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# RIVO report

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# Production of market size pikeperch (*Sander luciperca*) in a pilot recirculation system

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# Abstract

A pilot recirculation system was designed and constructed to investigate the production characteristics of pikeperch in recirculation systems. The design is based on a recirculation system for eel production. The pilot system consists of ten 7.5m$^3$ rectangular tanks, a drum filter for solids removal and a trickling filter for biological oxidation of ammonia to nitrate. An Excel spreadsheet was constructed to calculate the dimensions of the different parts of the pilot system. The pilot system was constructed at Philipsen Aquacultuur Horst. Five tanks were stocked with in total 6041 pikeperch. Average weights and stocking densities per tank ranged from 94 to 809g and 11 to 35kg/m$^3$, respectively. Fish performance was monitored by taking sub samples. In addition to the data collected in the pilot system, data collected since 1999 at Philipsen Aquacultuur Horst were used to construct a growth curve and to establish the relation between SGR and body weight for pikeperch reared in recirculation systems. Based on the growth results the productivity in the pilot system was determined and for each tank involved the productivity was evaluated. All the fish performance results served as input for the model for costs of production as developed within the framework of the same project Lucioperca.

Based on the data used in this report the growth of pikeperch in recirculation systems can be described as $W = 0.4006*A^{2.3717}$ (W = biomass (g), A = age (months post hatch)). According to this growth curve pikeperch can be grown to 1050g in 36 months. The SGR was found to relate to body weight as $SGR = 9.0896*W^{-0.4664}$ (SGR (%BW/d), W = biomass (g)).

A high productivity of 134 kg/m$^3$/year was obtained in only one tank. In this tank side conditions for high productivity were met: sufficient initial stocking (>220 fish/m$^3$), good growth (SGR > 0.75%BW/d) and low mortality. In general rearing conditions were often sub optimal and therefore there is room for improvement of the currently obtained growth performance.

# 1. Introduction

Application of a recirculation system makes it economically feasible to heat water for the culture of warm water species in a moderate climate as the majority of the energy required is maintained within the system. In a flow through system energy would be lost by discharge of the culture water.
At present recirculation systems are the only feasible fish culture systems for the culture of warm water species in large parts of Europe. Being a warm water species the development of recirculation system for pikeperch is essential for its culture.

The challenge of this task is not the development of a recirculation system as recirculation systems have been successfully applied for the culture of fish species like eel and African catfish over the last 20 years. Recirculation technology is fully established and systems can be bought of the shelf. Based on existing recirculation technology and knowledge of the biology of pikeperch a recirculation systems adapted to pikeperch can be designed on best available knowledge.
The question is how pikeperch will perform in this recirculation system and what side conditions they demand for good performance.

Goal of this Lucioperca task is to design and construct a pilot recirculation system for ongrowing of pikeperch and to monitor the performance of the fish. The data on growth performance are fed into the cost price model for pikeperch farming developed as part of Lucioperca. The ultimate goal of this task is an answer to the question if and how pikeperch can be farmed economically in a recirculation system.

# 2. Materials and Methods

## 2.1 General

The method applied is the design and construction of a pilot recirculation system for pikeperch in which juveniles are stocked and the growth performance of the fish is monitored. The pilot system was constructed at the fish farm of Philipsen Aquaculture Horst, The Netherlands.

## 2.2 System design

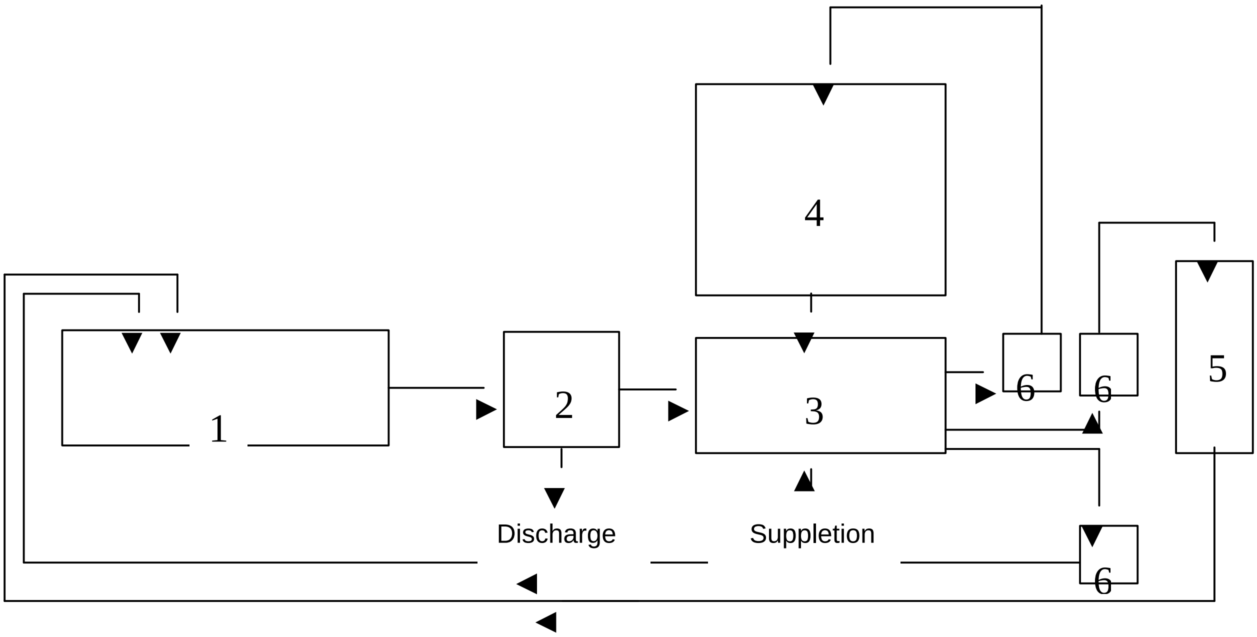
The recirculation system is based on a basic eel recirculation system: mechanical solids removal, biological oxidation of ammonia to nitrate in a trickling filter and oxygenation in an oxygen cone. The basic lay out is shown in Figure 1.

In principle either a sedimentation tank or a drum filter can achieve mechanical solids removal. Both systems are successfully applied in commercial recirculation systems for different species. For this pilot system solids removal by drum filtration was chosen above the use of a sedimentation tank. The reason for this choice is that given the relatively high flow rates expected to be required for pikeperch, a sedimentation tank would become too large and space consuming. A drum filter on the other hand is compact and can handle large flows.

As is shown in Figure 1 the recirculating water flow is split in two flows before being returned to the fish tanks and only one flow is led through the oxygen cone. This way the supply of oxygen and the flow rate over the tanks can be regulated independent from each other and thereby reduces the oxygen consumption of the system.

The system basic lay out as shown in Figure 1 functioned as a starting point for the construction of the pilot system. The theoretical design has been modified at certain points in order to make practically applicable.

*Figure 1: Basic system lay out*




1. Fish tanks
2. Solids removal: drum filter or sedimentation tank
3. Pump sump
4. Trickling filter
5. Oxygen cone
6. Pumps

An Excel spreadsheet was constructed and used to calculate the dimensions of the different components of the system. The spreadsheet consists of different fields dealing with different aspects of the system. These fields include:

- ?? Available space: dimensions of the building in which the system will be constructed;
- ?? Pikeperch: zootechnical parameters;
- ?? Tanks: dimensions and flow rates;
- ?? Trickling filter: dimensions;
- ?? Oxygen supply: consumption, demand;
- ?? Pump sump: dimensions;
- ?? Drum filter: type, dimensions, flow or Sedimentation tank: dimensions, flow;
- ?? Piping unoxygenated flow: flow, dimensions;
- ?? Piping oxygenated water: flow, dimensions;
- ?? Piping tanks to drum: flow, dimensions.

Each field contains data estimated on best available knowledge and data that are calculated from these estimates. The Excel spreadsheet is shown and explained in Results.

## 2.3 Stocking of the pilot system

On the 6th of June 2002 the first two tanks were stocked with juvenile pikeperch. Fish were either obtained as yolk sac larvae from the OVB fish culture centre, Valkenswaard, The Netherlands or originated from reproduction of breeders kept at Philipsen Aquaculture Horst. Before stocking in the pilot system the fish were ongrown to juveniles.
Table 1 provides an overview of the stocking of the pilot system

*Table 1: Stocking of the pilot recirculation system*

| Tank | Date | Total biomass (kg) | Number | Average weight (g) | Initial stocking density (kg/m$^3$) |
|---|---|---|---|---|---|
| 1 | 6-Jun-02 | 260 | 2758 | 94 | 35 |
| 2 | 6-Jun-02 | 192 | 1059 | 181 | 26 |
| 3 | 19-Aug-02 | 178 | 220 | 809 | 24 |
| 5 | 17-Mar-03 | 85 | 370 | 230 | 11 |
| 10 | 18-Mar-03 | 221 | 1634 | 135 | 29 |

## 2.4 Data collection and fish performance

In the past pikeperch was found to be sensitive to sampling. Sampling often resulted in mortality among the sampled fish and strongly reduced feed intake. Therefore sampling was forced to be reduced to a minimum and tanks were only sampled once.
Sub samples were taken at the 12th of August 2003 from tank 2, 3, 5 and 10 to determine the biomass of the fish.
Further, existing data on growth performance collected previously at Philipsen Aquaculture Horst were included in order to obtain as much data as possible.
Ultimate goal of monitoring fish performance was to establish the productivity of the pilot recirculation system, in other words the amount of pikeperch (kg) that can be produced in a cubic meter of system volume in a year. In addition the relation between weight and specific growth rate (SGR) was established. This relation enables to calculate the SGR at any given weight within the weight range for which the relation has been established. Within this project this relation is used in the Ongrowing model to calculate the productivity of pikeperch.

## 2.5 Calculations

Specific Growth Rate (%BM/day) SGR = $(\ln(W_t) - \ln(W_0))$* **Error!**

Feed Conversion Rate (kg/kg) **Error!**

Feeding Level (%/day) **Error!**

Where: $W_0$ = total biomass at day 1

$W_t$ = total biomass at day t

T = number of feeding days

Relation between specific growth rate and weight: SGR ? a ? $W^b$

Productivity (kg/m$^3$/year) **Error!**

Where: $W_0$ = total biomass at day 1

$W_t$ = total biomass at day t

T = number of days

V= tank volume (m$^3$)

# 3. Results and discussion

## 3.1 System design: spread sheet output

The pilot system was designed using an Excel spreadsheet. Below the output of each separate field of the spreadsheet is presented in detail.

**Available space**

| | | | |
|---|---|---|---|
| 1 | Length | 24 | m |
| 2 | Width | 8.5 | m |
| 3 | Area | 204 | m2 |
| 4 | Height | 3.65 | m |
| 5 | Max height biofilter | 4 | m |
| 6 | Max. width biofilter | 2.9 | m |

In this field the space available to place the pilot system is defined. The system is constructed inside a glass green house.

**Pike perch**

| | | | |
|---|---|---|---|
| 7 | Max stocking density | 125 | kg/m3 |
| 8 | Feeding level | 0.60% | /day |
| 9 | O2 consumption | 500 | g/kg feed |
| 10 | Max. fish stock | 9375 | kg |
| 11 | Max feedload | 56 | kg/day |

In the field Pikeperch the zootechnical parameters related to the fish are defined.

7. Maximum stocking density: estimated based on experience.
8. Feeding level: an estimated average feeding level based on experience.
9. Oxygen consumption: estimation based on other fish species.
10. Maximum fish stock: calculated as Max stocking density (7) * Total tank volume (13)
11. Maximum feed load: calculated as Feeding level (8) * Max. fish stock (10)

**Tanks**

| | | | |
|---|---|---|---|
| 12 | Total culture area | 75.0 | m2 |
| 13 | Total tank volume | 75.0 | m3 |
| 14 | Length | 3 | m |
| 15 | Width | 2.5 | |
| 16 | Water depth | 1 | m |
| 17 | Number | 10 | |
| 18 | Area | 7.5 | m2 |
| 19 | Volume | 7.5 | m3 |
| 20 | Max fish stock | 938 | kg/tank |
| 21 | Water renewal rate | 3 | #/hour |
| 22 | Flow rate per tank | 22.5 | m3/hour |
| 23 | Flow rate all tanks | 225 | m3/hour |

In this field the dimensions and flow rates related to the fish tanks are defined.

12. Total culture area: calculated as Tank area (18) * Number of tanks (17)
13. Total tank volume: calculated as Tank volume (19) * Number of tanks (17)
18. Tank area: calculated as Length (14) * Width (15)
19. Tank volume: calculated as Length (14) * Width (15) * Water depth (16)
20. Maximum fish stock per tank: calculated as Max. stocking density (7) * Volume (19)
21. Water renewal rate: number of times per hour the total water volume in a tank is replaced, chosen based on practical experience.
22. Flow rate per tank: calculated as Water renewal rate (21) * Volume (19)
23. Flow rate all tanks: calculated as Flow rate per tank (22) * Number of tanks (17).

**Trickling filter**

| | | | |
|---|---|---|---|
| 24 | Required filter volume | 28 | m3 |
| 25 | Volume | 21 | m3 |
| 26 | Area | 11.40 | m2 |
| 27 | Height | 1.8 | m |
| 28 | Length | 3.8 | m |
| 29 | Width | 3.0 | m |
| 30 | Loading | 2 | kg feed/m3/day |
| 31 | Max hydraulic surface loading | 25.0 | m3/m2/hour |
| 32 | Hydraulic surface loading | 19.7 | m3/m2/hour |
| 33 | Flow rate trickling filter | 225 | m3/hour |

In this field the dimensions and flow rate related to the trickling filter are defined.

24. Required filter volume: calculated as Loading (30) * Max. feed load (11)
25. Volume, actual trickling filter volume: calculated as Height (27) * Length (28) * Width (29)
26. Area, surface area horizontal cross section filter: calculated as Length (28) * Width (29)
30. Loading: amount of food per cubic meter of trickling filter that can be administered to the system daily without compromising water quality, 2 kg/$m^3$/day is a rule of thumb in fresh water systems at 20-25°C based on practical experience.

31. Hydraulic surface loading range: the hydraulic surface loading is a measure for the volume of water that passes one square meter of horizontal cross section of the trickling filter per hour. This should be within a certain range. The maximal hydraulic loading is determined by the minimal required residence time of the water in the trickling filter, the lower limit is determined by the minimal hydraulic loading required to prevent clogging of the filter. For a certain filter volume the hydraulic loading determines the shape.
32. Hydraulic surface loading: calculated as Flow rate trickling filter (33) / area horizontal cross section (26).
33. Flow rate trickling filter: equals at least the flow rate over the fish tanks (23) in order to prevent ammonia accumulation.

**Oxygen supply**

| | | | |
|---|---|---|---|
| 34 | Tanks [O2] in oxygen rich water | 20 | mg/l |
| 35 | Tanks [O2] in low oxygen water | 8 | mg/l |
| 36 | Tanks [O2] out | 8 | mg/l |
| 37 | Flow rate low oxygen water | 125 | m3/hour |
| 38 | Tanks O2 out | 43.2 | kg/day |
| 39 | Max O2 consumption | 28 | kg/day |
| 40 | Required O2 supply | 71.3 | kg/day |
| 41 | Flow rate oxygen rich water | 100 | m3/hour |
| 42 | O2 supply via oxygen rich water | 48.0 | kg/day |
| 43 | O2 supply via low oxygen water | 24.0 | kg/day |
| 44 | Total O2 supply | 72.0 | kg/day |

Tanks [$O_2$] in oxygen rich water: the oxygen concentration in the water supply to the tanks after oxygenation. Based on practical experience.

34. Tanks [$O_2$] in low oxygen water: oxygen concentration in the water supply to the tanks which is not oxygenated: equals the minimal desired oxygen concentration in the system.
35. Tanks [$O_2$] out: the oxygen concentration of the tank out flow. Equals the minimal desired oxygen concentration in the system.
36. Flow rate low oxygen water: is set such that the Total $O_2$ supply (44) corresponds with the Required oxygen supply (40).
37. Tanks $O_2$ out: amount of oxygen that is discharged daily from the fish tanks. Calculated as 24*Flow rate all tanks (23) * Tanks [$O_2$] out (36)/1000.
38. Max $O_2$ consumption: maximal daily oxygen consumption by the fish. Calculated as $O_2$ consumption (9) * Max feedload (11).
39. Required $O_2$ supply: daily average oxygen demand by the fish. Calculates as Tanks $O_2$ out (38) + Max $O_2$ consumption (39).
40. Flow rate oxygen rich water: flow required to supply the oxygen demand. Calculates as Flow rate all tanks (23) – Flow rate low oxygen water (37).
41. $O_2$ supply via oxygen rich water: amount of oxygen daily supplied by the oxygenated water supply to the fish tanks. Calculated as Tanks [$O_2$] in oxygen rich water/1000 (34) * Flow rate oxygen rich water (41)*24.

42. $O_2$ supply via low oxygen water: amount of oxygen daily supplied to the fish tanks by the unoxygenated water supply.
43. Total oxygen supply: total daily supply of oxygen to the fish tanks. Calculated as the sum of 42 and 43.

**Pump sump**

| | | | |
|---|---|---|---|
| 45 | Width | 3 | m |
| 46 | Length | 3.5 | m |
| 47 | Water depth | 0.6 | m |
| 48 | Height | 0.8 | m |
| 49 | Volume | 6.3 | m3 |
| 50 | Area | 10.5 | m2 |

Dimensions set (45 t/m 48) based on available space and calculated (49, 50).

**Drumfilter**

| | | | |
|---|---|---|---|
| 51 | Type | 1601 | |
| 52 | Filter mesh size | 40 | micron |
| 53 | Width | 1.9 | m |
| 54 | Length | 1.4 | m |
| 55 | Flow rate | 225 | m3/hour |

Based on the total flow rate in the system a suitable drum filter was selected from the producer's (Hydrotech) specifications.

**Piping: supply low oxygen water**

| | | | |
|---|---|---|---|
| 56 | Min flow speed | 0.5 | m/s |
| 57 | Diameter piping | 250 | mm |
| 58 | Flow rate | 125 | m3/hour |
| 59 | Flow speed | 0.71 | m/s |

**Piping: supply of oxygen rich water**

| | | | |
|---|---|---|---|
| 60 | Min flow speed | 0.5 | m/s |
| 61 | Diameter piping | 250 | mm |
| 62 | Flow rate | 100 | m3/hour |
| 63 | Flow speed | 0.57 | m/s |

**Piping: fish tanks-drumfilter**

| | | | |
|---|---|---|---|
| 64 | Min flow speed | 0.5 | m/s |
| 65 | Diameter piping | 300 | mm |
| 66 | Flow rate | 225 | m3/hour |
| 67 | Flow speed | 0.88 | m/s |

56, 60, 64 Min flow speed: Minimal desired flow speeds in the pipework in order to prevent biofilm growth. Based on practical experience.

57, 61, 65 Diameter of pipework set such that Flow speed (59, 63, 67) is more than the Min. flow speed.

58, 62, 66, Flow rate, equals respectively 37, 41and 23 .

59, 63, 67 actual speed of water. Calculated as

(Flow rate/3600)/(((diameter/1000)/2)$^2$* ?).

## 3.2 Construction of the pilot recirculation system

### *3.2.1 Introduction*

The output of the spreadsheet as shown above was the basis for the construction of the pilot recirculation system. It is clear that due to practical limitations the actual construction of the pilot system is not completely in line with the design. However, the basic outline and set up as presented in Figure 1 was maintained.
Below the construction and dimensions of the different components of the system are presented.

### *3.2.2 Fish tanks*

Ten rectangular tanks were constructed from a wooden core laminated with polyester. The tanks can contain a water volume of 7.5m$^3$ and measure (2.75m x 2.75m x 0.95m). A standing pipe placed in a corner controls the water level. The water level is set at 1.22m. The tanks were placed in two rows of five tanks with a walking path in between. The tanks were elevated 30cm above floor level by placing then on concrete bricks, enabling the placement of the pipe for transport of water from the tanks to the pump sump above floor level.
During operation of the pilot system two drawbacks of the current tank configuration arose. First of all the rectangular shape does not seem to be optimal. When stressed by e.g. vibrations or sampling fish respond by fast swimming and bumping into the tank walls. Injuries due to this response were generally observed. However, pikeperch were also kept outside the pilot system in a circular tank. These fish did not bump into the tank walls when stressed but were observed to swim in a circular motion. Hence bumping related injuries were not observed. These observations suggest that with respect to prevention of stress response related injuries, circular tanks are preferable above rectangular tanks. The second observed drawback of the current tank configuration also relates to the pikeperch' stress response. Currently adjacent tanks are placed wall to wall. As a result noise and vibrations caused by stressed fish bumping into the tank walls are easily transferred to adjacent tanks. This in turn stresses the neighbouring fish. The fact that tanks are placed wall to wall literally causes a domino effect in stress response once one tank is stressed. It is therefore preferable not to place tanks wall to wall but to leave some space between adjacent tanks.

### *3.2.3 Drum filter*

From the fish tanks the water first reaches the drum filter in which suspended solids are separated from the culture water. A Hydrotec 803 was installed.

*3.2.4 Trickling filter & Pump sump*

From the drum filter the recirculation water is led to the pump sump. The pump sump was constructed in the same way as the fish tanks and measured (2.75m x 2.75m x1.22m) and placed on floor level. The pump sump is internally divided in two compartments by a sheet. This sheet doesn't reach the bottom completely enabling free flow of water and thus communication between the two compartments. From the drum filter water is freely flows into the first compartment. From there it is pumped on top of the trickling filter. The 12.5$m^3$ trickling filter was constructed out of cross flow biofilteration blocks and measured (2.50m x 2.50m x 2m). The trickling filter was placed above the pump sump. After the water passed trickling filter it is collected in the pump sump. From the second compartment it is then pumped back to the fish tanks

*3.2.5 Oxygen cone*

An oxygen cone has not been installed so far.

## 3.3 Performance of the pikeperch in the pilot recirculation system

*3.3.1 Introduction*

The ultimate goal of monitoring the growth of the pikeperch in the pilot system is to establish the economic feasibility of pikeperch culture in a recirculation system. Based on growth data the productivity of the fish can be determined. Productivity, the amount of fish that can be produced in a cubic meter of tank per year, is a key factor in the economic feasibility.

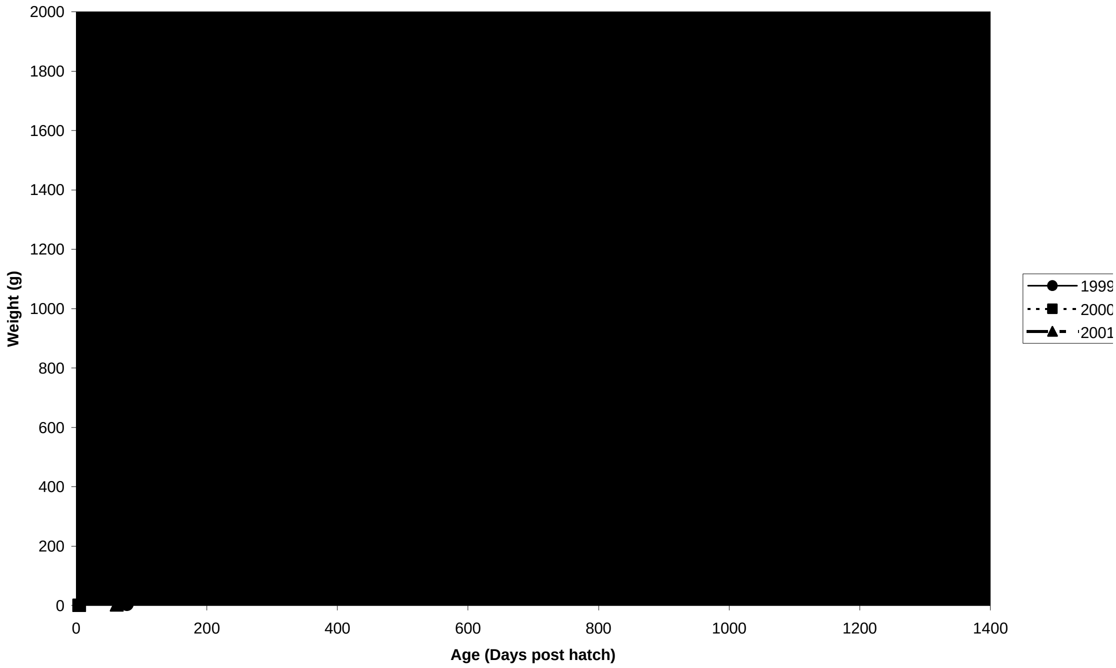
Prior to this project pikeperch were reared at Philipsen Aquaculture. Data collected are included in this report. In the first part of this chapter data collected at Philipsen Aquaculture since 1999 are presented. These include data collected in the pilot system. Annex I provides an overview of all data collected at Philipsen Aquaculture. Based on these data a growth curve, the relation between SGR and body weight and the relation between GR and body weight are established. These function as input for the Ongrowing model as developed in Task 4 of this project.

The second part of this chapter focuses on the actual performance of pikeperch stocked in the pilot recirculation system.

*3.3.2 Growth of year-classes 1999, 2000 and 2001*

For each year class, 1999, 2000 and 2001 the data are presented in summary in Appendix A. This Appendix also presents a relation between age and weight and a relation between weight and SGR for each year class based on data collected. Below these data are graphically presented in one figure. Figure 2 presents the growth curves of the 3 year-classes reared at Philipsen since 1999.

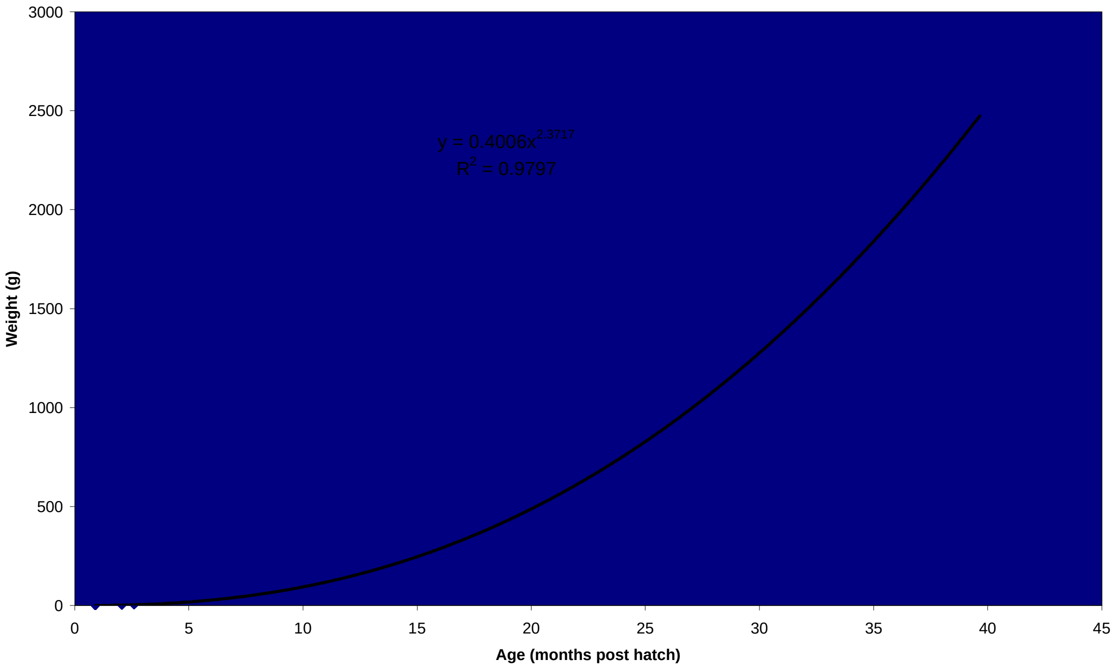
*Figure 2 Growth curves of three year-classes of Pikeperch reared at Philipsen.*




From Figure 2 it is clear that large differences in growth occurred between year classes but also within year classes over certain periods of time. Generally these are due to the experimental nature of the ongrowing. Fish have been kept under different and sub-optimal rearing conditions such as tank shape, high stocking density, low temperature, low dissolved oxygen and feed type and brand has been changed. No detailed records have been kept that would enable the identification of possible causes for each individual irregularity in growth within year classes. However, the rearing temperatures can explain two periods in which growth of year-class 2000 came to a hold. Generally temperature was kept at 22°C but in those two periods it was technically impossible to sufficiently heat the water. As a results water temperature did not exceed 17°C and growth stopped. It is clear from Figure 2 that rearing conditions have been sub-optimal and that growth as presented in Figure 2 can be improved.

All growth data collected since 1999 have been pooled in order to establish a growth curve for pikeperch (Figure 3) a relation between SGR and weight (Figure 4) and a relation between GR and weight (Figure 5). Periods of no growth were excluded from the data pool.

*Figure 3 Growth curve for pikeperch reared in recirculation system at Philipsen. Pooled data of year-classes 1999, 2000 and 2001.*




The correlation of the relation between age and weight is remarkably good ($r^2$ = 0.98). From Figure 3 it can be derived that from the day of hatching pikeperch can reach 119, 312, 618 and 1050g in respectively 12, 18, 24 and 36 months.

Figure 4 displays the relation between SGR and weight.

*Figure 4: Relation between SGR and weight reared in recirculation at Philipsen. Pooled data of year-classes 1999, 2000 and 2001.*

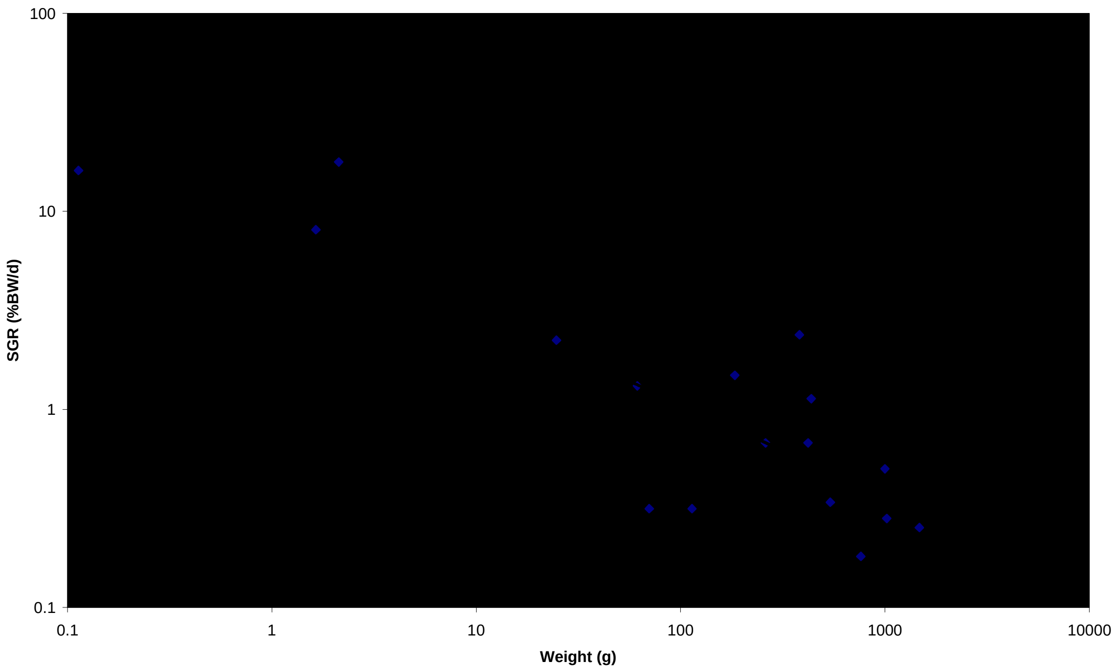


Figure 4 yields the following relation: $SGR = 9.0896*W^{-0.4664}$. It is clear from Figure 4 that for the range from 60g and up variation is high. First of all this is the result of the majority of data being collected within this range. It also reflects the variability in rearing conditions. If the determination of the relation between SGR and body weight focused on the range from 60g and up, this would result in the following relation: $SGR = 2.6916*W^{-0.2685}$, with a low correlation: $r^2 = 0.12$.

Table 2 provide easy access to both relations between SGR and weight. It must be noted that SGRs as presented for weights over 1500g lie outside the range of weights for which data have been collected.

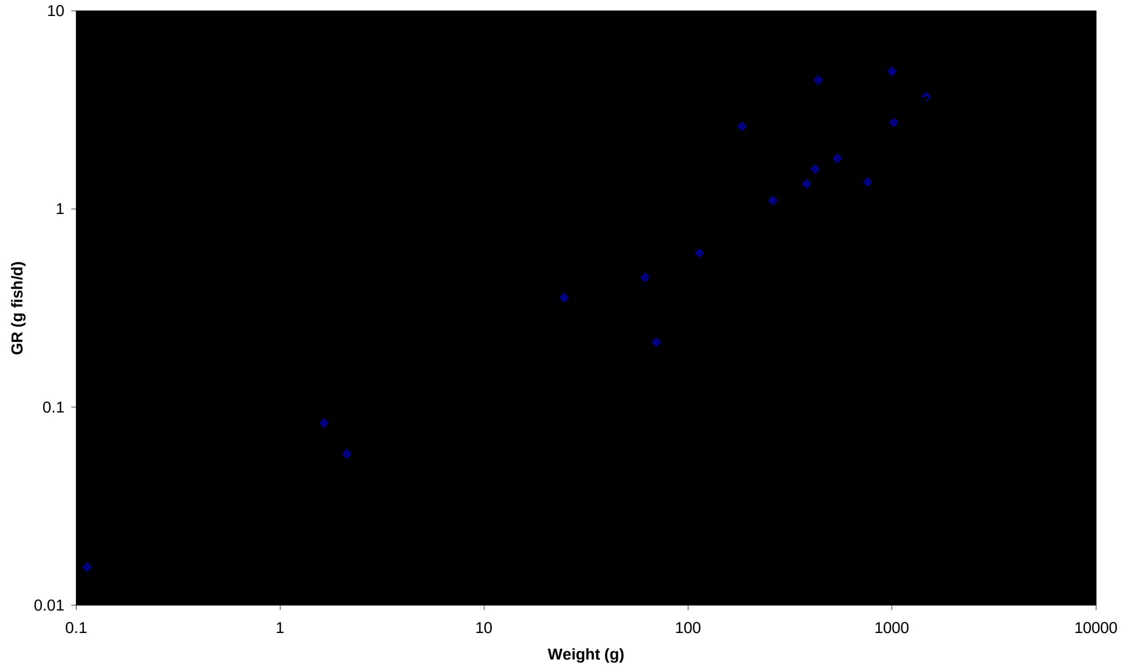
*Table 2: Specific growth rates for weight for pikeperch based on $SGR = 9.0896*W^{-0.4664}$ and $SGR = 2.6916*W^{-0.2685}$.*

| $SGR = 9.0896*W^{-0.4664}$ | | $SGR = 2.6916*W^{-0.2685}$ | |
|---|---|---|---|
| Body weight (g) | SGR (%BW/d) | Body weight (g) | SGR (%BW/d) |
| 10 | 3.11 | | |
| 50 | 1.47 | | |
| 100 | 1.06 | 100 | 0.78 |
| 200 | 0.77 | 200 | 0.65 |
| 500 | 0.50 | 500 | 0.51 |
| 750 | 0.41 | 750 | 0.46 |
| 1000 | 0.36 | 1000 | 0.42 |
| 1500 | 0.30 | 1500 | 0.38 |
| 2000 | 0.26 | 2000 | 0.35 |
| 2500 | 0.24 | 2500 | 0.33 |
| 3000 | 0.22 | 3000 | 0.31 |

As is clear from Table 2 the SGR to body weight relation based on all available data yields lower SGR for fish above 500g.

Figure 5 displays the relation between Growth rate and weight for pikeperch reared at Philipsen.

*Figure 5 Relation between Growth rate (GR) and body weight for pikeperch reared at Philipsen. Pooled data of year-classes 1999, 2000 and 2001.*




*3.3.3 Performance of pikeperch in the pilot recirculation system*

The pilot system was first stocked at 6 June 2002. Table 3 presents the stocking of different tanks and the resulting initial stocking density.

*Table 3: Stocking of the pilot recirculation system*

| Tank | Date | Total biomass (kg) | Number | Average weight (g) | Initial stocking density (kg/m$^3$) | Initial stocking density (#/m$^3$) |
|---|---|---|---|---|---|---|
| 1 | 6-Jun-02 | 260 | 2758 | 94 | 35 | 368 |
| 2 | 6-Jun-02 | 192 | 1059 | 181 | 26 | 141 |
| 3 | 19-Aug-02 | 178 | 220 | 809 | 24 | 29 |
| 5 | 17-Mar-03 | 85 | 370 | 230 | 11 | 49 |
| 10 | 18-Mar-03 | 221 | 1634 | 135 | 29 | 218 |

Of these five tanks four were sampled at the 12$^{th}$ of august 2003. Sub-samples were taken to determine the average weights. Recorded mortality was used to determine the final number of fish. Based on the initial and final data the productivity in each tank was calculated. The results are presented in Table 4

*Table 4: Final results pikeperch ongrowing in the pilot recirculation system*

| Tank | Date | Total biomass (kg) | Number | Average weight (g) | Final stocking density ($kg/m^3$) | SGR (%BW/d) | Productivity ($kg/m^3/yr$) |
|---|---|---|---|---|---|---|---|
| 2 | 12-Aug-03 | 570 | 660 | 863 | 76 | 0.36 | 43 |
| 3 | 12-Aug-03 | 384 | 220 | 1747 | 51 | 0.22 | 28 |
| 5 | 12-Aug-03 | 206 | 370 | 557 | 27 | 0.60 | 40 |
| 10 | 12-Aug-03 | 626 | 1600 | 391 | 83 | 0.72 | 134 |

Apart from tank 10, productivity is quite low. Below the productivity in each tank will be analysed.

***Tank 2***

Tank 2 is characterised by heavy mortality. Approximately one-third of the fish were lost. This of course has a major impact on productivity. In case no mortality had occurred tank 2 would have produced 81 $kg/m^3$/year with a final stocking density of 122 $kg/m^3$, provided the SGR was unaffected by the increased stocking density, Estimating the SGR for tank 2, based on SGR = $9.0896*W^{-.04664}$ and the average individual weight for tank 2 during the rearing period, results in an SGR of 0.51 %BW/d. Comparing this estimated SGR to the actual SGR for this tank, 0.36 %BW/d, makes it clear that growth in tank 2 was relatively poor. It can be concluded that the low productivity in tank 2 results from heavy mortality and poor growth.

***Tank 3***

Estimating the SGR for tank 3, based on SGR = $9.0896*W^{-.04664}$ and the average individual weight for tank 3 during the rearing period, results in an SGR of 0.37 %BW/d. Comparing this estimated SGR to the actual SGR for this tank, 0.22 %BW/d, makes it clear that growth in tank 3 was poor. Based on the growth curve (Figure 3) a final average weight of 1915g should have been reached. This however results in a limited increase in productivity, 28 to 33 $kg/m^3$/yr. The major cause for the poor productivity is the low number of fish stocked in tank 3. Productivity is linearly related to the number of stocked fish. In order to reach a productivity of 150 $kg/m^3$/year, approximately a fivefold of the current number of fish needed to be stocked. This however would have resulted in a final stocking density over 250 $kg/m^3$. It is there for concluded that with the current SGR in tank 3 a productivity of 150 $kg/m^3$/year could not have been reached.

***Tank 5***

Estimating the SGR for tank 5, based on SGR = $9.0896*W^{-.04664}$ and the average individual weight for tank 5 during the rearing period, results in an SGR of 0.43 %BW/d. Comparing this estimated SGR to the actual SGR for this tank, 0.60 %BW/d, it can be concluded that growth in tank 5 was in fact very good. The relatively poor productivity is due to the low number of fish initially stocked in tank 5. In case a fourfold of the currently stocked number was stocked, a productivity of 159 kg/$m^3$/year would have been reached at a final stocking density of 110 kg/$m^3$, provided, of course, that the SGR remains unaffected by the increased stocking. However, the good growth as currently obtained in tank 5 may very well result from its low stocking density.

***Tank 10***

Estimating the SGR for tank 10, based on SGR = $9.0896 * W^{-.04664}$ and the average individual weight for tank 10 during the rearing period, results in an SGR of 0.63 %BW/d. Comparing this estimated SGR to the actual SGR for this tank, 0.72 %BW/d, it can be concluded that growth in tank 5 was in fact good. This good growth combined with the high number of fish initially stocked explains the high productivity in this tank.

# 4. Conclusions

- The pilot recirculation system is suitable for ongrowing pikeperch. However circular tanks are preferable above the current rectangular tanks. In addition tanks should not be placed wall to wall.
- As rearing conditions were often sub optimal, there is room for improvement of the growth performance of pikeperch in recirculation systems, compared to the currently reported performance.
- Growth of pikeperch reared in the pilot recirculation system can be described as $W = 0.4006*A^{2.3717}$ (W = biomass (g), A = age (months post hatch).
- The specific growth rate of pikeperch reared in the pilot recirculation system can be described as $SGR = 9.0896*W^{-0.4664}$ (SGR (%BW/d), W = biomass (g)).
- High productivity (kg/$m^3$/year) was obtained in only one tank. Side conditions for high productivity are sufficient initial stocking (>220 fish/$m^3$), good growth (SGR > 0.75%BW/d) and low mortality.

## Annex 1