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Report

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A comparison of the growth potential of Dover sole (*Solea solea*) and Senegal sole (*Solea. Senegalensis*) under intensive rearing conditions

Final report for task 2.2 Nutrition and growth: Growth potential of *Solea solea* and *Solea senegalensis*

Design and development of commercial scale farming technologies for sole

SOLEMATES
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1. Introduction

It is generally believed that of the two sole species the growth performance of the Senegal sole is superior to the growth performance of Dover sole. This is based on comparison of growth data collected for both species at different farms and laboratories. The assumption that Senegal sole is faster growing can however not be supported with results obtained from controlled experimental set ups as such experiments have not been performed.
The goal of this Solemates task was to investigate the growth performance of the two sole species in two different types of farms. Within this task a long-term comparison has been made between S. Solea and S. senegalensis at (semi) commercial scale farming, in order to get a rough idea of the growth potential for both species in a water recirculation system and a water reuse system. The trial in a recirculation system was performed at RIVO, The Netherlands.

2. Materials and methods

Fish
The Dover sole in this experiment are the off spring of the Dover sole broodstock kept at RIVO. The fish originate from two of batches of eggs spawned at different days. The larvae were reared on artemia nauplii and artemia metanauplii enriched with Algamac 2000 and weaned on Algonorse between day 20 and 25 post hatching.
The Senegal sole in this experiment were obtained as larvae from project partner CCMAR. At the time of arrival the larvae were 5 days post hatch. They were further reared similar to the Dover sole used in this experiment.

Experimental rearing system
The experimental rearing system consisted of four 2m^3 square tanks measuring 2x2m. These tanks were part of a recirculation system. The water treatment in this system consisted of two sedimentation tanks with a total sedimentation surface area of 15.6m^2, a drumfilter and a 3.4m^3 trickling filter. Water temperature was kept at 20±0.9°C and the salinity at 24.4±1.6 mg/l. Both were measured daily. Figure A and B in the Appendix provide the water temperature and salinity throughout the experimental period.

Set up
On the 19th of August 2003 two tanks were stocked with Dover sole and two tanks were stocked with Senegal sole, yielding two replications per treatment. The fish were fed for the first time within the experiment on the 20th of August 2003 and this day is referred to as Day 1. Table 1 presents details of the initial experimental set up.

Table 1 Experimental set up of the growth potential trial at RIVO

	Tank A	Tank B	Tank C	Tank D
Species	S. senegalensis	S. senegalensis	S. Solea	S. solea
Initial number	2500	2500	2500	2500
Initial average weight (g)	1.91	2.04	5.61	5.46
Age at stocking (days post hatch)	126	126	135	135
Initial stocking density (kg/m^2)	1.19	1.28	3.51	3.41
Initial stocking density (% bottom cover)	57	60	115	113

Feeding
Feed was administered by belt feeder for 20 hours per day. The feeders were filled daily. The feeding schedule for the period from stocking to first sampling was based on an estimated specific growth rate (SGR) of 1%BW/d and a feed conversion rate (FCR) of 1.5. The results of sampling (SGR and FCR) were used to calculate a new feeding schedule of the following rearing period until the next sampling. The feeding level was managed on a daily basis by monitoring left over feed in the morning. Daily the amount of uneaten feed was quantified as “a lot”, “average” or “little” in each tank. Based on this observation the amount of feed for the next day according to the feeding schedule was either decreased, kept according to schedule or increased. This way the amount of feed was adjusted daily to the demand of the fish.

Sampling and data collection

<u>Mortality</u>
Mortalities were recorded and removed from the tanks daily.

<u>Average weight</u>
During the course of the experiment samples were taken form each tank to determine the average weight. The results were used to determine growth performance and to manage the rearing of the fish in terms of feeding level (see above) and stocking density (see below). Sub-samples were taken at day 15, 35, 43, 77, 104, 147, 205, 268 and 350 of the experiment for Dover sole and on experimental day 14, 35, 49, 77, 104, 147, 174, 246, 268 and 350 for Senegal sole. Fish where weighed in bulk.
On day 0 and day 456 of the experimental period the total weight of all fish was determined for all tanks by weighing in bulk. The average weights resulted form the number of fish in each tank.

<u>Individual weight, sex ratio, pigmentation, head deformation and tail quality</u>
In order to get an impression of the variation in growth among individual fish, the individual weight of a sub sample for each tank was determined at termination of the trial at day 456. From practical experience it is known that skewed sex ratios exists among populations of reared sole. Within this experiment the opportunity was taken to collect data. At termination of the trial at day 456 the sex of a sub sample for each tank was determined.
Among both the Dover and Senegal sole population mal pigmentation, malformations and poor tail quality were observed. At termination of the trial all fish these characteristics were quantified for sub samples from each tank to check for any relation with individual weight. Pigmentation of both sides was quantified as good/no irregularities at all (1), good pigmentation but white spots (2) and no good pigment at all, white, black and/or orange/yellow spots (3). Head deformation was quantified as not present (1) or present (2). Tail quality was quantified as good (1) or not good/any irregularity (2).
Table 2 presents the number of fish in the sub samples taken for each tank taken to determine individual weight and quantify the presence of head deformations.
Table 3 presents the number of fish in the sub samples taken for each tank to determine sex, pigmentation and tail quality.

Table 2. The number of fish in the sub samples taken from each tank for determination of individual weight and head deformation upon termination of the trial.

Tank	Species	No. in sub sample
Tank A	Solea senegalensis	355
Tank B	Solea senegalensis	399
Tank C	Solea solea	99
Tank D	Solea solea	92

Table 3. The number of fish in the sub samples taken from each tank for the assessment of the sex ratio, pigmentation and tail quality upon termination of the trial.

Tank	Species	No. in sub sample
Tank A	Solea senegalensis	101
Tank B	Solea senegalensis	110
Tank C	Solea solea	99
Tank D	Solea solea	92

Stocking density management

Stocking density was allowed to develop until approximately 180% bottom coverage. At that moment the stocking density was reduced to approximately 120% bottom coverage by randomly removing a number of fish. The number of fish to be removed was based on the results of the periodic sampling in each tank. Equal stocking density in terms of biomass was preferred over equal stocking density in numbers. In practice the number of fish and stocking density developed and was managed as is presented Figures 1 and 2. Due to differences in average individual weight between tank A and B observed at day 106, the number of fish in tank A and B was not equal between day 106 and 174 as is clear from Figure 1.

Figure 1: Stocking density (primary Y-axis) and number of fish (secondary Y-axis) development and management in Tank A and B (Senegal sole) during the course of the experiment. A sharp decrease in both number and stocking density indicates the removal of fish.

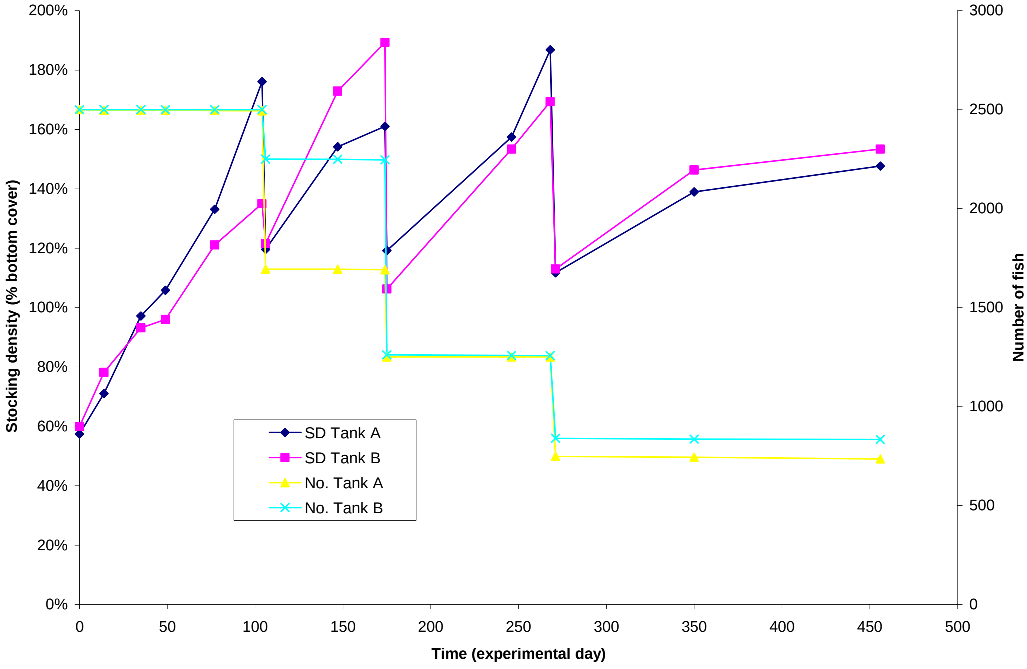
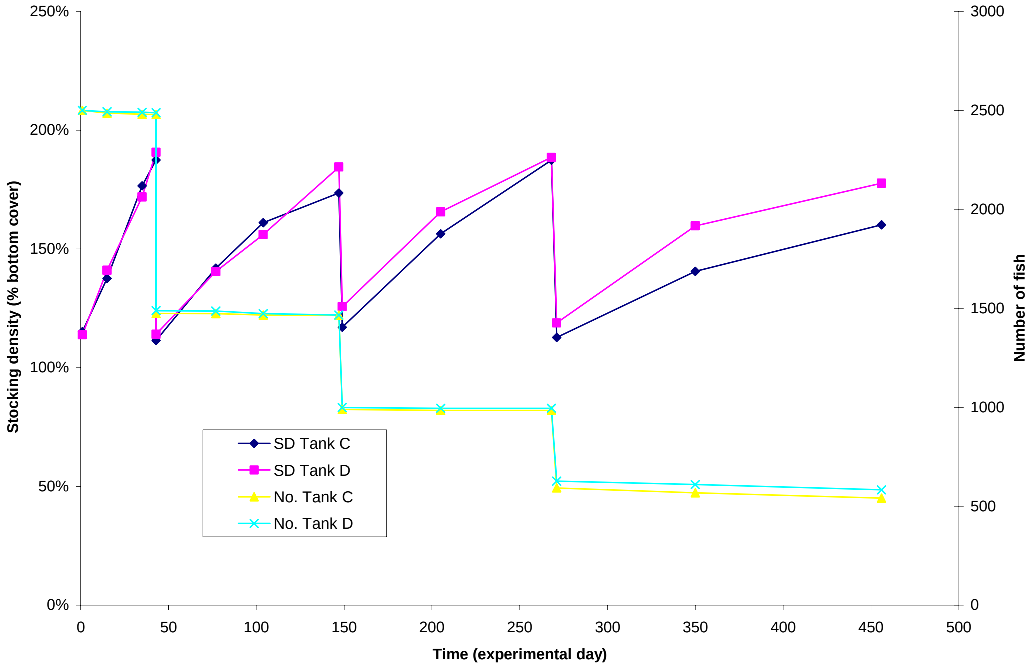


Figure 2: Stocking density (primary Y-axis) and number of fish (secondary Y-axis) development and management in Tank C and D (Dover sole) during the course of the experiment. A sharp decrease in both number and stocking density indicates the removal of fish.



Calculations

Relation weight –surface area
To express stocking density in this experiment as a relative proportion of bottom surface area covered by the fish, the surface area of the sole were calculated using the following relation:

$A = 6.0487 * W^{0.6467}$

Where: A = surface area Dover sole (cm^2)
W = Average weight Dover sole (g)

This relation was established within Solemates task 2.3 on density dependent growth for Dover sole. It is assumed that the same relation applies to Senegal sole.
This yields the average surface area of one sole. Multiplication by the total number of fish in a tank yields the total surface area.

Specific growth rate
From the average initial and final weight was calculated for each tank. Based on the average initial and final weight the specific growth rate was calculated per tank as follows:

$$SGR = (\ln(W_t) - \ln(W_0)) \times \frac{100}{T}$$

Where: SGR = Specific growth rate (%BW/d)
W_t = Average weight at day 55 (g)
W_0 = Average weight at day 1 (g)
T = Number of days

Coefficient of variation
The variation in individual weights within a group of fish can be expressed by the coefficient of variation (CV), which is calculated as follows:

$$CV = \frac{Standard\ deviation}{Average\ weight} \times 100\%$$

The CV was calculated for the last sampling day at which individual weights were determined.

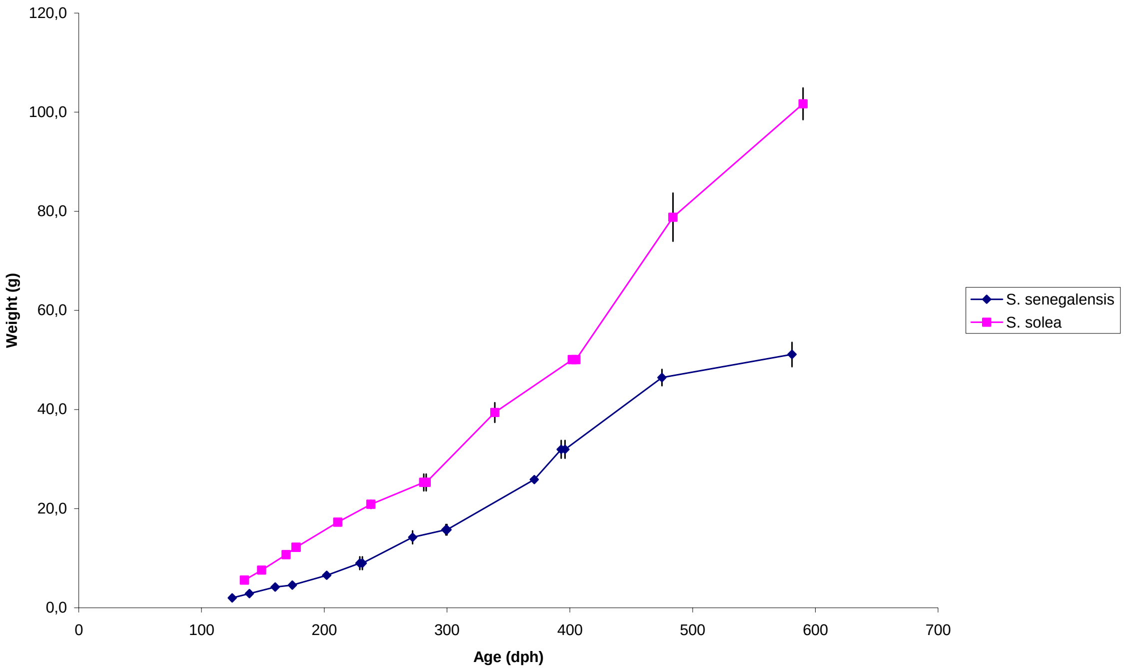
Statistics
All statistical analyses were performend with GenStat 8.1.
Differences in initial weight, final weight and SGR between species and within species and effects of sex and pigmentation on final weight were all tested for significance by ANOVA.

3. Results and discussion

Growth - general

The growth curves are presented in Figure 3. In this figure the average weights resulting from the periodic samplings are plotted to the age of the fish and not the experimental day to compensate for differences in initial weight. Table 4 presents the initial and final average weights and the resulting specific growth rates for both species.

Figure 3. Growth curves of Dover sole (Solea solea) and Senegal sole (Solea senegalensis) reared in a recirculation system for 456 days at an average water temperature of 20.0±0.9°C.



Tabel 4: Overview of growth data of Dover sole and Senegal sole reared in a recirculation system for 456 days at an average water temperature of 20.0±0.9°C.

	Solea solea	Solea senegalensis
Initial age (dph)	135	125
Initial average weight (g)	5.6	2.0
Final average weight (g)	101.7	51.1
Average SGR (%BW/d)	0.64	0.71

The initial average weight of Dover sole was significantly higher than the initial average weight of Senegal sole ($P < 0.001$).
The Dover sole reached a final average weight almost twice as high as the final average weight of the Senegal sole. This difference is final average weight between the two species is significant ($P < 0.007$). The final average weights are based on bulk weighing of the total populations.

Although the final average weight of Dover sole is significantly higher, the data suggest a lower SGR for Dover sole than for the Senegal sole (P< 0.083). This seems a contradiction but can easily be explained by the difference in initial weight. Although the absolute difference in initial average weight between the two species is small (see table 4), the relative difference between initial weights is larger than the relative difference between the final average weights of the two species. This clearly demonstrates the importance of equal initial weights in such trials. In practice however this is hard to achieve.

Since day 350 of the experiment both species were suspected to suffer from a disease as mortality increased. Until day 350 0.5% of the Senegal sole and 3% of the Dover sole were lost due to mortalities. From day 350 until termination of the trial at day 456, 1.2% of the Senegal sole and 8% of the Dover sole were lost due to mortalities. In addition, fish were lethargic and feed intake decreased to less than 0.5% of the biomass per day. Affected fish displayed swollen abdomen due to the accumulation of fluid in the abdominal cavity and eventually died. Fish were send to CIDC Lelystad, The Netherlands and CEFAS Fish disease laboratory, Weymouth, UK for diagnostics (virology, histology, bacteriology) but until to date nothing conclusive has been established. Although mortality and incidence (based on visual observations) was lower in Senegal sole, feed intake was more decreased for this species, resulting in relatively poor growth of this species after day 350 as is clear from figure 3. Although feed intake of Dover sole was also reduced in this period, growth was less affected as can be seen in figure 3.

Effect of sex, pigmentation, head deformation and tail quality on growth

General
Upon termination of the trial weight, sex, quality of pigmentation, the presence of head deformation and tail quality were determined for individual fish from all tanks. The results are presented in Table 5, 6 and 7. Raw data of individual measurements are presented in Table A in the Appendix. The effect of sex, pigmentation, head deformation and tail quality on final average weight was assessed within species.

Pigmentation and head deformation
The results of quantifying the pigment quality are presented in Table 5. Clearly the Dover sole were better pigmented than the Senegal sole, both on the upper side as on the blind side. Pigmentation was found to significantly affect growth of Dover sole (P<0.001). Post hoc analyses revealed that growth of Dover sole with good pigmentation but with white spots (2) did not differ significantly from growth of well pigmented Dover sole. However, Dover sole which displayed no good pigmentation at all (3) displayed significantly lower growth than Dover sole with white spots and well pigmented Dover sole.

Table 5. Results of the quantification of pigmentation quality for Dover sole (Tank C and D) and Senegal sole (Tank A and B) on the Upper side and the blind side

		Tank A	Tank B	Tank C	Tank D
	1 Good	28%	26%	83%	88%
Upper side	2 Average	9%	5%	2%	3%
	3 Poor	63%	69%	15%	9%
	1 Good	30%	25%	54%	58%
Blind side	2 Average	11%	6%	32%	30%
	3 Poor	59%	69%	14%	12%
N		100	110	99	92

1 Good, no irregularities at all
2 Good pigmentation but white spots (upper side) or white with pigment spots (blind side)
3 No good pigment at all, white, black and/or orange/yellow spots

In Senegal sole pigmentation was found to be strongly correlated to head deformation as is clear from Table 6: 99% of the Senegal sole suffering from head deformation also is poorly pigmented. Therefore the effect on final weight was assessed for head deformation only.

Table 6. The correlation between head deformation and pigmentation quality of the upper side for Senegal sole (n = 210)

	Good pigmentation (1)	Average pigmentation (2)	Poor pigmentation (3)
No head deformation (1)	72%	16%	11%
Head deformation (2)	0%	1%	99%

Figure C and D in the Appendix illustrate head deformation with Figure C being a normal head and Figure D a deformed head.
Clearly head deformation had a great effect on final weight of Senegal sole. The average final weight of the total Senegal sole population was 51.1g. The fish with head deformation yield a final average weight of 24.5g while the fish with no head deformation yield a final average weight of 87.0g. This difference in final average weight is significant (P<0.001). When comparing the final average final weight of Dover sole to the Senegal sole it is found that no significant difference exists (P<0.182).
In fact the Senegal sole population consisted of two sub populations which Figure 4 and 5 clearly illustrates for tank A and B respectively. These figures show the frequency distribution of Senegal sole size classes (10g intervals) with and without head deformation. From these figures it is clear that large part of the Senegal sole displayed poor growth: 40% of the fish is smaller than 20g. Figure 6 shows the frequency distribution of Dover sole size classes (10g intervals) for Tank C. Head deformation did not occur among Dover sole and no sub populations could be distinguished.
Large variation in individual final weights was observed. The smallest and largest fish upon termination of the trial were 8 and 325g for Dover sole and 2 and 378g for Senegal sole. Figure E in the Appendix clearly illustrates the differences in individual weight.

Figure 4 Frequency distribution of size classes (10g intervals) for Senegal sole with and without head deformation for tank A. Fish were reared in a recirculation system for 456 days at 20.0±0.9°C, Wo = 1.9g.

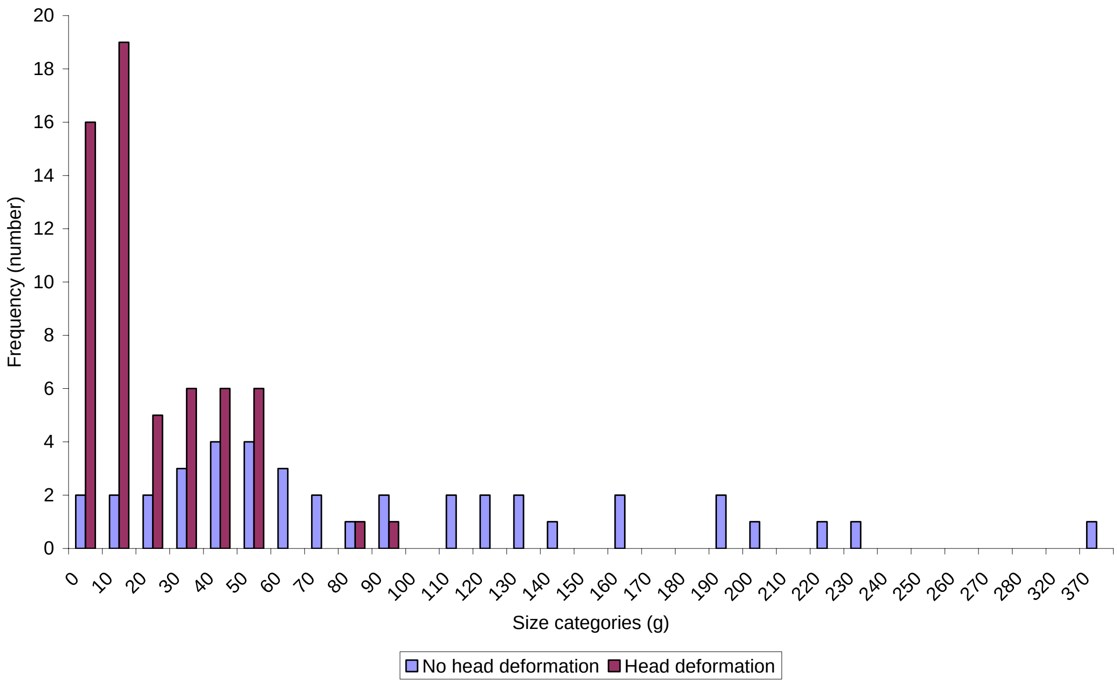


Figure 5 Frequency distribution of size classes (10g intervals) for Senegal sole with and without head deformation for tank B. Fish were reared in a recirculation system for 456 days at 20.0±0.9°C, Wo = 2.0g.

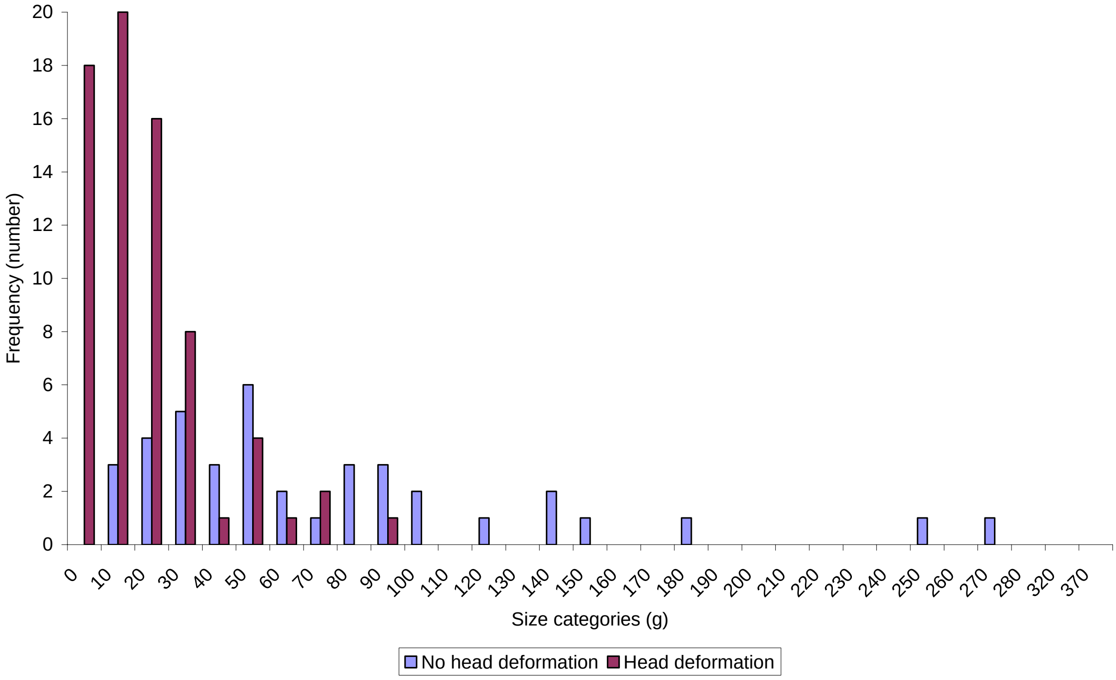
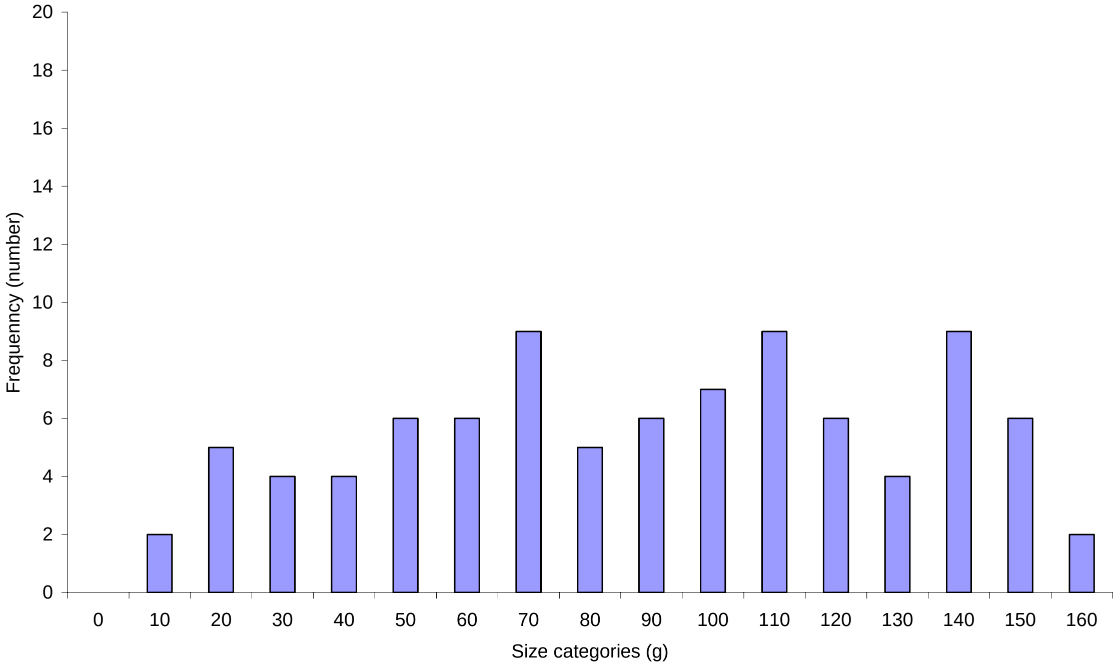


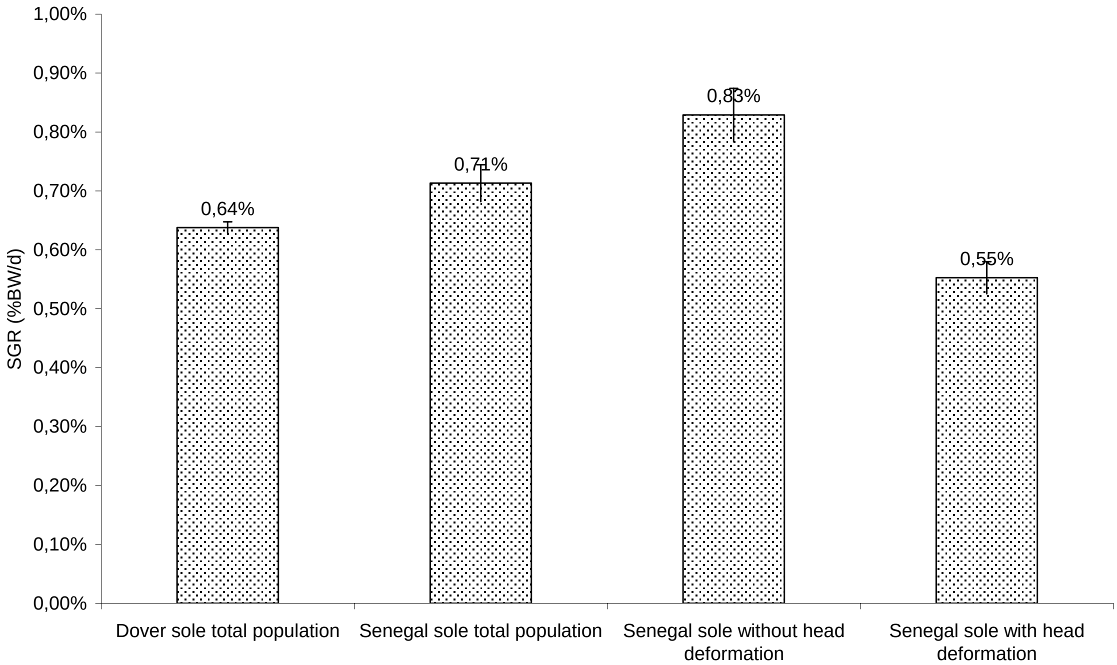
Figure 6. Frequency distribution of weight classes (10g intervals) for Dover sole reared in a recirculation system for 456 days at 20.0±0.9°C, Wo = 5.6g.



Head deformation was observed for 65% of the total Senegal sole population. Clearly the presence of such a large proportion of fish with reduced growth, had a great impact on the average final weight of the total population and the specific growth rate based on the total population. For a useful comparison of the growth of the two sole species, deformed fish should not be taken into account as they would be discarded in a commercial situation. Therefore the specific growth rate was recalculated for Senegal sole without head deformation. The results are presented in Figure 7.

The Senegal sole without head deformation yield the highest SGR, significantly higher than the Senegal sole with head deformation (P<0.001). In addition there was a tendency towards a significantly higher SGR for the Senegal sole without head deformation and the SGR of Dover sole (P<0.054). However the higher SGR found for Senegal sole without head deformation compared to Dover sole is probably partly due the lower initial weight of Senegal sole as in general smaller fish display faster growth.

Figure 7. Specific growth rate of Dover sole (total population) and Senegal sole (total population, without head deformation and with head deformation) reared in a recirculation system for 456 days at an average water temperature of 20.0°C±0.9.



The differences in initial weight between the two sole species makes it difficult to compare the SGR of Dover sole and of Senegal sole (sub) populations in this trial.
Head deformations are generally observed in Senegal sole batches but always in low numbers (Conceicao, pers. comm.). In this trial nearly 65% of the total Senegal sole population showed head deformation. The reasons are obscure but likely related to nutrition during larval rearing and metamorphosis. The reasons for poor growth of fish with head deformation were not investigated but it is not unlikely that feed intake by the affected fish was hampered as a result of the deformation. This clearly emphasizes the importance of larval rearing techniques that yield large proportions of good quality juveniles and the importance of identifying and discarding poor quality fish as early as possible for commercial ongrowing.
In this trial fish were always fed in excess. Therefore it is assumed that the presence of a large population of poorly eating fish among the Senegal sole did not offer any benefits for the other Senegal sole in terms of higher food availability and subsequently resulted in higher growth.
In this trial all fish were reared in the same recirculation system at the same average water temperature of 20.0±0.9°C. This means that the Dover sole were reared at their optimal temperature for growth (Imsland et at., 2004). The optimal temperature for ongrowning Senegal sole has never been systematically investigated, but based on practical experience in Spain expected to lie in the range of 20 to 22°C (Conceicao, pers. comm.). This means that in this trial Senegal sole were reared at a sub optimal temperature for growth and higher SGR can be obtained when rearing the fish at its optimal temperature for growth. It is therefore expected that the current difference in SGR between Dover sole and Senegal sole is larger when both species are reared at their optimal temperatures.

Tail quality
Two categories were used to assess tail quality: undamaged/complete and damaged/incomplete/absent. Tail quality was found to have no effect on average final weight of both Dover sole and Senegal sole.

Sex
Sex was found to have no significant effect on final average weight for both Dover sole (P<0.699) and Senegal sole (P<0.785).
The average final weights for the different sexes for the two species are presented in Figure 8. From this figure is appears that fish of which sex could not be determined have the lowest average final weight in both species. This is unsurprising as their small size was the bottleneck in sex determination of these fish. It is quite striking that for Dover sole the females yield the highest final weights while the opposite was observed for the Senegal sole.
The sex ratios are presented in Figure 9. Skewed sex ratios were found for Dover sole where 70% of the population were males. In previous trials at RIVO 95% males has been observed. For Senegal sole the sex could not be determined for 20% of the fish because they were too small. This makes it more difficult to conclude on the sex ratio. However, as female Senegal sole were found to be smaller than males (figure 9) it is likely that a large proportion of the fish that couldn't be sexed are in fact female. This would imply a more balanced sex ratio than currently found.

Figure 8. Average final weights of Dover sole males (n= 134), females (n=56) and fish of unknown sex (n=1), Senegal sole males (n=106) and females (n=63) and fish of unknown sex (n=41), reared for 456 days in a recirculation system at 20.0±0.9°C.

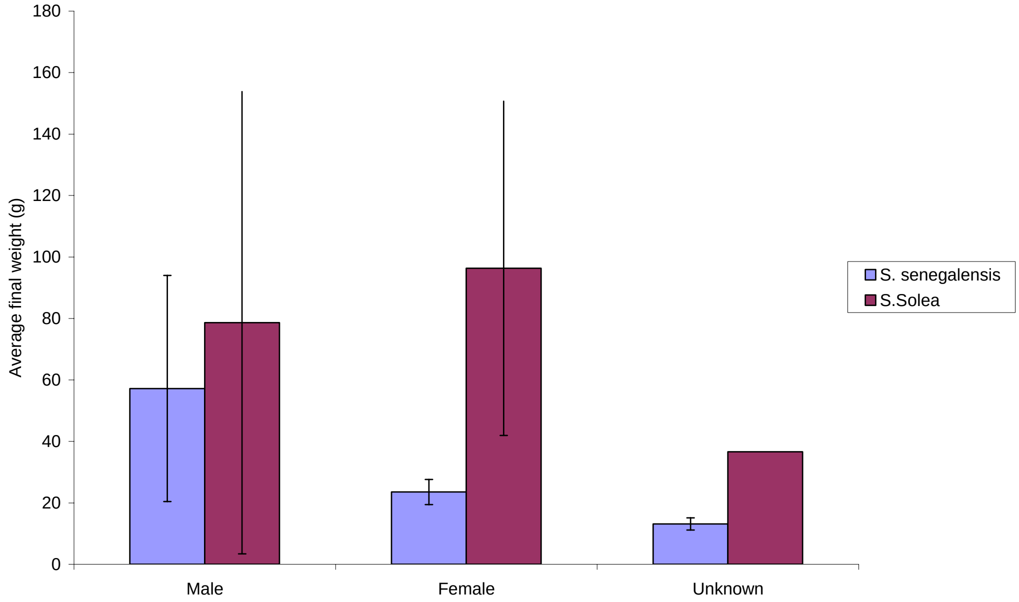
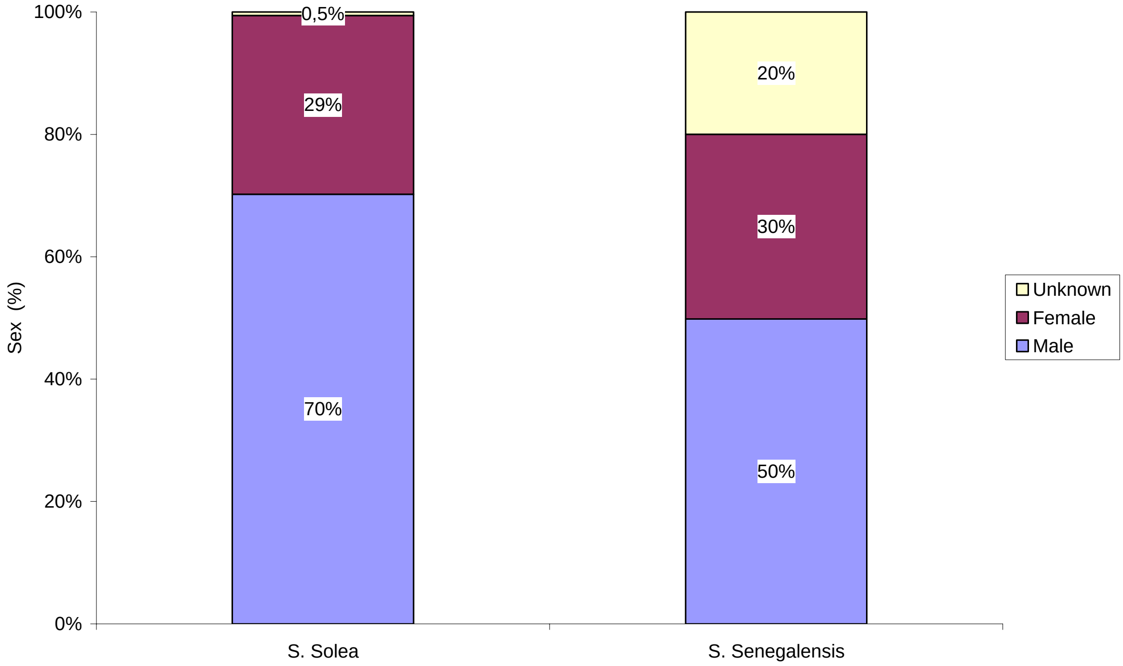


Figure 9. Sex ratios of Dover sole and Senegal sole reared in a recirculation system for 456 days at 20.0±0.9°C.



For both species production a large proportion of male fish is disadvantageous as males display higher growth dispersion.

<u>Relation between body weight and SGR</u>
This relation can be derived from the periodic sampling for growth. SGR can be calculated for the time interval between sampling and related to the average weight in that time interval. This relation can be used to determine the SGR of the fish for a given body weight within the range of body weights SGR have been determined for.
The relations between body weight and SGR for Dover sole and Senegal sole are presented in Figures 10 and 11 respectively. It should be noted that for Senegal sole all fish, including fish with head deformation which displayed significantly lower growth, were subject to sub sampling. In addition, Senegal sole were reared at sub optimal water temperature. This means that Figure 11 underestimates the potential SGR of Senegal sole.

Figure 10. Relation between Specific growth rate (SGR) and body weight for Dover sole. The data were obtained form periodic sub-sampling during a 456 day period of ongrowing in a recirculation system at an average water temperature of 20.0±0.9°C.

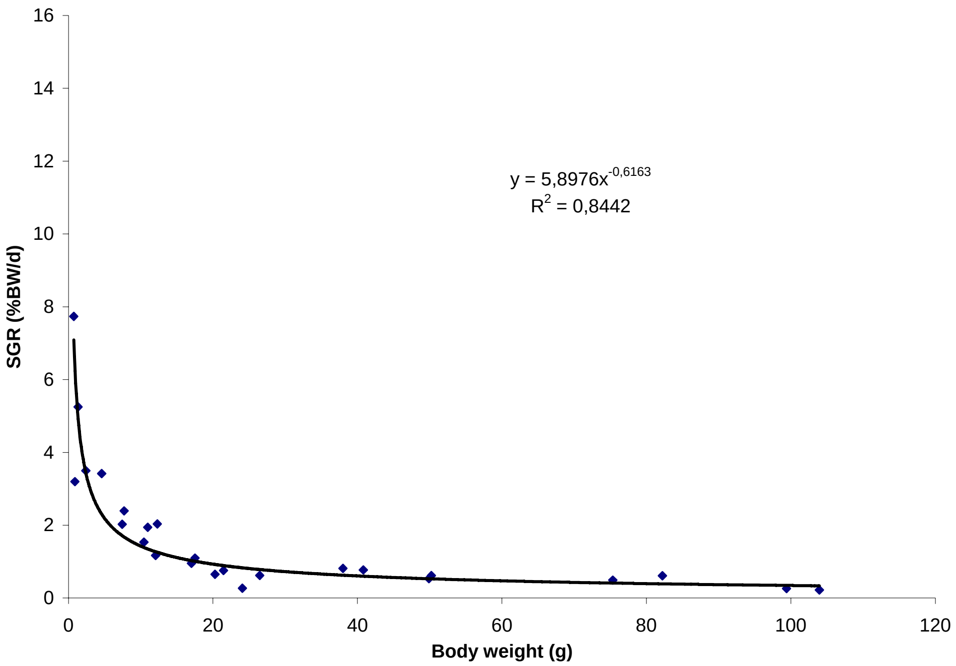
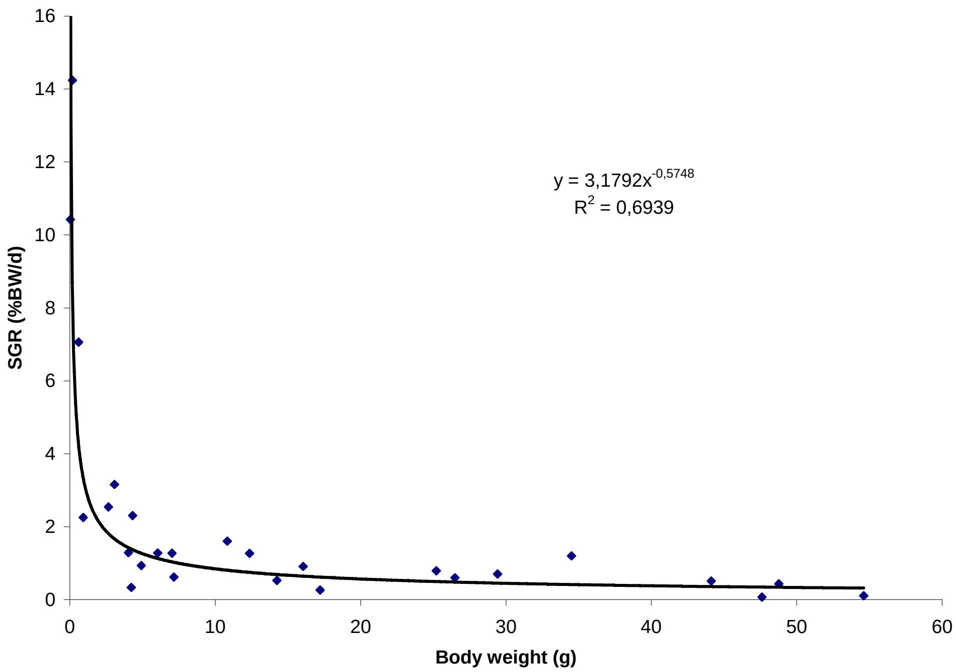


Figure 11. Relation between Specific growth rate (SGR) and body weight for Senegal sole. The data were obtained form periodic sub-sampling during a 456 day period of ongrowing in a recirculation system at an average water temperature of 20.0±0.9°C.



4. Conclusions

This trial was set up to compare the growth performance of Dover sole and Senegal sole under intensive rearing conditions. When comparing the growth performance of both species in this trial the following should be taken into account:

- Differences in initial weight make the comparison of SGR between species difficult.
- The Senegal sole population was found to consist of two sub populations as a result of the presence of head deformations. These sub populations displayed large differences in growth performance.
- All fish were reared at the same temperature of 20.0°C±0.9 during the trial which is probably sub optimal for Senegal sole.

The overall SGR for Senegal sole with no head deformation is 0.83% BW/d for the whole experimental period and 0.72% BW/d when starting at an average individual weight comparable to the initial average individual weight of Dover sole in this trial. Both these SGR values for Senegal sole without head deformation are higher than the overall SGR for Dover sole: 0.64% BW/d. The finding that the final weight of Senegal sole without head deformation was not significantly different from Dover sole and was reached starting at smaller size or within a shorter period, suggests that under the experimental conditions the Senegal sole without head deformation displayed better growth performance than Dover sole. This combined with the probably sub optimal temperature for growth for Senegal sole in this trail makes Senegal sole the best candidate for aquaculture based on growth performance.

This trial resulted in the following additional conclusions and recommendations:

- Senegal sole with head deformation should be discarded as early as possibly as they display poor growth;
- Sex did not significantly affect growth of both species. However males of both species were found to display higher growth dispersion.
- For both species tail quality was found not to affect growth performance.
- Pigmentation did affected the growth performance of Dover sole.

Appendix

Figure A. Temperature throughout the experimental period

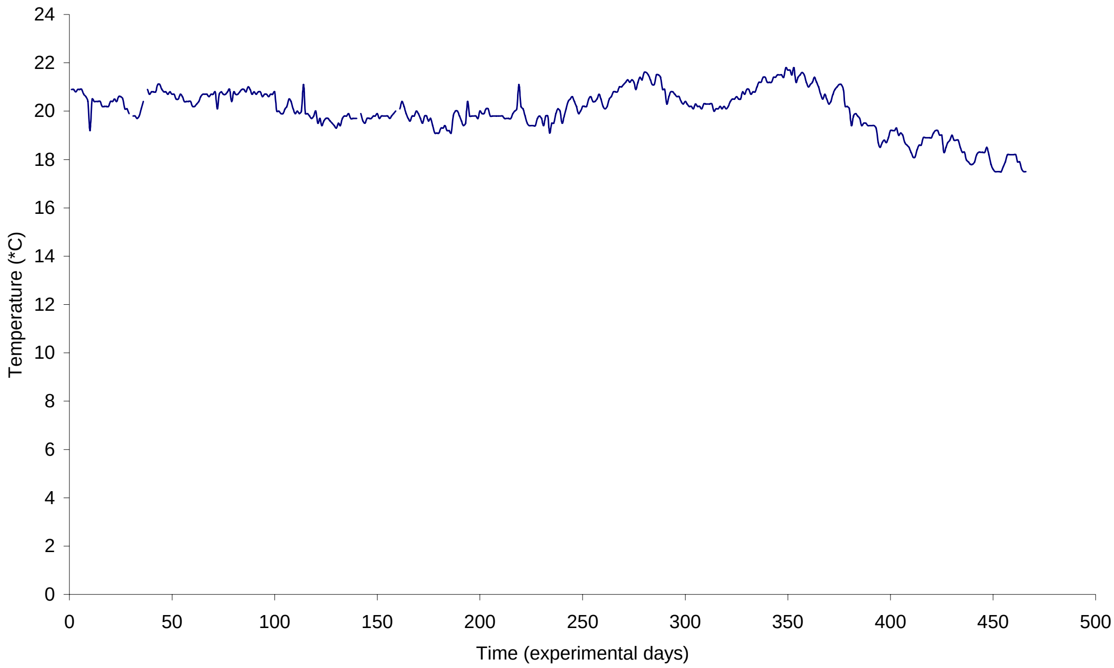
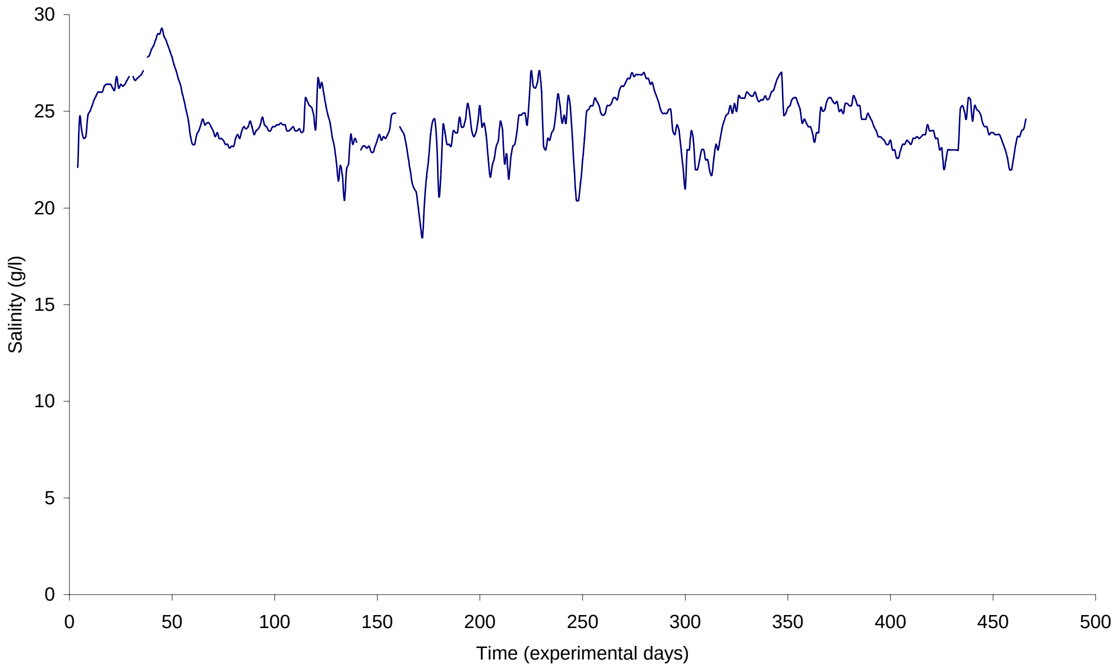


Figure B. Salinity throughout the experimental period



Individual data Growth potential trial Solemates
Sampling A en B 30/11/04, Sampling C en D 1/12/04

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
A	1	192,6	26	1	1	1	1	M	-
A	2	137,1	23,3	2	2	1	2	M	-
A	3	59,4	18,6	3	3	2	1	M	-
A	4	34,5	16,7	3	3	2	1	M	-
A	5	37,9	17	3	3	2	1	M	-
A	6	98,7	22,6	2	2	2	1	F	-
A	7	49,5	17,3	3	3	2	1	M	-
A	8	136,6	22,6	1	1	1	1	F	-
A	9	198,4	25,8	1	1	1	1	F	-
A	10	119,3	20	1	2	1	2	F	-
A	11	55,2	18,8	3	3	2	1	F	-
A	12	112,1	22	1	1	1	1	F	-
A	13	29,2	15,3	3	3	2	1	F	-
A	14	19,7	13,9	3	3	2	1	?	-
A	15	7	9,9	3	3	2	2	?	-
A	16	34,1	16,3	3	3	2	1	M	-
A	17	221,4	26,6	3	3	1	1	F	-
A	18	231,8	28,3	1	1	1	1	M	-
A	19	169,6	25	1	1	1	1	F	-
A	20	378,1	27,8	1	1	1	2	M	-
A	21	204,1	25,8	1	1	1	1	M	-
A	22	59,4	19,3	3	3	2	1	M	-
A	23	19,2	13,3	3	3	2	1	M	-
A	24	16,3	12,6	3	3	2	2	?	-
A	25	8,5	10,6	3	3	2	2	?	-
A	26	51,1	17,3	1	2	1	1	F	-
A	27	48,9	17,6	1	1	1	1	M	-
A	28	6,8	9,6	3	3	2	1	?	-
A	29	6,3	9,8	3	3	2	1	?	-
A	30	8,2	10,3	3	3	2	1	?	-
A	31	29,1	15,4	3	3	2	1	?	-
A	32	18,8	13,9	3	3	2	2	M	-
A	33	59,5	16,8	1	2	1	1	M	-
A	34	11,7	11,8	3	3	2	1	?	-
A	35	9,2	10,9	3	3	2	2	?	-
A	36	88,1	21,1	2	1	1	2	F	-
A	37	51,7	18,8	2	1	1	1	F	-
A	38	25,7	13,9	1	1	1	1	M	-
A	39	8,4	10,5	3	3	2	1	M	-
A	40	46	17,8	3	3	2	1	F	-
A	41	19,4	13,7	3	1	2	1	?	-
A	42	13,5	11,5	1	1	1	1	M	-
A	43	35,8	15,7	1	1	1	1	M	-
A	44	48,2	16,4	1	1	1	2	M	-
A	45	14,2	12	3	3	2	2	?	-
A	46	44,8	17,5	3	3	2	1	M	-
A	47	8,5	9,8	1	1	1	1	M	-
A	48	50,2	18,3	3	3	2	2	M	-
A	49	37,1	16,5	3	3	2	2	M	-
A	50	33	16,6	3	3	2	1	F	-
A	51	13,1	12	3	3	2	1	?	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
A	52	123,8	22,8	3	2	1	1	M	-
A	53	19,4	13,8	3	3	2	1	M	-
A	54	15,7	12,7	3	3	2	1	?	-
A	55	59,1	19,5	3	3	2	1	M	-
A	56	44,9	17,7	3	3	2	2	M	-
A	57	8,3	10,2	3	3	2	1	?	-
A	58	44,6	17,4	2	1	1	1	M	-
A	59	31,8	15,4	3	3	1	1	M	-
A	60	13,9	12,6	3	3	2	1	?	-
A	61	5,5	9,3	3	3	1	1	F	-
A	62	56,5	18,1	2	2	1	1	F	-
A	63	86,7	21	3	3	2	1	M	-
A	64	20,2	14	3	3	2	1	M	-
A	65	4,6	8,4	3	3	2	1	?	-
A	66	9,8	11	3	3	2	2	?	-
A	67	14,2	12	3	3	2	2	M	-
A	68	98	20,6	1	1	1	1	F	-
A	69	93,2	20,9	1	1	1	1	M	-
A	70	43,2	17,3	2	1	1	1	M	-
A	71	14,3	12,1	3	3	2	2	F	-
A	72	-	-	-					-
A	73	27,5	14,5	3	3	2	1	M	-
A	74	28,6	14,7	1	1	1	1	F	-
A	75	47,2	17,3	3	3	2	1	M	-
A	76	60,4	19,7	1	1	1	1	M	-
A	77	162	24	1	1	1	1	F	-
A	78	141,5	23,9	1	2	1	1	F	-
A	79	71,9	19,5	1	1	1	1	M	-
A	80	72,1	19,4	2	1	1	1	F	-
A	81	50,4	17,8	3	3	2	1	F	-
A	82	31,8	16,1	3	3	2	1	M	-
A	83	40,2	17,2	3	3	2	1	M	-
A	84	63,3	18	1	2	1	2	M	-
A	85	17,9	12,8	3	3	2	2	M	-
A	86	20,8	14,3	3	3	2	1	M	-
A	87	4,2	8,1	3	2	2	1	?	-
A	88	6,5	9,6	3	1	2	1	?	-
A	89	33,5	15,3	1	1	1	1	M	-
A	90	18,8	13,5	3	3	2	2	F	-
A	91	19,4	13,3	1	1	1	2	?	-
A	92	10,1	11,3	3	3	2	2	M	-
A	93	122,4	22,2	2	2	1	1	M	-
A	94	67,3	18,9	1	1	1	1	F	-
A	95	18,7	12,8	3	3	2	1	?	-
A	96	10,9	11,2	3	3	2	1	F	-
A	97	9,8	10,8	3	3	2	1	?	-
A	98	8,7	10,4	3	3	2	2	M	-
A	99	9	10,7	3	3	2	2	F	-
A	100	8,7	10,8	3	3	2	2	?	-
A	101	14,7	12	3	3	2	1	F	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
B	1	188	25,8	1	1	1	1	M	-
B	2	98,1	21,6	3	3	1	1	M	-
B	3	104,2	21,5	1	1	1	1	F	-
B	4	98,6	21,3	1	1	1	1	M	-
B	5	270,5	29,6	1	1	1	1	M	-
B	6	254,1	29,5	2	1	1	1	M	-
B	7	108,4	22,5	1	1	1	2	F	-
B	8	147,7	23,7	1	1	1	1	F	-
B	9	140,8	22,8	2	1	1	1	F	-
B	10	151,3	24,3	1	1	1	1	M	-
B	11	98,4	22	3	3	2	2	M	-
B	12	75,3	20,5	3	3	2	1	F	-
B	13	71,3	20,8	3	3	2	1	M	-
B	14	58,2	18,1	1	2	1	1	M	-
B	15	80	19,7	1	1	1	1	F	-
B	16	129,5	23,5	1	2	1	1	M	-
B	17	68,6	19,5	3	3	2	1	F	-
B	18	56,5	17,5	1	1	1	1	M	-
B	19	32,3	15,3	1	1	1	1	F	-
B	20	36,4	15,3	1	1	1	2	F	-
B	21	53,5	19,8	3	3	2	1	M	-
B	22	62,8	18,2	1	1	1	1	M	-
B	23	53,7	18,3	3	3	1	1	M	-
B	24	45,3	17,4	1	1	1	1	M	-
B	25	41,1	17,4	3	3	2	1	F	-
B	26	39,2	16,4	3	3	2	1	F	-
B	27	32,5	15,1	1	1	1	1	M	-
B	28	21,6	14,2	3	3	2	1	M	-
B	29	25,5	13,8	1	2	1	2	M	-
B	30	19,2	13	3	3	2	2	M	-
B	31	8,4	10,5	3	3	2	1	?	-
B	32	50,5	18,7	3	3	2	1	M	-
B	33	35,7	15,8	1	1	1	1	F	-
B	34	16	12,9	3	3	2	1	M	-
B	35	18,9	13,6	3	3	2	1	M	-
B	36	20,7	13,9	3	3	2	1	M	-
B	37	63,5	18,3	1	1	1	1	M	-
B	38	14,7	12,7	3	3	2	1	M	-
B	39	21,3	14,7	3	3	2	1	F	-
B	40	24,6	14,6	3	3	2	1	M	-
B	41	18,3	13,3	3	3	2	1	F	-
B	42	54,9	18,4	3	3	2	1	M	-
B	43	8	10,1	3	3	2	1	?	-
B	44	17,3	13,2	3	3	2	1	F	-
B	45	20,8	14,3	3	3	2	1	F	-
B	46	13,6	11,8	3	3	2	2	F	-
B	47	9,9	10,8	3	3	2	2	M	-
B	48	11,8	11,6	3	3	2	2	F	-
B	49	7	9,5	3	3	2	1	?	-
B	50	8	10,1	3	3	2	1	F	-
B	51	23,4	14,4	3	3	2	1	M	-
B	52	21,1	12,8	1	1	1	1	M	-
B	53	17,7	12,4	2	1	1	2	F	-
B	54	21,8	14	3	3	2	1	M	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
B	55	26,1	15,2	3	3	2	1	M	-
B	56	7	9,6	3	3	2	1	F	-
B	57	10,7	11,4	3	3	2	1	?	-
B	58	52,8	19	3	3	1	1	M	-
B	59	78,4	20	1	2	1	1	F	-
B	60	46,7	15,3	2	2	1	2	M	-
B	61	8,6	10	3	3	2	1	?	-
B	62	11,8	11,7	3	3	2	1	?	-
B	63	12,3	11,5	3	3	2	1	?	-
B	64	4,7	8,4	3	3	2	1	?	-
B	65	6,7	9,8	3	3	2	1	?	-
B	66	7,9	10,3	3	3	2	1	?	-
B	67	11	11,3	3	3	2	1	F	-
B	68	16,2	12	1	1	1	1	F	-
B	69	9,2	10,6	3	3	2	2	?	-
B	70	37,6	15,8	3	3	2	1	M	-
B	71	7,2	9,8	3	3	2	1	?	-
B	72	15	12,3	3	3	2	1	M	-
B	73	17,4	12,7	3	3	2	1	M	-
B	74	38,8	17	3	3	2	1	M	-
B	75	59,2	18,3	1	2	1	1	M	-
B	76	10,4	11	3	3	2	2	F	-
B	77	11,3	11,2	3	3	2	1	F	-
B	78	20,7	12,8	2	1	1	1	F	-
B	79	24,8	14,8	3	3	2	2	M	-
B	80	81,2	20	1	1	1	1	M	-
B	81	53,5	18,3	1	1	1	2	M	-
B	82	12,5	9,6	1	2	1	2	M	-
B	83	26,1	14,3	3	3	2	2	M	-
B	84	44,4	16,8	1	1	1	1	M	-
B	85	9,3	10,7	3	3	2	2	?	-
B	86	10,5	11,6	3	3	2	1	M	-
B	87	2,5	6,9	3	3	2	1	?	-
B	88	3,6	7,8	3	3	2	1	?	-
B	89	3,1	7,7	3	3	2	1	?	-
B	90	9,1	10,5	3	3	2	1	?	-
B	91	22,7	14,3	3	3	2	1	M	-
B	92	20,4	13,8	3	3	2	1	M	-
B	93	32,3	16	3	3	2	1	F	-
B	94	34,3	16,3	3	3	2	1	F	-
B	95	19	12,6	3	3	2	1	M	-
B	96	36,5	16,6	3	3	2	1	M	-
B	97	90,8	20	1	1	1	2	M	-
B	98	31,4	14,8	1	1	1	1	M	-
B	99	30,7	15,3	3	3	2	1	F	-
B	100	52,8	18,8	3	3	2	1	M	-
B	101	36,6	16,5	3	3	2	1	M	-
B	102	11,7	11,2	3	3	2	1	F	-
B	103	28,4	15,6	3	3	2	1	M	-
B	104	84,7	21,6	3	3	1	1	F	-
B	105	24,3	14,8	3	3	2	1	M	-
B	106	25,4	14,8	3	3	2	1	F	-
B	107	13,4	12,3	3	3	2	1	F	-
B	108	9,4	10,3	3	3	2	2	M	-
B	109	28,4	14,7	3	3	2	1	M	-
B	110	26,4	14,8	3	3	1	1	F	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
C	1	116,7	22,7	1	1	1	1	M	+
C	2	181,2	25,1	1	2	1	1	M	-
C	3	125,8	23	1	1	1	1	M	+
C	4	130,2	23,6	1	1	1	1	M	+
C	5	154,5	25,7	3	3	1	1	M	-
C	6	144,7	23,3	1	1	1	1	M	+
C	7	92,2	20,8	1	1	1	1	F	+
C	8	203,7	26,1	1	1	1	1	M	-
C	9	274,6	26,6	1	2	1	1	F	-
C	10	102,2	22,1	3	1	1	1	M	-
C	11	97,4	21,5	1	3	1	1	M	-
C	12	126,3	21,8	1	1	1	1	M	+
C	13	184,8	25	1	1	1	1	F	-
C	14	94,2	20,7	1	3	1	1	F	+
C	15	117,5	22,8	1	1	1	1	F	-
C	16	225,3	26,2	1	2	1	1	F	-
C	17	122,8	21,9	1	1	1	1	F	+
C	18	243,6	27,8	1	1	1	1	F	+
C	19	157,7	94,9	1	1	1	1	M	-
C	20	146,8	25,5	1	1	1	1	F	-
C	21	147,8	24,5	3	2	1	1	M	+
C	22	141	23,7	1	1	1	1	M	+
C	23	130,7	23,3	1	2	1	1	M	+
C	24	152,1	24,9	1	1	1	1	M	+
C	25	90,8	21,7	1	2	1	1	M	+
C	26	83,7	19,4	1	1	1	1	F	-
C	27	109,2	22,6	3	3	1	1	M	+
C	28	105,7	22,7	1	1	1	1	M	-
C	29	113,8	22,3	1	1	1	1	M	-
C	30	187,2	23,9	1	2	1	1	M	-
C	31	203	24,5	1	1	1	1	F	-
C	32	165	22,8	1	1	1	1	F	+
C	33	139	23,6	1	1	1	1	M	-
C	34	111,7	22,2	1	1	1	1	M	-
C	35	143,3	23,4	1	2	1	1	F	-
C	36	157,3	22,8	1	2	1	1	M	+
C	37	144,9	24,3	3	1	1	1	M	-
C	38	113,1	21,3	1	2	1	1	F	-
C	39	72,7	20,3	1	2	1	1	M	+
C	40	147,7	24,1	1	1	1	1	F	-
C	41	208	26,7	3	1	1	1	M	+
C	42	153,7	23,4	1	1	1	1	M	-
C	43	123,2	22,5	1	1	1	1	M	+
C	44	87,3	20,3	1	2	1	1	F	-
C	45	148,8	22,5	1	2	1	1	M	-
C	46	165,6	24,8	1	1	1	1	M	-
C	47	78,7	20,3	1	2	1	1	M	+
C	48	96,6	22	1	2	1	1	M	+
C	49	126,7	23,8	1	1	1	1	M	-
C	50	138,2	23	1	2	1	1	M	+
C	51	109,6	22,7	1	1	1	1	M	-
C	52	117,3	23	1	2	1	1	M	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
C	53	153,9	24	1	1	1	1	M	-
C	54	104,2	22,7	3	1	1	1	M	+
C	55	116,1	22,6	1	1	1	1	F	-
C	56	140,1	23	1	2	1	1	M	+
C	57	120	22,7	1	1	1	1	M	+
C	58	92,1	21	1	1	1	1	M	-
C	59	117,6	22,6	1	2	1	1	M	-
C	60	116,8	22	1	1	1	1	M	+
C	61	66,4	19,9	1	2	1	1	M	+
C	62	107,5	21,9	1	1	1	1	F	-
C	63	57	18,5	1	2	1	1	M	+
C	64	42,2	16,9	1	2	1	1	F	+
C	65	31,5	15,5	2	1	1	1	M	-
C	66	59,3	19,1	1	3	1	1	M	-
C	67	69,8	20,5	3	3	1	1	M	-
C	68	88,9	20,6	1	1	1	1	M	+
C	69	72,1	19,8	1	2	1	1	F	+
C	70	59,8	18,3	1	2	1	1	M	+
C	71	57,7	20,8	1	2	1	1	M	+
C	72	66	20	3	3	1	1	M	-
C	73	68,8	19,3	1	2	1	1	F	+
C	74	71,5	19,2	1	1	1	1	M	+
C	75	52	18,5	1	1	1	1	M	+
C	76	55,1	19,2	3	3	1	1	F	-
C	77	34,5	15,7	1	2	1	1	F	+
C	78	41,4	16,8	1	1	1	1	M	-
C	79	27,9	14,3	1	1	1	1	M	-
C	80	36,1	16,3	1	1	1	1	F	-
C	81	42,5	16,9	1	1	1	1	M	-
C	82	70,1	19,1	1	2	1	1	F	+
C	83	24,9	14,2	1	1	1	1	F	-
C	84	40,4	17	3	3	1	1	M	-
C	85	100,6	22,1	3	3	1	1	M	+
C	86	82,9	20,8	1	1	1	1	M	-
C	87	71,1	19,5	1	1	1	1	F	+
C	88	74,4	20,9	3	3	1	1	M	+
C	89	81,3	20,2	1	2	1	1	M	+
C	90	60,8	18,8	1	1	1	1	F	+
C	91	67,6	18,8	1	2	1	1	M	+
C	92	27,5	14,7	1	1	1	1	F	-
C	93	75,1	20,3	2	3	1	1	F	+
C	94	71,5	19,8	3	3	1	1	M	+
C	95	30,5	14,5	1	1	1	1	M	-
C	96	20,9	13,8	1	2	1	1	F	-
C	97	18,7	12,8	1	1	1	1	M	-
C	98	22,4	15	3	3	1	1	M	-
C	99	18,4	13,3	1	2	1	1	M	-

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
D	1	166	25	2	1	1	1	M	+
D	2	324,8	29,3	1	1	1	1	F	-
D	3	153,2	24,1	1	2	1	1	M	+
D	4	130,2	24,7	2	3	1	1	M	-
D	5	245	27,8	3	3	1	1	M	-
D	6	268,5	27,8	1	1	1	1	M	-
D	7	127,2	21,9	1	1	1	1	M	+
D	8	136,1	23,3	1	1	1	1	F	-
D	9	105,1	22,9	2	1	1	1	M	+
D	10	128,4	23	1	1	1	1	M	+
D	11	82,3	20,7	1	1	1	1	M	+
D	12	138,7	22,8	1	1	1	1	M	+
D	13	274,4	26,2	1	1	1	1	F	-
D	14	155,5	24,3	1	1	1	1	F	-
D	15	89,9	20,9	1	2	1	1	M	-
D	16	128,1	22,9	1	1	1	1	M	+
D	17	74,6	20,1	1	1	1	1	F	-
D	18	178,8	24,5	1	2	1	1	M	+
D	19	79	20,2	1	1	1	1	F	+
D	20	119,7	21,8	1	2	1	1	M	+
D	21	76,7	19,6	1	2	1	1	F	+
D	22	102	21,5	1	1	1	1	M	+
D	23	86,9	21	1	2	1	1	M	+
D	24	108	20,8	1	2	1	1	M	+
D	25	58,5	18	1	1	1	1	M	-
D	26	106,5	21,6	1	1	1	1	F	-
D	27	106,5	21,6	1	1	1	1	F	-
D	28	187,1	24,8	1	1	1	1	M	+
D	29	265,3	26,6	1	1	1	1	M	-
D	30	89,2	20,1	1	1	1	1	M	+
D	31	111,6	22	1	1	1	1	M	+
D	32	74	19,7	1	2	1	1	M	+
D	33	145,6	23	1	2	1	1	M	+
D	34	127	21,9	1	1	1	1	F	-
D	35	101,9	22,1	1	1	1	1	M	+
D	36	205	26	1	1	1	1	F	-
D	37	80,1	19,7	1	1	1	1	F	+
D	38	256,2	26,4	1	2	1	1	M	+
D	39	144,4	22,8	1	2	1	1	M	+
D	40	134,7	22,8	1	1	1	1	M	-
D	41	283,9	26,8	1	1	1	1	F	+
D	42	169,8	24,9	1	1	1	1	M	-
D	43	117	22,6	1	1	1	1	M	+
D	44	210,1	24,4	1	1	1	1	F	-
D	45	244,8	26,6	1	2	1	1	F	-
D	46	238,6	26	1	1	1	1	F	-
D	47	274,9	27,8	1	1	1	1	M	+
D	48	172,1	25,5	1	2	1	1	M	+
D	49	116	21,6	1	1	1	1	M	-
D	50	150,3	23,3	1	1	1	1	M	+
D	51	123,8	21,8	1	2	1	1	M	+
D	52	149,1	24,6	1	2	1	1	M	+
D	53	173	23,8	1	1	1	1	M	+
D	54	124,4	22,4	1	1	1	1	F	+
D	55	81	20,2	1	1	1	1	F	-
D	56	109	22,1	1	3	1	1	M	-
D	57	103,1	22,3	1	1	1	1	M	+
D	58	88	20,5	1	2	1	1	M	+
D	59	110,3	22,5	1	1	1	1	M	+
D	60	171,5	25	1	1	1	1	F	+
D	61	130,9	23,3	1	1	1	1	M	+

Tank	No.	W (g)	L (cm)	Pig. Up	Pig blind	Head deformation	Tail	Sex	Humb at tail
(A, B, C, D)				(1-2-3)	(1-2-3)	(1-2)	(1-2)	(M/F)	(+/-)
D	62	103,1	22,2	1	1	1	1	M	-
D	63	166,1	25,3	1	2	1	1	M	+
D	64	135,9	23,5	1	1	1	1	M	-
D	65	100,6	21,3	1	2	1	1	M	-
D	66	102,6	22,7	3	3	1	1	M	+
D	67	127	22,8	3	3	1	1	M	+
D	68	151,8	24,9	3	3	1	1	M	+
D	69	119,6	22	1	2	1	1	M	-
D	70	97,8	21,3	1	2	1	1	F	+
D	71	89,4	20,2	1	1	1	1	F	+
D	72	79,6	20	1	2	1	1	M	+
D	73	67	18,6	1	3	1	1	F	+
D	74	45	17,5	1	2	1	1	M	-
D	75	91,9	22	3	3	1	1	M	-
D	76	76,2	20,1	1	2	1	1	M	+
D	77	73,3	19,5	1	1	1	1	M	-
D	78	51,3	17,8	3	3	1	1	M	+
D	79	57,4	18,1	1	1	1	1	M	-
D	80	42	17,3	1	1	1	1	M	+
D	81	78,5	20	1	2	1	1	M	-
D	82	46,5	17,9	3	3	1	1	M	-
D	83	49,1	16,5	1	2	1	1	M	-
D	84	51,6	18,4	3	3	1	1	F	-
D	85	34,6	16,6	1	1	1	1	F	-
D	86	48,7	17,5	1	1	1	1	M	+
D	87	79,3	19,8	1	1	1	1	M	+
D	88	44,4	16,4	1	1	1	1	M	-
D	89	60,9	19	1	2	1	1	F	-
D	90	50,9	17,9	1	1	1	1	M	-
D	91	37,5	16,7	1	2	1	1	M	+
D	92	7,8	10	1	2	1	1	?	-

Figure C Nornal, undeformed head of Senegal sole

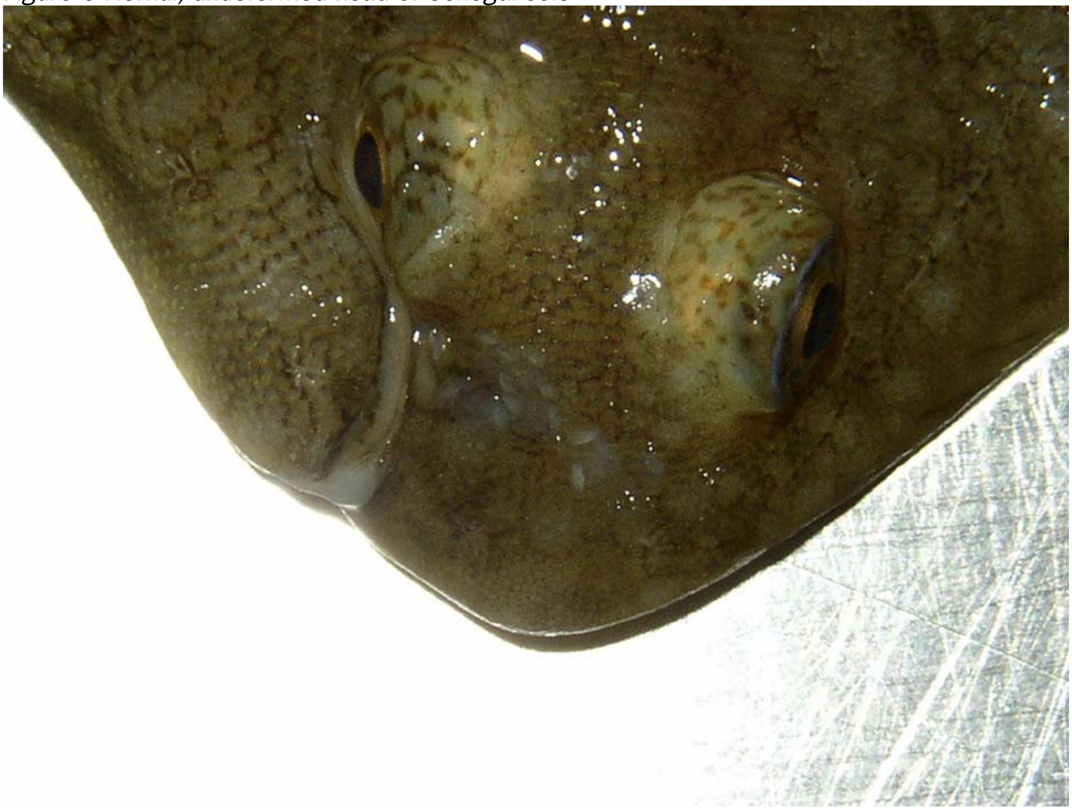


Figure D Head deformation in Senegal sole

Figure E Illustration of size variation among Senegal sole. Senegal sole reared at 20.0°C for 456 days from approx. 2g displayed large size variation. Final weight ranged from 8g to 325g for Senegal sole.