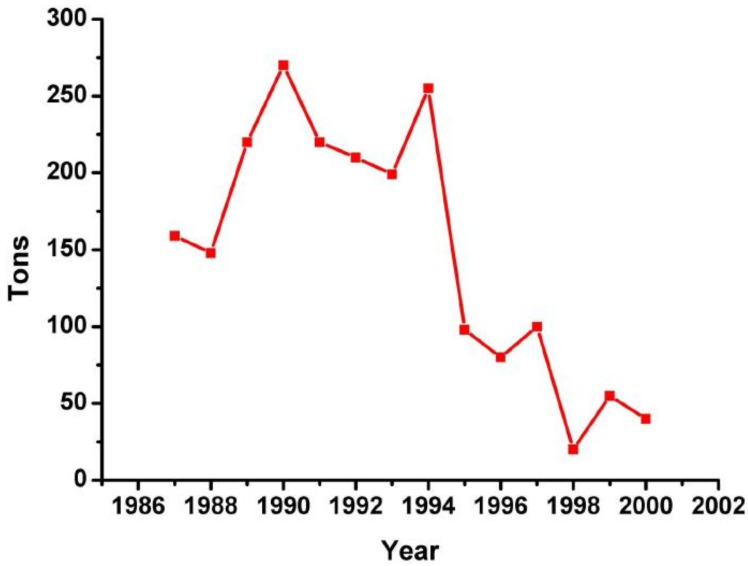
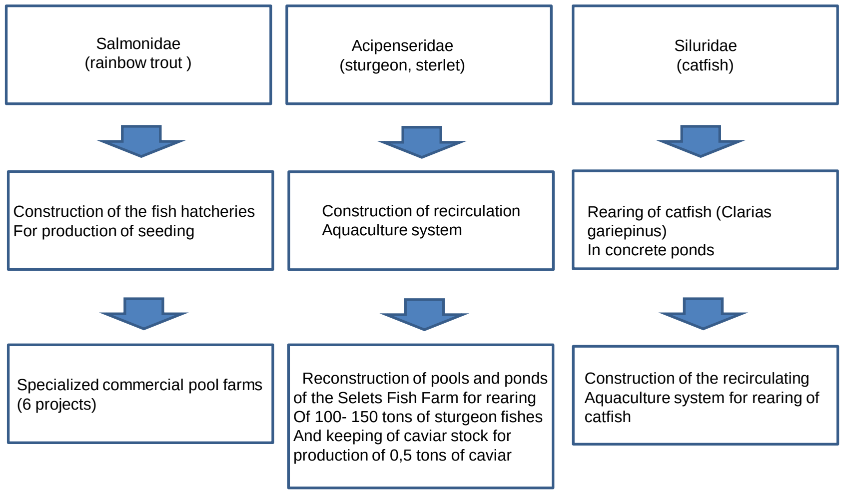


Figure 6. Production in RAS systems.

3.3. State plan for expansion of commercial fisheries activity

By initiative of the President of the Republic of Belarus in 2011 a state plan for expansion of commercial fisheries activity for the period 2011 – 2015 was approved by the Council of ministers. The top priority is introduction of industrial fish breeding, or aquaculture, using the state of the art intensive technology. The main aspects of the state program on the development of industrial fish breeding are presented in Figure 7. The state program includes scientific questions and until now results presented in Figure 8 have been achieved.



Souce: Department of Land Improvement and Water Economy

Figure 7. Target fish species for aquaculture development according to the state program.

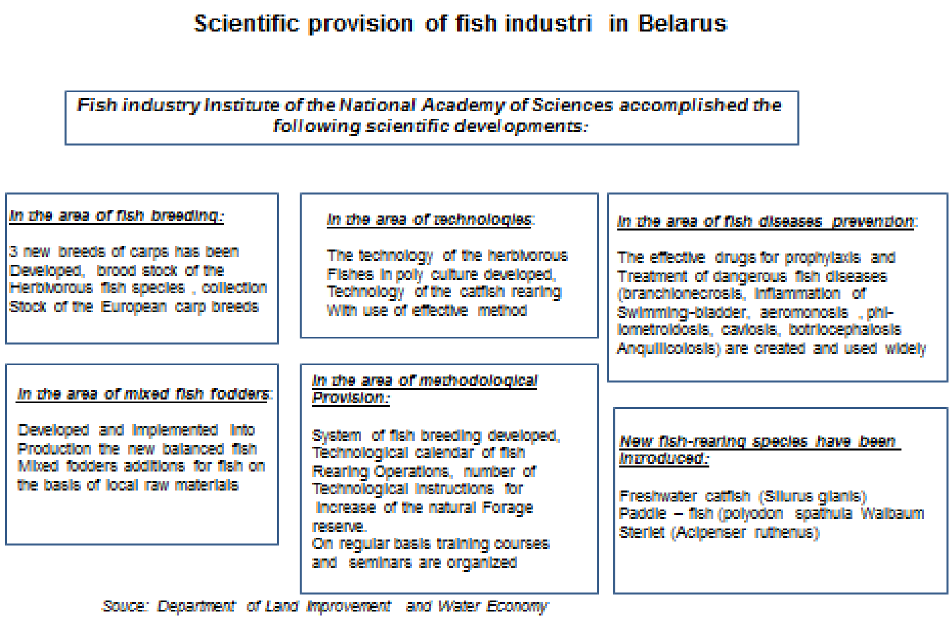


Figure 8. Current achievements in aquaculture research in Belarus.

The state program mentions the need for cooperation with foreign investors to invest in the following areas (Source: Department of Land Improvement and Water Economy):

- Direct investment into construction of the industrial complexes for breeding and rearing of the valuable fish species (trout, sturgeon, catfish) and into the construction of the fish processing shops
- Establishment of the joint ventures with shareholding of the foreign capital
- Extension of long term lax credits to the Republic of Belarus for implementation of concrete investment projects

3.4. Fisheries administration

Aquaculture in Belarus is not a licensable type of activity. Primary laws deal with

1. Legal regulation of fishing
2. Legal regulation of discharge of water (the resources are for lease)
3. Legal control of natural fishery resource conservation
4. Wildlife Act of the Republic of Belarus
5. The water code of the Republic of Belarus
6. Measures aimed at the implementation of the Rep. of Belarus Presidential Edict no. 580 (d/d) of December 10th, 2005 “on some ways of increasing the efficiency of fish and game management, as well as improving state administration of them” (Resolution of the Council of Ministers of the Republic of Belarus no. 466 (d/d) of April 6th, 2006)
7. Approval of the Provision on the procedure of putting water bodies (and their parts) out on lease for fish farming and other purposes (Resolution of the Council of Ministers of the Republic of Belarus no. 1260 (d/d) of October 4th, 2007)
8. Regulations of fishery management and fishing.

4. Environment and ecology

The legislation regulating the discharge from fish farms is mentioned in previous sections. It is planned by legislation to require farms to purify the discharge water through biological filters, which also will support an increased degree of reuse of water.

At present no standards for discharge of nitrogen, phosphorus and organic matter have been implemented, but fish farms are banned from discharging water to natural water bodies without post filtration. It is allowed to discharge untreated water from aquaculture to municipal sewage lines by paying the waste water tariff fee. The fee would increase the unit cost of produced fish. In practice it is only possible with high degree of recirculation and for example in fingerling production with high kilo price. Treating the outlet water and collecting the captured solids will be the preferred methods to reduce loads to environment.

4.1. Fish diseases

The current total production is small and fish diseases are not widely spread. With an increased production of more valuable species it must be predicted that some of the diseases connected to intensive breeding of the species will occur from time to time.

There are rules for veterinarians and farmers themselves about practices in fish health. Recycling farms are not specially considered in the rules and it would be a beneficial effort to have the instructions updated. Because the production of trout has so far been small it can be supposed that the practical work and processes in an outbreak of a disease have not yet been really tested. International cooperation between farmers and veterinarians and researchers is useful and can be recommended.

The new farm projects that are under construction should have a modification to the plans to utilize the latest experiences from Denmark. There are several construction projects which all would have a benefit from installing drum filters in the cycle to remove significant part of non-settleable small particles. Some experiences exist that some parasites could also be reduced by drum filters.

One of the feared parasites in the Salmonid production is *Ichthyophthirius multifiliis* causing the so called white spot disease. High mortalities may occur during an attack by this parasite in both RAS systems and flow through systems. The use of drum filters have been reported to reduce the mortality.

Drum filters have an ability to reduce especially this parasite in the phase of its life cycle where it is found free in the water. Experience from Denmark shows that it is impossible to remove all the parasites but possible to reduce their number significantly. The use of chemicals to treat the system against parasites will also be more effective if there are fewer solids in the water cycle. This may also have an obvious effect on the bacterial pressure to fish.

4.2. Current state and developmental bottlenecks

There is a growing interest in the Danish Model farm concept in Belarus. A model design is the basis for many of the new farms that are to be built according to the five year plan. The model farms under construction are so-called serial type. Capture of solids and handling of sludge are in the plans. The two visited farms that were built and already in operation had some malfunctions which should be corrected to get the production run efficiently and to reduce the nutrient load significantly. These suggestions/corrections are presented in Appendix 2, 3 and 9.

The visited new units under construction in Alba and Belynichi farms were serial raceways. Sludge collectors were built in the farms with settling ponds for sludge. Suggestions to improve the function of these new units are presented in Appendix 4 and 9.

Capture and removal of solids is the most important single matter to achieve a well running recycling fish farm. Collecting the solids makes a high reduction in phosphorus load from the farm and allow for recycling phosphorus as a fertilizer.

The aim is to produce trout with minimum environmental impact. Using recirculation technology the fish production may be performed significantly more environmental efficient and profitable compared to conventional flow through farms or net cages. The energy consumption to provide the sufficient flow, to strip CO_2 and to provide the biomass with sufficient amount of oxygen is the factor that is compared with the gains of water purification.

Post treatment can be done using plant lagoon or constructed wetland. The outlet water from the model unit consists of two separated flows. The total outflow is the overflow that is caused from the fact "what comes in must go out". The same flow that comes in with fresh water will leave the system as the total outflow. A part of the outflow water comes through drum filter rinsing and from conducting the sludge from sludge traps to reservoir. Releasing the sludge outlet to sludge reservoir will have an overflow to post treatment. If the outlet water is delivered to municipal sewage plant, the farm must pay the existing waste water tariff. This would mean in practice a significant increase in production cost.

Ground water should be the primary water source for model farms using recirculation technology. The temperature can be regulated keeping the higher peaks lower and lowest temperatures higher. The disease control is easier and the water can be used also for fish processing needs. The use of groundwater in the fish farm is possible without permission. The sanitary authorities check the site to be sure that it is safe to take the water.

There are differences in the quality of ground water in different parts of the country. The iron content in 70% of boreholes has been found to be above 0.3 mg/l which is considered to be around the limit to treat the water. To remove the iron from the water requires filtration. Depending on other water quality parameters the treatment normally can be aeration and filtration or ion exchange.

The water resources are about 43 million m^3 per year in the whole country. At present after year 2000 32-47 % of this amount was used annually mainly for drinking water and industrial purposes.

The bore holes are commonly 100-150 m deep, though much less in some areas and places. Normally the deepest may be 300-400 m. The average assumptions about flows that a single bore hole is providing are described in the map in Figure 9. In some aquifers water level drop has been noticed as a result of water pumping. The fresh ground water level depth in Belarus is presented in Figure 10.

In certain areas it has been found pollution from industry to affect the ground waters, heavy metals, pesticides, organic compounds for example have been found in ground waters. Some bore holes are closed because of too high contents. Industrial areas like Gomel and Soligorsk are the most typical affected areas.

Figure 9. Daily water capacity of a bore hole in m^3 in Belarus (www.hge.pu.ru).

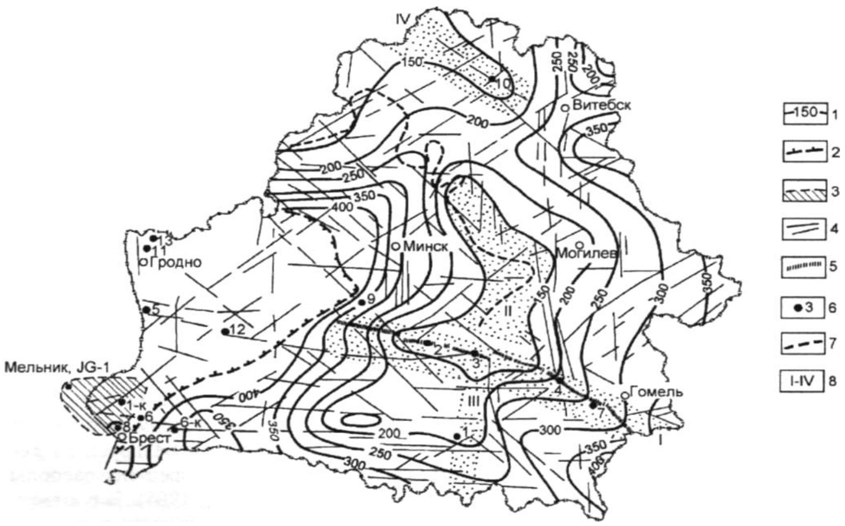


Figure 10. Fresh ground water level depths in Belarus.

5. Farmed fish markets

5.1. Import and export of farmed fish

Total import of all kind of fish to BY is 160 000 – 180 000 tons/year. Of this about 4 500 – 6 000 tons is the so called valuable fish, mainly salmon and trout (90 %). Import taxes are for fingerlings 10% and market fish 20%. Fish consumption in BY is about 16 - 17 kg/cap/year.

The maximum per capita fish consumption in the Republic of Belarus was noted in the 1980s (19.7 kg per capita), after which a significant decrease occurred, due to the reduced buying capacity of the population (Konchits, 2005). Domestic fish consumption was 152 900 tonnes in 2004 (about 15.5 kg per capita). The domestic production is less than 9 percent of total demand. Thus, most of fish consumption in the country is met by imports. According to FAO further increase of sale volumes of fish cultured in freshwaters is impeded by a limited demand from the population and saturation of the market with seafood products. http://www.fao.org/fishery/xml/countrysector/naso_belarus/en

5.2. Processing and product profile

Processing of fish is considered to be one of the bottlenecks in fish business according to the five year plan http://www.eurofish.dk/pdfs/Istanbul-presentations/Countries/Belarus.pdf

World Bank International Finance Corporation report tells the following:

“Belarusian food safety standards, regulations, and food safety inspection systems are outdated and limit Belarus’ export potential and investment opportunities. If brought in line with international food safety and quality standards, the Belarusian food industry could experience significant export market growth. For example, if Belarusian food products meet the European food safety requirements, the country could gain access to the EU market of 500 million consumers, which would help increase Belarus’ trade and support the country’s economic development.”

http://www.ifc.org/wps/wcm/connect/region__ext_content/regions/europe+middle+east+and+north+africa/ifc+in+europe+and+central+asia/countries/improving+food+safety+in+belarus

The product profile of trout is cleaned 500 g size packed in ice covered boxes, filleted trout in ice covered boxes or fish and frozen fillets. Smoked whole fish can also be among the trout products. If trout is raised up to 1 kg and more the product variation will be wider. There will be possibilities to have salted, cold smoked fillets, hot smoked fillets and whole fish.

5.3. Marketing, distributing channels

Most fish farmers sell their product directly to stores (supermarkets) and market places. Some five years ago stores were reluctant to purchase live fish as they had no fish tanks/aquariums. Some fish farms at their own cost installed aquariums for live fish in the stores. However recently, the government has decreed that large stores must install tanks for keeping live fish.

Another distribution channel is direct sales where fish farms sell their product directly from live fish carrier's at large markets in Minsk and other regional centers. There are 1 112 specialized places for selling fish alive in Belarus. More than 700 of sites are specially targeted for fish farms to use direct selling methods – from special transport equipment.

5.4. Future, i.e. potential for profitable marketing/sale

A growing demand of farmed fish is expected in the future. At present there is a lack of valid information about the price level of valuable fish species other than interviews during the visits, but it must be expected that an increase in prodution will make a decrease in the highest sales prices from the producers.

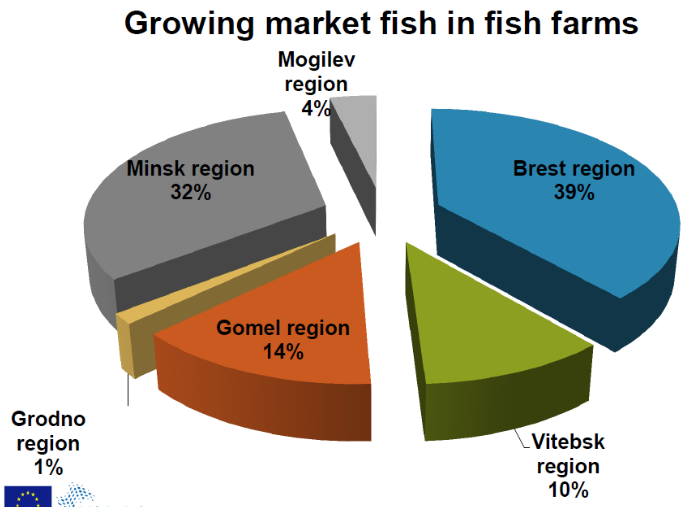


Figure 11. Distribution of aquaculture production in different areas in Belarus 2012 (Newsletter of Department of Statistics enterprises. National Statistical Committee the Republic of Belarus. – Minsk. – 2012).

6. Price competitiveness

6.1. Production costs

The following information is gathered through interviews with fish farmers and decision makers in the industry. The questions have only been related to Salmonids due to the fact that it is considered as one of the valuable species.

In addition to governmental plans, private companies take initiative to establish facilities and somehow become supported by the government. They can get loan after approval of a business plan. Typically interest rate is 7 - 8 %, and loan is paid off in 8 years. Normal interest rate is 30 % and similar to yearly inflation rate.

Import tax: Fingerling 10% + 18 % customer tax

Market fish 20 % + 18 % customer tax

Fish consumption in BY: 16 - 17 kg/cap/year

Because of the undeveloped fresh fish market it will be necessary to start to prepare the fish for markets like it is done for example in Denmark and Finland. The fish will be bleeded and gutted. It must be packed in isolated boxes covered with ice flakes, which makes a lower cost of transport per kg than for live fish. This means investments in the necessary preprocessing. Processing plants must be equipped with hygienic surfaces, washing equipment and flake ice machine. A storage room for temperature isolated boxes is needed and cooled storage room at least for one day production.

6.2. Feed and fingerling costs and quality assessment

Most of the western feed companies are represented in Belarus. The price we have got through interviews for quality feed for Salmonids is between 1.5 – 1.8 €/kg. To achieve the optimum performance from the model fish farm designs it's essential that they use high quality feed, to secure the proper function of the biological filter.

Price level of fingerlings (Salmonids) will vary, normally small fish have a higher price/kg than bigger fish, but the demand for fingerlings in a particular size will dictate the price of the fish. Price info for fingerling at size of: 50 g/psc. is gathered through interviews among fish farmers and decision makers in the industry, and are stated to be appr.13.3 €/kg.

6.3. Labor costs and educational skill

During our two visits in Belarus it's our impression that the educational skill to run a model farm is available among the employees. The National Academy of Sciences organizes on a regular basis training courses and seminars for employees in the fish farming industry. According to experiences it is very important to have a training program for the fish farmers and fish farm workers. The development of the business can only be created through the development of skills in the production

Based on available statistic information the average monthly salary is currently about 320 USD.

6.4. Production costs

Due to the lack of detailed information on slaughter, packing, distribution, transport and energy costs, it has been necessary to use data collected through interviews.

Production of valuable fish is so small that there can't be found any reliable data. There is no comparable system in handling the fish that is common in some EU countries. A lot of fish is sold alive.

The total production price for producing one kg of table size trout was reported to be Euro 3.3 / kg and 4.1/kg covering all expenses connected to the production. A sales price was reported 6.4 Euro per kg from the Bogushevsk farm. It is estimated that the overhead will be of such a size that it will allow implementation of the model fish farming technology in Belarus, and that the implementation will be beneficial for the local as well as for the whole society.

6.5. Production cycle for market fish

Fingerlings are bought when they are in size between 30 – 50 g/pc from specialized fingerling producers and then raised up to a size ~ 300 – 500 g/pc. It must be noticed that the demand from the consumers is moving towards bigger fish, a development that is similar to the rest of Europe.

To be competitive in this segment it's necessary to take this in consideration when planning to start up a model fish farm, due to the fact that a production of 100 ton of 1.0 kg fish requires more production volume than the same amount of fish raised to 500 g size.

6.6. Price competitiveness conclusion

The price for table size fish has been given as 80 000 BYR/kg ≈ 6.44 €/kg ab fish farm. The consumer price (on the market or shop) can reach 160.000 BYR/kg ≈ 12.48 €/kg. Imported salmon (cleaned) has a price of 80 000 BYR/kg ≈ 6.44 €/kg and imported trout (salted) 200 000 BYR/kg ≈ 16.1 €/kg. The production cost for trout in 2012 for example in Bogushevsk farm was informed to be 45-50 000 BYR, ~4 €/ kg.

Based on information above it seems as the production cost varies. If Danish model fish farm technology is implemented in Belarus it's predicted that the total production cost will be closer to 4 €/kg because of the relatively high investments. Compared to a sales price ab. fish farm of € 6.44 /kg there is still a margin of close to € 2.0 /kg.

7. Preconditions of a model farm

7.1. Requirement, permits and authorization

In Denmark the legislation regulating the construction of production units as a Danish model farm was changed by act. No. 130 of February 8, 2012. The main difference between the act and the previous legislation is that it will be possible to regulate the production of the farms according to control of emissions, and not as before on the basis of a maximum annual amount of feed. At the same time the act changes some of the dimension criteria's for the model fish farms.

In Belarus the requirements due to legislation can vary from site to site. Attention should be given to the state program for developing aquaculture in Belarus. This state plan gives an overview of the future possibility according to the national legislation to develop aquaculture in Belarus.

7.2. Advantages and disadvantages of Model fish farms

The analysis below show advantages and disadvantages for the environment and fish farming by running a farm according to the model fish farm concept. It must be noticed that the comparison is based on the assumption that a model farm is chosen instead of an open flow through fish farm.

Environment	Farming
Advantages • Free water flow up/down stream and natural variations in the water flow of the water course facilitated by water bypass. • No or reduced effect of damming • Free fauna passage • Reduced nutrient and organic matter losses per kg produced fish • Reduced discharge of medicines and therapeutants and reduced maximum concentrations • Improved oxygen conditions downstream of the fish farm • Reduced losses of fauna from water courses to fish farm	**Advantages** • Stable production conditions • Minor variations in water quality • Improved efficiency of cleaning devices • Using water from borehole or drainage pipes lead to fewer seasonal temperature variations • Improved control of management and production • Reduced external risk of infection with pathogens • Reduced need for medicine and thera-peutants • Improved work environment
Disadvantages • None	**Disadvantages** • Higher energy consumption per kg fish (1 – 2 kWh/kg fish) • Increased discharge of CO_2 (approx. 0.5 kg per kWh) • Risk of toxic levels of ammonia and risk of disagreeable taste in fish meat • Increased need of supervision and man-agement • Increased need of backup systems: elec-tricity, oxygen, pumps etc.

7.3. Land requirements

If it's decided to use a plant lagoon to clean discharged water the following dimension criteria, from the Danish legislation concerning fish farm act number 130 of the 8th of February 2012 shall be taken in consideration.

- Plant lagoon shall be constructed as a river course
- The hydraulic load may not be over 0.021 l/s/m^2 of lagoon
- The depth of the lagoons must be maximum 0.9 m the surface area of the lagoon should be 40 m^2 / ton of feed in a year
- The water retention time in the plant lagoon shall be more than 36 hours

7.4. Energy demand

At the public supported project concerning model fish farms performance in Denmark the average energy consumption was 1.7 kWh/kg of fish produced, but through optimizing processes it is possible to cut the energy consumption down to between 1 – 1.3 kWh/ kg produced fish. The main factor, which reduces the energy consumption, is to separate water transportation and aeration/degassing of the water.

It should also be noted that depending on the design and production, the size of main fuse must be determined.

7.5. Water quality

Normally, boreholes or artesian wells are used as water supply for recirculation aquaculture systems. The average depth of Danish wells is approx. 40 meter. In Belarus wells can reach 100m and deeper providing in some cases sufficient water pressure to bring water up without pumping. Water quality corresponds to norms with the exception of iron concentration, which can reach 3-8 mg/l. In this case iron removal plants must be built to eliminate iron from water.

7.6. Water quantity

The original legislation for model fish farms in Denmark was based on the following specification for the model farms which may be followed in Belarus:

Type of farm	Model 1	Model 2	Model 3
Pond material	Soil or concrete	Soil or concrete	Concrete or other material[4]
Water recirculation (minimum %)[1]	70	85	95
Water use (maximum l/s)[2]	125	60	15
Fish density (maximum kg/m^3)	50	50	50
Water residence time in production unit (minimum hours)	8.9	12.3	18.5
Maximum daily feeding (kg)[3]	800	800	800
Sludge collection in basins	Yes	Yes	Yes
Decentralized sedimentation (eg. sludge cones)	Yes	Yes	Yes
Devices for removal of particular matter (drum filters fixed media filters)	Yes	Yes	Yes
Biofilter	No	Yes	Yes
Plan lagoons	Yes	No	Yes

[1] (Internal recirculated flow / (internal recirculated flow+fresh water)) * 100
[2] Maximum fresh water use as l/s/100 ton feed
[3] Maximum daily feed per 100 t of allowed feed
[4] Impermeable material

Note: Some of the requirements in the table have been changed with act number 130 of the 8th of February 2012

Most of the model farms in Denmark are established as Model 1 farms, but this farm design can't be considered as a true RAS system. But Act number 130 of the 8th of February has forced the interest of fish farmers towards a farm design with significant higher recirculation than achieved at the indigenous Model 1 farm design. So currently nearly all rebuild farms in Denmark are built as model 3 farms.

The main deference between model 1 farm and model 3 is the degree of recirculation which is much higher in a model 3 farm compared to a model 1 farm. Due to this there is also a requirement of a biological filter at the model 3 farms which not is the case for model 1 farms.

Denmark had a publicly supported monitoring project for eight model 3 farms. It should also be emphasized that some of the Model 3 farms have reduced the use of fresh water, i.e. some farms down to 7.5 -10 l/s/100 ton = > 600-900 liters per kg produced fish. Due to the fact that there has not been build model 2 farms in Denmark in the last decade, and act no. 130 of the 8th of February 2012 has forced the interest towards a more recirculated design. Therefore, model 1 and 2 farms are not further discussed in this report.

7.7. Education and research

The major research and education centers involved in aquaculture, together with their scope of activity, are presented in the table below:

Table 4. Research and educational institutions involved in aquaculture

Name of institution	Scope of activity
Republican Unitary Enterprise «Institute for Fisheries of the National Academy of Sciences of Belarus», Minsk	Research in the fields of aquaculture, rational nature exploitation and protection of water resources
State Scientific Institution «Institute of Zoology of the National Academy of Sciences of Belarus», Minsk	Research on fish ecology, individual aspects of aquaculture, species diversity and protection of rare species
Belarus State University, Minsk	Research on aquatic ecosystems, training of specialists in hydro ecology
Belarus State Agricultural Academy, Gorki, Mogilev Province	Specialist training in the field of aquaculture (higher education)
Luban' Village Vocational Training School, Luban', Minsk Province	Pond worker training (specialized secondary education

In order to solve problems of food safety and supply to the population, the country adopted the State Programme of Fish and Seafood Supply for the Population for 1998–2005 and the State Programme of Rural Revival and Development 2005–2010. According to these program's research institutions formulate a number of issues to be addressed and they are submitted for consideration and approval to the Research and Technological Council of the Ministry of Agriculture and Food. Proposals are included in one of the State Research and Technological Programme, or are formulated as separate innovation projects. In order for the project to be approved, it must be partially financed by the potential user of the research product. Results from scientific research are applied on the basis of extension agreements between the developer and user of the scientific product. Training of personnel is ensured by the Ministry of Education and carried out in training centres of the Ministry of Agriculture and Food.

Based on available information the skills for running a model farm is available among the employees. It should be taken into consideration to offer short and long term courses with the following content:

- Identifying suboptimal water quality (rearing conditions) and assess corresponding actions
- Apply treatment components for solids removal and dissolved matter
- Function and processes in a biological filter incl. nitrification ctr. denitrification and factors influencing both processes
- Managing a biological filter
- Effects of feed loading and feed composition on the waste water treatment compo-nents
- Production planning

Going from traditional flow through farming to RAS system requires that the focus should be on both optimal fish performance, i.e. growth, health as well as proper function of the biological filters.

Experience from Denmark shows a change in paradigm which requires inservice training for at least some of the employees. The Belarusian State Agricultural Academy, Gorki, would be an excellent choice for these tasks as the Academy has the facilities and the basic expertise.

7.8. Suitable climate for cold water aquaculture

The farming system shall basically be designed to secure optimal water quality for the specific species to be reared in the facility. Optimum water quality parameters are different from species to species, eg. Salmonids have an optimum temperature of about 15 ºC and sturgeons usually above 20ºC and other differences for requirements to optimum water quality. The range for acceptable water quality for the above parameters is for Salmonids the following:

- Water temperature below 20 ºC
- pH between 6.5 - 7.5
- Oxygen levels higher than 70% saturation

8. Establishing standards for model farm units

8.1. Investment

The system is based on a unit containing 15 parallel connected raceways with the dimension 14 x 2.5 x 1.2 – 1.35 m corresponding to a volume of each raceway of approx. 45 m^3. The water transportation is done in open channels to minimize head lost in the system.

The design is equipped with mechanical removal of particles through a drum filter with mesh size at approx. 40 µm. The sludge water from the drum filter is lead to a sludge thickener consisting of three sludge cones. These cones shall be emptied regularly.

After the drum filter, the water is lead to a moving bed biofilter with a total volume of approx. 155 m^3 at a filling of 60 % of biomedia. The full amount of biomedia is approx. 92 m^3 corresponding with a surface of approx. 67 160 m^2. According to the Danish legislation this surface area corresponds to an annual use of feed of approx. 168 ton of feed. After the water has left the biofilter it is led to a central aeration area, designed to stabilize the total gas pressure in the system and at the same time keeping oxygen saturation at around 85% of the entire water flow. After the aeration area the water is pumped either through two oxygen injection platforms or by the primary pump to the supply channel for distribution between the 15 raceways.

For more detailed description of the design see Appendix 6. The layout of the described production facilities is shown in Figure 12.

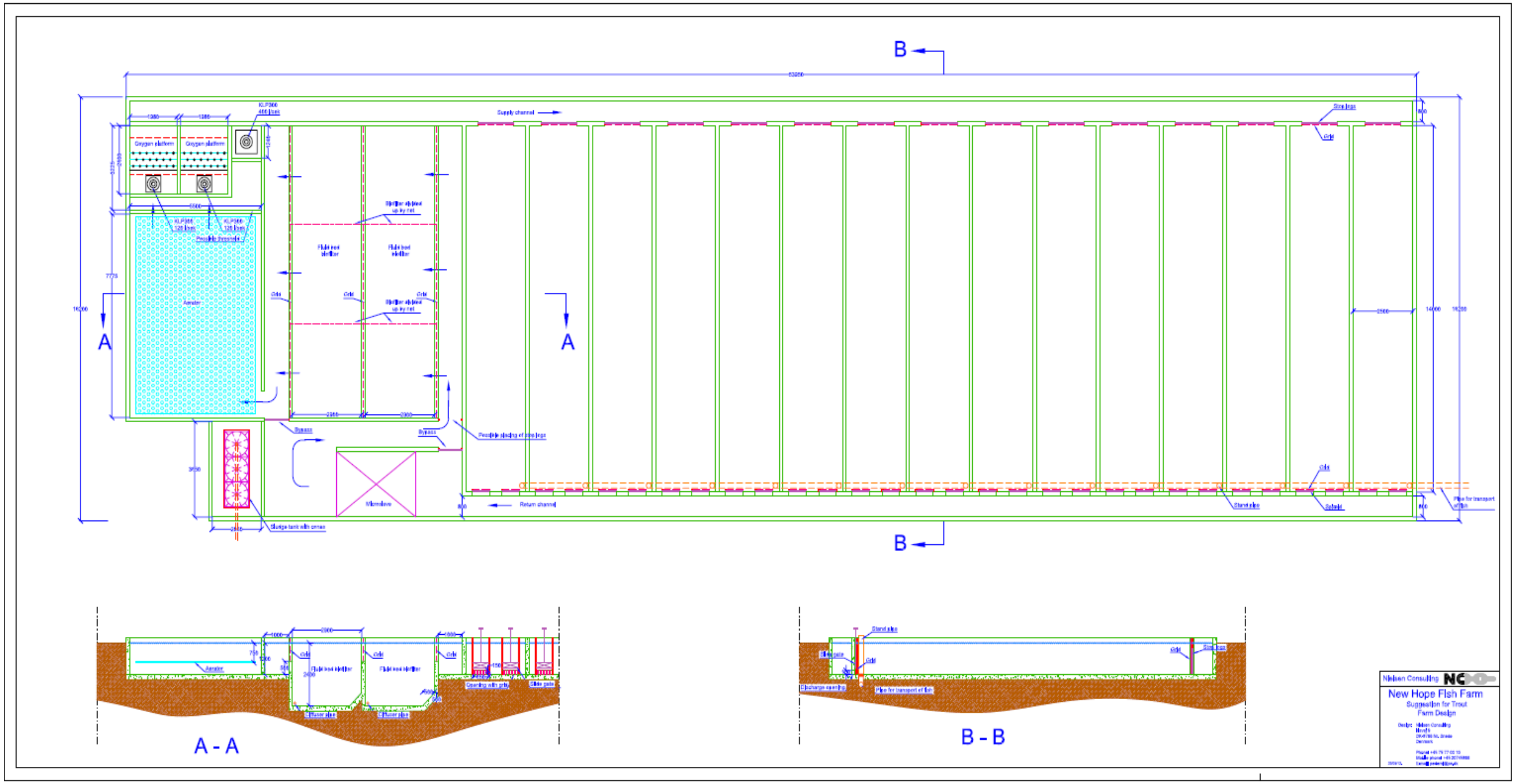


Figure 12. Layout of a production facility used as a feasibility study example for model type 3 fish farm.

8.1.1. Nature of investment, costs in Euro

The investment cost and expenses related to the investment for a unit as shown above with an estimated annual production capacity of approx. 150 t of table size fish, can be divided into the following items (Table 5; for more details about the investment see appendix 8A).

Table 5. Overview investment costs

Investment item	Estimated cost, €	Share of costs, %
Construction site preparation	25 000	2.9
Energy supply installations	50 000	5.8
Buildings	210 000	24.6
Concrete work	180 000	21.1
Machinery	150 000	17.5
Equipment	155 000	18.1
Mounting	45 000	5.3
Consultancy services (estimate for drawings, functional test, training)	40 000	4.7
Total estimated cost	**855 000**	**100**

8.2. Production strategies

8.2.1. Layout

In Belarus both parallel raceways and serial raceways are built or are under construction. In recent years there has been a growing interest in Denmark towards the design with smaller parallel connected raceways. This kind of design is much more flexible and safe compared to serial raceways. However, the investment cost is higher.

To add more flexibility to the production system there is a trend moving toward system based on round tanks design or parallel raceways. Parallel raceways are easier to operate and more safe, and suitable to the current market structure in Belarus.

8.2.2. Land area and water supply

With the suggested design based on parallel raceways the necessary land area will be approx. 2 500 m^2 exclusive land for possible plant lagoons and access roads. The most used design and waste water treatment system are most suitable for using ground water, but can also be constructed to use water directly from a river. The design is described in Appendix 6 and in Jokumsen & Svendsen, 2010. Based on experience the request of water will be between 1 – 20 l/s.

8.2.3. Waste water treatment

The most common design for RAS system in Belarus is after the principle shown below:

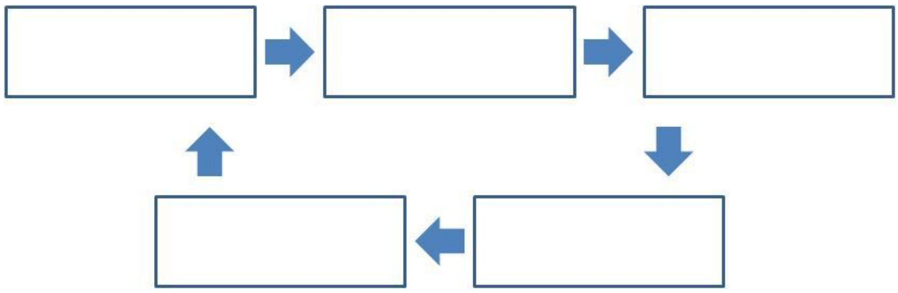


Figure 13. The most common design for RAS system in Belarus.

The sludge cones are effective for particles bigger than approx. 100 µm due to a high degree of recirculation and the total weight of particles. The sludge cones are not effective against the smaller sized particles, so if the system not equipped with a microsiew, small particles will accumulate in the system. Especially the moving bed filters are very sensitive to this type of particles, as they will be absorbed by the biofilm and impede the consumption rate of ammonia in the filter.

Moving bed filters are constructed as long channels where the biomedia is moved by air. According to laws of physics the biomedia will move from one end of the filter channel to the other end. However, to prevent this it's necessary to place some separation grids across the filter to separate the biomedia. However, it is crucial to replace the grids in the moving bed filter with a more suitable material. For further information about the model fish farms see Jokumsen & Svendsen, 2010.

8.2.4. Production plan

The production cycle for trout production in Belarus is based on fingerlings in different sizes from farms which are specialized in producing fingerlings. Normally the fish are bought at size between 30 – 50 g/pc and raised up to a size of approx. 300 – 500 g/pc.As noted earlier, there is growing demand from the market for fish up to 1.000 g/pc.

9. Evaluation of cost struture

9.1. Investment options

Investment costs of a model 3 farm are listed in the Table 5, and for more details see Appendix 8 A. The costs are mainly assumed to follow the Danish price level taking into account some local factors. The production is anticipated to be increased up to 150 t per year.

Total investment in the production unit is appr. 855 000 € including equipment, concrete raceways and reservoir constructions and water treatment devices. Local financing scheme is based on government supported rate which in practice means 7-8 % interest rate. For new fish farms the loan terms are special. Time to pay the loan is 18 years. This means a yearly cost using the annuity for 18 years and 7 % to be 0.102 x 855 000 =87 210 €. Inflation has been 30 % but it is not clear how aquaculture is affected by the strong state participation in business and support to companies.

Loans and lending programs can change every month. Currently feed loans and loans for other needs are given at the following interest: the refinancing rate (23 %) + 7 %. Altogether, a loan is given at 30 %, but at the end of the year a bank repays half of the refinancing rate, in other words 11.5 %. Thus, in the long run a loan is given at 18.5%. To build a new farm, for example, RAS, a bank gives a loan at 7% per annum for 18 years. And from the first year only interest on the loan is paid. Repayment of the principal + interest begins from the time of getting the first products.

For production of 100 t amortization and interest per year means unit cost 0.87 €/kg produced fish and for 150 t production about 0.58 €/kg fish.

Information about Bychav farm project in Mogilev region gives the realised construction cost to be about 8 000 000 €. Planned production is 500 -700 t in a year. This means with the equal values of interest rate and time to pay the loan average 1.3 € per kg fish in 18 years and 7 %

The following issues will influence investment and running costs:

- Getting the borehole or several of them drilled and connected to farming unit
- Underground water may contain iron. Treatment to accepted level may cause extra costs.

In most places, where fish farming is a new activity and basic premises don't exist, it is necessary to consider the effect of processing and packing of fish to the final investment cost. To develop the fresh fish market it is necessary to start to prepare the fish for market. The fish will be bleeded, gutted and cleaned. It must be packed in isolated boxes and covered with ice flakes. This way the transport will be cheaper per kg than for the live fish. Also in the shop the handling is cheaper and the cold chain from farm to customer possible to maintain. This means investment in the preprocessing (=slaughtering and cleaning of the fish). The plant must be equipped with hygienic surfaces and washing equipment and flake ice machine. A storage room for isolated boxes is needed and cooled storage room at least for one day production. A working space of about 60 m^2 will be the minimum size but it may be sufficient for a daily capacity of at least 3 t cleaned fish. Cold storage for six pallets means about 10 m^2 and storage without heating for Styrofoam boxes about 25 m^2. Dressing room for workers is necessary too.

Guttingf trout means a loss of weight about 17% from round weight. Grading of the fish during the growout period is necessary and can be done using grading machine. This means investment that must be added in the list of needed items. Using fish pump or fish elevator this work can be done without extra manpower. The work means visual control of fish pumping and grader performance and netting the fish to feed the pumping. The cost to get the system is about 40 000 – 60 000 €.

The above mentioned premises and equipment are capable of handling much more than the fish in one model system. Therefore they are not included in the investment costs. This must be taken into account anyway.

The costs of handling the wastes must also be added. The method to store the settleable solids collected with sludge cones and/or drum filters means usually a sludge tank or pond. The volume capacity shall be at least sufficient to store the sludge during winter period including the contribution from the winter production.

9.2. Variable costs

All the running costs are considered as variable cost. In the calculation sheet (Appendix 8B) the evaluated price factors are presented. According to the calculation the unit costs are the following for production levels 100 tons and 150 tons.

	100 tn	150 tn
Salaries	62 000	62 000
Feed	180 000	270 000
Fingerlings	156 275	156 275
Electricity	35 123	35 123
Other cost	12 000	12 000
Fuel	8 000	8 000
Variable costs, total	**450 398**	**635 812**
Variable costs, €/kg	4.53	4.24
Investment, €/kg	0.87	0.58
Total production cost, €/kg	5.40	4.82
Sales price, €/kg	6.40	6.40
Sales, €	640 000	960 000
Margin, €/kg	1.00	1.58
Profit, €	42 000	178 500

The salaries are assumed to be with taxes and social costs. Total number of workers is based on discussions and observations during the study group trips around Belarus. Costs are counted assuming a manager with biological skills, technician, 4 - 5 workers, book keeper and 2 guards. With this number of people it is possible to handle at least a double size unit. This can be taken into account on the variable cost evaluation.

The reported sales price 6.4 €/kg would be the minimum accepted price with 100 t year production.

As to the sensitivity of the calculation the biggest variation in percent will obviously be for the energy price. A 50 % increase could be possible. Currently the share of the total costs is only 9 %, but an increase in energy price with 50% would increase the total production costs by 4.5 %. Also the salaries can be calculated to be smaller per unit if the personnel is used in the work to take care of bigger system than just one module. Biggest effect will be with changes of the feed price and fingerling price.

Alternatively, production of bigger fish of 1-1.2 kg/pc will possibly bring the production cost slightly down if the volume of production is at least around 500 t per year. Fingerling costs will be smaller because of the smaller number of fingerlings and processing (cleaning) will be faster with smaller number of fish to handle.

9.3. Production volume estimations

Suggested growing module is model 3. The dimension of the module is chosen to be a practical multipurpose design with a possibility to multiply the number of modules for expanding the farm.

By choosing the module system it is also possible to get standard designs for building, electricity and possible feeding units. The size of module is also practical to produce for example 200 g trout for stocking material for further growing. This design is most suitable for trout, as sturgeon and European catfish might perform better in round or quadratic tanks with rounded corners. Catfish needs to be grown in higher temperature than trout, but it also tolerates higher fish densities.

For efficient utilization of the personnel, it may be reasonable to produce double or triple production in the same period by multiplying the module. This may also improve efficiency of the preprocessing plant (slaughter and cleaning) than one single module. The production of 500 t per year means a harvest of 10 t per week which would give a daily slaughter between 2 500-3 500 kg in four days per week.

Units like storages and similar facilities shall be planned from the beginning to fit the later expansion. This also concerns the traffic inside the farm area. Sludge handling and conducts to handling area are designed from the beginning with as short conducts as possible.

9.4. Cost estimation of various recirculation technologies

Investment costs are not compared between different designs. This is due to that the production takes place in a certain volume and the water treatment is similar and depends on the daily feeding.

The only variable is the construction cost of the tank system and the growing density specific to tank construction. Round or quadratic tanks can be deeper because of the rotational flow. The disadvantage of tank being deep is the difficulty to handle the fish if the unit is too big for the fish amount to be slaughtered during one week. The volume of the tank can be bigger and sludge can be collected easier than in a raceway. The experiences of this type model farm should be documented and the building costs compared before any judgements.

10. Environment and legislation

10.1. Environmental impacts

Calculation or estimation on the environmental impact can first be done when the size and design of the farm have been done. For general information see Jokumsen & Svendsen, 2010.

10.2. Types of waste

The waste from a model farm is similar to the waste from a traditional farm, and will mainly consist of organic matter (measured as BOD), nitrogen (N) and phosphorus (P). In the table below is a comparison between a traditional Danish farm compared to the discharge from a model 3 farm.

Specific discharges of N, P and BOD for 2006–2007 (kg/t produced fish) from eight intensively monitored type 3 model trout farms compared to specific discharges from Danish fresh water fish farms in 2006 (Svendsen et al., 2008).

Table 6. Comparison of discharges of Nitrogen (N), Phosphorus (P) and organic matter (BOD) from model trout farms (type 3) and traditional trout farms in Denmark during the monitoring project.

Kg/tn produced fish	Traditional farms in 2006	Model farm type 3 2006-2007	Model farms, % of traditional farms
Total nitrogen	31.2	20.0	64
Total phosphorus	2.9	1.1	38
BOD	93.6	5.6	6

The recorded measurements showed that the specific discharge (kg/t fish produced) of N, P, and organic matter from the model farms amounted to 64, 38, and 6%, respectively, of the corresponding estimated discharge from traditional Danish freshwater trout farms (Svendsen et al., 2008).

Evaluation can be extended to include emission of CO_2. This extension can first be made after the designation of the locality and the choice of design and production size has been done.

10.3. Waste reduction

The expected waste reduction is closely correlated to the waste water treatment. Jokumsen and Svendsen (2010) reported the removal percentages (RN) of nitrogen, phosphorus, and organic matter for the eight intensively monitored type 3 model trout farms being significantly higher than assumed.

Table 7. Average removal percentages (RN) from the eight intensively monitored type 3 model trout farms (Svendsen et al., 2008).

	Total nitrogen	Total phosphorus	BOD
Average removal (RN), %	50	76	93

The removal rate for phosphorus and BOD are high. Improvement of these reduction rates will be expensive and difficult to achieve. The main improvement of the reduction rates for phosphorus and BOD should be achieved through management of the waste water treatment and not by implementing further technology.

For nitrogen the situation is different. Currently, several Danish projects are focusing for the possibility of using the sludge produced on the fish farm as a carbon source by transforming some of the sludge to VFA (Volatile Fatty Acids) and using the VFA as "fuel" for denitrification. This process is well known and is common used in the traditional waste water treatment. By using the sludge for hydrolysis to VFA to be used in the denitrification filters, it should be possible to increase the nitrogen removal.

10.4. Biological and chemical environmental risks

The influence of the surrounding nature through the discharge of non-biodegradable substances of chemicals must be regarded as minimal. Emissions from model fish farms can be considered as fully biodegradable.

10.5. Other project risks

The risk of pollution of the water is minimal due to the fact that the water source is borehole water. The main risk in a recirculated system is formation of toxic compounds typical from sludge accumulation in the system. Another risk is that the oxygen and pH levels are unstable which can lead to increased morbidity, resulting in increased mortality. The risk of the above can be minimized by proper design of oxygen and water supply, and to establish management and control procedures.

11. Final conclusions

11.1. Human resources

The Danish model fish farm concept would create a possibility to create jobs and economic activity also in rural areas. The production potential is based primarily on ground water resources that are available in different areas of the country.

The existence of human resources depend on training systems that will support the management, biological and veterinary skills and practical methods for working routines. Also the technical knowledge of the modern growing system is of big importance. The training capacity should be coordinated to the state program plans to increase the production of so called valuable species.

If the Danish model fish farm concept is taken as a basis for this effort, the international education possibilities should be considered as an alternative to support the domestic training system in Belarus. The Aquabest training course that was arranged by DTU Aqua in Hirtshals, Denmark in October 2013 was an example of an international training possibility. It is an effective way to update knowledge in recirculation aquaculture technology. For the development of the environmental friendly and nutrient balanced aquaculture around the Baltic Sea training like this is of big importance and in many respects crucial.

When the full potential is reached in each region of Belarus, it will contribute to raise living standards in general by adding job for subcontractors and small construction companies in the local area. By a general increase in the production it will also be added job directly at the fish farms.

Future development goes towards products that are easier to prepare for food or are processed (smoked, salted etc.). This opens a potential for a fish farm to be extended with processing business both for small scale family enterprises and bigger industrial enterprises as well as the fish farms themselves. Trained people to start the food production will be needed.

11.2. Economic and financial feasibility

To invest in fish farming with model farm technology in Belarus it is essential to understand that the business is in the very beginning. There is no statistics available about prices for either customers or producers sales.

The development of the business is at present dependent on the governmental planning. Inflation has been so high that the prices may change almost monthly. This has an effect on the interest rates for loans (rubles), which can be very high (30%). Trout feed is imported and will follow the common price level. At present the prices of feed are considered to be higher than in the EU.

There have been a few RAS farms running for some time but despite of this the new farmers still are like pioneers using the model farm concept with challenges in marketing the product.

Prices of feed and energy are currently a little higher or at the same level as in the EU. Salaries are low for example compared to the Nordic countries. In practice anyway the salaries most likely will be higher when RAS trained people will be employed.

When the business grows and the market develops the prices of fingerlings are under pressure to go down. There will be fingerlings for sale also in neighboring countries like Poland, Lithuania and Latvia.

Size of the production must be sufficiently big to get the production cost down to acceptable level. Otherwise trout will stay only the delicacy of few in celebration times and the market will not grow. Bigger purchases will bring benefits when buying fingerlings and feed. The number of employed can be optimized. If the produced fish is used for processing there shall be the possibility to add value in the product. Otherwise either the material for processing is bought from abroad or imported as ready products.

Investment costs without subsidies are as high as about 1 € per kg fish which is partly dependent on the isolated cover over the raceway system. On the other hand the cover makes the winter growth possible. Inflation has been so high that it would make difficulties to arrange all the investments so rapidly that the prices wouldn't rise during the construction.

If a family business is started by an educated person the one unit model farm can be the correct size if he/she is prepared to take care of the whole production him/herself with his/her family. The production cost for trout in 2012 was for example in Bogushevsk farm 45 000-50 000 BR, 3-4 €/ kg.

Due to mainly the higher investment and energy costs it should be predicted that the production cost in a model 3 farm will be in the high end of this interval. (See section 9.2 Variable costs and Appendix 8B).

The conservative running budget (Appendix 8) shows a relative high overhead at a production of 100 t trout of annually appr. € 0.2 /kg of fish produced. When the full production of 150 t of fish /annually is achieved, there could be an overhead of appr. € 0.6 kg fish produced.

An implementation of the model farm technology in Belarus will force the size of the farms to become bigger and bigger, which could increase the profitability by decreasing production costs.

11.3. Appropriate technology

As a result of the problems in different model units that we saw during the visits, it is very important to get standardized designs that are tested in practice and proven to be functional. The existing units should also be modified using these principles.

An implementation of the model 3 farm concepts will have both advantages and disadvantages Table 8). The disadvantages are mainly correlated to higher production costs and higher risks for accidents (power failure, diseases etc.) but the risks can be minimized by adding a stand by generator with automatic transfer switch and by implementing proper routines when handling the fish.

The full advantage of implementing the technology will be a running process. Based on experience this process will take between 2 -3 years before the full advantage of the new system will be achieved. In Appendix 9 some of the identified challenges are discussed.

Table 8. Disadvantages and advantages by implementing model 3 farm technology.

Disadvantages	Advantages
• Higher operational cost • Higher energy consumption • Higher emission of CO_2	• Improved control and management • Improve work environment • Less hard manual work • Increase in the production capacity • Increase income to the society • Decrease in the use of water • Decrease in the discharge seen as kg/ton fish produced • Higher production compared to previous situation, and with a low environmental impact

11.4. Concluding remarks on the sustainability assessment

There is without doubt a huge potential by implementing modern fish farm technology in Belarus, but at the same time there is also a potential for failure. An additional requirement for the implementation to be a success formalized education and training of personnel must be establish for all farms using the modern recirculation aquaculture technology.

12. Executive summary

This study to investigate the feasibility and possibility to develop the Danish concept of model farms in Belarus was carried out in 2013. It was also partly performed to test the feasibility study guidelines, published as part of the Aquabest project (Nielsen et al. 2014).

Feasibility study consisted of two field trips around Belarus. Interviews with farmers, academia and authorities were done during the two field trips. A lot of information has been collected personally by group members in Belarus, Dr. Nikolai Barulin and Interpreter Dr. Tatjana Liakhnovitch.

Belarus is a country where development of fish farming is much dependent on state programs to develop the sector. Financing of the state owned farm investments follows the five year plan, presently 2011-2015. When this period ends there should be 16 new farms using recirculation technology producing trout. The target is about 4 000 ton of valuble fish (sturgeon, catfish and trouts) per year. The plans are based mostly on model farm concept.

The target is ambitious. Technically the farms can be built in time but to reach the production volume within this short time frame will be challenging. Use of the model farm concept should be based on the latest experiences from Denmark where research is done by Technical University of Denmark and by private companies. It was seen that the projects under construction were designed to fulfil also the environmental requirements in the Danish Model Farm concept.

Firstly the feasibility study focused on the possibilities to find the information about water sources, which are supposed to be ground water reserves. Groundwater is commonly used for almost all industrial and municipal purposes. A lot of information is available and water quality and quantity can be evaluated for the targeted purposes. Water analysis showed that certain areas are affected by pollution from industry or agriculture. Secondly focus was on the production costs based on the Danish experiences and assessing the level of investment costs to be expected by importing the whole model unit. The third focus was an example of a model 3 trout farm suggested to be implemented in Belarus.

Belarus is a country where trout farming has so far happened in a small scale. It was not possible to get statistical information on production and prices from recent years. The guidelines would have been more useful if the requested statistical information had been available. The group suggests an updating of the guidelines if needed for studying the production in start phase on area or country.

At present it appears that the State program is the guideline for expansion of the sector. Private farming also starts to attract interests from private business people and the feasibility to start private model farming is dependent on the development of the market chain from farm to customer. It is dependent on a transparent financing that is predictable and comparable to competitive EU countries including support to investments.

Finally the whole sector is dependent on education and training resources which are existing for example in the Belarusian State Agricultural Academy in Gorki. There are also other institutions to do research and education. International co-operation with EU countries that have more experience on training people to farm fish using recirculation technologies including the model concept is strongly recommended. It is of crucial importance to have training programs for fish farmers and the staff doing the practical work on the fish farms.

List of Appendixes

1. Event report Minsk
2. Event report Riga
3. Event report Minsk
4. Event report Pärnu
5. Partial translations of the five year plan
6. Serial model farm Construction info
7. Questionnaire and results
8. A Investments costs, B Running costs
9. Identified problems
   9 A. Drawings suggestions for changes

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Appendix 1
Event report Minsk

Project name: **Aquabest – Innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region**

Event Report

8th – 11th April 2013

General information

Name of the rapporteur	Name of the rapporteur's organisation
Alfred Jokumsen supported by input from the group (Martti Naukkarinen (FI), Armands Roze (LV), Jouni Vielma (FI), Nikolai Balurin (BY)	**DTU Aqua**
Event name	**Name of the event organiser (organisation)**
AQUABEST WP6 – Feasibility study kick off meeting	Belarusian State Agricultural Academy, Gorki, Belarus
Date of the event	**Location of the event**
8th – 11th April 2013	**Minsk – Dzerzhinsk – Bogushevsk – Gorki – Mogilev, Belarus**
Participants from the project in the event	
Nikolai Barulin, Belarusian State Agricultural Academy, Belarus **Martti Naukkarinen**, Kalavesi Consultants Ltd, Finland **Armands Roze**, Kalavesi Consultants Ltd, Latvia **Jouni Vielma**, FGFRI, AQUABEST Coordinator, Finland **Alfred Jokumsen**, DTU Aqua, WP 6 leader, Denmark In addition the following representatives were met/delegates participated during the visit: **VLADIMIR OLIN**, Director General of the company "Giprorybkhoz", Moscow. Designing and construction of RAS. **Maksim Arhireev**, Chief Project Engineer **VICTOR KHMELNITSKI** (Director) and **ANDREI TOMILOV** (engineer), AQUAFID Ltd., Kaliningrad, RU. Feed purchase and design and construction of RAS. **PAVEL AKSIMENTJEV**, Aquaculture expert and one of the promoters of RAS and sturgeon culture in BY. **VASILIJ VERGEICHIK**, Director General of VASILEK **ALEXANDER LASHKEVICH**, Director of AQUATORIA **ANATOLIJ LASHKEVICH**, Manager of AQUATORIA **SERGEJ VIL'CHINSKY**, Director of Bogushevsk trout farm **ALEXANDER NEKRYLOV**, Director of fish farm at the BY State Agri. Acad. **VLADIMIR** Director of "REMONA" Ltd sturgeon farm, Mogilev	

ANDREJ SERGEEV, Head of the Administration of Growing Valuable Species of Fish.

Description of the event

Agenda

The Kick-off meeting of the feasibility study in Belarus was as well a working meeting to assess the tasks ahead for most adequate and efficient execution of the feasibility study.

The Belarusian partner had prepared an intensive program for the visit (see below) – included Kick-off meeting(s) even though most issues was discussed throughout the event, site visits and meetings. The agenda for the Kick-off meeting included:

1. Brief presentation of the feasibility study guidelines – discussions and suggestions of amendments
2. Structuring of the feasibility study – division of labour
3. Time schedule
4. Other issues

Participants in the feasibility study group:

Nikolai Barulin, Partner 9, Belarusian State Agricultural Academy, Belarus
Martti Naukkarinen, Kalavesi Consultants Ltd, Finland
Armands Roze, Kalavesi Consultants Ltd, Latvia
Jouni Vielma, FGFRI, AQUABEST Coordinator, Finland
Peder Nielsen, NC Consulting, Denmark (prevented from travelling due to delayed appearance of visa from the embassy)
Alfred Jokumsen, DTU Aqua, WP 6 leader, Denmark
Taitiana Liakhnovitch, Interpreter, Belarusian State Agricultural Academy, Belarus

Kick-off/Work meeting of WP6
8th – 11th April, Minsk-Gorki, Belarus

PROGRAM

Date, time	Place	Notes
08/04/2013, Monday, 16.00 – 18.00	Minsk	Arrival at the airport. Hotel accommodation in Minsk. Dinner.
09/04/2013, Tuesday		
7.00	Minsk, hotel	breakfast
8.00 – 10.00		Drive and visit to the sturgeon fish farm

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		(recirculating aquaculture system (RAS), Belarus project)
12.00 – 13.00	Dzerzhinsk, Minsk region	lunch
13.00 – 17.00	Bogushevsk, Vitebsk region	Drive and visit to the trout fish farm (RAS, Danish system, Belarus project)
18.00 – 21.00	Gorki, Mogilev region	Drive to Gorki. Check in at the hotel. Dinner.
10/04/2013, Wednesday		
8.00	Dzerzhinsk, Minsk region Gorki, Mogilev region	breakfast
9.00 – 12.00	Gorki, Mogilev region	Visit to the trout fish farm (RAS, Finnish-Russian project). WP6-discussion
12.00 – 13.00	Gorki, Mogilev region	Meeting with the rector of the Belarusian State Agricultural Academy
13.00 – 14.00	Gorki, Mogilev region	lunch
14.00 – 16.00	Mogilev	Drive and visit to the sturgeon fish farm (RAS, Latvian project)
17.00 – 21.00	Minsk	Drive to Minsk. Check in at the hotel. Dinner.
11/04/2013, Thursday		
8.00	Minsk, hotel	breakfast
10.00 – 11.00	Minsk	Meeting with officials of the Ministry of Agriculture and Food of the Republic of Belarus
13.00 -	Minsk, airport	Departure

Summary of the event including information about the purpose of the event, matters discussed, results, next steps and other relevant information

8th April 2013

Welcomed by Nikolai Barulin and Tatiana. Dinner. Kick-off meeting: Nikolai presented the program of the following day's farm visits and meetings with Belarusian and Russian aquaculture experts and governmental officials followed by general discussions.

9th April 2013

Visit to sturgeon farm, **AQUATORIA, Nakvasy at Dzerzhinsk, Minsk region**.

Pavel Aksimentjev explained about the place, which covered 300 ha with forest, agriculture, deer, herbs for sauna, processing local food and wood etc. Developing Eco-tourism. Total 200 persons employed at the whole farming enterprise VASILEK.

The fish farm (sturgeon) was established about 12 years ago. The first recirculation system in BY. Produce 20 tons/year – 5 species (Starlet, Beluga, Russian, Siberian (Lena strain) and the most popular a hybrid of Russian/Siberian sturgeon.

Stocking density: 50 – 80 kg/m^3. Use ~150 kg feed/day. FCR ~ 2.

Temperature: 18 ^{0}C (winter) – 25 ^{0}C (Summer). Surplus heat from airlifts, ozonator, wood owen with heat exchanger.

They produce own fry. Use live Artemia and Hironomus (moskitos larvae) for first feeding.

7 persons employed in fish production.

Local market. Director lives in Minsk and supply daily (on way home) restaurants in Minsk with fresh sturgeon. Size varies from 350 g – 8 kg. Average size of year-round production was about 2.3 kg. 1.5 – 2 kg was most popular.

Director said many mistakes have been experienced with recirculation farming in BY. Their farm needs improvements, but has decided to construct a new farm. Director made some drafts of the existing farm, which were handed over to Martti.

The energy consumption was very high (water was lifted twice, at first 7 m and secondly 8 m). Price of energy was about 10 Euro-cents/kWh.

Fry feed from Aller-Aqua. On-grower feed from Poland. A representative collects orders for whole Belarus. Competitive prices. BioMar produces high quality feed, but was too expensive for them.

Lose money due to high energy costs and out-of-date construction. However, the relative low production (20 t/y) may be less economical/efficient than a significant up-scaled production? However, the production continues due to prosperous expectations to eco-tourism.

Tanks were long steel tanks 11-12 m^3 each. Totally 32 tanks, 6 tanks (round) in other room for broodstock; water supply separate; wintering possible, lowest temperature 2.5 ^{o}C. Water treatment tanks were also steel and using rebuilt drum filter taken lately in use; the system was in principle working. Only the double pumping (above) caused extra energy costs. Diffusers were used to feed ozone in the cycle in current flow reactor where also foam removal device existed.

Tanks were equipped with sludge separating "cone" at the end of each tank (in front of screen). The water was recycled in each tank using airlift, which striped CO_2. Natural temperature control was used to regulate spawning (river water, ground water). Hand feeding. Biofiltration was using submerged bed in combination with trickling filter as aeration tool.

Fresh water intake 20-30m^3/daily. Total amount of water 900 m^3; Q=300 m^3, for biofilter 200 m^3.

Ozonation was pretty strong (capacity 2.5 kg/day) currently about 400 g per day. Nitrogen compounds like ammonium and nitrite were low and nitrate about 200 mg/l. No UV device.

Start feeding was going on in small plastic tanks that were supported in long steel tanks so that they were submerging about 20 cm in steel tank water.

Improving the farm economy might be possible with some adjustments in pumping and water treatment. Maybe speed control with pumping. UV together with ozone is effective and reduces risk of getting strong ozone to fish. But on other hand this farm seems to work well with fishes in good condition.

Bogushevsk trout farm, Vitebsk region

Reconstructed farm using "model trout farm" principles.

Director **SERGEJ VIL'CHINSKY** explained about the farm, which produced about 50 tons of mainly rainbow trout and gold-trout/year. They buy fry/fingerlings and grow them to marketable size, i.e. average 1,3 kg.

Due to freezing the trout are overwintered in ponds. Ice removed by hand for maintenance feeding. Temperature was 1 ^oC.
Used bore hole water for mixing in summer, when temperature in river water may be up to 22 ^oC.

Recirculation system simulating Danish Model farm concept:
Concrete parallel connected tanks for fingerling. Airlift pumped the water in full speed affecting the uneven distribution of water flow to the different parallel channels. This should be corrected to get better growth results. Possible way might be to prevent the free flow to channels so that the flow needs 3-4 cm level difference from inlet channel to each fish channel.

On growing serial connected tanks. Airlift. Biological filter before mechanical filter caused inefficiency. Filter material of mechanical filter (small plastic units) seemed not efficient.

Stocking density: 25 kg fish/m^3. Oxygen level low (5 mg/l in outlet).
FCR 1.1 – 1.3 - high. Maybe due to low oxygen and high NH_3 (inefficient mechanical and biological filtration and low oxygen level). Feed was rather expensive (~ EURO 2,5/kg) due to import taxes and tolles.
Disease problem with "White spot disease" (*Ichtyophtirius multifilis*). Treated with salt and malachite green.

Government stimulates investments in aquaculture for governmental enterprises including cheap bank loan. However, investments by private companies in aquaculture may have difficulties to obtain bank loan and the interest rate will be from 30 % to 8-7%, credit for 8 years; loan should be payed back after 1 year after starting the production. The inflation is about 30 %/year.

Russia support aquaculture significantly, i.e. economic support for purchase of feed, medicine, vaccination etc.

10th April 2013

Belarusian State Agricultural Academy, GORKI, Mogilev region.
Department of Ichthyology and Fish Farming.

Director **ALEXANDER NEKRYLOV** explained about the newly installed recirculation system including separate hatchery, fingerling and on-growing sections. All systems had mechanical (micro sieve, 30 micron), biological/trickling filters (incl. moving bed), UV and O_3 treatment.

Before entrance visitors were requested to wear shoe covers and plastic coat.

The total volume of the recirculation facility was 1000 m^3. 5 % water exchange/day, i.e. 4 m^3/h fresh water – 9 – 11 ^oC.

The **hatchery** included 54 trays. 900.000 eyed eggs imported from France. We were not allowed to enter the hatchery due to risk of contamination/disturbance.

No treatments against disease/prevention. 5 % mortality until 0.5 g stage in hatchery (45 days).

Fry facility – 8 circular tanks for growing from 0.5 g fry to 5 g fingerling.

Fingerling facility – 40 circular tanks (Ø~ 5 m) - 18 m^3 tanks each stocked with 30.000 fry about 3 g. Density ~ 5 kg/m^3. For growing from 5 g to 50 g fingerling sold for on-growing to marketable size.

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Oxygenation in each tank by diffusers in closed pipes (Ø~ 30 cm) vertical along the side of each tank. Water inlet in bottom of the tank, which may impede uniform water circulation in the tank? Maybe checked with colorant?

The whole facility was on-line computer monitored with sensors for vital water quality parameters. However, NO_2 and NO_3 were manually checked 4 times per day and so was Fe and P level once per week.

No diseases were registered. During startup feeding this first time the fish were stressed due to high nitrite and solids in the water. Salt was diluted using "swimming" salt bags in tanks. Feeding was reduced in several tanks. Hope the ozone will help improving water quality. O_3 level in room were controlled.

The biofilters were activated by specific bacteria strain (buy dry, activated in water).

Production target was to produce juveniles (50 g/pcs) for a 3000 ton production/year. Currently the production was 100 tons/year, so a huge gap to be filled in/market development.

Profit goes to Academy. Roe + feed paid by the government.

Price: 50 g/psc.; 18$/kg
Ab farm: 10 $/kg for market.
80.000 BR rubles/kg price in the fish farm; on the market same fish price is 160.000 BRr/kg; imported salmon cleaned 80.000 BRr/kg; imported trout salted 200.000BRr/kg.

Prod. Costs: 4.5 $/kg?

The farm was planning their own brood stock production in Gorki area – to have 4 times delivery of eyed eggs/year.

Current total trout production in BY 100 tons/y. In 2016 is expected 3800 tons production of trout.
15 - 25 new recirculation farms were planned at selected sites.

In addition to governmental plans, private companies take initiative to establish facilities and somehow supported by the government. They can get loan from governmental investment bank after approval of a business plan. 7 - 8 % interest rate. Payback starts 1 year after production has started and the pay off period was 8 years. Normal interest rate was 30 % similar to yearly inflation rate.

Sturgeon (Starlet): Ultrasonic technique to sort male/female was tested. Grow from 10 to 500 g each in 10 months. Further 6 months they may grow to 1 kg. Break-even price (recirc.) 14 $/kg. In traditional farm (pond) production the

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break-even price was 10$/kg.
It means competition between pond and recirculation farms. Maybe only caviar production in recirculation systems.

Total import of all kind of fish to BY: 160.000 - 180.000 tons/year. Of this about 4.500 – 6.000 tons valuable fish, mainly salmon and trout (90 %), which may be competitive for the farming sector?

The biggest sturgeon company in Belarus produces about 80 tons/year sturgeon in cooling water from power plant. The production is exported to Moscow due to purchasing power in Belarus.

Import tax: Fingerling – 10% + 18 % customer tax
Market fish – 20 % + 18 % customer tax

Fish consumption in BY: 16 - 17 kg/cap/year.

Meeting with **Administration of Belarusian State Agricultural Academy, Gorki.**

Rector KURDEKO ALEKSANDR welcomed the group to the Academy. Nikolai introduced the group for Rector and the Dean. Rector and the Dean explained about the academy and the activities and perspectives. Jouni gave a brief presentation of AQUABEST project.

REMONA Ltd sturgeon farm – Mogilev region.

Director of the farm **VLADIMIR** explained about the farm.

It was 3 years old producing about 6 – 6.5 tons sturgeon/year for consumption. There were 4 tanks Ø 5 m and 1 m high. The tanks on the other side of the room were rectangular for big sturgeons and the rest were smaller.

Buy fry and grow them from 5 g – 1.5 kg (1 % mortality).

Use water from bore hole 300 m deep – 6 ppt salinity – 10 - 12 ^{o}C.
Central heating to achieve optimal 21.5 ^{o}C in tanks (possible to go up to 25 ^{0}C). Use surplus heat from air compressor and heat from city central heat supply system. Used iron removal facility to remove iron from fresh water.

Produced oxygen (OXYMAT) for Ozone and oxygen cone (2.9 kg/h).

Mechanical filtration (Hydrotec micro sieve) – water goes to a loop with Ozone treatment and skimming. A part of the water passed a biofilter (fixed bioblocks) – also functioning as trickling filter.
There was a separate loop with pump to tanks and separate with another pump to

water treatment. NO_2 and NO_3 were measured every 2-3 days.
60 m^3/h - 90 m^3/h

Water exchange: 0.3 m^3/h, 7 m^3/day; max available amount 30 m^3/h

700 – 800 kg fish/tank

Used 60 kg feed/day

They plan to build own hatchery. They have access to 30 m^3/h water from borehole lifted by own pressure

Showed a hall with several high concrete tanks that have been used for wine. The farmer asked for suggestions on how to use the tanks.
The tanks may be cut down to half height and adapted for small recirculation system for trout, but may be better for charr (temperature, density) production.

The owners plan was to make experiment with a few tanks to grow rainbow trout in conditions with artificial light and aeration.

New tanks and water treatment under construction for expansion.

11th April 2013
Meeting at the **Department of Land Reclamation and Water Management of the Ministry of Agriculture and Food Products of the Republic of Belarus**

ANDREJ SERGEEV introduced the delegates invited for the meeting including:
ANATOLIY MOROZ - Deputy Director of Department of Land Reclamation and Water Management.
SERGEI SVENTORJIZKII - Deputy Head of of the Administration of Growing Valuable Species of Fish.
Svetlana Dunaevskaja – Director "Belgiprovodhoz".

Nikolai introduced the AQUABEST group and the delegates that had accompanied the group during the trip.

The chairman of the meeting Anatoliy Moroz welcomed to the meeting at the Ministry.

Jouni presented AQUABEST project: Best Aquaculture Practices for the Baltic Sea Region.

Alfred presented the joint presentation of him and Peder Nielsen: New trends in Recirculation Aquaculture Systems (RAS). The presentation was followed by questions and discussions of the perspectives of aquaculture production and utilization of recirculation technologies in Belarus.

After this session the chairman concluded, that the meeting had been very informative and useful. The government of the Republic of Belarus stimulates aquaculture development in BY and keeps attention to taking care of the environment and this was in line with fish production using recirculation systems. The government was very interested in international cooperation and he expressed hope for continued mutual cooperation between Belarus and any initiatives mediated through Nikolai, i.e. AQUABEST and others. Showed interest for the RAS training course as well as the RAS workshop in Denmark in October.

Feasibility study group meeting in the Minsk Airport

A summing up meeting of the feasibility study group was held in Minsk Airport prior to departure.

The group made the following tentative conclusions:

1. The feasibility study will based on the current guidelines
2. One or two of the sites already selected in Belarus for establishing aquaculture RAS systems will be selected as cases for the study (Brood stock and on-growing facility). Maybe a private small scale (50 – 150 t) farm will be included as well.
3. Nikolai was asked to provide a few sentences of info for each of the issues/sub-issues of the guideline, preferably medio May. We need a certain amount of specific basic information about the conditions in Belarus to achieve the most efficient and informative feasibility evaluation providing a robust basis for decision on new investments and technology transfer. We aim at identifying and characterize the most important bottlenecks for the case, cf. Objectives of the study.
4. A meeting in the group (including Peder Nielsen) will be held on 21th May 2013 in Riga prior to the AQUABEST project meeting. At this meeting final decisions about the strategy of execution of the study shall be taken and case study plan including time schedule for the work ahead shall be agreed on.

Appendix 2
Event report Riga

Project name:	**Aquabest – Innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region**

Event Report

21st May 2013

General information

Name of the rapporteur	Name of the rapporteur's organisation
Alfred Jokumsen supported by input from the group (Nikolai Balurin and Taitiana Liakhnovitch (BY), Martti Naukkarinen (FI), Armands Roze (LV), Jouni Vielma (FI) and Peder Nielsen (DK)	**DTU Aqua**
Event name	**Name of the event organiser (organisation)**
AQUABEST WP6 – Feasibility study meeting	Institute of Food Safety, Animal Health and Environment
Date of the event	**Location of the event**
21^{st} May 2013	**Riga, Latvia**
Participants from the project in the event	
Nikolai Barulin, Belarusian State Agricultural Academy, Belarus **Taitiana Liakhnovitch**, Interpreter, Belarusian State Agricultural Academy, Belarus **Martti Naukkarinen**, Kalavesi Consultants Ltd, Finland **Armands Roze**, Kalavesi Consultants Ltd, Latvia **Jouni Vielma**, FGFRI, AQUABEST Coordinator, Finland **Peder Nielsen,** NC Consulting ApS, Subcontractor to P10 **Alfred Jokumsen**, DTU Aqua, WP 6 leader, Denmark **Ruta Medne,** Institute of Food Safety, Animal Health and Environment, Riga, Latvia **Marcis Zingis,** Institute of Food Safety, Animal Health and Environment, Riga, Latvia	

Description of the event

Agenda
AGENDA: 1. Discussion (sum-up) of visit in Belarus based on attached report and pictures provided by all participants (except Peder Nielsen, who finally has received a 1 year visa for Belarus)

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2. Presentation and discussion of input from Nikolai Balurin to the feasibility report (cf. meeting in Belarus Airport and attached report and following correspondence)

3. Planning next steps:

   a. Data collection
   b. Selection of a case/2 cases in Belarus?
   c. Feasibility fact finding visit in Belarus of Peder, Armands and Martti – Planning and time schedule
   d. Time schedule - incl. structuring of the work/report, division of labor, deadlines of preparation of feasibility study report

4. Other issues

Summary of the event including information about the purpose of the event, matters discussed, results, next steps and other relevant information

Re. 1.
Alfred Jokumsen expressed thanks to the Institute of Food Safety, Animal Health and Environment for hosting the meeting.

Alfred Jokumsen presented the event report from the visit in Belarus in April 2013 as well as series of pictures from sites visited. Various issues were discussed and clarified among the group participants.

Re. 2.
Nikolai Balurin and Taitiana Liakhnovitch presented information on issues/sub-issues of the Feasibility study guideline, i.e. information about specific conditions in Belarus to achieve the most efficient and informative feasibility evaluation providing a robust basis for decision on new investments and technology transfer. Further to identify and characterize the most important bottlenecks for the case. Several questions and issues were discussed and the presentation provided a good basis for the ensuing work with the feasibility study and the report.

Re. 3.
Based on the discussions it was concluded that the work to be done in the ensuing months included:

1. Based on the information so far (including the Event Report of the fact finding visit in April in Belarus, the presentation of Nikolai Balurin and further information provided/collected Peder Nielsen will prepare a first draft report by 1. July 2013.

2. Nikolai Balurin will send suggestions of sites (2) for the case study.

3. Martti Naukkarinen, Armands Roze and Peder Nielsen plan a fact finding visit to Belarus to collect further requested data and information from 1st – 6th July 2013.

4. The final feasibility report is scheduled to be delivered by latest 1st December 2013.

Re. 4.
Nothing

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Appendix 3
Event report Minsk

Project name: **Aquabest – Innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region**

Event Report

2nd – 6th September 2013

General information

Name of the rapporteur	Name of the rapporteur's organisation
Peder Nielsen supported by input from the group (Martti Naukkarinen (FI), Armands Roze (LV) Jan Kouril (CZ), Nikolai Barulin (BY), Ekaterina Novikova (BY), Tatyana Liakhnovich (BY)	**NC Consulting ApS, (subcontractor DTU Aqua)**
Event name	**Name of the event organiser (organisation)**
AQUABEST WP6 – Feasibility study kick off meeting	Belarusian State Agricultural Academy, Gorki, Belarus
Date of the event	**Location of the event**
2nd –6th September 2013	**Minsk – Stolbzy – Bereza – Beloozersk - Belynichi – Gorki, Belarus**
Participants from the project in the event	
Nikolai Barulin, Belarusian State Agricultural Academy, Belarus **Peder Nielsen,** Nielsen Consultancy ApS. Denmark **Martti Naukkarinen**, Kalavesi Consultants Ltd, Finland **Armands Roze**, Kalavesi Consultants Ltd, Latvia **Jan Kouril,** Assoc.Prof.Dipl.-Ing. Jan Kouril,Ph.D., University of South Bohemia, Czeck Republic In addition the following representatives were met/delegates participated during the visit: **Sergey,** Director of "Alba" fish farm, Stobzy, Minsk region **Bazhenov Jurii**, Director of biggest fish farm in Belarus ''Selec'', Bereza, Brest region **Tsarikov Andrei**, Director of trout farm ''PMK84'', Belinichy, Mogilev region	

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Description of the event

Agenda

The Belarusian partner had prepared an intensive program for the visit (see below) – included Kick-off meeting(s) even though most issues was discussed throughout the event, site visits and meetings. The agenda for the Kick-off meeting included:

1. Visiting the fish farms
2. Consideration of visited fish farms
3. Discussions and suggestions for completing the study of feasibility
4. *Change in the objectives of feasibility study*
5. Structuring of the feasibility study – division of labor
6. Time schedule
7. Other issues

Participants in the feasibility study group:

Nikolai Barulin, Partner 9, Belarusian State Agricultural Academy, Belarus
Martti Naukkarinen, Kalavesi Consultants Ltd, Finland
Armands Roze, Kalavesi Consultants Ltd, Latvia
Peder Nielsen, NC Consulting, Denmark
Jan Kouril, Assoc.Prof.Dipl.-Ing. Jan Kouril,Ph.D., University of South Bohemia, Czeck Republic
Taitiana Liakhnovitch, Interpreter, Belarusian State Agricultural Academy, Belarus

Work meeting on WP6

(Draft programme)
September 2th – 6th, 2013 Belarus

PROGRAMME

Date, time	Place	Notes
02/09/2013, Monday		
15.00 – 20.00	Minsk	Arrival at the airport. Hotel accommodation in Minsk. Dinner.
03/09/2013, Tuesday		
7.00	Minsk, hotel	Breakfast
8.30 – 14.00	Stolbzy, Minsk region Fish farm “Alba”	Travel to the city Stolbzy. Visit to construction site of trout fish farm (recirculating aquaculture system (RAS)
14.00 – 15.00	lunch	
15.00 – 18.00	Bereza, Brest region	Travel to the sity Bereza.

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	Fish farm “Selec”	Visit to the biggest farm in Belarus ‘’Selec’’
19.00	Beloozersk, Brest region	Accommodation in hotel ‘’Energiya’’. Dinner.
04/09/2013, Wednesday		
8.00	Beloozersk, Brest region	Breakfast
9.00 – 17.00	Belynichi, Mogilev region	Travel to the city Belynichi. Visit to the trout fish farm (RAS, Belarusian project).
19.00	Gorki, Mogilev region	Travel to the city Gorki. Hotel accommodation. Dinner
05/09/2013, Thursday		
8.00	Gorki	breakfast
09.00 – 13.00	Gorki	Visit to the trout fish farm (RAS). Lunch. WP-6 Discussion. Dinner.
13:00-14:00	Gorki	Lunch
14:00-18:00	Gorki	WP-6 discussion
20:00	Gorki	Dinner
06/09/2013, Friday		
8.00	Gorki	breakfast
9:00-12:30	Minsk	Departure
Travel to Minsk. Departure.		

Summary of the event including information about the purpose of the event, matters discussed, results, next steps and other relevant information

2nd September 2013

Welcomed by, Nikolai Barulin and Tatiana Liakhnovitch. Dinner. Kick-off meeting: Nikolai presented the program of the following day’s farm visits and meetings with Belarusian aquaculture experts followed by general discussions.

3rd September 2013

Visit to trout farm ‘’**Alba’’, Stolbzy, Minsk region**.

Leader of the construction work Sergei explained about the place. A total of 25 persons planned to be employed there, but now 8 employers are at this farming site. For the whole enterprise Alba there are more.

The fish farm Alba (mainly cultivated common carp) was established about 30 years ago. The construction site is the first project of RAS for

Alba company. Production planned 200 tons/year – trout up to size ~1kg. Stocking density: ~50 kg/m^3. Water source: Sula river and 2 bore holes (20l/s, 5l/s)

Temperature: river 12–16^{0}C (Summer), bore hole 7-9^{0}C

Target - local market. Size planned – 1 kg.

Feed from Aller-Aqua.

In the plans there were 4 separate recycling systems. The one that was under construction is placed in an isolated building the rest outdoors. The system is U-form raceway having the water treatment in the other end and sludge collectors (cones) in the end of both sides of the channels. The other row of cones will be placed just in front of bio filter. The sludge will be collected in four tanks for settling, and from her the surface water will lead through a approx. 200 m long constructed plant lagoon and from her all the water from the production units will be discharged into the river.

The water will be recycled in the U formed raceways using airlift for transportation, stripping CO_2 and adding some oxygen to the water.

Natural temperature control will be used to regulate the temperature (river water, ground water).

The planned fresh water intake from river is 40l/s in summer time and if necessary ground water 20l/s. There is emergency borehole 5 l/s but it is possible to use both boreholes all year.

Bio filtration will consist of moving media reactor followed by submerged static media filter beds as mechanical filtration.

Improving the economy of the farm might be possible with some adjustments in pumping and water treatment.

''Selec'' fish farm, Bereza, Brest region

The biggest fish farm in Belarus 2.600ha – annual production in 2012 was almost 4.000t (3.100t table fish, 850t fingerlings). Selec has 270 employees.

Director Bazhenov Juri explained about the Selec farm and answered questions connected to the farming activities. The main production is common carp (75-80%, from which 80% is mirror carp), 10-15 % is grass carp, bighead and the rest 5% is pike,

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European catfish, silver carp (Carrassius auratus) and sturgeon (100t).

For sturgeon farming Aller Aqua feed is used with FCR of 1,4. Most demanded size of carp is over 1kg. Every year the quality of the carp is tested with analysis in Brussel. Productivity of ponds is 1-1.5t/ha, max 3.5t/ha and average 1.8t/ha per year.

The company has a processing factory producing 250t/year mainly smoked and dried fish, and another plant producing 300t/year deep frozen vacuum packed fillets. Looking for processed production export to Russia and other countries. There has been small export of live fish to Russia, Lithuania, Latvia, Poland and other countries.

In all Belorussia there are 6 processing factories, with a future plan of establishing 3 new ones. Profitability with recent prices had been 1%-2%. For this year the price for carp is planned to be raised to 2.9USD/kg to reach 10% profitability. If it won't be possible, the profitability goes back to same level. Biggest problem is connected with feed purchases for carp, pellet feed and grain. It is necessary to take a loan for feed from bank; 3-year old eat 10.000 t per season (20% grain, 80% pellets), support from state is 4% from value of all feed. Own ability is to cover 22% from all feed expenses, other is borrowed from state. There was a not any tax for agricultural production till 2012.

In the discussions, different main problems for the industry was defined:

- Market is shared by authorities in different regions which causes higher running costs
- Interest rate is high for borrowed money
- Employing problems to retain workers (drivers, pond workers, guardians etc.) because competition for employers exists in the area where 5 new enterprises established attracting ~600 employers.

Some numbers describing potential market for aquaculture production in 2012:

- Total amount of consumed (fresh and see) fish 180.000 t/year, which means 18 kg/cap/year;

- only 16.000t was domestic aquaculture production which means 1.6kg/cap/year;

- 1.000 t was industrial fishery input.

4th September 2013
Trout farm, RAS, Belynichi, Mogilev region

The new recirculation system that was under construction was built using the same design as in Alba project.

The total water volume in all 4 raceways was approx. 780 m^3 with a tank depth 1.3 m Current stocking density: below 10 kg fish/m^3, in all system 6t of rainbow trout, the water circulation was slow approx. less than 2 cm/s, due to that were sludge settlement seen in all of the system.

The outdoor concrete tanks were parallel 4 channels and recycled water was pumped by one airlift. The return flow was arranged using one channel on one side of the four raceways. An uneven distribution of water flow to the different parallel channels was noticed.

This should be corrected to reach the farms full potential. A possible way might be to prevent the free flow to channels so that the flow needs 3-4 cm level difference from inlet channel to each fish channel.

Moving bed reactors could be provided with screens that would keep the bio media migrating randomly in the filter sections. The order of bio filters was opposite to the practice for example in Denmark.

First was moving bed and after that the static bed, which main purpose is to reduce smaller particles in the water. Due to the fact that the smaller particles are not removed before the water entering the moving bed filter is causing restricted capacity of nitrification in the filters.

The flow in the system should be generated with propeller pump(s) getting better economy (because of higher efficiency of pumping compared to the existing airlift). The airlift pump has the lifting height of appr. 25 cm. The capacity of blowers should be used to aerate the water and to add oxygen using diffusers that would be placed only max 1 m deep having lower energy consumption.

Besides the running system, a new model is building under roof conditions but with same technology: after fish tank is located sludge cones and nearby moving bio filter media after that is fixed media filter for particle removal.

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5th September 2013

Belarusian State Agricultural Academy, GORKI, Mogilev region. Department of Ichthyology and Fish Farming.

Director **ALEXANDER NEKRYLOV** explained about the newly installed and almost one year running recirculation system including hatchery, fingerling and on-growing sections. All systems had mechanical (drum filters 30 micron), biological/trickling filters (incl. moving bed), UV and O_3 treatment.

Before entrance, visitors were requested to step in disinfection solution.

The total volume of the recirculation facility is 1.000 m^3. 5 % water exchange/day, i.e. 4 m^3/h fresh water – 9 – 11 ^oC.

The **hatchery** includes 54 trays. 800.000 eyed eggs imported from France. We were allowed to enter the hatchery (It was not a time of incubation).

No treatments against disease/prevention. 5 % mortality until 0.35 g stage in hatchery.

Fry facility – 8 circular tanks for growing from 0.35 g fry to 10-15 g fingerling.

Fingerling facility – 40 circular tanks (Ø~ 5 m) - 18 m^3 tanks each stocked with 30.000 fry about 3 g. Density ~ 5 kg/m^3. Growing from 5 g to 50 g fingerling to be sold for on-growing to marketable size. Oxygenation in each tank by diffusers in closed pipes (Ø~ 30 cm) vertical along the side of each tank. Water inlet in bottom of the tank, which was checked with colorant which showed that there is even distribution of water in the tank collecting only small amount of sludge around the inlet pipe basement.

The whole facility is on-line computer monitored with sensors for vital water quality parameters. However, NO_2 and NO_3 were manually checked 4 times per day and so was Fe and P level once per week.

No diseases were registered. Ozone treatment helps to improve water quality. O_3 level in the room was controlled.

Production target is 150 tons/year – 50 g/pcs.

Profit goes to Academy. Roe + feed paid by the government.

Feasibility study group meeting at the Belarusian State Agricultural Academy 5th of September 2013

The group went through the second draft for the Feasibility study and made the following tentative conclusions:

1. Due to the fact that the part of fish farming business that the feasibility study is planned for, is so small in volume that the future progress of trout production will totally change the economical environment in few years (even one 500 t unit would triple the production). This would cause false results in the study.

   Because of the general lack of validity of this basic information, the group decided to focus on the technology transfer in the study instead of special focus on the economic issues. The study will solely concentrate on the direct production costs associated with the model farms technology. This decision corresponding with our agreement on the Riga meeting previous this year.

2. It was decided that one or two of the RAS sites, already designed or under construction in Belarus, shall be selected as cases for the study.

   Nikolai was asked to decide which of the farms shall attend the study and supply the group with the necessary information about the sites, including drawings.

3. We still need a certain amount of specific basic information about the conditions in Belarus to achieve the efficient and informative feasibility evaluation providing a robust basis for decision on new investments and technology transfer. The group therefore decided to send a questionnaire to selected fish farms to try to gather the information. The questionnaire is shown below:

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Basic information

Type of farming
Pond farming
Flow- through system
Cage farming
RAS

Species
Trout (rainbow, brown trout, brook trout, etc.)
Sturgeons (Beluga, etc.)
Catfish (European, channel, etc.)
Carp
Other species (please write what kind)

Production
Annual production in 2012 (in tons)
Annual sold fish in 2012 (in tons)

Sales per 2012

Average price per kg in 2012

Product
Live
Round fish
Other (please define-fresh,frozen,smoked,etc)

Economy

Fixed costs

Production licenses and monitoring
Salaries for the employees
Advertising
Electricity
Travel
Research and development expenses
Insurance
Other

Investment costs total

Capital costs and taxes
Capital interest % short term <1 year
Optional return on capital % long term > 1 year

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<u>Variable costs</u>

Egg/ Fry/ Fingerling costs
Insurance
Vaccination
Medicine
Fuel
Electricity
Liquid oxygen
Transport
Waste water

The main purpose with the questionnaire is to expand the data material

The questionnaire will be send to selected fish farmers in Belarus

4. The information gathered during our visit will be implemented in the third draft for the feasibility study this draft will be prepared by NC Consulting ApS, and send to the group around the 1st of October so the group has time to response to the report before we meet in Aalborg at the 2nd workshop on recirculating Aquaculture systems at the 10th to the 11th of October.

Other market information
Government stimulates investments in aquaculture for governmental enterprises including cheap bank loan. However, investments by private companies in aquaculture may have difficulties to obtain bank loan and the interest rate will be from 30 % to 8-7%, credit for 8 years; loan should be paid back after 1 year after starting. The inflation is about 30 %/year.

In 2012 pond farming achieved planned results – totally 16.600 t market fish, hereof 500 t only were produced by private farmers. Production from lakes and rivers is overachieved but valuable fish production was only 75% from planned amount.

99% - pond production; 1% - valuable fish 228.9t (trout 71.8t, sturgeon 97.5t, catfish 59.6t).

Till 2015 is planned to reach 3800 t annual production.
Trout farm Bogushevsk – actual cost (prime cost of trout) in 2012 was 45-50.000BR, but sales price was 72.000BR.
Trout and sturgeon feed price from Poland was 1.5-1.8Euro/kg

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Appendix 4
Event report Pärnu

Project name: **Aquabest – Innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region**

Event Report

31 October – 1st November 2013

General information

Name of the rapporteur	Name of the rapporteur's organisation
Armands Roze (LV) **Peder Nielsen (DK)** **Martti Naukkarinen (FI),**	**Kalavesi Consultants Ltd** **NC Consulting ApS** **Kalavesi Consultants Ltd**
Event name	**Name of the event organiser (organisation)**
AQUABEST WP6 – Feasibility study kick off meeting	**NC Consulting ApS** **Kalavesi Consultants Ltd**
Date of the event	**Location of the event**
30th –1st September 2013	**Pärnu, Estonia**
Participants from the project in the event	
Peder Nielsen, Nielsen Consultancy ApS, Denmark **Martti Naukkarinen**, Kalavesi Consultants Ltd, Finland **Armands Roze**, Kalavesi Consultants Ltd, Latvia In addition the following representatives were met/delegates participated during the visit: -	

Description of the event

Agenda
The agenda for the meeting included: 1. To finalize the recommendation for the already existing Belorussian farms to improve their performance. 2. To decide and prepare the contents of technical recommendations for modeldambrug of Belarus. 3. To decide the contents of the report on the basis of Aquabest feasibility study guidelines and find out if we can use existing

calculation models.

4. To decide finalizing of work, share the rest of work among our group and have the time plan for it agreed.
5. Other issues

Participants in the feasibility study group:

Martti Naukkarinen, Kalavesi Consultants Ltd, Finland
Armands Roze, Kalavesi Consultants Ltd, Latvia
Peder Nielsen, NC Consulting, Denmark

- **- Nikolai Barulin**, Partner 9, Belarusian State Agricultural Academy, Belarus, as external participant.

Work meeting on WP6

October 30th – 1st, 2013, Estonia

PROGRAMME

Date, time	Place	Notes
30/10/2013, Wednesday		
22.00 -	Parnu	Arrival at the Tallinn airport. Travel by car to Pärnu.Hotel accommodation in Parnu.
31/10/2013, Thursday		
8.00	Parnu, hotel	Breakfast
8.30 – 14.00	Legend hotel Conference room	Working on the project
14.00 – 15.00	lunch	
15.00 – 19.00	Legend hotel Conference room	Working on the project
19.00	Parnu	Dinner.
01/11/2013, Friday		
7.00	Hotel	Breakfast
8.00 – 12:00	Legend hotel Conference room	Working on the project
12:00 -	Parnu - Tallinn	Travel to the Tallinn airport.
Travel to Tallinn. Departure.		

Summary of the event including information about the purpose of the event, matters discussed, results, next steps and other relevant information

30th **October 2013**

31st October 2013

The third draft for the feasibility study and feasibility study guidelines was prepared by NC Consulting ApS and discussed in the group.

The answers on questionnaire were discussed.

The group finalizes the recommendation for the already existing Belorussian farms to improve their performance.

The group discusses and prepares the contents of technical recommendations for modeldambrug of Belarus.

The decision about the contents of the report on the basis of Aquabest feasibility study guidelines is still open.

The group shares the rest of work among the group and has the time plan for it agreed.

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1st November 2013

Feasibility study group went through the third draft for the Feasibility study and made the following tentative conclusions:

1. Because of incompatibility of this questionnaire information, the group decided to send a new request of questionnaire to selected fish farms to try to gather the information again.

2. We still need a certain amount of specific basic information about the conditions in Belarus to achieve the efficient and informative feasibility evaluation providing a robust basis for decision on new investments and technology transfer.

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Appendix 5
Partial translations of the five year plan

STATE PROGRAMME
on the development of fishery management for 2011 – 2015

Passport of the State programme on the development of fishery management for 2011-2015

Name of the State programme	State programme on the development of fishery management for 2011-2015
Reason for the development of the State programme	Order of the Council of Ministers of the Republic of Belarus d/d 11 February 2010, № 06/18
Acquirer and coordinator of the State programme	Ministry of Agriculture and Food
Principal writers of the State programme	Ministry of Agriculture and Food , Institute of Fishery of the National Academy of Sciences of Belarus
Objectives and targets of the State programme	providing stable supply of high quality fish to the population of the republic; increasing consumption of gourmet fish and their products; exporting fish; increasing overall output of fish products ; import substitution; sustainable use of fish resources in fishing areas
Key activities of the State programme	development of pond fish culture and industrial aquaculture; construction and renovation of breeding complexes to get stocking materials of salmons, sturgeons, whitefishes; setting-up a new capacity for commercial growing of salmons, sturgeons, catfishes; sustainable use of fishing areas, preservation of biological diversity of fish; processing of home-raised fish; import reduction
Customers and contractors of the State programme key activities	Ministry of Agriculture and Food, Administrative Department of the President of the Republic of Belarus, Ministry of Finance, Ministry of Natural Resources and Environmental Protection, the republican state-public association "Belarusian hunting and fishing society" , regional and district executive committees
State programme funding allocation and sources of funding	total costs of the state programme implementation – 1 880 492.2 million rubles (measured in 2010 rubles), including funds from the republican budget – 291 806 million rubles, funds from local budgets – 91 758 million rubles, bank loans – 466 015.2 million rubles, long-term bank loans – 604 540 million rubles, international credits – 300 000 million rubles , direct investments – 88 300 million rubles, equity funds – 21 050 million rubles, finance leasing – 17 023 million rubles

1. STATE PROGRAMME FEASIBILITY STUDY

One of the main tasks of the Ministry of Agriculture and Food is creating conditions for enhancement of food and agricultural resources, improving supply of the population of the republic with high quality food stuffs. According to the food-based dietary guidelines, approved by the Public Health Ministry, average annual consumption of fish and sea food is to be from 16 to 24 kg per man (depending on their age and physical activity). Not less than 200,000 tons of fish and fish products is needed to meet the demand of the population. The maximum volume of fish and fish products imported to the Republic of Belarus in 2006 was 193 K tons, which includes 140.5 K tons of imports and 2.5 K tons of undocumented imports. According to the data from the National Statistical Committee of the Republic of Belarus (Belstat) resource provision of the internal market with fish in 2010 was 211.9 K tons, of which 165.1 K tons was imported (139.6 K tons – imports, 25.5 K tons – undocumented imports). Imports of fish and fish products basically consisted of frozen fish – 91.5 K tons, frozen fish fillet – 27.5 K tons, finished fish products or preserved fish (tinned goods, semipreserves, caviar) – 6.7 K tons. Import of freshwater frozen fish was 3.4 K tons (share of fresh water fish in the total import – 2 percent), freshwater fillet – 6.6 K tons (4 percent of the total import). Altogether, import of freshwater fish was 10 thousand tons. Own produced fish and fish products, including amateur fishing, in 2010 constituted 23.2 K tons. 32.6 K tons of fish and fish products was exported in 2010. All in all, 160.5 K tons of fish and sea food was consumed, personal consumption being 149.6 K tons. Average per capita consumption of fish and fish products increased from 9.5 kg in 2000 to 15.8 kg in 2010. Customer share of fish from inland water bodies made up 13.8 percent of the total volume (2.4kg per capita).

The State programme includes a package of measures ensuring accomplishment of tasks to boost production of fish and fish products at affordable prices, to raise level of consumption of fish and fish products per capita and to achieve full import substitution of freshwater fish by 2015.

2. OBJECTIVES AND TARGETS OF THE STATE PROGRAMME, EXPECTED RESULTS

The objective of the State programme is to provide stable supply of high quality fish to the population of the republic and to export fish products. The main target is to raise overall production of marketable fish to 33.2 K tons by 2015, to increase volume of freshwater fish processing to 4.3 K tons per annum. To reach the targets the following tasks are to be solved:

- creation of 16 specialized industrial complexes to grow commercial yield of salmons, sturgeons, catfishes; creation of sturgeon complexes, two specialized fish hatcheries-multiplying farms to produce stocking material of salmons, whitefishes and other species of fish;
- carrying out multicenter studies aimed at strengthening genetic potential of fish, introduction of new breeding methods, cheapening of fish food and raising quality of feeds, introduction of economically sound innovation technologies of rearing valuable species of fish;
- development and conservation (in Belarus on the basis of trout and sturgeon complexes) of brood stock of native and commercially valuable species of fish (sturgeons, salmons, whitefishes, carps, herbivorous fishes) consisting of 105 K fishes as a backup gene pool to form and replenish local fish populations;
- business facilitation of exporting fish products and securing competitiveness of output products; promotion of entrepreneurship, expansion of service industries, ensuring employment of the population; sound management of bio resources of natural reservoirs;
- formation of sustainable fishery resources and introduction of up-to-date industrial processing of freshwater fish on fish-rearing farms; fine-tuning technologies of growing marketable salmons, sturgeons, catfishes and other species of fish on different types of farms in the conditions of Belarus

To fulfil the objectives and to solve the specified tasks it is necessary in the course of the State programme

- to create new and develop existing aquaculture complexes for growing promising fish varieties;
- to carry out technical re-equipment of fish-rearing enterprises;
- to maintain ponds in usable condition;
- to take prevention and treatment measures;
- to lime ponds;
- to manage selective and breeding work and to introduce additional species of fish for optimum utilization of fodder base;
- to support business entities through the creation of favourable economic conditions for their development;
- to produce promising objects of aquaculture;
- to create conditions for reproduction of fish resources;
- to install specialized production lines to make domestic fish feeds for salmons, sturgeons, catfishes and other species of fish;
- to stock fishing areas with 198.2 million fish of different age and to restore natural spawning grounds;
- to do marketing and logistic research;
- to improve the system of industry-based research and education;
- to develop fish farms and recreational fishing;

- to extend cooperation with foreign states in the field of aquaculture on the basis of mutual benefit

- Objectives and targets of the State programme correspond to the Principal directions of social and economic development of the Republic of Belarus for 2006-2015, approved by the Resolution of the Council of Ministers of the Republic of Belarus d/d November 4th, 2006, № 1475 (National register of legal acts of the Republic of Belarus, 2006, № 186, 5/24172). Implementation of the activities envisaged by the State programme will help to produce in the republic 25.2 K tons of marketable fish by 2015 , including pond as well as lake and river fish – up to 19.7 K. tons, lake and river fish – 1.7 K tons, valuable species of fish (salmons, sturgeons and catfishes) – up to 3.8 K tons.

- to output up to 4.3 K tons of fish products per annum;
- to considerably reduce imports of freshwater fish and fish products (by 10 K tons in 2015) and decrease the transfers of foreign currency out of the country;
- to expand the number of jobs at fish-breeding enterprises in rural areas by 28 percent;
- to create conditions for dynamic raise in pay for workers involved in aquaculture;
- to increase the volume of annual budget revenues by 67.5 million rubles;
- to extend the assortment and improve the material of valuable fish;
- to promote investment attractiveness of fisheries sector.

In what follows in the State programme there are following chapters and headings:

Chapter 3 – Resource provision of the state programme
Chapter 4 – Action items of the state programme
4.1. Commercial production of fish
4.2. Pond fish culture
4.3. Industrial aquaculture
4.4. Selection and stock breeding
4.5. Feed production
4.6. Measures to provide security of fish breeding enterprises
4.7. Reproduction of wild animals, falling into the category of fishing objects, preservation and rehabilitation of their natural environment
4.8. Fish processing in the republic
4.9. Canning
4.10. Processing of freshwater fish at fish breeding enterprises
4.11. Modernization of the existing fish processing plants and construction of new production facilities for fish processing
4.12. Human resourcing of fisheries management and fish processing
Chapter 5 – Import capacity of the state programme
Chapter 6 – Science service of fisheries management

Appendix 6
Serial model farm Construction info

Description of design of a model 3 fish farm with parallel connected raceways

This appendix contains a description of and a comparison between the most common design of model 3 farms using serial connected raceways and airlift pumps. Both designs meet the requirements imposed on model 3 fish farms according to the Danish legislation.

In addition, the appendix gives a comparative analysis of traditional model 3 fish farms constructed with serial connected raceways, and the former design. The regulatory requirements for a type 3 model farm, according to Danish legislation on model fish farms are described in Section 6.

Design

The system is based on 15 parallel connected raceways with the dimension 14 x 2.5 x 1.2 – 1.35 m corresponding to a volume of each raceway of approx. 45 m^3

The water distribution is done in open channels to minimize head loos in the system.

This model farm is equipped with mechanical removal of particles by a drum filter with clothing of approx. 40 µm. The sludge water from the drum filter is lead to a sludge thickener containing 3 sludge cones, which shall be emptied regularly.

After the drum filter the water is passed to a moving bed bio filter with a total volume of approx. 155 m^3, 60 % of this volume is bio media, i.e. the amount of bio media is approx. 92 m^3 corresponding to a surface area of approx. 67,160 m^2. According to the Danish legislation this surface area corresponds with an annual use of feed of approx. 168 ton.

After the water has left the bio filter it is passed to a central aeration area designed to stabilize the total gas pressure in the system and at same time keeping oxygen saturation at around 85% of the entire water flow. After the aeration area the water is pumped either through 2 oxygen injection platforms or by the primary pump to the supply channel for distribution between the 15 raceways.

Water and oxygen supply

To provide the fish with sufficient oxygen at water temperatures below 12 – 13 C^o the oxygen supply is done by the primary pump and at higher temperature by the injector platforms. Both the injector platforms and the primary pump are equipped with frequency converters, so the flow can be adapted to the amount of feed used and the standing stock.

The maximum flow rate for the primary pump is 400 l/s, and the max flow through the injector platforms is 240 l/s resulting in a maximum flow of 640 l/s with a possible oxygen saturation of 150 %.

The lifting height of the primary pump is approx. 25 - 30 cm, and for the pumps for the injector platforms the lifting height is approx. 0.9 – 1.0 m.

The necessary amount of fresh water to operate the system is between 3 - 20 l/s, depending on handling sequences and water temperature. This includes approx. 1 l water/s for cleaning the clothing on the drum filter.

In periods with low water temperature below 12 -13 C^o it will not be necessary to use the injector platforms, but they can as well be used in peak situation.

For reasons of treatment options and flexibility, each biological filter has a bypass, which ensures smooth operation of the system during treatment in the system.

Waste water treatment
The water is transported from the 15 raceways through a conic discharge channel to reduce the head loos in the system. The water is passed to and taken out of the single raceway close to the bottom through sluice gates to prevent sedimentation in the raceways and channels.

From the discharge channel the water is passed to the drum filter, which is equipped with filter cloth with mesh size of app. 40 µm. The drum filter can be equipped with a level regulator, which at a given water level in the drum starts the high pressure pump (1 l/s) for cleaning the filter cloth.

The waste water from flushing the drum filter cloth is passed to the sludge thickener, while the main part of the water is passed to the bio filter.

The biological filters are designed as moving bed filters with a total volume of approx. 155 m^3. 60 % filling of bio media of the total volume can be calculated to approx. 168 ton of feed ≈ 460 kg of feed daily.

Practical experience with a similar system shows that more feed can be fed on a daily basis, but it requires high quality feed and proper management.

The capacity calculation is done under the following assumptions:

400 m^2 of active filter surface for every ton of feed used annually [1)]

The filter media has specific surface area of 730 m^2/m^3

After the bio filter the water is passed to an aeration area. In addition to degassing, the centralized pool aerator will normally keep the CO_2 level below 10 mg/l and the TGP at 100 – 102 %. At the same time the aeration area will secure an oxygen saturation level of approx. 85 %

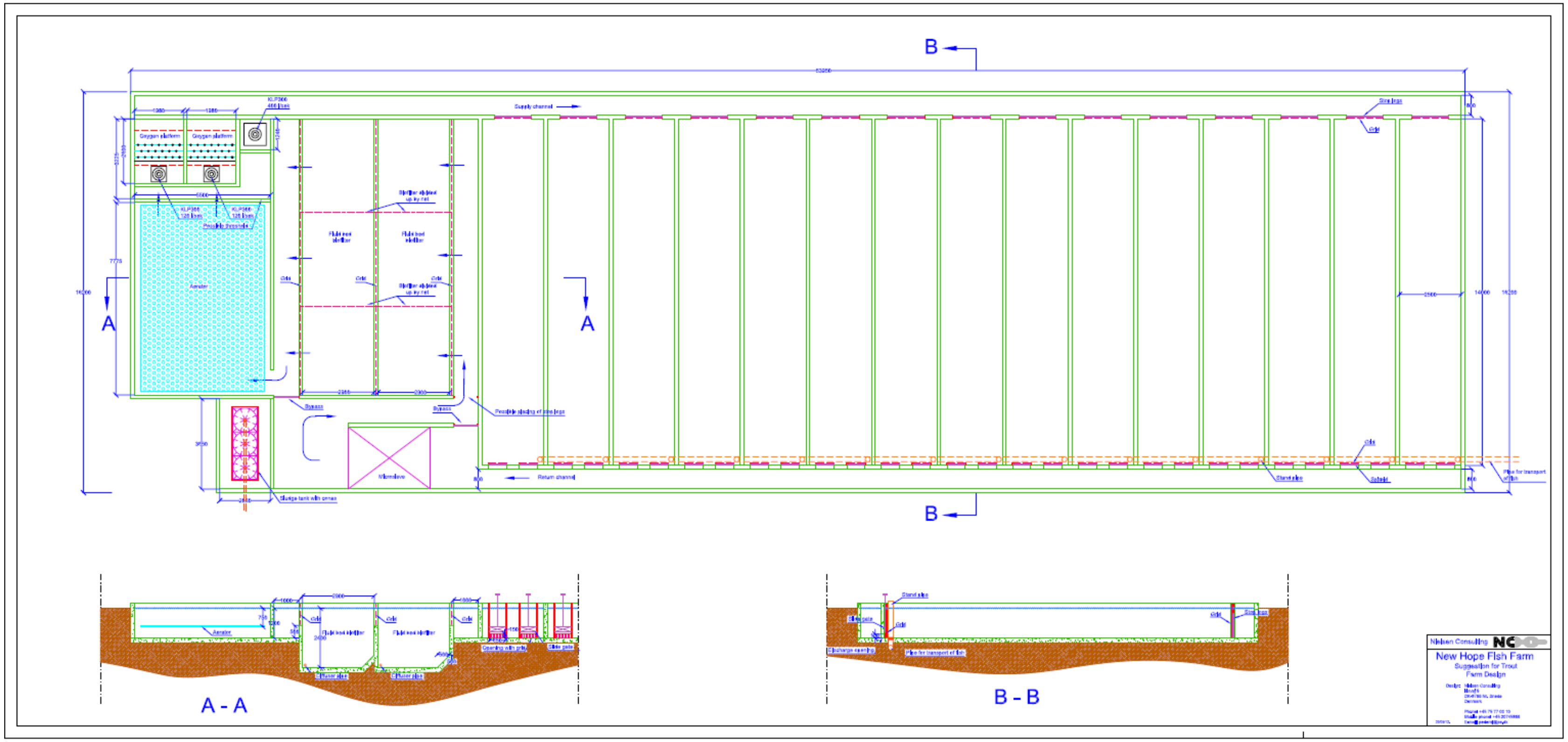
Components:

Equipment name	*Purpose*	*Capacity*	*Energy consumption*
Primary pump	Primary pump	400 l/s lifting height 0.3 m	2.6 KW
2 Pumps for injector platforms	Adding pure oxygen to the water with up to 170 % of natural saturation in 640 l/s	120 l/s each lifting height 1.0 m	2 X 1.6 KW total 3.2 KW
1 Micro sieve	Removal of particles and parasites	Capacity 500 l/s 40 µm clothing	4.5 KW
Capsel blower	Moving and oxidization of the moving bed filter	Capacity 780 m^3 air/hour, at 2.5 m depth.	6.9 KW
2 (Venture) Air blowers	For degassing	Capacity 3.000 m^3 air/hour, at 0,8 m depth.	11 KW

Estimating of the energy consumption it's assumed that one oxygen platform is used all year round together with the primary pump. Total maximum energy consumption	26.6 KW
Energy consumption (KW/kg produced fish). The calculation is performed based on a daily use of feed of 460 kg. Assuming a FCR of 0.91 the production will be 505 kg fish a day	1.26 KW/kg fish produced

Experience shows that the energy consumption will be lower under normal conditions and that an energy consumption of less than 1 kw/kg produced fish is realistic.

Appendix 6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Nielsen Consulting
New Hope Fish Farm
Suggestion for Trout
Farm Design
Design: Nielsen Consulting
Denmark

General SWOT

Model 3 fish farm serial connected raceways	Model 3 fish farm parallel connected raceways
Advantages: Simple design and construction Relative low establishing cost Easy handling of fish Relative low energy consumption. During the public supported model farm project in Denmark the energy consumption on average was 1.7 kW / kg fish produced (without hatcheries) **Disadvantages:** Possibility for sedimentation in the fish free section Sedimentation if not all section of a system is in use Fluctuating TGP and CO_2 levels Fluctuation in oxygen level from one end to another due to the size of each section Fluctuation in oxygen levels from one end of the raceway to the other. Fluctuation in temperature	**Advantages:** Simple design Simple operations More secure production system Easier treatment of the fish Easy handling and cleaning of the raceways Low TGP and CO_2 levels Stable oxygen levels Low energy consumption, can be calculated to approx. 1.26 kW/kg fish produced. **Disadvantages:** Slightly more expensive construction Risk of sedimentation in raceways and channels at low standing stocks

1) During the Master Management project in the period 2006 – 2007 the average FCR at the Model farm's on average was 0.91 this FCR has been used to calculate the energy consumption in the parallel raceway system (kWh /kg fish produced). More than 4 years of experience with this system has shown that the energy consumption has been less than 1.0 kW/kg fish producing fingerlings up to 80 g/pc.

Appendix 7
Questionnaire and results

Fish farm "Selec", Brest region		Cost per t
Annual production in 2012, (in tons)	***3 470,00***	
cost price (euro), including:	5 947 960,69	1 714
salary (with taxes)	1 352 911,93	390
feed for fish	2 870 972,43	827
depreciation	331 976,60	96
services of other organizations	94 983,75	27
energy (gas, electricity, thermal energy)	98 062,79	28
fuel and other petroleum products	266 383,69	77
other costs	266 383,69	77
management of production	666 285,80	192

Fish farm "Beloe", Gomel region		
Annual production in 2012, (in centner)	***801,40***	
cost price (euro), including:	1 450 508,20	1 810
salary (with taxes)	333 469,47	416
feed for fish	740 089,48	923
depreciation	104 407,48	130
services of other organizations	1 772,78	2
energy (gas, electricity, thermal energy)	139 676,49	174
fuel and other petroleum products	42 546,75	53
other costs	88 545,75	110
management of production	-	-

Fish farm "Krasnaya sloboda", Minsk region		
Annual production in 2012, (in tons)	***2 110,40***	
cost price (euro), including:	2 792 130,32	1 323
salary (with taxes)	486 115,25	230
feed for fish	1 293 570,42	613
depreciation	280 472,64	133
services of other organizations	11 663,03	6
energy (gas, electricity, thermal energy)	118 309,82	56
fuel and other petroleum products	153 578,83	73
other costs	272 635,08	129
management of production	175 785,25	83

Fish farm "Krasnaya zorka", Minsk region		
Annual production in 2012, (in tons)	***932,80***	
cost price (euro), including:	1 216 221,18	1 304
salary (with taxes)	301 186,19	323
feed for fish	615 901,50	660
depreciation	138 930,06	149
services of other organizations	5 318,34	6
energy (gas, electricity, thermal energy)	16 981,38	18
fuel and other petroleum products	137 903,71	148
other costs	-	-
management of production	-	-

Fish farm "Lortyshy", Brest region		

Annual production in 2012, (in tons)	***720,80***	
cost price (euro), including:	977 082,33	1 356
salary (with taxes)	97 036,44	135
feed for fish	753 618,60	1 046
depreciation	115 230,78	160
services of other organizations	-	-
energy (gas, electricity, thermal energy)	1 399,56	2
fuel and other petroleum products	9 610,34	13
other costs	186,61	0
management of production	-	-

Fish farm "Grizevo", Minsk region		
Annual production in 2012, (in tons)	***270,2***	
cost price (euro), including:	233 908,92	866
salary (with taxes)	38 383,57	142
feed for fish	95 670,34	354
depreciation	4 617,57	17
services of other organizations	-	-
energy (gas, electricity, thermal energy)	1 154,39	4
fuel and other petroleum products	2 308,79	9
other costs	61 904,33	229
management of production	29 869,92	111

Fish farm "Luban", Minsk region		
Annual production in 2012, (in tons)	***2 180,50***	
cost price (euro), including:	3 403 151,13	1 561
salary (with taxes)	538 091,53	247
feed for fish	1 338 951,80	614
depreciation	124 963,06	57
services of other organizations	36 651,98	17
energy (gas, electricity, thermal energy)	45 887,13	21
fuel and other petroleum products	55 555,17	25
other costs	748 335,39	343
management of production	514 715,06	236

Fish farm "Novinki", Vitebsk region		
Annual production in 2012, (in tons)	***1 440,60***	
cost price (euro), including:	1 549 917,16	1 076
salary (with taxes)	277 198,66	192
feed for fish	771 711,85	536
depreciation	230 012,84	160
services of other organizations	-	-
energy (gas, electricity, thermal energy)	46 464,33	32
fuel and other petroleum products	112 553,34	78
other costs	48 340,21	34
management of production	63 635,92	44

Fish farm "Polesye", Brest region		
Annual production in 2012, (in tons)	***1 211,00***	
cost price (euro), including:	1 730 146,79	1 429
salary (with taxes)	597 109,88	493
feed for fish	574 599,21	474
depreciation	87 012,39	72
services of other organizations	11 543,93	10
energy (gas, electricity, thermal energy)	75 035,56	62
fuel and other petroleum products	162 336,54	134
other costs	190 619,18	157
management of production	31 890,11	26

Fish farm "Svisloch", Mogilev region		
Annual production in 2012, (in tons)	***520,10***	
cost price (euro), including:	581 236,97	1 118
salary (with taxes)	130 013,53	250
feed for fish	264 067,44	508
depreciation	37 084,88	71
services of other organizations	4 328,97	8
energy (gas, electricity, thermal energy)	6 349,16	12
fuel and other petroleum products	27 272,54	52
other costs	62 770,13	121
management of production	49 350,31	95

Fish farm "Soly", Grodno region		
Annual production in 2012, (in tons)	***150,10***	
cost price (euro), including:	225 828,17	1 505
salary (with taxes)	56 709,57	378
feed for fish	45 598,53	304
depreciation	82 394,81	549
services of other organizations	3 174,58	21
energy (gas, electricity, thermal energy)	577,20	4
fuel and other petroleum products	7 070,66	47
other costs	8 946,55	60
management of production	21 356,27	142

Appendix 8
A Investments costs, B Running costs

Construction site preparation (estimate based on Danish price level in Euro)		
	Drainage	
	earth moving and exavacion	**25 000**

Energy supply installations (estimate based on Danish price level in Euro)		
	Establishing main fuse	
	Main cable 100A	
	Mounting of equipment and mainboard	
		50 000

Buildings (estimate based on Danish price level in Euro)		
	Building for breeding facilities 1.400 m2 inclusiv vetilataion	**210 000**

Concrete work (estimate based on Danish price level in Euro)		
	Concrete construction tanks, biofilter channels etc.	**180 000**

Machinery (estimate based on Danish price level in Euro)		
	2 pc VENTUR low pressure blower type HPB 260D, 5,5 KW. Capacity 1500 m3/hour of	
	2 pc WA 3125 rotary blowers 15/18 kW	
	Deere disel enigene	
	2 pc stirres 1,5 kw RW 300 15/6	
	1pc . Hydrotech drumfilter with 40 µm clothing	
	2 pc Grundfos spray pums	
	1 pc sludge pump for drum filter	
	1 pc. Seine	
	1. LMPump Fresh PR400/500 inklusiv motor 400 l/s at 1 mvh.	
	2 pc of oxygen injection platforms with pumps 120 l/s	
		150 000

Equipment (estimate based on Danish price level in Euro)		
	15 inlet grids aluminium	
	15 outlet grids aluminium	
	Frames and U-ion for mounting grids	
	Separation grids for moving bed filters	
	Frames and u-ion for separation grids	
	3 sludge cones	
	Catwalks	
	15 pc. Feeding automats	
	15 pc of stands for feeding automats	
	Diffusor frames and diffusors for degassing	
	Frames and U-ion for bio filter	
	Piping for suplying degasing area	
	Clamps, brackets and fittings	
	Frames and u-ion for by pass at the bio filter	
	100 m3 bio elements	

		155 000
Mounting (estimate based on Danish price level in Euro)		
	Piping valves fitings in connection with mounting	
	Mounting 1 week Danish supervision	
	Transport cost for 2 pcs. 40 HC containers with equipment from Denmark to Belarus	**45 000**

Consultancy services drawings functional test training (estimate in Euro)	**40 000**

Total estimated costs in Euro	***855 000***

		Produced in model 3 system covered by building									
		Target size 1,2 kg starting from 200 g	(price assumption for 200g fish 8,00 € per kg)								
		Production volume	kg/year				**100 000**		**150000**		Carp production
											average
		Production costs									From questionnaire
1.		Salaries/year					€	€ per kg	€	€per kg	
	1.	Manager&biospecialist(1)					12000	0,12	12000	0,08	
	2.	Specialist (tech) (1)					10000	0,1	10000	0,07	
	3.	Workers (4)					20000	0,2	20000	0,13	
	4.	Guarding(2)					10000	0,1	10000	0,07	
	5.	Book keeping(1)					10000	0,1	10000	0,07	
							62000	0,62	**62000**	0,41	0,31
2.		Feed	FCR	€/kg							
	1.	Feed cost with average kg price	1	1,8			**180000**	1,8	**270000**	1,8	0,5
3.		Fingerlings			size g	number					
	1.	350 g (average growing size 1200g)	€/kg	8	200	80 000	**128000**	**1,28**			
				8	200	120 000			**192000**	**1,28**	
3.		Energy	€/kWh	0,1	kW						
	1.	Pumping	l/s	640	6,6		5781,6	0,06	5781,6	0,04	
	2.	Aeration	m3/h	2000	17,2		15067,2	0,15	15067,2	0,10	
	3.	Oxygenation (generator)	0,7 kgO2/kg fish	1,8 kWh/kgO2			12600	0,13	18900	0,13	
	4.	Other energy(lights, ventilation etc)	average round year		1,5		1674	0,02	1314	0,01	
							35122,8	**0,35**	**41062,8**	**0,27**	0,03
4.		Other costs									
	1.	Treatments(chemicals)	€ per kg fish	0,05			5000	0,05	7500	0,05	
	2.	Sludge handling	€ per kg fish	0,02			2000	0,02	3000	0,02	
	3.	Maintenance machinery+equipm	€ per kg fish	0,05			5000	0,05	7500	0,05	
							12000	**0,12**	**18000**	**0,12**	0,08
5.		Fuel									
	1.	Transports	€ per kg fish	0,08			**8000**	**0,08**	**12000**	**0,08**	0,05
6.		Variable costs per kg trout					**4,251**		**3,967**		

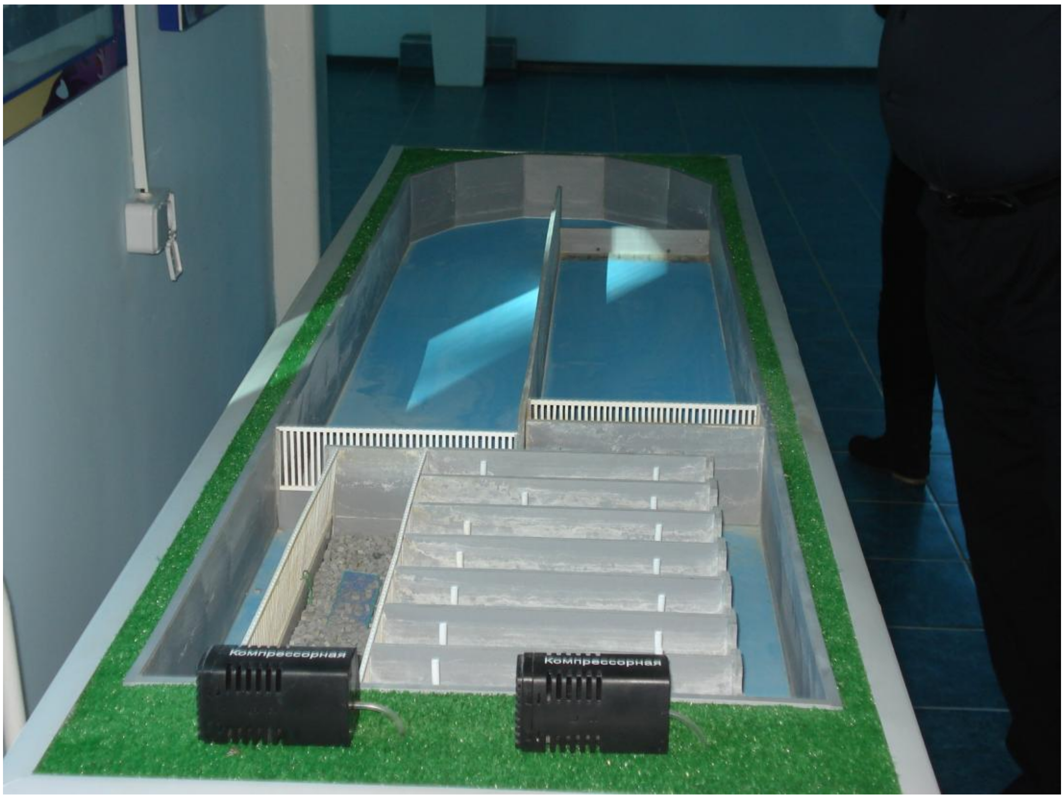
Because increased production could be to certain limits possible with the same number of employed. The possible affect in unit price is a reduction with 0,2 -0,3 €.

Appendix 9 and 9 A
Identified problems
Drawings suggestions for changes

AQUABEST

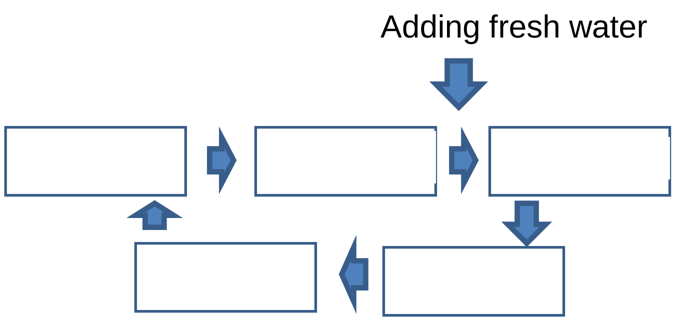
Identified problems

After our visit to Belarus in September 2013 I have received drawing's showing a system similar to the model below which is similar to the most used design for "model" like fish farms in Belarus.



Based on interviews and experience from Danish Model fish farms this design has some frequently occurring problems, this document aims to give one possible solution to the problems.

A flow charge of the design is shown below:



The following problems are often seen connected to this design:

1. Sedimentation in the raceways due to purely particle transportation caused by a huge flow through area and a low flow rate
2. Low operational standing stock due to poor oxygen conditions and different CO_2 level from one end of the raceways to the other end.
3. Airlift pump
4. Accumulation of small particles in the water.
5. Dysfunctional moving bed filter

Ad.1 and 2
Due to a huge flow through area and a low flow rate, sedimentation was common in the raceway, which can lead to serious problems by formation of toxic gases such as hydrogen sulphide and methane. To prevent sedimentation in the raceways and secure particle transport to the sludge cones requires a water speed of approx. 40 cm/s which is very difficult to achieve, only by movement of the water itself. Therefore it's necessary to rely on movement of the fish combined with the water speed in the channels to secure the particle transportation in the raceways.

Experience shows that it will be necessary to have a stocking density of at least 35 kg fish/ m^3 of water for transporting the main part of the particles to the sludge cones.

The low standing stock we observed at the farm we visited can be explained by poor oxygen conditions in the whole system. Therefore it is suggested to divide the two raceways into 4 sections by placing two decentralized aerator units, one in each raceway.

The main purpose with the aerators is to add oxygen to the water and remove CO_2.

With reference to appendix 10 A the total production volume in one system can be calculated to approx. 588 m^3.

The production volume is calculated after implementation of the degassers.

With a stocking density of 35 kg/m^3 the average standing stock can be calculated to 20.580 kg of fish.

The necessary water flow with this standing stock and the below mentioned assumptions can be calculated to approx. 400 l/s.

An average standing stock of fish of 20.580 kg divided into 2 sections (two degassers), the feeding level is assumed to be 1 and the water temperature is assumed to be 14 ^{0}C. The average size of the fish is assumed to be approx. 200 g/pc and the oxygen saturation just after the degasser is 85 % and the lowest saturation that can be measured in each system is 67 %.

The necessary water flow will change due to temperature, feeding level and average fish sizes.

The operation of the system will be improved if the stocking density is increased to 50 kg/m^3, but this will require implementation of adding liquid oxygen to the water through cones or injector platforms.

Ad.3
The water transportation used in the predominant design of existing model farms is airlift. However this design is suggested to be changed to propeller pumps, as lifting water with an airlift has shown to be very inefficient. The efficiency of an airlift operating at a low depth will on average not exceed 10 %.

Normally airlift pumps are used in aquaculture system in serial connected raceways with multiple airlifts. Using this design each airlift only shall lift the height divided by the numbers of airlifts, which normally results in only very few centimeters of lifting height for each airlift.

Based on experience, airlifts are also very sensitive to increase in lifting height, which means that only a few centimeters more lifting height will cause a dramatically decrease in the water flow.

Therefore it is suggested to replace the airlift with two propeller pumps each with a capacity of 150 - 200 l/s controlled by a frequency converter, and at a lifting height of approx. 0.35 m. assuming an efficiency of the pumps of 0.4 the total energy consumption will be approx. 4.0 kW for both pumps.

Ad.4
When the recirculation of water is increased a bigger part of the particle mass can be found as smaller particles, due to pumping, the fish's movement and other mechanical impacts.

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Sludge cones are most effective against huge particles bigger than 100 µm, and less effective against smaller particles. In a flow through system most of the particles can be trapped by sludge cones but in a recirculated system most of the smaller particles must be trapped by a micro sieve or by a fixed media filter. If the particle removal is effected by means of a fixed media filter, the filter must be placed in front of the moving bed filter.

Placing a micro sieve in front of the moving bed filter will reduce particulate mass in the whole system, as a large proportion of the very small particles generated by the moving bed filter will be removed in the fixed media filter.

The problem in the predominant systems is that there will be very few sufficiently big particles to be trapped by the sludge cones, which is due to a combination of low stocking density and a low water speed.

Increasing the stocking density as suggested to at least 35 kg/m^3 will improve the particle removal to each row of sludge cones at the end of each channel. However, it may further be necessary to install one or two micro sieves in front of the moving bed filter to reduce the load of small particles, as the small particles will result in a significant reduction of the capacity of the moving bed filter.

In case it turns out to be necessary to place micro sieves in front of the moving bed filter it is suggested to use two micro sieves with a clothing of 40 µm.

If the micro sieves are level-controlled the energy consumption will be approx. 6 kW for both micro sieves.

Ad.5
In the predominant systems, the inlet and outlet grid from the moving bed filter must be exchanged with grids made of poly ethylene or aluminum. By using polyethylene or aluminum grids with oval holes the bio elements will be rejected onto the grids and this will reduce the head loos by reducing the accumulation of bio media on the grids.

The existing grid is made of metal net, which make them catch the single bio media which cause an accumulation of media on the grid increasing the total head loos through the filter.

The channel which is used as moving bed filter must be separated into 3 chambers, primarily, to separate the bio elements into smaller quantities to improve the hydraulic movement of the media in the filter. This separation can be made of the former inlet and outlet grids.

Further the aeration of the filter must be separated into three sections to improve distribution of air to each filter section.

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With reference to the received drawing I have tried to calculate the theoretically capacity of the filter under the following assumptions.

Moving bed filter in the predominant system

Length 14.87 m
Wide 2.0 m
Water depth 1.8m
Filling rate of bio media 50 %
Surface area m^2/m^3 730 m^2
Volume of moving bed filter 53.5 m^3
Volume of bio media 26.7 m^3
Surface of bio media 19,491 m^2

Assuming a consumption rate of 0.2 g NH_3 + NH_4-N /m^2/day the capacity of the filter can be calculated to 3,898 g NH_3 + NH_4-N /day

Fixed bed filters

'

The filter consists of:
7 chambers
Length 5.75 m
Wide 2.0 m
Thickness of bio media 0.7 m
Surface area m^2/m^3 730 m^2
Volume of bio media 56.35 m^3

Surface of bio media 41,135 m^2

By using the same consumption rate of 0.2 g NH_3 + NH_4-N /m^2/day the capacity of the filter can be calculated to 8,227 g NH_3 + NH_4-N /day

The whole filter capacity is calculated for the moving bed filter and fixed filter, combined under the following assumptions:

A consumption rate of 0.2 g NH_3 + NH_4-N m^2 filter surface/24 hours at 14°C is used in both the moving bed and the fixed bed filter. By using this consumption rate a daily amount of feed can be estimated to approx. 303 kg feed /daily

The consumption rate is in the low end of what can be found on existing outdoor Danish farms.

The calculation is further more done by assuming a contribution of 40 g NH_3 + NH_4-N/kg feed.

At a standing stock of approx. 30,000 kg in one system corresponding to a stocking density of approx. 50 kg fish/m3, and given the suggested changes are implemented it should be possible to produce approx. 100 t table size fish annually in this system.

A production of this size will require an average use of feed of approx. 275 kg feed daily.

To reach the potential of the bio filter of the whole system, it's absolutely necessary to improve particle removal before the water is lead to the moving bed filter, and improve the hydraulic pattern in the moving bed filter.

Final remarks
The suggestion for improvement for the predominant system should be implemented in the following order:

1. Replacing the airlift pump with propeller pumps, and establishing low pressure aerator zones (see drawings)
2. Increase the stocking density to 35 kg/m3 – 50 kg/m3
   If necessary establish the possibility of adding liquid oxygen
3. Replace the sludge cones in front of the moving bed filter with one- or two microsiews.

Ad.1.Replacing the airlift with propeller pumps will stabilize the flow and together with the degassers dramatically improve the oxygen condition everywhere in the system, compared to the current situation it will also make a decrease in the energy consumption due to the fact that the Capsel blower can be switch of and replaced with a low pressure blower, the total energy consumption for pumps and low pressure blower will be approx. 11,5 kWh.

Ad.2. to optimize the particle transportation in the raceways its necessary to rely mainly on the movement of the fish, therefore its necessary to increase the stocking density to at least 35 kg/m3. And even better up to 50 kg/m3 but it will most likely require establishing equipment for adding liquid oxygen to the water

Ad.3. to prevent a decrease in the moving bed filters nitrification capacity it's likely that it will be necessary to place one- or two microsiews in front of the moving bed filter, experience from Denmark shows that it normally will increase the moving bed filters consumption rate of ammonia with up to 30 – 40 %, ending up in a higher growth rate and a higher annual production.

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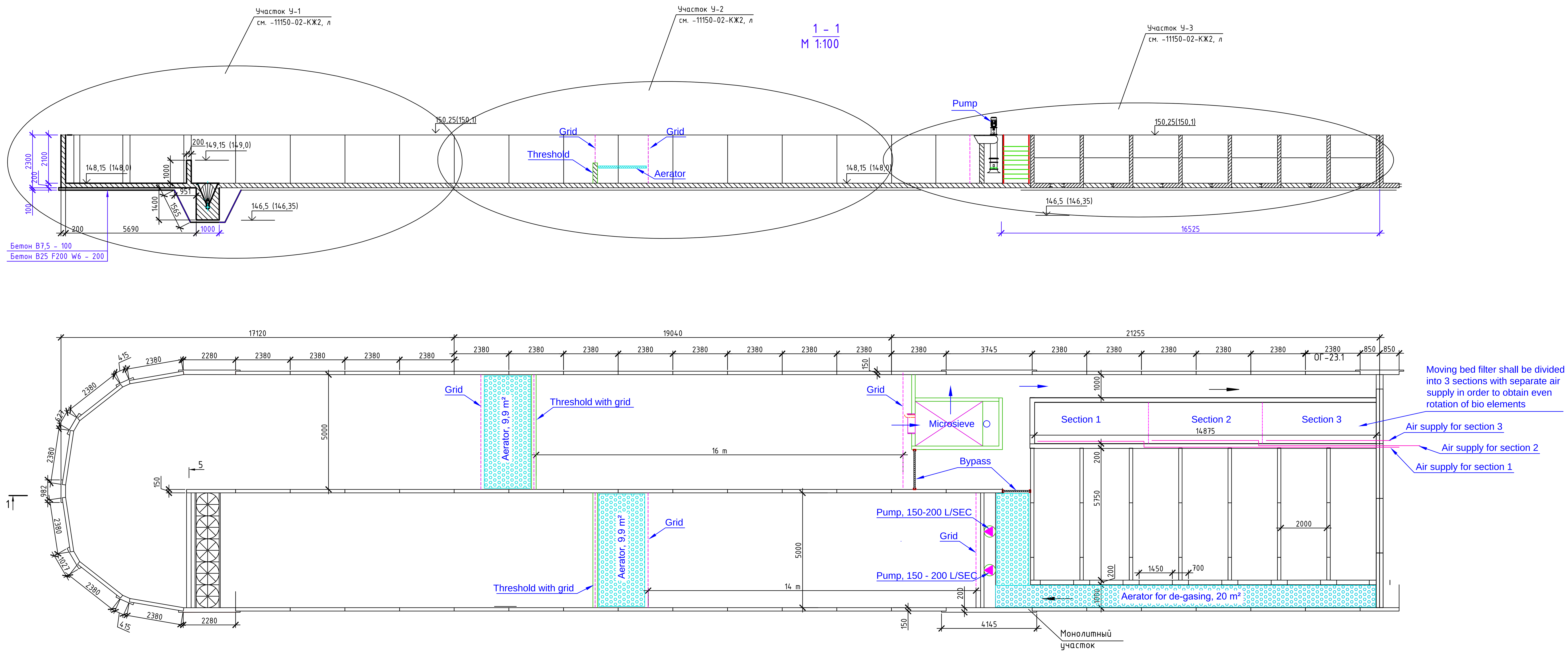

Nielsen Consulting NC

Suggestions for improvements of trout farm in Belarus

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